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Theme: *Decision Support Systems*

Colorado State University

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Highlights

In Every Issue

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This page: *An aerial view of a river canyon in southwest Colorado. Photo © Copyright 2010 Roy Tennant, FreeLargePhotos.com*

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Editorial

Reagan Waskom, Director, Colorado Water Institute

Our river basins function as part of dynamic watersheds where snowpack, reservoirs, land use, water rights administration, groundwater levels, and instream flows are in a constant state of flux. A river basin is a highly complex system where physical, biological, social, and institutional elements overlap and interact to create synergies and conflicts. This complexity, coupled with uncertainty about future weather and hydrology, can make it tricky for water managers to predict how the system will behave.

Colorado water managers have been making difficult decisions since we first began formalizing water administration in Colorado some 150 years ago. For most of this time, our river commissioners, ditch riders, municipal water providers, and division engineers made management decisions based upon their experience, paper records, and direct observations of current conditions. They did a remarkable job considering the technological limits they faced.

What's different today is that we have the benefit of networked monitoring systems, geographic information systems (GIS), sophisticated databases, and computer simulation models. With the flood of data available today from stream gauges, climate monitoring, remote sensing, water quality sensors, and monitoring well networks, managers have access to much more data about water systems than they can hope to assimilate and evaluate on their own.

Computers facilitate rapid assimilation and organization of data, and if we are clever, they can help us transform the cascade of data into information that is reliable enough to improve the decision making process. Databases, visualization tools, and analytical models are component tools that can help evaluate alternative water administration and management strategies. Decision support systems (DSS) are software platforms designed to simulate and visualize systems behavior; this provides managers with tools to analyze competing objectives and evaluate the effects of changing various components within their water systems. Other variables, such as climate, changing demand, and new infrastructure, can be added and evaluated, often using GIS to help create visualization tools and indices. DSS models typically use data that water managers already have access to but are not able to use to full advantage.

Decision Support Systems tend to fall within a couple of categories: planning tools, water administration tools, and management tools. DSS are fairly specific to the tasks they were meant to accomplish, so it is important to understand and be realistic about what they can reliably simulate. To be

used for real-time system management, there must be some capability for the system to learn from actual conditions and acquire new data.

Perhaps the best known DSS in Colorado are the systems being developed by the Colorado Water Conservation Board (CWCB) and the Division of Water Resources (DWR) as planning tools for Colorado's major water basins. Presently, the Colorado and Rio Grande DSS are online and usable; components of the South Platte DSS are online but still under development. A feasibility analysis is underway for a new Arkansas River DSS. For more information, see cdss.state.co.us/DNN

This issue of *Colorado Water* newsletter explores a few of the different approaches to DSS that are currently being developed at Colorado State University. Faculty and graduate students are applying their expertise to solving management problems in our river basins related to water quantity, water quality, and economic decisions.

While it is often appropriate to conduct classical scientific experiments without direct involvement of practitioners to avoid biasing results, collaborating with end-users is critical in developing decision support tools so that they can meet real needs and help solve management problems. As with the CWCB's Colorado Decision Support Systems, the research and the water management community must work together to develop and refine systems that help us optimize the use of Colorado's water resources. Finding that right balance of detail, reliability, and ease of use is key to making these tools useful for busy managers. If the DSS work reported within this newsletter is of interest to you or your organization, we encourage your involvement in the evaluation and testing of these products.

Spatial Decision Support System for Integrated Water Quantity/Quality Management in the Lower Arkansas River Basin

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Introduction

The Lower Arkansas River Valley in Colorado (Figure 1) has been experiencing the damaging effects of waterlogging from shallow water tables, excessive salt buildup, and high selenium concentrations, both on the land (Figure 2) and in the river ecosystem. As the pristine source waters of the Arkansas River (less than 100 mg/l total dissolved solids, TDS, concentrations) are conveyed along the 300 km (~186.4 mi) river length from the Pueblo Reservoir outlet to the Colorado-Kansas state line, they are degraded into highly saline flows (average TDS exceeding 2500 mg/l) due to the concentrating effects of repeated downstream reuse of irrigation return flows. Excessive recharge from inefficient irrigation and canal seepage exacerbates the problem through increased dissolution of minerals in ancient marine shale formations underlying the valley. Innovative methods for reducing land and river salinization are needed to ensure sustainability of the valley's productive agricultural base, preserve and revitalize its rural communities, and enhance the overall river environment.

Since 1999, Colorado State University (CSU) has conducted extensive field data collection in the modeled regions of the Lower Arkansas Valley shown in Figure 1 to better understand the salinity problem and to calibrate regional and basin-scale modeling tools to identify promising solution strategies for consideration by water managers and stakeholders. This has led to development of a spatial decision support system for integrated basin-wide management called River GeoDSS by Enrique Triana for his Ph.D. research at CSU (see E. Triana, J. Labadie, and T. Gates, Journal of Water Resources Planning and Management, Vol. 136, No. 2, pp. 177-200). River GeoDSS has been customized to apply to the Lower Arkansas River Basin to evaluate the impacts of strategies for improving on-farm application efficiency, reducing canal seepage, and expanding subsurface drainage in order to: (1) increase the net economic benefits of agricultural production by reducing salinity and waterlogging in productive agricultural lands; (2) reduce salt concentrations at key river locations; and (3) salvage water by reducing non-beneficial

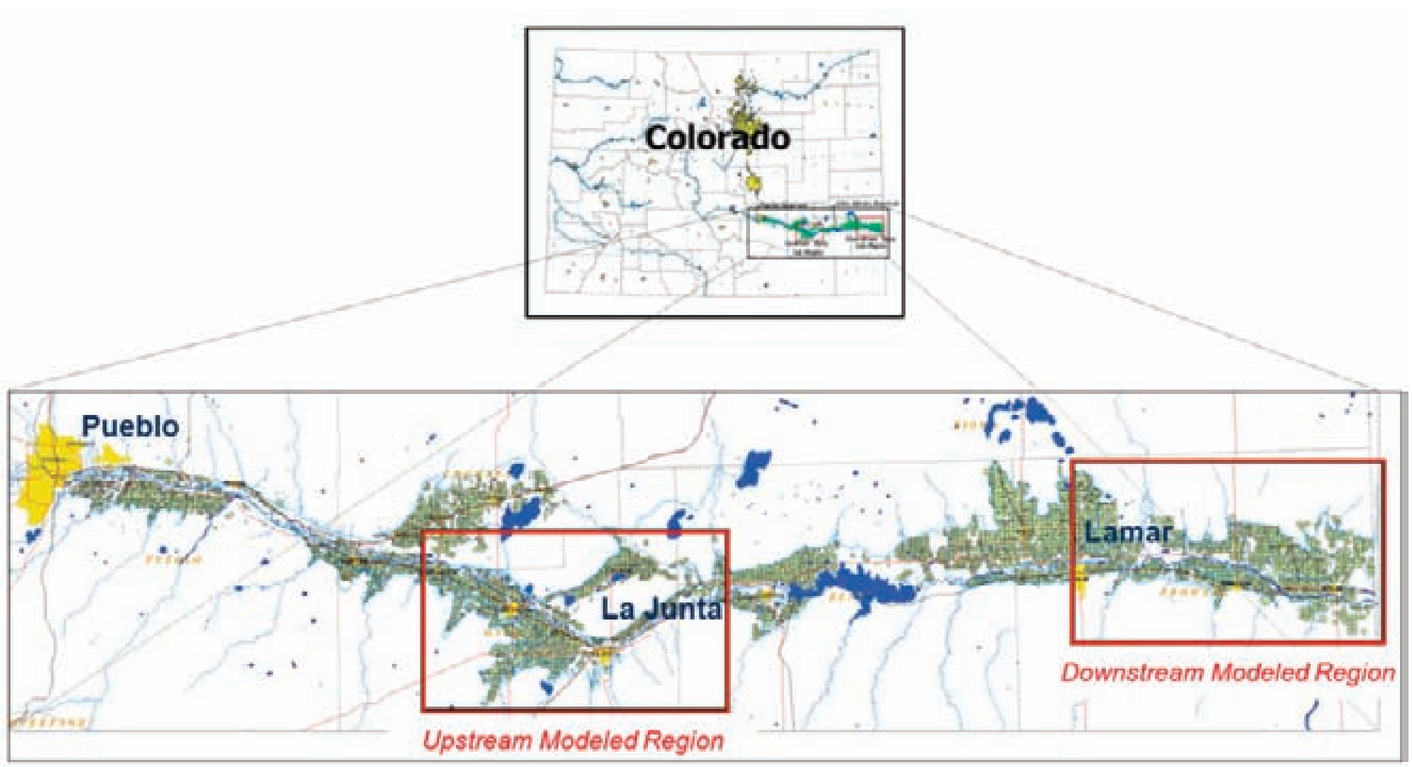


Figure 1. *Lower Arkansas River Basin showing regions of intensive data collection and MODFLOW-MT3DMS modeling.*

Figure 2. *Aerial photo showing salinity-affected lands of the Lower Arkansas River Valley, Colo.*

consumptive use from high water tables under fallow and naturally-vegetated alluvial lands. These goals must be achieved without damaging senior water rights, without increasing consumptive use, and with adherence to the Colorado-Kansas Arkansas River Compact agreement.

River GeoDSS for the Lower Arkansas River Basin

Geo-MODSIM River Basin Network Solver

The integrated modules and interfaces comprising the River GeoDSS are illustrated in Figure 3. River GeoDSS is defined as a spatial decision support system, since it integrates modules for river basin modeling, database management, and graphical user interfaces (GUI) into a geographic information system (GIS) platform for spatial modeling and analysis. The centerpiece of River GeoDSS is Geo-MODSIM, a GIS-based implementation of the MODSIM generalized river basin network flow model developed at CSU. As an extension of MODSIM, Geo-MODSIM networks include all of the essential functionality for comprehensive water rights modeling and river basin management. MODSIM is designed to model the physical and hydrologic aspects of river basin management along with the legal and institutional mechanisms governing the allocation and use of surface water and groundwater resources. These models include direct flow water rights; multiple storage right accounts; exchanges; trades; plans for augmentation; coloring of water to distinguish native, transbasin, and other non-native water sources; alternate points of diversion; reservoir operation rules; instream flow requirements for environmental/ecological protection; and dynamic streamflow routing for daily administration.

MODSIM simulates water rights allocation using a highly efficient network flow optimization algorithm that applies to large-scale river basin systems. The network flow optimization algorithm serves to efficiently simulate institutional and legal structures governing water rights administration by distributing water in order of priority. Any complex river basin system can be accurately modeled as interconnected networks of node and link objects, where nodes represent locations of flow confluence, diversion, measurement, and storage, and links convey flows and water right decrees between nodes. Figure 4 shows a portion of the geometric network for the Lower Arkansas River Basin in Colorado based on the Geo-MODSIM Data Model as displayed in the ArcMap interface.

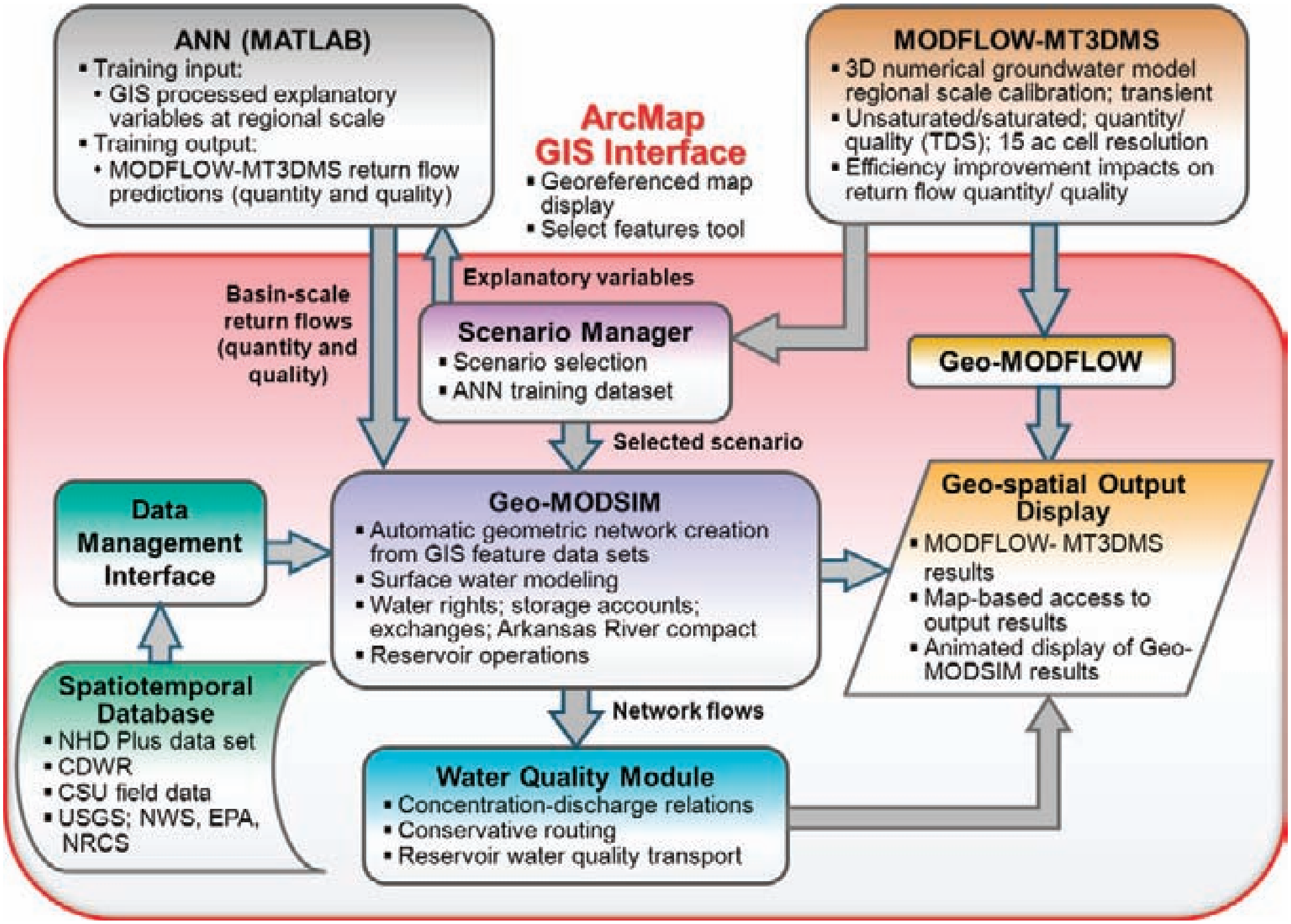


Figure 3. *River GeoDSS spatial decision support system integrating Geo-MODSIM with a water quality module and artificial neural network (ANN) for stream-aquifer modeling.*

River Basin Networks Constructed from GIS Feature Data Sets

Implementation of River GeoDSS as a registered extension in the ArcMapTM interface to ArcGISTM Desktop (Esri, Inc.) allows automated construction of Geo-MODSIM networks from GIS feature data sets. The topology and infrastructure of a river basin network is represented using ArcGIS geometric networks. The geometric network is assembled from a custom Geo-MODSIM Data Model designed to accommodate MODSIM features in a geographic environment containing spatial information on surface water features such as lakes, ponds, streams, rivers, canals, drains, springs, and wells. Reservoir nodes are imported into the MODSIM_ReservoirNodes feature class based on locations of water bodies in the National Hydrography Dataset (NHD) layer and linked to the appropriate streams and canals. Demand Nodes are connected to canal edges close to the diversion points. Figure 4 shows a portion of the geometric network for the Lower Arkansas River Basin in Colorado based on the Geo-MODSIM Data Model as displayed in the ArcMap interface.

Time Series Data and Water Rights Database

The Import TimeSeries dialog can be opened in the GeoDSS GUI for importing time series data from database management systems (DBMS). Supported DBMS software include Microsoft (MS) Access, MS Excel, and comma separated value (CSV) ASCII files. This tool imports measured data from various federal, state, and local agencies, including streamflow measurements, canal diversion records, groundwater pumping data, and reservoir contents, with time series data processed in correct model time steps and units.

The Water Rights Extension Dialog menu item in the GeoDSS GUI opens the Water Rights–Priorities utility for processing large numbers of water rights and transactions and locating them in a MODSIM network at georeferenced sites. The Colorado Division of Water Resources Water Rights Database is accessed directly for original water rights in the database management system as well as modifications in decrees. The Water Rights Utility is able to distinguish abandoned water rights, change diversion location and amounts, alternate points of diversion, and change original appropriation dates.

Calculation of Natural Flows

MODSIM networks are executed from the GeoDSS GUI in ArcMap in either Calibration Mode or Management Mode. Calibration Mode automatically calculates natural flows in the river system based on historical canal diversion data, measured flows at streamflow gauging stations, and measured reservoir storage levels. Natural flow data can also be derived from watershed models based on rainfall time series and NEXRAD data or generated from climate change scenarios. The estimated natural flows can then be utilized for executing MODSIM networks in Management Mode for simulation of the impacts of various efficiency improvement scenarios.

Geo-spatial Output Display and Scenarios Analysis

Georeferenced access to MODSIM model output is available by simply clicking the Display MODSIM Output icon on the GeoDSS toolbar in ArcMap and selecting any desired network feature in the ArcMap display. The resulting display contains a comprehensive summary of the variables modeled in each time step including flow, link losses, routed network flows, water demands and shortages, groundwater variables, reservoir storage, storage right accounting, and many others. A Scenario Analysis tool allows comparisons of the performance of several management scenarios for any selected output variable. Also, a tool has been developed in Esri ArcObjects where users may play an animated movie of MODSIM simulation results in the ArcMap display with dynamically varying sizes and colors of MODSIM nodes and links reflecting flow and storage magnitudes occurring during the simulation.

Application to the Lower Arkansas River Basin, Colorado

Stream-Aquifer Interaction

Although MODSIM includes stream-aquifer modeling capabilities with the options of applying the Glover method, the SDF method, or input of unit response functions generated from the MODFLOW numerical finite difference model, the linear superposition requirements associated with these methods raise serious concerns about their accuracy. Although the ideal solution would be directly linking MODFLOW-MT3DMS with Geo-MODSIM for calculating spatially distributed return flows to the river system, basin-wide application of MODFLOW-MT3DMS is not possible due to the lack of sufficient data for calibrating the refined cell resolution (15 acres for this study) needed to accurately model efficiency

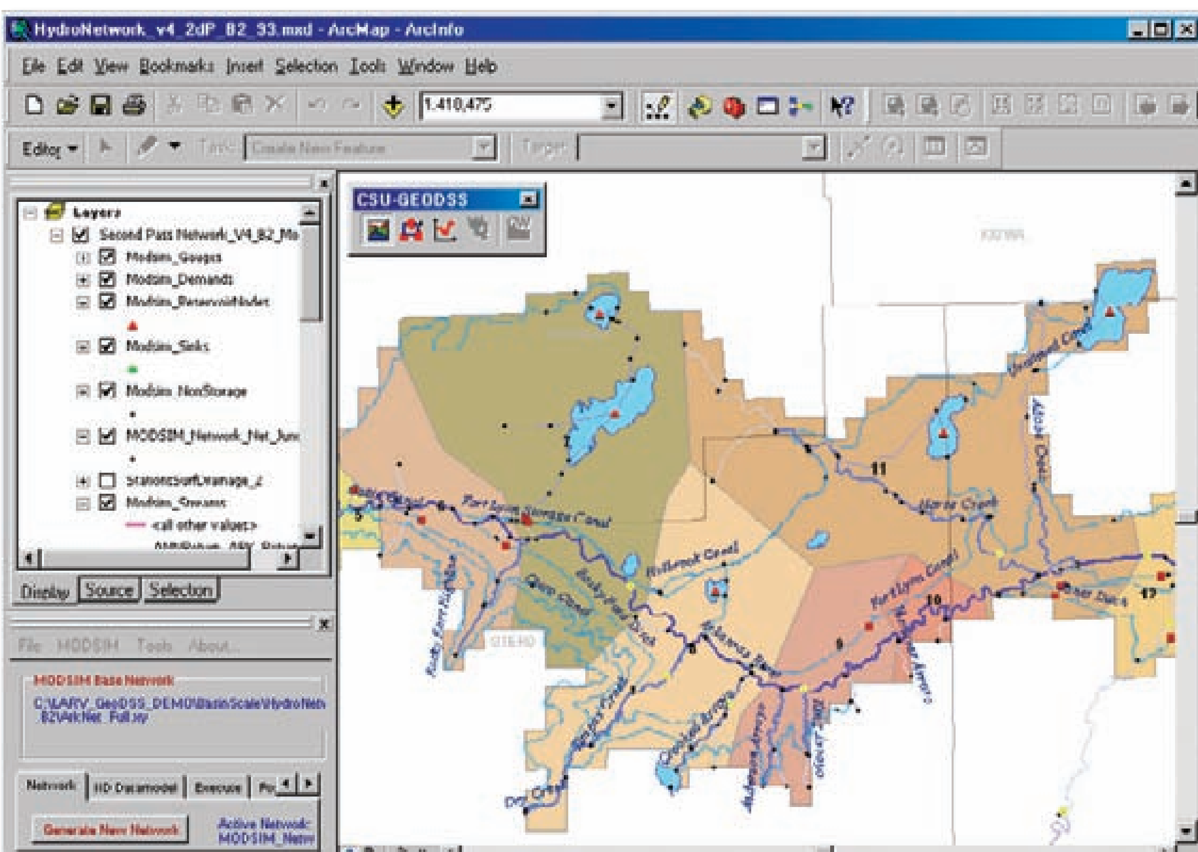


Figure 4. *MODSIM network for the Lower Arkansas River Basin created from ESRI geometric network and Geo-MODSIM Data Model.*

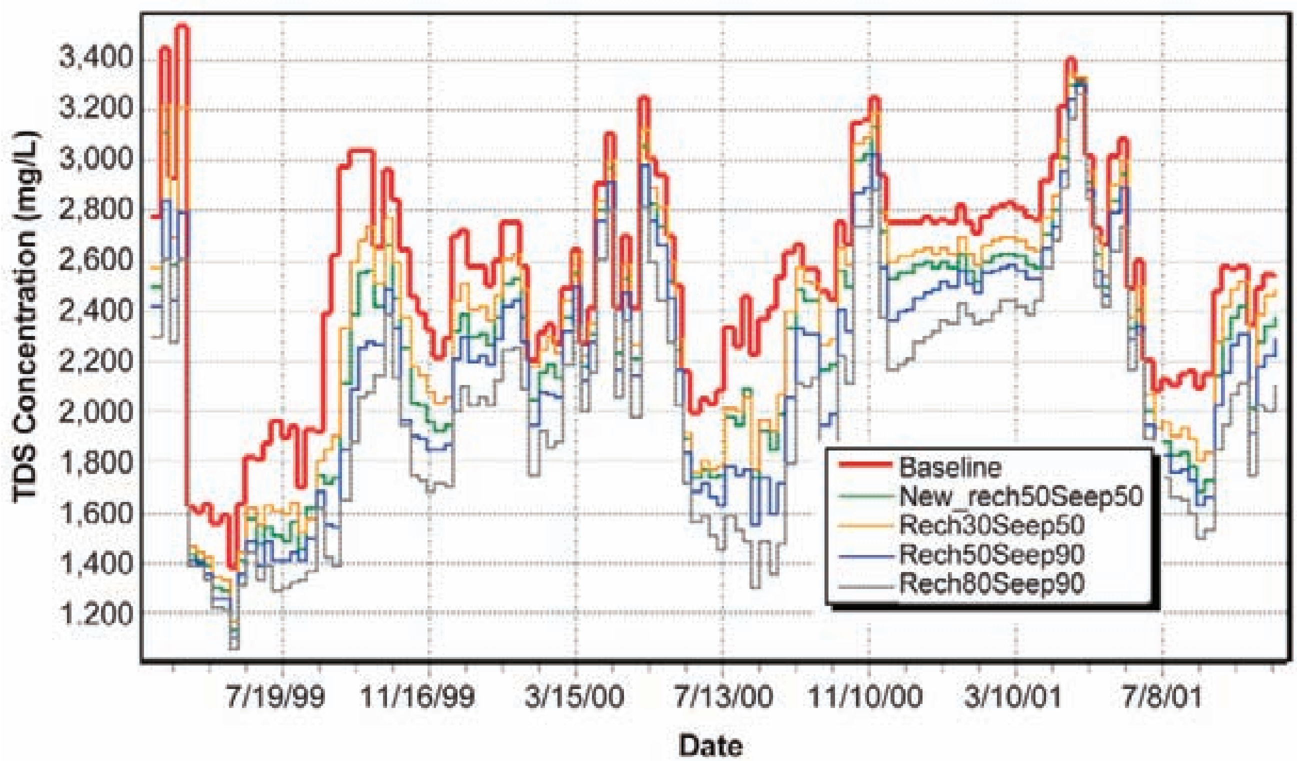


Figure 5. *TDS concentrations at the Colorado-Kansas border comparing the baseline (historical) with basin-wide implementation of selected efficiency improvement scenarios for various percent recharge and canal seepage reductions.*

improvement impacts and the immense computational load.

An innovative methodology employed in River GeoDSS is to train an artificial neural network (ANN) using input-output data sets generated from the calibrated MODFLOW-MT3DMS groundwater modeling system in the modeled regions shown in Figure 1 (for more information, see the article "Neural network approach to stream-aquifer modeling for improved river basin management," Journal of Hydrology, Vol. 391, 2010). The input data sets include explanatory variables correlated to spatially distributed return flow quantity and quality as calculated by MODFLOW-MT3DMS. The explanatory variables are calculated using the spatial analysis tools in ArcGIS both within the MODFLOW-MT3DMS modeled regions and throughout the entire basin. They include spatially-dependent variables such as canal length and elevation in the adjacent buffer areas, temporal variables such as precipitation, and scenario-dependent variables such as percent recharge reduction from implementation of efficient irrigation methods. The ANN training and testing datasets are organized by the Scenario Manager in River GeoDSS (Figure 3). The trained and tested ANN then provides basin-wide estimates of return flow quantity and quality to the basin-scale Geo-MODSIM network.

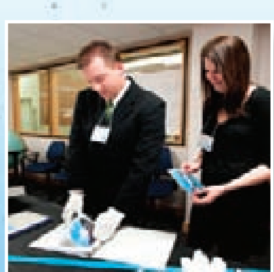
Water Quality Module

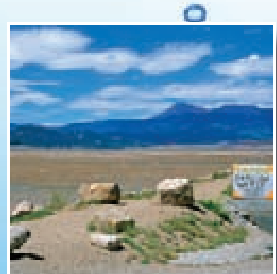
Custom tools in ArcMap provide import and processing of intermittent and regular water quality samples in a river basin. Salt concentration data are imported as total dissolved solids (TDS) using a user-selected conversion equation and are visualized in the ArcMap environment through user dialogs activated by the water quality modeling tool (WQM) in the GeoDSS toolbar. A semi-automatic calibration procedure allows adjustment of concentrations at upstream nodes with missing concentration data such that measured calculations at downstream nodes are matched as closely as possible. An efficient georeferenced network tracing algorithm navigates throughout the network from upstream to downstream and computes changes in water quality constituents while accessing user data, MODSIM flows, and GIS-spatial data. Geo-MODSIM is coupled with the WQM and the ANN module at run time to provide conjunctive surface and groundwater salt mass routing throughout the entire basin. Combined with simulated flow results, the user is capable of monitoring solute concentrations throughout the river system using the georeferenced output display capabilities in the ArcMap interface.

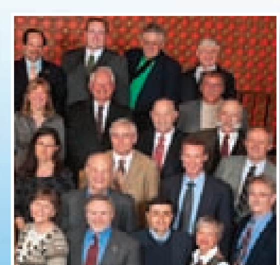
Optimal Conjunctive Management Strategies

Geo-MODSIM, as integrated with the groundwater and water quality modules in River GeoDSS, is being applied to investigate the impacts of alternative conjunctive management strategies, including increased irrigation efficiency and reduction in canal seepage. These strategies reduce soil water salinity and waterlogging with consequent increases in crop yield and reduced return flows and solute loads to the river. Sample results are given in Figure 5, showing significant reductions in TDS concentrations at the Colorado-Kansas border as compared to the baseline or historical conditions under a variety of basin-wide efficiency improvement scenarios. Salt loadings and selenium concentrations in return flows are markedly reduced under these strategies, thereby enhancing river water quality.

Under the assumption that consumptive use cannot be increased under these efficiency improvement strategies, associated changes in the rates and timing of canal diversions and return flows alter the patterns of river flows available for downstream diversion, in-stream use, and discharge into Kansas. River GeoDSS can be used to develop operational strategies for offsetting these impacts by establishing new accounts in existing on-stream and off-stream reservoirs to store water volumes from reduced canal diversions and by optimizing the timing of releases that would adequately preserve historical river flow patterns in compliance with Colorado water law and the Arkansas River Compact. Other strategies include altering groundwater pumping patterns to facilitate efficient irrigation practices in exchange for use of surface water rights; altered rates and quality of inflows from Fountain Creek (primarily composed of drainage and stormwater runoff from the city of Colorado Springs) upstream of the study area; optional water exchange agreements within the basin; and short-term leasing of water by individual ditch companies or collective entities such as the recently proposed "Super Ditch" that would fallow farm land on a rotational basis for water leases, according to the Water Information Program.







Decision Support Systems for Efficient Irrigation Water Management in the Middle Rio Grande

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Background and Problem Statement

Water use and management are extremely contentious issues in the Middle Rio Grande Valley (MRG) in New Mexico. The complex hydrology of highly interactive surface and ground water systems, years of tradition and cultural evolution, wild swings in water supply, and booming population growth make the MRG a fascinating but baffling area for water management. There is extreme competition for water since the demand for water in the valley has increased drastically; most recently, this includes the environmental demand to maintain adequate stream flow for fish and wildlife habitat. The Rio Grande Silvery Minnow has been listed as a federally endangered fish species since 1994. Extirpated from over 95 percent of its historic range along the Rio Grande, wild populations of the minnow are currently found only in the MRG Valley. Since irrigated agriculture in the MRG is by far the largest water user, it is expected to be an efficient water user so that it can meet its requirements while minimizing its river water diversions.

Water supply available for use in the MRG Valley includes native flow allocated according to the Rio Grande Compact of 1938, San Juan-Chama (SJC) trans-mountain diversion, tributary inflows, and ground water gains. Not only is the water supply fully appropriated in the region, but also priority of use has not been determined through the adjudication process. Further, the Rio Grande Compact seriously limits the utilization of native river flow in the MRG valley – Title VII of the Compact forbids storage of native flow in any upstream reservoir if the amount of water storage in the Elephant Butte reservoir, a delivery point for Texas, falls below 400,000 acre-feet.

The Middle Rio Grande Valley looking south from the Cochiti Dam.
Courtesy of Ramchand Oad

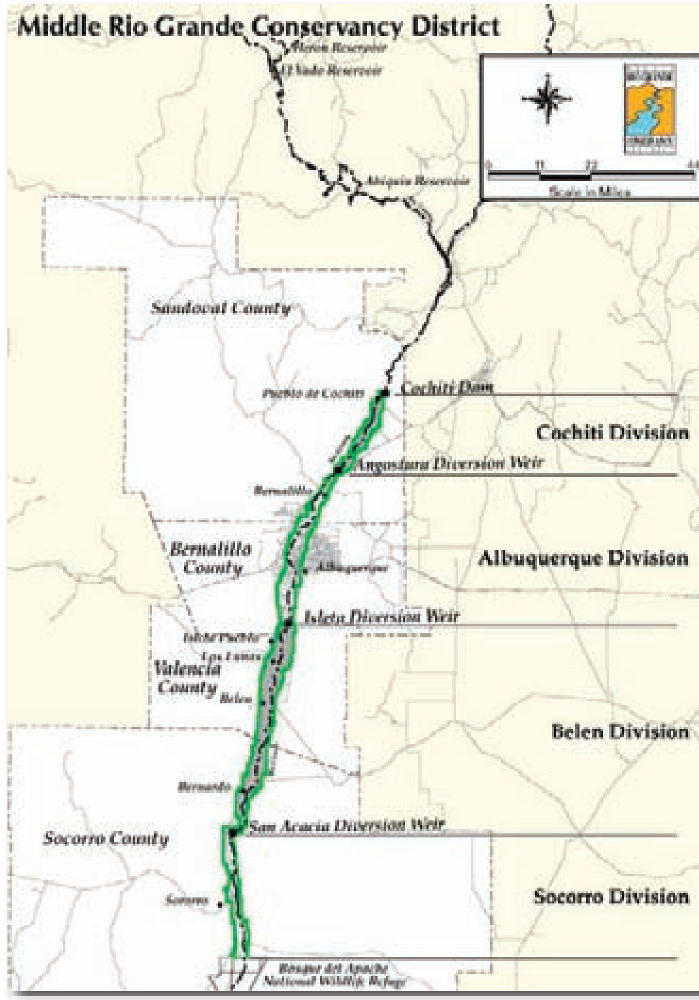

Figure 1. *The Middle Rio Grande Conservancy District, highlighted in green.*

Water demand includes the Rio Grande Compact delivery requirements for delivery to Texas and southern New Mexico, urban and industrial consumption, the Endangered Species Act (ESA) requirements, and irrigated agriculture including six Indian pueblos (about 70,000 acres of cropped lands). In addition to these demands, there are significant consumptive uses associated with riparian vegetation and wetland and reservoir evaporation.

The Middle Rio Grande Conservancy District (MRGCD) serves irrigators in the MRG valley from Cochiti Reservoir to the Bosque del Apache National Wildlife Refuge (a distance of about 200 river miles - see Figure 1). It supplies water to its four divisions – Cochiti, Albuquerque, Belen and Socorro – through Cochiti, Angostura, Isleta, and San Acacia diversion structures, respectively. The MRGCD was formed in 1925 in response to flooding and the deterioration of irrigation works. Irrigation in the MRG Valley, however, is much older, dating back to at least the 1700s and perhaps earlier.

The MRGCD and its water users have promoted efficiency improvements in their management and use of available water, especially for the past eight years. By adopting more efficient water delivery and distribution procedures, and by modernizing their irrigation infrastructure, MRGCD reduced river diversions for irrigation by approximately 30 percent of its diversions before the year 2000.

Decision Support Systems for Irrigation Water Management

Computer-based Decision support systems (DSS) can essentially "mimic" an irrigation system with data files that comprehensively represent the water supply canal network and the water demand situation at the farm. They can enable irrigation system managers to more efficiently match available water supplies to on-farm water use, thereby reducing the river water diversions necessary to meet the crop water demand. Over the last eight years, Colorado State University has assisted MRGCD in developing a DSS to improve the efficiency of water delivery operations within the MRGCD service area.

The DSS model software is essentially a linear optimization with the objective of minimizing river water diversion while meeting all crop water requirements. The DSS recommended irrigation delivery schedules can be imported into the MRGCD Supervisory Control and Data Acquisition (SCADA) system so that the actual deliveries along the canal system can be compared to the DSS recommended deliveries. This will provide better water management within the MRGCD and allow for a minimized river diversion as the required and actual diversion values converge. A decade ago the MRGCD was diverting over 600,000 acre-feet/year from the Rio Grande. Over the last 3 years, diversions have averaged less than 350,000 ac-ft. /year.

DSS consists of three elements or modules: a water demand module that calculates crop consumptive use and soil moisture storage, aggregated by lateral service area (laterals are branches off the main system); a water supply network module that represents the layout of the conveyance system, main canal inflow, conveyance system physical properties, and the relative location of diversions for lateral service area; and a scheduling module that routes water through the supply network to meet irrigation demand, using a mass-balance approach and based on a priority ranking system that depends on the existing water deficit in the root-zone. A graphical user interface (GUI) links the three modules of the DSS and allows users to access data and output for the system. The project GIS and databases are used to develop input for both the *water demand* and the *supply network* modules. The DSS has two modes of operation: planning mode and operations mode. In planning mode, the user inputs an anticipated cropping pattern for the season and other related data, and the model calculates the required main canal diversions as a function of time based on the calculated demand. In operations mode, the user inputs the available main canal flows, and the model recommends a water delivery schedule for the lateral canal service areas within the main canal that optimizes the use of the available water. Figure 2 shows an example of this input and output.

Field Implementation of DSS-Assisted Water Management

During the 2009 irrigation season, water delivery schedules developed using the DSS were implemented in the Peralta Main Canal service area on the east side of the Belen Division. The DSS model output was linked to the MRGCD SCADA network as part of the technical assistance provided to the MRGCD. This was done so that the water operations personnel can compare the actual canal diversions to the DSS recommendations on a real-time basis. The overall goal is to match the canal diversions from the Rio Grande to the real-time crop water requirement calculated using the DSS. The overall results

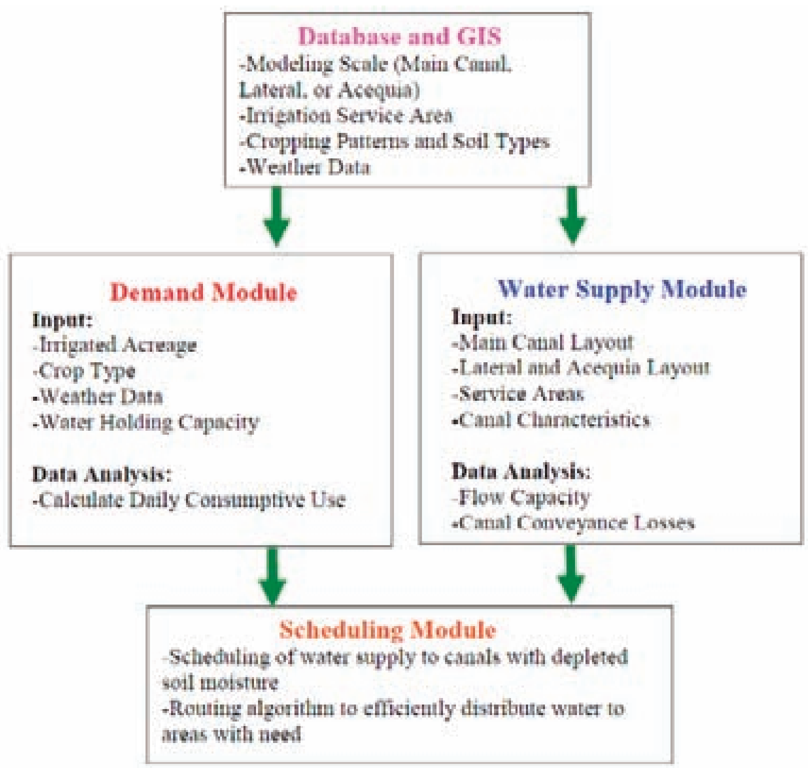

Figure 2. *An example of what the database, supply, and scheduling modules may include.*

of implementing scheduled water delivery utilizing the DSS have been positive. Throughout the 2009 irrigation season, the ditch riders (irrigation system operators) were able to follow the recommended water delivery schedules, and as a result, water distribution was significantly improved.

During the implementation, several concerns related to the scheduled water delivery were discovered. For several laterals, the time to irrigation value in the DSS was too short to supply adequate water to all irrigators. Another refinement to the DSS consisted of adjusting the canal capacity for each lateral on the Peralta Main Canal. This was done because several of the ditch riders did not utilize the full capacity of the lateral due to operational constraints. During the field implementation, several issues were identified that will need to be addressed in future DSS refinements. These included:

- Farming practices such as cutting, bailing, and fertilizer application
- The planting of new fields in the spring and fall
- Pueblo irrigators utilizing upstream water
- Farmers not being able to utilize water when it was available

Although many irrigators miss the old days of unscheduled irrigation at the time of their choice, they have reaped a major benefit from these changes. The MRGCD water operations staff believes the DSS is a useful tool that provides needed organization to the water delivery and distribution operations. Having water delivery schedules in advance provides a roadmap and facilitates coordination between the ditch riders, the division water master, and the water users. The schedules developed using the DSS also lead to better coordination between farmers and ditch riders because the ditch riders must contact farmers and notify them when water is going to be available.

New Mexico has experienced a decade of drought, and reservoir storage has been minimal. Due to its structural modernization and more efficient operational procedures, a much smaller volume of water is released from upstream storage reservoirs to meet a given demand. Therefore, the limited supply of stored water is stretched farther, and irrigators have continued to receive their full annual deliveries. Additionally, New Mexico has done unusually well in meeting Rio Grande Compact delivery obligations over the last few years. This is due to many factors, but one major reason is the more efficient movement of water through the middle valley by the MRGCD. This is a subtle change but one that may ultimately provide more good for endangered species and the general welfare of the river system.

Acknowledgment

The authors want to thank the Middle Rio Grande Conservancy District staff and water users for their complete support to the project. They also appreciate the financial assistance and technical advice received from the New Mexico Interstate Stream Commission and the USBR Endangered Species Act Program.

A User-Centered Approach To Developing Decision Support Systems For Estimating Pumping And Augmentation Needs In Colorado's South Platte Basin

Luis Garcia and David Patterson
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Throughout the United States, new models for computing augmentation requirements are being developed and applied. For the past twelve years, the Integrated Decision Support Group (IDS) has had the opportunity to study the data and modeling needs of water users in the Lower South Platte River region in Colorado. With the active participation of the water users, IDS has prioritized needs and then collected or generated the data and modeling tools necessary to meet these needs. This approach to decision support system (DSS) development is based on the premise that the user has a good understanding of what their current and future needs are, and with this in mind, we have developed an interactive and dynamic development process in which the users play an integral part. This what we call a "user-centered approach" to developing DSS tools. As part of this approach, several data-driven tools have been identified and developed that are widely used in the South Platte Basin and other parts of Colorado. These tools are collectively called the "South Platte Mapping and Analysis Program" (SPMAP) (www.ids.colostate.edu/projects/splatte). The project has been funded by water users, the Colorado Water Institute, Colorado Cooperative Extension, Colorado Agricultural Experiment Station, the Division One Office of the Colorado State Engineer, and the United States Bureau of Reclamation.

Introduction

In Colorado there is increased scrutiny of the amount of groundwater depletions caused by well pumping in alluvial aquifers. The impact of these depletions on river flows has prompted renewed interest in the methods used to calculate them.

Prolonged, severe drought and rapidly growing urban populations have exacerbated conflicts between ground and surface water users. Water managers are attempting to reconcile the desire to make use of the large amount of storage in the alluvial aquifer with the need to protect Colorado's Doctrine of Prior Appropriation and more senior surface water rights. In order to manage conjunctive use of surface and groundwater, four components need to be evaluated: 1) water demands, 2) water supplies, 3) depletions of groundwater, and 4) impacts to rivers due to depletions of groundwater and resulting augmentation requirements. SPMAP tools have been developed to deal with each one of these components.

Quantifying Water Demands

In many instances, groundwater in the South Platte Basin in Colorado is used as a supplemental water supply: groundwater is pumped when surface water supplies are unable to meet demand. Therefore, one of the first steps in modeling a groundwater/surface water system is calculating the water demand for the system. In agricultural systems, the demand is normally determined using either crop evapotranspiration (ET) or an estimate derived from multiplying well pumping by a factor (normally referred to as a presumptive depletion factor - PDF). In order to quantify consumptive use, the IDS Group developed two consumptive use models, one called IDSCU, and the other called Remote Sensing of ET (ReSET). The IDSCU Model allows users to determine crop consumptive use, irrigation water requirements, and depletions of groundwater using both traditional ET methods (Penman Monteith, ASCE, Blaney Criddle, etc.) and PDF methods. In addition, IDS had developed the ReSET model, which is an energy balance model that uses remote sensing to determine the "actual" ET. The IDSCU allows the user to choose between traditional ET methods, ReSET, or PDFs to estimate ET as part of the water balance.

Figure 1. *IDSCU Main Interface Window.*

The IDSCU model enables water managers to estimate the consumptive use (CU) of groundwater based on surface water supplies and crop consumptive use estimates. Surface water supply information and information collected by local weather stations can be imported from the Colorado State Engineer's Office database, HydroBase, or manually entered by the user. Weather station information can also be imported from the Northern Colorado Water Conservancy District weather stations or from the Colorado Agricultural Meteorological Network (CoAgMet), or users can manually enter data. The IDSCU Model can compute monthly CU using the SCS Blaney Criddle, Calibrated Blaney-Criddle, Hargreaves, and Pochop methods. Daily CU estimates can be computed by the model using the Penman-Monteith, Kimberly-Penman, the new ASCE standardized reference evapotranspiration equation, or user-defined ET such as the one estimated using the ReSET model. The IDSCU Model graphical user interface (GUI) main window is shown in Figure 1. On the lower right hand side of the main screen, a number of buttons are displayed that allow the user to access pop-up screens for entering or modifying data pertaining to: crop characteristics, crop coefficients, weather data, surface water supplies, modeling area information, well information, and modeling area weather station weighting.

The IDSCU Model allows users to generate input data before (pre) or after (post) the historical data period. The user may select to generate pre- or post-historical data by averaging selected years, repeating a selected year, or repeating a sequence of years and computing the CU for them. The model is also capable of formatting input and output displays for all year types (calendar, irrigation, and water).

The model can calculate CU or Irrigation Water Requirements (IWR) with or without using soil moisture. The model does a water budget and determines the times when crops might be water short as well as the amount of CU met from both surface and groundwater. The GUI allows users to compare the CU computed with different methods and computes ratios between the different methods. This allows users to evaluate the difference between ET methods and provides some guidance for users if they are interested in calibrating a monthly method based on the differences between the monthly aggregated values of daily ET methods and computed monthly ET values.

Quantification of Water Supplies

Water supplies normally come from surface water supplies and groundwater pumping. The model allows users to query HydroBase in order to generate a set of diversion records for different ditches or diversion structures. Users may also build a set of diversion records for different

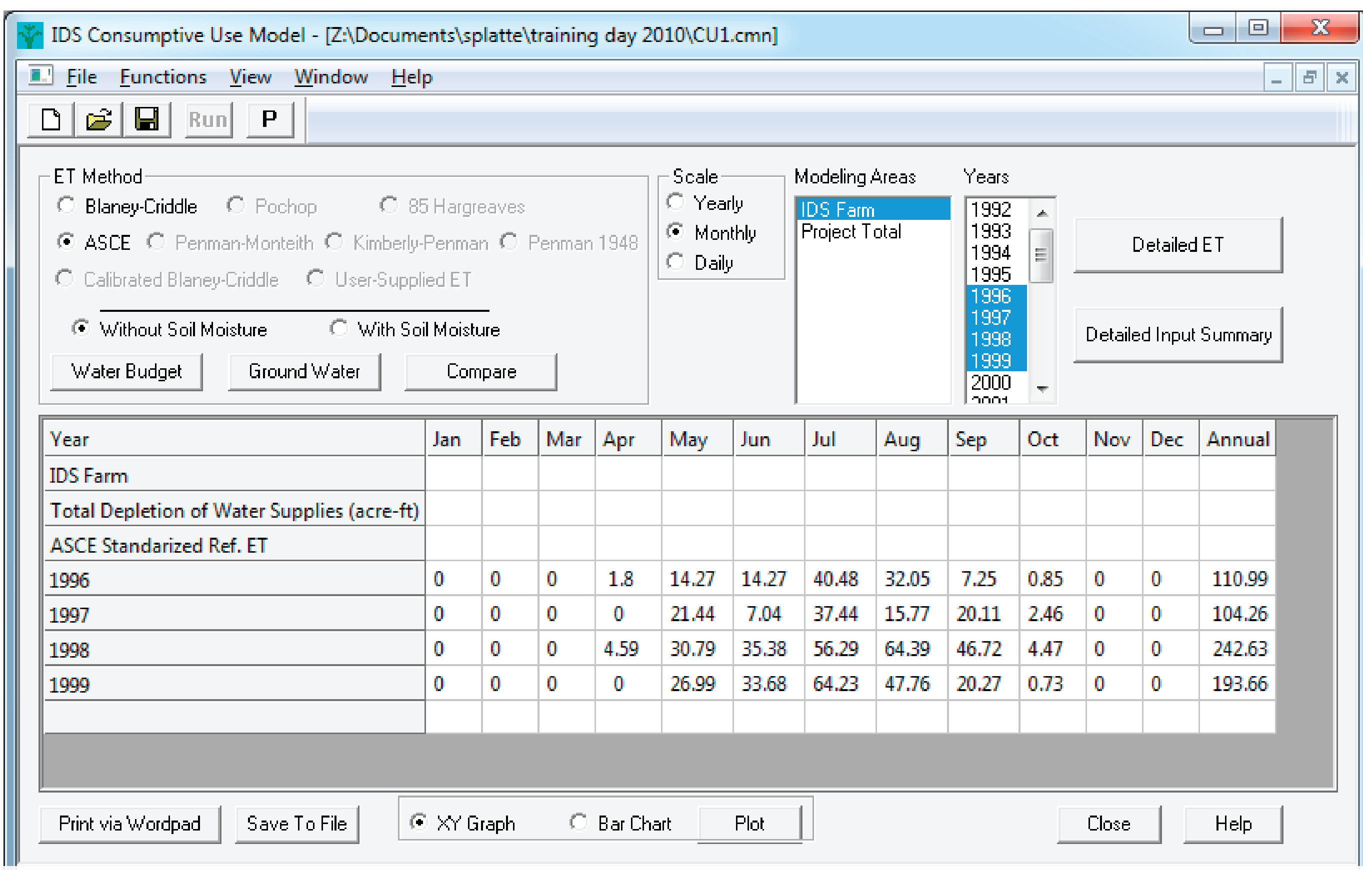

Figure 2. *IDSCU GUI General Output Screen.*

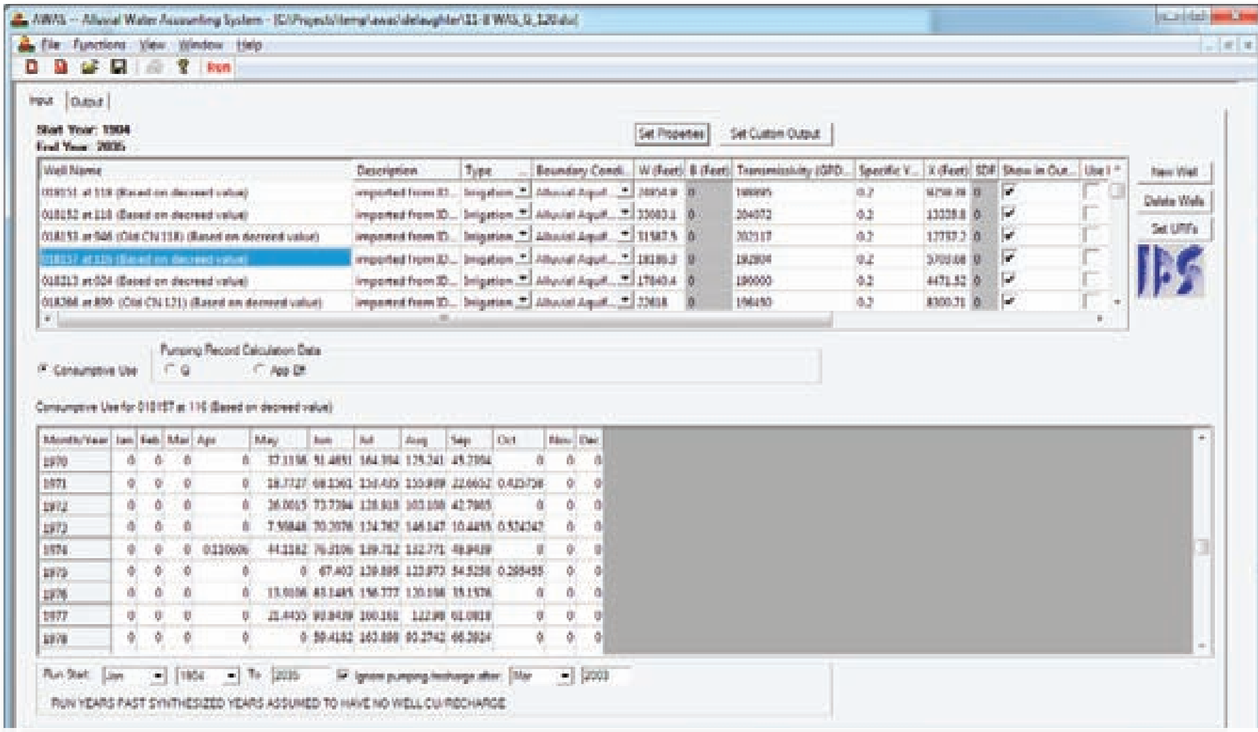

Figure 3. *IDS AWAS GUI Input Screen.*

ditches or diversion structures by entering the diversion records manually. The surface supply for each modeling area is then calculated by assigning one or more surface supply ditches or structures to it. The IDSCU Model requires users to enter the shares for each ditch or structure owned by each modeling area. The amount of shares for a particular ditch that are assigned to a modeling area can vary from year to year, enabling users to evaluate the impact of leasing water in certain years. In the event that the user has headgate diversion records, these can be entered for each modeling area.

For groundwater pumping, users may enter monthly groundwater pumping, or if the user only has total annual pumping, the model can distribute annual pumping into monthly values for agricultural and non-agricultural wells.

Quantification of Depletion of Groundwater

After obtaining an estimate of the water demand and supply, the IDSCU model can compute depletions of both surface and groundwater. Users may evaluate the impacts of the groundwater depletions by examining whether the groundwater is a primary or supplemental source of water and by examining well efficiency using a PDF. The model also can compute groundwater depletions based on a water budget. Results may be plotted with the click of a button using the IDSCU model's built-in graphics package. Users may compare the results of CU of groundwater based on a water budget versus well efficiency multiplied by well pumping to evaluate if the two results are in general agreement.

Quantification of Augmentation Requirements

Colorado water managers need to determine the lag time from when a well is pumped or water is recharged to a recharge site and when a depletion or accretion happens in the river. A model based on HydroBase was implemented by the IDS Group and is called the IDS Alluvial Water Accounting System (IDS AWAS). Figure 3 shows the IDS AWAS input screen.

IDS AWAS provides users with the option of calculating river depletions using The Analytical Stream Depletion method developed in 1987 by Dewayne R. Schroeder. This method uses analytical equations described by Glover (Glover, 1977) and others. The model allows users to calculate depletions using daily or monthly time steps. The user may evaluate a number of different boundary conditions (alluvial, infinite, no flow and effective SDF). IDS AWAS can create model input in two ways: 1) each well can have a list of pumping records consisting of a pumping rate and duration (original mode), or 2) input records consisting of net consumptive use or recharge in a daily or monthly time step can be used. Year type can be set to calendar, irrigation, or U.S. Geologic Survey (USGS). Data can be projected into the future or past based on historical data, and the effect of turning off the well by specifying an end date beyond the period of record can be simulated.

The IDS Group's work in the South Platte is one framework for the development and implementation of decision support tools to assist water managers. There continue to be opportunities for updating the current methodology used for calculating augmentation requirements. Fertile areas for ongoing research include developing, maintaining, updating, and deploying DSS.

Software Development Approach

Building on good communication with water users, the IDS Group adopts a user-centered approach to DSS development. Using this approach, we have developed several data driven tools that are widely used in the South Platte and other parts of Colorado. These tools are collectively called the SPMAP (www.ids.colostate.edu/projects/splatte).

The SPMAP tools include a GIS tool that calculates CU, and a tool for calculating depletions to an aquifer. The GIS tools can be used to determine the location and size of irrigated lands, groundwater wells, weather stations, and other data important for determining consumptive use for an area. This data can then be used to run the IDSCU Model to estimate CU as well as groundwater withdrawals to meet crop water needs. The CU withdrawals by pumping can then be exported to IDS AWAS, which can estimate the impact that groundwater pumping will have on the river. IDS AWAS can also be used to determine the effects of groundwater recharge on the river. They provide a comprehensive and flexible approach to meeting the modeling needs of water managers on the South Platte River.

At each major stage of development, the software is provided to the participating organizations via the Web along with online documentation and hardcopy documentation that can be downloaded and printed.

To make the programs easier to use and provide new options for building input files and viewing output, GUIs are constructed in Visual C. The development and user platform is a PC running Windows 95/98/NT/2000. Development has proceeded by using a "modular" approach, meaning tools can be used as stand-alone components or used in tandem. New components and tools can be substituted or added to the system with minimal changes to the other components or the data storage.

User documentation for the software is available on the Internet and can be accessed from help menus in the model interfaces. The combination of using developed models, building graphical interfaces, using Avenue scripts, following a modular approach, and developing good documentation makes this software flexible, generalized, and easy to use.

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Environmental Risk Assessment and Management System (eRAMS)

Mazdak Arabi, Department of Civil and Environmental Engineering, Colorado State University

The environmental Risk Assessment and Management System (eRAMS) is a comprehensive support system that enhances decision makers' capacity to target conservation practices for sediment, nutrient, and pesticide control. The tool can incorporate economic, environmental, and management criteria in the decision making process at the watershed scale. The eRAMS tool provides a Web-based participatory geographic information system (GIS) platform and requires no software installation by the end users. Users can access all components of the platform online at www.eramsinfo.com. The tool works across spatial scales from farmland to watersheds and daily or larger time steps (e.g., monthly, seasonal, or annual) and is fully compatible with other commonly used databases/GIS technologies and thus takes advantage of readily available data. Since these capacities are implemented and maintained on the host server, users will not be required to master the underlying database management and modeling algorithms. Ultimately, watershed stakeholders across the U.S. will be able to use this targeting tool for conservation planning and the implementation of watershed plans.

The development of eRAMS hinges on the nexus of technical and institutional barriers in the adoption of targeting strategies. Technical barriers are addressed by automating the data collections and organization, modeling, and multi-criteria decision analysis process on the Internet. While conservation practices are implemented at the field, water quality improvements are often desired at the watershed scale. In this context, the use of simulation models is ubiquitous. Complicated modeling approaches can estimate the field and watershed scale benefits but require significant computational resources that are not afforded to most stakeholders. The eRAMS technology automates spatial overlay of soil, land use, terrain, and other data layers in order to create input files for complex hydrologic and water quality models used to evaluate management practices. A cost model is included to evaluate of the cost-effectiveness of watershed plans. The technology also includes a system optimization module that fully explores the tradeoffs between conflicting socioeconomic and environmental criteria at the watershed scale, but more importantly, can unambiguously identify the range of solutions that are most consistent with stakeholders' priorities.

eRAMS takes technology transfer to a whole new level, because extension of the tool does not require installation of any specialized hardware and software by end-users. Watershed planners will benefit from vast data resources and models that are currently accessible to the research community and will be empowered to assess the costs and conservation benefits of alternative management scenarios. To foster broad participation, the Web technology is developed under the supervision of an advisory group from agencies that are likely to use the tool to assess and plan conservation systems and to make management decisions. In addition, farmers and landowners are included in this group, since decisions are implemented at a landowner and farm level. To address institutional barriers to the adoption of new technologies, the development of eRAMS is coordinated with federal and state agencies that are responsible for building capacities for conservation planning and watershed management. The eRAMS tool and its components are designed in line with the data and modeling infrastructure of these institutions.

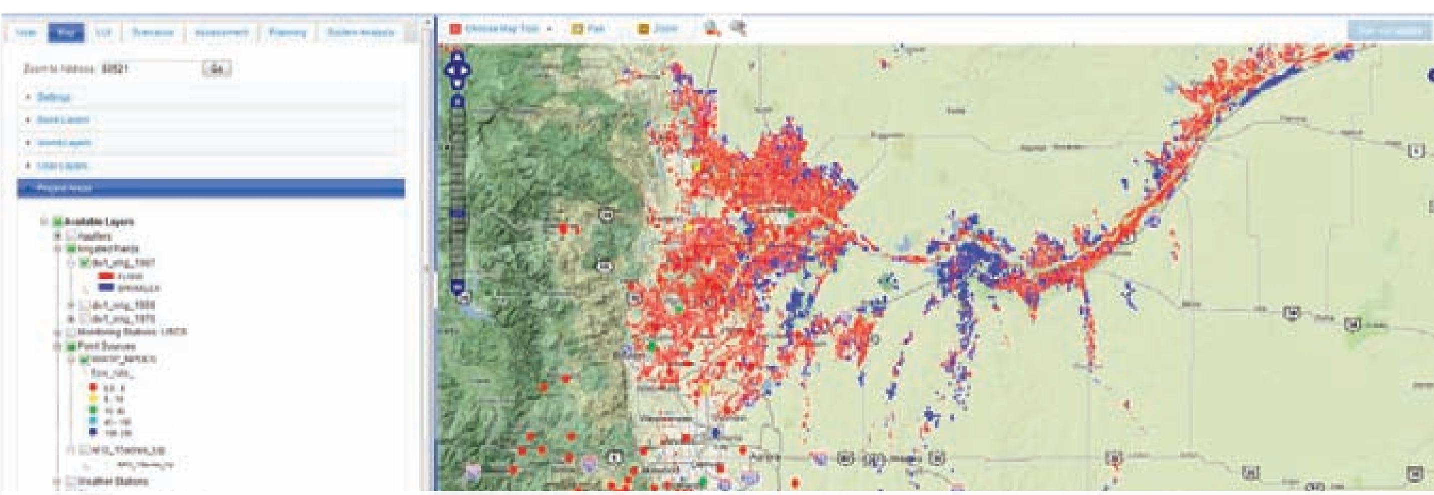

Figure 1. *An illustration of data overlay in eRAMS showing the location of irrigated fields and type of irrigation practices, along with the location and capacities of wastewater treatment plants.*

Although the initial efforts have focused on the South Platte River Basin in Colorado, the applicability of the technology will be spatially corroborated in other watersheds within the U.S. with significantly different eco-hydrologic regimes. Figure 1 illustrates the data overlay capacities of eRAMS in the South Platte River Basin, Colorado.

Data Inventory: eRAMS is equipped with a digitization module that facilitates drawing point, line, and/or polygon features on Google Maps or Bing Maps to specify field boundaries or conservation practices and enter their attributes (Figure 2). The digitized features are automatically overlaid with data sources such as soils, land use, and elevation for conservation assessment and planning. Specifically, major soil types, land use, and slopes of polygons are extracted and stored. Additionally, eRAMS enables the stakeholders to identify their water quality goals for the assessment/planning process. Goals might include reducing pollutant loads from a field or at the outlet of the watershed. The stakeholders then select the conservation practices that will be included in the analysis and the costs that are included in the analysis. The economic analysis may be a maximum total budget, or the goal may be to reduce costs to achieve a certain water quality target.

Watershed Modeling: The field-scale water quality benefits of conservation practices are evaluated using the Agricultural Policy/Environmental eXtender (APEX) model, while the watershed scale benefits are estimated using the Soil and Water Assessment Tool (SWAT). Both of the models have been extensively examined for conservation planning and watershed assessment. The U.S. Geologic Survey's MODFLOW (three-dimensional finite-difference ground water model) and SPARROW (surface water quality model) are among other capacities that will be integrated with eRAMS.

System Analysis: eRAMS is equipped with sensitivity analysis, uncertainty analysis, and automatic calibration engines that facilitate parameterization of the SWAT, APEX, and other models for the area of interest on a parallel computing platform. eRAMS benefits from distributed/parallel computing capacities that will expedite the convergence of the computational procedure.

Conservation Practices (Best Management Practices or BMP) [1]: The BMP module simulates the impact(s) of conservation practices on fate and transport of pollutants. Various processes that are considered when representing a practice include: infiltration, surface runoff (peak and volume), upland erosion (sheet and rill erosion), gully and channel erosion, nutrient and pesticide loadings from upland areas, and within-channel processes. The list of management practices incorporated in eRAMS includes: wetlands, irrigation practices, buffer strips, tillage and residue management, detention ponds, grassed waterways, and other agricultural and urban stormwater management practices.

Scenario Analysis: With this module, the user can compare various scenarios and evaluate the tradeoffs between costs and conservation benefits of different management decisions. For example, they will be able to compare the performance of buffer strips with varying widths or evaluate the impacts of different fertilizer application rates, timing, and methods.

Optimization [2]: The system optimization component of eRAMS enables users to identify desired cost-effective conservation plans that achieve their water quality targets. This tool explores the tradeoffs between environmental, economic, and sustainability criteria. In several case studies, we demonstrated that conservation plans derived from this optimization approach could achieve the same conservation benefits in term of reduction of pollutant

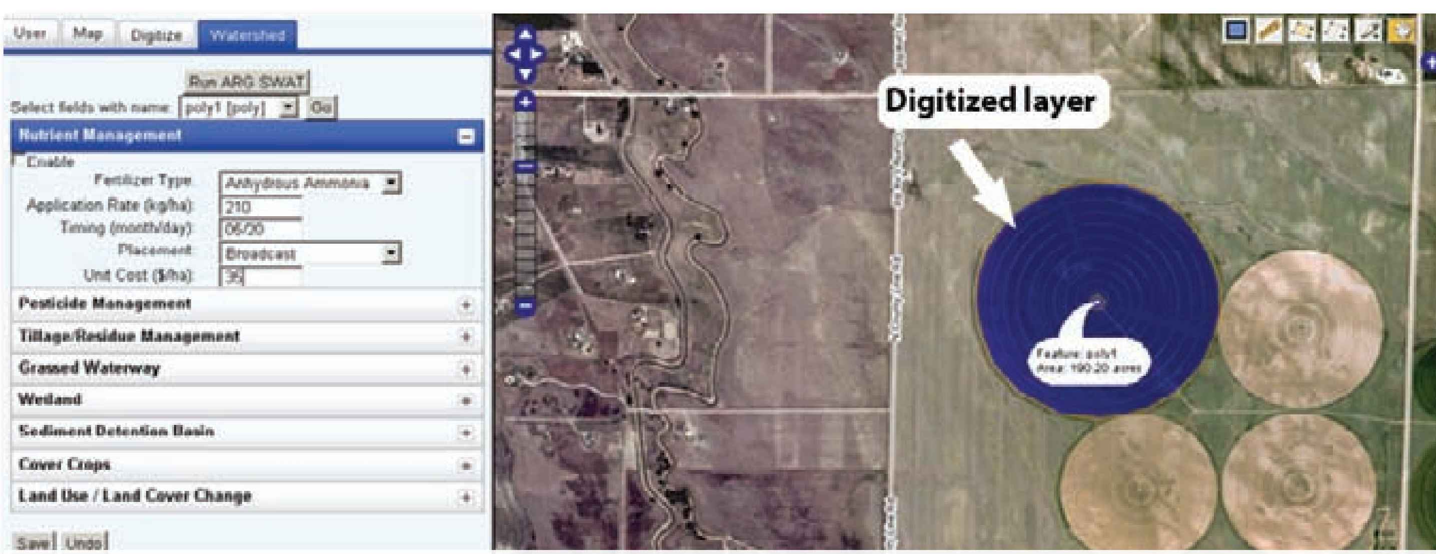

Figure 2. *An illustration of mapping a field boundary and specifying attributes of conservation practices.*

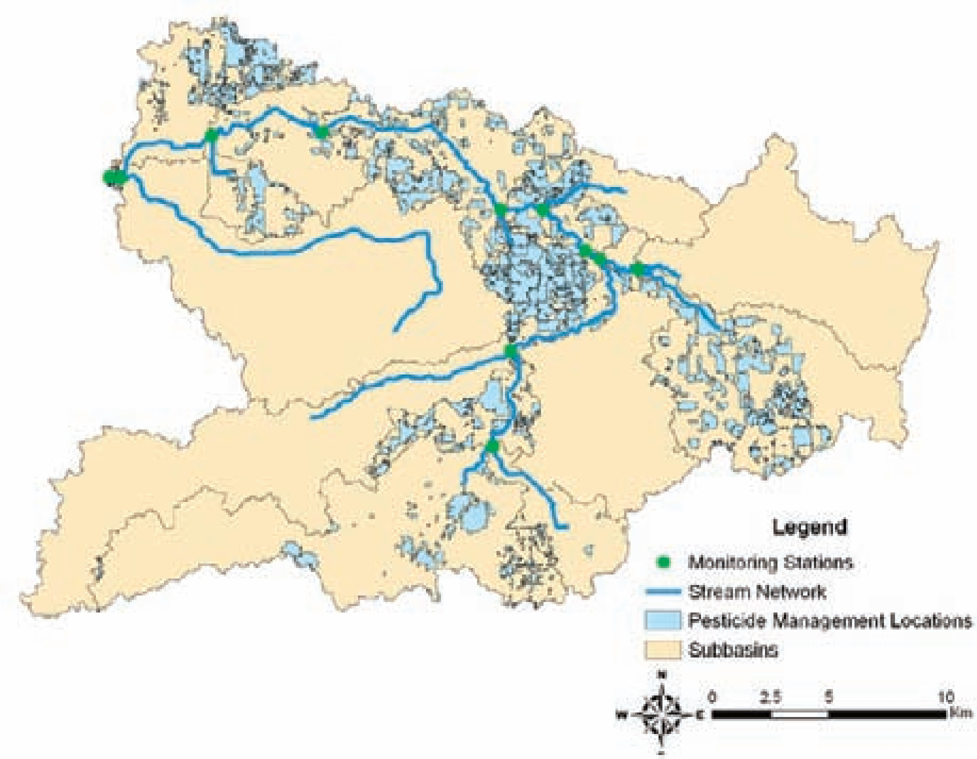

Figure 3. *An example of outputs of eRAMS identifying the landscape position of most effective management practices for pesticide control at the watershed scale.*

loads at significantly lower costs when compared to existing watershed plans. Figure 3 depicts an example of maps created from optimization and planning module of eRAMS.

Map Production: eRAMS provides the ability to quickly define map collections for the production of map sheets that can facilitate the conservation planning and watershed assessment process.

Other Modules: eRAMS is also equipped with modules for location-based information on management, recreation, renewable energy assessment, solar energy park development, and urban drainage, to name a few.

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An Integrated Urban Water Model to Provide Decision Support on Water Conservation Practices

Sybil Sharvelle and Larry Roesner
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As utilities grapple with limits on resources, rate structures, and workforce capacity, they must integrate their management systems more fully. This will require data integration, decision-making, and use of facilities, as well as integration of water, wastewater, stormwater, and other resources. Integration methods should be worked out conceptually and practically using both top-down and bottom-up approaches. For example, dual water systems and use of graywater are integration issues that must be worked out at both local levels and systemic levels, where regulatory controls apply. The CSU Urban Water Center is developing a simple Integrated Urban Water Model (IUWM) that will allow users to examine a variety of alternatives for integrating water, wastewater, and stormwater infrastructure into a single "system" that minimizes the import of external water into the system and the discharge of wastewater out of the system by reusing the water within the system for non-potable demands. The model also will examine the capital and operating cost tradeoffs between alternative scenarios.

Sybil Sharvelle (left) and Larry Roesner (right) with a former graduate student.
Photo by CSU photography

The goal behind this model is to allow a user such as an urban planner or water utility manager to quickly generate expected water use and cost figures over a defined service period. The model generates a baseline assessment of standard water supply and wastewater practices and allows the user to compare those results to alternative scenarios involving sustainable water practices. Over the long term, the IUWM will serve as a tool that may be easily applied to determine the efficacy and suitability of sustainable water conservation and reuse practices to any location within the United States.

Currently, the model is capable of evaluating the efficacy of the following practices: water conservation (indoor and outdoor), reclaimed wastewater reuse for irrigation, graywater reuse for irrigation and toilet flushing, and stormwater capture for irrigation and other non-potable uses. The final version of the model will be freely distributed to the public. Ideally, an urban planner or water utility manager will be able to approach the model with an understanding of their region's needs and gain an understanding of whether the practices available in the model would prove beneficial to their community. The number of alternative scenarios is unlimited, and the ability to compare the results of five scenarios is included. The user will input data for an area of interest such as water demand (shower, laundry, kitchen, outdoor irrigation etc.), hydrology of the area, and costs associated with the delivery of water and treatment of generated wastewater. Output results include treated water demand, irrigation demand, total costs, treated water savings, wastewater reduction, and total cost savings. By comparing these outputs for several different water conservation scenarios, users can make decisions about the most effective methods to achieve cost and water savings for their area.

Currently, Drs. Roesner and Sharvelle are managing the model's development. Previous versions of the model have been spreadsheet-based, while the most recent version is a standalone application with a user-friendly interface. Beta testing of the model will be conducted in collaboration with the city of Fort Collins. The model will be applied to an area of Fort Collins, and its usability will be confirmed based on the type of data that the city has available for input. Upon completion of the Fort Collins pilot test, the model will be improved and applied to several different cities in the United States. The long-term vision for the model is that it will be integrated into a Web-based geographical information system (GIS) platform whereby location-specific data inputs will be directly uploaded once a user selects the area of interest. Our goal is that urban planners and water utility managers nationwide will apply the IUWM to make better decisions about how to manage water.

The Story of Regenesis Management Group: Balancing Water Use for Profit and Conservation

Jerd Smith

Denver-based Regenesis Management Group (www.regenmg.com) is developing an innovative water monitoring, analysis, and forecasting product that will allow farmers to use billions of gallons of water more efficiently, sell some of the excess to thirsty cities and power plants, and leave the rest of the water in streams. Regenesis hopes the system might support not only capitalistic concerns, but environmental concerns as well.

The company, founded in 2009, believes its suite of water management tools, known as the SWIIM™ System (Sustainable Water & Innovative Irrigation Management™), will help transform the way agricultural water is distributed, bought, and sold. Using about $1 million in start-up funding, a test farm on Colorado's northern plains, and a team of researchers at the United States Department of Agriculture and Colorado State University (CSU), Regenesis hopes to launch a beta version of SWIIM™ later this year.

"This is a way of solving the water crisis on the Front Range," said Ed Warner, a philanthropist and one of four original founders. "It's a crisis of culture – urban versus rural. It's a crisis of usage – use it or lose it, and dry up farms or manage for conservation and maximization of benefit to all water users."

In addition to Warner's work with Regenesis, he funded the Chairs of Geophysics and Economic Geology at CSU. He is known for his philanthropic work in natural resource conservation and in 2005, CSU named the Warner College of Natural Resources after him. The company's team also includes hydrogeologist and research director Robert Stollar who recently funded the Chair of Hydrogeology at CSU, water engineer and irrigation expert Stephen Smith, and Kevin France, a businessman with experience in water transactions.

A farmer typically only fully consumes a portion of his water right. While the rest eventually returns to the stream and satisfies other water right holders or keeps streams and man-made wetlands alive, there is still much that could be redirected and used by water-thirsty cities looking to identify their long range needs. The goal at Regenesis is to make this redistribution easier and faster.

The mission at Regenesis is a difficult one, in part because it hasn't been until fairly recently that new measuring systems – computer-controlled irrigation gates, networks of stream gauges, soil moisture sensors, and remote data gathering devices – have become affordable enough to allow farmers and irrigation companies to use them, and demand for such devices has increased with the increased demands for water use.

Kendall DeJonge, a graduate student in Civil and Environmental Engineering, installed soil moisture sensing equipment on the Regenesis research farm last Spring.

Photo by Stephen Smith with Regenesis Management Group

These changes are the foundation on which Regenesis is building new cropping and management regimes, where field-based water and crop data can be fed instantly into computers and stored in databases. Open and close commands for irrigation systems can be issued as soon as stream gauges change or soil sensors register a new reading. Annual water supply forecasts can be coupled with cropping plans, all to help farmers decide how best to use their water and to allow cities and industrial users easy entry to a nascent water market where farmers can sell the use of an acre-foot of water almost as easily as they can sell a bushel of corn.

Technology, however, isn't the only issue with re-allocating water to protect farms and streams. In Colorado and other western states, water laws make water marketing and leasing, as well as pure conservation, difficult. These laws also sharply limit the ability to move water from one use to another quickly. Both usually require expensive engineering studies and years in special water courts, proving that the changes - from farm use to municipal or industrial use - aren't harming someone else's water rights.

"It's not that we don't have enough water," Warner said. "It's that our laws don't allow for enough flexibility" in how water is used and distributed.

If a farmer opts to use only 3,500 acre-feet of a 4,000 acre-foot consumptive use water right, and leases the remaining 500 to a city, he must prove definitively that he really had a consumptive use right of 4,000 acre-feet. Otherwise, the sale of that 500 acre-feet would represent an expansion of his water right. That's illegal in Colorado and many other western states operating under prior appropriation. Lawsuits over consumptive use are common, long, and expensive, because if you've expanded your water right by misstating the consumptive portion, that means someone else's right has been diminished.

This is where Regenesis hopes to make its mark by combining precise measurement with in-depth, computerized record keeping, powerful databases, and easily accessible water models whose accuracy and data can be verified by regulators and those who want to buy or lease water. Regenesis' France said the company doesn't envision any need to change water law. Rather it hopes to minimize the amount of time farmers and cities must spend in court to transact sales and leases while creating an efficient system to manage these transactions in the long term.

Regenesis believes it can do that using the SWIIM™ System and educating farmers and cities about new options and cooperation potential. It is the difference between spreading water over a field and using rough numbers to determine amounts applied and amounts used and running a carefully controlled, carefully monitored agricultural plumbing system that can generate data-driven reports on the hour, leaving little to guess work and best estimates.

Regenesis co-founder Stephen Smith – an irrigation expert – has spent 35 years observing and solving the problems inherent in irrigation systems. He, with the help of the U.S. Department of Agriculture and CSU, has been instrumental in developing a unique set of tools that allow farmers to sit down at their desks, open an application on their computers, and observe how their crops are performing, how much water is being applied to a field, how much water the crops are actually using, how much water is likely to be available from snowpack in any given year, and as a result, what the demand will be for this scarce resource.

In a dry year, if water is scarce and water prices high, farmers could develop a significant revenue stream by parting off a piece of their water for lease to a city. At the same time, cities save money because they won't need to develop a new dam and reservoir to meet demand. And streams benefit because no one needs to take more water from their flows.

There are a number of new cropping methods Regenesis is utilizing in its water models. Traditionally, cities have purchased farms outright and taken the water off the land, storing it in their reservoirs. More recently, farmers have begun implementing rotational fallowing plans, where, depending on agreements with urban areas, they have opted not to plant certain fields and crops in a given year, fallowing some lands, and selling or leasing the unused water to a city. Under new planting regimes, researchers working with Regenesis are looking at something known as "deficit irrigation." With this technique, new soil sensors and other climatic monitoring devices help farmers cultivate healthy crops with less consumptive use water. Using all the above planting techniques gives farmers more flexibility in deciding which crops to plant each year and to make an existing asset – water – yield more revenue.

"We want farmers to be able to look at a computer and understand what their options are. We're putting together technology options they can understand. They look at the computer and say, "Here's my farming operation. Here's how I might operate in the future. What does that look like?" Smith said.

The market for such a product has huge potential. While the product is likely to be attractive worldwide in the future, global warming, population growth, and semi-arid climates make the American West an ideal proving ground.

Part of the instrumentation on the Regenesis research farm includes an internet-accessed camera that records plantwater stress at multiple times during the day.

Photo by Stephen Smith with Regenesis Management Group

Regenesis first plans to focus marketing efforts on 10 test states: Colorado, California, western Nebraska, Utah, Idaho, New Mexico, Arizona, northwestern Wyoming, Nevada and Texas. Within these states, more than 500,000 farms operate and about 33 million acres are irrigated, France said. Water laws are strict, and demand is growing.

"In these areas, there is high pressure for alternative use, where sharing water has become an actual need. We think these states have need and provide a ripe opportunity," France said.

Jonathan King, a graduate student in GeoSciences, is shown completing the wiring for six drainage lysimeters that monitor subsurface return flows under the research plots.

Photo by Stephen Smith with Regenesis Management Group

Even with SWIIM™, transferring water faces challenges. Pipeline and storage systems must be used and for farms in remote regions, new delivery systems must be built or exchanges initiated. But perhaps the greatest challenge, the SWIIM™ System founders believe, is convincing lawmakers, regulators, cities and farmers, that the concept and system are sound.

Irrigation manager Don Magnuson with Cache La Poudre Management Co. said he thinks the SWIIM™ team has most of the engineering, scientific and financial expertise it takes to make the company a success. "But there is a lot of skepticism among farmers, water lawyers and regulators," he said. "That's the major challenge, but if you have good documentation, it can be done. The science and the financing is always easier than the people."

Platte River Study Published: Implementing the Endangered Species Act on the Platte Basin Water Commons

David M. Freeman
Professor Emeritus of Sociology, Colorado State University

After more than 30 years of negotiations, representatives of Colorado, Wyoming, Nebraska, the environmental community, and the U.S. Department of the Interior have agreed on ways and means to reorganize about 11 percent of the average annual surface flow of the Platte River as measured near Grand Island, Nebraska. The objective is to recover and sustain river and terrestrial habitats along a 70-mile main-stem central Platte River reach on behalf of whooping cranes, interior least terns, and piping plovers. The recovery effort will also examine the hypothesis that program actions will serve habitat requirements of the pallid sturgeon. The Platte River Habitat Recovery Program was launched January 1, 2007.

Now the story about how three fractious states negotiated a deal with federal authorities is available in detail. The book *Implementing the Endangered Species Act on the Platte Basin Water Commons* relates contending positions as parties opposed to the very idea of such negotiations slowly and haltingly moved from negative emotional venting to problem solving. It is a tale documented by a sociologist who attended the bulk of the negotiating sessions from 1997 through the conclusion in 2006. The text captures aspects of a major western water negotiation not to be found elsewhere.

Parties had fundamental needs that were deeply conflicting. The United States' Fish and Wildlife Service (USFWS), steward of the Endangered Species Act, had to demonstrate that it was possible to advance a meaningful federal environmental agenda in the midst of sovereign states' water regimes' historic emphases on utilitarian water uses. How could the USFWS successfully introduce a river restoration agenda centering on enhancement of natural flows in a manner that would satisfy environmentalists, who had access to courts to assert their displeasure if the habitat restoration agenda should be gutted on the high plains? How could water users in the three basin states work out historically troubled relationships among themselves in order to collaborate with each other while simultaneously finding ways to suffer a federal ecological agenda on hard-working basin waters? Given that the dynamics of river restoration will require continued learning and adaptation, how can the long voyage of discovery about what does and does not work be reconciled with state water providers' needs for predictability in demands to be made upon their project water yields and treasuries? What was the interplay of science, politics, and the federal regulatory process?

Forging a multi-level (local, state, federal), multi-federal-agency (primarily the USFWS and U.S. Bureau of Reclamation but also involving the Federal Energy Regulatory Commission and the U.S. Forest Service), and multi-state deal to reorganize precious water – especially during a time of intense basin-wide drought (1999-2006) – was a prolonged process, sometimes tumultuous and bitter. Negotiators repeatedly flirted with the prospect of collapse. Yet, in the end, representatives of the colliding interests were able to lash themselves together in a cooperative Platte River Basin Habitat Recovery Program.

Peoples of the Platte waters are now riding together as they integrate – on a large landscape scale – a set of endangered species environmental agendas with those of historic utilitarian uses. What have they done? How did they do it? Why did they not abandon the enterprise? What are

the lessons to be learned? What are the implications for environmental policy? What are the implications for a policy-relevant sociology? These questions are explored in the book. What can be clearly stated here is that, in launching the program, people of the Platte have creatively and audaciously demonstrated a capacity to advance self-governance of their water commonwealth.

David M. Freeman, Professor Emeritus of Sociology at CSU, wrote Implementing the Endangered Species Act on the Platte Basin Water Commons. Boulder: University Press of Colorado, October, 2010. $45.00 hardcover. Order at your local bookstore or online: www.upcolorado.com or telephone: 800-627-7377 or 405-325-2000.

National Science Foundation Funds CSU WATER Program

Lindsey A. Knebel
Editor, Colorado Water Institute

Hydrology, meteorology, ecology, sociology, and economics might not seem like related fields, but according to Jorge A. Ramirez, Colorado State University (CSU) professor of civil and environmental engineering and Principal Investigator (PI) for the new WATER program, these distinct academic areas are all important for the multi-disciplinary research necessary to solve the water and environmental problems facing society.

The new WATER program, which stands for Integrated Water, Atmosphere, and Ecosystems Education and Research, is funded through the Integrative Graduate Education and Research Traineeship (IGERT) program of the National Science Foundation (NSF). The prestigious $2.75 million grant that Ramirez and his collaborators received is to develop a new doctoral program in integrated, multidisciplinary research and education that addresses the complex hydrologic, climatic, ecologic, and socio-economic challenges of future WATER related decisions.

In addition to Ramirez, three other CSU professors are Co-PIs: Neil Grigg, LeRoy Poff, and Scott Denning, professors of civil and environmental engineering, biology, and atmospheric science, respectively. The PIs expect that faculty from eleven science and engineering departments across CSU will become involved as faculty mentors in the WATER program.

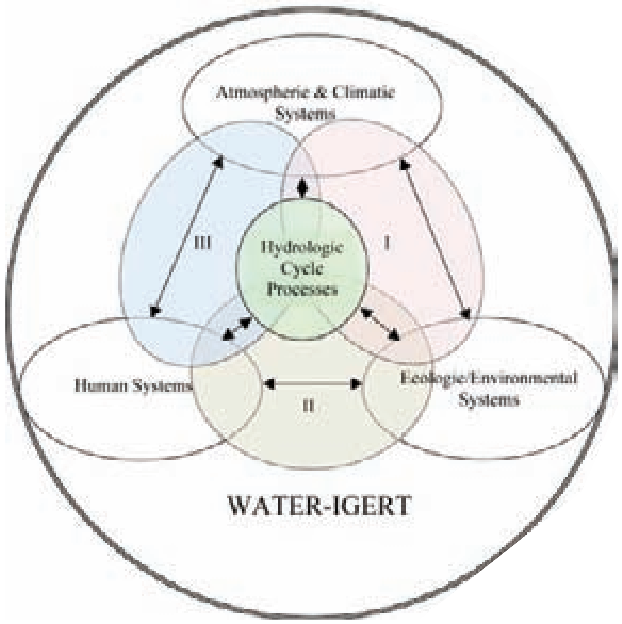
Ramirez says that up to 30 new Ph.D. students with backgrounds in hydrology, atmospheric science, ecology, and socio-economics will be funded under the WATER program. Each student will work closely with a faculty member in the research theme areas defined by the WATER program. Student recruitment for the WATER program will target students from across the U.S.

NSF's Integrative Graduate Education and Research Traineeship program or IGERT is intended to meet the challenges of educating U.S. scientists and engineers with the interdisciplinary background, deep knowledge in a chosen discipline, and the technical, professional, and personal skills needed for career demands of the future. The program is intended to catalyze a cultural change in graduate education by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries.

Contact Dr. Jorge Ramirez at ramirez@engr.colostate.edu with questions about WATER or to get involved.

From Left to Right: Principal Investigator Jorge Ramirez and Co-Principal Investigators Neil Grigg, Scott Denning, and LeRoy Poff.

According to Ramirez, the WATER program focuses on four major research themes, each of which addresses research questions at the interfaces between atmospheric, ecologic, and socio-economic systems, all permeated and modulated by the hydrologic cycle processes (see schematic). Examples of general research topics in each theme are:



Research Themes I-III depicted above in colored ovals.

Research Theme I: Hydrologic, atmospheric, and ecologic systems (HAE):

a. Coupling atmospheric, ecologic, and hydrologic processes: understanding the two-way interactions between atmospheric and land-surface processes is critical to understanding climate change, vegetation function, and watershed hydrology

b. Spatial and temporal scaling issues in hydrologic processes

Research Theme II: Hydrologic, ecologic, and socio-economic systems (HES):

a. Defining changes in water, nutrients and sediment transports due to variability and change in climate/weather, land cover/use, and water resources management

b. Developing models to 'optimize' ecosystem resilience and human economic activity that bear on the hydrologic cycle at regional scales

Research Theme III: Hydrologic, atmospheric, and socio-economic systems (HAS):

a. Regional, integrated assessment of vulnerability of hydrologic and water resource, ecologic, and socio-economic systems to environmental variability and climate change

b. The fourth Research Theme arises from the need for integration and synthesis

Research Theme IV: WATER-research integration and synthesis

a. Tradeoffs, alternative solutions, adaptation strategies, global feedbacks, and global integration

AgLet: A Water Leasing Decision Tool

James Pritchett and Perry Cabot
Colorado State University Extension Water Team

What is irrigation water worth to a farm operation in a context of statewide competition for water shares? Are the proceeds from 'alternative' agriculture transfers agreements, such as interruptible supply or rotational fallowing programs, enough of a draw that farmers may wish to lease water from their operations? For how long? A single season, or multiple years? The answers to these questions are specific to each farmer's water portfolio, resource base, and productive capacity; after all, farms have different crop rotations, yield goals, equipment, and capital. Creating a decision support tool that might help many different farm operations answer these questions is the objective of a collaborative effort under the Colorado Water Conservation Board's (CWCB) Alternative to Agriculture Transfers Program. This effort has led to the development of the Agriculture Leasing Economics Tool – AgLet.

The AgLet decision support tool was designed by Harvey Economics in collaboration with Colorado State University Extension's Water Team, Colorado Corn Growers Association, and Brown and Caldwell.[1] The tool is multi-level Excel spreadsheet that combines input costs, prices, farm production practices, and crop water production functions in an easy-to-use format. The spreadsheet delivers a comparison between the net returns of continuing a farm's existing production plan and leasing options that include interruptible supply agreements, rotational fallow leases, and limited irrigation. The spreadsheet can also perform what-if analyses that evaluate how sensitive these alternatives are with respect to changes in crop prices, yield, and production costs information.

The bottom line for a farmer in making a leasing decision depends importantly on an established baseline (current or expected profits under their full water allocation) versus the profits that would accrue to the operation under a water lease and partial cropping strategy. In AgLet, profits are calculated as a gross margin in which operating costs are subtracted from the gross revenues of the farm. The gross margin is considered a contribution to overhead, management, land, and risk (Box 1 in Figure 1). Gross margins are reported on a per acre basis and a break-even price per acre that make water leasing gains as profitable as baseline irrigated cropping gains (Box 2 in Figure 1). Should prices be higher or lower than expected, profits are changed, and this variation is reported in the financial summary sheet (Box 3 in Figure 1). Likewise, yields may be better or worse than expected, and these alternative profits are reported.

The designers of AgLet sought to create a tool that was adaptable to a variety of farming operations that at the same time would be easy to use by farmers and water managers. For this reason, users can either rely on default crop management practices and cost information provided

Box 1:

	Baseline	Water Lease	Difference
Total Gross Margins	$ 476,195	$ 482,663	$ 6,468
% Gain over Baseline			1.4%

Box 2:

	Baseline	Water Lease	
Water Lease Revenue		$ 150,000	
Acres Under Lease		500	
	Break Even	Actual	Difference
Price (per Acre)	$ 287.06	$ 300.00	$ 12.94

Box 4 (Optional):

	Baseline	Water Lease
Other Income:	$ -	$ -
Fixed Costs:		
Debt Service:	$ 10,000	
Property Taxes:	$ 5,000	
Living Expenses:	$ 40,000	
Other:		
Total Fixed Costs:	$ 55,000	

Does the Total Gross Margin meet Total Fixed Costs?

Baseline	Water Lease
Yes	Yes

Box 3:

Risk Anlaysis
This table shows what the Difference value from Box 1 would equal if crop prices and yields changed by plus or minus 10%. Green indicates you are better off, red, worse off.

		Overall Yields				
		-10%	-5%	0%	+5%	+10%
Overall Prices	-10%	$ 57,810	$ 45,650	$ 33,490	$ 21,330	$ 9,170
	-5%	$ 45,650	$ 32,814	$ 19,979	$ 7,143	$ (5,693)
	0%	$ 33,490	$ 19,979	$ 6,468	$ (7,044)	$ (20,555)
	+5%	$ 21,330	$ 7,143	$ (7,044)	$ (21,231)	$ (35,417)
	+10%	$ 9,170	$ (5,693)	$ (20,555)	$ (35,417)	$ (50,280)

For Example: If your yields on all your crops were down by 10% and all your prices were down 10%, the Difference in Box 1 would change from $6,468 to $57,810.

Box 5: (Only applicable to Interruptible Supply scenario)

Figure 1. *The financial summary tab in AgLet that compares full irrigation and other water leasing scenarios.*

[1] The project is funded through the CWCB's Alternatives to Agriculture Transfer program. The CWCB grant provided a consortium of stakeholders, including the Colorado Corn Growers Association, Ducks Unlimited, and the city of Aurora, with funds to explore innovations in water sharing. AgLet is on part of the cooperative grant effort.

by the AgLet team, or they may adapt any part of this information to their own operation. More specifically, AgLet consists of worksheet tabs that include:

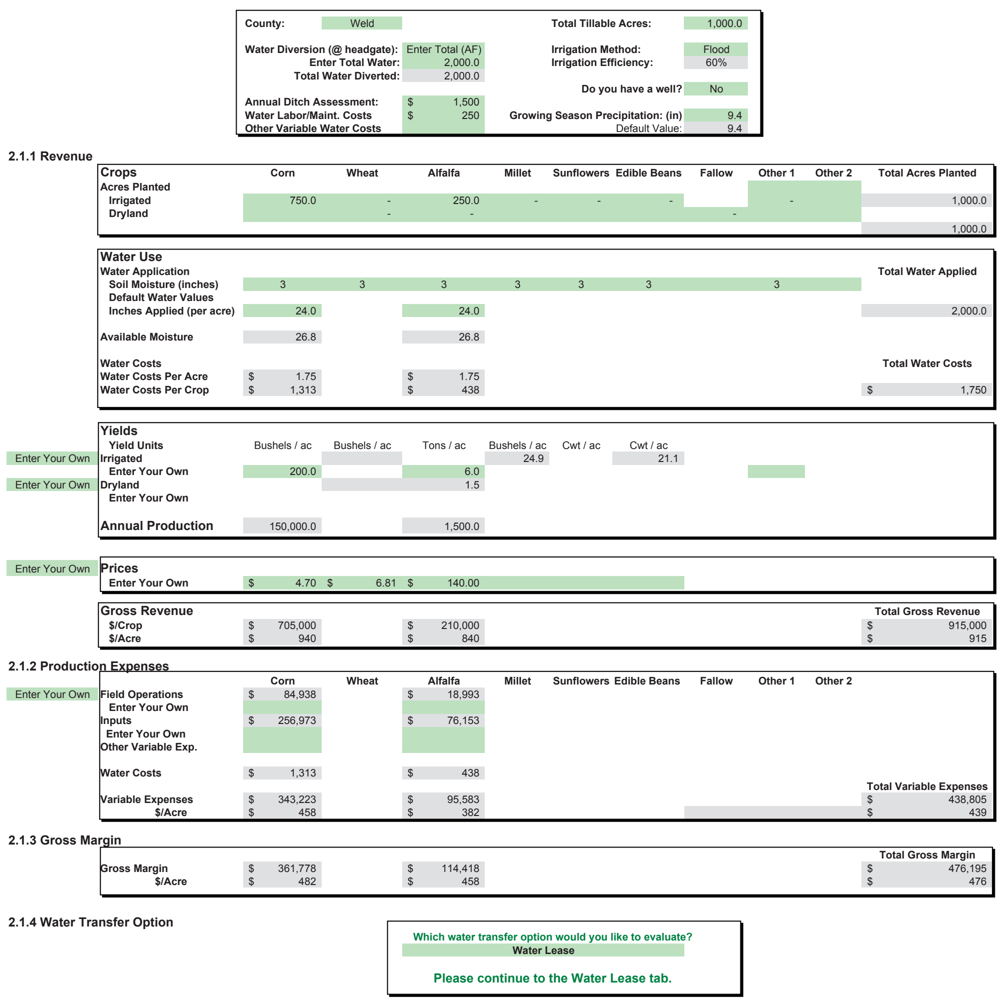
General Farm Information Spreadsheet Tab: AgLet allows users to input information specific to their own farm. As the user enters data at the beginning of this section (Figure 2), they are prompted to choose the Colorado county in which their farm is located. Designating a location is important, as county average precipitation and yields are automatically provided in AgLet. Users are not restricted to default information – the users can also input their water portfolio, expected precipitation, water costs, irrigation methods, and irrigation efficiency. The lower portion of this spreadsheet tab is dedicated to crop choices and costs. Drop down menus permit the use of default values for crop yields and costs, or the user may input their own values. Users can calculate cost information using worksheets in AgLet.

Alternative Transfers: AgLet dedicates individual worksheet tabs to three alternative transfer arrangements: water leases, interruptible supply arrangements, and deficit irrigation in which consumptive use savings are leased. In each case, the user can specify lease payments in terms of dollars per acre and then update their cropping information. As an example, a user might wish to compare a rotational fallowing approach to an interruptible supply agreement (Figure 3) in which the user expects that water will be leased three of 10 years with dryland crops grown during those leased years.

Lessons Learned

We had the chance to run AgLet under specific assumptions and were able to develop rules of thumb. These rules are true for a specific operation, and every user should take the time to adjust AgLet to their own situation. A few of these points:

Reservation Water Price: The minimum that a farmer might accept to lease water is the farm's reservation price. In some sense, this is a break-even price that must be received in order for a farmer to lease water. We've found a farm's break-even price for water leasing is seldom greater than $50 per acre-foot. The reservation price is sensitive to crop choice and crop prices – a higher break-even price is needed for crops with greater revenues per acre. The break-even price is more sensitive to a five percent change in price and yields compared to a five percent change in costs.



County:	Weld	Total Tillable Acres:	1,000.0
Water Diversion (@ headgate):	Enter Total (AF)	Irrigation Method:	Flood
Enter Total Water:	2,000.0	Irrigation Efficiency:	60%
Total Water Diverted:	2,000.0		
		Do you have a well?	No
Annual Ditch Assessment:	$ 1,500		
Water Labor/Maint. Costs	$ 250	Growing Season Precipitation: (in)	9.4
Other Variable Water Costs		Default Value:	9.4

2.1.1 Revenue

	Crops	Corn	Wheat	Alfalfa	Millet	Sunflowers	Edible Beans	Fallow	Other 1	Other 2	Total Acres Planted
	Acres Planted										
	Irrigated	750.0	-	250.0	-	-	-		-		1,000.0
	Dryland		-	-				-			
											1,000.0
	Water Use										
	Water Application										Total Water Applied
	Soil Moisture (inches)	3	3	3	3	3	3		3		
	Default Water Values										
	Inches Applied (per acre)	24.0		24.0							2,000.0
	Available Moisture	26.8		26.8							
	Water Costs										Total Water Costs
	Water Costs Per Acre	$ 1.75		$ 1.75							
	Water Costs Per Crop	$ 1,313		$ 438							$ 1,750
	Yields										
	Yield Units	Bushels / ac	Bushels / ac	Tons / ac	Bushels / ac	Cwt / ac	Cwt / ac				
Enter Your Own	Irrigated				24.9		21.1				
	Enter Your Own	200.0		6.0							
Enter Your Own	Dryland			1.5							
	Enter Your Own										
	Annual Production	150,000.0		1,500.0							
Enter Your Own	**Prices**										
	Enter Your Own	$ 4.70	$ 6.81	$ 140.00							
	Gross Revenue										Total Gross Revenue
	$/Crop	$ 705,000		$ 210,000							$ 915,000
	$/Acre	$ 940		$ 840							$ 915

2.1.2 Production Expenses

		Corn	Wheat	Alfalfa	Millet	Sunflowers	Edible Beans	Fallow	Other 1	Other 2	
Enter Your Own	Field Operations	$ 84,938		$ 18,993							
	Enter Your Own										
	Inputs	$ 256,973		$ 76,153							
	Enter Your Own										
	Other Variable Exp.										
	Water Costs	$ 1,313		$ 438							Total Variable Expenses
	Variable Expenses	$ 343,223		$ 95,583							$ 438,805
	$/Acre	$ 458		$ 382							$ 439

2.1.3 Gross Margin

			Total Gross Margin
Gross Margin	$ 361,778	$ 114,418	$ 476,195
$/Acre	$ 482	$ 458	$ 476

2.1.4 Water Transfer Option

Which water transfer option would you like to evaluate?
Water Lease
Please continue to the Water Lease tab.

Figure 2. *The general farm information portion of AgLet.*

Better to Fully Irrigate a Smaller Acreage: Repeated use of the AgLet model suggests that fully irrigating a smaller parcel is better than deficit irrigating the entire farm. This is primarily true when a dryland crop can be grown on the fallowed acreage, and the preferred crop on this portion of non-irrigated land is dryland wheat. Returns to wheat production are quite favorable at the current time as harvest delivery prices are quoted at more than $7 per bushel. These prices are not likely to persist, but even $4.50 per bushel, wheat encourages fully irrigating a small parcel.

Value at Risk: The gross margins in AgLet's financial summary depend on prices, yields, and costs. An important distinction needs to be made between pre-harvest costs and harvest costs. Grain crop costs, such as those found when growing corn, are dominated by establishment costs including seed costs, seedbed preparation, fertilizer, and pre-plant or early post-emergence chemical treatments. If a deficit irrigated crop fails due to insufficient precipitation, then these costs are lost.[2] Alternatively, alfalfa and irrigated hay crop costs are primarily based on harvest activities. In the case of alfalfa, if too little precipitation is realized, operating costs are also reduced proportionally. In this sense, alfalfa has a smaller value-at-risk when compared to corn in a deficit irrigated environment.

AgLet's Limitations: AgLet provides interesting insights into the decision to sign water leases and interruptible supply agreements. However, limitations to this tool include:

- Explicit and Implicit Assumptions: Underlying the AgLet financial summary are specific assumptions on how crop yields respond to limited irrigation, as well as assumptions underlying production costs and market prices. Users are encouraged to validate and update this information to match their own circumstances.
- Institutional Arrangements: Examples of water leasing and interruptible supply agreements can be found in Colorado, but these arrangements may require specific change of use provisions in the Colorado water court system. Change of use can be quite expensive, and the cost of the transaction might eliminate potential returns. Moreover, deficit irrigation and the leasing of consumptive use savings has not been the subject of a change of use case.
- Contract Provisions: As with signing any contract, water leasers should carefully review contract stipulations with their own legal representation. Care must be taken when considering contract stipulations, including recourse in the case of contract default, timing of payments and tax liability, etc.
- Multiple Year Impacts: AgLet has been designed for decision making at the beginning of a single cropping season. Multiple year impacts, such as the growth in farm equity over time, investments in irrigation monitoring, and measuring equipment and changes in crop rotations may have multiple year implications.

Water Lease Rate:	$ 350	($/ac)	Water Lease Years:	3
Annual Payment Amount:	$ 25	($/ac)	Contract Length:	10
Percent of Water Leased:	50%			

This sheet deals with a year in which they take your water. The payments for the years in which they do not take your water are dealt with in the Financial Summary Tab.

Revenue

Enter Your Own

Crops	Corn	Wheat	Alfalfa	Millet	Sunflowers	Edible Beans	Fallow	Other 1	Other 2	Total Acres Planted
Orig. Acres Planted	750.0		250.0							1,000.0
Revised Irrigated	375.0		125.0							
Enter Your Own										500.0
Existing Dryland							500.0			500.0
Modified Dryland										-
										1,000.0

Yields	Corn	Wheat	Alfalfa
Yield Units	Bushels / ac		Tons / ac
Irrigated	200.0		6.0
Dryland			
Production	75,000		750

Prices	Corn	Wheat	Alfalfa	Total
Prices	$ 4.70	$ 6.81	$ 140.00	
Water Lease Revenue				Water Lease Revenue: $ 175,000
Gross Revenue	$ 352,500		$ 105,000	Total Gross Revenue: $ 632,500
$/Acre	$ 940		$ 840	$ 633

Production Expenses

	Corn	Wheat	Alfalfa	Millet	Sunflowers	Edible Beans	Fallow	Other 1	Other 2	Total
Field Operations	$ 42,469		$ 9,496				#DIV/0!			
Inputs	$ 128,486		$ 38,076				#DIV/0!			
Additional Costs										
Water Costs										$ 1,750
										Total Variable Expenses
Variable Expenses	$ 170,955		$ 47,573				#DIV/0!			
$/Acre	$ 456		$ 381							
										Total Gross Margin
Gross Margin	$ 181,545		$ 57,428				#DIV/0!			
$/Acre	$ 484		$ 459							

For final results, please continue to the Financial Summary tab.

Figure 3. *An example of leasing in AgLet: Interruptible Supply Agreement Worksheet Tab.*

2. Nitrogen fertilizer may be available to subsequent crops.

- **Operational Risk:** The financial summary page provides a sensitivity analysis to prices and yields, but the variation in prices and yields is not necessarily consistent with the statistical nature of yield and price occurrences. More specifically, users are reminded that a five percent price increase need not be as likely as a five percent price decrease, and low prices are much more likely to accompany high yields than the converse. In addition, crop insurance may not be available for crops that are not fully irrigated. Users should perform many what-if scenarios when considering leasing decisions.
- **Timing:** The AgLet tool is a pre-plant decision tool and not intended to help farmers decide whether or not to lease additional irrigation water within the growing season or to shift water between crops during a growing season.

Future Work: The Colorado State University Extension Water Team will provide and host training on the AgLet in 2011 at the request of stakeholders. Training is best accomplished in smaller groups (20 or less), and interested parties can contact James Pritchett at James.Pritchett@ColoState.edu or 970-491-5496 and Perry Cabot at Perry.Cabot@Colostate.edu, 719-549-2045 for more information.

Presenters and the audience discuss AgLet after it was presented at a conference. From left to right: David Langford; Matt Lindburg of Brown and Caldwell; and Mark Sponsler, Executive Director of the Colorado Corn Growers Association.

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Recent Publications

A Geochemical Mass- Balance Method for Base-Flow Separation, Upper Hillsborough River Watershed, West-Central Florida, 2003-2005 and 2009 by G.R. Kish, C.E. Stringer, M.T. Stewart, M.C. Rains, and A.E. Torres http://pubs.er.usgs.gov/publication/sir20105092/

The National Map: New Viewer, Services, and Data Download http://pubs.er.usgs.gov/publication/fs20101123/

A Review of Aeromagnetic Anomalies in the Sawatch Range, Central Colorado by V. Bankey http://pubs.er.usgs.gov/publication/ofr20101095/

Arsenic-related water quality with depth and water quality of well-head samples from production wells, Oklahoma, 2008 by C.J. Becker, S.J. Smith, J.R. Greer, and K.A. Smith http://pubs.er.usgs.gov/publication/sir20105047/

Distribution of Isotopic and Environmental Tracers in Groundwater, Northern Ada County, Southwestern Idaho by C.B. Adkins, and J.R. Bartolino http://pubs.er.usgs.gov/publication/sir20105144/

In-Place Oil Shale Resources Underlying Federal Lands in the Piceance Basin, Western Colorado by T.J. Mercier, R.C. Johnson, M.E. Brownfield, and J.G. Self http://pubs.er.usgs.gov/publication/fs20103041/

Occurrence and distribution of dissolved solids, selenium, and uranium in groundwater and surface water in the Arkansas River Basin from the headwaters to Coolidge, Kansas 1970-2009 by L.D. Miller, K.R. Watts, R.F. Ortiz, and T. Ivahnenko http://pubs.er.usgs.gov/publication/sir20105069/

Proceedings of the Colorado River Basin Science and Resource Management Symposium, November 18-20, 2008, Scottsdale, Arizona by T.S. Melis, J.F. Hamill, L.G. Coggins, Jr., P.E. Grams, T.A. Kennedy, D.M. Kubly, and B.E. Ralston http://pubs.er.usgs.gov/publication/sir20105135/

Rock Geochemistry and Mineralogy from Fault Zones and Polymetallic Fault Veins of the Central Front Range, Colorado by J.S. Caine, and D.J. Bove http://pubs.er.usgs.gov/publication/ds492/

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Simulated Groundwater Flow in the Ogallala and Arikaree Aquifers, Rosebud Indian Reservation Area, South Dakota-Revisions with Data Through Water Years 2008 and Simulations of Potential Future Scenarios by A.J. Long, and L.D. Putnam http://pubs.er.usgs.gov/publication/sir20105105/

U.S. Geological Survey Colorado Water Science Center: co.water.usgs.gov

Rolling Up the Sleeves: Agricultural/Urban/Environmental Leaders Tackle Water Sharing Obstacles in the Colorado River Basin

MaryLou Smith
Policy & Collaboration Specialist, Colorado Water Institute

What can a group of 35 highly motivated water leaders accomplish by retreating for two days to a secluded castle on a 3,100-acre ranch overlooking the Front Range of Colorado? Can a group selected to represent western agricultural, urban, and environmental interests agree on recommendations for overcoming obstacles to sharing water for all their needs?

Reagan Waskom, director of the Colorado Water Institute, facilitates a small group session.
Photo by John Foster

To answer the first question, a great deal can be accomplished. And yes, diverse interests can agree, and given a tightly focused agenda and pre-meeting assignments, two days of concentrated work can produce a bold set of recommendations.

Water presently diverted for agriculture is under intense pressure as urban and environmental needs increase. A grant to the Colorado Water Institute from the Walton Family Foundation funded the convening of stakeholders in a workshop to determine how the status quo approach of permanently transferring water from agriculture could be supplanted by overcoming obstacles to creative water-sharing strategies, which provide multiple benefits for agriculture, cities, and the environment.

An extensive interview process resulted in a rich toolbox of water sharing strategies. Participants selected from those interviews agreed to provide in advance of the workshop a one-page paper describing the strategies with which they had experience and the obstacles they faced. Sharing this information ahead of time enabled participants to hit the deck running—to immediately zero in on recommendations to address common obstacles.

A strategy and obstacle example provided by a pair of participants is that of the Elephant Butte Irrigation District and the New Mexico Audubon Society. Together they developed an environmental water transaction program so that Audubon could acquire water rights from a farmer to support habitat in the same way one farmer could acquire water rights from another farmer to grow a crop. Of concern is whether allowing agriculture to environmental transfers such as this will cause problems down the road if application of the acquired water is used to provide habitat for species listed as threatened or endangered. The unanswered question is whether an endangered species will get precedence over agriculture when the region experiences a low water year.

What was the motivation for all this? In a 2008 report, western governors asked the Western States Water Council (WSWC) to work with states and stakeholders to address the issue of how agriculture to urban water transfers could be accomplished without harming rural communities or the environment. WSWC reached out to the Family Farm Alliance, Western Urban Water Coalition, The Nature Conservancy, and others to cooperate in addressing the issue.

Choosing the right mix of participants was critical to the success of the workshop. Participants were chosen to reflect a diversity of states, primarily from the Colorado River Basin, but also from other western states. A representative mix of practitioners and academics added to the strength of the group, as did a mix of those falling in the categories of attorney, engineer, farmer, economist, professor, policy analyst, irrigation district manager, and municipal water provider.

The goal of the group of 35 who met in the summer of 2010 was to showcase real opportunities for policy improvement.

Their recommendations, along with the toolbox of water sharing strategies uncovered through the pre-workshop interviews, are included in the report *Agricultural/Urban/Environmental Innovative Water Sharing Strategies for the Colorado River Basin and the West* at cwi.colostate.edu.

Expedited Review Process Pilots

Participants find that even when they have broad support from urban, environmental, and agricultural stakeholders, projects and programs for effectively sharing water often get bogged down in regulatory review. They recommend that each state pilot an expedited review process to facilitate a one-stop-shopping means to reduce costs and gain more timely approval. Needed:

- A multi-use water sharing project or program that has broad support
- A governor-appointed liaison to guide the project through state and federal approvals
- A governor-requested lead federal party designated to be involved in all review process aspects
- Cooperation of the liaison and federal lead to minimize repetitive agency information exchanges and lead to reduced costs and timely approval

Flexible Basin Wide Approach

Participants believe that coordinating decisions about water infrastructure, storage, release, and other programs at the watershed level would lead to solutions for agricultural, urban, and environmental water sharing that might not otherwise be obvious when working only at smaller scales.

They recommend:

- Simulation of management strategies that benefit multiple uses and sectors
- Watershed scenario modeling and studies to look for opportunities for various sectors to cooperate
- Improved institutional frameworks for better operation and management, flexibility, and resiliency

View from Cherokee Park Ranch and Castle, where the event was held. Photo from Cherokee Park Ranch and Castle Files

- Planning tools that accurately depict the complexity of a basin's available flow and multiple demands across its geography, not just its mainstem rivers and large storage projects

Clearing Obstacles to Creative Water Sharing and Transfers

Because they experience significant obstacles to sharing water for multiple needs without permanent fallowing of agricultural lands, participants recommend ways to reduce those obstacles. Their recommendations include:

- The appointment of a cabinet level advocate in each state who would work to empower the success of collaborative water sharing solutions
- Incentives and pilot programs that encourage temporary transfers but do not infringe on vested property rights
- Development of multiple interest criteria and thresholds that define best management practices for transfers/water sharing strategies to be applied in lieu of expensive regulatory approval
- Encouragement of mutually beneficial infrastructure sharing and development, including cooperation in the optimal use of already existing infrastructure
- Voluntary water resource sharing zones based on grassroots water partnerships between municipal/industrial, agricultural, and environmental users, within which water and financial resources might be traded more freely to the mutual benefit of sectors, using such elements as tax incentives
- Promotion and restoration of Conservation Title funding to programs such as EQIP (Environmental Quality Improvement Program) in the next U.S. Farm Bill

Stakeholder Process to Facilitate Multi-Benefit Water Sharing Solutions

Participants believed that successful water sharing strategies require effective collaboration between multiple parties with a variety of interests. They believe that decision makers must pay serious attention to the process in which stakeholders are engaged in order to increase the likelihood of success. Their recommendations include:

- Early and broad stakeholder involvement in creating solutions that satisfy diverse needs
- Empowering relationship building and the development of partnerships between stakeholder groups via means such as basin wide water roundtables
- Interest-based process which addresses stakeholder needs and encourages the development of outcomes that address multiple needs and values
- Process tools and incentives including effective resources, information, and facilitation, including modeling tools and funding for studies and pilot projects
- Research-based public outreach

What's next? The Agriculture/Urban/Environmental Water Sharing Work Group that developed this initiative will lead in working with participants to carry these recommendations to the Western States Water Council, the Western Governors Association, the Bureau of Reclamation, all of their constituent groups and others. Their intent is to affect change in policy and procedure that currently creates obstacles to creative sharing of water to meet demands that are increasingly in conflict.

Perhaps a retreat to a castle on a ranch looking down on Front Range cities will result in down to earth, practical change to promote agricultural, environmental, and urban water sharing.

Group of participants at workshop representing seven western states and Washington, D.C. Photo by Ron Bend

Colorado State Forest Service Strategy Addresses Watershed Concerns

Ryan Lockwood, Public and Media Relations Coordinator, Colorado State Forest Service

The Colorado State Forest Service (CSFS) recently released a comprehensive statewide forest resource strategy designed to address threats to Colorado forests, including the declining health of forested watersheds and riparian ecosystems.

The *Colorado Statewide Forest Resource Strategy* is aimed at focusing limited resources where they will achieve the greatest benefit, and was developed in cooperation with forestry stakeholders throughout Colorado. The strategy accompanies and builds on the *Colorado Statewide Forest Resource Assessment*, a geospatial analysis of current forest conditions in Colorado watersheds that was completed by the CSFS in December 2009.

A tamarisk-infested riparian ecosystem in southeast Colorado.
Courtesy of CSFS

A healthy riparian ecosystem in southeast Colorado.
Courtesy of CSFS

"Our assessment led to the identification of 10 major threats to Colorado's important forest landscapes, and the strategy provides us with the tools necessary to address those threats," said Jeff Jahnke, state forester and director of the CSFS. "The assessment and strategy will help guide the CSFS and other forestry stakeholders as we take a landscape-level approach to leveraging limited resources where they will achieve the greatest benefit."

Two of the 10 threats specifically addressed in the strategy are declining forest watershed health and declining riparian ecosystems. The other threats to Colorado's important forest landscapes identified in the strategy are forest fragmentation, a decline in forest products businesses, insect and disease activity at record levels, wildfires both inside and outside the wildland-urban interface, community forests at risk to insects and diseases, forest resiliency and adaptability to changing climatic conditions, and air quality issues associated with forest conditions.

"Emphasizing watershed and riparian health was vital to a comprehensive forest resource strategy," said Jahnke. "Colorado's rivers provide water to 18 states, making it essential that we protect our watersheds from wildfire, insects and other threats that negatively impact our forests."

The CSFS strategy document attributes the threat of declining watershed health to forest conditions that may allow fires to burn more intensely and severely than in pre-human settlement conditions. Intense fires can sterilize soils, inhibit regeneration, and increase runoff and erosion. Regarding riparian ecosystem decline, the strategy document identifies invasive tree species, such as tamarisk and Russian olive, as the primary cause. These invasive species adversely affect water flows and decrease species richness in riparian areas by out-competing native flora, which can impact wildlife habitat, recreation, and water supplies.

To address riparian and forested watershed health concerns, the CSFS strategy identifies forest management sub-strategies, including the following:

- Facilitate collaborative approaches to implement activities that help protect watersheds and water supplies
- Integrate forest management plans at a watershed scale to enhance forest resiliency and adaptability
- Adapt silvicultural activities to promote flexible forest response to a changing climate

- Ensure best management practices are applied to protect and enhance riparian areas
- Promote large-scale mitigation and rehabilitation of riparian ecosystems through collaborative processes
- Promote conservation easements that allow management around riparian areas
- Encourage invasive species removal from managed riparian areas

The strategy also lists a number of possible tactics for addressing these sub-strategies, including working with water providers to protect forests upstream of high-priority water supplies, planning multi-objective projects designed to stabilize and restore stream channels, and developing educational campaigns to address the impacts of invasive species.

Development of the statewide forest resource assessment and strategy evolved as a result of decreased availability of resources, including funding, and threats to forests that are posing challenges at state and national levels. Realizing these challenges, in 2007, the U.S. Forest Service (USFS) sought a way to better shape and influence the use of forest land on a scale that would optimize public benefit for current and future generations. With this goal in mind, the USFS State & Private Forestry Program Redesign Initiative was reportedly introduced to "improve the ability to identify the greatest threats to forest sustainability and accomplish meaningful change in high-priority areas."

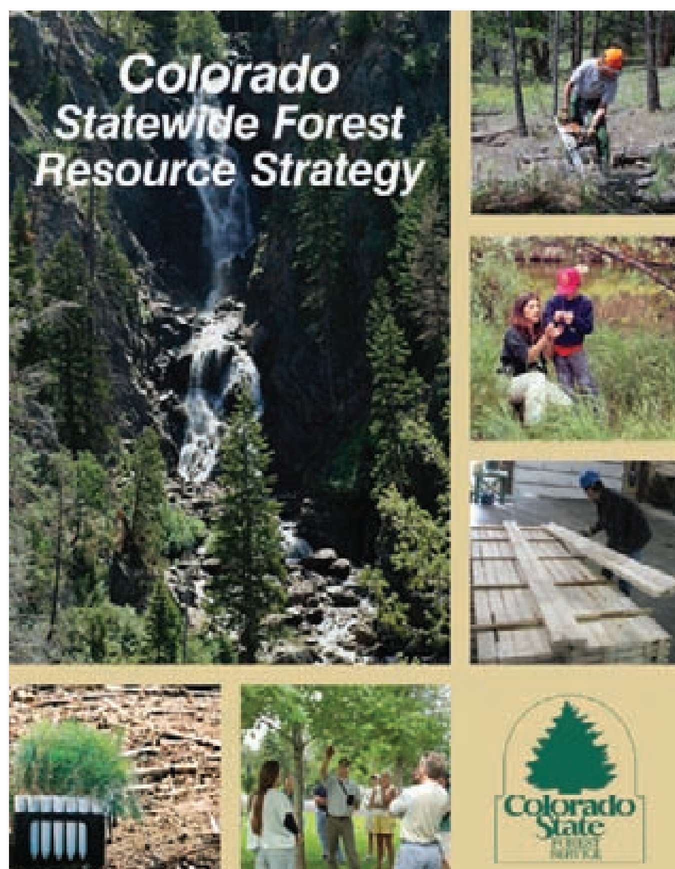
To guide the process, the USFS identified three national themes and associated management objectives that will be used to direct State & Private Forestry Program funds – conserve working forest landscapes, protect forests from harm, and enhance public benefits from trees and forests. The watershed-specific strategies fall under the last category.

Following completion of the statewide assessment, the CSFS invited 550 interested stakeholders to participate in facilitated regional focus group meetings to assist in developing strategies that address the 10 threats. Meetings were held in Fort Collins, Steamboat Springs, Durango, Salida, Glenwood Springs, and Colorado Springs. Participants included representatives from federal agencies, state and local governments, non-governmental conservation organizations, wood-processing businesses, homeowners associations, and other stakeholder groups.

Ten overarching strategies emerged from the focus group discussions, such as managing forests based on appropriate science-based information, developing a strategic marketing and communications plan to promote the benefits of active forest management, creating and sustaining a viable forest products industry in Colorado, and focusing on-the-ground efforts to leverage resources. Strategies that specifically address each of the 10 threats also were developed, including those listed above that address watershed and riparian concerns.

"Next, we must develop a clear vision of our future forests and then work together to direct resources that will achieve that vision," said Joe Duda, CSFS Forest Management Division supervisor, who also led development of the assessment and strategy. "This will require a long-term commitment that involves monitoring and adapting strategies as conditions change, because our future forests will be shaped by natural factors and by the decisions we make now."

The *Colorado Statewide Forest Resource Strategy* is considered a dynamic document and will be reviewed and revised at least once every five years, or more often if necessary. For more information or to view the statewide forest resource assessment and strategy, visit the CSFS website at www.csfs.colostate.edu.



The Colorado Statewide Forest Resource Strategy can be found online at csfs.colostate.edu.

Progress Report: Toward Sustaining the Colorado Agricultural Meteorological Network

Nolan Doesken
State Climatologist, Colorado State University

Progress has been made this year (2010) toward improving the operation and maintenance of the Colorado Agricultural Meteorological Network (CoAgMet) and toward laying a foundation for long-term support. CoAgMet is a network of automated weather stations designed to measure aspects of current weather and long-term climate of particular interest to Colorado agriculture.

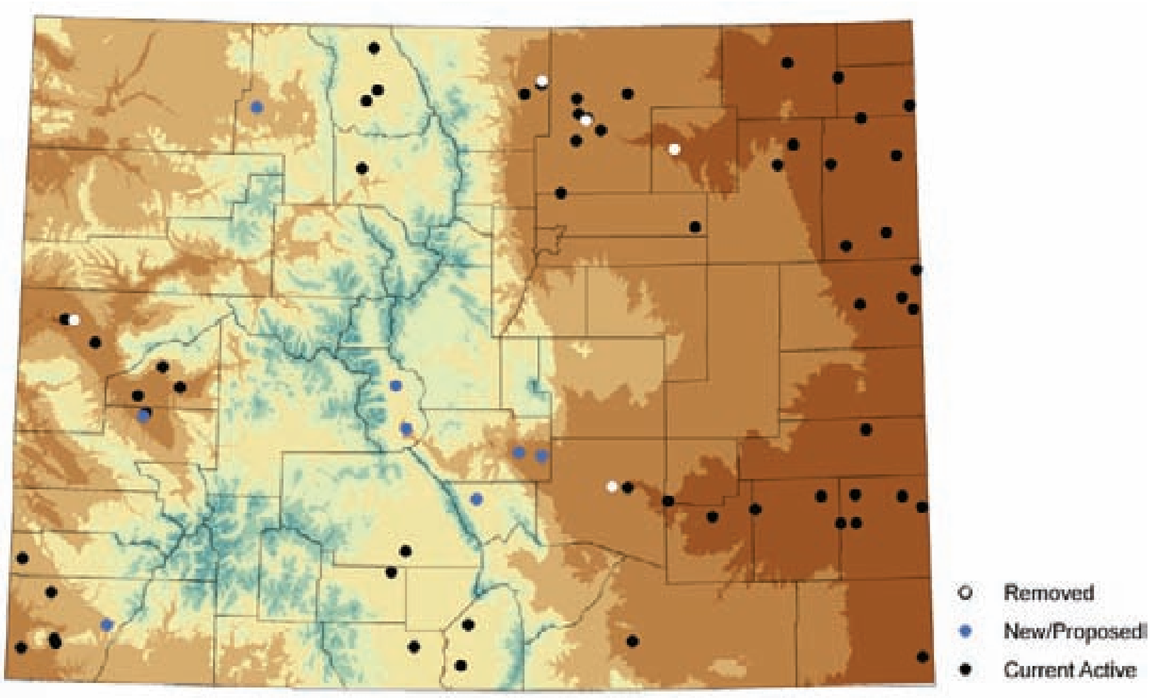
The CoAgMet network has been described in some detail in previous CWI newsletters (most recently, in March/April 2010). CoAgMet's connection to Colorado water resources is particularly strong. Each weather station measures the key weather elements of temperature, humidity, wind, and solar energy that jointly control the water needs and consumptive use of agricultural crops on a daily, weekly, and seasonal basis. Together, this network is helping to track reference and crop evapotranspiration geographically and over time, making it a unique resource to the state of Colorado.

A major accomplishment of 2010 was the Evapotranspiration Workshop held on March 12 in Fort Collins. This workshop drew nearly 175 attendees including water managers, administrators, river commissioners, agriculture and water consultants, and attorneys. The workshop raised nearly $20,000 - funds that were immediately needed to cover operational expenses of the network and to perform the critical annual maintenance and calibration of the nearly 60 weather stations.

Thanks to the workshop, other outreach efforts and strong advocates around the state, new users, and several new sponsors for CoAgMet have stepped forward. Several of the basin roundtables in Colorado are now providing short-term support for CoAgMet data collection efforts. The Upper Arkansas Water Conservancy District has built a team of sponsors to improve monitoring in the Upper Arkansas. Five weather stations that were closed down in other parts of the state were relocated this summer and fall to sites near Buena Vista, Salida, Westcliffe, Canon City, and Penrose. A station was also relocated to California Mesa in a high-production agricultural area near Olathe. The Mancos Conservation District has purchased and installed a new station, helping fill an observation gap in southwestern Colorado. The Colorado Water Conservation Board has recommended funding for the 2011-12 state fiscal year from severance taxes that may be available to help match sponsor support provided at the local level.

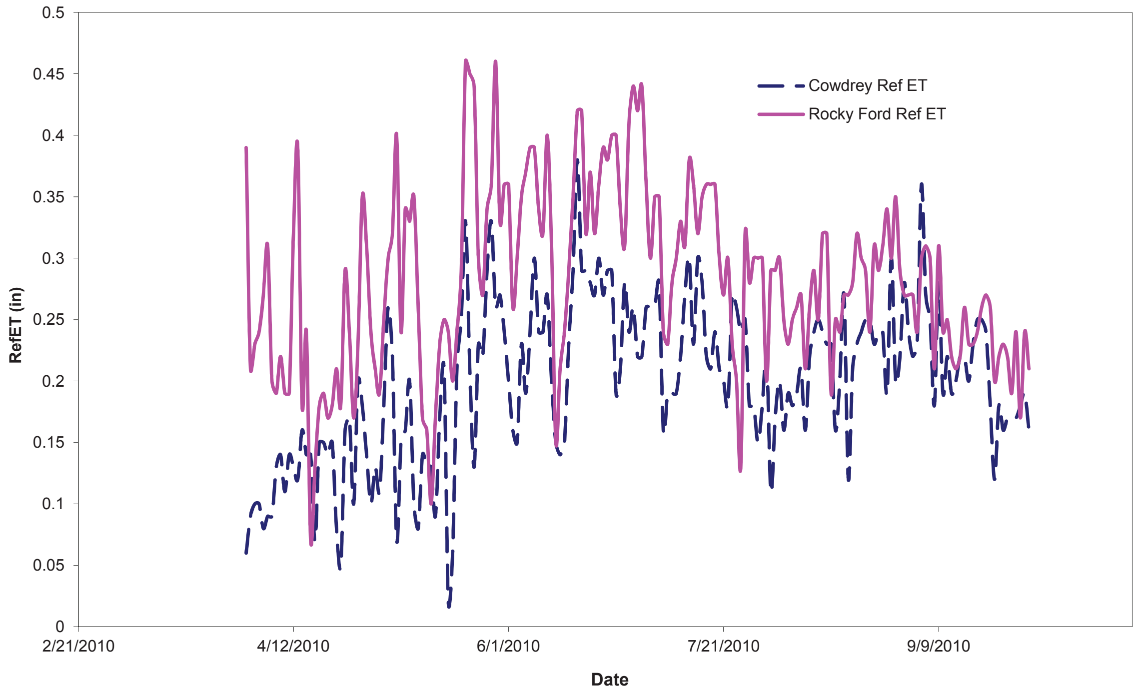
Current Priorities and Next Steps

Up until now, our main priority has been to keep CoAgMet alive during challenging economic times and to make sure



CoAgMet active station locations and changes to the network as of October 2010.

Daily Kimberly-Penman Reference Evapotranspiration



Daily Kimberly-Penman reference evapotranspiration for a high altitude hay meadow in the North Platte (Cowdrey) and lower elevation Arkansas Valley (Rocky Ford) station.

that we are collecting and archiving high quality data that will be easy to access and use and that can pass critical scrutiny. We are making good strides in this direction. But having good, raw data is not enough. Our next efforts will be to better develop and promote the use of CoAgMet and to develop tools and data visualization products that will make it easier for farmers, water managers, and others to make good use of CoAgMet data in critical management decisions. For example, tracking evapotranspiration compared to historic averages is greatly needed to enhance drought monitoring and early warning.

The current funding model that is being used to sustain CoAgMet is one of station sponsorship. As of fall 2010, sponsors have been found for about half of the network weather stations. If your organization would like to contribute to help sustain a statewide agricultural and water resources weather monitoring network, the cost is currently $2000/year/station. Contact Nolan Doesken at 970 491-3690 or Nolan.Doesken@Colostate.edu

Acknowledgement

Many thanks to all who have helped CoAgMet this past year and before – CSU Agricultural Experiment Station, Cooperative Extension, the Colorado Department of Natural Resources Division of Water Resources, USDA Agricultural Research Service and Natural Resources Conservation Service, several local conservation districts, Northern Colorado Water Conservancy District, and many more.

On March 12th, 2010, an Evapotranspiration (ET) workshop to benefit the Colorado Agricultural Meteorological Network (CoAgMet) was held in Fort Collins, Colorado. The workshop included various presenters from the ET research field, spanning topics from ET calculation methods to quality control of data, remote sensing of ET, and more! The goal of this workshop was to inform users about the CoAgMet network and how they can utilize the data collected for their monitoring or research efforts. In order to reach as wide an audience as possible, DVDs were produced during the workshop and are currently available for purchase. The cost is $35.00, which includes recorded presentations from the workshop. Proceeds of the DVD sales will be used for CoAgMet operation and maintenance. If you are interested in purchasing the DVD, please contact the Colorado Climate Center at 970-491-8506 or by email: wendy.ryan@colostate.edu. Payment methods include: cash, check or credit card.
(Visa and MasterCard only)

Being Selective: Digitization of Historical Documents

Clarissa Trapp and Patricia J. Rettig, Water Resources Archive, Colorado State University Libraries

Upon learning that the Water Resources Archive (WRA) at Colorado State University offers online access to its collection, many people want to know what sorts of information they can find online. Further, many also wonder why certain parts of the collection have been digitized while others have not.

Why digitize archival materials?

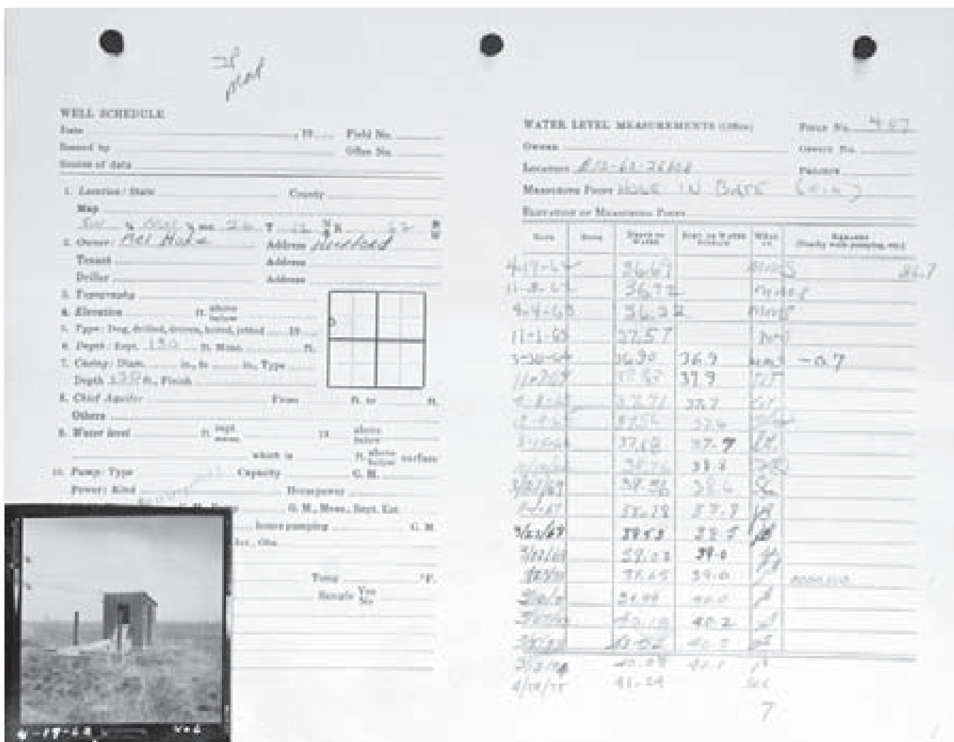
People have come to expect to find "everything" online, with archival materials being no exception. The WRA began scanning materials several years ago to begin meeting this expectation. In addition, digitizing materials allows patrons easy, convenient access to items that otherwise can only be viewed in the library in Fort Collins. Researchers can view online materials anywhere that they have computer access, thus enabling broader, even worldwide, access. Finally, digitizing materials can help protect fragile pieces from excessive handling.

Why select certain materials instead of digitizing them all?

The WRA houses approximately 1,200 boxes of personal papers, diaries, letters, raw data, reports, photographs, and slides. Because of limitations imposed by time and money, the WRA cannot digitize everything. Digitization is expensive for archives. Unlike businesses that may scan their records following minimum standards, archival digitization calls for high quality scans, which are expensive to produce. In addition, digitizing archival documents requires condition assessment of individual items as well as information generation in order to track everything. This means archives have to budget a lot of time and money for digitization projects! Also, the WRA's top priority is to collect and preserve materials related to Colorado water issues, so digitization is a secondary priority. Clearly, without collections being saved, there would be nothing to digitize! Further, the reality is that not all materials are good candidates for digitization, so objects are selected for digitization only when they meet certain criteria.

How are materials selected?

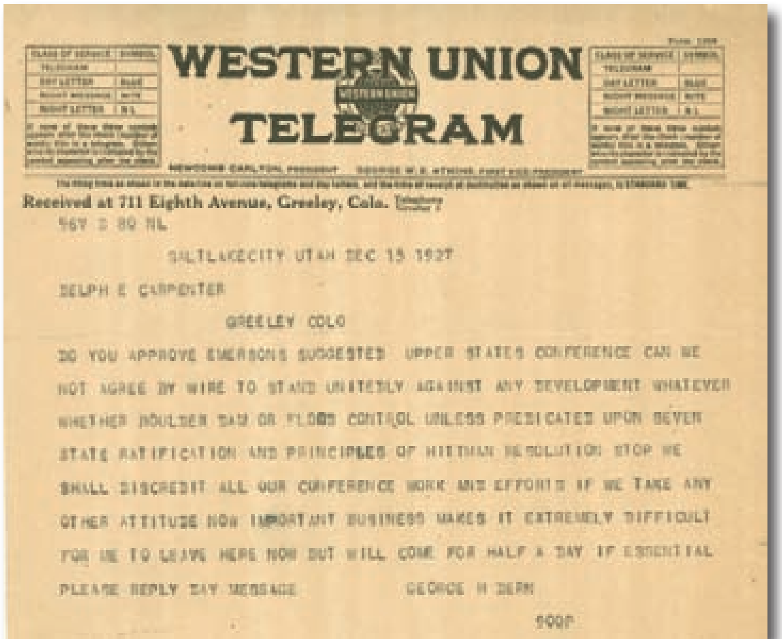
Digitization projects typically happen only with grant funding rather than through the annual budget. Each grant comes with guidelines and stipulations about what materials should be digitized. For example, several years ago the WRA was part of an academic library consortium that digitized materials to create the Western Waters Digital Library. The project focused on four specific river basins, including the South Platte and Colorado Rivers, so the WRA selected materials accordingly. The WRA's current digitization project is funded by the Colorado Water Conservation Board (CWCB), which has an interest in groundwater information, so that will guide present selections.



A page of groundwater data, with a photograph attached. Thousands more pages like this will be digitized with the generous support of the Colorado Water Conservation Board.

Courtesy of the Water Resources Archive

The WRA selects items it believes will be most useful and interesting to researchers. For instance, Delph Carpenter's correspondence concerning river compact negotiations is more interesting to greater numbers of people than Robert Glover's mathematical equations and computations. Both may be historically important, but online accessibility may provide more benefits in one case than the other.



WESTERN UNION
TELEGRAM

Received at 711 Eighth Avenue, Greeley, Colo.

SALTLAKECITY UTAH DEC 15 1927

DELPH E CARPENTER

GREELEY COLO

DO YOU APPROVE EMERSONS SUGGESTED UPPER STATES CONFERENCE CAN WE NOT AGREE BY WIRE TO STAND UNITEDLY AGAINST ANY DEVELOPMENT WHATEVER WHETHER BOULDER DAM OR FLOOD CONTROL UNLESS PREDICATED UPON SEVEN STATE RATIFICATION AND PRINCIPLES OF HITTMAN RESOLUTION STOP WE SHALL DISCREDIT ALL OUR CONFERENCE WORK AND EFFORTS IF WE TAKE ANY OTHER ATTITUDE NOW IMPORTANT BUSINESS MAKES IT EXTREMELY DIFFICULT FOR ME TO LEAVE HERE NOW BUT WILL COME FOR HALF A DAY IF ESSENTIAL PLEASE REPLY DAY MESSAGE

GEORGE H DERN

Telegram sent to Delph Carpenter, December 15, 1927. One of thousands of pages digitized from the Carpenter collection.

Courtesy of the Water Resources Archive

Usually the WRA digitizes items that directly relate to Colorado water. The WRA contains information on river basins throughout the United States and the world, but diaries and photographs that do not specifically reference water issues rarely make the cut.

Factors of copyright and privacy also restrict selections. The WRA has to take copyright into consideration for all digitization candidates, whether published or unpublished. For example, entire folders of newspaper clippings from the 1960s are avoided since they would likely all be copyrighted. However, even unpublished personal letters may be under copyright protection, so care has to be taken to make sure the archive is not violating these rights. Also, though the archive does not have much that is restricted from public access due to privacy or confidentiality, those types of materials must be avoided for digitization projects.

Size and format are also taken into consideration. Text-based materials dominate the WRA, but that does not mean that visual materials such as slides, photographs, and even maps and charts should be neglected. However, some of these materials may be larger than normal or require specialized scanners. The high cost of this is a limiting factor. While the WRA has digitized these types of materials, it has not yet digitized films, videos, or audio materials in its collection.

While digitization can help preserve documents, some documents are so fragile that digitizing them risks further deterioration. To protect these documents, they are digitized by library staff, which is more expensive than sending items to a vendor.

What materials are online?

So far, the WRA has nearly 30,000 pages of correspondence, reports, data, and diaries online, along with slides and maps. This represents an estimated one percent of the archive's total holdings. The current digitization project funded by the CWCB will add approximately 20,000 pages, 100 maps, and 2,000 slides to the online offerings. The goal is to have these materials, which will focus on groundwater, especially in the Arkansas, Rio Grande, and South Platte basins, online by the end of June 2011.

To find the WRA's digitized materials, go to its website, lib.colostate.edu/archives/water. There, you can conduct a keyword search of either online finding aids or digital objects. If you want to browse, click on the *Collections* button at the top of the page and look for a CD icon, which indicates where digital material is available online. After selecting a collection, look for *VIEW* links in the finding aid inventory.

Also remember that you can always contact Patty Rettig, the WRA head archivist (970-491-1939; Patricia.Rettig@ColoState.edu), with any questions or difficulties you may encounter on your digital hunt. Online items are convenient, but a friendly archivist can provide helpful guidance for your search.

Parker Dam (1946), downstream from Hoover Dam on the Colorado River. One of hundreds of slides digitized from the Papers of Robert E. Glover.

Courtesy of the Water Resources Archive

Lohman Receives NPS Lifetime Achievement Award

Colorado NPS Program Staff

Early in the day, before most people have even thought of the news or what it holds concerning water, articles are being reviewed, categorized, and stored for retrieval by water professionals across the state and beyond. Loretta Lohman accomplishes this task, placing the articles under the Current News link at www.npscolorado.com.

Lohman serves as the nonpoint source (NPS) information and education coordinator for the Colorado NPS program. She has held this position for over 10 years, providing consultation and resources to spread the message about managing NPS.

Lohman, who oversees the NPS Colorado Web site, is quick to tell anyone using the site, "If something is needed or not working right, just let me know and I'll work it out."

That dedicated, "can-do" spirit was recognized at the Sustaining Colorado Watersheds conference in October, when Lohman received the 2010 NPS Lifetime Achievement award. Managers, colleagues and family were present to offer perspectives and congratulations on her professional accomplishments.

Annually, individuals and organizations are recognized for exceptional water quality accomplishments that address NPS pollution. The Colorado NPS program, which is part of the Colorado Department of Public Health and Environment's Water Quality Control Division, presents this award. Lohman was the sole recipient this year.

"Information and education efforts have a critical role in meeting the state's needs of NPS management," says Lucia Machado, Colorado NPS coordinator. "Loretta's valued background and dedication has provided the program with a solid foundation over the years."

Lohman completed bachelor and doctorate degrees in political science and American History, respectively, at the University of Denver. Her master's is in social science from the University of Northern Colorado. Lohman applied her education to consulting, teaching and research. Much of her work has focused on the state's water issues. She has authored over 60 publications and articles throughout her career; most deal with water reuse, economics, and the Colorado River.

The oldest of three, Lohman was raised in a home that valued education – from regular trips to the library to the expectation of earning a college degree. Her parents also instilled the importance of valuing diversity and assisting those less fortunate.

At the recent award presentation, Lohman's brother and his wife described instances that typify how Loretta cares and appreciates others.

In accepting the award, and in true fashion, Lohman quickly turned the spotlight to the many volunteers who play key roles managing Colorado's water resources, especially in the fields of water quality and NPS.

Faculty Profile: Craig Bond

Lindsey A. Knebel, *Editor, Colorado Water Institute*

The study of natural resource economics typically involves investigating the consequences of making decisions about environmental variables when these decisions are linked over time. These linkages typically make analysis complicated. Factor in the fact that ecosystems are characterized by highly complex, non-linear, uncertain relationships between variables, and the potential exists to know more about these relationships as time goes on, and the problems get even more interesting. How should one manage a resource if one knows that they don't know, but might know more in the future? Even more specifically, what is the value of learning about the system, and how should we manage in order to gain information more efficiently? For Dr. Craig A. Bond, assistant professor in the Department of Agricultural and Resource Economics at Colorado State University, these questions motivate a host of interesting research.

Bond holds degrees from several universities – a Bachelor of Science in Economics from Frostburg State University in Maryland, a Master of Arts in Economics from CSU, and a Ph.D. in Agricultural and Resource Economics from the University of California, Davis. His current research includes topics in economics related to the environment, natural resources, agriculture, and other natural sciences.

For example, Bond is working on modeling adaptive natural resource management – developing decision-making tools that allow investigators to look into problems where parameters and thresholds that define ecosystem relationships are unknown but might be learned about in the future. His collaborative research on the possible invasion of zebra and quagga mussels in the Colorado water system (an article in *Colorado Water, September/October 2010* discusses this at length) provides an opportunity to take this research in a more applied direction. He says these mussels, which can cause harm to water ecosystems and infrastructure, are already well-established in areas like the Great Lakes, but researchers are unsure of whether the mussels can survive in parts of Colorado water systems. From an economic standpoint, the question is how to manage the reservoir system for a potential mussel invasion in the face of this uncertainty. Applications of this research are broad, including management of other invasive species, habitat management, endangered species, and climate change, among others.

Dynamic modeling is just one small sample of Bond's research work. Since starting at CSU in 2005 he has investigated such diverse topics as agroecosystem sustainability, the valuation of food attributes, the economic impacts of the aquacultural suppliers of recreational fish, and the management of high-elevation forests. Above all, says Bond, "I try to do research that matters." "I'm hoping the modeling I do can help people make better decisions." He says research is important because both the benefit and cost sides of a problem have to be understood in order to make an educated decision.

Despite his research efforts, he claims that "my biggest impact is through my students." Bond recalls the feeling of performing on stage when he was in bands several years ago, and he equates that feeling with the "rush when you're doing a really good job educating." He says his work with students "really has the potential to make society better through recognition of the tradeoffs that we all face."

As a freshman, Bond says he switched between several majors before signing up for a microeconomics class with Dr. John Neral of Frostburg State University, a self-proclaimed "philosophical anarchist" who did economic experiments in the classroom and turned him on to the study of economics. With his guidance, Bond went on to earn a master's degree and worked as an economist in the field before realizing he wanted to do something more. His Ph.D. research on sustainability bridged the fields of natural resource and agricultural economics and provided the background necessary for his current appointment.

Since then, Bond has delved into the world of agricultural, natural resource, and environmental economics, and says he enjoys where he is. He says working at CSU is the perfect job for him – "I get paid to teach and to learn," he says, "and you really don't beat that at any level."

Craig Bond
Assistant Professor

Colorado State University

Department of Agricultural and Resource Economics
Colorado State University

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Fort Collins, CO 80523-1172
Phone: (970) 491-6951
craig.bond@colostate.edu

Water Research Awards

Colorado State University (August 15 to November 15, 2010)

Bauder, Troy A, Soil & Crop Sciences, USDA-Natural Resources Conservation Service, Demonstrating Conservation Tillage Methods and Benefits Under Furrow Irrigation, $73,906

Brick, Mark A, Soil & Crop Sciences, Colorado Department of Agriculture, Irrigation Efficiency of Three Water Delivery Systems on Diverse Dry Bean Market Classes of Dry Edible Bean, $33,000

Cabot, Perry E, CSU Extension, USDA-Natural Resources Conservation Service, Strategies for Permanent Fallowing of Previously Irrigated Cropland Under Groundwater Pumping Restrictions in the San Louis Valley, $24,306

Caldwell, Elizabeth D, CEMML, DOD-ARMY-Corps of Engineers, Stormwater Modeling - Circle Loop for Fort Richardson, Alaska, $52,300

Collett, Jeffrey L, Atmospheric Science, DOI-National Park Service, Nitrogen Deposition in the Rocky Mountain Region, $679,629

Cooper, David J, Forest Rangeland Watershed Steward, DOI-National Park Service, Wetland Ecological Integrity Monitoring in Glacier National Park, $44,219

Doesken, Nolan J, Atmospheric Science, National Science Foundation, The Community Collaborative Rain, Hail and Snow (CoCoRaHS) Network: Enhancements to Increase Participation for Tens of Thousands in an Important Nationwide Climate Literacy Project, $230,626

Doherty Jr, Paul F, Fish, Wildlife & Conservation Biology, Exxon Mobil Corporation, 2010 Exxon Mobil: Piceance Basin Wildlife and Habitat Studies, $40,188

Fassnacht, Steven, Natural Resource Ecology Lab, DOI-National Park Service, Understanding the Historical & Potential Future Effects of Climate Change on Water-Dependant Cultural & Natural Resources, $71,270

Fausch, Kurt D, Fish, Wildlife & Conservation Biology, USDA-USFS-Forest Research, Developing a Tool to Assess Effects of Climate Change on Colorado River Cutthroat Trout, $25,000

Fausch, Kurt D, Fish, Wildlife & Conservation Biology, National Science Foundation, OPUS: RiverWebs-Crossing Boundaries to Explore the Hidden Mysteries of Streams, $205,041

Garcia, Luis, Civil & Environmental Engineering, USDA-Foreign Agricultural Service, 2010 Global Research Alliance Fellowship, $25,213

Liston, Glen E, CIRA, National Science Foundation, Collaborative Research-AON: A Snow Observing Network to Detect Arctic Climate Change - SnowNet-II, $409,463

Loftis, Jim C, Civil & Environmental Engineering, DOI-National Park Service, Compilation and Development of National Park Service Water Resources Databases and Tools, $224,000

Nissen, Scott J, Bioagricultural Sciences & Pest Management, USDA-Natural Resources Conservation Service, Improving Tamarisk Control Following Fire Using Integrated Management Strategies, $72,210

Nissen, Scott J, Bioagricultural Sciences & Pest Management, Colorado State Water Conservation Board, Tamarisk Grant - Russian Knapweed Management & Riparian Restoration along the Delores & Ark Rivers, $15,000

Norton, Andrew P, Bioagricultural Sciences & Pest Management, Three Rivers Alliance, Assessing Vegetation Change Following Russian Olive Control, $9,000

Poff, N LeRoy, Biology, Camp Dresser McKee, Yampa Basin Watershed Flow Evaluation Tool, $14,301

Pritchett, James G, Agriculture & Resource Economics, Alliance for Sustainable Energy-NREL, Energy-Water nexus in a Drying West: A Case Study Analysis and Methodology, $21,196

Calendar

January

21-23 Colorado Farm Bureau Young Farmer and Rancher Committee Annual Leadership Conference; Colorado Springs, Colorado
cofarmbureaublog.files.wordpress.com

26-28 Colorado Water Congress; Denver, Colorado
The Colorado Water Congress 52nd Annual Convention
cowatercongress.org

February

2 Bureau of Reclamation Water District Workshop; Grand Junction, Colorado
Topics will include conservation measures, water law and micro-hydro opportunities. For more information, email: SCaskey@usbr.gov

4-5 Landscape Symposium, Peak to Prairie; Colorado Springs, Colorado
An educational forum inspiring the communities of Southern Colorado to create appealing and enduring landscapes suitable for our soils, climate and finite water resources.
peaktoprairielandscapesymposium.org

8-11 AWWA/WEF Utility Managment Conference; Denver, Colorado
awwa.org/conferences

14-17 Colorado Rural Water Users Conference; Colorado Springs, Colorado
CRWA 30th Annual Conference and Exhibition
crwa.net/crwaconf.html

15-17 Nutrients and Water Quality: A Region 8 Collaborative Workshop; Salt Lake City, Utah
Agencies and universities in the six states of EPA Region 8 (Colorado, Montana, North Dakota, South Dakota, Utah and Wyoming) are hosting a three-day workshop in February 2011 to explore the science and institutional context regarding nutrients and water quality.
cwi.colostate.edu/nutrients

16-17 Tamarisk Research Conference; Tucson, Arizona
This conference will promote dialogue between researchers and land managers to identify future research needs for the development of effective policy and management decisions.
tamariskcoalition.org/2011ResearchConference.html

17-18 DARCA Annual Convention; Loveland, Colorado
The 9th Annual Convention, Resource Allocation to Enhance Survival, to be held in Loveland, will provide a wealth of information on a broad array of issues relevant to Colorado's water providers. The theme of the convention is all about economics, the study of resource allocation.
darca.org

24-25 International Conference on Stormwater & Urban Water Systems Modeling; Toronto, Canada
This is a forum for professionals from across North America and overseas to exchange ideas and experience on current practices and emerging technologies.
chiwater.com

March

3 Statewide Roundtable Summit; Westminster, Colorado
All Basin Roundtable members and the public are invited to attend the Statewide Roundtable Summit on Thursday, March 3, 2011. The meeting is an opportunity to meet your fellow cohorts from around the state and continue connecting the activities and entities within the 1177 process.
cfwe.org

3-4 Rocky Mountain Land Use Institute Conference; Denver, Colorado
The Next West: Landscapes, Livelihoods and the Future of the Rocky Mountain Region
law.du.edu/index.php/rmlui

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The Water Center of Colorado State University
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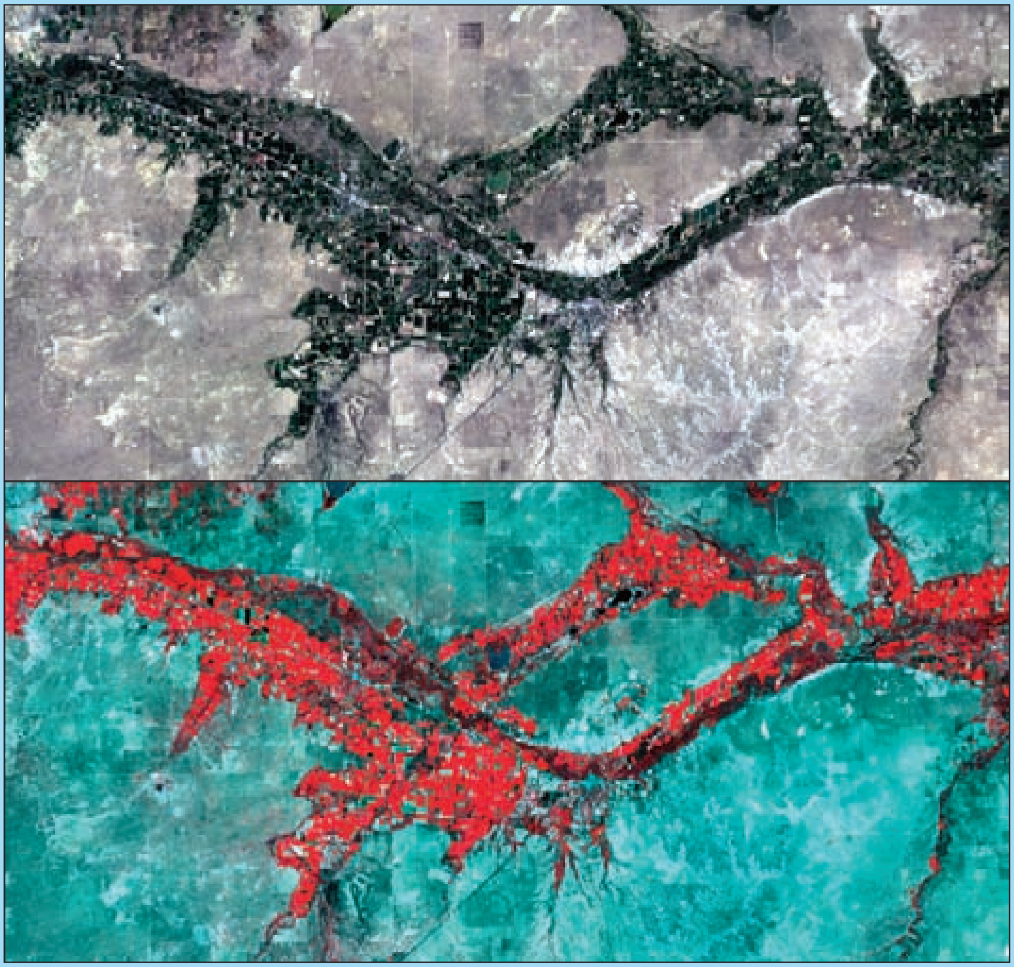

Satellite imagery used in decision support system analysis depicts a portion of the Arkansas Valley, including the cities Rocky Ford and La Junta, Colo. Acquired 7 Oct., 2009. Above: a true color image; below: false coloring created by a combination of near-infra red, red, and green color bands. The resulting red color depicts vegetated areas.

Provided by José Chávez.