Colorado Water

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Theme

International Water

Colorado State University

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Highlights:

In Every Issue:

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Cover Photo: A pictorial collage represents CSU's international water efforts work. See image captions (left to right) on pages 11, 10, 18, 26, and 9.

Editorial

by Reagan Waskom, Director, Colorado Water Institute

Thinking Globally About Water

Any recounting of the great global water challenges ends up sounding a lot like the list of major water problems in Colorado—rapid development, limited supplies, competition between human and natural needs, transboundary disputes, and the search for workable paradigms for water management. This issue of *Colorado Water* focuses on current efforts at CSU to bring Colorado water expertise to other countries around the globe.

The statistics on global water issues makes Colorado's problems pale by comparison: 1.1 billion people without access to clean water, 2.4 billion people without access to sanitation, 2 million child mortalities each year from waterborne disease, and so on. Globally, water-related extreme events, such as floods and droughts, kill more people than any other natural disaster. Transboundary disputes, the threat of terrorism, and the potential impact of climate change underscore the fragile relationship between safe water supplies and global prosperity. Clearly, the capabilities of the next generation of water scientists, engineers, managers, and policymakers are vital to the world's economy, ecosystems, and human health and well-being.

CSU has a history of international water research and service, most notably in irrigation development and management, water infrastructure, and water quality. It can be argued that global water research activities are consistent with CSU's land grant mission and benefit the state of Colorado in several ways. First, the issues of water scarcity, rapid urbanization, and environmental sustainability facing much of the planet are the same issues facing Colorado. University faculty working on these issues abroad benefit from understanding water management in foreign countries and can gain a greater appreciation for the complexity of Colorado's water issues. International activities expose CSU students and faculty to fresh approaches and alternative solutions, causing us to think about our domestic water problems in new ways. On the other hand, Colorado provides a unique real world classroom for our international students, showcasing a wide range of water issues and solutions for semi-arid, water-stressed environments. Finally, our current students will live in a global economy and must be trained to understand and function in this environment to be effective leaders who can sustain our economic viability.

Recently, a group of CSU faculty members organized to reenergize international water activities at CSU, producing a strategic plan for international water at CSU that calls for a renewed vision for international water research, education and outreach. The plan identifies several strategic assets at CSU; among these are senior water faculty with rich international experience, numerous international alumni of CSU water programs, and new CSU faculty with cutting-edge research and teaching skills. CSU's legacy of international water programs, dating back to the 1950s and culminating with the large USAID-funded projects in Pakistan and Egypt in the 1980s, created an enduring network of CSU graduates who are now highly placed in water and natural resource ministries around the globe.

A number of activities have already been initiated under the CSU International Water Initiative. Last spring a Global Water Colloquium was held to engage CSU faculty in a dialog on international water concerns and research needs. This year a UNESCO Category II Center has been initiated in cooperation with the U.S. Army Corps of Engineers and provides some excellent linkages between CSU and U.S. State Department and European Union water initiatives. In August a small group from CSU attended the World Water Week in Stockholm, where they held a reception for "Friends and Alumni of Colorado State" to reconnect with key international alumni. One of the outcomes of this meeting is a request for CSU to provide distance water education to Arabic-speaking scientists and water managers. CSU will offer an Executive Water Leadership Seminar next summer that will be targeted to mid- to high-level water leaders from around the world. Several other international water initiatives are also occurring on campus, including a weekly global water seminar this fall.

CSU faculty are committed to our land grant mission of serving the people of Colorado by engaging in research, teaching, and outreach that benefits this state. Engaging in international water activities informs and strengthens that mission by broadening our view and giving our students much needed international exposure. As we think globally about water, we are also compelled to act locally, as the prosperity of Colorado is now connected to the well being of the rest of our planet. This issue of our newsletter provides a glimpse at some of the international water activities occurring at Colorado State—I look forward to bringing you future stories from other faculty and water professionals in Colorado that are engaged in water projects abroad.

Guest Editorial

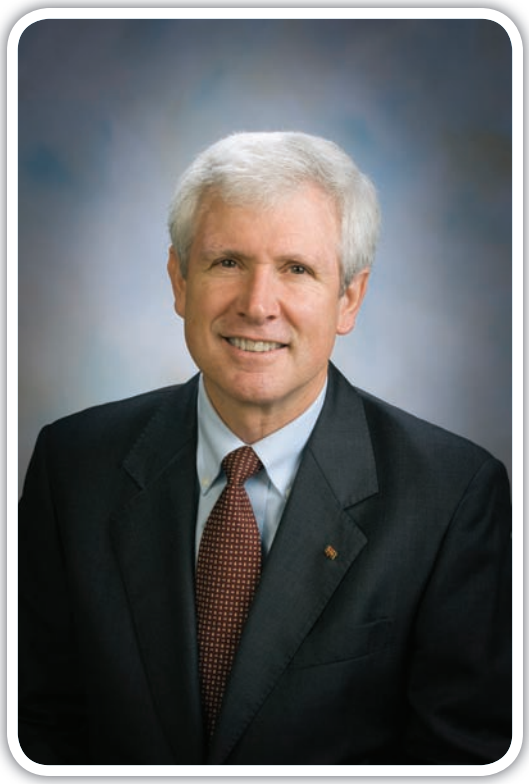
by Jim Cooney, Vice Provost for International Affairs, Colorado State University

Water and CSU's Internationalization Strategy

It is impossible to hear a speech from Colorado State University (CSU) President Larry Penley without understanding that our university is deeply committed to dealing with global issues. It also is impossible to look back at the history of CSU without recognizing the key role that water issues have played, whether one looks back 20–30 years or 130 years. The university is moving forward with "internationalization" at so many levels, and international water issues promise to be one of the most critical areas to explore. This fits well with what my office, the Office of International Programs, is responsible for—namely, "campus internationalization."

CSU has an *Internationalization Plan* that was adopted in 2006. We are proud of the plan, and "NAFSA: The Association of International Educators" presented CSU with an award for being one of eight outstanding campus internationalization plans for 2007–08. NAFSA prepares a 60–70 page booklet describing the campuses that receive awards, and international water developments figure prominently in the CSU write-up. Likewise, in the new CSU publication, *Engaging Colorado: The 21st Century Land-Grant University*, a major emphasis is on how CSU's global research network relates to "a new generation of water professionals." The clear message that is conveyed in our *Internationalization Plan*, reported in our university publications, and described in President Penley's speeches is that our efforts in the water arena are prime examples of what a land-grant university can and should be doing in a globalized world.

I had an eye-opening experience when I attended the 2008 CSU Global Water Research Colloquium, *From Conflict to Sustainability: Challenges and Opportunities in an Interdependent World*. I was only there for the sessions designed for laypeople, but I was impressed by the depth of CSU's involvement in water and by the sheer numbers of faculty active in the field. As Evan Vlachos delights in saying, not even MIT comes close to the number of faculty CSU has who deal with water. (Full disclosure: my doctorate is from MIT, and I am delighted to have CSU trump MIT in this area!) I remember well the presentation at the colloquium by Brian Richter in which he talked about global water opportunities from a practical ecological perspective, and I especially enjoyed the thoughtful panel discussion on opportunities for a land-grant university to engage in global water issues. To hear representatives from engineering, geosciences, political



science [my field], and water stewardship, as well as outside voices from The Nature Conservancy and the Army Corps of Engineers, share thoughts was extremely helpful.

The driving idea behind the CSU *Internationalization Plan* is that internationalization is not "one thing" or one formula; it has to take place at every level of the university. The plan, therefore, aims to build bridges across colleges and departments, and CSU is looking to establish "key institutional partnerships" across the world. This plan does not prevent any professor from having individual research connections, but it specifically encourages broader collaboration. Having some money to award to faculty and students is one way to do this, and approximately $200,000 will be awarded annually for activities ranging from international conferences in Fort Collins to research travel grants to Study Abroad scholarships. There is also funding for developing the key partnerships, and it is easy to imagine that the international water links that CSU has had for decades will lead to important institutional partnerships too—in Egypt or Pakistan, for example, where we have long historical ties. CSU has developed three "Superclusters" thus far, all of which are required to have a global focus. Although water has not yet been designated as a CSU supercluster, it will not be a surprise if water is a strong future candidate for this special funding and emphasis on bringing technology to the global market place.

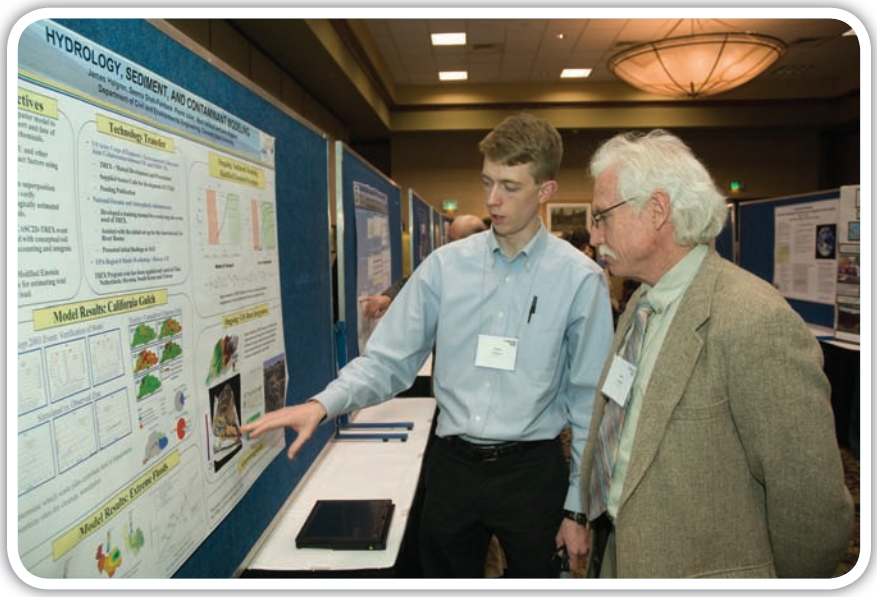
The report, *Matching the Land-Grant University to a Global Mission: Addressing Internationalization of Water Programs at Colorado State University*, complements the *Internationalization Plan*. It, too, blends short-term and long-term goals to build our capacity in the water area and, quite frankly, recapture CSU's leadership role in the water resources field. The efforts may be as simple as providing some faculty grants, particularly to attract new young scholars to the field, or compiling an "international water faculty network" that maximizes the chance to use CSU's world-wide connections in the water area. They can also be more farsighted, such as securing an endowed faculty chair in international water or establishing an "International Water Institute" at CSU. Whatever approach is taken, it will be vital to include campus-wide faculty in discussions for these new steps.

CSU civil engineering professor Neil Grigg speaks at the Global Water Research Colloquium.

In my own work for the university, I am often involved with water discussions in many important contexts. Last February, while traveling in Saudi Arabia with the Dean of the College of Business, we met with the Deputy Minister for Water Resources and learned that most senior Saudi managers for water policy were trained at CSU. (In addition, the Minister of Finance is also a CSU graduate, and he is the longest serving minister in the Saudi government.) When Taiwan sent its senior water official to CSU last year, he pointed out that probably 500 Taiwanese policymakers went through CSU training programs. The Peace Corps is preparing to celebrate its 50th anniversary in 2011; we know that Maury Albertson, Pauline Birky-Kreutzer, and Andrew Rice were instrumental in conceptualizing the Peace Corps, and I just learned how critical CSU's contributions in water were during the early years of the Peace Corps, especially in Pakistan. Egypt is so grateful for CSU's role in training its water officials that both the Minister of Water Resources and his son, who runs the leading national institute for water research, are eager to rekindle links to CSU. President Penley is likely to travel to Egypt early in 2009.

As a political scientist, I have always been partial to Aristotle's argument that "all things are water." (He attributes this to an earlier Greek philosopher, Thales of Miletus.) I will not try to assess Thales' belief that Earth floated in water and everything came from water, but the notion that water is critical to our future still remains valid. At CSU, we are carrying forward the discussion in innovative ways by connecting issues relating to health, natural resources, the environment, urban development, and of course our traditional agricultural mission. We do that by reaching across our entire campus, and our real asset is the remarkable network of alumni who have been trained at CSU over the past decades.

Jim Cooney, Ph.D.
Vice Provost for International Affairs
Professor of Political Science
Colorado State University



CSU civil engineering student James Halgren describes his poster to John Nuckols, CSU professor in environmental and radiological health sciences, at the Global Water Research Colloquium.

Wood in Neotropical Headwater Streams

by Ellen Wohl, Dan Cadol, and Jaime Goode, Department of Geosciences, Colorado State University

Numerous studies document the geomorphic and ecological importance of wood in temperate headwater streams. Large wood, typically defined as being at least 1 meter long and 10 centimeters in diameter, increases the roughness of the channel boundaries and promotes storage of fine sediment and organic matter. It also enhances localized channel scour that creates pools and overhung banks, which improves instream habitat diversity.

Although the majority of existing literature on instream wood comes from the Pacific Northwest, within the past decade studies from elsewhere in the United States, as well as from Europe, Asia, Australia, and South America, have expanded our understanding of regional differences that influence instream wood. Nothing has yet been published, however, on wood in tropical headwater streams.

The amount of wood within a stream segment reflects the integrated effects of wood recruitment, storage, and transfer. The amount of instream wood, typically referred to as wood load, can be measured as pieces per length of stream channel or volume of wood per unit area of channel. The controls on wood load can be conceptualized as a simple linear function:

$$\Delta Sc = [Li - Lo + Qi/\Delta x - Qo/\Delta x - D + B]\Delta t \quad (1)$$

where ΔSc is change in wood storage within a reach of length Δx over time interval Δt, Li is recruitment of wood from lateral sources (bank erosion, wildfire, debris flows, chronic tree mortality, etc), Lo is loss of wood to overbank deposition and channel movement, Qi is fluvial transport of wood into the stream segment, Qo is fluvial transport out of the segment, D is in situ decay, and B is storage in beaver dams (modified from Benda and Sais, 2003). The volume of wood in tropical streams might be expected to differ from volumes in temperate streams for at least two reasons: tropical environments have higher magnitudes of streamflow per unit drainage area, which would affect the Qi and Qo terms in equation 1, and much higher rates of wood decay (D in equation 1).

We are quantifying some of the variables in equation 1 for study sites in Costa Rica and Panama. In Costa Rica we work at the La Selva Biological Station, a 1,600-hectare reserve that includes 730 hectares of old-growth tropical wet forest. We have 30 study sites (each a 50-meter length of stream) along small channels (0.1–8.5 square kilometers) tributary to the Puerto Viejo or Sarapiquí Rivers.

Jaime Goode (at right) stands beside one of the logjams on the Upper Rio Chagres, Panama.

During our initial field work in March 2007, we surveyed valley and channel characteristics and measured wood load at each study site. We found that wood load ranged from 3.0–34.7 cubic meters of wood per 100 meters of channel and 41–612 cubic meters of wood per acre of channel. These values are within the range reported for temperate streams. Statistical models for wood load consistently selected the variables wood diameter/flow depth, stream power, the presence of backflooding, and width/depth. These variables explain half to two-thirds of the variability in wood load. These results, along with the spatial distribution of wood with respect to the thalweg, suggest that transport exerts a greater influence on wood loads than recruitment.

Since March 2007, we have returned to La Selva every four months to continue monitoring a subset of 10 study sites. We are using repeat surveys of these sites to characterize mobility and exchange of individual pieces of wood. We have set up stream gages at some of the sites, marked tracer clasts in the streambed for periodic repeat surveys that indicate bed mobility, and anchored fresh pieces of wood in the channel to monitor decay rates. Together, these measurements will allow us to evaluate the relative importance of recruitment, decay, and transport in controlling wood loads at La Selva.

Our field site in Panama is the Upper Rio Chagres, a 400-square kilometer catchment that is the main water supply for the Panama Canal. Accessible only by helicopter, the Upper Chagres is a remote, mountainous environment

with old growth tropical forest. Unlike the more gentle terrain of La Selva, the steep slopes along the Chagres frequently experience landslides that introduce large volumes of sediment and wood to the main channel. The very large discharges and high rates of wood decay, however, prevent the wood from remaining in the channel for more than 1–2 years.

During initial field work in the Upper Chagres during 2002, we noticed the dearth of wood in the stream. Intense rainfall over the uppermost portion of the catchment during July 2007 created numerous landslides, which resulted in large wood jams in the channel. We surveyed three of these jams in February 2008 and will repeat these surveys in February 2009. Although the jams cover up to 2,400 square meters and include logs 27 meters long and 1.9 meters wide, we hypothesize that more than half the volume of wood in each jam will be gone by February 2009. This is partly based on observations of the dynamic nature of this system; a storm in 1999 of magnitude comparable to the 2007 storm left no remnants of landslides and wood in the channel that were visible during our 2002 field work.

The field areas in Costa Rica and Panama provide very contrasting scenarios of wood recruitment and retention in neotropical regions. Results thus far in Costa Rica indicate relatively little variation in wood load through time at each stream site, despite the fact that the toppling of a single large tree can more than double the existing volume of wood in the channel (a phenomenon that we observed at one of our study sites). By contrast, wood along the Upper Chagres River in Panama goes through "boom and bust" cycles of very large wood volumes in the stream created by intense rainfall every few years, followed by a few years with essentially no wood retained in the stream.

Continued comparison of these and other tropical sites will help us to constrain the differences in wood dynamics between temperate and tropical headwater streams and to make comparisons across regions. With this in mind, we are also investigating wood characteristics in streams of the Colorado Front Range, which has had far fewer studies of instream wood than the Pacific Northwest. Finally, we hope to develop recommendations for sustaining stream functions associated with wood in tropical catchments subject to timber harvest and related land uses.

Dan Cadol surveys one of the small streams at La Selva Biological Station, Costa Rica.

Ellen Wohl (at top left) surveys one of the logjams at the mouth of a tributary on the Upper Rio Chagres, Panama.

Integrated Water Management and Law in Colombia

by Neil S. Grigg, Professor of Civil Engineering, Colorado State University

CSU Water Research in Colombia

As the world shrinks, Colorado State University (CSU) water research encompasses many students and water issues around the globe. As an example, CSU undertook a project in 2004 to assist Colombia with reforming its water law and institutional arrangements for the water sector. The project involved a CSU team that reviewed Colombia's water laws and institutional arrangements and worked with a national team of water managers and lawyers to draft a proposed new water law.

As the map at right shows, Colombia is located at the top of South America adjacent to Panama. It is about the size of Texas, New Mexico, and Oklahoma combined and has varied topography, dominated by the Cordillera of the Andes with a highest peak at 19,000 feet (5,800 m). Colombia's longest river, the Magdalena, is used extensively used extensively for economic purposes such as water supply, navigation, and power generation. At 970 miles (1,555 kilometers) long, its coastlines cover 1,000 miles (1,610 kilometers) on the Caribbean and 800 miles (1,290 kilometers) on the Pacific. Only five percent of the land is cultivated, and agricultural regions have soil erosion problems due to poor cultivation practices.

In recent times, Colombia has been recognized for its conflicts and internal problems, but it also exhibits impressive public policies. Its government is divided into 32 departments, which are like states in the United States. It also has a district capitol, where Bogotá is located. Colombia's population is about 45 million, about 70 percent of which is urban with diverse racial and regional groups. Bogotá is the largest city and is one of the world's larger urban agglomerations, with about eight million in population. Other large cities with populations of one million or greater are Medellín, Cali, Barranquilla, and Cartagena.

Although Colombia has a long history of armed conflict, the situation has improved and violence is down. Under President Uribe the number of incidents has fallen, and public confidence that the armed forces can handle the conflict has risen. Despite these challenges, Colombia has made surprising advances in delivery of public services and in development of its water laws.

Map of Colombia, Image source: Instituto Geográfico Agustín Codazzi.

Colombia's Water Laws

Several Latin American nations have reformed their water law in the last two decades. Mexico, Brazil, and Chile have received publicity for these reforms, for example. Although it has not been publicized as much, Colombia has also innovated in water law, and it has useful experiences to share.

Briefly, Colombia introduced a new "Code of Natural Resources" during the 1970s and implemented water laws that were ahead of those in other Latin American countries. With this code and later laws and decrees, Colombia introduced systems for water ownership, water use concessions (or permits), and discharge concessions (discharge permits). It also introduced systems of charges for water use and for discharges, following the principle of "polluter pays."

During the 1950s, Colombia organized its first "regional autonomous corporation," which was essentially a development organization for a particular region. The first one, for the Valle del Cauca region near the City of Cali, was modeled after the Tennessee Valley Authority. After passing a new Constitution in 1991 and a landmark environmental law in 1993, Colombia now has over 30

of these corporations and has designated them as the country's main environmental authorities.

Delivery of Water Services

There is a close link between Colombia's environmental and water law and delivery of water and wastewater services. As in many countries, Colombia's service delivery and public health improved dramatically in the last 50 years. Prior to 1875, the nation was emerging from the Colonial Period, and services were basic, if they existed at all. In 1886, the first water supply system was inaugurated in Bogotá. It was only in 1957 that sewerage service began to be considered important. According to a 2001 government document entitled "Basic Water and Sanitation Sector: Challenges and Results," water supply coverage in urban areas increased from 11 percent in 1938 to 29 percent in 1951 and to about 90 percent by 1990. Today, urban coverage is even higher, but rural coverage still lags.

In 1994, Colombia introduced a new law for public services (Law 142), which brought into effect new encouragement for private delivery of public services and new regulatory structures and agencies. Private sector involvement has increased in a number of public service areas, with visible results. While success is not universal, there have been improvements in delivery of water supply and sanitation services, especially in the larger cities.

As part of its regulatory strategy, Colombia has experimented with an innovative way to transfer income from wealthier to poorer utility customers. This is done through a system of classification of service zones by income, in which higher income customers pay more and lower income customers pay less. Regulatory agencies regulate rates according to the proof by the public service authority that they are implementing this system.

Colorado State University Project

During summer of 2004, a team from CSU worked with staff and consultants of Colombia's Ministry of Environment, Housing, and Territorial Development to develop a new draft water law to be introduced in the Congress of Colombia in October of that year. The new law is expected to coordinate the many disparate articles governing water use, water quality, natural areas, groundwater, and water management in coastal and marine zones. In preparation for the new law, a number of important issues have been identified, such as:

- Municipal sources are the largest source of contamination in Colombia. Only about five percent of municipal wastewater is treated, and the extent of industrial discharges to sewer networks is unknown. A culture to promote treatment of municipal wastewater is largely absent. Funding is inadequate and prospects for improvement seem limited in the near term. An integrated system of information to control withdrawals and coordination of water uses are both lacking. Most of the smaller municipalities use small, vulnerable sources. Groundwater management is largely missing. Municipalities and service authorities lack funding for infrastructure. Service coverage for aqueducts and sewerage is inadequate, especially in rural areas and smaller municipalities. Waterborne disease is a major problem.
- The Magdalena River, Colombia's most economically important river, is severely polluted and carries an excessive level of sediment, thus threatening coastal and downstream areas. It is the major source of contamination to the southern Caribbean Sea system. Together, the Magdalena River and the Mississippi River explain a large share of the pollution in the Gulf of Mexico-Caribbean system.
- There are no programs to aid municipalities and local governments in designing and implementing stormwater and flood control systems, and there is no national system for flood damage mitigation.

Conclusions

Our neighbor Colombia is endowed with rich water resources, which offer the nation much potential for utilization and many opportunities for stewardship. These water resources are supplying the population, industry, and agriculture, and they are being used to generate nearly 80 percent of Colombia's electric energy. Thus, the country is taking advantage of its water resources to meet national needs at its present level of development.

However, Colombia has reached a crossroads in its use of water resources and in delivery of public services. With a growing population, many problems of contamination and over-exploitation threaten the country's resources and quality of life. These problems have emerged in spite of innovative and forward-looking approaches to water law. Complex institutional problems that have heretofore been allowed to persist cannot be tolerated if the nation is to solve problems that inhibit more effective management of the water resource.

As it recovers from its legacy of conflict and violence, Colombia has many lessons to offer to its neighboring countries in Latin America, to other developing countries, and to North America. Perhaps these lessons can be shared in the context of more future cooperation in sharing how water law can be reformed to help improve the world's water resources.

CSU Extension Welcomes New Associate Director

Colorado State University (CSU) Extension recently welcomed Jan Carroll, Ph.D., as its new associate director. In her new role, Carroll will provide leadership, strategic planning, project management, and summary evaluation and assessment processes for statewide programs. To identify and prioritize local needs, foster interdisciplinary team efforts, and increase grant funding she will work closely with college leadership and Extension specialists on campus and Extension field leadership and agents throughout Colorado.

"There are many issues in Colorado that are of critical interest to Colorado and CSU Extension," said Carroll. "Many of them are appropriate for our involvement. I believe we can mobilize resources to realize our vision, to lead the University in helping the people of Colorado put knowledge to work."

Carroll began her career with CSU Extension in 1994 as a family resource specialist. Since 1996 she has led K-12, military 4-H, and workforce preparation efforts as a 4-H Youth Development Specialist. She has also administered Colorado's Children, Youth & Families at Risk (CYFAR) projects for over 10 years, securing nearly $2 million in external funding for Extension programming for Colorado families and youth.

Carroll earned her Ph.D. in vocational education with an emphasis in human resource development and her master's degree in consumer science, both from CSU. She currently serves as an honorary trustee of the Women's Foundation of Colorado, a sustaining member of the Junior League of Fort Collins, and the CSU representative on the Colorado Prevention Leadership Council.

Soil and Crop Sciences
Fall 2008 Seminar Schedule
12:00 – 12:50 PM in W9 Plant Science Building

Oct 16	Jens Blotevogel, Soil and Crop Sciences, CSU **Modeling of Contaminant Fate in Subsurface Environments**
Oct 23	John Frank and Bill Massman, U.S. Forest Service, Ft. Collins **Introduction to Eddy Covariance**
Oct 30	Dwayne Westfall, Soil and Crop Sciences, CSU **Wheat Based, No-Till Dryland Cropping Systems: Past, Present, and Future**
Nov 6	Tim Gates, Civil Engineering, CSU **Basin Scale Salinity Modeling in the Arkansas Valley**
Nov 13	Elizabeth Ryan, CSU **Crops for Health**
Nov 20	Jean-Nicolas Enjalbert, Syndi Anderson, Gaelle Berges, CSU **A Multidisciplinary Approach to Oilseed Improvement for Food and Fuel**
Nov 27	No Seminar - Thanksgiving
Dec 4	Sarah Ward, Soil & Crop Sciences, CSU **Hybridization in the Invaded Range between Two Non-Native Toadflax Species: Cause for Concern?**
Dec 11	Burl Scherler **A Southeast Colorado Wheat-Based No-Till Cropping Systems – Farmer Prospective**

Providing Rural Honduran Communities with Drinking Water through Gravity Fed Systems

by Ben Latham, Peace Corps Masters International Program, Colorado State University

Since its inception in 1961, the U.S. Peace Corps has sent nearly 200,000 volunteers to 139 developing countries with the underlying task of working with host countries on development issues while fostering peace and friendship with the United States. Currently, 8,000 volunteers serve in 74 countries, working on critical water resources projects such as watershed protection, drinking water system infrastructure, sanitation, and community development programs related to water and environmental protection.

The Peace Corps Masters International Program gives potential applicants the opportunity to combine Peace Corps service with a master's degree program. Students generally follow the same program of study as traditional master's students but conduct their research overseas while serving two years in the Peace Corps.

In January 2005 Benjamin (Ben) Latham and Kelly Latham began serving in the Peace Corps Masters International Program, a joint program between the U.S. Peace Corps and select U.S. universities. They began a course of study at Colorado State University (CSU) in watershed science and were assigned by the Peace Corps to work in Honduras as water and sanitation engineers.

Peace Corps Honduras Water and Sanitation Program

The Peace Corps Honduras Water and Sanitation program focuses on water issues related to the rural population that comprises 55 percent of the total 7.5 million people in Honduras. Less than 80 percent of the rural population has access to improved drinking water, defined as having access to 20 liters per person per day from a designated and protected source and access within 1 kilometer of the point of consumption. In rural areas the water supply and treatment is significantly less reliable, with less treatment and disinfection than for the larger population.

Ben Latham performs a topographic survey in the community of Aldea Nueva, Copán Ruinas, using theodolite equipment for subsequent system design.

A 25,000-gallon tank is constructed in the community of Union Otuta, Santa Rita. On top of the completed tank is the drip chlorination device used for disinfection.

Rural Honduran Gravity Fed Drinking Water System

Due to the mountainous topography of Honduras and the relative abundance of surface water for much of the year, the majority of rural water systems use surface water and are gravity fed. Combined with educational programs, gravity fed systems can be maintained by the rural communities that use them, which is vital in areas not accessible by roads and with under-educated populations. Technical expertise is necessary during system design and construction, but local self-governing water boards are capable of managing the systems.

The goal of these projects is to transport water using gravitational force from a protected source to a tank for storage and chlorination. From the tank, the water is distributed through a piped network to individual houses. Although the process described here is specific to Honduras, it has been applied throughout the developing world.

Initial Feasibility Study

The first step in designing and constructing a rural gravity fed water system is to assess the feasibility for that specific community. After a potential water source has been identified, the feasibility of a project is assessed through on-site inspection. In the case of Honduras, water sources

can be greater than 10 kilometers from a community, accessible only via rugged terrain without maintained trails. Assessment includes three primary components:

1. Assessment of the watershed
2. Measurement of available water
3. Measurement of elevations

Watershed Assessment

Assessment of the watershed contributing to the water source is critical for protecting both the quality and quantity of water. The water sources used in these water systems tend to be 1st order mountain streams or springs. Although these water systems have simple chlorination systems, further treatment is usually unavailable, and due to the lack of laboratories and monitoring equipment there is little capacity for water quality assessment. Thus, the use of water from pristine sources is important to protect the population consuming the water. Deforested watersheds will also have more flashy flow regimes, and the reduced storage capacity will adversely affect base flows.

If the watershed is in poor condition and there is no alternative water source available, it is not necessarily eliminated from consideration. A system could be constructed, but steps are needed to eliminate or reduce the potential contaminant sources.

Flow Rate Measurement

The systems are generally designed for a 20-year life, and the future water demand is calculated assuming a six percent growth rate and an average daily consumption rate of 25 gallons per person. It is important to measure the flow during base flow conditions to ensure that the water source will provide sufficient water throughout the year.

The majority of rural villages in Honduras have populations less than 1,000, and the water sources are not large. For instance, a 100-house village needs a minimum flow at the source of 25 gallons per minute to meet future demand. Water flows of this size are effectively measured manually by constructing a simple dam structure to capture flow and then measuring the flow over the dam using a vessel with a known volume.

Elevation Consideration

The elevation of the water source must be measured to ensure that the water will be able to flow to a tank location and then onto the community itself through gravitational force alone. Elevation is most easily measured using basic Global Positioning System (GPS) equipment. Although the potential for error with this equipment is fairly high, it is generally sufficient for an initial assessment.

Local community members work on a typical dam structure at the water source for the community of Tres Aldeas, Copán Ruinas.

Water System Design Phase

After assessing the initial feasibility, a system design can be completed, which includes assessing pipe materials and diameters, addressing pressures, calculating flow rates, and predicting the operating conditions of the fully constructed system. Next, the materials lists and cost estimating can be completed.

Topographic Survey

The first step in the design phase is to collect more accurate elevation data along the potential path of the pipe between the water source and the tank and along the distribution network. This is most accurately done with survey equipment such as a theodolite. In certain situations, a GPS can be used where there is sufficient elevation difference between the critical points in the system to compensate for the error of the GPS equipment. The survey data are collected with consideration for high and low points along the pathway of the pipes and the distribution network.

System Design

The survey data are used to calculate the pressures and flows throughout the system. The hydraulic calculations for the system are performed using the average daily demand of 25 gallons per person per day adjusted for peak demand. The primary calculations of interest are pipe distances, flow rates, velocity, frictional head losses, and static and dynamic pressure. These calculations are performed at each station location collected during the topographic survey. The pipe diameters, pipe materials, and location of pressure break points are varied and adjusted to ensure that sufficient water will arrive at the tank location without excessive pressure in the system, potentially jeopardizing the integrity of the pipes. Similar calculations and adjustments are performed along the distribution network, but adjustments are made to address the water exiting the system at the household connections.

Local community members work on the excavation trenching for piping in the community of Carrizalon, Copán Ruinas.

A tank is necessary to provide sufficient storage capacity during times when the water demand exceeds the flow entering the system for any given period during the day. Based on demand, a 100-house village would require about a 10,000-gallon tank when population is projected over the design life of the system.

To complete hydraulic calculations, preformatted spreadsheets specific to water system designs can be developed, and modeling programs such as EPANET are generally necessary for calculations and designs of more complicated distribution networks.

Beyond the pipes, fittings, and the tank, other structures will be included in a system. At the water source, a concrete dam or other catchment structure captures and directs flow to the inlet of the water system, removing debris and settling out sediment. Pressure break points are typically needed in a gravity fed system to elevate high pressure that could rupture pipes. Additionally, considerations are given to cleanout and air valves, system control valves, concrete valve boxes, and the household connections.

At the water source for Porvenires, Copán Ruinas, a small dam structure was constructed and flow is being measured by hand.

Overall system expense depends significantly on the distance from the water source to the community, the size of the community, transportation requirements, and necessary piping materials. Materials available in Latin America are consistent with materials available in the United States. In Honduras the recent materials cost for a gravity fed system has been between $15,000 and $100,000 for communities of 20 to 300 houses.

System Construction

Typically, it is the community's responsibility to provide necessary labor for the construction of a water system, including trenching, carrying materials, and other manual labor. A skilled construction foreman with experience in water system construction is responsible for construction and directs the community, and a supervisory engineer advises the construction foreman, gives technical advice, and makes any changes.

The length of time needed for construction depends on factors such as the number of available workers, the size of the project, the weather conditions, and the complexity of the project. Generally in Honduras, system construction takes between one and five months.

Non-Technical Aspects

In Honduras a rural water system is generally managed by the user community through a self-governing water board. The water board is responsible for collecting monthly fees per connection (unmetered), preventing overconsumption, protecting the watershed, fixing service problems, chlorinating the water, and assigning a plumber. For an isolated community that is uneducated or illiterate, managing a water system can be difficult. Funding institutions should, but frequently do not, take on the responsibility to educate the community and periodically monitor the systems.

Conclusions

A gravity fed water system is a relatively straightforward type of water system to design and construct to meet the water needs of rural communities. The materials are widely available, and the model has been applied successfully in many developing countries. Although upfront costs may be high, minimal technical expertise is needed following completion of the construction. Provided the system is accurately designed and constructed, and the community is adequately trained in the operation, maintenance, and management of the water system, a gravity fed system should operate successfully throughout its 20-year design life.

Feasibility Study for Water Resources Development in the Chonta and Mashcon Rivers; Cajamarca, Perú

by Jose D. Salas, *Professor of Civil & Environmental Engineering, Colorado State University*
Manuel Paulet, *Purdue University, formerly at the Interamerican Center for Cooperation on Agriculture*
Carlos Vasconcelos, *Manager of SISA Consulting Co., Consulting Engineer, Lima, Perú*

During the past few years, the economy of Perú (South America) has been growing at an annual rate of 8–10 percent, making it an attractive area for capital investment and growth. One of the major reasons for such unprecedented growth has been the mining industry.

Many regions in Perú have important mineral stock and have attracted the attention of major mining corporations. One example is the Department of Cajamarca in the north of Perú, where the regional economy primarily hinges on agriculture, livestock industry, and mining. Because the region houses the historical "Baños del Inca" (Pools of the Inca), a well known hot springs and tourist attraction, tourism is also important to the economy. Specifically, in the headwaters of the Mashcon and Chonta Rivers, which are located in the south of Cajamarca, major mining operations to extract gold from the earth's crust have been developing in the past several years. While this has brought employment opportunities for thousands of Peruvian workers and has helped boost the regional and national economy, it has also brought a number of concerns related to the impact of mining operations on the environment. These impacts include effects on the water quantity and quality of nearby streams, depletion of groundwater levels and water flow from the so called "manantiales" (springs), and increased soil erosion. In addition, the mining boom has raised concern about the vulnerability of inhabitants, livestock, wildlife, vegetation, soil, and water to toxic waste that may result from accidents and other industrial operations.

The Peruvian central and regional governments have responded to the people's concerns about assessing impacts and consequences and studying ways of approaching and managing them. One proposed solution is a water resources development project in the Mashcon and Chonta Rivers, which will enable impacts from industrial mining operations to be compensated via the construction of canals and reservoirs.

The project's objectives include:

- assessment of water resources availability in the Mashcon and Chonta Basins
- assessment of water quality throughout the basins, including point and non-point contamination and toxic and non-toxic wastes
- investigation of alternatives to water resources development to meet current and future water demands in the study regions
- development of organization and management schemes for implementing the proposed development plans

The project recently began with financing from the Japanese government and the Interamerican Development Bank (IDB). The contracting agency for the project is Nippon Koei, which has assembled a team of national and international consultants to conduct the various phases of the project. Dr. M. Paulet leads a team of consultants to develop an institutional framework to plan and manage the watersheds, and Ing. Carlos Vasconcelos leads the

The effluence of groundwater results from mining excavations at the Yanacocha Mine, partially located at the headwaters of the Mashcon and Chonta Rivers in south Cajamarca, Peru.

effort to develop alternative water resources schemes and coordinates the various aspects of the project.

The overarching premise of the project is to propose alternatives that can contribute to sustainable development in the study region and involve the local community in identifying water resources problems and proposing workable solutions that are acceptable to the community. For this purpose, workshops are being organized in which local interest groups and individuals discuss their positions, problems, and limitations; express their wishes and goals; and become involved in discussing the possible solutions.

As part of this project, Professor Jose D. Salas, the leading international consultant on surface hydrology, is involved in developing a framework for studying the surface water availability and quantifying the variability of monthly streamflows at any point along the stream networks. Salas has been modifying a seasonal precipitation-runoff model (called SEAMOD) that he and graduate students at Colorado State University (CSU) developed over the years to account for the effects of groundwater pumping and spring effluents (there are about 2,000 of them in the study area). The approach also includes regionalizing the parameters of probabilistic models on a seasonal basis so that flow estimates can be made at ungaged locations. In addition, stochastic simulation studies will be performed using the SAMS (stochastic analysis, modeling and simulation) software, also developed by Salas and CSU graduate students and colleagues at the U.S. Bureau of Reclamation, so that the streamflow uncertainty is considered in designing and testing project alternatives. Furthermore, software called MODSIM—developed by CSU professor John W. Labadie d graduate students—will be used to evaluate various project alternatives.

The Rejo Dam was constructed as part of the effort to control increasing sediment accumulation resulting from mining operations in the Mashcon Basin.

2008 National Conference in Desert Hot Springs, California

"Going Green for Groundwater"

The 2008 Groundwater Foundation National Conference and Groundwater Guardian Designation Celebration will be held at Miracle Springs Resort and Spa in Desert Hot Springs, California, **November 18-20** 2008.

The 2008 National Groundwater Foundation Conference is co-sponsored by The Groundwater Foundation and the Awwa Research Foundation. Additional support provided by United States Geological Survey and the W.K. Kellogg Foundation.

Additional details and registration information will be posted at http://www.groundwater.org/pe/conference.html

Land and Water: Quality of Life in the Peruvian Amazon

by Faith R. Sternlieb, Research Associate, Colorado Water Institute
Laura Girard, Peru Team Leader, Ayres Associates

The Peruvian Amazon

The Ucayali Department in the central-eastern lowlands of Peru is named after the Ucayali River, an upper tributary to the Amazon River that covers 3,000 meandering kilometers. The Ucayali River Basin occupies an area of 352,388 square kilometers, with tropical forest covering 55 percent of the region, according to 1998 estimates by the World Resources Institute. A rare account of the indigenous movement in the Upper Amazon Basin, titled *Dreams Coming True: An Indigenous Health Programme in the Peruvian Amazon* by Søren Hvalkof, describes the Ucayali River as largely unstable with an alluvial flood plain that fluctuates in width between 400–2,000 meters with a variation in water depth of up to 12 meters. Agriculture along the floodplains, with crops such as beans and rice, is possible during low flow or the dry season; however, annual variability of seasonal precipitation renders an undependable yield from subsistent and commercial agricultural production.

Within the Ucayali Department is the capital city of Pucallpa, and roughly 90 kilometers upstream lies the village of Santa Rosa de Dinamarca. Santa Rosa de Dinamarca is a community with an estimated 750 inhabitants, all of whom belong to the Shipibo-Conibo indigenous cultural group who primarily speak the language Shipibo, although Spanish is spoken and understood by most. There is a stark seasonal contrast in distance from the village to the river due to the large difference between high and low flows. Taking this into consideration, the village lies about 1.5 kilometers east of the river. Because access in and out of the village is only by boat or plane, it remains isolated from neighboring villages and the capital city.

Within the past couple of years, *mestizos* (a term used for Peruvians who are not a member of an officially recognized indigenous group) from the northeastern town of Masisea have been encroaching on the Shipibo-Conibos' territory, the extent of which has changed within the past quarter century. In 1975, the area granted to Santa Rosa de Dinamarca was 2,981 hectares (29.81 square km) and was enlarged in 1991 to 5,411 hectares (54.11 square km). The exploitation and mining of precious natural resources within the boundaries of their territory, including natural gas, crude oil, hardwood and freshwater fish, has environmentally and culturally taken its toll on the community's economic development capacity.

Engineers Without Borders (EWB) Fort Collins Professionals

The community of Santa Rosa de Dinamarca requested the assistance of EWB–Fort Collins Professionals in the design and construction of a water storage and distribution system. The EWB group included 10 participants from EWB Fort Collins Professionals: Laura Girard, Summer Jawson, Bob Willhour, John Von Neida, Tim Von Neida, Bryan Baker, Amy Weber, Rebecca Norton, and Aaron Orechwa. I went along as the official translator but was thankful for the assistance of the others who spoke Spanish; their collective contribution to translating was invaluable to the success of the project. The project also captured the interest of the program coordinator Colin Lacy at EWB National (also a translator), who joined the team. Finally, the Central Texas EWB chapter collaborated with Fort Collins to work on the health survey. This was the first time that two EWB chapters worked together in the same community.

Current Challenges

The village is currently using four hand pump wells for their water supply. The women of the community typically collect water from four shallow wells for their water supply. During the June 2007 and 2008 visits, tests showed these wells to be positive for coliform bacteria. According to the village council's vice president in charge of women and children's affairs, on any given day 50 percent of the children in the community have diarrhea. A second health assessment was conducted, for which we are still waiting the results in order to monitor quality of health over time.

Parents within the community are aware that lack of sanitation and clean water are a major factor in their children's health, as well as their own. Furthermore, community leaders expressed concerned that their future water source be independent from the surface water system, because several indigenous communities in the area have been severely impacted by exposure to petroleum seepage from unregulated mining activities. The goal of the June 2007 assessment trip was to test the existing water source for contaminants, to determine a future well site, and to establish a preliminary plan for implementation. The existing wells in the village were tested for coliform bacteria and all tested positive. Water samples tested for inorganic contaminants showed that, with the exception of coliform, the existing water supply meets U.S. and World Health Organization (WHO) drinking water standards.

It was determined that a future well site would be located near the schools and hospital. The June 2008 implementation trip included interim measures to improve the existing drinking water supply and gather additional information.

Another pressing issue is related to the demarcation of indigenous territory throughout the Peruvian Amazon. Resource governance continues to change dynamics of the use, conservation, development, and general management of resources that are essential to the livelihood of indigenous communities along the Ucayali River. Santa Rosa de Dinamarca requested that EWB assist with the demarcation of its titled territory. There are two competing systems of governance: (1) the national and regional institutions charged with managing natural resources, and (2) the community that is directly dependent on those resources. In addition, the Peruvian government is trying to pass laws that will encourage foreign investment, many of which are at the expense of indigenous communities whose home is now prime real estate on the global market.

Distribution System

EWB conducted a series of meetings with the village leaders and members of the community to better understand their need for a permanent clean water supply. It was, in fact, what they had wanted from the very beginning, but lack of communication during the 2007 trip made this request impossible to deliver in 2008. In 2009, EWB will look into partnering with Living Water to build a new well that penetrates the many layers of clay substrate to the aquifer. In addition, they will be looking for a pump to transport the water to a tank. Discussions are in progress about the required materials and their local availability to build the tank and install the pipes once the well is completed. Finally, EWB will be looking for local solar panels that will deliver the appropriate technology for the system. Because the project involves multiple phases, completion could take up to five years. The construction of the tank will be a challenge, as it will require a team of engineers to be on site for no less than two months.

Filter System

During our visit in June 2008, EWB trained the 'Water Team'—six elected individuals—to learn about the water filtration system. The first day of workshops was geared towards learning about the different parts of the system and teaching the group about sanitation and the importance of filtering water. The second day, we started building the systems. Each member of the team received a construction and maintenance booklet in Spanish and the materials needed to build the filter systems. EWB provided enough materials for each family (150 families total) to receive one complete system. To test the group on what they learned, the system was presented to the mothers in the community. This presentation helped us determine two key variables central to the success of the water quality project: (1) whether the technology we were introducing would be accepted, and (2) how well the team had learned the information regarding the system's use, maintenance, and construction. We delivered these particular systems to the community knowing they were not a long-term solution and they were not what had been requested; however, we hoped that it would serve their purposes for clean drinking water while we worked on the distribution system.

The 'water team' demonstrates the new water filter system to mothers in the community of Santa Rosa de Dinamarca, Peruvian Amazon.

Land Surveying

The land surveying project was successful due largely to cooperation from the Ministry of Agriculture and COFOPRI (the governing arms responsible for land cadastres and geographic information systems data), who recognize the technical boundaries that have been identified by Instituto del Bien Común (a non-governmental advocacy organization for indigenous rights) and technically adjusted by EWB in 2007. Survey data were collected so the village could establish a topographic map and begin the process of demarcating their legal boundaries. In addition, during the 2008 visit, EWB scheduled a flight for the leader of the community and his two advisors in order to obtain aerial photography of the territory to better assess encroachment and illegal mining activities. The challenge will be for the community to get acceptance for the 'social' boundaries from all of the involved parties—the local, regional, and national government agencies, as well as private families. In the future, the community will need monuments at each of the territory's four corners and a signed document by the local and regional governments recognizing those monuments. The Ministry of Agriculture has asked EWB to assist with the more than 250 indigenous communities in the area who will need to demarcate their territories before they legally lose the battle of entitlement to their cultural legacy.

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DENVER WATER

Peace Corps Hosts Water and Sanitation Extension Volunteers

The Peace Corps traces its roots and mission to 1960, when then Senator John F. Kennedy challenged students at the University of Michigan to serve their country in the cause of peace by living and working in developing countries. From that inspiration grew an agency of the federal government devoted to world peace and friendship.

Since that time, more than 190,000 Peace Corps Volunteers have served in 139 host countries to work on issues ranging from AIDS education, water sanitation, and health to information technology and environmental preservation.

Today's Peace Corps is more vital than ever, working in emerging and essential areas such as information technology and business development and committing more than 1,000 new volunteers as a part of the President's Emergency Plan for AIDS Relief. Peace Corps Volunteers continue to help countless individuals who want to build a better life for themselves, their children, and their communities.

Water and Sanitation Extension volunteers serve in a broad range of health projects, including organizing and mobilizing communities to provide health and hygiene education; tapping springs, constructing wells, and building latrines; improving potable water storage facilities; and doing community outreach to heighten awareness of water and sanitation issues, health issues, and environmental issues.

If you are interested in finding out how you can volunteer after graduation, please come to the next general information meeting on Friday, October 17, from 3–5pm in Laurel Hall, located on the CSU campus Oval, or contact Tami Wolff, Peace Corps Representative, at pcorps@colostate.edu or (970) 491-7706.

Peace Corps Master's International Program

Interested in the Peace Corps and in graduate school? Why not do both? Colorado State University (CSU) and Peace Corps participate in four cooperative master's degree programs, giving students the opportunity to earn a master's degree and get hands-on experience in English, food science and human nutrition, natural resources, or agriculture.

Normally, three semesters of coursework are completed on the CSU campus before Peace Corps service begins. After Peace Corps service is completed, students return to campus for an additional semester(s) to complete a professional paper or other requirements. The program of study is designed within departmental parameters to meet student needs while taking into consideration the needs of the host country. Former CSU students have taught English in Macedonia, completed environmental work in the Philippines, and worked with allied health fields and water sanitation in Cameroon. For most participants, it is an experience of a lifetime. Please contact Karen Gardenier, Coordinator, International Education in the Office of International Programs for more information at intled@colostate.edu or (970) 491-5917.

CSU students Ben and Kelly Latham worked as water and sanitation engineers in Honduras through the Peace Corps Master's International Program.

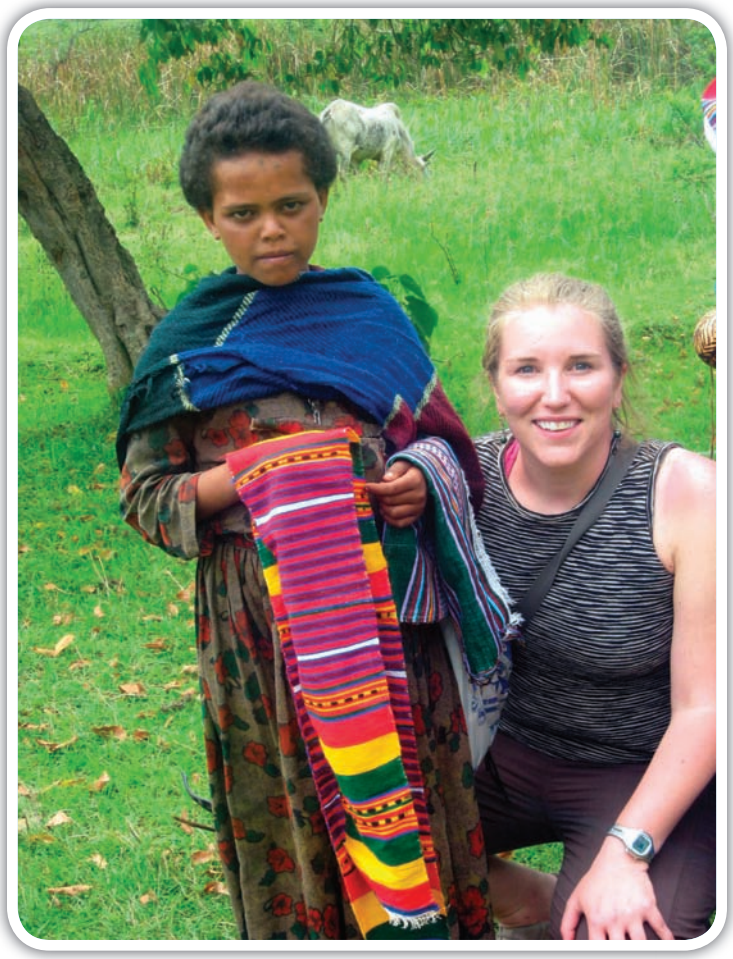
Pumping Water = *Serious Business*

by Carl Hammerdorfer, Director of Global Social and Sustainable Enterprise (GSSE), Colorado State University
Chelsea DeFoort, GSSE student, Colorado State University

Colorado State University faculty have for decades been important players in addressing global water resource issues. From irrigation systems in Egypt to water supply projects in Latin America, faculty and staff from a wide range of academic disciplines, including engineering, natural resources, and sociology, have gravitated towards what might now be called the mother of all sustainability issues: water. Conspicuously absent from the roster of CSU's "Team Water" have been the faculty and students of the College of Business (COB). At least until recently...

Last year the College of Business launched a cutting-edge effort of its own called the Global Social & Sustainable Enterprise program, or GSSE. The COB offers an MSBA degree to students who wish to apply a business/entrepreneurial approach towards solving challenging international development issues such as poverty, climate change, disease, and social inequality. The sustainability focus of GSSE students flies in the face of the old stereotype of business students as just more grist for the corporate mill, more interested in personal income than in global justice.

Chelsea DeFoort collects engine specs for a Robin Pumpset, one of the most popular pumpsets in Ethiopia.



Chelsea DeFoort meets a local entrepreneur (selling scarves) on a path in northern Ethiopia, about 30 kilometers downstream of Lake Tana near the Blue Nile River.

The GSSE's first student cohort matriculated just over a year ago and included engineers, agricultural economists, managers, returned Peace Corps volunteers, environmentalists, and entrepreneurs. The average age of these students is about 30, and the program is designed to field an annual cohort of 25 students, made up of 50 percent international students. While the students receive training in the standard business disciplines such as accounting, finance, marketing, and management, the program's applied nature sets it apart from the burgeoning herd of "sustainable" MBA programs. Students form enterprise teams that take on challenges ranging from developing a business model to bring energy-related products to isolated Andean campasinos, to preserving wildlife habitat by improving incomes of subsistence rice producers in Cambodia. The Enterprise Projects form the core upon which the entire program is built.

With water resource issues front and center in the world's efforts to close the development gaps between rich and poor, it is not surprising that one GSSE team took on the challenge of developing a commercial and technical solution to one of the major challenges facing close to a billion small farmers around the world: irrigation. From Bolivia to Botswana, from Ethiopia to Ecuador, one of the most

Chelsea DeFoort and her teammate Krupa Ventrapati conduct an interview with a farmer who uses a treadle pump to grow vegetables. The people surrounding him are his children and neighbors. Location: Arsi Negele, a region in the Central Rift Valley of Ethiopia.

promising—yet elusive—solutions to rural poverty is an improvement in the ability of small farmers to deliver water to their fields efficiently, accurately, and inexpensively.

One GSSE partner, Denver-based International Development Enterprises (IDE), has sold millions of treadle pumps in Bangladesh and India, lifting millions of families out of poverty. However, these pumps—which work much like a stair-stepper—require that a family member (often the wife and mother) operate it for 10–12 hours per day. Despite enabling a farmer to double or even triple his/her income, the efficiency of the 1/10th horsepower treadle pump leaves much to be desired.

Enter Small Engines for Economic Development (SEED), a GSSE enterprise team from the first cohort of students. SEED chose as their project the challenge of developing and selling a fuel efficient micro-diesel engine pump-set that could eventually be run on bio-fuel. The challenge presented itself when IDE approached GSSE and CSU's Engines and Energy Conversion Lab with a request to improve an old bicycle motor design, making it more efficient and applicable to small-scale irrigation. Never short on imagination and zeal, Professor Bryan Willson, the lab's director, put a senior design team of 10 mechanical engineering students on the job. While the engineers got busy designing an engine, SEED went to work to further define the need for it in developing countries. If IDE could sell millions of treadle pumps in India and Bangladesh, the team hypothesized, then surely there must be a business opportunity for their imagined small engine.

Chelsea DeFoort and her teammate Krupa Ventrapati spend a morning observing while a farmer and his two children irrigate a piece of land using furrow irrigation. Location: Just north of Ziway, Ethiopia, in the Central Rift Valley.

Four GSSE students formed the SEED team: Mitesh Gala and Krupa Ventrapati from India, Chelsea DeFoort of Fort Collins, and Angelina Pramatarova of Bulgaria. By combining their international and professional backgrounds (engineering, environmental science, finance); their firsthand knowledge of social, economic, and environmental issues facing farmers in developing countries; and their training from GSSE coursework, they hoped to have the right ingredients to build a sustainable enterprise. The bigger goal? To commercialize a technology developed by CSU engineers and develop a business model that might transform agricultural production in the developing world.

Between 600–850 million farmers in developing countries lack access to efficient irrigation technologies. From a business perspective, achieving just one percent penetration of that market would constitute a viable business that could attract investment and other support. By building

Chelsea DeFoort and her teammate Krupa Ventrapati listen to a field agent from IDE (International Development Enterprises) as he translates the local dialogue.

a sustainable business model, SEED believed that it could help bring water to the people who need it most and generate profit with which to grow the business. While the senior design team worked on the engine prototype, the GSSE team spent months researching the market and bringing an essentially alien business concept to business leaders and potential investors across the United States. Simply getting corporate America to view several hundred million farmers as potential customers rather than as objects of charity was in itself a challenge. SEED developed its business plan and entered 10 business plan competitions across the United States. Often presenting to more mainstream venture capitalists and panels, SEED placed in 8 of the 10 competitions and won over $15,000 for continued project development.

Having gained the attention and favor of a small crowd in the United States, the team prepared to meet the most important players along their entrepreneurial path—its customers. The four graduate students set out for a full summer in Bangladesh, Ethiopia, and India to test the micro-diesel concept and find out exactly what their customers needed, wanted, and could realistically afford. The SEED team split up, two of them covering Ethiopia and two covering Bangladesh, and later convened in India to compare notes and make decisions on their most viable market. Scores of meetings with farmers, extension agents, retailers, wholesalers, importers, and other key actors in the irrigation chain provided valuable firsthand information on the differing needs for efficient irrigation.

Said one student, "In Ethiopia, we focused on areas with available surface water, which is such a small portion of the country compared to Bangladesh and India. However, by combining the micro-diesel engine with other innovative water technologies such as low-cost manual drilling and the rope and washer pump (which can pull ground water from 20+ meters depth), we could significantly increase the amount of irrigated land in Ethiopia, regardless of surface water availability."

In Bangladesh and India, farmers were much more familiar with mechanized irrigation, owing to the enormous quantity of surface water that floods a majority of the two nations and supports extensive rice production. Farmers in these regions have been moving water for years using time- and labor-intensive methods, such as treadle pumps, or costly, inefficient, and dirty diesel engine pumps, many imported from China.

Despite major differences between agriculture in Bangladesh and Ethiopia, SEED has identified a significant

From left: The dean of the Business College at Addis Ababa University in Addis Ababa, Ethiopia; Carl Hammerdorfer, director of the GSSE program; Krupa Ventrapati; and Chelsea DeFoort.

demand for its micro-diesel engine. The students believe they can provide a solution for the treadle pump farmer who is barely producing enough food to give him or her the energy to work the treadle pump, and for the producer who produces crops for market yet remains poor due to rising fuel costs and efficiency losses from old diesel pump-sets.

During the summer field work, SEED identified, analyzed, and defined alternative fuel possibilities, design specifications, and distribution channels that will shape the product and project development as they move forward in their final semester of the GSSE program. Over the next three months, and with the help of the CSU Engines and Energy Conversion Lab, they hope to finalize and begin testing of a prototype of the first engine. They are also working to secure funding to continue the project after graduation as they work towards a product that is ready for commercial production.

Chelsea DeFoort and teammate Krupa Ventrapati get first-hand experience with manual well drilling, tugging on a rope with individuals from a local well drilling organization.

Agriculture remains the main source of income for over 70 percent of the population in Bangladesh, Ethiopia, and India. Moving from rain-fed to irrigated crops is one of the best ways for farmers to improve their income and rise above the poverty that drives health, social, and environmental problems. SEED's effort to create and distribute affordable and sustainable irrigation technologies for farmers faces the same odds that any entrepreneurial venture faces. But the students are driven by the grand vision that their venture could be the beginning of the end of poverty for rural Bangladesh, Ethiopia, and India.

UNESCO International Conference on Water Scarcity, Global Changes and Groundwater Management December 1–5 in Irvine, California

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- THEME II: **Improving water governance for sustainable responses to water scarcity and global change impacts on water**
- THEME III: **Ecohydrology for sustainability**
- THEME IV: **Water and life support systems**
- THEME V: **Traditional and Innovative techniques and technologies supporting the identification and remediation of water scarcity issues and global change impacts on water resources**
- THEME VI: **Information and communication, education and capacity building**

Visit http://www.waterunifies.com for more information or to register.

Irvine Declaration

Water scarcity is not always the result of a physical lack of resources, but also the result of inadequate institutional and managerial organization. For instance, according to the 2nd World Water Development Report, an estimated 26 countries, totalling more than 350 million people, with an apparent adequate availability of water, suffer from severe water scarcity because of problems in water management and governance.

One of the conference objectives is to produce a policy proposal and action plan for a concrete and practical follow-up to the conference and prepare for the 5th World Water Forum (Istanbul, Turkey, March 2009).

The Irvine Declaration identifies water resources management principles aimed at answering global change and scarcity challenges, and recognizes the role and significance of groundwater and the interdependency of surface water and groundwater resources.

CSU Team Visits Mongolia to Scope Climate and Water Resources Research

by Steven Fassnacht, Melinda Laituri, Maria E. Fernandez-Gimenez, and Robin Reid
Warner College of Natural Resources, Colorado State University

The climate of Mongolia has shown one of the strongest warming trends on Earth over the past 20 years, with the annual mean temperatures increasing 1.8 degrees Celsius between 1940 and 2003. Models predict an additional increase of 2.5 to 5 degrees Celsius. These warming trends will influence precipitation, soil moisture, and consequently, plant growth, and coupled with declining precipitation would decrease soil moisture. These rapid and significant climate changes are likely to have a considerable impact on pastoral production systems and can result in decreased access to sufficient forage and water for herder livestock. Access to these resources depends on the ability to move herds to fresh grass and water as it becomes available seasonally and interannually. Pastoralists depend almost entirely on native pasture and hay, together with natural surface water and wells, as the basis for animal production. The projected climate-induced loss of pasture productivity and observed loss of surface water sources will have significant impacts on the sustainability of rangelands and pastoral livelihoods in Mongolia.

Climate change is an important driver for water resources availability, especially in the context of rangeland resources for the Mongolian herder community. With the potential impact of climate change in mind, researchers from CSU's Warner College of Natural Resources travelled to Mongolia for a research planning visit in June 2008. This project was led by Forest, Rangeland, and Watershed Stewardship (FRWS) faculty Maria Fernandez-Gimenez. Other CSU participants included watershed science faculty Melinda Laituri and Steven Fassnacht, Center for Collaborative Conservation director Robin Reid, and graduate students Batkhishig Baival and Corrine Knapp.

CSU and Mongolian researchers stand in the Tuul River discussing streamflow.

The team met with Mongolian scientists, donor organizations and non-governmental organizations, community-based natural resource management (CBNRM) practitioners, and government policymakers. The trip included two field excursions and a planning meeting. The main objectives of the trip were to (1) experience Mongolian rangelands, herder and CBNRM activities, and related water resources issues through two field excursions, and (2) develop a collaborative, interdisciplinary research proposal. The overall goals of the proposed work are to:

- advance the theory and practice of CBNRM through interdisciplinary, applied research
- build the capacity of young Mongolian and U.S. scientists to conduct well designed applied interdisciplinary research
- strengthen linkages between natural resource science and policy in Mongolia

The first field excursion was a trip to Hustai National Park and Ondershereet Sum (County) in Tuv Aimag (Province). Both venues are near or along the Tuul River; rivers such as the Tuul are a crucial resource for herders. In the summer, herders depend on the river to meet their livestock's needs, and the vegetation in adjacent riparian areas provides important summer forage. During the trip, participants examined the impact of livestock movement within the riparian corridor and accessing of stream water (see photo). In the winter, herders rely on springs and wells in the foothills, but in recent years these groundwater sources have been disappearing. A component of this project is to determine the cause(s) of lower water tables, whether anthropogenic and/or climate change induced.

The second excursion was a day trip to Bayangol Sum in Selenge Aimag. Local herder group leaders stated that they have observed climate-based changes such as the drying of intermittent streams, the disappearance of winter snows in some areas, and the decrease of snow in forested areas. The herders attribute the stream drying to the snowpack decline. However, the influence of the decreased water

resources on herder activities and the resilience of the rangelands are unknown.

To develop the proposal, the group held an interdisciplinary collaborative research planning meeting entitled "Does Community-based Rangeland Ecosystem Management Increase Resilience of Rural Communities to Climate Change in Mongolia?" The meeting was held from June 16 through 20, 2008, at the Kempinski Khan Palace Hotel in Ulaanbaatar, Mongolia. Participants came from a wide spectrum of backgrounds and professions, including herders, community leaders, Mongolian university and government scientists, international scientists and donors, and policymakers. Research specialties included social, ecological, and physical sciences. The interaction between the various participants provided the integration of different perspectives to yield broad scale ideas. Through simultaneous translation during the meeting or consecutive translation facilitated by bilingual scientists during small group discussion, the people on the ground (i.e., herders and community leaders) were able to communicate about important issues and the changes that they have observed. These issues and changes were melded with researchers' specialties to develop the basis for research focusing on whether community-based rangeland ecosystem management increases resilience of rural communities to climate change in Mongolia.

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Colorado River District Annual Seminar

by Laurie Schmidt, Colorado Water Institute

The Colorado River District Annual Water Seminar was held on September 19, 2008, at the Two Rivers Convention Center in Grand Junction, Colorado. More than 200 water resources managers and practitioners and elected officials attended the seminar, and the meeting was structured to accommodate questions following each discussion. "This workshop is intended to be a dialogue," said Chris Treese, manager of external affairs at the Colorado River District as he welcomed attendees.

With the title, *What Would an Intra-State Colorado River Compact Look Like and How Would it Work?*, the meeting opened with a panel that included Greg Hobbs, Colorado Supreme Court Justice; David Robbins, Esq., Hill & Robbins, P.C.; Eric Kuhn, general manager of the Colorado River District; and Colorado State Senator Josh Penry (R-Grand Junction). Hobbs explained the responsibility of the river districts and the Colorado Water Conservation Board, as related to the Colorado River Compact entitlements, saying "We can only legally consume one-third of the water that comes through our state; two-thirds must go downstream according to the interstate compact." Asserting that storage water must get us through times when nature doesn't give us what we need, he posed the questions: "What do we have to develop? And can we afford to develop it?"

Addressing the idea of an intra-state compact, David Robbins drove home the point that in order to have an enforceable document, the legislature will need to play a strong role—any other agreement will only bind the entities that are signatory to the agreement. Senator Penry, who sponsored the legislation establishing roundtables and the Interbasin Compact Committee (IBCC), focused on the

Steve Boand, Douglas County, and Laurie DePaolo, Colorado River District, enjoy the afternoon break.

Mark Pifher (left) and Eric Wilkinson participate in a panel titled "Front Range Vision for a Water Supply."

idea that "Mother Nature" is in charge. "In spite of all the advances we've made in developing water, Mother Nature still claims the senior water right," he said. Kuhn concluded the panel session by discussing risk, uncertainty, and the value of public consensus on a development project.

The second panel session, titled *Limiting the Risk of a Compact Call with Water Bank*, focused on the topics of a potential compact "call" and the idea of water banking. Panel members were Bruce Whitehead, general manager of the Southwestern Water Conservation District; Peter Fleming, Esq., general counsel for the Colorado River District; and Steve Harris, Southwestern Water Conservation District.

The lunchtime keynote speaker was Larry Walkoviak, Upper Colorado Regional Director for the U.S. Bureau of Reclamation, after which the afternoon session began with a panel discussion titled *Front Range Vision for a Water Supply Future*. The presenters were Eric Wilkinson, general manager of Northern Water, and Mark Pifher, director of Aurora Water. Wilkinson discussed the importance of mutually beneficial solutions, saying "Decisions made in any basin affect all the other basins."

Melissa Elliott, manager of water conservation at Denver Water, provided an overview of Denver Water's successful campaign to encourage wise water use, "Use Only What You Need." She talked about the importance of educating water customers so that they understand where the water they use comes from: outside their basin. Denver Water's goal is reduce per capita daily water consumption by 22 percent by 2016. "Our goal is to make water waste socially unacceptable," Elliott said.

The meeting concluded with an energy-water supply study update by Dan Birch, Deputy General Manager of the Colorado River District, who discussed the potential implications of future oil shale mining, saying that power requirements associated with shale would place an enormous demand on water.

ICWEHS - Call for Papers

International Conference on Water, Environment and Health Sciences: The Challenges of the Climate Changes
April 13-17, 2009 at Universidad de las Americas, Puebla Cholula, Puebla, Mexico

OBJECTIVE OF ICWEHS

ICWEHS will provide a forum for the interdisciplinary exchange of issues, views, experiences, and needs for research in the areas of water, environment, and health sciences under the influence of climate change.

TECHNICAL PROGRAM HIGHLIGHTS

Suggested conference paper or poster and session categories, trade-offs are not only accepted but encouraged:

Water
-Precipitation
-Potential Evaporation
-Groundwater
-Surface Water
-Interaction between Surface and Ground Water

Environment
-Water and Wastewater Treatment
-Pesticides
-Remediation
-Hazardous Waste
-Heavy Metals

Health Sciences
-Epidemiology
-Toxicology
-Exposure Assessment
-Risk Assessment and Communication

Education

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GUIDELINES FOR ABSTRACT SUBMISSION

Abstracts should be sent to the following e-mail addresses:
icwehs@yahoo.com
icwehs@hotmail.com
The abstracts should be in English and no longer that 500 words. Deadlines will be strictly adhered to and authors whose abstracts are accepted for oral or poster presentations and who submit a final paper are expected to attend the Conference, pay the conference registration fees, and make their presentation in person. For questions, contact the Technical Program Chair. The Proceedings will be published on CD.

IMPORTANT DATES

Abstracts Due: Friday September 5, 2008
Authors Notified: Friday November 14, 2008
Final Papers Due: Friday January 30, 2009

THE VENUE

The ancient and beautiful town of Cholula, Mexico, where the Universidad de las Americas, Puebla is located, has been chosen as the site of the celebration of the ICWEHS. The city of Puebla, just three miles away from Cholula, is the 4th largest city in Mexico. The international airport of Puebla is served by an international flight connecting with Houston. Mexico City, Mexico´s capitol city, is just 1.5 hours away by bus. Mexico City's airport has flights connecting to many cities of the world.

Registration is $500* before February 13, 2009 and $600* after February 13, 2009 (* price in U.S. Dollars)
For more information email the ICWEHS Organizing Committee: icwehs@yahoo.com or icwehs@hotmail.com

Afghanistan Water, Agriculture, and Technology Transfer (AWATT)

by Ajay K Jha and James Pritchett, Department of Agricultural and Resource Economics, Colorado State University

Ajay Jha, Colorado State University; Roger Beck, New Mexico State University; and Dr. Qayyum, AWATT Chief of Party visit Khurram and Khoja Irrigation Canals in Kapisa Province, Afghanistan.

Afghanistan's agricultural production and farm productivity are at critically low levels, resulting from three decades of conflict, ineffectual definition of land and water rights, and a harsh environment characterized by persistent drought. Food security is a pressing issue for most Afghans, especially the 75 percent of the population living in rural areas.

Clearly, agricultural production, food security, and rural prosperity are inextricably woven with water resource management in a semi-arid region like Afghanistan. The country suffers from water shortages due to limited fresh water resources, inefficient use of aquifers and river basins, and mounting human needs. Also, water planning and regulation is missing at all levels, including for household usage, and an agricultural and industrial sector makes it difficult to improve efficient water management systems in Afghanistan.

A multidisciplinary team at Colorado State University (CSU) is using its water resource knowledge to stabilize rural Afghan agriculture and encourage economic development. The team is part of a larger consortium receiving a $20 million grant from the United States Aid for International Development (USAID). The consortium's overarching objectives fall under the heading of Afghanistan Water, Agriculture and Technology Transfer (AWATT).

The AWATT consortium is a collaborative effort involving New Mexico State University (NMSU), CSU, University of Illinois at Urbana Champaign (UIUC), Southern Illinois University-Carbondale (SIUC), the four Afghanistan universities (Balkh University, Nangarhar University, Herat University, and Kabul University) and Afghanistan's Ministry of Agriculture, Irrigation and Livestock (MAIL). The AWATT project is designed to:

- identify feasible, sustainable natural resource-based technologies that improve water management and increase agriculture production
- identify water and land use policies and institutional frameworks that encourage individuals and local and provincial governments to increase sustainable economic development from the agriculture and natural resource sectors
- improve the capabilities of the professional staffs of Afghanistan's ministries and universities by partnering with them on research-based decision making and outreach projects to benefit the people and economy of their country

The Panjshir River flows through Kapisa Province in Afghanistan.

In July 2008, three members of the CSU team (Ajay Jha, Steve Davies, and Ramchand Oad) travelled to Afghanistan for initial assessment of the agricultural sector and irrigation infrastructure. During that visit, they met with important stakeholders, including MAIL officials, USAID Afghanistan, and other international agencies such as ICARDA, the World Bank, and the Asian Development Bank. Travelling mostly in northern Afghanistan, the group found potential water resources to be bountiful; however, deteriorating physical infrastructure, ineffective water resource management resulting in inequitable distribution among water users, and inefficient water use on farms were endemic. The most significant constraint, in terms of irrigation water availability, is the deterioration of the water capture and conveyance facilities during the last 30–40 years.

Rehabilitation projects are being financed by the World Bank and the Asian Development Bank, but this investment will prove insufficient if the human capacity for integrated water resource management (IWRM) is not developed. At present, there is no effective measurement of water as it is diverted from a river, conveyed through canal networks, and distributed among users. Upstream water users may well be applying unnecessary large water quantities to their land, while downstream neighbors suffer acute water shortages. Installing gauging stations at key control points in irrigation systems and using the information to better organize and manage water distribution can be a very significant contribution of the AWATT project. The AWATT project will address the "management" side of the water problem, especially in irrigation systems that have been already rehabilitated or are currently under rehabilitation. Moreover, the CSU team will work with Afghan officials and professionals to increase the capacity of Afghan institutions when providing training in integrated water resource management (IWRM).

Technology transfer and demonstration of IWRM principles is central to CSU's objectives in the AWATT project. Afghanistan currently lacks sufficient infrastructure for demonstrating and teaching IWRM principles in universities and extending this knowledge to rural communities. CSU's assistance will begin with the training of key Afghan stakeholders in developing demonstration and outreach activities. Irrigation water measurement, water conveyance, and irrigation technology demonstrations will be combined with curriculum modules to build human capacity among Afghan government officials and agricultural specialists. Curriculum modules are likely to include the principles of IWRM, efficient irrigation systems, water-saving crop rotations, alternative cropping systems, conservation tillage systems, farm record keeping, and management. Most of the training program will be customized based on regional needs, available resources, and agro climatic condition for suitability of specific crops. Moreover, courses in water policy evaluation and economic assessment of various potential improvements to the agricultural sector will be critical to enhancing decision making in Afghanistan.

A guiding principle of demonstration farms is local participatory management. Each demonstration site plan and management process will be reviewed by an advisory committee consisting of local farmers, ministry officials, university educators, an in-country AWATT team member, and other stakeholders. Advisory committees will provide insights into the technology and practices that need to be demonstrated, given local farming challenges and opportunities. Local input will ensure that the demonstrated practices will have local impacts and will increase the participation of Afghan farmers. A key priority for the assembled advisory committee includes adaptive rather than basic research, farmer participation in setting priorities, implementation, and evaluation of demonstration programs.

For more information about the AWATT program, contact Ajay K Jha by email at ajayjha@colostate.edu, or by phone at 970-491-0923. The CSU team members include Ajay K Jha, Steve Davies, and James Pritchett, Department of Agricultural and Resource Economics; and Ramchand Oad, Department of Civil Engineering; Colorado State University.

A New Regional Method for Ecological Flow Requirements

by Thomas Wilding, Ph.D. student, Department of Biology, Colorado State University
N. LeRoy Poff, Professor; Department of Biology, Colorado State University

Introduction

The health and welfare of our society depends in no small measure on access to fresh water for municipal, agricultural, and industrial use. We have successfully modified the natural hydrologic cycle to our benefit on a global scale, but with increasing population growth and greater ability to manage the water cycle, we are compromising the self-sustainability of natural ecosystems. Our future welfare depends, in part, on maintaining healthy aquatic and riparian ecosystems. These ecosystems provide numerous goods and services and also support our planet's biodiversity. On a global scale, there is a freshwater biodiversity crisis. River scientists worldwide are concerned about the irreplaceable loss of unique ecosystems and the eventual economic costs of overexploitation of water resources.

Research in the last decade or so has clearly demonstrated that rivers need to be managed with some semblance of a naturally-variable flow regime, if long-term ecosystem health is the goal. In 2007, more than 800 delegates from 57 countries agreed on a formal pronouncement—The Brisbane Declaration. Specifically, the Declaration calls on water managers, governments, non-government organizations (NGOs), and others to:

- actively engage all stakeholders in environmental flow management
- formulate environmental flow standards
- establish legislative, regulatory, and institutional policies and frameworks to enable effective quantification, implementation, and enforcement of environmental flows

The integration of ecosystem requirements into water management is hampered by the difficulty, cost, and time required for scientific investigations. Detailed assessments of ecosystem response are only carried out for a small minority of water projects (e.g., large hydroelectric dams). It is simply not possible to carry out detailed studies across more than a fraction of the landscape. Simple and defensible methods are needed to improve our understanding of the state of water resources and ecosystem response.

To meet this need, scientists from Colorado State University (CSU) and around the world have come up with a new approach to setting regional flow standards, even on rivers that lack adequate hydrological and biological data. The Ecological Limits of Hydrologic Alteration (ELOHA) is a new framework that represents a consensus view from a group of international scientists for developing and implementing environmental flow standards at the regional scale (Poff et al., In Press). This consensus reflects the experience and knowledge of environmental flows gained through both scientific research and practical applications from many places around the word, including Australia, South Africa, Europe, and North America. The goal is to present a logical approach that flexibly allows scientists, water resource managers, and other stakeholders to analyze and synthesize available scientific information into coherent, ecologically based, and socially acceptable goals and standards for management of environmental flows. This requires collaboration at both an interdisciplinary and interagency level. Scientists from universities, federal agencies, and NGOs are working together, representing the fields of hydrology, geomorphology, and aquatic and riparian ecology.

ELOHA is stimulating collaborative research at a global scale, with efforts to apply the method in the United

An irrigation system uses water from the Colorado River near Moab, Utah.

CSU student Thomas Wilding observes the hydrology and ecosystem of the 10,000 Islands in the Florida Everglades.

States, Australia, China, South Africa, and Europe. Several jurisdictions within the United States are already applying elements of the ELOHA framework to accelerate the integration of environmental flows into regional planning and resource management. The Colorado Water Conservation Board is trialing the ELOHA approach to assist the Interbasin Compact Roundtables with their Non-Consumptive Needs Assessments.

The Scientific Process for ELOHA

Central to the ELOHA framework is the concurrent development of both scientific and social processes. The scientific process involves several steps. To understand ecosystem response to flow at a regional scale, we must first determine the hydrology of the region. A regional database is constructed, representing both baseline (pre-development) and developed flow conditions for river segments. These segments are classified into stream types that have similar flow regimes, with geomorphic variation sometimes necessitating further subdivisions of stream types (e.g., meandering rivers, canyons). Hydrologic alteration is calculated to describe the deviation of present-day flow from the baseline condition. Relationships between flow alteration and ecological response can be developed using existing datasets for each river type (Figure 1). Sustaining a valued trout fishery, for example, may necessitate specific goals for clean spawning gravels and invertebrates as the food source. The more research and monitoring data that are available for an area, the less the method depends on extrapolation from outside areas or informed opinion.

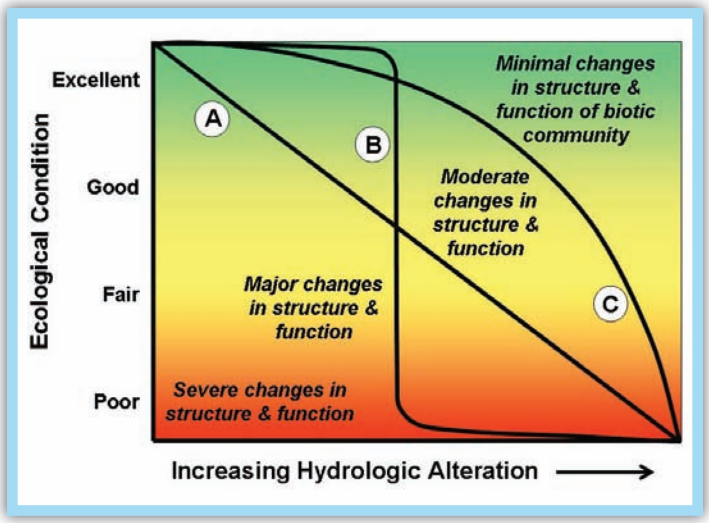

Figure 1. This chart illustrates three of several possible forms of flow alteration-ecological response relationships: linear (A), threshold (B), and curvilinear (C). The form of the curve depends on the specific ecological and hydrological variables analyzed. (TNC 2008)

The Social Process

The goal of ELOHA is not to maintain or restore pristine conditions in all rivers; rather, it is to understand the tradeoffs between our use of water and ecological change. The acceptable level of ecological change will ultimately be determined by community aspirations for natural areas and our willingness to compromise existing and future water use. Stakeholders might decide that some rivers should be protected from development, but other rivers will be managed for fair, rather than excellent, ecological condition. This approach lends flexibility to regional water development. Having established an acceptable level of change, we can produce a flow target for each stream type using the relationship between flow and the environmental attributes. Environmental flow targets can be incorporated into the broader water planning process, for example, by ranking streams most in need of restoration or more detailed investigation. Integrating the environmental flow targets into a spatial hydrologic database will provide an excellent tool for the presentation and distribution of this information.

Monitoring and Refinement

Flow decisions need to be made now because water development is happening now. An inseparable part of resource management, therefore, is ongoing monitoring of ecosystem response for the refinement of flow targets. But ecological response is often slow and difficult to isolate from responses to other changes in land use. In providing quick and simple guidance for flow management, mistakes will be made, and monitoring is no silver bullet to this problem.

Summary

ELOHA offers a robust framework for assessing environmental flows at a regional scale. It can be used anywhere in the world, across a spectrum of social and political contexts. We can apply the method to various causes of flow alteration, from modified land use, surface- and ground-water diversions, to river regulation by dams. The flexible design allows a range of data sources to be used. It is not a replacement for detailed site-specific studies, but is instead complementary: drawing on the results of previous intensive studies and prioritizing subsequent investigations.

Achieving the right balance between ecosystem conservation and water resources development represents a tremendous societal challenge. Moving the dialogue forward on freshwater sustainability will require leadership from the technical experts engaged in water development. Scientists, engineers, economists, and water planners are all necessary participants in collaborations to balance the needs of future water development with ecosystem sustainability at both local and global scales.

Further Reading

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The Nature Conservancy. 2008. Ecological Limits of Hydrologic Alteration Environmental Flows for Regional Water Management. Fact sheet URL: www.nature.org/initiatives/freshwater/files/eloha_final_single_page_low_res.pdf.

Upper Yampa Water Conservancy District Scholarship Awarded to CSU Student

The Upper Yampa Water Conservancy District (UYWCD) funds an annual scholarship in support of CSU students preparing for careers in water-related fields. The scholarship program is administered by the CSU Water Center and provides financial assistance to committed and talented students who are pursuing water-related careers at CSU. The UYWCD $3,000 scholarship is open to any major at CSU. Criteria require the recipient to be a full-time student enrolled at CSU with a minimum GPA of 3.0. Financial need may be considered, and preference is given to students from western Colorado. The scholarship duration is one year.

The Upper Yampa Water Conservancy District Scholarship recipient for the 2008–09 academic year is Kyle Eitel. A senior majoring in civil engineering at CSU, Kyle was born and raised in Craig, Colorado. During the summers of 2007 and 2008, he participated in an internship at Colowyo Mine in Meeker, Colorado, where he gained valuable experience with GPS and SurvCAD and assisted with project management. His coursework at CSU has stimulated his interest in water-related engineering topics, and he hopes to further his studies and pursue a career in fluid mechanics, hydraulics, and water resources management and securities. Kyle has been a member of the American Society of Civil Engineers (ASCE) Chi Epsilon,

the civil engineering honors society, and the National Honor Society. On a personal level, he enjoys the outdoors, particularly activities and recreation involving water.

The CSU Water Center and Colorado Water Institute congratulate Kyle and wish him success in his future academic studies and career. The ongoing support of CSU students by the UYWCD is acknowledged and greatly appreciated.

GRAD592
Interdisciplinary Water Resources Seminar

Fall 2008 Theme: Global Water Issues and Challenges
Mondays at 4:00 PM, Clark A 206

The purpose of the 2008 Interdisciplinary Water Resources Seminar (GRAD592), through a series of invited speakers, is to examine the state of global water resources and the institutional responses to water shortage, water quality concerns, drought, and climate change. More specifically, the seminar will:

- Examine water resource case studies from a variety of nations and perspectives
- Understand the global environmental challenges of water management and development
- Discuss various approaches employed by governmental and non-governmental organizations to manage water supply and sanitation challenges
- Explore various opportunities to work and serve in international water management

25 Aug.	No class
1 Sept.	*Labor Day*—No class
8 Sept.	**The Looming Global Water Crisis**—Ellen Wohl, CSU
15 Sept.	**Integrated Water Resources Management in South America**—Neil Grigg, CSU
22 Sept.	**Global Change, Global Water and Responses to Stress and Scarcity**—Evan Vlachos, CSU
29 Sept.	**Water Organizations and the Developing World**—David Freeman, CSU
6 Oct.	**Water for People**—Colleen Stiles, Executive Director
13 Oct.	**Irrigation Water Management and Agriculture**—Terry Podmore, CSU
20 Oct.	**Engineers Without Borders/CSU Global Impact Program**—Brian Bledsoe, CSU
27 Oct.	**Transboundary Water Management on the U.S.-Mexico Border**—Stephen Mumme, CSU
3 Nov.	**Water Quality in a Changing Environment**—KJ Reddy, University of Wyoming
10 Nov.	**Water Development in the Peace Corps**—Ben and Kelly Latham, CSU
17 Nov.	**River Basin Decision Support Systems: The Nile**—Larry Brazil, Riverside Technology
24 Nov.	*Thanksgiving Break*— No class
1 Dec.	**Global Change and Global Water**—Scott Denning, CSU
8 Dec.	**Service/Career Opportunities in International Water**—Peter McCornick, Duke Univ
15 Dec.	*Finals Week*— No class

Presentations will be posted online each week if available.
http://www.cwi.colostate.edu/grad592.asp

All interested faculty, students, and off-campus water professionals are encouraged to attend.
For more information, contact Reagan Waskom at reagan.waskom@colostate.edu or visit the CWI web site

Learning to Do Good

by Mark Schlink, Graduate Student Adviser to Engineers Without Borders and Global Impact, Colorado State University

Mornings in El Chile, El Salvador, used to be difficult for the women of the community. First thing in the morning, they would walk down a steep hill with an empty six-gallon cantaro to fill with water, haul the 55 pounds of water back up the hill, and repeat the process until they had enough water for the day. This back-breaking, monotonous work has been made much easier through the work of Colorado State University's Engineers Without Borders chapter (CSU EWB). With financial support from the Fort Collins Rotary Club, the CSU EWB-ers designed a water distribution system for the villages and then worked with community members to install the system.

El Chile is perched on the slopes of the San Vincente Volcano; its water source is a spring located downhill from the village. The CSU EWB team began work in the area by designing a system to pump the water up the hill and above the village, where it is stored in a cistern that also collects rainwater. In the middle of town, the team also designed a tap system. EWB emphasizes community involvement, and in this case community members contributed a great deal of the labor. This "sweat equity" ensures that the community has ownership of the system. But completion of the initial project does not mean EWB's involvement is over. According to one team member, Christine Sednek, EWB will remain in contact with the community and will conduct post-assessment trips with CSU or with University of El Salvador students to continue improvements and keep the systems maintained. The system will improve the villagers' standard of living for years to come.

In addition to the work in El Chile, another EWB team has been working on a water project in San Antonio Abad, and a third team has recently been formed to work on a project in Los Colinas. San Antonio Abad is a small village of 700 people located near the Guatemalan border. Community members get their water from a limited number of privately held wells or at a gas station located two kilometers from town. The wells tend to dry up during the dry months (October to March), and even when there is water, it is often highly contaminated from nearby latrines. The EWB team designed a system that will provide clean, chlorinated, and reliably distributed water to the town center that can be expanded to all the homes in the village one day. A new well was drilled in January, and the community helped install the infrastructure. While there were technical

The CSU Engineers Without Borders team worked on water source projects in El Salvador.

challenges, the cultural challenges faced by the team members were often greater. Eric Golike, president of EWB, recounted:

I had the opportunity to travel with the San Antonio Abad implementation trip in January 2008. While I expected the most challenging work to be the actual pump, tank, and chlorination installation, the biggest challenge was adapting to working in a completely different culture and training community members to set up responsible management of the project. I had a lot of expectations, but I learned quickly that cross-cultural development work is never what you expect. The language barriers were easily overcome through our Peace Corp interpreters, but the different expectations took effort to work through. Our first challenge occurred when we arrived in San Antonio Abad; the pump house that was supposed to be built two weeks earlier was still just a foundation. We learned that there is much less priority on timeliness and deadlines in El Salvador. To deal with that we had to accept their way of working and change our day-to-day plans. We also had a challenge interacting with the local governing board to establish rules and operating procedures for the new village water. The first problem was a trust issue—the villagers didn't want to go through training or take responsibility until they actually saw water coming from the ground. After we showed them that our system worked, we still had to have intensive meetings to plan with the community how to best manage their water resource.... something very new to them. In the end, I believe that all of the work going into adapting and understanding each other made possible this positive impact on their lives. It was not just something we planned and implemented, but something both our team and the community cooperated together on to improve life in the village.

EWB will continue to work with the community of San Antonio Abad. Project leader Ryan Jensen explained:

We have plans to expand the limited system that we have already installed. Right now, we're waiting for some community feedback on a small-scale expansion we tentatively plan to install over winter break. After that, we will complete the final technical design and cost estimate for a community-wide system that will deliver water to every household. This document can be used to solicit assistance from the local government and various other potential sources of funding. Additionally, we're looking into other problems, such as erosion control and grey water disposal, which are serious issues for the community.

Today, the villages of San Antonio Abad and El Chile have access to water and are grateful for the assistance from CSU EWB. More importantly, they take pride in the new systems they worked so hard to build and in ownership from their "sweat equity."

This year, EWB will enter a new community in El Salvador. Los Colinas is located near Santa Domingo, and while the latter has a good water distribution system, the former does not. The EWB team will make a site assessment trip in January to design a system that will tie Los Colinas into Santa Domingo's water system.

Engineers Without Borders has always welcomed non-engineers, and although many of the students who have been working in El Salvador are not engineers, the projects have always been engineering oriented. CSU Global Impact is a new organization that seeks to provide experiential learning and service opportunities in the developing world that transcend traditional disciplinary boundaries. EWB and Global Impact are working together to increase the scope of current EWB projects in terms of simultaneously considering water, energy, and health in their social context.

Individuals interested in CSU's Chapter of Engineers Without Borders or CSU Global Impact should contact Mark Schlink at mschlink@colostate.edu.

The CSU Engineers Without Borders team emphasized community involvement when constructing water resource structures in El Salvador.

Faculty Profile

Domenico Baú, Assistant Professor, Department of Civil and Environmental Engineering

I joined Colorado State University's Department of Civil and Environmental Engineering as an assistant professor in fall 2007. I originally hail from Padova, Italy, which is located on the Bacchiglione River about 40 kilometers west of Venice. I am the youngest of eight children—coming after seven sisters, which made my dad and me quite an underrepresented minority in the household. Like many other kids in my country, I grew up playing soccer in local leagues, and until I went to college that was pretty much all I cared about. Not being skilled enough to make a living from it, I decided I would become an engineer. I received my degree, called Laurea in Italy, in civil engineering in the School of Engineering at the University of Padova.

Following my graduation, I started working as a research scientist in the Department of Mathematical Models and Methods for Applied Sciences of the University of Padova. There, I was involved in projects that assessed the land subsidence caused by fluid extraction from gas reservoirs and groundwater-aquifer systems in the Upper Adriatic sedimentary basin. In the region, intensive groundwater withdrawals, which occurred in the decades following World War II to support a booming industry, produced a settlement of the land surface that, for example, in the city of Ravenna was on the order of tens of centimeters. In addition, the development of several in-shore and off-shore gas reservoirs discovered beginning in the early 1950s enhanced land subsidence, particularly in the areas overlying the gas-bearing formations.

Land subsidence raises great concern in northeastern Italy. Since the average ground elevation along the coastline is just a few feet above mean sea level, land subsidence has greatly enhanced the intrusion of seawater inland and exposed the shore to a high risk of flooding during high tides and severe storm events.

My work at the University of Padova strengthened my interest in the impact of anthropogenic activities on the environment. I also became fascinated by the challenges that come into play when scientists and engineers interact with stakeholders in the environmental decision-making process. This prompted me to move to the United States and enter the PhD program in environmental engineering at the Michigan Technological University (MTU) in 2001, which I completed in 2006.

At MTU, my doctoral research focused on the development of decision-making frameworks for the optimal design and management of groundwater remediation systems under

conditions of parameter uncertainty. This research required the development and implementation of stochastic numerical models to simulate the flow and transport of pollutants in the subsurface and their combination with optimization algorithms to identify best cleanup alternatives in terms of both cost and contaminant removal efficiency.

Over the years, I have co-authored about 25 papers published in refereed scientific journals and proceedings of international conferences, and I have contributed to several technical reports.

My current research interests cover the topics of environmental subsurface hydrology, with a focus on the use of simulation models to assist the sustainable management of groundwater systems under scarcity of data for site characterization. I am particularly interested in groundwater supply systems and groundwater remediation system. I recently started a new project funded by the Colorado Agricultural Experiment Station related to the quantitative study of the hydrologic linkages between surface water and groundwater resources in the lower Arkansas River Basin in southeastern Colorado. This study will rely on the development of a fully coupled groundwater/surface water flow model, which will be included in a data assimilation framework to identify the hydrogeological and watershed parameters characterizing the investigated basin, thus advancing a structure best suited to represent flow pathways and transport of solutes.

Teaching is another focal point of my activity. I love teaching because it enables me to interact and share my knowledge with students, helping them through the process of analyzing, assimilating, and elaborating scientific

concepts with the ultimate goal of contributing to diffuse technical and scientific skills. So far, I have taught classes in groundwater engineering and groundwater hydrology, and in the spring semester I will also be teaching a new course on the conjunctive use of surface and groundwater resources. The rationale behind this new course is the recognition that groundwater and surface water are most often intimately connected systems and basic understanding of their connection is necessary for an informed management of water resources.

The innovative research projects conducted by CSU's civil and environmental engineering faculty were an important factor in my decision to join Colorado State University. I believe this is an ideal environment to do research and grow professionally as a scientist, and personally as an educator. Last but not least, Colorado's outdoors and landscapes, which are among the most gorgeous I have ever seen, influenced my decision to live here. Having grown up at the foot of the Italian Alps, I enjoy skiing and hiking, and when I am in the Rockies I feel like I'm at home.

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USGS science for a changing world — Recent Publications

Analytical Results for Municipal Biosolids Samples from a Monitoring Program Near Dear Trail, Colorado (USA), 1999 through 2006 by J.G. Crock, D.B. Smith, T.J.B. Yager, Z.A. Brown, and M.G. Adams http://pubs.usgs.gov/of/2008/1172/

Concentrations and Loads of Selenium in Selected Tributaries to the Colorado River in the Grand Valley, Western Colorado, 2004-2006 by K.J. Leib http://pubs.usgs.gov/sir/2008/5036/

Net Acid Production, Acid Neutralizing Capacity, and Associated Mineralogical and Geochemical Characteristics of Animas River Watershed Igneous Rocks Near Silverton, Colorado by D.B. Yager, L. Choate, and M.R. Staton http://pubs.usgs.gov/sir//2008/5063/

The Yampa Bed — A Regionally Extensive Tonstein in the Williams Fork Formation, Northwestern Piceance Creek and Southern Sand Wash Basins, Colorado by M.E. Brownfield, and E.A. Johnson http://pubs.usgs.gov/sir/2008/5033/

Temporal and Spatial Variations in Precipitation, Streamflow, Suspended-Sediment Loads and Yields, and Land-Condition Trend Analysis at the U.S. Army Pinon Canyon Maneuver Site, Las Animas County, Colorado 1983 through 2007 by M.R. Stevens, J. Dupree, and M.J. Kuzmiak http://pubs.usgs.gov/sir/2008/5111/

Estimated Probability of Post-Wildfire Debris-Flow Occurrence and Estimated Volume of Debris Flows from a Pre-Fire Analysis in the Three Lakes Watershed, Grand County, Colorado by M.R. Stevens, C.R. Bossong, D.W. Litke, R.J. Viger, M.G. Rupert, and S.J. Char http://pubs.usgs.gov/sim/3009/

Estimated Withdrawals from Stream-Valley Aquifers and Refined Estimated Withdrawals from Selected Aquifers in the United State, 2000 by B.P. Sargent, M.A. Maupin, and S.R. Hinkle http://pubs.usgs.gov/sir/2008/5003/

Geologic Map of the Eaton Reservoir Quadrangle, Larimer County, Colorado and Albany County, Wyoming by J.B. Workman http://pubs.usgs.gov/sim/3029/

Ground-Water Availability in the United States by T.E. Reilly, K.F. Dennehy, W.M. Alley, and W.L. Cunningham http://pubs.usgs.gov/circ/1323/

Preliminary Geologic Map of the Culebra Peak Area, Sangre de Cristo Mountains, Las Animas and Costilla Counties, Colorado by C.J. Fridrich, and R.M. Kirkham http://pubs.usgs.gov/of/2007/1428/

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

Research Awards

Awards for June 10, 2008 to August 14, 2008

Ballweber, Jeffery A, Mississippi State University, Southeast Regional-Small Public Water Systems Technical Assistance Center: Strategic Planning, $73,926

Bauder, Troy A, Colorado Department of Agriculture, Training and Education for Agricultural Chemicals and Groundwater Protection, $185,000

Bestgen, Kevin R, Colorado Division of Wildlife, Eastern Plains Native Fish Investigations, $60,000

Bestgen, Kevin R, DOI-Bureau of Reclamation, Effects of Flaming Gorge Dam Releases on Lodore/ Whirlpool Canyon Fish Community, $62,111

Brozka, Robert J, USDA-USFS-Rocky Mtn. Research Station - CO, Watershed Management for Natural Resource Protection & Training Land Enhancement at Fort McCoy, WI, $108,119

Byrne, Patrick F, USDA-CSREES-Coop State Research Edu & Ext, Enhancing Education and Research Capacity in Plant Breeding for Drought Tolerance, $454,932

Cabot, Perry, USDA-CSREES, Improving Canola Adaptation using Deficit Irrigation and Cropping Management in the Southern High Plains, $21,215

Cabot, Perry, CSU Extension, Strategies for Rotational and Permanent Fallowing of Previously Irrigated Cropland Under Groundwater Pumping Restrictions in the San Luis Valley, $5,000

Cabot, Perry, Lower Arkansas Valley Water Conservancy District, Winter Canola Variety Trials for Biodiesel Production in the Lower Arkansas Valley of Colorado, $16,057

Cooper, David Jonathan, DOI-NPS-National Park Service, Water Rights - Technical Assistance on a Diversity of Issues, $18,580

Cooper, David Jonathan, USDA-USFS-Forest Research, Winter Recreation Impacts on Wetlands, $8,000

Davies, Stephen P, New Mexico State University, Afghanistan Water, Agriculture and Technology Transfer Program (AWATT), $1,427,655

Fausch, Kurt D, Colorado Division of Wildlife, Effect of Agricultural Water Use & Drought on Groundwater that Sustains Critical Habitats for State-Listed Fish, $55,321

Fausch, Kurt D, Colorado Division of Wildlife, Plains Fish Translocation Success, $63,000

Gates, Timothy K, Colorado State Water Conservation Board, Late-Season Monitoring of Irrigation Practices Under Conventional and Improved Technologies in Colorado's Lower ..., $96,664

Johnson, Brett Michael, DOI-Bureau of Reclamation, Chemically Fingerprinting Nonnative Fishes in Reservoirs (Project No. C18/19), $33,642

Johnson, James Bradley, Colorado Department of Transportation, Phase 2 Development of the Functional Assessment of Colorado Wetlands (FACWet) Methodology: Calibration, Validation ..., $44,162

Kelly, Eugene F, USDA-USFS-Rocky Mtn. Research Station - CO, Monitoring Forest Recovery and Watershed Protection in Beetle-Killed and Salvage-Logged Rocky Mountain Forests, $38,316

Kummerow, Christian D, DOC-NOAA-National Oceanic & Atmospheric Admn, Development of an Improved Climate Rainfall Dataset from SSM/I, $104,748

Kummerow, Christian D, NASA - National Aeronautics & Space Admin., A Cooperative Climate Rainfall Data Center, $267,085

Lemly, Joanna, Colorado Division of Wildlife, Statewide Wetland Strategies, $194,045

Liston, Glen E, NASA - National Aeronautics & Space Admin., Improving the Representation of Global Snow Cover, Snow Water Equivalent, and Snow Albedo in Climate Models by Applying..., $124,972

Oad, Ramchand, New Mexico Interstate Stream Commission, Decision Support Systems for Efficient Irrigation Management in the Middle Rio Grande, $167,556

Qian, Yaling, HRI-Horticultural Research Institute, Interactive Impacts of Salts and Surfactants in Recycled Wastewater on Landscape Plants, $16,000

Ramirez, Jorge A, USDA-USFS-Rocky Mtn. Research Station - CO, Vulnerability of the United States Water Supply System to Shortage, $40,000

Rathburn, Sara L, DOI-NPS-National Park Service, Channel Restoration Planning & Preparation for Colorado River & Lulu Creek, $27,800

Roesner, Larry A, City of Fort Collins, Assist Fort Collins Stormwater Utility with Review of Stormwater Best Management Practices Program, $303,012

Roesner, Larry A, Water Environment Research Foundation, Linking Stormwater BMP Systems Performance to Receiving Water Protection to Improve BMP Selection and Design, $38,610

Swift, David M, DOI-NPS-National Park Service, Investigation of Nitrogen Deposition into Loch Vale, $10,000

Theobald, David M, USDA-USFS-Rocky Mtn. Research Station - CO, Fire & Water in Colorado: Resource Trends & Interactions in a Changing Landscape, $44,400

Thompson, David, NSF - National Science Foundation, Analyses of Climate Variability and Climate Change, $155,872

Thornton, Christopher I, International Coastal Revetment Products, Overtopping and Manning Roughness Testing on Articulating Concrete Block System, $52,455

Wickramasinghe, Sumith Ranil, University of Colorado, Assessment of Membrane Adsorber for Removal of Residual Trace Impurities, $32,500

Winkelman, Dana, Colorado Division of Wildlife, Creel Program, $20,000

Winkelman, Dana, Colorado Division of Wildlife, Evaluation & Control of Whirling Disease in the White River, CO, $30,000

Winkelman, Dana, Colorado Division of Wildlife, High Elevation Lakes/Streams Whirling Disease Sampling, $27,500

Winkelman, Dana, Colorado Division of Wildlife, Whirling Disease-Resistant Trout Evaluation, $198,102

Wohl, Ellen E, NSF - National Science Foundation, Influence of Post-Glacial Rebound on River Longitudinal Profiles in Sweden, $34,986

Calendar

October 2008

22-23 **19th Annual South Platte Forum, Longmont, Colorado**
This year's theme is "News, Weather, and Water."
http://www.southplatteforum.org

26-30 **2008 International Water Conference; San Antonio, Texas**
Learn about the latest applications available in the industrial water treatment industry.
http://www.eswp.com/water

28 **Big Thompson Watershed Forum; Berthoud, Colorado**
The theme for the 10th Annual Meeting is "Voices from the Watershed."
To register, call 970-613-6163 or email zshelley@btwatershed.org.

November 2008

17-20 **Coastal Cities Summit 2008: Values and Vulnerabilities; St. Petersburg Beach, Florida**
Will cover public resource strains, challenges, and viable solutions.
http://www.coastalcities.org/callforpapers.html

17-20 **2008 AWRA Annual Water Resources Conference; New Orleans, Louisiana**
Discuss the blows of Hurricanes Katrina and Rita and the Mississippi River problems.
http://www.awra.org/meetings/NewOrleans2008/index.html

18-20 **Groundwater Foundation 2008 National Conference; Desert Hot Springs, California**
This year's conference theme is "Going Green for Groundwater."
http://www.groundwater.org/pe/conference.html

19-20 **NWRA Annual Meeting; San Diego, California**
http://www.nwra.org/index.cfm

December 2008

1-5 **UNESCO International Conference on Water Scarcity, Global Changes and Groundwater Management Responses; Irvine, California**
Brings together leading water management and climate change experts.
http://www.waterunifies.com

2-5 **NGWA Ground Water Expo and Annual Meeting; Las Vegas, Nevada**
Focuses on groundwater awareness and protection through education and outreach.
http://www.ngwa.org

4 **Adjusting to Less Water: Climate Change and the Colorado River; Salt Lake City, Utah**
Focuses on the latest scientific research to ensure a sustainable water supply while protecting the Colorado River and its ecosystems.
http://www.glencanyon.org/conference.php

15-17 **CRWUA Annual Conference; Las Vegas, Nevada**
This year's theme is "Power of Water."
http://www.crwua.org

15-19 **American Geophysical Union (AGU) Fall Meeting; San Francisco, California**
Opportunity to review the latest issues in Earth and space sciences.
http://www.agu.org

January 2009

25-27 **2009 AWWA Water Conservation Workshop; Portland, Oregon**
Focuses on the challenges facing utilities in meeting diverse demands for water.
http://www.awwa.org/Conferences/

28-30 **CWC Annual Convention; Denver, Colorado**
The 51st annual conference of the Colorado Water Congress.
http://www.cowatercongress.org

February 2009

8-12 **USDA-CSREES National Water Conference; St. Louis, Missouri**
Provides opportunities for water professionals to share knowledge and ideas.
http://www.usawaterquality.org/news/2009abstract.html

19-20 **DARCA 2009 Convention; Pueblo, Colorado**
Will cover strategies and alternatives to buy and dry arrangements.
http://www.darca.org

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Colorado Water Knowledge
http://www.waterknowledge.colostate.edu

The only double diversion dam on the Cache la Poudre River is located near Laporte, Colorado (see CWI Special Report 15).
Image courtesy of Rose Brinks.