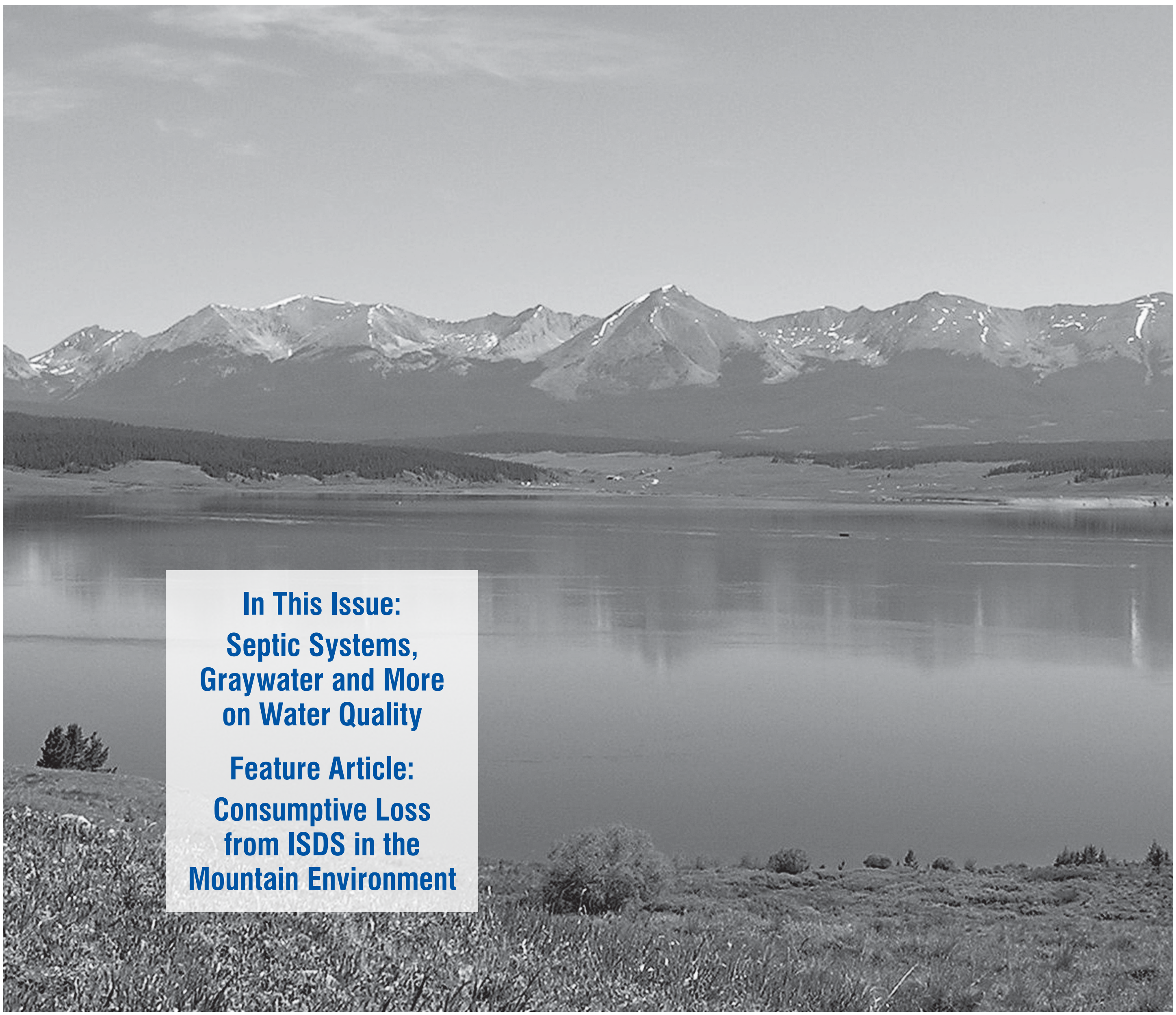
Colorado State University

COLORADO WATER

Newsletter of the Water Center of Colorado State University

August/September 2007 Volume 24, Issue 4



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Septic Systems, Graywater and More on Water Quality

Feature Article:

Consumptive Loss from ISDS in the Mountain Environment

Co-Sponsored by Colorado Water Resources Research Institute, Colorado State University Agricultural Experiment Station, Colorado State University Extension, and Colorado State Forest Service

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COLORADO WATER is a publication of the Colorado Water Resources Research Institute at Colorado State University. The scope of the newsletter is devoted to enhancing communication between Colorado water users and managers, and faculty at the research universities in the state. This newsletter is financed in part by the U.S. Department of the Interior, Geological Survey, through the Colorado Water Resources Research Institute. The contents of this publication do not necessarily reflect the views and policies of the U.S. Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the United States Government.

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Published by the Colorado Water Resources Research Institute • Colorado State University, Fort Collins, CO 80523-1033
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Web Sites
Colorado Water Resources Research Institute: http://cwrri.colostate.edu
CSU Water Center: http://watercenter.colostate.edu
Colorado Water Knowledge: http://waterknowledge.colostate.edu

Cover Photo: Taylor Reservoir in Gunnison County filled by early July 2007 in spite of below-average snowpack.

EDITORIAL

Small Flows, Big Consequences

by Reagan Waskom, Director, Colorado Water Resources Research Institute

What do high-altitude crop coefficients, septic system consumptive use, post-pumping well depletions, *Blaney-Criddle vs. Penman-Monteith ET* calculations, and exempt wells all have in common? They were each at some time and place considered relatively minor – small impacts that individually, if not negligible, were at least within the margin of error in the larger environment. These relatively small flows are now receiving serious consideration and discussion in Colorado. Most notably at present, the depletions and subsequent augmentation requirements of wells along the South Platte are the subject of a very intense conversation as Colorado Governor Bill Ritter's appointed Task Force meets over the summer to seek a compromise that might avoid complete curtailment of hundreds of irrigation wells.

It is when you reach the margins of any developed resource that the small individual impacts aggregate to reach a critical mass – the death by a thousand small cuts, if you will.

Meanwhile, the Basin Roundtables are raising old questions in new ways. The North Platte Roundtable wants more clarity on high-altitude crop water coefficients. The South Platte Roundtable recently had a discussion on what was the "right" number for septic system consumptive use. As you will read in his article in this edition of *Colorado Water*, Ralf Topper of the Colorado Geologic Survey looked into the literature for the South Platte Roundtable and found that the commonly held assumption that septic systems are about 10% consumptive was reasonably close to past State Engineer Kuiper's finding in 1974 that they were on average 12.3% consumptive on an annual basis. Fortunately, Colorado School of Mines Professor Eileen Poeter has been studying this problem for several years. Her recent graduate student Bill Paul found in his master's thesis work that the 95% confidence range on the volume of water available for potential recharge is 81.4 to 87.4% of the water pumped into the home, with an observed average of 15.6% consumptive use. Do a few percentage points make a difference? They might, particularly when you consider there are presently over 600,000 onsite systems in operation in Colorado and that 7,000 to 10,000 new systems are being installed each year.

We are currently witnessing in Colorado what has been aptly termed "cumulative impacts." The depletive effect of one or even several wells on a river system or aquifer is negligible; the same is true for septic systems and exempt wells. On the South Platte, we are starting to suspect that the widespread installation of center pivot systems and the newly lined gravel pits for capturing water for reuse are starting to be felt on the annual hydrograph. It is when you reach the margins of any developed resource that the small individual impacts aggregate to reach a critical mass – the death by a thousand small cuts, if you will. The hard thing is to know when you will reach that point where small things add up to something big and how to manage the system so this tipping point never occurs. The hydrologists, engineers, and legal minds of previous generations understood this concept, and certainly they knew that eventually these small flows and small differences would someday become significant. They, like us, were limited by the boundaries of their knowledge and vision. How can we avoid unintended consequences from cumulative impacts as Colorado strives for maximum beneficial use of our water resources to meet growing needs? The old adage, "Don't sweat the small stuff," is not useful guidance here.

Scientific and scholarly research provides a partial solution to this dilemma, particularly if the information reaches the practitioner and is translated into action. In this issue of *Colorado Water*, you will find a research report by Larry Roesner and his co-authors on graywater that was undertaken for the benefit of the Water Environment Research Foundation and a study from the School of Mines on septic system water quality that was partially funded by the Colorado Water Resources Research Institute. Also included in this issue is an article from the Colorado State Forest Service, "Protecting Front Range Forest Watersheds from High-Severity Wildfires," written by Dave Hessel, Front Range Fuels Treatment Partnership, and Dennis LeMaster, Pinchot Institute for Conservation. This issue's Faculty Profile is Larry Goodrich who is a new faculty member of CSU's Department of Animal Sciences.

It is our mission at Colorado State University to extend research-based information to the community of practicing water professionals in Colorado and, hopefully, to have relevance and impact in the management process. To that end, we announce the FY08 CWRRI water research funding competition, which is open to faculty from all institutions of higher education in Colorado (see page 2). We are very grateful to the Colorado Legislature and the individual representatives and senators who labored for water research funding and to those of you who supported this effort. I welcome your input on water research needs for Colorado, and we will do our best to help find research faculty and agencies that can address these needs.

Colorado Water Resources Research Institute

FY 2008 Request for Proposals

CLOSING DATE: SEPTEMBER 20, 2007

Proposals are invited for the Colorado Water Resources Research Institute FY 2008 water research program.

The Colorado Water Resources Research Institute (CWRRI) is established under the federal Water Resources Research Act, as amended, and is authorized by the Colorado Legislature, most recently in 2006, under S.B. 06-183. At the federal level, CWRRI is one of 54 water institutes administered by the U.S. Geological Survey in the Department of Interior. Under Section 104(b) of the Water Resources Research Act, CWRRI is to "...plan, conduct, or otherwise arrange for competent research..." that fosters the entry of new scientists into water resources fields, the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and disseminates research results to water managers and the public. The research program is open to faculty in any institution of higher education in Colorado that has "demonstrated capabilities for research, information dissemination, and graduate training ... to resolve State and regional water and related land problems."

Priority Research Topics

For the FY 2008 competition, the CWRRI Advisory Committee for Water Research Policy has identified needs for new water knowledge that will assist in answering the following questions:

What are the water quality concerns relative to oil shale development, what is the extent of these problems in western Colorado, and what is the potential for mitigation?

What new tools, methods, and demonstration projects are needed to analyze the changes and vulnerability of water systems in Colorado to climate variability, including new or improved hydrologic models that convert changes in temperature and precipitation into changes in streamflow?

What is the array of technically feasible agriculture water conservation strategies and options for Colorado, and what are the basin-level impacts of implementing these measures?

How can we refine current groundwater augmentation accounting procedures and methods for replacing depletions caused by ground water pumping?

What are the direct and indirect water-related impacts and needs surrounding bioenergy production in Colorado?

Funds Available

The FY08 CWRRI Request for Proposals is supported by the State of Colorado, with supplemental funding provided through the U.S. Geological Survey, pending federal budget allocations. It is anticipated that approximately $150,000 in funds will be available for the FY08 competition. CWRRI research funds are awarded through a competitive process guided by the CWRRI Advisory Committee on Water Research Policy. Proposals that contain matching funds from Colorado water and water-related organizations are strongly encouraged.

Proposal Review Process

All proposals are due in the CWRRI office by September 20, 2007, at 5:00 p.m. (MDT). Proposals will be peer-reviewed before final review and ranking by the CWRRI Advisory Committee for Water Research Policy. The general criteria used for proposal evaluation include: (1) scientific merit; (2) responsiveness to RFP; (3) qualifications of investigators; (4) originality of approach; (5) budget; and (6) extent to which Colorado water managers and users are collaborating.

Eligibility

The competition is open to regular, full-time faculty at Colorado's research universities.

Applications Not Eligible for Funding

A. Applications for research on health effects involving human subjects.
B. Applications for research involving oceanography.
C. Applications submitted by an investigator that has not met reporting requirements on a previous award from the USGS or CWRRI.

Project Budget Amount and Duration

The total life of the project must not exceed 24 months in duration. The total budget request cannot exceed $50,000 during the 24-month period. Projects of shorter duration and/or budgets less than $50,000 will also be considered. Project start date will be January 1, 2008.

Proposal Submission

Proposals, in both hard and electronic copy, are to be submitted no later than 5:00 p.m. MDT, September 20, 2007.

Hard Copy Submission
Colorado Water Resources Research Institute
E102 Engineering Building
Colorado State University
1033 Campus Delivery
Fort Collins, CO 80523-1033

Electronic Submission
E-mail to: nancy.grice@research.colostate.edu

Questions: If there are questions about this solicitation, contact Reagan Waskom by phone at (970) 491-6308 or by e-mail at reagan.waskom@colostate.edu.

http://cwrri.colostate.edu

Internship in Water Resources Research

The Watershed Modeling project of the U.S. Geological Survey (USGS) National Research Program (NRP) is seeking a currently enrolled graduate student to work on development of simulation models and modeling tools across environmental and computer science disciplines. The intern would be employed by the Colorado Water Resources Research Institute.

PROJECT DESCRIPTION: Due to the increasing complexity of environmental and water resource problems and ad hoc development of effective simulation models and modeling tools, policy and management decisions regarding natural and engineered systems are often made without considering the interaction between atmospheric, surface, and subsurface processes. The common theme among these problems is the need for integration: integration of computer science and environmental science, integration of different types of GIS and water resources data, integration of processes across spatial and temporal scales, and integration of science and management objectives. The Integrated Watershed Modeling project builds upon a solid foundation of watershed modeling to investigate, formalize, and document integration methods.

STATEMENT OF WORK: Software development and research to integrate USGS watershed models and data preparation and analysis tools with the Object Modeling System (OMS) and other environmental models and modeling tools. The OMS, using a modular programming strategy, facilitates integration, evaluation, and deployment of simulation models and other natural resource technology from various disciplines, provides interfaces to geospatial tools, linkages to databases, and analysis and visualization tools for parameter estimation, delineations, and uncertainty. The OMS is being developed by the Agricultural Research Service (ARS) and Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture in cooperation with the USGS, the EPA, and Friedrich-Schiller-University Jena, Germany.

SKILLS: Interns at all degree levels are considered. Applicants should already have attained undergraduate core technical skills, with interest in multidisciplinary study. Object-oriented programming experience using Java and an integrated development environment (IDE), such as, the NetBeans IDE, is required. Experience in one or more of the following is desired: a Geographic Information System (GIS), simulation models, optimization and sensitivity tools, and database design and management.

LOCATION: U.S. Department of Agriculture Building, Fort Collins, Colorado, with oversight from the USGS Integrated Modeling project located at the Denver Federal Center in Lakewood, Colorado.

DURATION: Up to three years, beginning September 1, 2007.

COMPENSATION: $13.83 to $20.95/hour dependent upon amount of education completed.

APPLICATION: For more information or to apply, please contact R. Steve Regan:

rsregan@usgs.gov	PO Box 25046, MS 412
(303) 236-5008 (office)	Denver Federal Center
(303) 236-5034 (fax)	Lakewood, CO 80225-0046

Recent Publications

Effect of Drought on Streamflow and Stream-Water Quality in Colorado, July Through September 2002, by D.T. Chafin, and A.D. Druliner, U.S. Geological Survey Scientific Investigations Report 2006-5322, http://pubs.usgs.gov/sir/2006/5322/

Aquatic Communities and Selected Water Chemistry in St. Vrain Creek Near the City of Longmont, Colorado, Wastewater-Treatment Plan, by R.E. Zuellig, L.A. Sprague, J.A. Collins, and N. Oliver, U.S. Geological Survey Data Series 2007-253, http://pubs.usgs.gov/ds/2007/253/

Percentage of Probability of Nonpoint-Source Nitrate Contamination of Recently Recharged Ground Water in the High Plains Aquifer, by S.L. Qi, and J.J. Gurdak, U.S. Geological Survey Data Series 2006-192**,** http://pubs.er.usgs.gov/usgspubs/ds/ds192

Toward a Transport-Based Analysis of Nutrient Spiraling and Uptake in Streams, by R.L. Runkel, *Limnology and Oceanography*: Methods, 5:50-62**,** www.aslo.org/lomethods/free/2007/0050.pdf

Selenium and Mercury Concentrations in Fish, Wolford Mountain Reservoir, Colorado, 2005, by N.J. Bauch, U.S. Geological Survey Scientific Investigations Report 2007-5019, http://pubs.usgs.gov/sir/2007/5019/

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

Consumptive Loss from an Individual Sewage Disposal System in a Semi-Arid Mountain Environment

by William Paul[1], Eileen Poeter[2], and Roy Laws[3]

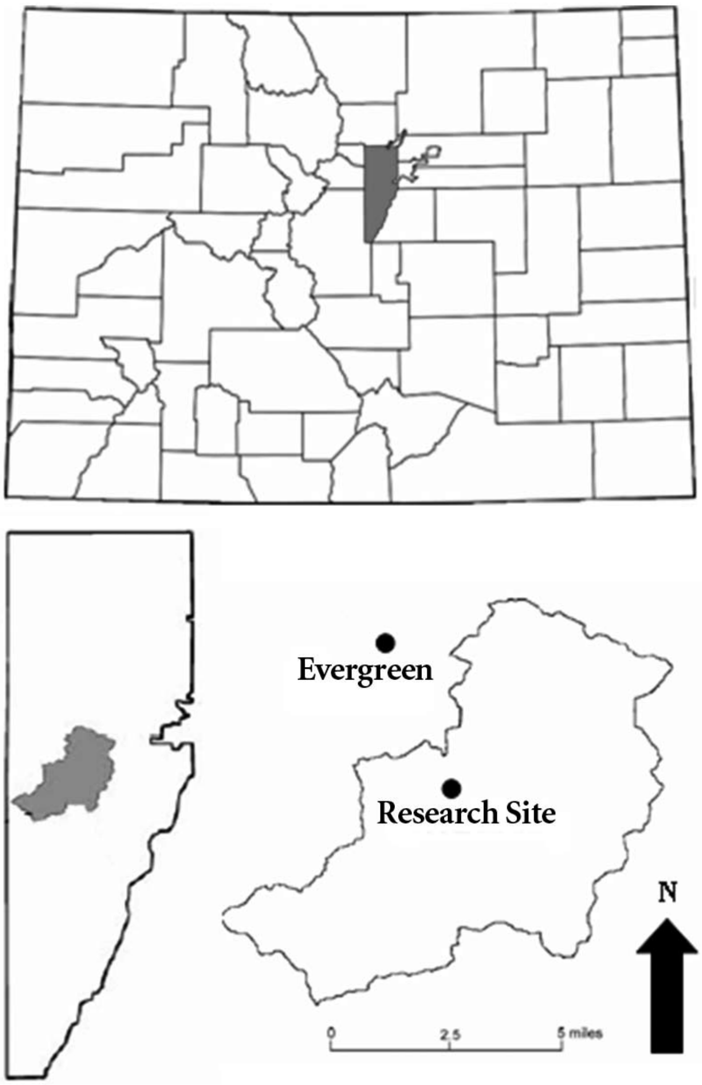

Figure 1. Location of Research Site in Turkey Creek Basin.

Abstract

Consumptive loss from an individual sewage disposal system (ISDS) located at a residence in the foothills of the Rocky Mountains near Evergreen, Colorado (Figure 1), was calculated using field data. Water pumped from the fractured crystalline bedrock unconfined aquifer was metered, and the volume of effluent dosed to the infiltration area was monitored. Actual evapotranspiration (AET) was measured intermittently using a plastic, hemisphere-shaped chamber that monitored humidity. Potential evapotranspiration (PET) was calculated using data from an on-site meteorological station. A model of continuous PET based on meteorological data was calibrated with the intermittent AET data to estimate continuous AET throughout the study period. Calculated water loss in the residence and AET of ISDS effluent were combined to estimate the percent of pumped water available to recharge the underlying fractured bedrock. At this site, an average of 84.4% of water pumped to the residence was estimated to be available to recharge the underlying aquifer. This is comparable to the potential amount of return flow (87.7%) inferred from the 12.3% consumptive loss of water estimated by the Colorado Division of Water Resources in 1974 (Vanslyke and Simpson, 1974). This loss may not be representative of loss from ISDS sites throughout the foothills. Future study is recommended to characterize the average amount of water lost in and around the ISDS infiltration area throughout the foothills.

Research Site Location, Background, and Setting

Turkey Creek Basin (TCB) encompasses an area of approximately 47.2 mi^2 (122 km^2) in Jefferson County, Colorado (Figure 1). Like many mountain regions, the majority of the residences depend on individual wells for water and on-site ISDSs to dispose of waste water because central sewer collection and water distribution systems are not available due to the rugged setting and low density of residential dwellings.

The Colorado Office of the State Engineer regulates water well permitting for all wells in Colorado. One of the considerations in determining water availability is the percent of water pumped that is returned to the aquifer. In 1974 the Colorado Division of Water Resources estimated that the average annual consumptive use of water for a residence with a well and an ISDS

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is 12.3% (Vanslyke and Simpson, 1974), from which it can be inferred that 87.7% of the water pumped returns to the stream and/or aquifer system.

The study evaluates an ISDS on a two-acre lot in Jefferson County, Colorado, with the infiltration area installed on a 10% slope. The original residence was a two-bedroom home built in 1971. The ISDS permit issued by Jefferson County Health Department in 1971 required the installation of a 750-gallon (2.84-m^3) septic tank and a 720-ft^2 (66.9-m^2) infiltration area. In 2001, two bedrooms were added when the home was remodeled. The ISDS permit issued for the remodel required the proper abandonment of the existing ISDS and the installation of a 1500-gallon (5.68-m^3) septic tank with a dosing siphon, along with a 960-ft^2 (89.2-m^2) infiltration area. As built, the ISDS consisted of a 1250-gallon (4.73-m^3), two-compartment septic tank with a dosing siphon configured to yield approximately 125 gallons (0.47 m^3) per dose (Church, 2001) along with an infiltration area of 960-ft^2 (89.2 m^2-12 ft (3.66 m) in width by 80 feet (24.4 m) in length. The regolith thickness (soil and weathered bedrock) was determined to be less than 6 ft (1.83 m); thus the bedrock was excavated to meet regulations regarding vertical distance from the gravel layer of the infiltration area to bedrock. Based on Jefferson County guidelines, the design flow for this residence is 900 gallons per day (~3 m^3/day). Two percolation tests performed in 1971 resulted in rates of 20 mpi (~8 mpcm) and 80 mpi (~32 mpcm). The size of infiltration area was designed based on the 20-mpi infiltration rate with the stipulation that the infiltration area be installed in the area characterized by the 20-mpi infiltration rate. It does not appear that percolation tests were conducted for the ISDS that was designed and installed in 2001 for the remodeled four-bedroom house. Soil profile holes excavated near the ISDS indicated 4 ft to 6.5 ft of silty-sand and gravel overlying weathered gneiss. The site is underlain by a contact between migmatite and Silver Plume Quartz Monzonite (Bossong et al., 2003, Bryant, 1974). Rock outcrops on and around the property are considerably weathered and highly fractured. The regolith varies in thickness from 0 ft to approximately 10 ft (3.05 m). Some locally derived fill is present due to building activities.

Methods

Measurement of Pumped Water

A water flow meter was installed in the residence in July 2003 and read periodically to measure the volume of water pumped from the well. No other source of water was available. It is not unlikely, though undocumented, that a limited amount of bottled water may have been used as drinking water; however, this volume of water is assumed to be insignificant.

Figure 2. Author Bill Paul and the ET chamber used to measure actual evapotranspiration.

Measurement of Water Discharged to Infiltration Area

A pressure transducer was installed in the dosing chamber of the septic tank in February 2004 and recorded pressure at various intervals to track dosing events. Each dose resulted in the discharge of approximately 320 gallons (1.21 m^3) of effluent to the infiltration area (Laws, 2005). According to design specifications by Church (2001), each dosing event was designed to release 125 gallons (0.47 m^3). The increased dose volume was due to direct communication between the inlet compartment and the outlet dosing compartment of the two-compartment septic tank.

Measurement of Actual Evapotranspiration

Actual evapotranspiration (AET) measurements were collected intermittently at six locations including a moist (green/soggy) zone adjacent to the infiltration area, which was presumed to be influenced by shallow ISDS effluent, as well as other locations that were thought to represent the conditions outside of the moist zone. This was accomplished by measuring humidity in a plastic hemisphere (ET chamber, Figure 2) placed over vegetation at each measurement location. Small fans in the chamber simulated wind at a constant velocity of approximately 2 miles per hour (3.2 kilometers per hour), and the difference between temperature of wet- and dry-bulb thermometers in the chamber determined absolute humidity (i.e., vapor density; Stannard, 1988). The rate of increase of vapor density in the ET chamber (g/m^3s) was proportional to AET. Collection of a set of measurements from all six stations took approximately 0.5 hours.

Measurement of Meteorological Conditions

A meteorological station was installed at the research site in June 2004. Variables were recorded by a data logger. The variables included date and time, net radiation, soil heat flux, relative humidity, soil moisture, wind (speed, direction, and variability of direction), and rainfall. Variables were measured over the moist zone and the surrounding area. The values were measured every 10 seconds and averaged every half-hour for storage and downloading.

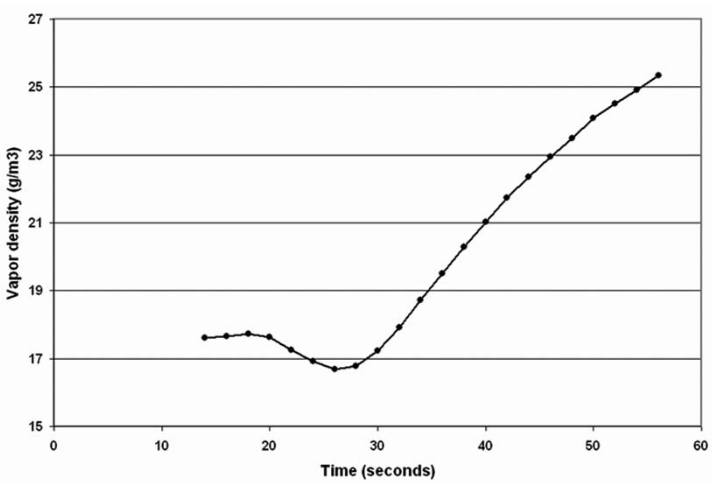

Figure 3. Vapor density as a function of time for one ET chamber measurement.

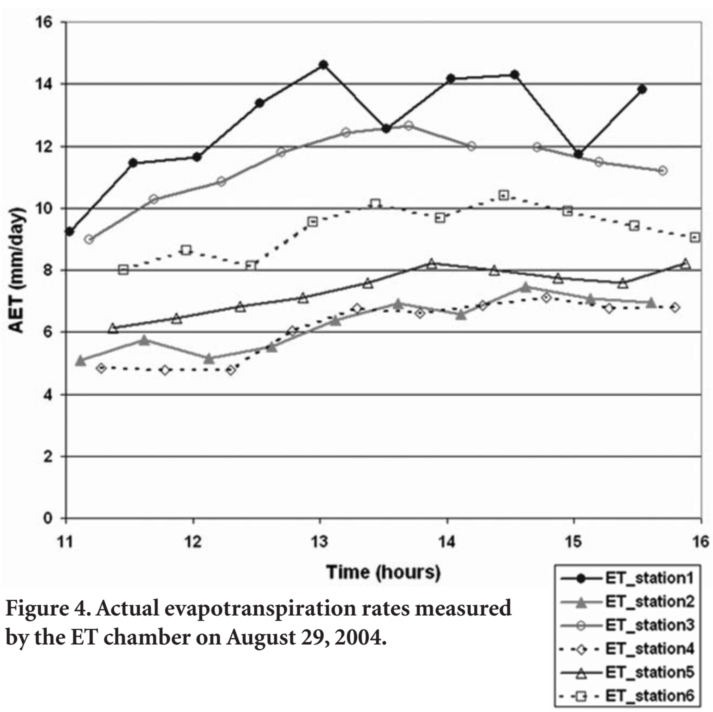

Figure 4. Actual evapotranspiration rates measured by the ET chamber on August 29, 2004.

Analysis

Water Pumped and Discharged

Water use was calculated as the quotient of volume pumped and the number of days between readings. Pressure data from the transducer was converted to feet (meters) of water and plotted versus time. Each water-level peak was interpreted as a dose of 320 gallons (1.21 m^3).

Actual Evapotranspiration

For each ET chamber measurement, vapor density was calculated and plotted as a function of time (Figure 3). The steepest slope, which typically occurred within the first 25 seconds to 35 seconds of the measurement period, represented the highest rate at which vapor density accumulated in the chamber). The ET rate was calculated as:

$$ET=86.4\,\frac{MVC}{A}$$

where: ET = evapotranspiration (mm/day)
M = maximum slope of vapor density vs. time (grams $m^{-3}\ s^{-1}$)
V = chamber volume (m^3)
C = chamber calibration factor (dimensionless)
A = area covered by chamber (m^2)
86.4 = conversion factor, converts (grams $m^{-2}\ s^{-1}$) to (mm day^{-1})

ET chamber measurements resulted in a time series of AET rates (Figure 4) that varied for each measurement location (Figure 5). Typically in April and May, perched water saturated the regolith to the ground surface resulting in localized sheet flow in the vicinity of the moist zone. The flow moved laterally on the surface for approximately 2 meters, then infiltrated back into the regolith. The moist zone was the first to produce green vegetation in the spring, and the vegetation remained green and vigorous throughout the summer, while vegetation in the surrounding area withered and browned. During the summer, when precipitation was low, vegetation (thus evapotranspiration) in this moist zone was sustained by shallow ISDS effluent and occasional surface flow of effluent that leaked from the infiltration area. No outside irrigation in the vicinity of the infiltration area was observed by the research team.

Calculation of Continuous Actual Evapotranspiration

Potential evapotranspiration (PET) represents a maximum ET rate that occurs when availability of water does not limit ET and can be calculated using meteorological data. A modified Priestley-Taylor (Priestley and Taylor, 1972) equation was used to estimate latent heat flux, which is the energy equivalent of ET. When calculating PET, the Priestley-Taylor coefficient, α, is equal to 1.26, which assumes that water is freely available. However, during the majority of the year, AET is less than PET. Consequently, for times when AET measurements were available, the reduced value of α was calculated. These α values were regressed onto variables measured by the meteorological station to determine which variables had high sensitivity to α. Variables that were well correlated with α were used to estimate values of α, and thus AET, during other times of year. Two models for α were developed because transpiration and soil moisture evaporation were not active at the same level throughout the year. Adjustment was made for the difference between evaporation from bare and vegetated soil and for the degree of shading, which varies seasonally (Stannard, 2006). Continuous values of AET were calculated using the relationship between α and the meteorological data for both the moist zone and the surrounding area. Calculated daily average values of PET and AET from ET stations 1 and 3 represent the moist zone, while values from ET stations 2, 4, 5, and 6 represent conditions in the surrounding area (Figures 6 and 7).

Results

Water Pumped

The home was sold during the study period, so two overall average water use values were calculated. The first owner occupied the home from April 2004 through June 2005, while the second owner was present from October 2005 through the end of study period. The first owner, a family of four, used an average of 176 gallons per day (GPD) (0.67 m^3 per day). The second owner, a family of three, used an average of 247 GPD (0.93 m^3 per day). This represents water use ranging from 44 GPD to 82 GPD per person (0.17 m^3 to 0.31 m^3 per day per person).

Effluent Discharged to Infiltration Area

Monthly volumes of effluent discharge were calculated based on the number of doses from the septic tank given that each does was calculated to be 320 gallons (1.21 m^3) by Laws (2005). Each dosing event discharged approximately 256% of the proposed design dosing volume. The first owner had an average discharge of 148 gallons per day (0.56 m^3 per day). The second owner had an average discharge of 217 GPD (0.82 m^3 per day).

Actual Evapotranspiration

Different AET rates were calculated for the moist zone (ET1 and ET3) and the surrounding area (ET 2, 4, 5, and 6) (Figure 5). The two stations in the moist zone (ET1 and ET3) had, on average, 30% higher ET rates than the remaining four sites (Figure 8). The volume of ET resulting from the presence of the shallow ISDS effluent is calculated as the difference between the AET rate over the moist zone and the surrounding area multiplied by the area of the moist zone which was 130 ft^2 (12 m^2).

Water Loss to Evapotranspiration

Assuming that the size of the moist zone was approximately the same for both homeowners, the percent of water pumped to the home that was lost to ET from the ISDS ranged from approximately 0 to 2% depending on the time of year, with an average of 0.8%. The first owner lost an average of 0.8% of the water pumped to the residence to actual evapotranspiration, while the second owner lost an average 0.9%.

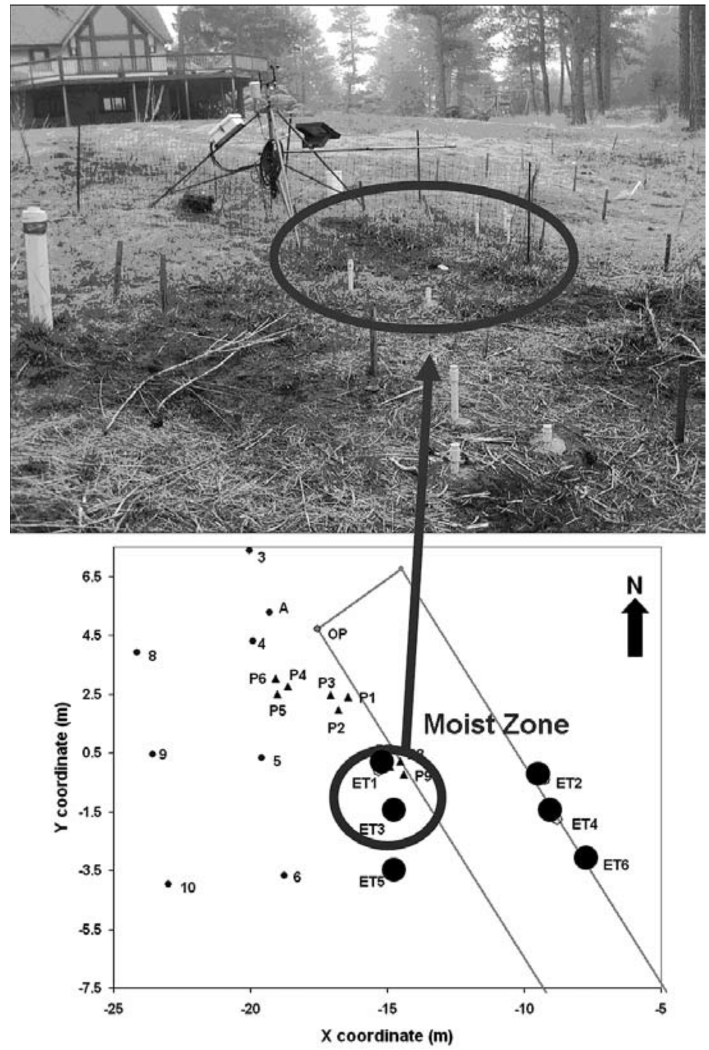

Figure 5. Locations of ET chamber measurements relative to infiltration area. Piezometer locations are also shown. When the study began, the southern end of the infiltration area was dry as indicated by geophysical surveys and exploratory holes, so the investigation focused on the north end of the area.

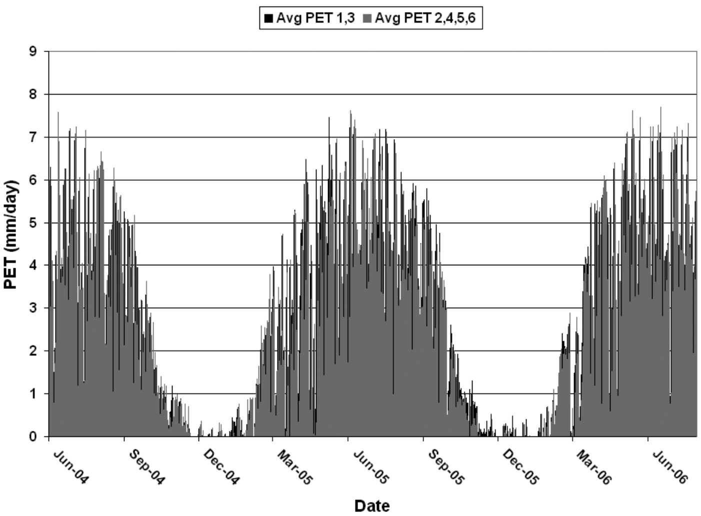

Figure 6. Average potential evapotranspiration rates (mm/day) from ET stations 1 and 3 (black) and ET stations 2, 4, 5 and 6 (gray).

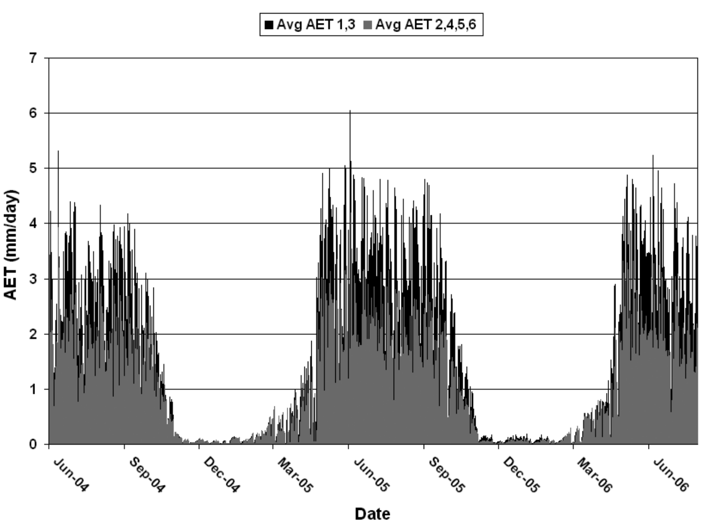

Figure 7. Modeled average actual evapotranspiration rates (mm/day) from ET stations 1 and 3 (black) and ET stations 2, 4, 5 and 6 (gray).

Water Loss Within the Residence

The more significant loss occurred within the residence. Residential loss is the difference between the volume of water pumped and the volume of effluent dosed to the infiltration area. Depending on the month, residential loss ranged from 0.5% to 35%. The first owner had an average residential loss of 16%. The second owner had an average residential loss of 12%. The largest losses were calculated during July 2004 and June 2005. It is not known if these losses resulted from outdoor water use, significant evaporation loss in the home, or the use of an average volume of water pumped in the residential loss calculation. Over the entire study period, average residential loss was estimated as 14.8%, corresponding to a volumetric loss of 31.2 GPD (0.12 m^3/day).

Colorado Division of Water Resources estimates that 8.4% of water pumped into a home of four residents will be lost within the residence (Vanslyke and Simpson, 1974). They did not consider outdoor water uses, since such use is prohibited by residential well permits. Although the first homeowner indicated they did not use much water outside of the home, data were not collected to quantify outdoor water use at the site. It was noted that the home did not have features that might be expected to lead to large evaporation in the home (e.g., they did not have a humidifier, house plants, fish tanks, nor gardens that might require water from an outdoor tap, and they used less than the expected average amount of water per person). In spite of this, consumptive use within the residence was still approximately 14.8%. Regardless of the status of outdoor water use, these data define average water use within the residence, which is likely similar to average water use of other mountain residences.

Combined Water Loss

Given the approximate water loss of 14.8% in the residence and 0.8% loss due to higher AET from the moist zone, the combined loss was approximately 15.6% of the original volume of water pumped at this site. The first homeowner had a higher combined loss of approximately 16.9%, albeit resulting in a smaller volume lost, than the second homeowner, who had a combined loss of approximately 12.9%. The average loss throughout the year, considering both homeowners, was approximately 15.6%. Therefore, return flow available for potential recharge (Figure 9) was approximately 84.4%.

Error Associated with Calculation of Consumptive Loss Components

Variances were calculated for the three components involved in estimating total water loss. The variance from each component was summed (assuming independence) to calculate the total variance associated with estimating total water loss. Accuracy of the water meter that measured pumped water into the residence was determined to be ± 0.5% after performing a test involving pumping known volumes of water and comparing these volumes to the volumes determined by the water meter during the pumping period. Accuracy of effluent discharged to the infiltration area was determined to be ± 2%, and accuracy of actual evapotranspiration rates was estimated to be ± 20%.

Summary of Results

Given measured volumes of water pumped, effluent discharged to an infiltration area, and evapotranspiration; total consumptive use of water for a single-family residential dwelling with a water well and an individual sewage disposal system (ISDS) was estimated. Water lost within the residence was approximately 14.8% of water pumped, and effluent lost to evapotranspiration averaged 0.8% of water pumped. The combined water loss of 15.6% was 27% larger than the 12.3% consumptive use of water estimated in 1974 by the Colorado Division of Water Resources. Consequently, for this residence, an estimated 84.4% of the water pumped to the residence returned to the subsurface and was available to recharge the underlying fractured bedrock aquifer.

The percentage of water lost to evapotranspiration at this site may be lower or higher than other ISDS sites in the foothills. Future study is recommended to better characterize the average amount of water lost due to evapotranspiration in and around the ISDS infiltration area throughout the foothills.

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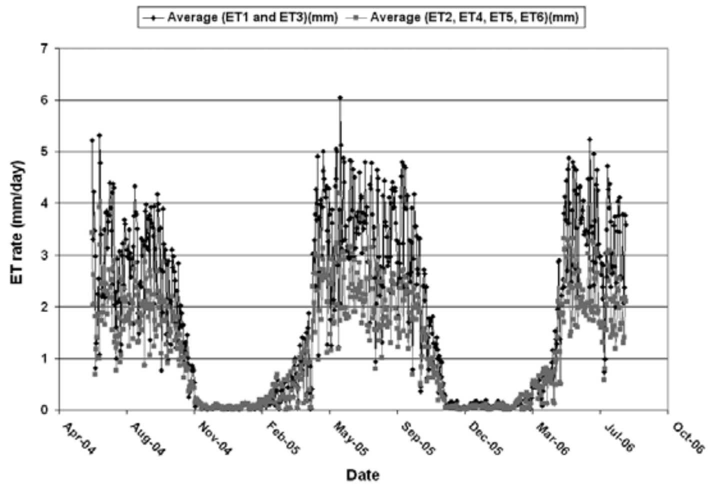


Figure 8. Average daily rate of AET at ET1 and 3 (moist zone) are shown in black while average rate of AET at ET2, 4, 5 and 6 (surrounding area) are shown in gray.

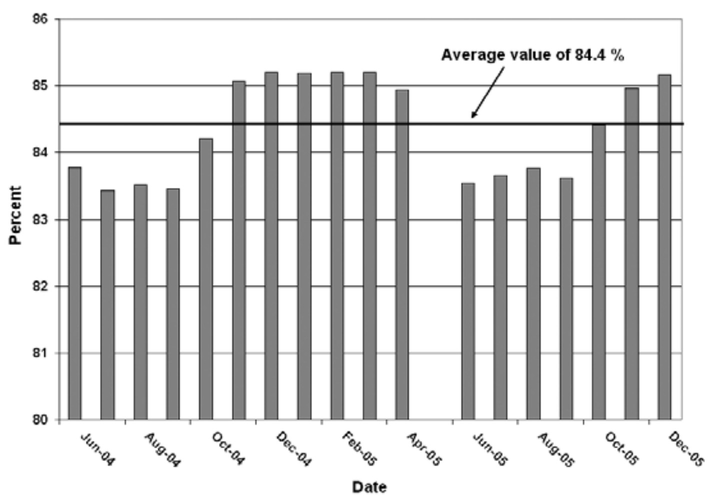
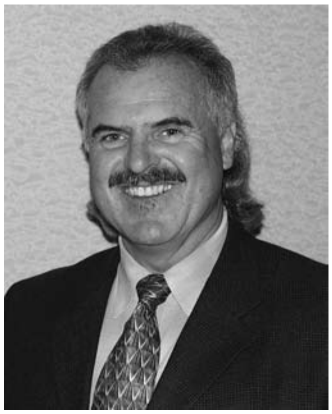


Figure 9. Percent of pumped water returned to the subsurface that was available to potentially recharge the fractured bedrock aquifer.

Consumptive Use Estimates for Return Flows from Individual Sewage Disposal Systems

by Ralf Topper, CPG, Senior Hydrogeologist, Colorado Geological Survey



Author Ralf Topper, Colorado Geological Survey

The competition for water in Colorado has heightened due to increased demands resulting from population growth and increased prosperity. Consequently, the administration and management of water for sustained future growth has become increasingly complex. The water community has instituted new practices and invested in new technology to save water. In this conservation process, previously acceptable uses and applications are being questioned. One of the concerns currently under discussion is the impact of exempt domestic water supply wells and the associated return flows from individual sewage disposal systems (ISDS). There is undoubtedly a local variability in the water balance between residential water supply withdrawals and wastewater treatment system return flows depending upon the political beliefs, economic status, and personal behavior of the occupants. The significance of this potential imbalance is now under consideration by water managers who are attempting to maximize water conservation. How significant might a 10% difference in domestic water consumptive use be in the administration of Colorado's water rights?

How significant might a 10% difference in domestic water consumptive use be in the administration of Colorado's water rights?

In February 1974, then State Engineer C.J. Kuiper asked staff to investigate the consumptive use of water by homes using leach fields for sewage disposal. In preparing a plan of augmentation, developers relying on leach fields for effluent disposal were submitting the figure of 10% consumptive use within the system. The State Engineer had accepted this value without knowing whether or not the figure is accurate. Division of Water Resources staff spent considerable time reviewing the published literature but found no direct studies pertaining to consumptive use of residential septic systems. Literature with ancillary information useful to their investigation was obtained. In addition, a number of persons and agencies were contacted to solicit additional information and input. Based on their findings, staff concluded that 80% of the water entering a house was used by toilets and in bathing. Applying estimates for in-house consumption and evaporation, they determined that 8.4% of the water would be consumptively used before entering the septic tank. Evaluating the results of the then new (1976/77) field investigation by Dr. Paul Trost in conjunction with consumptive use determinations using the Blaney-Criddle or similar methods, staff determined that during the growing season approximately 9.6% of the water was consumed within the leach field. On an annual basis, this amounted to only 3.9%. Thus, on an annual basis, the total consumptive use (in-house + leach field) was estimated at 12.3% (8.4% + 3.9%).

Even today, few Colorado site-specific studies related to individual sewage disposal systems, also referred to as onsite wastewater systems, have been conducted. Where those studies exist, they predominantly focus on the water quality impacts to ground water. In February 2002, Recommendations of the Individual Sewage Disposal System Steering Committee, established by the Executive Director of the Colorado Department of Public Health and Environment, were published. This committee identified issues with ground-water quality impacts, operation, administration, and management of ISDS systems and made 13 recommendations, but none of those dealt with consumptive or nonconsumptive use. In response to Health Department officials, county planning staff, and commissioners in Park County, the U.S. Geological Survey conducted a series of site-specific investigations of ISDS and their potential to effect ground-water quality in the vicinity of Bailey, Fairplay and Alma, and Lake George and

Two-stage septic tank.

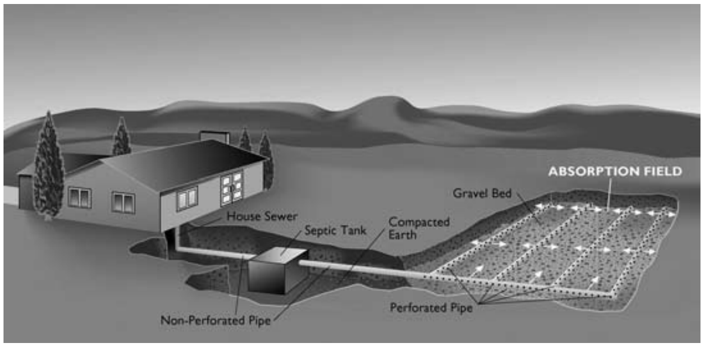
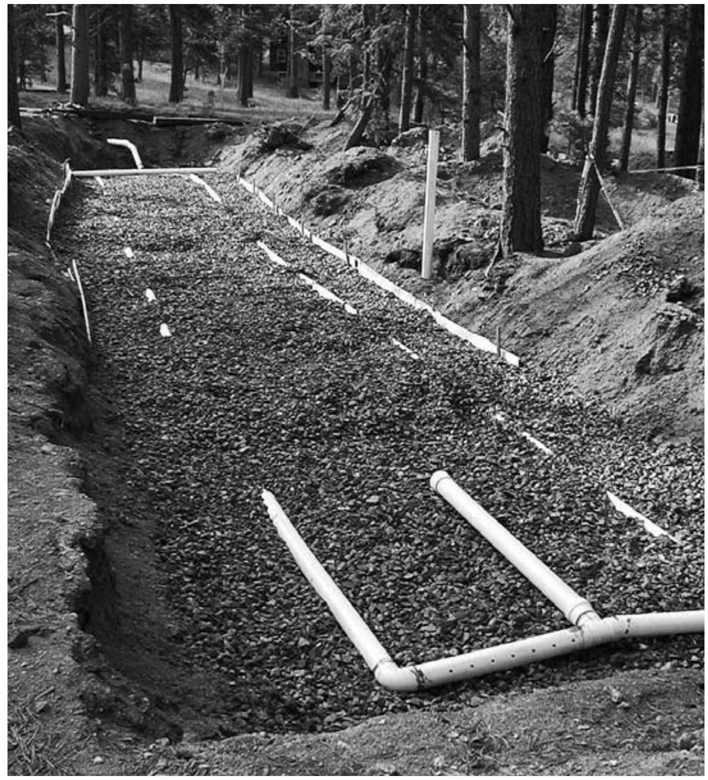


Diagram of typical septic system layout.

Guffey between 2000 and 2003. These studies focused on water quality and did not address the water budget.

To my knowledge, the only published studies that address Colorado site-specific domestic-use water budgets are associated with the Colorado School of Mines, Turkey Creek Basin Project in Jefferson County. Dr. Eileen Poeter, fellow CSM researchers/staff, and graduate students have published a number of papers documenting their findings in characterizing the ground-water system in the Turkey Creek Basin. Some of these studies include water budgets associated with ISDS. Cited values for the consumptive use of water, in the home, have ranged from 7% to 15%. For a properly functioning septic/leach field system, the estimated increase in evapotranspiration is small (~1%). In a recently completed master's thesis, "Water Budget of Mountain Residence," Bill Paul (CSM) estimated that 84% of the ground water pumped returns to the subsurface.

It would thus appear that the current research has produced consumptive use values that are still in the range (± 5%) cited by the State Engineer's Office in the mid-1970s. Clearly, existing Colorado specific studies on water budgets of ISDS are limited. Additional investigations are warranted to better understand the variations in consumptive use estimates associated with on-site wastewater systems and their potential impact to Colorado's water resources.



Septic system leach field.

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Colorado School of Mines (CSM) Research Regarding Occurrence and Fate of Organic Wastewater Contaminants During Onsite Wastewater Treatment

by Kathleen Conn, Ph.D. Candidate, Environmental Science and Engineering, CSM, Golden, Colo.;
Dr. Robert L. Siegrist, Professor and Director, Environmental Science and Engineering, CSM, Golden, Colo.;
Dr. Larry B. Barber, Research Scientist, U.S. Geological Survey, Boulder, Colo.

Organic wastewater contaminants (OWCs) such as pharmaceuticals and personal care products have received increasing attention in the last decade due to their possible adverse effects on ecosystems and human health. Several studies have identified wastewater as a primary contributing source of OWCs to the environment, but few have quantified their occurrence and fate in onsite wastewater treatment systems and associated receiving environments. A substantial portion of the wastewater generated in the United States is processed by onsite wastewater treatment systems before discharge to the environment. For example, in Colorado there are over 600,000 onsite systems in operation, serving approximately 25% of the state's population, and 7,000 to 10,000 new systems are being installed each year. As a result, over 100 billion liters of wastewater are being processed by onsite systems and then discharged to the environment every year in Colorado alone. A research project was initiated by the Colorado School of Mines (CSM) in collaboration with the U.S. Geological Survey (USGS) (1) to determine the occurrence of OWCs in wastewaters produced from varying sources and by different types of onsite wastewater treatment units, (2) to assess the treatment of OWCs in confined treatment units such as septic tanks and packed-bed biofilters, (3) to assess the fate and transport of OWCs in soil treatment units prior to groundwater and surface water recharge, and (4) to assess the potential for OWCs to impact receiving waters.

CSM Graduate student Kathy Conn

Between 2002 and 2005, the CSM/USGS research team quantified the occurrence of OWCs in 30 Colorado onsite wastewater treatment systems serving different homes, businesses, institutions, and varied types of confined treatment units (Conn *et al.* 2006). Of the 24 OWCs studied, 21 were identified in at least one onsite system effluent, and six compounds – caffeine, the sterols cholesterol and coprostanol, the metal-chelating agent EDTA, the disinfectant 4-methylphenol, and the surfactant metabolite group 4-nonylphenolethoxycarboxylates – were identified in every residential septic tank effluent. Wastewater concentrations of OWCs were highly variable, ranging from less than 1 μg/L to greater than 500 μ/L. Differences in wastewater compositions regarding OWCs may be due to differences in water- and chemical-using activities at the source. For example, residential systems receive wastewater from a number of indoor activities, including toilets, kitchen and bathroom faucets, dishwashers, clothes washers, and showers. Onsite system wastewaters from residential sources were composed of a diluted mix of biogenic and anthropogenic compounds. Wastewater treated by onsite systems serving veterinary hospitals, on the other hand, originates mostly from cleaning activities such as disinfecting and washing practices. The OWC composition from veterinary hospitals was composed of high concentrations of surfactant metabolites and other cleaning product chemicals. In contrast, most of the wastewater entering an onsite system serving convenience stores originates from public restrooms. The highest concentrations of 14 pharmaceuticals and antibiotics were found in convenience store wastewater,

Dr. Robert L. Siegrist

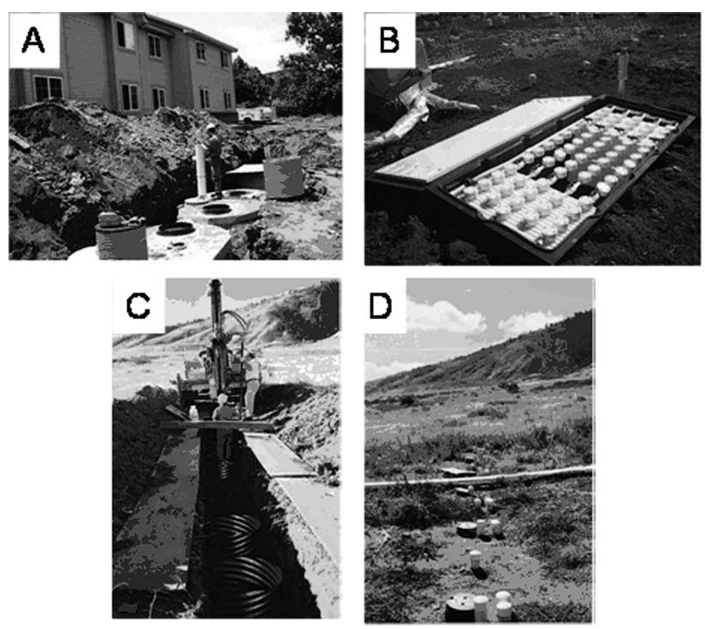

Figure 1. The fate of organic wastewater contaminants in onsite wastewater treatment systems is currently being investigated at the Mines Park Test Site, where wastewater from a multifamily residence is intercepted (A) and managed using pilot-scale unit operations such as a textile biofilter (B) and in-ground soil test cells (C, D).

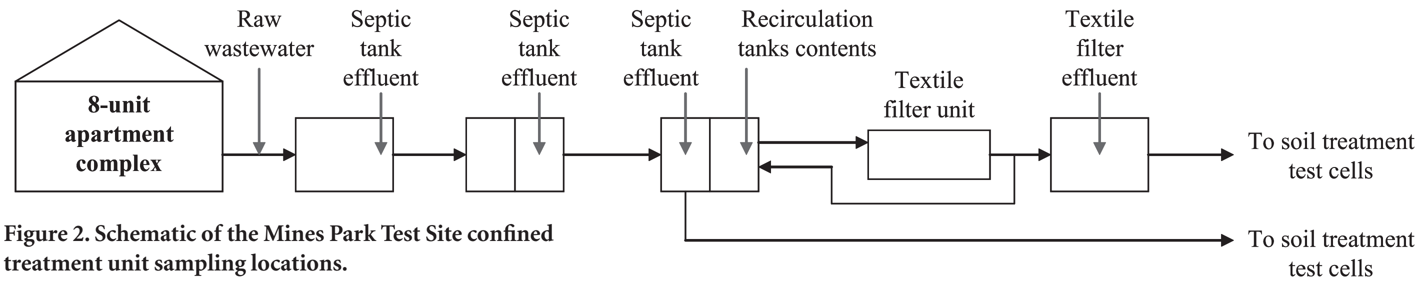

Figure 2. Schematic of the Mines Park Test Site confined treatment unit sampling locations.

reflecting the large and diverse population visiting the stores each day.

To understand the fate of OWCs during onsite wastewater treatment, wastewater samples from confined treatment units (e.g., septic tank, textile biofilter) were collected and analyzed for OWCs to identify potential removal during confined unit treatment. Concentrations of OWCs in effluents before and after septic tank treatment were usually similar, suggesting low to negligible removal of OWCs during septic tank treatment alone. Apparent removal efficiencies during textile biofilter treatment varied by compound. OWCs that have been shown to be aerobically biotransformed, such as caffeine, 4-methylphenol, and 1,4-dichlorobenzene, had apparent removal efficiencies of greater than 90% during textile biofilter treatment. Other compounds such as EDTA that are resistant to the removal mechanisms employed during aerobic biofilter treatment (e.g., biotransformation, sorption, and volatilization) showed similar concentrations in effluents before and after the biofilter unit. Concentrations of compounds that are the degradation products of biotransformed OWCs, such as the surfactant metabolites nonylphenolethoxycarboxylates, increased during textile biofilter treatment. Therefore, concentrations of some OWCs were higher in the effluent from a confined treatment unit and which might be applied to the soil treatment unit than in the wastewater entering the onsite system. Additional sampling of confined treatment unit influent and effluent is underway at the Mines Park Test Site on the CSM campus (Figures 1 and 2) to better quantify expected removal efficiencies by accounting for temporal variability and hydraulic detention time within the treatment units.

Results from the reconnaissance survey of 30 onsite wastewater treatment systems suggest that OWCs are being applied to onsite system soil treatment units at environmentally relevant concentrations. To help understand the fate of OWCs in wastewater effluents during soil treatment, a tracer test was conducted at the CSM Mines Park Test Site using a conservative tracer (potassium bromide) and a pharmaceutical surrogate (rhodamine WT). Known concentrations of both tracers were added to tap water dosed to 14 soil test cells for 22 days at hydraulic loading rates ranging from 2 cm/d to 8 cm/d. Soil solution at 60 cm, 120 cm, and 240 cm below the infiltrative surface of each test cell was collected using *in situ* soil suction lysimeters and analyzed for both tracers for 20 months. Results indicate significant retardation of the pharmaceutical surrogate relative to water movement, as indicated by the conservative tracer (Fig-

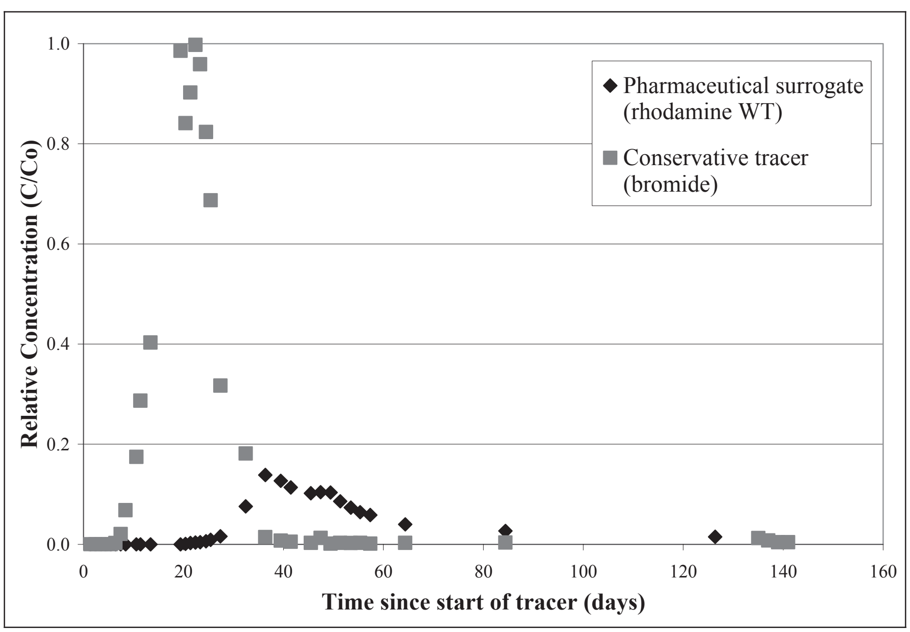

Figure 3. Comparison of the breakthrough curves at 60 cm below the infiltrative surface for a conservative tracer (bromide) and a pharmaceutical surrogate (rhodamine WT) added to an onsite system soil test cell.

ure 3). Water travel times from the infiltrative surface to 60 cm below the infiltrative surface ranged from 5 days to 25 days. The time required for 10% of the added pharmaceutical surrogate to reach 60 cm below the infiltrative surface ranged from 35 days to over 200 days between test cells. After 20 months, mass recovery of the pharmaceutical surrogate at 60 cm below the infiltrative surface varied between test cells, ranging from less than 1% to approximately 100% (average = 40%) recovery of the total mass of pharmaceutical surrogate added. The differences in mass recovery are likely due to differences in hydraulic loading rates and inherent variability in the native soil properties between test cells. The results suggest that OWCs with similar properties as the pharmaceutical surrogate may be retarded and/or removed during onsite system soil treatment depending on the site-specific soil characteristics.

To further elucidate the fate and transport of OWCs during onsite system soil treatment, soil solution is being collected from 60 cm, 120 cm, and 240 cm below the infiltrative surface of the Mines Park soil treatment test cells for analysis of a suite of conventional wastewater parameters and OWCs. The absence of ammonia, presence of nitrate, and low levels of dissolved organic carbon and phosphorus in the soil solution suggests that treatment processes such as nitrification and sorption are occurring in the vadose zone. Target OWCs have been identified that are amenable to analysis by the sample collection methods, which exclude some volatile and sorptive compounds. Results of the occurrence of OWCs in the soil solution compared to levels measured in the effluent being applied will provide information regarding expected removal efficiencies of select OWCs during vadose zone soil treatment prior to recharge of underlying groundwater.

The occurrence of endocrine disruptors such as surfactant metabolites in wastewater raises concerns about their adverse impacts on the environment following recharge of groundwater and potential recharge of surface waters. The U.S. Environmental Protection Agency has established a toxicity-based water quality criteria for the surfactant metabolite 4-nonylphenol with the four-day average concentration in freshwater systems not to exceed 6.6 μg/L. Twenty five of the 30 sites included in the study had detectable concentrations of 4-nonylphenol in their confined unit effluents and approximately half of those exceeded the water quality criteria, some by greater than 10 times. The effect from multiple endocrine disruptors, such as the suite of alkylphenolic compounds studied here, is unknown, but studies have indicated an additive effect. Understanding the additional treatment that occurs during soil infiltration and percolation through the vadose zone and within the groundwater and surface water receiving environments is critical to aid in defining potential adverse effects to ecosystem and human health due to OWCs being discharged from onsite wastewater treatment systems. Such information will also enable a comparison of onsite system performance relative to that associated with centralized systems. Laboratory and field research is ongoing at CSM along with modeling studies, the results of which will help guide wastewater facilities planning and design.

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Long-Term Effects of Landscape Irrigation Using Household Graywater

by Melanie Criswell and Larry Roesner
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The Water Environment Research Foundation (WERF) recently funded a comprehensive literature review and synthesis of graywater issues related to its use for landscape irrigation to identify the current state of knowledge and identify research gaps. This report (excerpted below) was published by WERF as Report 03-CTS-1830 and can be ordered online at http://www.werf.org.

Introduction

The use of household graywater for landscape irrigation is gaining in popularity in the United States. A study conducted by the Soap and Detergent Association (SDA) in 1999 revealed that 7% of U.S. households were reusing graywater (NPD Group, 1999). Another study in the same year (Little, 1999) found that 13% of the households in Arizona used graywater for irrigation with the most utilized source being from clothes washers (66%). Several states, including California, Arizona, New Mexico, Utah, and Texas, have regulated the practice. But there are two areas of concern with the practice. One is the potential threat to human health, and the other is the potential long-term impact of graywater on plants, soil chemistry, and microbiology.

Graywater constitutes about 50% of the total wastewater generated (69 gallons/person/day) within a household.

The objective of this literature review was to bring together the current state of knowledge on potential long-term impacts of landscape irrigation with household graywater and to identify the data gaps that need to be addressed in future research. The literature review comprises Chapters 1-4 of this report, and they focus on (1) overall graywater issues including quantity, quality, treatment methods, and legality; (2) possible graywater effects on residential landscape plants; (3) effects on soil microbial function; (4) use of indicator organisms for human health considerations; and (5) soil chemistry changes due to graywater application. Chapter 5 synthesizes the key findings and knowledge gaps from four subject categories forming the basis for a research program to fill in the knowledge gaps.

Graywater Quantity and Graywater Systems

By the strictest definition, graywater is any wastewater not generated from toilet flushing, otherwise referred to as blackwater, and this definition is used rather widely, especially in Europe and Australia. But in the United States, the more common definition of graywater is wastewater that originates from residential clothes washers, bathtubs, showers, and sinks but does not include wastewater from kitchen sinks, dishwashers, and toilets. Kitchen sinks and dishwashers are not usually incorporated into graywater flow due to the high organic content leading to oxygen depletion and increased microbial activity of the graywater. In this report, graywater is defined as wastewater that originates from residential clothes washers, bathtubs, showers, and sinks. Toilets, kitchen sinks, and dishwashers are not included.

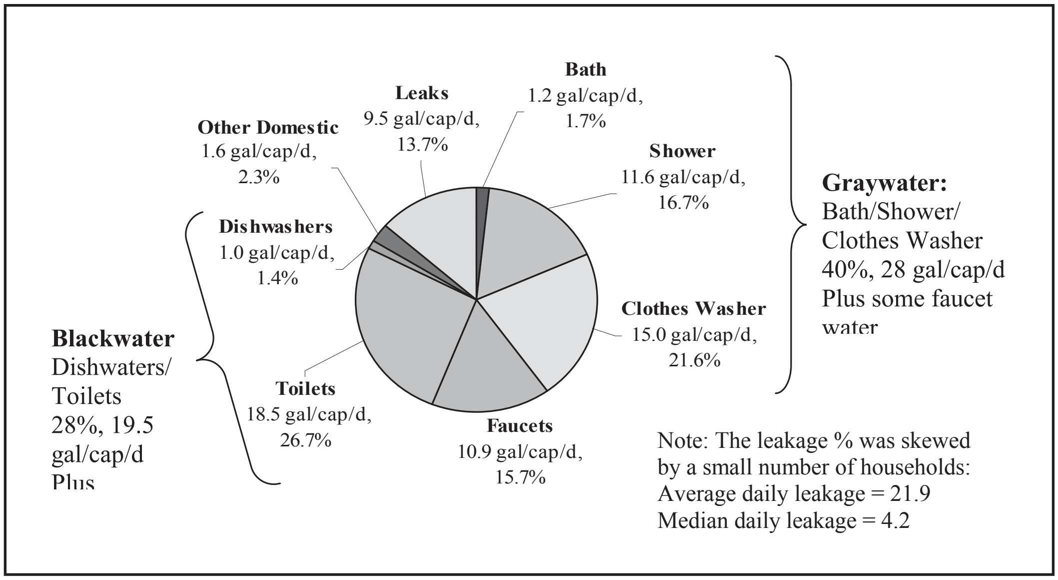
Dr. Larry Roesner

Graywater constitutes about 50% of the total wastewater generated (69 gallons/person/day) within a household. Given an average household population of 2.6 persons in the United States, there are approximately 90 gallons of graywater per day per household available for outside use. This supply is not sufficient to irrigate an entire yard landscaped in bedding plants and bluegrass, but a homeowner with a 2,500 ft^2 house on a 1/4 acre lot could irrigate about 1/2 of the yard with graywater if xeriscaping is used.

In order install an efficient graywater irrigation system, it is necessary to know the water requirements of the plants to be irrigated and to have a collection and storage system that will deliver graywater at the appropriate time and in the appropriate amount to the landscape. But currently, *guidance on application rates is lacking. While some very sophisticated graywater systems are available for the storage, treatment, and delivery of graywater to its end use, guidance is lacking for the homeowner to design a proper system in terms the size of storage tank required and the required pump capacity where a gravity system is not feasible.*

Graywater Chemistry Issues

Graywater contains a complex mixture of chemicals used in a variety of household products. These chemicals can be categorized according to their function in the products such as surfactants, detergents, bleaches, dyes, enzymes, fragrances, flavorings, preservatives, builders, etc. A survey by the National Institute of Medicine and the National Institute of Health reported that household products contain over 2,500 chemicals in 5,000 products (National Institute of Health, 2004). It is assumed that



many, if not most, of these chemicals occur in graywater. These chemicals can change the bulk chemical characteristics of the water such as pH, suspended solids, biological oxygen demand, and conductivity.

The literature reveals that a number of constituents in typical graywater are known to be potentially harmful to plants singly or in combination with other chemicals in the graywater. But *it remains to be documented whether or not these constituents will accumulate in the soil in sufficient quantities to harm plants or perhaps be transported below the root zone, possibly to the groundwater, during the rainy season.* Although there are a number of graywater systems that have been in operation for some years with no obvious detriment to vegetation, the scientific documentation is lacking. *No published studies were found that examined the changes in soil chemistry as a result of irrigation with graywater.*

Effects of Graywater Irrigation on Landscape Plants

Information on the effects of graywater irrigation on landscape plants is scarce. In Arizona, a two-year study on landscape plants irrigated with graywater in residential areas revealed that, except for a slight increase in boron, no salts had accumulated in either the plants or the surrounding soil (NSFC, 2002). In California, a graywater pilot project was conducted Los Angeles in the early 1990s, consisting of eight residential graywater test systems (City of Los Angeles, 1992). This study found that the Soil Adsorption Ratio (SAR) and Na+ increased over the course of the study; however, negative effects on plant growth and quality of landscape plants were not observed. The authors pointed out that any harmful effects might take a number of years to manifest themselves. At this time, knowledge is lacking on the long-term effects of graywater irrigation on landscape plants.

Plant resistance levels have been mainly extrapolated from other salinity experiments or from experiments with recycled wastewater used for irrigation. These studies found that most deciduous trees are more tolerant to salt than evergreens because they lose their leaves each fall, thereby preventing a great degree of build up of harmful constituents from season to season. The literature review reveals clearly that we do not know much about how bedding plants, which are one of the most likely candidates for graywater irrigation, will respond to irrigation with either reused wastewater or graywater. Since most bedding plants are annuals and will not accumulate chemicals from year to year, it seems that this group should be high on the priority list for further research.

While treated wastewater reuse research may provide a first estimate of which plants are most likely to do poorly if irrigated with graywater, and which plants can be expected to perform well, there are several important differences that must be considered. For example, the chemical composition of graywater differs from treated wastewater in some aspects, such as the proportions of salts, organic matter, and surfactants. Also, treated wastewater is aerobic and nearly neutral pH, while graywater will have a lower DO and if stored prior to application may be anaerobic with low pH potentially resulting in a different chemistry in the applied water. The application method for household graywater irrigation is typically via subsurface, drip, or surface flooding on small areas, whereas the majority of recycled treated wastewater is applied via sprinkler irrigation in large landscapes. Drip and subsurface irrigation concentrates the application area and may result in higher chemical concentrations in the root zone. But a related issue, noted above, is the role of rainfall. The rain may reduce chemical concentrations in the soil by transporting them to low soil horizons, thus mitigating on a seasonal basis the chemical buildup that occurs during the irrigation period. For these reasons, it is necessary that an experimental program be developed in which actual graywater is used for studies similar to those that have been done with treated wastewater. Extrapolation of short-term results to long-term impacts will be a key consideration in designing an experimental plan.

Table 1. Graywater Characteristics by Source[1].

Water Source	Characteristics
Automatic Clothes Washer	Bleach, foam, high pH, hot water, nitrate, oil and grease, oxygen demand, phosphate, salinity, soaps, sodium, suspended solids, and turbidity
Automatic Dishwasher	Bacteria, foam, food particles, high pH, hot water, odor, oil and grease, organic matter, oxygen demand, salinity, soaps, suspended solids, and turbidity
Bathtub and Shower	Bacteria, hair, hot water, odor, oil and grease, oxygen demand, soaps, suspended solids, and turbidity
Evaporative Cooler	Salinity
Sinks, Including Kitchen	Bacteria, food particles, hot water, odor, oil and grease, organic matter, oxygen demand, soaps, suspended solids, and turbidity

[1] Adapted from the New Mexico State University's Safe Use of Household Graywater guide (1994).

Public Health Issues

It is well established that the levels of fecal coliform in graywater exceed allowable criteria set by regulatory agencies for discharge of wastewater and for natural waters subject to body contact. But there is controversy regarding whether the indicator organism counts are an accurate indicator of the actual health threat posed to the homeowner who comes into direct contact with graywater because fecal coliform concentrations have been observed to multiply in graywater, whereas pathogens die off rapidly. Therefore, a high graywater fecal coliform count may not indicate the same level of pathogen exposure risk as the same fecal coliform count found in treated wastewater. Even so, many states that permit graywater use require a subsurface irrigation system to reduce human exposure to pathogens, but this requirement detracts significantly from its attractiveness to the average homeowner. Drip irrigation would be much more attractive, but before it is recommended, it is important to determine how well the fecal bacteria survive in the surface layer of the soil.

Additional experiments are needed on raw and stored graywater to determine the survivability (or growth) of different indicator organisms and the correlation of their concentrations to the concentration of pathogens in the same graywater sample leading to the determination of a suitable indicator organism that is a good measure of actual human health risk. If possible, the tests should be run on a (large) sample of fresh graywater and on the same sample periodically as it is stored at room temperature.

Summary and Recommendations

Most of the knowledge gaps identified in this report are interrelated, even though they have been identified in connection with an individual scientific field like graywater chemistry, plant and soil health, human health, or groundwater pollution. To fill the knowledge gaps, a targeted research program is needed that includes all applicable scientific disciplines. This research should seek to answer with some certainty the following three broad questions:

1. Over the long term, will a residential landscape that is irrigated with graywater remain healthy and vibrant? If not, are there steps that can be taken to minimize or mitigate the impact?

2. Over the long term, does irrigation of a residential landscape with graywater pose a threat to the quality of groundwater? If so, can these threats be minimized or eliminated?

3. Over the long term, does irrigation of a residential landscape with graywater pose a health risk to humans? Can these risks be minimized?

Answering these three basic questions will result in solid scientific underpinnings for the practice of residential irrigation with graywater by providing proper guidance to homeowners on the proper type of collection and distribution system to install, the type of plants that can be irrigated with graywater, and the proper application rates for the selected landscape. Homeowners will know by examining their landscape when it is time to amend soil or take other mitigation measures to restore plant health and vigor and what methods to use. In doing so, the regulatory community (plumbing inspectors, public health officials, and environmental regulators) can take comfort in knowing that the systems are adequate, safe, and pose little or no threat to the quality of the environment. Simultaneously, they will know that household demands for potable water can be reduced by 30 to 50 percent.

SAVE the DATE!

October 2-4, 2007
Summit County, CO
The Village at Breckenridge

A joint conference hosted by: Colorado Watershed Network, Colorado Watershed Assembly, Colorado Riparian Association, Colorado Lake & Reservoir Management Association, and AWARE Colorado/ League of Women Voters of Colorado Education Fund.

Sustaining Colorado's Watersheds:

Making the Water Quality Connections

Please join us for the second annual joint Sustaining Colorado's Watershed Conference. Water quality issues continue to affect our water resources. In Colorado, they include new legislation, standards, abandoned mines, coal bed methane development, riparian mitigation, and increasing urban growth.

For more information or instructions for submitting a poster abstract (due by ***August 15, 2007****) visit* **www.coloradowater.org**

Rapid Detection of FRNA Bacteriophages, and Their Use in Water Quality Assessment

by Lawrence D. Goodridge, Department of Animal Sciences, Colorado State University, 350 West Pitkin Street, Fort Collins, CO 80523-1171

Inadequate drinking water and sanitation are considered two of the world's major causes of preventable morbidity and mortality, and international bodies such as the World Health Organization (WHO) estimate that 50,000 deaths per day are due to water-related diseases. While the majority of waterborne illness occurs in the developing world, water quality problems also abound in the developed world. The detection, isolation, and identification of waterborne pathogens continues to be expensive, difficult, and labor intensive.

To alleviate the issues with waterborne pathogen testing, indicator microorganisms are commonly used to determine the relative risk from the possible presence of pathogenic microorganisms in a sample. The detection, isolation, and identification of waterborne pathogens continues to be expensive, difficult, and labor intensive (Scott *et al.* 2002). To alleviate the issues with waterborne pathogen testing, indicator microorganisms are commonly used to determine the relative risk from the possible presence of pathogenic microorganisms in a sample. Since most of the microbial pathogens present in water are of fecal origin, the detection of fecal contamination has been the main aim of the testing methodologies. Historically, the coliform, thermotolerant coliform group, enterococci, and *Clostridium perfringens* have been the bacterial indicators used to detect fecal contamination (Scott *et al.* 2002), based on the rationale that these indicator organisms are indigenous to feces, and their presence in the environment is therefore indicative of fecal pollution. However, there are major problems with the current use of indicator bacteria to detect fecal pollution. Many of these bacteria are routinely isolated from soil and water environments that have not been impacted by fecal pollution. In addition, these bacteria are able to grow in biofilms within drinking water distribution systems and are occasionally absent in water supplies during outbreaks of waterborne disease. Also, while the persistence of these bacteria in water distribution systems is comparable to that of some bacterial pathogens, the relationship between bacterial indicators and the presence of enteric viruses and protozoa is poor. Viruses and protozoa account for approximately 44% of waterborne outbreaks in the United States, where the etiologic agent has been identified (Blackburn *et al.* 2004). Finally, the methods used to detect the indicators are problematic. While there are established culture and molecular methods for the detection of most microbial pathogens, most of these methods have important limitations, including the length of time required for the test result (1-5 days) and the specificity and sensitivity of detection (Scott *et al.* 2002). Due to the limitations of the bacterial indicators, and the problems with their rapid detection, other biological indicators of water quality have been proposed.

Figure 1. Graduate student Travis Steiner completes a plaque assay for detection of FRNA phages in a water sample.

Several researchers have investigated the presence of coliphages (bacteriophages [phages] that grow on *Escherichia coli*) as indicators of the presence of fecal contamination in water. These studies have originated from the idea that certain phages isolated from water could serve as indicators of fecal contamination. In this scenario, the presence of these phages would indicate the presence of their bacterial hosts (i.e., *E. coli*, which may be present in low concentrations, making them difficult to detect), which grow in the intestines of warm-blooded animals and are therefore indicative of the presence of fecal contamination from these animals. FRNA phages have attracted interest as useful alternatives to bacterial indicators because their morphology and survival characteristics closely resemble the human enteric gastrointestinal viruses (Scott *et al.* 2002), meaning that, in addition to the usefulness of these phages as indicators of the presence of their host bacteria (*E. coli*), and therefore the presence of fecal pollution, they could also indicate the presence of enteric viruses (noroviruses, rotaviruses) in water. Several studies have confirmed that for monitoring purposes, FRNA phages are reliable indicators of the possible presence of human enteric viruses because they behave like water-borne viruses (Havelaar 1993). The most commonly used technique to detect phages is the plaque assay, in which dilutions of the water sample to be tested are incubated with a suitable host bacterial strain, and the mixture is added to a dilute concentration (0.5%) of molten agar and poured onto solidified agar in a petri plate. After incubation at 37°C overnight, the bacteria will form a homogeneous lawn in the top layer of agar, except in areas where phages have infected the cells. These areas will be clear (and are known as plaques), because phage infection has caused the death of bacterial cells. However, the plaque assay is tedious, requires standard laboratory equipment (Petri plates, incubators, etc), and takes at least 24 hours to complete (Figure 1). These attributes mean that the plaque assay method is not amenable for use in the field, where water quality testing would ideally be situated.

In this study, we have developed a rapid method to detect FRNA phages based on the use of a lateral flow device (LFD) that can identify the presence of these phages within 5 minutes. The LFD is a simplified version of the Enzyme Linked Immunosorbant Assay (ELISA), and these single step immunochromatographic assays utilize similar technology to that used in home pregnancy tests. Furthermore, the LFDs are portable, rapid, require no instrumentation, and can be used with little or no previous experience. This will allow for the rapid evaluation of the presence of FRNA phages in water, directly in field. To demonstrate the feasibility of using LFDs to detect FRNA phages in water, a LFD based upon the FRNA phage MS2 was developed. A series of 10 fold dilutions of MS2 were added to water obtained from a feedlot, and the LFDs were used to determine the concentration at which the MS2 could no longer be detected (Figure 2). The results indicated that less than 106 PFU/ml of MS2 was undetectable. This result demonstrates the usefulness of the LFD technique and also indicates that water samples will need to be concentrated to enable detection of FRNA phages in the water, since the concentration of FRNA phage observed in water can be as low as 100-1000 PFU/ml.

Current work is focused on developing a method to rapidly concentrate FRNA phages from water samples, based on the use of cationically charged paramagnetic beads. These 2.8 µm beads have the unique property of becoming magnetized in the presence of a magnetic field, but upon removal of the field, the beads lose their magnetism, allowing them to resuspend in a liquid sample. Cationically charged paramagnetic particles can selectively bind and capture viruses, including phages. For example, these beads have been utilized as an efficient way to capture enteric viruses including hepatitis A virus and the noroviruses (Plante *et al.* 2005a, 2005b). We have developed a method that allows for water samples to be incubated with the cationically charged beads. A portable hand-held magnet allows for the beads (and any bound phages) to be concentrated (Figure 3). Once the phages have been concentrated, they can be detected with the lateral flow device.

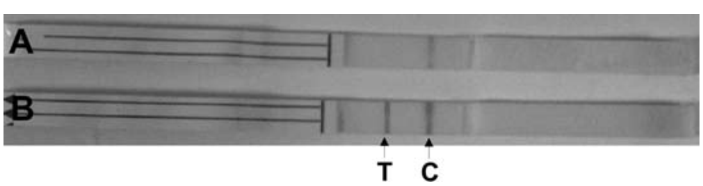


Figure 2. Lateral Flow Devices (LFDs) used to detect the presence or absence of phage MS2 in water obtained from a feedlot. The test line (T) and quality control Line (C) are denoted. (A) The LFD indicates that the level of phage in the water was not detectable (< 106 PFU/ml) (absence of the test line). (B) The LFD indicates that the level of phage in the water is detectable (> 106 PFU/ml) (presence of the test line). The presence of the quality control line indicates that the test is working properly.

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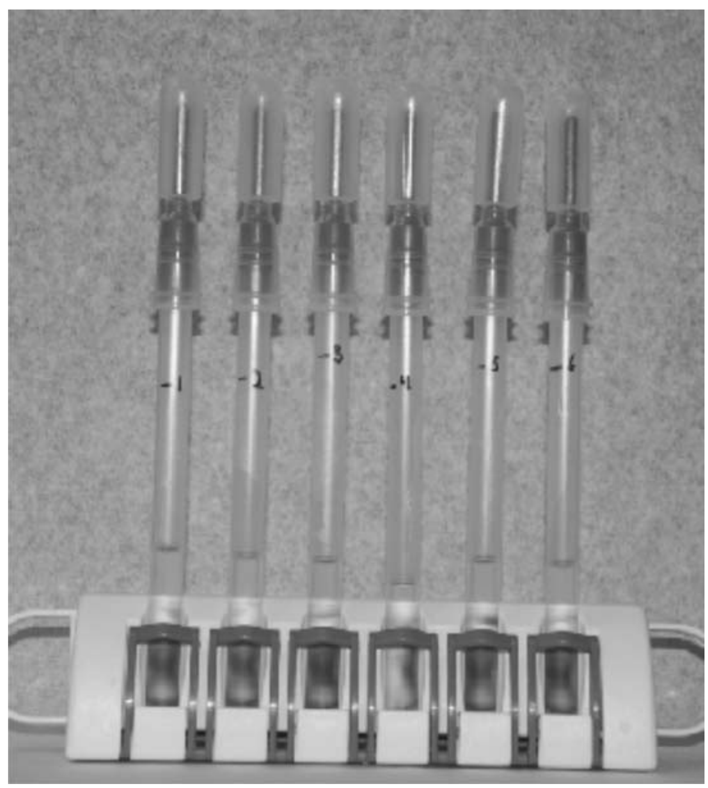

Figure 3. Concentration of FRNA phages from water samples using cationically charged paramagnetic beads. The water sample is placed into a disposable test device, and the beads are added. After a 10-minute incubation, the test devices are placed into a portable magnet, and the beads (and any bound phage) are attracted to the magnet, allowing the water to removed from the device. The phages are then eluted from the surface of the beads in a small volume of elution buffer, followed by detection with the lateral flow device.

Building the Western Waters Digital Library: Phase Two – The Foundations of American Water Policy

by Dawn Bastian, Coordinator for Digital Repositories Services, Colorado State University Libraries

The National Endowment for the Humanities (NEH) has awarded $338,444 in grant funds to Colorado State University and its project partners (the University of Utah, Brigham Young University, Washington State University, and the University of California at Berkeley) to fund further development of the Western Waters Digital Library (WWDL). This project will engage a 16-member team of archivists, librarians, technical experts, and faculty advisors from institutions with demonstrated leadership in water archives and digital libraries to provide integrated access to archival holdings related to water policy and environmental history for the Colorado and Columbia River basins.

Delph Carpenter's copy of the official Colorado River Compact (1922; from the Delph Carpenter Papers, CSU Water Resources Archive).

This second phase of WWDL development will occur from July 2007 to June 2009. Participants will create an initial online repository of 29 finding aids for 558 linear feet of archival collections and approximately 20,000 digital objects from selected resources in those collections for inclusion. The finding aids will link directly to the digital files, providing context for the digital items and resulting in significantly enhanced access to archival and manuscript materials for historians and other scholars, faculty, and students. Providing online access to the finding aids and the digitized materials will complement traditional archival research and encourage scholars to utilize archival holdings onsite.

The materials proposed for digitization will be selected based on research value, uniqueness, and previous demand by faculty and other scholars using resources in water archives and special collections. A detailed collection development policy will also provide guidance. Consideration will be given to feedback from researchers, faculty, students, and other users collected throughout the implementation of the WWDL. This project will expand the productive collaborative relationships established during the 2003-2005 WWDL pilot project, funded by a National Leadership Grant from the Institute of Museum and Library Services. For this initiative, Colorado State and 11 other institutions in eight western states digitized key materials from their holdings, with a focus on the Columbia, Colorado, Platte, and Rio Grande river basins. Examples of collections currently available in the WWDL via centralized searching include:

Arizona vs. California Legal Records
Central Utah Project Records
Hoover Dam Collection
Native American Water Rights in Arizona
Colorado River/Central Arizona Project Records
Exploration of the Colorado River of the West
Stuart L. Udall Papers on the Mexican Water Treaty and the Colorado River
Seattle Power and Water Supply Collection
Grand Coulee Dam Collection
Government Reports on the Columbia River
The Platte River Basin in Nebraska
New Mexico Waters

This effort laid the foundation for continued development of a comprehensive digital information resource about water in the western United States. The vision of the WWDL is to increase geographic coverage, subject matter, and contributing institutions incrementally over time as the project develops.

The proposed materials include the papers of the National Water Resources Association, Colorado Water Congress Newsletters, the Colorado River Bed Case transcripts, holographic Utah territorial documents, Pioneer Cooperative Irrigation Records, and the unpublished papers of key figures in the development and implementation of western water law and policy, including:

Delph E. Carpenter	*Frank Adams*
Ival V. Goslin	*John S. Eastwood*
Robert E. Glover	*Charles H. Lee*
James L. Ogilvie	*Thomas H. Means*
Frank A. Banks	*Milton Norman Nathanson*
Clifford Koester	*James D. Schuyler*
John S. Boyden	*Dorothy Harvey*
Stephen G. Boyden	*Floyd A. O'Neil*
C. Gregory Crampton	*Edward Hyatt*
E. Richard Hart	*Joseph B. Lippincott*

Western Waters Digital Library home page
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The Colorado's Waters Digital Archive is Colorado State University's collection currently available in the WWDL. The CSU project team for the current phase of development is led by Dr. Mark Fiege of the Department of History, a specialist in the environmental history of the American West. Patty Rettig, head archivist, Water Resources Archive, Morgan Library, and graduate student Nick Kryloff are working with Dr. Fiege to identify materials for inclusion in the WWDL that are critically important for research into the historical, legal, economic, and environmental precedents that influence contemporary water issues. If you would like to suggest specific items be considered for addition to the collection, please contact Archives and Special Collections.

For more information about the grant, please contact co-Principal Investigator Dawn Bastian, coordinator for Digital Repositories Services, Morgan Library, at (970) 491-1849 or dawn.bastian@colostate.edu.

2007 Tamarisk Symposium
Wednesday, October 24, to Friday, October 26
Two Rivers Convention Center
159 Main Street
Grand Junction, Colorado

Mark your calendars! The Tamarisk Coalition and CSU Cooperative Extension are hosting the 2007 Tamarisk Symposium at the Two Rivers Convention Center, in the heart of downtown Grand Junction. In addition, we are planning a fieldtrip to a beetle release site on the 26th.

Revegetation is the focus of this year's Symposium.

This conference, held every two years, is considered the preeminent conference on the tamarisk problem and will bring together nearly 300 people from throughout the West that include key researchers, on-the-ground program managers, environmental interests, and federal/Tribal/state/local interests to better understand the nature of the tamarisk problem, and develop and implement long-term solutions.

The Symposium's focus is on implementation and is a sister conference to the 2006 Tamarisk Research Conference. For more information on these past conferences see our website (www.tamariskcoalition.org).

Water – and Whooping Crane – Information Flowing Upstream

by Patricia J. Rettig, Head Archivist, Water Resources Archive, Colorado State University Libraries

This spring, the Water Resources Archive acquired the records of the Platte River Whooping Crane Maintenance Trust, a Nebraska-based, nonprofit organization. The mission of the Water Resources Archive, in a nutshell, is to document Colorado's water. So at first glance, one may wonder about the connection between the archive and these majestic birds.

Whooping cranes, one of the rarest birds in North America, rely on the central part of the Platte River in Nebraska for crucial habitat during spring migration. The water in the river, formed by the North and South Platte rivers which flow out of Colorado, is one of the key ingredients for maintaining the delicate balance of this ecosystem.

For the benefit of the ecosystem, the Platte River Whooping Crane Maintenance Trust works "to protect and maintain the physical, hydrological, and biological integrity of the Platte as a life support system for whooping cranes and other migratory birds." The trust therefore relies on working with upstream entities to keep the Platte healthy. This work has resulted in various court cases, negotiations, and agreements with the states of Colorado and Wyoming, as well as other agencies, over the past 30 years.

This past April, the trust donated the documentation of its work to the Water Resources Archive. In preparing for the donation, the archivist made a trip to the trust's Wood River headquarters. After spending an evening witnessing the influx of approximately 30,000 sandhill cranes for their nightly roost, the archivist spent a day and a half inspecting boxes, map drawers, and filing cabinets to determine what should be transferred to the archive. This resulted in identifying the equivalent of more than 60 boxes of materials that have historical value.

In July, the trust delivered all of this to the CSU Libraries. Included are reports, legal documents, correspondence, newsletters, slides, maps, and more. The staff of the Water Resources Archive will now inventory and organize these materials to properly house them as well as create a finding aid for the collection.

Once the collection is available to researchers later in the year, it will provide the chance to investigate many aspects of water (and whooping cranes!) previously undocumented at the archive. These include the *Nebraska vs. Wyoming* case, instream flow studies, the trust's land acquisitions, and Nebraska's perspective on Two Forks, among other topics. This certainly makes for a valuable addition in documenting Colorado's water.

For more information about this and other collections, visit the Water Resources Archive website at http://lib.colostate.edu/archives/water/ or contact the author at (970) 491-1939 or patricia.rettig@colostate.edu at any time.

Protecting Front Range Forest Watersheds from High-Severity Wildfires

by Dave Hessel, Front Range Fuels Treatment Partnership;
Dennis Lemaster, Pinchot Institute for Conservation

On August 16, the Colorado State Forest Service, U.S. Forest Service, and the Pinchot Institute will meet with the seven major Front Range water providers to engage in dialog about the potential risks of wildfires to Colorado's Front Range watersheds and to identify actions that will help mitigate those risks.

The threat of high-severity wildfires to Colorado Front Range communities and their water supplies is real and unprecedented. The 11,900-acre Buffalo Creek Fire in 1996 put Colorado on alert about the seriousness and potential for wildfires in the state's watersheds and the after-effects of these fires on water delivery and quality. And the high-severity 2002 Hayman Fire burned 138,000 acres of forest and destroyed 133 homes and 466 outbuildings at an estimated cost of $238 million. It also surrounded Denver Water's 101-year-old Cheesman Reservoir exposing mud, ash, and decomposed granite, which continue to pour into the reservoir after rainstorms.

Since the Hayman Fire, the U.S. Forest Service, Denver Water, and Colorado State Forest Service have been working with the Pinchot Institute, a national conservation organization in Washington, D.C., to develop a strategy to assess Colorado's critical Front Range watersheds and the potential for wildfires within these watersheds. The Pinchot Institute has just completed its assessment.

The Front Range of Colorado was selected over other fire-prone states in the west to participate in the assessment due to past fire events, the resulting impacts of these fires and the importance of water to Colorado's Front Range communities.

The Increasing Threat of High-Severity Wildfires in Colorado

The short-term impacts of high-severity wildfires – destruction of timber, forage, wildlife habitat, scenic vistas, and water supplies – are well known. Somewhat less familiar are the impacts of soil erosion and sediment and organic debris flows in the immediate post-fire period. However, it is certain that the latter impacts can impose a heavy toll on water infrastructures such as conveyances and storage reservoirs, which are costly to fix.

The threat of high-severity wildfires to Colorado's Front Range communities is serious. The annual number of wildfires has increased from an average of 457 fires per year in the 1960s to an average of 2,707 fires per year in the current decade. The annual number of acres burned also has increased from an average of 8,170 acres per year in the 1960s to an average of 97,408 acres in this decade.

When forests burn, watersheds also are affected. In the case of high-severity wildfires, watersheds are substantially altered. For example, roughly 56% of the area burned by the Hayman Fire drains directly into Cheesman Reservoir. This reservoir alone stores approximately 15% of Denver Metro's water supply. To reduce the amount of sediment and organic debris entering the reservoir, extensive rehabilitation efforts were implemented around the reservoir, and two upstream dams were built. Years later, rain continues to carry sediment and debris from the Buffalo Creek and Hayman fires into Strontia Springs and Cheesman reservoirs. Consequently, the annual cost to maintain and rehabilitate these reservoirs is enormous.

High-Severity Wildfires, Soil Erosion, and Watersheds

Depending on intensity and duration, wildfires can change the soil composition of a watershed by consuming the litter layer at the surface of the soil and by destroying binding organic matter in the soil itself. A water-repellent zone or layer forms when hydrophobic organic compounds from burning vegetation coat soil aggregates or minerals at or parallel to the surface. This hydrophobic layer prevents water from penetrating soil aggregates and seals off soil during rainfall events, which accelerates surface runoff resulting in the transport and deposit of sediments.

The adverse impacts continue when the water, sediment, and debris pour off slopes into receiving channels, scouring banks and bottoms, often overwhelming them and causing flooding, sometimes many miles away from the precipitating wildfire event. Such sediment and organic debris can dramatically alter water courses.

Colorado's Increasing Demand for Water

As the size of wildfires has increased, so has Colorado's population. From 1990-2000, Colorado had the third largest percentage increase in population – 30.6% – among the 50 states. And Colorado has continued to grow, but the population is not evenly distributed. The fastest growing counties generally are east of the Continental Divide along the Front Range. Ten of the 11 counties with populations over 100,000 – Adams, Arapahoe, Boulder, Denver, Douglas, El Paso, Jefferson, Larimer, Pueblo, and Weld – are contiguous and contain 81 percent of Colorado's human population. Five of these counties – Boulder, Douglas, El Paso, Jefferson, and Larimer – plus Clear Creek, Gilpin, Grand, Park and Teller counties are part of the Front Range Fuels Treatment Partnership and are referred to in The Pinchot Institute's assessment the "ten Front Range counties."

Critical Front Range Watersheds

Watershed	Principal Water Courses	County	Water Provider
Big Thompson 10190006[1]	Big Thompson River, Little Thompson River	Larimer	Greeley, NCWCD[2]
Black Squirrel 11020001[1]	Black Squirrel Creek	El Paso	None
Blue River 14010001[1]	Blue River	Summit	Denver Water, Colorado Springs
Cache la Poudre 10190007[1]	Cache la Poudre River, Fossil Creek, Spring Creek, North Fork Cache la Poudre River	Larimer	Greeley, Fort Collins
Clear Creek 10190004[1]	Clear Creek, Ralston Creek	Clear Creek, Jefferson	Denver Water, Golden, Westminster
Eagle River 14010002[1]	Eagle River, Homestake Creek	Eagle	Colorado Springs
Fountain 11020003[1]	Fountain Creek, Monument Creek	El Paso	Colorado Springs
St. Vrain 10190005[1]	St. Vrain Creek, Boulder Creek	Boulder	Boulder, Denver Water, Longmont
South Park 10190001[1]	Middle Fork South Platte River, Plum Creek, Tarryall Creek, South Fork South Platte River	Park, Teller	Aurora, Denver Water, Thornton
Upper Arkansas 11020001[1]	Arkansas River, Chalk Creek, Clear Creek, Cottonwood Creek, Lake Creek	Lake, Chafee, Fremont, El Paso	Aurora, Colorado Springs
Upper Colorado 14010001[1]	Colorado River, Fraser River, Williams Fork River Willow Creek	Grand	Aurora, Denver Water, Greeley, NCWCD[2]
Upper South Platte 10190002[1]	Bear Creek, North Fork South Platte River, Trout Creek	Park, Jefferson, Douglas	Aurora, Denver Water, Thornton

[1]Eight-digit Hydrologic Unit Code (HUC), U.S. Geological Survey
[2]Northern Colorado Water Conservancy District

Seven Water Providers for 2.9 Million Front Range Residents

The seven largest Front Range water providers are Aurora, Boulder, Colorado Springs, Denver Water, Fort Collins, Northern Colorado, and Westminster; they draw their water from 10 critical watersheds. Studies done in 2006 indicate that six of the water providers – Aurora, Boulder, Denver Water, Colorado Springs Utilities, and the Northern Colorado Water Conservancy District – provide water to approximately 63 percent of Colorado's 4.7 million people, either directly or through contracts or shares. And of the seven, Westminster is the only one that does not take water from west of the Continental Divide and deliver it to their customers using a complex system of pumps, conveyances, and storage reservoirs.

Numerous other cities, towns, and small communities also depend on the water from these major watersheds. All water users along the Front Range can be adversely affected by high-severity wildfire.

Wildfires and the Threat to Critical Watersheds

The Pinchot Institute has just completed an overall watershed assessment of the risks of high-severity fire and the potential impacts to critical Front Range watersheds. Findings indicate that the accumulation of forest fuels, along with increasingly flammable forest conditions, place Front Range watersheds at risk of high-severity wildfires that could impact the ability of water providers to supply water for the foreseeable future. Wildfires not only threaten water supplies but, as noted earlier, the sediment transport and organic debris flows that often follow wildfires can be even more problematic. If watersheds are not protected through mitigation projects such as fuelbreaks, then sediment and organic debris can destroy reservoirs as a functional part of the water supply system. The alternatives to mitigation include the installation of costly post-fire catch basins and other structures that require maintenance.

The broad assessment by the Pinchot Institute analyzed (1) forest wildfire hazards, (2) fire regimes of Front Range forest types, (3) public and private landownership within the ten Front Range counties (including Grand County), (4) soil erodibility and erosion hazards, and (5) water infrastructure in Front Range counties' watersheds. The risk of high-severity wildfire to critical Front Range watersheds, which could impact the quality and quantity of water going to Front Range communities and other users, is unprecedented. The Buffalo Creek and Hayman fires serve as reminders that such high-severity wildfires can adversely affect and seriously impact the Front Range economy.

The Pinchot Institute assessment also identified climate change and global warming as factors that have the potential to exacerbate fire severity. The past five- to ten-year drought cycle reflects larger and more intense wildfires on Colorado's Front Range.

Mitigating Wildfire Risks on Front Range Watersheds

Water is essential – and scarce – along the Front Range, and the threat of high-severity wildfire is imminent due to years of fire suppression and overcrowded, unhealthy forests approaching an age where stand-replacing wildfire can be expected. The need for water and the threat of wildfires presents major long-term challenges for Front Range water providers and Front Range residents who rely on them for safe, clean drinking water. It also presents an opportunity for water providers to leverage the development and implementation of public policy aimed at reducing the threat of high-severity wildfires in Colorado.

One way to exercise this leverage is through the development and coordinated implementation of Critical Community Watershed Wildfire Protection Plans (CCWWPP) for each critical watershed. Plans would be comparable to Community Wildfire Protection Plans (CWPP) provided for in the Healthy Forests Restoration Act of 2003. Elements of successful CCWWPPs would include:

- Engagement of concerned federal, state, and local government agencies
- Open participation of all interested parties
- Preparation of a base map of the watershed including:
  - ✓ Major terrain features
  - ✓ Forest and range vegetation types
  - ✓ Local communities
  - ✓ Roads and major power and communication lines
  - ✓ Water supply structures and conveyances
- An assessment of:
  - ✓ Vegetative fuel hazards
  - ✓ Risk of wildfire occurrence
  - ✓ Potential impacts on water supply and infrastructure, communities, and other human values
- A fuel-hazard reduction program including:
  - ✓ Priorities
  - ✓ Treatments
  - ✓ Roles and responsibilities
  - ✓ Specific timetables
  - ✓ Funding needs
- A monitoring program to assess implementation of the fuel-hazard reduction program

Development and implementation of CCWWPPs would provide a viable mechanism for reducing the risk of high-severity wildfires to critical Front Range watersheds. Because the plans would be modeled after CWPPs, they are likely to be supported by decision makers, community leaders, fire departments, homeowners associations, and other stakeholders. In addition, land management agency personnel are familiar with CWPPs and are prepared to provide the technical expertise that is essential to developing and assisting with the successful implementation of plans.

For more information about the Front Range forest watershed assessment, contact Dave Hessel, Colorado State Forest Service, at dhessel@lamar.colostate.edu; Hal Gibbs, U.S. Forest Service, at hdgibbs@fs.fed.us; or Cheri Bashor, U.S. Forest Service at ckbashor@fs.fed.us.

Colorado State Forest Service

32nd Colorado Water Workshop Examines the Colorado River

Over 200 people gathered on the campus of Western State College in Gunnison for the 32nd Colorado Water Workshop on May 22-24. The meeting was the first organized by WSC Professor Pete Lavigne and had as a theme, "Equalizations, Equity and Environment: Opportunities in the Colorado River Watershed." A wide spectrum of viewpoints on the Colorado River were aired by 25 speakers and the audience as they discussed future challenges faced in the basin.

Patricia Mulroy, general manager of the Southern Nevada Water Authority and the Las Vegas Water District, stated that "global warming is the 800-pound gorilla in the room. It's going to change everything in the West. It will force us to change relationships." Mulroy described the recently negotiated shortage guidelines that may help provide relief during drought – alleviating fears of a compact call that could shut off water in Colorado as well as in the other upper basin states of New Mexico, Wyoming, and Utah. The lower basin states in the Colorado River Compact have agreed under these guidelines to "share shortages" in the future, rather than insisting on full entitlements. The agreement, awaiting approval from the Interior Department, states that during drought years, the upper basin states would be allowed to deliver less water to the lower basin states of California, Nevada, and Arizona. Western water rights are shifting to water responsibility, Mulroy said.

One of the presentations during the workshop came from Ferrell Secakuku, a former chairman of the Hopi nation. He described Hopi attempts to balance an ancient world view against the pressures of modern development. Secakuku explained that the Hopis were largely unaware of the West's code of water rights until the 1950s and did not realize their supply of water was threatened. In the 1960s, the tribe began drilling wells, making life easier but changing the balance of it. "Our water use is intensifying, both in population growth and per capita use," Secakuku said. "Our elders taught us that economics, material possessions, and education are necessary but secondary. The average Hopi still uses only about one-eighth of the water of the average American. The core of life is a sustainable core," Secakuku said. "Our way of life promotes ecological morality."

Climate change was on many speakers' minds. "All of the studies point in one direction – that's drier," Kuhn said. "It doesn't matter if you believe in Al Gore or Rush Limbaugh – what you ought to be concerned about is what should we be doing to avoid unacceptable outcomes?" Dave Wegner, a former Bureau of Reclamation scientist from Durango, said models show a much drier Southwest and a 10% to 30% decrease in runoff into the Colorado River by 2030. "This drought has reminded everyone that this water supply is limited," said Scott Balcomb, Colorado's representative on the Upper Colorado River Commission. "This piddling river is not among the 25 largest in the United States, but it has the two largest reservoirs. That shows you how important the water is," said Jack Schmidt, a Utah State University professor. Workshop speakers also included Rep. Kathleen Curry, Mary Lou Smith, Larry MacDonnell, Jim Lochhead, Dave Wegner, Scott Balcomb, Robert Adler, and many others representing an array of agencies and perspectives on the Colorado River.

Make plans to attend the 2008 workshop and join in the highly engaging and insightful dialogue that is the hallmark of the annual water meeting in Gunnison. Dates for the 2008 workshop have not been determined at this time of this printing. Contact Pete Lavigne at Western State College for more information on the 2007 or 2008 Water Workshop.

From top, left to right: Workshop organizer Pete Lavigne visits with Jeremy Meyer; Pat Mulroy, general manager of the Southern Nevada Water Authority mingles with Coloradans; Hopi Tribal elder Ferrell Secakuku addresses the workshop; workshop participants relax and visit at social hour; lunchtime talk; Eric Kuhn describes the state of the river.

Colorado Foundation for Water Education 2007 Headwaters Tour Visits Gunnison River Basin

The Colorado Foundation for Water Education hosted two busloads of participants on a tour of the Gunnison River on June 24-26 to learn more about how this unique and important basin functions. Approximately 65 people, including members of the Interim Water Committee, travelled from Taylor Reservoir to the Aspinall Unit to the Uncompahgre Valley. Stops along the way included briefings by the Upper Gunnison Water Conservancy District and the Colorado River Conservation District, as well as a tour inside the Morrow Point Dam. Trip highlights included a dinner hosted by the Uncompahgre Valley Water Users Association.

Tour stop in the high country.

Chris Treese, Matt Cook, and Don Glaser discuss the next tour stop.

Learning about hydropower and the Western power grid.

Tour participants enjoy a picnic by the Gunnison River.

On top of Morrow Point Dam.

Rep. Curry explains RICDs.

FACULTY PROFILE

Dr. Lawrence Goodridge

Dr. Lawrence Goodridge

Dr. Lawrence Goodridge is a native of Hamilton, Ontario, Canada, who received his B.S., M.S., and Ph.D degrees from the University of Guelph. Upon completion of his Ph.D. in 2002, Dr. Goodridge accepted a post-doctoral fellowship at the Center for Food Safety at the University of Georgia. Dr. Goodridge was an assistant professor at the University of Wyoming from 2003 to 2006. In August 2006, Dr. Goodridge moved to the Department of Animal Sciences at Colorado State University, where he is an assistant professor in the Center for Red Meat Safety and Quality. His research interests include the development of rapid diagnostics for food- and water-borne pathogens, and his research is currently supported by grants from the National Oceanic and Atmospheric Administration (NOAA), the United States Department of Agriculture (USDA), the National Pork Board, Colorado Space Grant, and the Colorado Water Resources Research Institute.

GRAD 592
INTERDISCIPLINARY WATER RESOURCES SEMINAR

Mondays, 4:00 - 5:30 p.m.
A-206 Clark Building
Colorado State University, Fort Collins, Colorado

Fall 2007 Theme:
Colorado Water Development in the 21st Century

The purpose of the 2007 Interdisciplinary Water Resources Seminar (GRAD 592), through a series of invited speakers, is to examine how new water supplies are being developed in Colorado during the current era and to study an array of projects that are in various stages of development. These projects include Animas La Plata, Elkhead Reservoir, Reuter Hess Reservoir, NISP, Barr Lake pipeline, the Prairie Water project, and others. More specifically, the seminar will:

1. Examine the steps and processes involved in water supply development.
2. Understand the legal and environmental aspects of water development.
3. Discuss the intra- and interstate issues that increase the complexity of water supply planning in the 21st century.
4. Examine current Colorado water projects to understand the issues of public water supply, drought protection, environmental mitigation, transfer of agricultural water, endangered species needs, interstate compacts, water quality protection, and other topics.

All interested faculty, students, and off-campus water professionals are encouraged to attend and participate.

Aug. 20	Dave Little, Denver Water	Life after Two Forks – What happened and how the Two Forks veto changed our approach to water resources planning
Aug. 27	Rick Brown, Colorado Water Conservation Board	Colorado's water development needs for the 21st Century
Sept. 10	Dave Merritt, Colorado River Water Conservation District	Intrabasin, interbasin, and transmountain water movement to meet growing water demands – Case studies: Wolford Mt. Reservoir, Union Park, and the Gunnison pumpback
Sept. 17	Mark Pifher, Aurora Water	The Prairie Waters Project – A sustainable approach to increasing water demands
Sept. 24	Dan Birch, Colorado River District	Elkhead Reservoir Enlargement – Partnerships and "multiple use" as a mechanism to build new projects
Oct. 1	Frank Jaeger, Parker Water	Permitting, water acquisition, and other legal aspects of developing water projects – Case study, Rueter Hess Reservoir
Oct. 8	Dave Kaunisto, East Cherry Creek Valley Water and Sanitation District	Urban partnership and competition for a limited water supply – Barr Lake pipeline project
Oct. 15	Carl Brouwer, Northern Colorado Water Conservancy District	Navigating the EIS process – Northern Integrated Supply Project
Oct. 22	Sean Cronin, Greeley Water	Integrated Water Resources Planning in Northern Colorado
Oct. 29	Wayne Vanderschuere, Colorado Springs Utility	Development of new water resources, Southern Delivery System, planning, process, and challenges
Nov. 5	Jay Winner, Lower Arkansas Water Conservancy District	The Super Ditch – Ag Transfer as a new source of M&I Water
Nov. 12	Kelly DiNatale, CDM	South Metro water needs and supply options
Nov. 26	John Hendrick, Centennial Water and Sanitation	Highlands Ranch: 0 to 100,000 in 30 years
Dec. 3	David Robbins, Council for the Southwest Colorado Water Conservation District	Animas La Plata Project – Last of the big federal projects in Colorado?

Interactive Forum: **Sept. 27-28, 2007 Doubletree Hotel, Colorado Springs**

(Full program and registration details at www.agwt.org)

COLORADO GROUND WATER MANAGEMENT POLICY:

Legal and Institutional Opportunities for Aquifer Recharge and Storage

Forum Organizers: **American Ground Water Trust** and **Arkansas Basin Roundtable**

How to maximize the state's ground water resources in alignment with hydrologic reality, engineering capability, environmental needs, and legal rights

♦ Recharge problems identified and solved ♦ Use of aquifers for storage in other states ♦ Legal parameters for implementing artificial recharge ♦ Sources of water for artificial recharge ♦ Opportunities to better use the alluvial aquifers of Colorado ♦ Recharge stories from Colorado – Where? Why? How? ♦ Impact of water rights, legal opinions and compacts on recharge options ♦ What is holding up our moving forward? ♦ What will be the role of artificial recharge in meeting Colorado's needs?

More than 40 program presenters, including:

♦ Harris Sherman, Executive Director of the Colorado Department of Natural Resources ♦ Gregory Hobbs, Colorado Supreme Court Justice ♦ Colorado State Senators: Gail Schwartz and Jack Taylor ♦ Colorado State Representatives: Amy Stephens, Marsha Looper, Kathleen Curry, Mary Hodge, Frank McNulty, Cory Gardner, and Liane McFayden ♦ Don Shawcroft, Colorado Agricultural Water Alliance and Farm Bureau ♦ Doug Kemper, Executive Director, Colorado Water Congress ♦ Denise Fort, Professor, University of New Mexico School of Law ♦ Craig Miller, Assistant General Manager, Orange County Water District, California ♦ Gregg Houtz, Deputy Counsel, Arizona Department of Water Resources ♦Karl Dreher, Brown and Caldwell, former Director Idaho Department of Water Resources ♦ Fred Anderson, Former President of Colorado Senate ♦ Alexandra Davis, Attorney, Colorado DNR ♦ Eric Hecox, Interbasin Compact Negotiations, Colorado DNR ♦Colorado Water Attorneys: Mike Shimmin, Vranesh & Raisch; David Robbins, Hill and Robbins; Melinda Kassen, Trout Unlimited; Sandy McDougal, McDougal and Woolrich; Steven Sims, Brownstein Hyatt & Farber plus more than 20 other experts in this field.

Special session for forum participants: Identifying the Solutions

Facilitated by MaryLou Smith, Aqua Engineering, and Gary Barber, Arkansas Basin Roundtable

♦ Participant opportunity to contribute to the state's artificial recharge discussion ♦ Collective ideas from all participants to be brought forward for afternoon dialogue with legislators ♦ Ideas and suggestions to be incorporated into a post-forum report

REGISTRATION: "Early Bird" (prior to August 17)

	GENERAL	STUDENT RATE	$ AMOUNT (registrations before August 17)
BOTH DAYS	$230	$130	$……………….. ☐ **Both days**
DAY ONE ONLY	$130	$65	$……………….. ☐ **Day 1** (Thursday, August 27)
DAY TWO ONLY	$130	$65	$……………….. ☐ **Day 2** (Friday, August 28)

For registrations received after August17 but before September 26)

BOTH DAYS	$260	$150	$……………….. ☐ **Both days**
DAY ONE ONLY	$140	$75	$……………….. ☐ **Day 1** (Thursday, August 27)
DAY TWO ONLY	$140	$75	$………………. ☐ **Day 2** (Friday, August 28)
EXHIBIT TABLE	$300		$……………….. ☐ **Table**

One 6-foot skirted table. (Does not include registration)

Total $………………..

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Return by mail: American Ground Water Trust, 16 Centre Street, Concord, NH 03301

Return by fax: (603) 228-6557 Questions? Call (603) 228-5444 Register on line www.agwt.org

A RIVER OF CHANGE

The 18th Annual South Platte Forum

October 24-25, 2007—Radisson Conference Center—Longmont, Colorado

A Change of Pace—*projects*
Peter Binney, City of Aurora
Alan Berryman, Northern Colorado Water Conservancy District
Carl Brouwer, Northern Colorado Water Conservancy District
Lisa McVickers, P.C.

An Inconvenient Climate
Brad Udall, CU-NOAA Western Water Assessment
Greg McCabe, U.S. Geological Survey
Marc Waage and Bob Steger, Denver Water
David Clow, U.S. Geological Survey

Change Your Ways—*regulations*
Patti Tyler, U.S. Environmental Protection Agency
Amy Woodis, Metro Wastewater Reclamation District
Gabe Racz, Trout, Raley, Montano, Witwer & Freeman P.C.

Changing Faces
Harris Sherman, Department of Natural Resources
John Stulp, Department of Agriculture

Changing Hearts and Minds—*education*
Don Glaser, Colorado Foundation for Water Education
Curry Rosato, Keep It Clean Partnership
Brent Mecham, Northern Colorado Water Conservancy District

Fields of Change
James Pritchett , Colorado State University
Frank Jaeger, Parker Water and Sanitation District
Neil Hansen, Colorado State University

Modeling the Change
Suzanne Paschke, U.S. Geological Survey
Chris Goemans, Western Water Assessment
Ray Alvarado, Colorado Water Conservation Board

Call for Posters
You are invited to submit a one-page abstract to the organizing committee by Aug. 1, 2007. Selected posters will be displayed throughout the forum with a staffed poster session from 4:45—6:00 p.m., Wed., Oct. 24. Authors will be notified of acceptance by Sept. 1. Send your abstract to Jennifer Brown, Jennifer@jjbrown.com.

REGISTRATION FEES
Registration fees include meals, breaks and reception.

Early Registration - by Oct. 1....................$100
Registration after Oct. 1...........................$115

Register at www.southplatteforum.org.

FOR MORE INFORMATION
Visit www.southplatteforum.org to see schedule updates, register and get more information.
Or contact Jennifer Brown, (402) 960-3670,
Jennifer@jjbrown.com

Sponsored By
Northern Colorado Water Conservancy District
Colorado Water Resources Research Institute
Metro Wastewater Reclamation District
CSU Cooperative Extension
Parker Water and Sanitation District
U.S. Fish and Wildlife Service
City of Aurora
Colorado Division of Wildlife
Denver Water
U.S. Geological Survey
U.S. Bureau of Reclamation

WWW.SOUTHPLATTEFORUM.ORG

Photos courtesy of southplatteoutfitters.com.

Upper Yampa Water Conservancy District Scholarship Awarded to CSU Student

The Upper Yampa Water Conservancy District (UYWCD) continues to fund a scholarship in support of CSU students preparing for careers in water-related fields. The scholarship program is administered by the CSU Water Center.

The scholarship provides financial assistance to committed and talented students who are pursuing water-related careers at CSU. The UYWCD $2,500 scholarship is open to any major at CSU. Criteria for the scholarships require the recipient to be a full-time student enrolled at CSU; financial need may be considered; preference is given to students from the Yampa Valley area; and a minimum GPA of 3.0 is required. The scholarships are for one year.

The Upper Yampa Water Conservancy District Scholarship Recipient for the 2007-08 academic year is Samantha Winter. A senior majoring in civil engineering at CSU, Samantha is from Steamboat Springs, Colorado. Her areas of interest in water include small-scale water system design and implementation, aquaculture, irrigation engineering, and water conservation. Samantha currently works as a GIS student technician at the USDA-APHIS, where she works in their information technology program. Past accomplishments include volunteer work as a tutor, participation in Engineers Without Borders, international work in Latin America, study abroad in England, and numerous scholarship awards and achievements. Samantha plans to pursue a career in sustainable development of water resources with Native American tribes and in the international arena.

We had a number of outstanding applicants for this year's Upper Yampa Water Conservancy District scholarship, and we congratulate Samantha and wish her success in her studies. The ongoing support of CSU students by the UYWCD is acknowledged and greatly appreciated.

What's New: Water Information

A new Produced Water Management Informa tion System (PWMIS) website opened to th public on June 15. PWMIS was developed by Argonne National Laboratory in partnership with the National Energy Technology Laboratory through funding provided by the DOE Office of Fossil Energy's Oil and Natural Gas Program. PWMIS contains three functional modules:

- A Technology Description Module, which provides basic information about practices that are currently employed to manage produced water. Users can click on any of the 25 listed technologies to access separate fact sheets describing each technology and including references for additional information.
- A Regulatory Module, which identifies and summarizes existing state and federal regulations or guidelines on produced water management. Users can click on EPA, BLM, MMS or on any state to be sent to pages that offer more information about each agency's requirements. Hot links in the agency summary take the readers directly to the agency websites.
- A Technology Identification Module, in which users are asked to answer a series of questions. The replies to these questions (mostly yes/no answers) lead users through a decision tree, resulting in a suggested subset of water management options that would make the most sense for a given geographical or environmental setting.

The website address for PWMIS is http://web.evs.anl.gov/pwmis

RESEARCH AWARDS

Colorado State University, Fort Collins, Colorado Awards for May 2007 to July 2007

Bauder, Troy A., Soil and Crop Sciences-Colorado Department of Agriculture. *Training and Education for Agricultural Chemicals and Groundwater Protection.* $185,000.

Bestgen, Kevin R., Fish, Wildlife, and Conservation Biology-DOI-Bureau of Reclamation. *Research Framework for the Upper Colorado River Basin.* $9,171.

Bestgen, Kevin R., Fish, Wildlife, and Conservation Biology-DOI-Bureau of Reclamation. *Evaluating Effects of Non-Native Predator Removal on Native Fishes in the Yampa River.* $45,120.

Bestgen, Kevin R., Fish, Wildlife, and Conservation Biology-DOI-Bureau of Reclamation. *Effects of Flaming Gorge Dam Releases on Lodore/ Whirlpool Canyon Fish Community.* $60,339.

Bestgen, Kevin R., Fish, Wildlife, and Conservation Biology-DOI-Bureau of Reclamation. *Verification of Stocked Razorback Sucker Reproduction in the Gunnison River via Annual Collections of Larvae.* $22,000.

Bestgen, Kevin R., Fish, Wildlife, and Conservation Biology-DOI-Bureau of Reclamation. *Abundance Estimates for Colorado Pikeminnow in the Green River Basin, Utah and Colorado.* $85,183.

Brozka, Robert J., Center for Environmental Management of Military Lands (CEMML)-USDA-USFS-Rocky Mtn. Rsrch Station, CO. *Mitigation Wetland Monitoring and Clean Water Act Section 404 Support for Fort Drum, New York*. $6,405.

Douglas, Marlis R., Fish, Wildlife, and Conservation Biology-Wyoming Game and Fish Department. *Genetic Assessment of Native Fishes in the Blacks Fork and Upper Green River Subdrainages of Wyoming.* $9,997.

Fausch, Kurt D., Fish, Wildlife, and Conservation Biology-Colorado Division of Wildlife. *Effect of Agricultural Water Use and Drought on Groundwater that Sustains Critical Habitats for State-Listed Fish?* $54,473.

Fausch, Kurt D., Fish, Wildlife, and Conservation Biology-Wyoming Game and Fish Department. *Effects of Cattle Grazing on Riparian Vegetation and Trout Populations.* $5,000.

Garcia, Luis, Civil Engineering-Colorado State Water Conservation Board. *Arkansas Valley Research Center Lysimeter Project.* $57,000.

Garcia, Luis, Civil Engineering-Various Nonprofit Sponsors. *Developing a Decision Support System for the South Platte Basin.* $2,500.

Garcia, Luis, Civil Engineering-Central State University. *Alliance Universities Application of Remote Sensing Technologies to Water Supply Problems in the Western United States.* $180,000.

Hansen, Neil, Soil and Crop Sciences-DOI-Bureau of Reclamation. *Demonstrating Limited Irrigation Technology as an Approach to Sustain Irrigated Agriculture While Meeting Increased Urban Water Demand in Colorado.* $65,800.

Hawkins, John A., Fish, Wildlife, and Conservation Biology-DOI-Bureau of Reclamation. *Yampa River Nonnative Fish Control: Translocation of Northern Pike from the Yampa River.* $193,915.

Knapp, Alan Keith, Biology-Michigan Technological University. *Interactive Effects of Altered Rainfall Timing and Elevated Temperature on Soil Communities and Processes.* $60,581.

Kummerow, Christian D., Atmospheric Science-NASA – National Aeronautics and Space Admin. *A Cooperative Climate Rainfall Data Center.* $256,087.

Niemann, Jeffrey D., Civil Engineering-DOD-ARMY-ARO-Army Research Office. *Instrumentation to Monitor Soil Moisture in a Semi-Arid Climate: Characterizing Interactions Between Soil.* $60,176.

Qian, Yaling, Horticulture and Landscape Architecture-Denver Water Department. *Urban Landscape Irrigation with Recycled Wastewater: Landscape Plant Selections and Interactive Effect.* $15,000.

Thompson, David, Atmospheric Science-NSF – National Science Foundation. *Analyses of Climate Variability and Climate Change.* $149,314.

Thornton, Christopher I., Civil Engineering-Hydrau-Tech, Inc. *Valenciano Dam Spillway.* $42,398.

2007-2008 Calendar

2007	Aug. 20-23	**StormCon: The North American Surface Water Quality Conference and Exposition.** Phoenix, Arizona. For more information and to register, visit http://www.stormcon.com/sc.html.
	Aug 22-24	**Colorado Water Congress 2007 Summer Convention.** Steamboat Springs, Colorado. For more information, visit www.cowatercongress.org or call (303) 837-0812
	Aug. 27-29	**NARF/WSWC Symposium on the Settlement of Indian Water Right Claims: "Indian Water Right Claims Settlement Symposium."** For more information, visit http://www.westgov.org/wswc/meetings.html.
	Sept. 14	**Colorado River District Annual Water Seminar.** Grand Junction, Colorado. For more information, please visit http://www.crwcd.org/.
	Sept 27-28	**Colorado Ground Water Management Policy.** Colorado Springs, Colorado. For more information, please visit www.agwt.org.
	Sep. 30 to Oct. 5	**USCID Fourth International Conference on Irrigation and Drainage: Role of Irrigation and Drainage in a Sustainable Future.** Sacramento, California. For more information about conference and call for papers, go to http://www.uscid.org/.
	Oct. 2-4	**Sustaining Colorado's Watersheds Conference: Making the Water Quality Connections.** Breckenridge, Colorado. For more information and/or to register, visit www.coloradowater.org/conference/.
	Oct. 23-26	**ASDSO Advanced Technical Seminar on Slope Stability for Embankment Dams.** Denver, Colorado. For more information, please contact Susan Sorrell by phone at (859) 257-5146, or for online registration, please visit www.damsafety.org.
	Oct. 24-25	**South Platte Forum 2007.** Longmont, Colorado. For more information, visit http://www.southplatteforum.org/.
	Oct. 24-25	**2007 Tamarisk Symposium.** Grand Junction, Colorado. For more information, visit www.tamariskcoalition.org.
	Oct. 25-27	**MODFLOW: Introduction to Numerical Modeling short course.** Golden, Colorado. For more information, please visit http://typhoon.mines.edu/short-course/.
	Nov. 7-9	**NWRA Annual Conference.** Albuquerque, New Mexico. For more information, visit www.nwra.org.
	Nov. 12-15	**AWRA Annual Water Resources Conference.** Albuquerque, New Mexico. For more information, and/or to register, please visit www.awra.org.
	Nov. 29-30	**Groundwater Foundation Conference.** Lakewood, Colorado. For more information, please visit www.groundwater.org.
	Dec. 12-14	**CRWUA Annual Meeting: Global Changes, Local Impacts.** Las Vegas, Nevada. For conference information, visit http://www.crwua.org/.
2008	Feb. 9	**Water Tables: From Water Fights to Water Rights.** Fort Collins, Colorado. More information available at http://lib.colostate.edu/archives/water/.
	March 5-6	**The 18th High Altitude Revegetation Workshop.** Fort Collins, Colorado. For more information, please call (303) 422-2440 or (303) 279-8532.
	May 19-21	**IGWMC Conference: MODFLOW and More – Groundwater and Public Policy.** Golden, Colorado. For more information, please visit http://typhoon.mines.edu/events/modflow2008/modflow2008.shtml.
	May 28-31	**USCID Water Management Conference: Urbanization of Irrigated Land and Water Transfers.** Scottsdale, Arizona. For more information, visit www.uscid.org.

COLORADO WATER

Newsletter of the Water Center of Colorado State University

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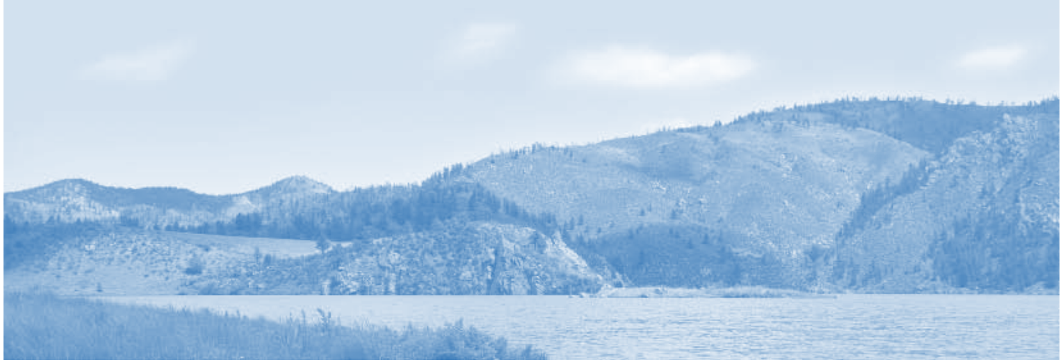

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