Colorado Water Resources Research Institute

Annual Technical Report

FY 1999

Introduction

WATER PROBLEMS AND ISSUES IN COLORADO

With restoration of a small amount of research funds in the federal State Water Institute Program for FY1999, the Advisory Council on Water Research Policy (ACWRP) for the Colorado Water Resources Research Institute (CWRRI) was activated. The Council held its initial meeting in Denver on February 12, 1999. Prior to the meeting, members were polled for their assessments of the highest-priority water problems in Colorado.

The Colorado Water Resources Research Institute's Research Planning Advisory Committee at its initial meeting on February 12th in Denver. From right: David Robbins, Lee Sommers, Brad Young, Fred Anderson, Sara Duncan, Greg Parsons and John Porter.

The new ACWRP established CWRRI water research priorities as follows:

Understanding the life cycle of plains minnows
Impact of urban water conservation programs upon the green industry
Impact of forest management practices on water flows and quality
Salinity overview of the Arkansas River Basin
Water quality criteria for agricultural diversions in Colorado
Groundwater quality monitoring strategies in Colorado from a statewide management perspectiive

The following research topics were discussed by CWRRI's ACWRP during preparation of the 1999 Call for Proposals.These topics were not included for FY1999, but become the basis for developing CWRRI's research priorities for its FY2000 State Water Institute Program.

Are crop coefficients used to estimate consumptive use for hybrid crops correct?
The total maximum daily load (TMDL): program, process or Pandora's box?
The impacts of agricultural land conversion to golf courses
Water quality impacts
Timing of flows
Assessment of water quality impacts from confined animal feeding operations.
Assessment of origins and impacts of selenium on waters in the Colorado River Basin
Collective impact of septic tanks on water quality in the foothills along the Front Range
Colorado watershed organizations: inventory, funding, status, institutional structures, stakeholders and purposes.
Public understanding of water rights and administration.

Impact of urban water conservation plans on Colorado's 'green' industry.

Project updates were provided to the members of the ACWRP at its February 13, 2000 meeting by principal investigators Kurt Fausch and Tim Gates.

Kurt Fausch updates ACWRP on his brassy minnow project

Tim Gates describes his ongoing research on salinity in the Arkansas Valley

The Advisory Council on Water Research Policy, as provided for in CWRRI's by-laws, is comprised of: the Chair of the Colorado Senate Committee on Agriculture, Natural Resources and Energy, the Chair of the Colorado House Committee on Agriculture, Livestock and Natural Resources, the Executive Director of the Colorado Department of Natural Resources, the Executive Director of the Colorado Department of Public Health and Environment, the Commissioner of the ColoradoDepartment of Agriculture; and six members of the general public "selected based on their participation in setting Colorado water policy in the legislative process and involvement in obtaining funding for such policy."

The ACWRP's mandate is to address two functions: advising CWRRI regarding research to be undertaken as part of the federally supported, state-based water research program; and seeking state and local water research funding to provide the state match required.A list of members of the CWRRI Advisory Council on Water Research Policy is included with supplemental materials sent to the U.S. Geological Survey..

STATE WATER INSTITUTE PROGRAM>

In FY1999 funds appropriated for the State Water Institute Program included $48,178 to each institute for research in addition to the $20,000 base grant for each.This permitted CWRRI to fund three projects deemed to be high-priority by the ACWRP.The three projects are described below:

Description and Interpretation of Salinization in the Lower Arkansas River Valley, Colorado

Monitoring salinity in the Arkansas River Basin

In Colorado's lower Arkansas River Valley, saline high-water tables began to appear in the early part of the 20th century.Installation of subsurface drains in the l930s seemed to assuage the problems for awhile; however, water tables began to rise again in the late l970s.Investigators suggested the cause was increased diversions from the river for irrigation application and associated reduction in groundwater pumping.And indeed, in the l950s-'70s, two reservoirs began operations that have drastically changed the river.Flushing from floods was substantially reduced and controlled releases were made from the reservoirs.This allowed year-round, or at least prolonged, supplies of water to the canals on the perimeter of the valley.Seepage from these canals and lower velocity in the river have caused the river channel to widen, sediments to deposit on the bed, and the river level to rise.Also, since 1991 irrigation water supplies from snowpack and rainfall have been far above average, leading many in the area to divert more water, and with the Kansas-Colorado court ruling, groundwater pumping has diminished.There is growing evidence that the irrigated lands of the lower Arkansas are subjected to forces that are elevating the severity of waterlogging and salinization.This project will strengthen the data foundation needed to characterize salinization problems in the lower Arkansas River Valley.Principal investigators will consider soil salinity, water table depth and salinity; river level, flow and salinity; water levels, flows, and salinity in canals and drains; irrigation practices; hydraulic conductivity of surface soils; well pumping; and crop yields.The project results will include a digital spatially-referenced (ArcView^{TM} GIS format) database.

The Principal Investigators are Timothy K. Gates and John W. Labadie, Department of Civil Engineering, Colorado State University; Co-Investigators are Grant E. Cardon, Department of Soil and Crop Sciences, Colorado State University, Israel Broner, Department of Chemical and Bioresource Engineering, Colorado State University, and James C. Valliant, Extension Irrigation Specialist, Cooperative Extension, Colorado State University.Partial funding for this project was received from the CSU Agricultural Experiment Station.

Distribution, Habitat and Life History of Brassy Minnow in Eastern Colorado

Julie Scheurer and Mark Minner sein an Eastern Plains stream.Photo by Kurt Fausch.

Results of a recent survey, compared with earlier surveys, show that ten native fish species are either rare or imperiled in the South Platte River Basin.A review also reported that almost nothing is known about the habitat and life history of most eastern Colorado plains fishes.The Colorado Division of Wildlife recently selected brassy minnow as the highest priority for study.This research project will:

Define the original distribution and current status of brassy minnow in the South Platte River Basin in Colorado, based on historical data and specimens and resampling of all sites where previously collected.

Assess effects of flow fluctuations and habitat modifications on brassy minnow populations by measuring dynamics of stream habitat, and its use by brassy minnow, in study reaches that contrast in flow regime (strong vs. moderate flow fluctuations), longitudinal position (foothills vs. plains streams), and channel form (natural stream channels vs. irrigation channels).

Relate basic life history characteristics of brassy minnow to flow and habitat to understand critical habitats needed for survival and reproduction.

The Principal Investigator is Kurt Fausch, Department of Fishery and Wildlife Biology, Colorado State University.Funding for this project was also provided by the Colorado Division of Wildlife.

Protocol for a State-wide Groundwater Quality Monitoring Program

The Department of Soil and Crop Science at Colorado recently pulled together existing groundwater quality data in the state as part of an effort by the Colorado Water Quality Control Commission (WQCC) to delineate aquifers meeting the "high quality" classification criteria.A key outcome of this project was the discovery of a significant lack of comprehensive groundwater quality data.Many aquifers in the state have not been sampled, at least not to the degree that would allow a scientifically defensible evaluation of their quality.Moreover, most of the databases lacked sufficient descriptive data necessary to fully compare the data to other sources, particularly sample location, sample depth, analytical methodology, and quality assurance/quality control parameters on the data.This project's objectives are to:

Work with the Colorado Water Quality Control Commission to develop a protocol for a statewide groundwater quality-monitoring program.

Organize and execute an educational effort to put the protocol in the hands of all agencies working with ground water in the state.

Develop and deploy an Internet-based information source for all groundwater quality monitoring activities in the state.

The Principal Investigator is Grant Cardon, Department of Soil and Crop Science, Colorado State University; Co-investigators are Jessica Davis, Department of Soil and Crop Science, Jim Loftis, Department of Chemical and Bioresource Engineering, Colorado State University, and Jose Salas, Department of Civil Engineering, Colorado State University.Additional funding for this project was provided by the Colorado Department of Environment and Public Health.

U.S. COMPETITIVE GRANT PROGRAM<

Four proposals were submitted to the FY1999 U.S. Geological Survey National Competitive Grants Program by the Colorado Water Resources Research Institute. The proposals are listed below.

A Stochastic Approach to Environmental Exposure Assessment Related to Groundwater Nitrate Concentration.*Principal Investigators:Luis Garcia and Jim Loftis, Department of Chemical and Bioresource Engineering, Colorado State University.*

Characterization of Advective, Diffusive and Dispersive Processes Controlling Salt Transport Due to Irrigation Return Flows in the Arid Upper Colorado River Basin.*Principal Investigators:Ronald R. Hewitt Cohen and Tissa Illangasekare, Department of Civil Engineering, Colorado School of Mines.*

Aspects of Nutrient Sources and Transport in Rivers: Nitrate and Soil Organic Matter; Trace Elements and Aquatic Colloids.*Principal Investigators: James Ranville and Thomas Wildeman, Department of Chemistry and Geochemistry, Colorado School of Mines; Donald Macalady, Center for Environmental Risk Assessment, Colorado School of Mines.*

Innovative Methods for Estimating Average and Peak Urban Water Use and Wastewater Demands.Principal Investigator:*James Heaney, Department of Civil, Environmental and Architectural Engineering, University of Colorado at Boulder.*

None of the proposals submitted for this fiscal year were funded.

REGIONAL GRANT - FY1998 Award

Meeting Time-Dependent Instream Flow Requirements in a Fully Appropriated Multi-state River Basin

Water users in the three basin states of Colorado, Wyoming, and Nebraska have effectively fully appropriated the flows of the South Platte, North Platte, and Platte Rivers -- primarily for irrigation uses.At the same time, species dependent on the habitat are listed as threatened or endangered.To comply with the ESA mandate for recovery of these species, the U.S. Fish and Wildlife Service estimates that on average as much as 373,000 acre-feet of additional water must be made available.In 1997 the Governors of Colorado, Wyoming and Nebraska, along with the Secretary of the Interior, signed a Memorandum of Agreement to develop a program to meet ESA requirements.A ten-person Governance Committee is responsible for implementation of the MOA.In the first 10 to 13-year increment of the agreement, the parties commit to reduce shortages to target flows at Grand Island an average of 130,000 acre-feet.Approximately half of the water commitment is to come from specific water projects in the three states.The remaining half is expected to come from water conservation and water supply options to be identified initially by a consultant and included in an action plan by the Committee.This research complements the efforts of the Committee and its consultant to dentify potential water conservation and water supply projects.The investigators will develop a conceptual analytical framework in which to evaluate the feasibility, effectiveness, and effects of alternative approaches for supplying additional instream

flows to the central Platte River in Nebraska.

Principal Investigators:Dr. Marshall Frasier and Dr. Robert A. Young,Department of Agricultural and Resource Economics, Colorado StateUniversity; Dr. Tim Gates, Department of Civil Engineering, Colorado State University; Dr. Ari Michelsen,;Agricultural Research Center, Texas A&M University; Dr. James Booker, Department of Economics, Alfred University, NY; Dr. Garth Taylor,Department of Agricultural Economics, University of Idaho; Dr. Steve Gloss, Spatial Data and Visualization Center, University of Wyoming; Dr. Mark Squillace, College of Law, University of Wyoming; and Robert C. Ward, CWRRI Director, Colorado State University.

Research Program

STATE RESEARCH PROGRAM

The Colorado Water Resources Research Institute continued its modest "seed" money research program by providing funds for the project described below, which was considered to be of high priorityby the ACWRP and also by participating local and state agencies and organizations.

South Platte Mapping and Analysis Program (SPMAP)

The Issue
Water managers in Colorado are facing many competing demands for water: sustaining irrigated food production; providing high-quality water to growing populations; mimicking natural flow rhythms to protect aquatic habitats for endangered species; and meeting growing water recreation needs.

The challenges facing water managers' decision-making abilities demand thedevelopment of sophisticated computer based technology to support decisionmaking in the hope that all needs can be met. In particular, there is a need to upgrade current technology used to manage the conjunctive use of surface and ground water resources in the South Platte Basin.

Modern decision support systems employed to enhance water management involve carefully matching data acquisition system design, modeling, and user interfaces to meet the manager's needs. New approaches to water research are being employed on this project. University researchers are working hand-in-hand with water managers so that the computer tools are carefully crafted to aid the decision process.

The Experience
In the 1970s and 1980s, CWRRI funded basic research to develop mathematical relationships (models) describing interactions between surface and groundwater in alluvium aquifers along the South Platte River. Data acquisition and computer technology at the time did not permit integrating the models into data acquisition systems or provide user-friendly interfaces with decision-makers. The ability to acquire basic resource management data via satellite, combined with the exploding power of the microcomputer (both hardware and software), has given water managers the ability to further develop decision support technology. Since 1995 Dr. Luis Garcia, Professor of Chemical and Bioresource Engineering Colorado State University, has been working with a number of local

and regional water management organizations along the South Platte River below Denver. Each of the cooperating organizations agrees to financially support the research while also providing regular (approximately every six weeks) feedback to the researchers on the latest developments.

CWRRI has continued to match the water managers' funding. The water managers and university researchers form a 'team' that works closely on all aspects of the research, which has focused on the development of a set of computer tools that are called the South Platte Mapping and Analysis Program (SPMAP).

The SPMAP 'team' has been promoting the idea of 'modular' development based on a data-centered approach. This means that the data are generic and developed in such a way that all modeling efforts can use the same data. Individual models are being developed that can be part of a larger framework and can be substituted or added with little impact to the overall structure of the system.

Due to the modular and data center approach, the SPMAP 'team' identified the development of an accurate spatial database and analytical tools for computing farm water budgets and consumptive use (CU) of groundwater as two of the most pressing needs for the South Platte River Basin. Out-of-priority impact of ground water well pumping on South Platte River flows must be augmented, but this impact needs to be accurately quantified, thus the need for spatial databases and associated analytical tools. During 1995-96, project efforts focused on spatial data collection and evaluation. A Geographic Information System module was developed as an extension to ArcView 3.0a to provide users the capability to view and use spatial data. The GIS module allows the user to view point, line, polygon and image coverages. The current system contains themes for irrigated lands, well locations, stream depletion factors, hydrography, weather stations, county boundaries, roads, and cities.

During 1997-98, efforts focused on developing a Consumptive Use (CU) model and an interface for a Stream Depletion Factor (SDF) Model. Satellite images were purchased to determine irrigated land area, as well as field delineation, and crop type classifications. A Graphical User Interface (GUI) for the CU model was constructed. The system development has been modular and each component can be operated in a stand-alone mode. The user can use the GIS module to locate fields and the surface and/or groundwater sources that provide water to them, and this information (along with the crop types grown in each field and weather stations) can then be stored in an ASCII file. The CU model imports the created ASCII file and uses it to create an input file, which then is used to calculate the CU and any pumping requirements.

During 1998-99, efforts focused on the release of the Stream Depletion Factor (SDF) Model interface called SDF View. This interface can be used to estimate the lag time when irrigation well water is pumped from, or water is recharged to, an alluvial unconfined river aquifer and when a depletion or accretion happens in the river. Required input information for SDF View is irrigated consumptive use from well water or net recharge amounts and SDF values for irrigation wells or recharge basins. SDF View is a stand-alone interface for Windows 95/98/NT that has online and hard-copy documentation. SDF View was released as part of the Three-State Agreement to the State of Nebraska to help them manage South Platte groundwater wells in Nebraska.

Progress for the Current Fiscal Year

The focus during this fiscal year was to finish the SPMAP, SDF View and CU Model Interfaces to the satisfaction of all 'team' members. One of the major tasks included the development of the CU

Model as a stand-alone interface. Although coordination with SPMAP makes the data entry tasks easier and more comprehensive, the CU Model is more flexible with a stand-alone interface. Additional methods and options have been added to the model with close coordination with 'team' members. For example, the CU Model can retrieve data from the statewide database being developed by the State Engineer's office called HYDROBASE. A new version of the CU Model complete with documentation will be available by the end of the summer. The current project will be finishing this fiscal year. This conclusion will provide a well-defined set of deliverables and bring closure to the initial goals of the project. Copies of the software and documentation can be downloaded from the following Internet site: **http://www.ids.colostate.edu/projects/splatte.**CSU will continue to work closely with local water organizations. On going efforts will include updating GIS layers and coordinating data collection efforts. An additional goal for the future may be to couple the SPMAP tools with a real-time water management system developed for the South Platte (SPWRMS). This capability will allow users to use current flow and diversion records for modeling tasks in SPMAP. New projects may emerge or new tools may be identified that need development. One of these tasks may be to better model and define habitat requirements for endangered fish species in the South Platte and additional tools and monitoring to define groundwater and surface water interactions to provide water resources at critical time periods for endangered species both in Colorado and Nebraska.

Team Participants for this Year:

Luis Garcia, Colorado State University
Jon Altenhofen, Northern Colorado Water Conservancy District
James Hall, State Engineer's Office
Forrest Leaf, Central Colorado Water Conservancy District
Jack Odor, Groundwater Appropriators of the South Platte
Brent Nation, Groundwater Appropriators of the South Platte
Paul Weiss, City of Fort Collins

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Meeting Time-Dependent Instream Flow Requirements in a Fully Appropriated Multi-State River Basin
Project Number	1434-HQ-96-GR-02660
Start Date	09/01/1998
End Date	08/31/2000
Research Category	Social Sciences
Focus Category #1	Law, Institutions, and Policy
Focus Category #2	Economics
Focus Category #3	Management and Planning
Lead Institution	Colorado State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Marshall Frasier	Assistant Professor	Colorado State University	01
Robert A. Young	Professor	Colorado State University	02
Ari M. Michelsen	Professor	Colorado State University	03
James F. Booker	Assistant Professor	Alfred University	04
R. (Garth) G. Taylor	Assistant Professor	University of Idaho	05
Timothy K. Gates	Associate Professor	Colorado State University	06
Steve P. Gloss	Professor	University of Wyoming	07
Mark Squillace	Associate Professor	University of Wyoming	08
Robert C. Ward	Professor	Colorado State University	09
Ray G. Huffaker	Associate Professor	Washington State University	10

Problem and Research Objectives

Water users in Colorado, Wyoming, and Nebraska have effectively fully appropriated the developed flows of the South Platte, North Platte, and Platte Rivers — primarily for irrigation uses. Water demand and the competition for existing supplies is growing throughout the basin and especially along the Front Range of the Rocky Mountains. At the same time, four species—the Whooping Crane, Piping Plover, Interior Least Tern, and Pallid Sturgeon—dependent on habitat associated with the Platte River in central Nebraska, are listed under the federal Endangered Species Act (ESA) as either threatened or endangered. A three-mile wide, 56- mile long section of the central Platte River in Nebraska has been designated as critical habitat for the Whooping Crane under the ESA. To comply with the ESA mandate for recovery of these species, the three states have agreed to increase stream flow through this reach by an average of 130,000 acre feet annually for the next 10 to 13 years. Approximately half of the water commitment is to come from specific water projects previously identified in the three states. However, the source of the remaining half of the committed water has yet to be identified and significantly more may be required in the future.

Altering existing Platte River water uses to make such a substantial amount of water available presents a major challenge. Throughout the West, state water laws establish priorities for intrastate water use, while interstate compacts (utilizing a broad range of formulas) provide rules for allocation between states. These rules have been established primarily to mediate water allocation among controlled diversions for out of stream uses. In contrast, institutions for satisfying emerging instream flow requirements are in their infancy. There is little actual experience in addressing needs for increased instream flows that are dependent on changes in management (e.g., reservoir operations), consumptive uses and legal institutions in multiple states. Further, the impacts and effectiveness of alternative approaches for meeting instream flow requirements are typically not well understood. Little is known about the required conditions and impacts of potential alternatives such as, interstate coordination, or use of market-type mechanisms, particularly in complex hydrologic systems with highly variable consumptive and nonconsumptive use demands.

Research Objectives

The overriding objective of this study is to evaluate the feasibility, effectiveness and distribution of impacts and benefits of alternative institutional arrangements in delivering water for instream use in the lower reaches of the Platte River Basin. Specific objectives of this research are to:

- Identify a broad range of institutional, water management, and economic conceptual alternatives that may be used to satisfy instream flow quantity and timing requirements. The primary focus will be on alternatives that are consistent with existing interstate apportionments.

- Evaluate the institutional, legal, hydrologic and economic requirements of each of the conceptual alternatives and establish the necessary or prohibitive conditions for implementation. Explicit knowledge of the conditions necessary for alternatives will assist water resource managers and decision makers in developing effective programs.

- Identify economic costs and benefits to Platte River economic users impacted by the conceptual alternatives.

- Develop an integrated hydrologic, institutional, and economic river basin model that accounts for dominant sources and uses of water in the Platte River Basin under present water laws, policies and management institutions.

- Use the integrated model under baseline conditions to illustrate and evaluate the relative effectiveness in satisfying instream flow requirements and economic impacts of feasible selected alternatives.

- Conduct sensitivity analysis to explore the robustness and thresholds of feasible alternatives to variability in hydrologic and climatic conditions (e.g. streamflows and evapotranspiration requirements), and model assumptions (e.g. agricultural market conditions, characteristics of stream-aquifer interactions.)

Methodology

Identification and Evaluation of Institutional Alternatives

In a fully appropriated system such as the Platte, there are three general ways in which additional instream flows of water potentially can be made available: changing system water management, improving water use efficiency of existing uses, and transferring water.

We have arrayed the broad range of options for producing additional instream flows that might exist under each of these three general approaches. These options have been identified through a survey of the relevant literature, from the extensive knowledge and experience of the members of the research team, and from interviews with key water managers and water users in the basin. We are developing summary discussions that explain the identified options as a general matter and highlight general advantages and disadvantages, creating a broad menu of

the possibilities that might be available for better meeting instream flow requirements in a western river basin. Requirements and opportunities specific to the Platte River Basin are being developed simultaneously.

To narrow the set of potential alternatives, each is being evaluated for feasibility according to a set of criteria that are determined as most important to those who rely upon the services of the river system. A set of feasibility criteria emerge naturally from the principles adopted to guide the project–legal, hydrologic, water potential, financial cost, third party impacts, and political. Legal feasibility evaluates the degree to which a given alternative can be implemented under existing state, interstate and federal laws and regulations. Hydrologic feasibility assesses the physical capability to generate stream flows in the critical reach during the necessary period of time for species protection. Water potential appraises the quantity of water that could potentially be made available and the reliability of that supply. Financial cost considers the likely annualized per-acre-foot financial cost of the alternative. Third party impacts identify the likelihood and magnitude of positive or negative effects to those not protected by water rights (includes changes in quantity, timing, quality or reliability of water resources). Political feasibility assesses the likely political and social acceptability of a given alternative, especially for issues of state sovereignty and the distribution of the burden allocated between and within states.

Identify Economic Impacts of Feasible Alternatives

Offstream and instream users of Platte River water will be impacted by alternatives which increase minimum instream flow levels in the critical reach. Because offstream water use is predominately agricultural, a major focus of our effort in this project is estimating economic impacts to agricultural uses in the three basin states. Some alternatives also impact municipal and industrial uses; economic impacts in these sectors are also being identified. Platte River water is also used instream for generation of hydropower and for recreation. (Offstream reservoirs are also important recreational resources.) We are inventorying these uses and identifying any that are likely to be significantly impacted by the feasible alternatives. If the magnitude of impacts is determined to be comparable to identified offstream impacts in agricultural and municipal and industrial sectors, we will include hydropower and recreation in estimating economic impacts of the feasible alternatives.

The objective is to obtain the economic value and shadow price of water and the corresponding water usage from the various uses and benefits from the states and subregions within the Platte River Basin. The resulting economic benefit functions will then be utilized in an integrated modeling framework to evaluate the impacts of the feasible alternatives.

Over 90 percent of the water in the Platte Basin is used by agriculture. Therefore when we look at opportunities to increase instream flows a primary focus is on agricultural use and impacts. Direct economic impact to agriculture is measured as the associated change in net income with a change in the timing and quantity of water use. Given the size and diversity of agricultural production, coupled with the hydrologic characteristics (timing and availability) over the broad region of the Platte River Basin, representative farm models are being constructed for identified sub-regions.

A single optimization framework has been adopted for representative farms in the Platte Basin, which can be customized to "regional" conditions of crop production, markets and water

timings and availability. Discrete Sequential Stochastic Programming (DSSP) models have been formulated to accommodate the stochastic nature of water. We are particularly concerned with developing economic impact estimates across states (and regions within states, as necessary) which are comparable. We recognize that methodologies based on residual imputation (such as linear programming) can be particularly sensitive to assumptions such as cropping constraints, yields, and production costs. While these factors do vary across regions and hence lead to real differences between economic impacts of unit changes in water use across regions, it is important that valuation methodologies minimize the bias in estimates of these differences.

Integrated Framework for Evaluation of Selected Conceptual Alternatives

The conceptual alternatives identified above include approaches that reduce consumptive uses, change diversion levels, or alter the timing of deliveries. The spatial distribution and timing of such changes are a function of the conceptual alternative. Evaluating the effectiveness of the alternatives for achieving instream flow goals requires a framework for projecting economic and hydrologic impacts. Institutional alternatives may allocate water on the basis of hydrologic conditions (e.g. priority systems), economic values (e.g. water markets), or a combination of factors. A framework integrating institutions, hydrology, and economic value is being developed to provide a basis for evaluating the effectiveness of institutional alternatives.

While currently pre-existing models are not be capable of addressing the effectiveness of our conceptual alternatives, they have played a critical role in providing data and calibration for our proposed Platte Basin model. The integrated framework provides a flexible environment for representing alternative institutions while accounting for a set of interactions between uses, storage (including groundwater), and flows (including diversions and return flows) in the Platte River Basin. The framework is spatially integrated to include major uses, storage, and flows in North, South, and central reaches of the Platte River. Because of the importance of interstate issues, including representation of relevant compacts and decrees, uses, storage, and flows are clearly identified by state (e.g. Colorado, Wyoming, or Nebraska).

Economic impacts can be both a consequence, and a determinant of the water allocations which are the solutions to models of the type discussed above. Because economic impacts of providing instream use are of central concern, it is appropriate to directly calculate such impacts within the model structure. In practice it is also necessary to make such calculations to determine allocations which maximize beneficial use. We will calculate and report such impacts by state, river reach, and sector (agriculture, municipal, and industrial uses).

Because of the inherent variability in the hydrologic and economic parameters it is important to conduct extensive sensitivity and threshold analysis of the feasible alternatives. A primary purpose of the sensitivity and threshold analysis is to explore the robustness of feasible alternatives to variability in hydrologic and climatic conditions (e.g. streamflows and evapotranspiration requirements), and assumptions (e.g. agricultural market conditions, characteristics of stream?aquifer interactions.) For example, an alternative such as irrigation efficiency improvements may be effective in one region (e.g. just upstream of critical instream reaches), but may do little to increase instream flows if implemented far upstream of critical reaches. The effectiveness of a policy of subsidizing irrigation efficiency improvements would thus be highly sensitive to the financial benefits of adopting these technologies at different basin locations. The sensitivity analysis will help to identify the robustness of the alternative over a

range of conditions.

Principal Findings and Significance

Principal findings and significance to date

This research project is built upon a system of mathematical models that are currently being developed. Significant progress has been made in four general areas. 1) identifying and screening alternatives, 2) constructing the representative farm models, 3) developing and parameterizing basin hydrology model, 4) constructing the integrated basin model. However, few intermediate findings are available for disclosure at this time. The publications and papers that have come out of the project focus on institutional and methodological developments that have arisen in working on the specific objectives. Significant work remains to be completed before significant findings can be generated. Because the work remaining cannot be completed before the scheduled termination of the project, a no-cost extension has been requested.

Descriptors

Institutional adjustments, economics, multiple-objective planning, decision models

Articles in Refereed Scientific Journals

Frasier, W.M., A.M. Michelsen, R.G. Taylor, J.F. Booker, and R.G. Huffaker. "Evaluating Economic and Institutional Alternatives for Meeting Interstate ESA Instream Flow Requirements in the Platte River Basin." American Journal of Agricultural Economics, 81(December 1999): 1257-1261.

Huffaker, R.G., W.M. Frasier, and J.R. Hamilton. "The "Intrastate-Trade-Restriction" Defense in Commerce-Clause Challenges of State-Imposed Restrictions on Water Exports to Neighboring States." International Journal of Water Resource Development. 16:2(June 2000):275-279.

Book Chapters

Dissertations

Houk, Eric. "Valuing the Characteristics of Irrigation Water in the Platte River Basin," MS Thesis. University of Idaho, Moscow, ID. Spring 2000.

Water Resources Research Institute Reports

Conference Proceedings

Huffaker, R.G., W.M. Frasier, and J.R. Hamilton, " The Constitutionality of State Restrictions on Interstate Water Transfers," proceedings paper Water: Lessons of World

Development, Universities Council on Water Resources 1999 Annual Conference, Kamuela, HI, June 29 - July 2, 1999.

Michelsen, A.M., J.F. Booker, and W.M. Frasier, "Feasibility Of Alternatives To Manage Platte River Instream Flows To Accommodate Endangered Species," proceedings paper Water: Lessons of World Development, Universities Council on Water Resources 1999 Annual Conference, Kamuela, HI, June 29 - July 2, 1999.

Other Publications

Frasier, W.M., A.M. Michelsen, R.G. Taylor, J.F. Booker and R.G. Huffaker. "Evaluating Economic and Institutional Alternatives for Meeting Interstate ESA Instream Flow Requirements in the Platte River Basin," Principal paper presented at the 1999 annual meeting of the American Agricultural Economics Association, August 8-11, Nashville, TN.

Frasier, W.M. "Politics and Academics: A Modern Alchemy in the Platte River Basin," presented at the W-190 Technical Committee Meeting, Denver, CO, October 13-15, 1999.

Frasier, W.M. "CSU Research as it Relates to Federal Issues," Invited presentation at the Colorado Water Congress Workshop on A Review of Federal Environmental Laws, Denver, CO, November 12, 1998.

Houk, E., R.G. Taylor, and W.M. Frasier. "Valuing Water Characteristics in the Platte River Basin," Selected paper presented at the 2000 Annual Meeting of the Western Agricultural Economics Association, June 29-July 3, Vancouver, BC.

Huffaker, R.G., A.M. Michelsen, J.R. Hamilton, and W.M. Frasier. "The Uneasy Hierarchy of Federal and State Water Laws and Policies," Selected paper presented at the 2000 Annual Meeting of the Western Agricultural Economics Association, June 29-July 3, Vancouver, BC.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Description and Interpretation of Salinization in the Lower Arkansas River Valley, Colorado
Project Number	02
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Water Quality
Focus Category #1	Water Quality
Focus Category #2	Groundwater
Focus Category #3	Agriculture
Lead Institution	Colorado State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Timothy K. Gates	Associate Professor	Colorado State University	01

Problem and Research Objectives

Introduction

Recent changes within the Lower Arkansas River Valley system, such as the construction of Pueblo Reservoir and subsequent modification of basin-wide system operations (winter water storage program), as well as decreased groundwater pumping, have intensified problems of high water table elevations and high salinity levels (Watts and Lindner-Lunsford 1992). Problems have increased to the point where land is being taken out of production and significant yield losses are occurring (Valliant 1997). Within the Lower Arkansas River Valley, extending from Pueblo Reservoir to the Colorado/Kansas state line, water tables rose from 0.3 to 1.3 meters between the years 1969 and 1994 (Cain 1997). Additionally, according to the U.S. Environmental Protection Agency, portions of the valley are classified with the highest salinity hazard rating.

Anecdotal evidence of high water table and salinity problems exists in many places within the Arkansas Valley. Evaluating the economic and environmental outcomes of best management practices (BMP's) to alleviate these problems is extremely difficult because the system is hydrologically and legally very complex. Therefore, the problems have not been investigated or quantified on a large scale. The goal of this project is to address this growing need and conduct an investigation which fulfills, on a regional scale, two primary purposes:

- Describe the high water table and salinity problems within the basin through intensive data collection and analysis.
- Prescribe solutions to the problems through detailed modeling of solution alternatives.

A study reach within Otero County, Colorado, was selected which extends for about 40 kilometers from Manzanola to the Otero-Bent County line. The study area encompasses around 22,000 hectares (55,000 acres). This size should be large enough to capture variations in soil types, hydrogeology, irrigation and drainage infrastructure, and crops that are characteristic of the Valley, but small enough so that data collection is feasible.

Two major efforts are currently underway to meet project goals. These efforts, as well as some preliminary results, are described herein. The groundwater modeling phase is described initially, with preliminary results from steady-state flow and salt transport models presented. Following is a description of on-going data collection efforts. Initial findings and analysis of these efforts are also presented and discussed.

Methodology

Groundwater Modeling

The Department of Defense Groundwater Modeling System (GMS) (Brigham Young University 1997) was used to create flow and salt transport models of the study reach. Designed to serve as a comprehensive groundwater modeling environment, GMS acts as a graphical "GIS-style" interface for several different models. The GMS interface is divided into modules which allow the user to enter and analyze the various data types for the particular models being utilized. The two models within the GMS package employed in this investigation include: MODFLOW, a modular three-dimensional finite-difference groundwater flow model, and MT3D, a modular three-dimensional contaminant transport model that uses MODFLOW results in its analysis. Both of these models use three-dimensional finite-difference analysis techniques; however, due to existing data availability, they currently are applied as two-dimensional models utilizing depth averaging within the vertical dimension.

The key steps involved in the development of the GMS model of the study reach are:

1. Selection and creation of a background image.
2. Description of the system by creation of a conceptual model, including the surface water system, field boundaries, and pumping wells.
3. Creation of the finite-difference grid.
4. Input of additional data sets into GMS, including data sets for ground elevation, hydraulic conductivity, water table elevation, and aquifer bottom elevation.
5. Estimation of recharge and evapotranspiration (ET), which includes:

    a. Analysis of crop types
    b. Assignment of crop types to modeled fields
    c. Estimation of crop water requirements, crop ET, and deep percolation using CropFlex98

6. Calculation of recharge values6. Incorporation of salinity data into the conceptual model, including data on surface water electrical conductivity (EC), groundwater EC, and soil bulk EC.

Data Collection

The main purposes of the data collection effort are twofold: to accurately describe high water table and salinity problems within the study area, and to collect sufficient data so that a transient model may be constructed to help prescribe solutions to these problems. Based on the knowledge gained from the preliminary modeling investigation described earlier, the major data needs were identified. The types of data currently being collected include water table elevation, groundwater salinity, soil salinity, land elevation, surface water salinity, soil texture, crop yield estimated, river and tributary geometry, drainage system inventory, and total dissolved solids in water samples. Complete discussions on the methodology for collection of each data type is available in the Annual Progress Report.

Principal Findings and Significance

Groundwater Modeling

The GMS interface was used to translate all of the conceptual model data sets into MODFLOW and MT3D input file format. After a series of debugging procedures, the models were used to investigate the following scenarios:

· Scenario 1: Baseline Conditions
· Scenario 2: Increasing of Pumping Rates by 20%
· Scenario 3: Increasing of Pumping Rates by 30%
· Scenario 4: Reduction of Recharge Rates by 20%
· Scenario 5: Reduction of Recharge Rates by 30%
· Scenario 6: Increasing of Pumping Rates by 20% and Reduction of Recharge Rates by 20%
· Scenario 7: Increasing of Pumping Rates by 30% and Reduction of Recharge Rates by 30%

The purpose of the preliminary modeling described in this document is to aid in directing the future course of data collection and modeling efforts and to give a preliminary indication of the sensitivity of the groundwater system to general widespread changes as described in the scenario descriptions. Of key importance to this study is the reduction in water table elevation. From the MODFLOW modeling results, the following important conclusions were drawn about reducing the water table level:

1. The effects of increased pumping are localized.
2. Changing irrigation practices to reduce aquifer recharge can have widespread effects.
3. Plans incorporating multiple solution alternatives will have cumulative effects.

Coupled with the objective of lowering high water tables is the reduction of high salinity levels. The steady-state model yielded only limited information about decreasing salinity. Once a transient model has been established, the long-term effects of alternatives on salinity levels will become more evident. One interesting output result can, however, be extracted from this preliminary salinity model. The reduction of accumulated salinity deposited in the root zone, due to groundwater upflux, can be estimated from the MT3D output. This parameter is a bit misleading, although, since it does not reflect salinity that would be removed from the root zone by the increased leaching that might accompany the lowering of the water table (only a transient model will quantify this effect).

Besides these conclusions, this preliminary modeling effort reinforces the need for extensive, well distributed, time-varied data. These data need to be collected at a frequency which will be adequate to capture any significant changes over the course of a year. Also, these data need to have adequate spatial density to effectively describe the groundwater system. In response to these needs, a major data collection effort was initiated in the summer of 1999.

Data Collection

Water Table Depth: The data indicate distinct rises in the water table over the course of the season in certain areas. Notably, the area in the southwestern part of the study region (i.e. near Patterson Hollow) shows a shallower water table depth as the season progresses. Other areas that display this trend include the south central (south of the town of Swink) and the east central (northeast of La Junta along Highway 194) parts of the study region. In much of the

region, however, there was no evidence of substantial change in the water table depth. The flow gradient is directed toward the river over the course of the study reach (except for one small area on the western edge) for each time period. This means that the river generally acts as a sink, receiving return flow from the groundwater system, during the irrigation season.

Groundwater Salinity: Groundwater salinity levels declined in some areas over the course of the irrigation season. This is likely due to dilution effects as recharge filled the aquifer. Areas where a decrease can be seen include the northwest area (near the town of Manzanola) and the central area (east of Rocky Ford) of the study region. Interestingly, however, there are two areas (east central - near La Junta, and northeast - near the town of Cheraw) which show a noticeable increase in salinity. This is surprising and there is currently no recognized reason for these anomalous areas; however, one possible cause could be the dissolution of native salts.

Soil Salinity and Water Table Depth: In the early season reading, 55 fields had all or some portion of the measured sites which were above the approximate value above which typical crops (namely corn and alfalfa) will experience yield losses (i.e. at an ECe of 2.0 dS/m). The overall average for the study area was 2.74 dS/m for the early season. For the late season reading, 64 fields had all or some portion of measurements above the salinity threshold, and the overall average increased to 2.84 dS/m. This slight rise in average ECe is likely tied to the prolonged high water table which was observed over the course of the irrigation season. High water table levels reduce the ability to leach salts out of the root zone and cause an increase in water losses due to evaporation. When the soil salinity values were plotted against water table depth, a power function game the best fit curve to describe an approximate relationship between the variables. For the early season data, the following equation was developed:

$$ECe = 3.05D - 0.71$$

where D represents the average depth as described above. The relationship described by this curve represents an r2 value of 0.36, indicating that some level of correlation exists. For the late season data, the equation developed is slightly different:

$$ECe = 3.64D - 0.65$$

The r2 value for the late season data relationship is 0.34, indicating a slightly lower, but still notable, correlation.

Field data confirms extensive and severe saline-high-water-table problems in the Lower Arkansas Valley. Salinity of overlying soils indicates levels that diminish crop productivity. However, though the salinity is serious, it seems recoverable through implementation of strategies developed by careful modeling.

The preliminary groundwater flow and salinity modeling of the study region indicates that the effects of increased pumping are localized, whereas the potential effects of changing irrigation practices to reduce groundwater recharge can be widespread. However, solution alternatives incorporating multiple BMP's including seepage control and subsurface drainage systems, and alternatives investigating the reduction of river levels should be considered in future modeling efforts. Additionally, the current steady-state model should be expanded to consider time-varied (i.e. transient) changes to the system so that the long-term effects of alternatives can be evaluated.

Critical to the need to develop transient models is the continuation of the described data collection activities. The current data collection methods including equipment used, observation well depth, measurement frequency, etc., need to be evaluated following the first full data period (year). Changes in these methods should be made if necessary. Also, improvements to existing calibration equations and to parameter estimation techniques should be possible following the analysis of all collected water and soil samples, the completion of the slug test analysis, and the collection of crop yield data.

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Descriptors

Data storage and retrieval, Groundwater quality, Water quality, Water quality monitoring

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Gates, Timothy K., John W. Labadie, and J. Philip Burkhalter. March 2000. Identification and Solution of Waterlogging and Salinity Problems in the Lower Arkansas River Valley, Colorado, Progress Report to Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Distribution, Habitat, and Life History of Brassy Minnow (Hybognathus hankinsoni) in Eastern Colorado Streams
Project Number	03
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Biological Sciences
Focus Category #1	Ecology
Focus Category #2	Hydrology
Focus Category #3	Geomorpological and Geochemical Processes
Lead Institution	Colorado State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Kurt D Fausch	Professor	Colorado State University	01

Problem and Research Objectives

Recent surveys of fish distributions in the South Platte and Republican River basins in comparison with previous studies indicate that 10 native fish species have declined. In 1998, the Colorado Wildlife Commission added three fish species from the plains portion of these basins to the State of Colorado list of threatened and endangered species. Brassy minnow *(Hybognathus hankinsoni)* was listed as threatened, while plains minnow *(H. placitus)* and suckermouth minnow *(Phenacobius mirabilis)* were designated endangered. The brassy minnow was selected by the Colorado Division of Wildlife as of high priority for further study, primarily because there were thought to be sufficient numbers at widely distributed sites to allow research. Understanding the ecology of these fishes will help direct efforts to restore fish

to critical habitats, and to restore habitat and flow conditions that will allow brassy minnow to thrive and prevent further endangerment and possible federal listing.

Research on brassy minnow began in June 1999. This research is being conducted as two concurrent studies: a study of the brassy minnow systematics, i.e. the taxonomy of the species; and a study of the brassy minnow ecology. A literature review has also been completed this year to support both studies.

Systematics

The first step in understanding brassy minnow ecology is to determine its historic distribution in Colorado. Until 1929, brassy minnow and plains minnow were considered variants of the same species, H. nuchalis, Mississippi silvery minnow (Hubbs 1929 in Bailey 1954). The majority of early museum collections are still catalogued as H. nuchalis. Therefore, the first goal of this research is to retrieve and identify the extant museum collections of Hybognathus specimens from Colorado to help clarify the historic distribution and thereby provide guidance for conservation and restoration efforts. Analysis and proper identification of all extant museum specimens of Hybognathus from Colorado and adjacent counties will clarify the historic distribution of H. hankinsoni and H. placitus in Colorado. From this analysis, an identification key may be developed for use by managers to identify brassy minnow and plains minnow in the field or laboratory. The research objectives for the systematics study are:

Objectives for 1999-2000

1. Retrieve museum specimens of all Hybognathus species from Colorado, and counties adjacent to Colorado in the Platte, Republican, and Arkansas River basins.
2. Measure morphometric and meristic characters of museum specimens to identify them by comparing to known brassy minnow and plains minnow, and for future use in developing a key for identification.

Objectives for 2000-2001

3. Identify all extant museum specimens of Hybognathus from Colorado and adjacent counties to clarify the historic distribution of H. hankinsoni and H. placitus in the state.
4. Analyze the taxonomic characters using univariate and multivariate statistics to develop a set of key characteristics to separate H. hankinsoni from H. placitus in Colorado.

Ecology

Despite its widespread distribution in North America, little is known about the life history of brassy minnow. Species accounts provide conflicting information about habitat requirements and reproductive biology. Only one study (Copes 1975) provides substantial detail about brassy minnow ecology. Therefore, a second main goal of this research is to relate movement, habitat use, reproduction and growth of brassy minnow to important habitat factors to provide managers with information to preserve and restore critical habitats. The objectives for the ecology study are:

Objectives for 1999-2000

1. Sample locations where brassy minnow were most recently found in Colorado to identify populations for future study. The top priorities were nine sites in the South Platte River basin where brassy minnow were found during 1993-94 sampling by the Colorado Division of Wildlife (Nesler et al. 1997). Additional sites were selected from those where Platania (1990) and Cancalosi (1980) captured brassy minnow and plains minnow in the South Platte and Republican River basins.

Objectives for 2000-2001

2. Study and compare the habitat use and life history of brassy minnow in the Arikaree River (TNC) and Lonetree Creek, as follows:

a. Select sites for further study.
b. Determine attributes of critical habitats needed for survival, growth, and reproduction.
c. Determine patterns of movement, local extinction, and recolonization across landscape scales and relate them to environmental factors.
d. Determine habitat selected for reproduction, and relate it to environmental conditions.

Methodology

Systematics

Museum collections of all extant Hybognathus spp. from Colorado and adjacent counties in neighboring states have been requested from the Smithsonian Institution (Washington, D.C.), University of Colorado Museum (Boulder, CO), University of Kansas Museum of Natural History (Lawrence, KS), Museum of Southwestern Biology (Alburquerque, NM), University of Nebraska (Lincoln, NE), Sternberg Museum of Natural History (Hayes, KS), US Fish and Wildlife Service (Albuquerque, NM), and CDOW (Fort Collins, CO). A total of 52 lots and over 600 individuals have been received for analysis, and more are pending. These collections include specimens from the earliest collections in the state by David Starr Jordan (1891). Many of these lots are still catalogued as H. nuchalis and so have not been properly identified. To date, nine quantitative and five qualitative characters suggested by Dr. Kevin Bestgen of the Colorado State University Larval Fish Laboratory have been measured using digital calipers to compare with characters from known brassy minnow and plains minnow. Analysis and proper identification of these specimens with Dr. Bestgen's help should provide a clearer picture of the original distribution and overlap of brassy and plains minnow.

Ecology

Field sampling began in June 1999 to locate suitable brassy minnow populations for study. Fifteen sites where brassy minnow had recently been located (nine sites by the Colorado Division of Wildlife and six sites by Cancalosi (1980) most recently located brassy minnow were resampled, among others. At several locations, additional sites were sampled upstream and downstream of the target sites to establish the limits of brassy minnow distribution. At each site, reaches for sampling were selected to include a variety of habitat types. Fish were sampled and identified, voucher specimens preserved, and basic habitat information measured at each site. At each sampling site, data were collected regarding the habitat and water

chemistry. The habitat characteristics measured about the reaches sampled included total length, wetted width, bankfull width, thalweg depth, maximum depth, substrate composition, primary land use, erosion, and riparian vegetation type. Water chemistry measurements included temperature, pH, and conductivity. These data will be used to select sites for further study of brassy minnow life history and habitat requirements during 2000-2001.

Principal Findings and Significance

Systematics

The 14 taxonomic characters shown in Table 1 of the Annual Progress Report have been measured for approximately 400 known and unknown specimens so far. Positively identified brassy and plains minnow specimens have been supplied by Dr. Bestgen from the Colorado State University Larval Fish Laboratory museum collection. Preliminary statistical analysis of these data in ongoing, and will be used to direct our future systematics research. This taxonomic work will continue throughout the project.

Ecology

Of the nine sites in Lonetree Creek with brassy minnow present, only two contained fish over 35 mm fork length (FL). All of the brassy minnow captured in the main South Platte River and Republican River tributaries exceeded 35 mm FL, probably due in part to sampling later in the season. The number of brassy minnow at sites in Lonetree Creek and South Fork Republican River were estimated from the number of unknown individuals recorded in the field and the relative percentage of vouchered unknowns subsequently identified as brassy minnow. The number of bigmouth shiner (Notropis dorsalis) at the South Platte River site was probably underestimated due to their similar appearance to sand shiner.

The habitat analysis showed that most sites sampled had silt or sand substrates. Only Transition Zone streams (Lonetree, Boulder, and St. Vrain creeks) had substantial amounts of gravel or cobble. Grasses predominated the riparian vegetation at most sites, although 7 of 31 sites had at least 50% area as trees. Erosion was low at the majority of sites, with only one site, Dry Creek 1, classified as having high erosion. Primary land uses were grazing and agriculture.

Average water temperatures ranged from 8 to 28° C at the sites sampled. Brassy minnow were found at sites with temperatures ranging from 8 to 24.5° C. The pH ranged from 6.18 to 8.69 across sites (median= 7.67), and conductivity ranged from 100 to 1400 microsiemens (median= 600 ?S). Laboratory measurements were typically within 0.5 pH unit of those measured in the field and within 200 microsiemens of conductivity. Overall, the water chemistry in these plains streams was slightly alkaline and highly conductive.

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Descriptors

Plains fish ecology, Ecohydrology, Conservation

Articles in Refereed Scientific Journals

None yet.

Book Chapters

None.

Dissertations

Thesis is in process.

Water Resources Research Institute Reports

Scheurer, Julie A., and Kurt D. Fausch. April 2000. Habitat Requirements and Systematics of Brassy Minnow in Intermittent Plains Streams in Eastern Colorado. Annual Progress Report, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO, 80523. 29 pp.

Conference Proceedings

None.

Other Publications

None.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Protocol for a State-Wide Groundwater Quality Monitoring Progra and Establishment of a Groundwater Quality Data Clearinghouse
Project Number	04
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Water Quality
Focus Category #1	Groundwater
Focus Category #2	Water Quality
Focus Category #3	Management and Planning
Lead Institution	Colorado State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Grant E. Cardon	Associate Professor	Colorado State University	01

Problem and Research Objectives

The Department of Soil and Crop Sciences at Colorado State University recently pulled together existing groundwater quality data in the state as part of an effort by the Colorado Water Quality Control Commission (WQCC) to delineate aquifers meeting the "high quality" classification criteria. A key outcome of this project was the discovery of a significant lack of comprehensive groundwater quality data. Many aquifers in the state have not been sampled, at least not to the degree that would allow a scientifically defensible evaluation of their quality. Moreover, most of the databases lacked sufficient descriptive data necessary to fully compare the data to other sources -- particularly sample location, sample depth, analytical methodology, and quality assurance/quality-control parameters on the data. This project's objectives are to:

Work with the Colorado Water Quality Control Commission to develop a protocol for a state-wide groundwater quality monitoring program.

Organize and execute an educational effort to put the protocol in the hands of all agencies working with groundwater in the state.

Develop and deploy an Internet-based information source for all groundwater quality monitoring activities in the state.

Methodology

After meetings with personnel at the Water Quality Control Commission, discussion caused an alteration in the project design to narrow the scope of the work to the primary objective of documenting, as completely as possible, the existing groundwater quality databases in the state. Subordinate to that objective are a number of tasks which include:

Creating a list of contacts and database managers.

Gathering as much descriptive, or meta-data, for these databases as possible.

Determining the degree of confidence that is possible in making decisions based on the existing data, particularly as it relates to comparing the various databases to one another to create a comprehensive "big picture" of groundwater quality in Colorado.

It was determined that the original objectives represented future phases of work in this area, after contacts with database managers and gathering of information is completed.

Principal Findings and Significance

A key outcome of previous work by members of the research team, presented to the Colorado Water Quality Control Commission, was the discovery of a significant lack of comprehensive groundwater quality data. Many aquifers in the state have not been sampled, at least not to the degree that would allow a scientifically defensible evaluation of their quality. Moreover, most of the existing databases lack sufficient descriptive data, or "meta-data," necessary to fully compare the data to other sources, particularly with respect to sample location, sample depth, analytical methodology, and quality assurance/quality control parameters on the data.

The lack of information, particularly complete meta-data, makes any statistical conslusions based on existing data scientifically questionable if not indefensible. Two graduate research assistants working on the project are now beginning to evaluate the databases for reliability and comparability, as their thesis topics.

The primary graduate student on the project is approaching the completion of a plan-B Masters degree in Soil Science, and only needs to put the finishing touches on her professional paper that covers the first phase of this project. Her experience on the project was instrumental in getting a full-time position with the National Park Service gathering and compiling groundwater data and evaluating groundwater quality on National Park Service Lands.

The second graduate student will complete her Masters degree this year, and has been awarded a National Science Foundation fellowship to pursue a Ph.D degree in the Department of Soil and Crop Science.

Descriptors

Data storage and retrieval, Groundwater quality, Water quality, Water quality monitoring

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Information Transfer Program

The latest water information and research results are provided to Colorado water users, managers and the public via an active technology transfer program that includes:

The CWRRI newsletter, *COLORADO WATER*, is published six times a year, with approximately 30-40 pages of water information including research findings, lists of water faculty and water courses, upcoming water conferences, short courses and seminars, new water research projects, and water news summaries. The newsletter is distributed widely throughout Colorado, to state water institutes, selected federal agency personnel out-of-state, and to others upon request.

W E B P A G E S

CWRRI maintains three home pages on the World-Wide Web: The CWRRI Homepage, the Water Center Homepage, and the Colorado Water Knowledge Homepage.

http://cwrri.colostate.edu

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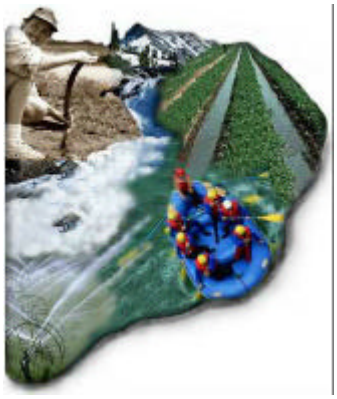
http://watercenter.colostate.edu



Welcome to the Water Center!
What is the Water Center?

People Involved
Overview of Programs
Meetings/Seminars

Short Courses
Jobs in Water Resources
Educational Opportunities
Water-Related Courses at CSU
Colorado Water Resources Research Institute

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http://waterknowledge.colostate.edu

- Colorado Water - A huge list of water facts!
- Colorado Water - A description of stream processes and an

overview of Colorado's geology, water history, and climate.

- Colorado Water - Sources, Uses, Management, and Conservation - A description of Colorado's major river basins and aquifers, how the water from these sources are used and managed, and methods for conserving Colorado's water.
- Colorado Water - Aquatic Life, Wetlands, Water Quality, and Environmental Water Law - A description of the fish and aquatic insects present in Colorado's waters, wetlands, water quality, and links to environmental laws.
- Colorado Water - Water Administration - A description of transmountain diversions, interstate compacts, Colorado water rights law, and federal, state, and local administrative agencies.
- Colorado Water - Frequently Asked Questions - A list of frequently asked questions and answers about Colorado water.
- Colorado Water - The Incredible Journey of the Greenback Cutthroat - Information about this recovering species.

In addition, CWRRI maintains home pages for the annual meetings of the South Platte Forum and Hydrology Days. **http://southplatteforum.colostate.edu/**

Money Flowing Through the South Platte Basin:

The Business of Water
First Announcement-Call for Posters

11th Annual South Platte Forum

October 24-25, 2000
Raintree Plaza Conference Center
Longmont, Colorado

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http://HydrologyDays.colostate.edu

20th Annual American Geophysical Union
HYDROLOGY DAYS
April 3-6, 2000

Lory Student Center
Colorado State University
Fort Collins, Colorado USA

Sponsored by: Hydrology Section of the American Geophysical Union
Dedicated to HUBERT J. MOREL-SEYTOUX

P U B L I C A T I O N S

- WATER IN THE BALANCE, a user-friendly new publication series that provides a condensed version of research completion reports that gives water users a 16-24 page review and analysis of the results of research conducted under the auspices of the State Water Institute Program.
- COMPLETION REPORTS--Final reports on completed research containing details of procedure, analysis of data and conclusions reached.
- TECHNICAL REPORTS--Technical information of interest to water resource professionals.
- INFORMATION SERIES--Information of general public interest on water-related subjects.
- OPEN-FILE REPORTS--Complete reports of research that are provided at cost upon request. These reports consist primarily of theses and dissertations from CWRRI-funded research projects.

M E E T I N G S AND C O N F E R E N C E S

Arkansas River Basin Water Forum
Colorado Springs, Colorado
March 16-17, 1999

The Fountain Creek watershed headlined this year's Arkansas River Basin Water Forum. Fountain Creek is a major tributary of the Arkansas River, collecting water from the mountains and plains in the area surrounding Colorado Springs and flowing south to become a part of the Arkansas River

at Pueblo. The spring 1999 flooding that originated in the Fountain Creek basin highlighted the importance of this tributary. Also, the effects of water rights transfers for urban use can be seen in the Fountain Creek flows. Streambank erosion, sediment and higher peak flow rates were issues addressed at the forum. The forum also addressed many broader issues in the basin. An update on the Kansas v. Colorado lawsuit detailed recent events in this continuing saga, and the issues of salinity, TMDL (daily pollutant load) regulations, fluoridation proposals and future water needs were discussed as well. CWRRI is a cosponsor of this annual forum.

Garden of Dreams vs. High-Desert Reality: Can We Save Everything, Keep Our Lawns Green, AND Have Enough Water for Everyone?
Western State College, Gunnison, Colorado
July 28-30, 1999

Right: John Sayre, Living Legend Honoree, and Robin Helken,Colorado Water Workshop Director

The 24th annual Colorado Water Workshop attracted 185 people to the campus of Western State College in Gunnison July 28-30, 1999. The workshop included the 1st Annual Water Conservation-Conservancy District Managers' Forum, as well as a number of pre-conference water education sessions. Water attorney Dick Bratton's keynote address, 'The Appropriation Doctrine Meets Miss Manners: Can a Social Conscience be Developed Within the Prior Appropriation Doctrine?,' provided a thorough examination of the Denver Metropolitan Water Supply Investigation report in light of the need to supply water for a growing population while also attempting to protect the environmental, social and economic values of Colorado citizens. Commissioner of Agriculture Don Ament, Arapahoe County Commissioner Polly Page, CH2MHILL Vice President Peter Blinney, and Environmental Defense Fund Senior Scientist Dan Luecke provided responses to the keynote address. David Robbins provided an excellent overview of Colorado's interstate compact obligations and the impacts such obligations have on the water supply for Colorado. CWRRI is a cosponsor of this annual forum.

John M. Sayre, Attorney at Law, and Retired Brigadier General Felix L. Sparks were honored as Living Legends in Western Water, an annual event of the Colorado Water Workshop.

The South Platte: Old River – New Course?
Changes in Land and Water Use in the South Platte Basin
10th Annual South Platte Forum
October 27-28, 1999
Raintree Plaza Conference Center, Longmont, Colorado

Left: Gene Schleiger, Northern Colorado Water Conservancy District; Lindsay Martin, South Platte Forum Coordinator, and Rob Henneke, Environmental Protection Agency, Region VIII.

The 1999 South Platte Forum provided attendees with an excellent overview of a number of key issues facing water and wildlife managers, as well as citizens, in the South Platte Basin. Beyond the immediate need to address endangered species,the forum had sessions on source water protection and its implications to water supply providers and the people living in the watersheds providing the water. The Confined Animal Feeding Operation regulations, emerging from passage of Amendment 14 by Colorado voters in 1998, were discussed. Another session focused on broader non-point source pollution issues and solutions.

Cosponsors for this annual meeting are: the Northern Colorado Water Conservancy District, the Colorado Division of Wlidlife, Colorado State University Cooperative Extension, Denver Water, the U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, and the U.S. Geological Survey.

Hydrology Days
Colorado State University
August 16-20, 1999

The ***19th Annual Hydrology Days***, co-sponsored by the Water Resources Engineering Division of the American Society of Civil Engineers, was held August 16-20, 1999 on the campus of Colorado State University.

*Right: Greg Hobbs, Justice, Colorado Supreme Court, and Hubert Morel-Seytoux at 19th Annual Hydrology Days.*The meeting was dedicated to Dr. Roger E. Smith and Dr. David A. Woolhiser, scientists with the Agricultural Research Service, U.S. Department of Agriculture (retired); and former students and professional colleagues of Professor Morel-Seytoux.

The four-day program drew speakers from across the United States and from across the world – from Canada, the United Kingdom, Mexico, Australia, Brazil, France, Iran, Japan, Saudi Arabia and New Zealand. Presentations made by university faculty included Colorado State; the Colorado School of Mines; the Universities of Alabama, California, Colorado, Connecticut, Georgia, Nebraska, Oklahoma, and South Florida; City College of the City University of New York, Cornell University, Manhattan College (NY), Massachusetts Institute of Technology; Michigan State

University; Princeton (NJ); Oregon State College; Simpson College, (IA); Utah State University, Virginia Polytechnic Institute; the Mexican Institute of Water Technology, Kochi University, Japan; the Universidade Federal de Ceara, Brazil; the National Institute of Water and Atmospheric Research, New Zealand; King Saud University, Saudi Arabia; the University of Grenoble, France; the University of Quebec and the Ecole Polytechnique, Montreal, Canada; the University of Technology, Tehran, Iran; and the University of Reading and the University of East Anglia, the United Kingdom.

Federal agencies represented included the U.S. Geological Survey's Denver office and the EROS Data Center in Sioux Falls, South Dakota; the U.S. Environmental Protection Agency's Athens, Georgia Lab, and from the USDA's Agricultural Research Service representatives from Arizona, Colorado, Idaho, Mississippi, Ohio, Oklahoma, and Oregon. Others presenting papers or posters included representatives from the South Florida Water Management District, the Pacific NW National Laboratory (WA); the National Institute for Environmental Renewal (PA); the Swiss Federal Institute of Technology, Zurich; Soai Co., Ltd., Kochi-shi, Japan; the Ministry of Energy, Tehran, Iran; and the Institute of Technology, India. CWRRI is a cosponsor of this annual forum.

Student Water Symposium
Colorado State University
November 3-5, 1999

The 1999 Colorado State University Student Water Symposium was held November 3-5 at the Lory Student Center on the CSU campus. The event began with a poster session held Wednesday afternoon.

The keynote address, given by Marc Reisner, author of Cadillac Desert, was held November 3rd at the Lory Student Center Theatre. His topic of water management in the west: "Dams and their Legacy", drew an audience of 400, including students, faculty, community members, and out-of-town attendees.

Left: Marc Reisner with students and faculty at reception following his keynote address.

Governor's Conference on Flood and Drought Preparedness
Denver, Colorado
December 2-3, 1999

Right: Tom McKee and Nolan Doesken listen to questions from the press.

Flood and drought preparedness were the topics at a two-day conference convened by Colorado Governor Bill Owens December 2-3, 1999 at the Adam's Mark Hotel in Denver, Colorado. The conference was cosponsored by the Colorado Department of Natural Resources, the Colorado Department of Agriculture, and the Colorado Department of Local Affairs. Invited attendees included representatives from federal, state and local agencies and organizations; business representatives; and individuals from across the state.

Governor Owens and Greg Walcher, Executive Director of the Colorado Department of Natural Resources, set the stage with a discussion of the impacts of recent floods and droughts in the state, including the damage caused by the Spring 1999 floods in the Arkansas Valley. Then, Tom McKee, former Colorado Climatologist and member of the Atmospheric Science Department at Colorado State University, provided a scientific perspective of Colorado's vulnerability to flood and drought disasters. Nancy McCallin, Director of the Governor's Office of State Planning and Budgeting, looked at impacts of floods and droughts in Colorado from an economic perspective. Luncheon keynote speaker Hank Brown, former U.S. Senator and President of the University of Northern Colorado, described flood and drought challenges and Colorado's water future. The conference included sessions that provided attendees with an opportunity to express their own ideas on how to improve Colorado's preparation for and response to floods and droughts.

In preparation for the meeting, CWRRI prepared a report, A History of Drought in Colorado: Lessons Learned and What Lies Ahead, authored by Former State Climatologist Tom McKee, Assistant State Climatologist Nolan Doesken, and John Kleist of the Colorado Climate Center (CCC). The report was drafted and edited by Cat Shrier, CWRRI student intern.. It provides a summary of a study completed by the Colorado Climate Center on the Historical Dry and Wet Periods in Colorado from 1890 to 1999, and results of an analysis of the time and space patterns of Colorado's droughts. The publication provides extensive background information on drought and drought management in general, and on water supply, water use, and drought response in Colorado, with extensive maps and illustrations.

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Information Transfer Program
Description	
Start Date	03/01/1999
End Date	02/28/2000
Type	Newsletter
Lead Institution	Colorado State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Robert C. Ward	Professor	Colorado State University	01

Problem and Research Objectives

Methodology

Principal Findings and Significance

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	CWRRI Publications
Description	Publications not research-related
Start Date	03/01/1999
End Date	02/28/2000
Type	Publications
Lead Institution	Colorado State University

Principal Investigators

Problem and Research Objectives

Methodology

Principal Findings and Significance

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

McKee, Thomas B., Nolan J. Doesken, John Kleist, and Catherine J. Shrier in collaboration with William P. Stanton. February 2000. A History of Drought in Colorado: Lessons Learned and What Lies Ahead, Water in the Balance No. 9, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, 80523.

Conference Proceedings

Martin, Lindsay. October 1999. The South Platte: Old River - New Course? Changes in Land and Water Use in the South Platte Basin, Proceedings of the 10th Annual South Platte Forum, October 27-28, 1999, Information Series No. 90, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, 80523.

Other Publications

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	N/A	N/A	N/A	2
Masters	5	N/A	N/A	2	7
Ph.D.	3	3	N/A	N/A	6
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	10	3	N/A	2	15

Awards & Achievements

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CWRRI: A Model Program

The Colorado Water Resources Research Institute (CWRRI) is one of 54 water institutes established under the Federal Water Resources Research Act of 1964, and authorized currently by the Water Resources Research Act of 1984, as amended.There is one institute in each state, the District of Columbia and three territories.The institutes connect the water research expertise of higher education to the information needs of water users and managers. CWRRI is also authorized by the Colorado legislature.

The Federal legislation requires the Secretary of the Interior to "conduct a careful and detailed evaluation of each institute at least once every 5 years to determine that the quality and relevance of its water resources research and its effectiveness as an institution for planning, conducting and arranging for research warrants its continued support under this section."A four-member external panel, operating under the auspices of the U.S. Geological Survey, the agency that administers the state water resources research institute program, conducted a review of all 54 institutes during 1999.The panel's findings were released in November.

The Colorado Water Resources Research Institute was designated one of four 'exceptional programs' during the USGS's 1999 review process.The Evaluation Panel's comments regarding CWRRI included the following:

> "The Colorado Institute is not large in terms of over-all financial support.Its program is truly a model of how a smaller institute without access to discretionary or extramural funds ought to function.The Institute's program is clearly defined and well focused on the development of synthesized information and the dissemination of that information to water users and managers throughout Colorado.The research

and information development programs are tightly integrated with the information transfer program.Both programs are excellent given that the programmatic emphasis is on the synthesis and transfer of known information rather than on the generation of new knowledge per se.The Institute's website is exemplary and allows the Institute to serve as a clearinghouse for a number of water related activities in Colorado.The Institute has done a good job of involving other institutions of higher education, including the University of Colorado and the Colorado School of Mines, in its programs and activities."

CWRRI is fortunate to have a large group of faculty that supports the mission of CWRRI, and also the active support of the Vice President for Research and Information Technology.

Water Management Science and Technology Program

In 1999, Colorado State University President Albert Yates selected the Water Management Science and Technology Program as one of 14 programs designated as a Program of Research and Scholarly Excellence for the coming four years.As Colorado, the U.S. and the World move from a strictly 'development' focus on water resources to one more guided by 'sustainability,' Colorado State can provide much of the science, technology, information and education that will be needed to support this transition.Colorado State houses 22 departments that apply their expertise to solving water problems.This extensive water-related expertise at Colorado State has resulted in the development of over 150 senior and graduate-level courses that address water issues.

The Water Center also has developed an undergraduate water 'minor' to help guide undergraduate students into the richness and depth of this water expertise in an organized manner.Core faculty are initiating development of a graduate-level water 'minor.'In all, this core water faculty group has guided 216 graduate students to completion over the past five years.

Faculty Water Center Awards

Luis Garcia
Department of Chemical
& Bioresource Engineering

Luis Garcia coordinates the South Platte Advisory Committee, which is comprised of local and state water organizations and agencies.The group has identified critical areas of technology needed for state and regional water planning and management goals in the South Platte River Basin.By using an interdisciplinary approach with collaboration and active participation of these organizations and agencies, the project has developed key pieces of software including a Stream Depletion Factor Interface (being used by Nebraska as part of Colorado's contribution to the Three-State Agreement), a Consumptive Use Model, and a Mapping and Analysis Program that includes data layers assembled for future use as a framework for future Decision Support Systems in the South Platte Basin. Dr. Garcia, along with other faculty members, is also improving water quality and agricultural sustainability in the Arkansas Basin by working with local farmers to manage irrigation and drainage systems.He implements the technology developments in the classroom with practical,

hands-on courses , has participated in a number of development committees for minority students, and directs the Integrated Decision Support Group which provides an excellent environment for Ph.D. and Masters candidates to work on water-related research projects and gain valuable work experience.

Brett Johnson
Department of Fishery
& Wildlife Biology

Brett Johnson has worked for the past three years on an interdisciplinary research effort at Shasta Lake in northern California, with the U.S. Geological Survey.He became interested in the project while serving as a non-departmental member of Laurel Saito's graduate committee.Dr. Johnson "…put in hundreds of hours providing guidance to Laurel in her research and contributing substantively to her project," according to John Bartholow, Ecologist with the U.S. Geological Survey.Bartholow added, "Devoted efforts like his are the best way to foster interdisciplinary collaboration in today's educational system."Dr. Johnson's research collaboration on other projects includes Effects of Dam Operations on Reservoir Physics and Biology, Blue Mesa Reservoir, Colorado, with John Bartholow; Water Quality in Front Range Reservoirs, with Ben Alexander of the City of Fort Collins Water Treatment Facility; and Biogeochemistry and Biology of Nitrogen Deposition in Alpine Lakes, with Dr. Jill Baron of CSU's Natural Resource Ecology Laboratory.

Robert Ward Receives UCOWR Award

Robert Ward, Director of the Colorado Water Resources Research Institute and the CSU Water Center, received a Friend of UCOWR award from the Universitie Council on Water Resources at its annual meeting June 29-July 2, 1999, in Kamuela, Hawaii.The UCOWR award is given in appreciation of the recipient's vision and leadership in the advancement of water resources research and education.

More Awards for Colorado Water Knowledge Web Site

Colorado Water Knowledge was named as 26th in a list of the 100 best web sites in Colorado by the Rocky Mountain News in its January 10, 2000 edition.It was also selected as a featured site in StudyWeb as one of the best eductional resources on the web.StudyWeb is one of the Internet's premiere sites for educational resources for students and teachers.

Publications from Prior Projects

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Hobbins, Michael T. and Jorge A. Ramirez with Thomas C. Brown. June 2000. The Complementary Relationship in the Estimation of Regional Evapotranspiration: An Enhanced Advection-Aridity Model, Open File Report No. 13, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado, 80523. 60pp.

Conference Proceedings

Other Publications