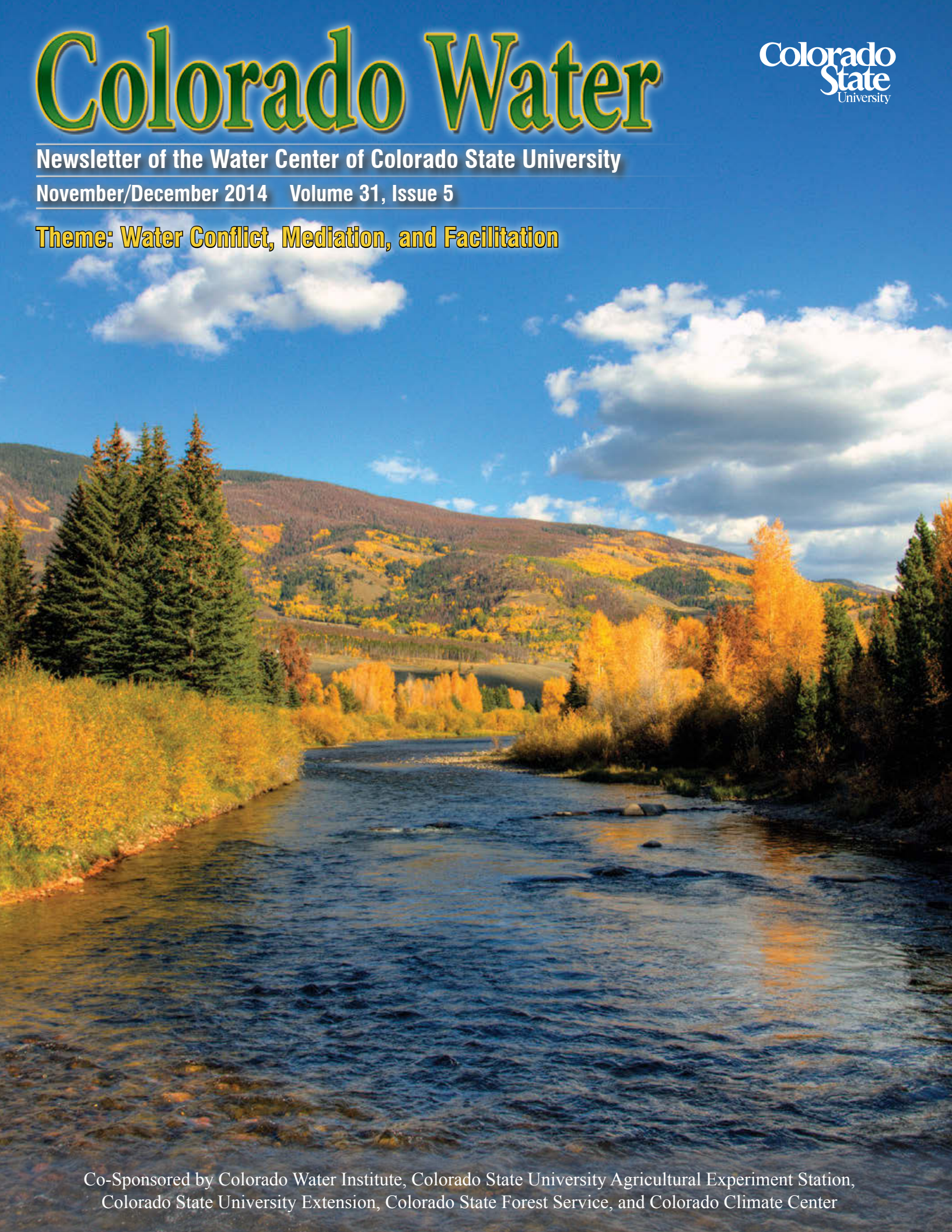
Colorado Water

Newsletter of the Water Center of Colorado State University

November/December 2014 Volume 31, Issue 5

Theme: Water Conflict, Mediation, and Facilitation



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

Highlights

In Every Issue

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

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Front Cover: Fall colors surround the Blue River near Silverthorn, Colorado. Courtesy of Scott Ingram
This Page: Colorado River Trail near Palisade, Colorado. Courtesy of Scott Ingram

Editorial

by Reagan Waskom, Director, Colorado Water Institute

Today's water professionals must not only be technical experts—they must also have the ability to engage in collaborative stakeholder processes that meet the public's growing expectations of transparency and accountability. Public participation can be difficult and time consuming, but the costs of failing to achieve cooperation and public support can be high and may result in bad press, delays, lawsuits, and failed projects.

The nature of water requires us to work across competing values, sectors, and jurisdictions. Moreover, the uneven distribution of power and information can intensify distrust. There is growing public awareness of the limits of water resources, along with a general perception that future water disputes may lead to serious international conflicts. Priscoli and Wolfe point out in their 2009 book *Managing and Transforming Water Conflicts* that international disputes over water resulting in serious conflicts are rare, with only 37 acute conflicts occurring since the 1950s, thirty of which involved Israel. They point out that lower level conflicts over shared water resources often lead to cooperation, as the problems must of necessity be peaceably resolved. This is not to say that everything is okay in water. Many issues remain, and there are instances of noncooperation in Colorado and throughout the world.

This newsletter focuses on the transformation of conflict to improve policy and management outcomes through the participatory process. The causes of conflict tend to be disagreements over water allocation, problems with relationships between parties, and perceived or actual competing interests and values. Colorado State University researchers like Taylor, Carcasson, and Freeman (in this issue) apply their disciplines to the study of conflict and collaboration so that we can better understand and improve the process. But are there also opportunities for university faculty to engage more directly in the process? There is clearly a need for skillful conveners, facilitators, & mediators that can remain neutral and effective in the midst of conflict.

Scientists have the ability to inform the process, but must remain neutral in this role. Most university scientists believe their research results are unbiased. After all, the scientific method is designed to be objective and iterative, with scientific understanding evolving as more observations are collected and analyzed. However, many water managers believe they see a propensity toward an environmental bias in university faculty. Are our research results indeed unbiased, or are we influenced by preferences that become subtly embedded into our analyses? Public confidence in

science appears to be shaken—witness the lack of trust in both climate change information and the safety of GMOs, where people on opposite sides of the political spectrum distrust science when it does not fit their values. Policymakers value sound scientific information, but this is never the sole input in difficult decisions where they must balance competing interests, economics, and the risks of known and unknown consequences. As scientists, we need to take a hard look at how our values and preferences may be subtly embedded in what appears to be policy neutral information, particularly when engaged in conflict-ridden contemporary problems.

So how can university researchers best contribute to the transformation of conflict into balanced outcomes? Our role includes acquiring, analyzing, and communicating the needed data and developing decision tools that can help integrate sound science into the process. University students must be prepared to do more than design the next water project—they must also be trained in an integrated fashion that results in better stakeholder processes. In the end, our best role as scientists may be less about providing absolute answers in policy debates and more about asking questions that lead to new thinking and new approaches.

In closing this editorial, I want to acknowledge Rep. Randy Fischer, who has contributed an article to this newsletter based upon his observations from eight years of service in the Colorado legislature. Rep. Fischer leaves office as the leading voice for water and natural resources management and conservation. He has been a tireless supporter of Colorado State University and has ably served on the advisory committee for the Colorado Water Institute. We are grateful for his eight years of outstanding service and will miss his leadership for Colorado water.

Emerging Environmental Flow Governance on the Upper Colorado River

A Collaborative Alternative?

Pete Taylor, Sociology, Colorado State University

Upper Colorado River environmental flow collaborations were studied, including the Upper Colorado River Endangered Fish Recovery Program, the Upper Colorado River Wild and Scenic Stakeholder Group, and Colorado River Cooperative Agreements. Interviews were conducted with irrigation leaders, municipal suppliers, environmental and recreation representatives, water attorneys, state and federal officials, and others. These examples show cooperation among East and West slope entities facing water shortages and serve as examples for modeling future collaborations in the arid West.

The Colorado River today faces an unprecedented supply-demand "imbalance," exacerbated by extended drought, demographic growth, and predicted climate change. Many observers predict increased conflict over Western water in the future, but crisis can also generate opportunities for creative collaboration. Nowhere is this more apparent than in the Upper Colorado River, the location of three interrelated experiences of cooperation around environmental flows: the Upper Colorado River Endangered Fish Recovery Program at 15 Mile Reach, the Upper Colorado River Wild and Scenic Stakeholder Group, and a set of three Colorado River Cooperative Agreement and related intergovernmental accords. These three experiences are arguably developing, among institutions often seen as adversaries, a new level of coordination of flows for consumptive and non-consumptive purposes.

The Brisbane Declaration has defined environmental flows as "the quantity, timing, and quality of water flows required to

sustain freshwater and estuarian ecosystems and the human livelihoods and well-being that depend on those ecosystems." Over 18 months I carried out sociological fieldwork and did 60 in-depth-interviews with environmental flow cooperation participants, including irrigation leaders, municipal suppliers, environmental and recreation representatives, water attorneys, state and federal officials, and others. My research was supported by CSU Extension, the Experiment Station, and the Colorado Water Institute. I was interested in learning what drove water interests often seen as adversaries to cooperate around environmental flows; what governance features help make consensus decision-making work even when participants have unequal power and resources; and what were these collaborative efforts' achievements and challenges, and what can be learned from them.

The Upper Colorado River is of great importance to Colorado, as it encompasses key West Slope senior water rights, trans-basin diversions that supply Front Range populations, five crucial reservoirs, and the state line across which the state meets its interstate water obligations. "If you were to identify one stretch of river in the state that is critical to our future consumptive uses and our ability to fully use them," remarked one Colorado Water Conservation Board (CWCB) official, "I would say this is the stretch right here." The Upper Colorado River also faces severe ecological threats, leading to its recent designation as the second-most threatened River in America.

The Upper Colorado River Endangered Fish Recovery Program

Established in 1988, the Upper Colorado River Endangered Fish Recovery Program (UCREFRP) manages environmental flows to protect four species of endangered native fish: the Humpback Chub (*Gila cypha*), Colorado Pikeminnow (*Ptychocheilus lucius*), Razorback Sucker (*Xyrauchen texanus*) and the Bonytail (*Gila elegans*) (www.coloradoriverrecovery.org 2014). In Colorado, Wyoming, and Utah, the UCREFRP engages in habitat restoration, non-native fish management, propagation and stocking, research and monitoring, and information and education. My study focused on the UCREFRP's activities in the critical habitat of the 15 Mile Reach near Grand Junction. To obtain group compliance with the Endangered Species Act via U.S. Fish and Wildlife's Programmatic Biological Opinion, Grand Valley irrigators, federal authorities, Colorado River District and municipal reservoir operators, and others have developed innovative consensus-based management arrangements. They coordinate releases for augmented spring peak flows and, through a weekly Historic Users' Pool (HUP) telephone conference during irrigation season, manage 10,825 acre-feet (AF) of water, contributed equally by East and West Slope participants, in support of endangered fish in the 15 Mile Reach (Figure 1).

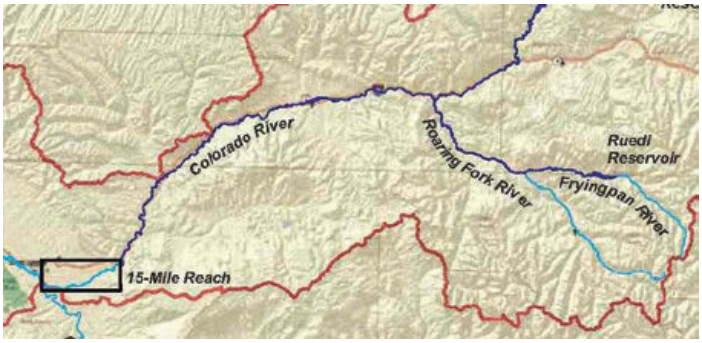


Figure 1. *The Upper Colorado River Endangered Fish Recovery Program at the 15 Mile Reach (USBR 2009).*

The Upper Colorado River Wild and Scenic Stakeholder Group

The Upper Colorado River Wild and Scenic Stakeholder Group (WSSG) emerged in 2007, when the U.S. Bureau of Reclamation and U.S. Forest Service announced formal consideration of the Upper Colorado River for federal Wild and Scenic River Act designation. A unique group of East and West slope water users, including the Colorado River District, Middle Park Water Conservancy District, Denver Water, Northern Water, CWCB, environmental and recreation representatives, and others, came together to develop and submit a consensus-based plan that might serve as an alternative to designation. The Stakeholder Group, which today includes nearly 100 individuals in 20 water entities, is cautiously optimistic that its plan to protect biological, social, and recreational "outstandingly remarkable values" on four river reaches will be formally approved in fall of 2014 (Figure 2). In the meantime, the group is working hard to prepare for its monitoring and cooperative flow activities once the Record of Decision is issued. Significantly, the WSSG group worked closely with the CWCB to obtain in 2013 for the Upper Colorado River one of the largest instream flow decrees in the state.

The CRCA and Related Intergovernmental Agreements

A third instance of cooperation emerges from a set of interrelated legal agreements to cooperatively manage Upper Colorado River environmental flows: the Colorado River Cooperative Agreement (CRCA) and three related intergovernmental agreements (IGAs). Completed formally in September 2013, the CRCA accord between Denver Water and more than 35 West Slope water entities encompasses some 40 agreements addressing long-standing mutual water issues (Figure 3). Part of the CRCA, the Shoshone Outage Protocol, formalizes governance of the senior water rights of the power plant near Glenwood Springs to keep its 1,020

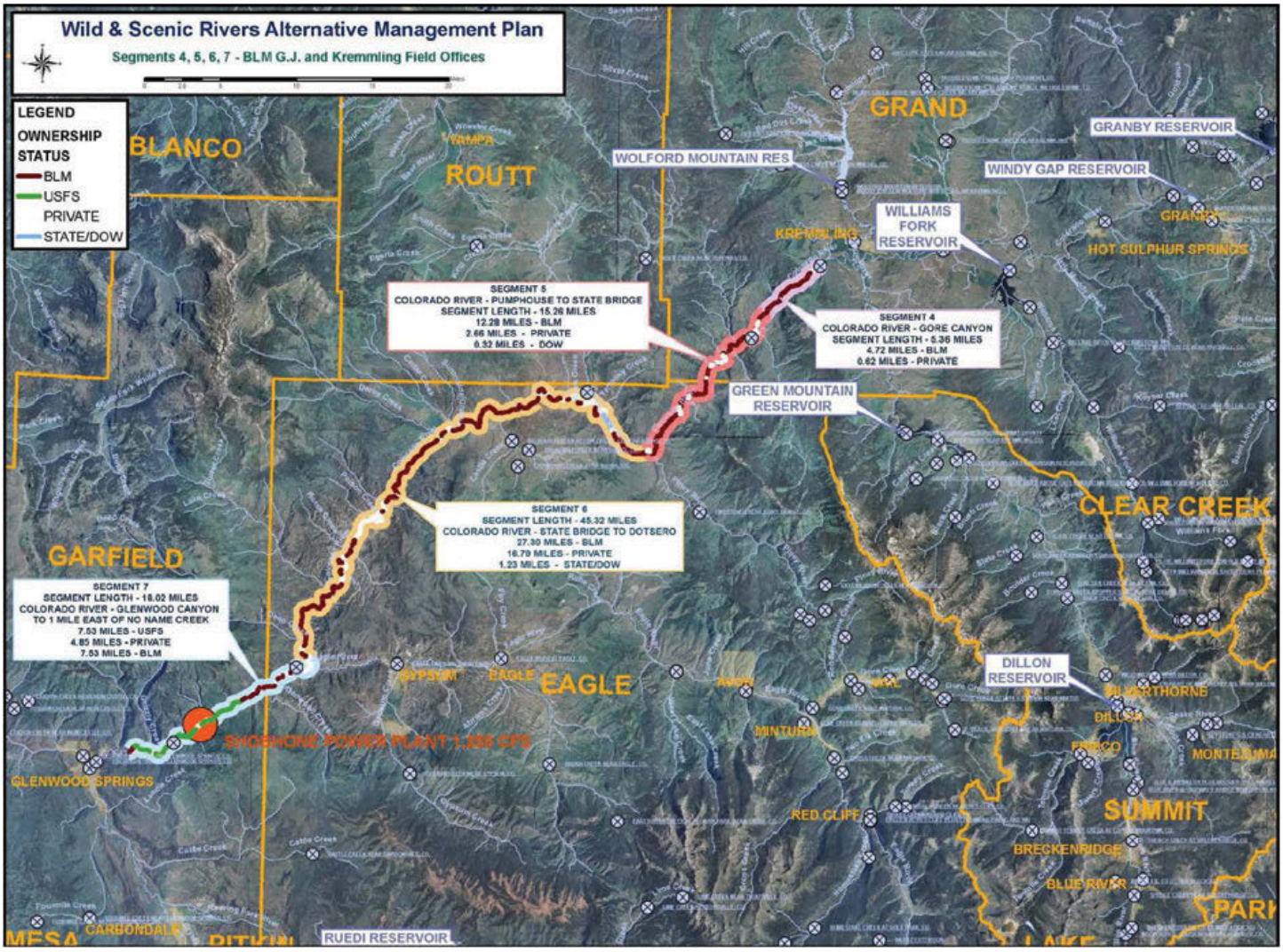


Figure 2. *Upper Colorado River WSSG Alternative Management Plan (WSSG 2014).*

cubic feet per second coming downstream from Green Mountain, Williams Fork, and Wolford reservoirs even when its aging turbines are down for repair. The CRCA also supports enhancement measures benefiting Grand County, including re-timing of some seasonal flows, additional water, and others. A closely related IGA between Northern Water and Grand County, Middle Park Water Conservancy District, and the Colorado River District agrees, with Reclamation approval, to relocate the East Slope's 5,412 AF UCREFRP fish water from Williams Fork Reservoir to Granby Reservoir. This change allows the fish water to enhance flows in Grand County on the way downstream to the 15 Mile Reach. Two other IGAs between these West Slope entities and Denver Water and Northern Water respectively, aim to establish a consensus-based "learning by doing" governance framework to cooperatively manage flows upstream of the Upper Colorado River's confluence with the Blue River.

These three experiences in environmental flow cooperation are encouraging an incipient but purposeful effort to coordinate flows between Grand Junction and Granby Reservoir within the existing state water system. This emerging coordination is not managed or controlled by a single overarching entity, but involves what sociologists call "polycentric governance" with multiple entities with overlapping jurisdictions, shared or compatible purposes, information sharing, and networks of institutions and individuals working across two or more programs.

The interconnections among these efforts are visible in several governance mechanisms that span the Upper Colorado River mainstem. First, the UCREFRP's HUP telephone call has expanded in recent years to include County officials; municipal, environmental, and recreation groups; and others, including the WSSG. One WSSG-affiliated northern water official remarked "it's not like you have a valve you can turn on or off. But it's a voice in all of the things that are going on." Second, the East Slope's UCREFRP 5412 fish water, now relocated to Granby Reservoir, "has to get shepherded to the 15 Mile Reach…" explained a county official. "It gets to enhance the environment on its way down, it gets to cool things off. It has a plethora of benefits." The recent CWCB instream

Figure 3. *Colorado River Cooperative Agreement and related IGAs (Denver Water 2014).*

flow decree established through WSSG efforts benefits the environment, recreation, and other users downstream. "Even though it's not very much, it goes clear to the state line to the 15 Mile Reach," remarked a WSSG participant. The CRCA's Shoshone Outage Protocol is widely viewed as crucial keeping whole the current downstream system of coordinated reservoir operations, diversions, and other non-consumptive water use. Many interviewees see these emerging, interconnected flow governance efforts as helping give birth to a new view of the river. One municipal supplier representative said, "It's kind of like opening a window to that stretch of the river and seeing what's going on on all sides… There's endangered species, there's wild and scenic, there's all these other small initiatives between entities, but it's getting more interrelated as we go."

What has made these experiences in environmental flow cooperation possible? West and East slope water interests share a sense of urgency about future water supplies. Many report growing exhaustion with litigation as a way to resolve water conflicts. Push factors like the Endangered Species Act (ESA) and Wild and Scenic Rivers Act represent "hammers" that drive traditional adversaries to cooperate together to either seek compliance or develop alternatives to federal regulation. But as significant are pull factors that allow participating groups to pursue their interests through collaboration. Grand Valley irrigators report UCREFRP-generated benefits, including improved water quality and delivery efficiencies. Municipal water suppliers in the WSSG, CRCA, and related IGAs explicitly seek support for their Windy Gap and Moffat Firming projects through cooperation with other sectors. Environmental and recreation representatives see opportunities to secure "wet water" and mitigation for decades of ecological degradation not readily accessible through win-lose litigation. State agencies see opportunities to preserve Colorado's right to manage its own water and ensure flexibility to develop its compact allocation in the future. Federal authorities view collaboration as a way to bring together expertise and resources for effective river management that could not be mobilized by any agency alone.

Interviewees, proud of the significant strengths of their environmental flow cooperation efforts, also spoke of significant challenges. The overall UCREFRP has invested $337 million and generated ESA compliance for nearly 2,400 projects, but struggles with non-native fish that compete with the protected native fish. The WSSG developed consensus on a complex Management Plan, but now faces the task of developing agreement on concrete cooperative flow measures. The CRCA/IGA Learning by Doing mechanism, modeled largely on the HUP and WSSG processes, is still under development. Interviewees also expressed concern about the inevitable turnover of key participating institutions and individuals, potentially weakening agreements facilitated by longstanding relationships of trust. Changing political and economic conditions could alter the calculus of institutional interests that keep participating groups at the negotiating table. Climate change threatens to reduce future water supplies, potentially pushing institutions back into historic adversarial modes.

Despite their formidable challenges, these environmental flow cooperation experiences are generating useful lessons. First, river flow interest groups need to have sufficient motive to make cooperation a rational strategy rather than an institutional sacrifice. Consensus decision-making, despite its slow pace and purported inefficiency, can help sustain cooperation by preventing any single group from capturing the process. The natural and institutional organization of the water resource must permit sufficient management flexibility to support cooperation. A social space like the HUP call is needed for broad-based negotiation, monitoring, and decision-making. Finally, stable participation by key institutions and individuals encourages the development of relationships of trust via shared accomplishments over time.

These environmental flow experiences show that water in Colorado does not have to be just "for fighting." Water has also always been "for cooperation." These experiences of environmental flow cooperation on the Upper Colorado River face many challenges, but they also suggest lessons useful for developing a resilient, decentralized, but coordinated and uniquely Western governance system for a new era of limits.

Social Spadework

Preparing for Effective Negotiations in Polarized Contexts

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

Negotiations often take place in a high-stakes environment of conflicting interest. Two helpful kinds of negotiation preparation are discussed: analysis of conflict patterns, and futures for choices foregone.

Water policies impact people unevenly. Proposals to hold fast to a status quo, or to change it, become mired in a clash of opposing values where each alternative has its desirable side, but advantages come at a cost to some parties more than to others. Policy choice reflects, and produces, social conflict. Given a need to negotiate solutions amidst a thicket of conflicting interests for whom the stakes are high, how can facilitators prior to negotiations best prepare the table for problem solving?

Challenge

Negotiations are about installing a revised social organizational regime. Nineteenth century conflicts among irrigation ditch organizations over water allocations to headgates led to the establishment of the Office of the State Engineer, equipped with Division Engineers on river basins, and River Commissioners. Conflict breeds negotiations; negotiations breed organizations and rules.

Successful negotiations, to lay groundwork for organization building, must integrate two kinds of knowledge: 1) generalized knowledge encoded in law and science without connection to particular places or time; and 2) local knowledge of site-specific realities (Freeman, 1992: 18-23). Generalized knowledge must be fitted to local realities. Negotiations are well served by social spadework that gives voice to both kinds of knowledge in a non-threatening manner.

Successful negotiations must also reconcile conflicting organizational agendas. Individuals populate negotiating rooms, but they are carriers of organizational interests. To be admitted to negotiations, a person must legitimately represent a stakeholder. Stakeholders are organizational entities with something to potentially lose. Those who sit at the negotiating table seek terms of settlement that can win support of their organizational employers. Good preliminary social spadework permits each player to comprehend the latitudes available to, and constraints pressing upon, other organizational entities at the table.

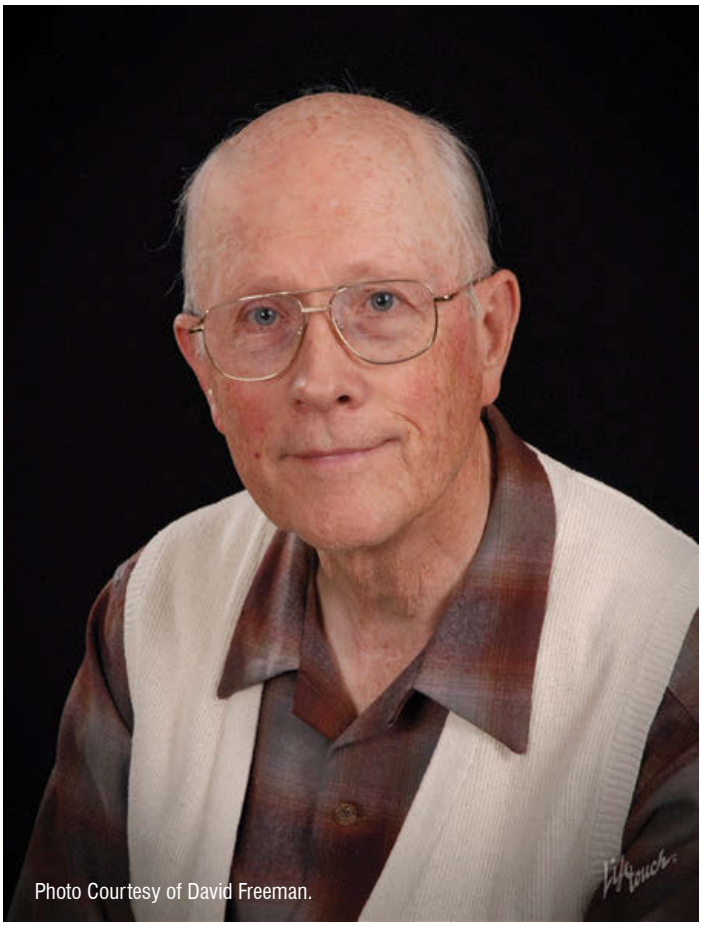


Photo Courtesy of David Freeman.

Preparations for negotiations can involve many things. Two helpful kinds of spadework, especially in polarized contexts, are analyses of conflict patterns and futures for choices foregone.

Two Methodologies

Conflict Analysis

Social conflict erupts when people engage in incompatible activities. The unkind rub of conflicting human purposes is always with us. But conflict can be either constructive or destructive. For negotiations to succeed, players must find and expand opportunities for constructive conflict management.

Figures 1 and 2 display two ends of a continuum of conflict patterns. The bars on the circles represent cleavages—i.e., lines of division over incompatible values. If party A values groundwater policy G while organization B values groundwater policy anti-G, there is a conflict cleavage dividing the opponents. Question: does that cleavage

contribute to high polarization (an obstacle to successful negotiations) or does that same cleavage contribute to a cross-cutting (low polarization) pattern conducive to successful negotiation? When conflicting parties find common ground, it is because cross-cutting cleavages have created it.

In Figure 1, opponents A and B confront each other as adversaries on all fronts. There are no common interests. There is, in this extreme, nothing to negotiate.

In Figure 2, all A's confront all B's on the vertical (yellow) cleavage, some A's are allied with some B's on each of the other cleavages (green and purple). There is opportunity to negotiate solutions eventuating in a new problem-solving organizational regime.

Social spadework prior to the opening of formal negotiations constructs a conflict map revealing two things: 1) base cleavage patterns present among the stakeholding organizations; and 2) patterns of support for, and opposition to, proposed policies. Methods of polarization measurement have been devised and field-tested in challenging Colorado conflict situations. One then calculates the degree of existing base polarizations (ranging from none to total) and the impact of alternative policies on that base (i.e., will policy proposal X increase or decrease polarization?). Such analysis permits representatives to learn about the organizational interests at play, correct error in estimates, and visualize how policy proposals can be expected to make matters better or worse.

Futures Foregone

Cost is always with us; it reflects what must be sacrificed to do something. Economists have developed techniques for calculating dollar costs of policy options. But many costs are not reflected in market exchange. This spadework examines non-market costs and provides a method to evaluate which can be most, and least, afforded.

A foregone future means that implementation of a policy alternative, including today's *status quo*, cancels futures for incompatible activities. There are three measurements to be made:

1. *Scope of Loss*: In the designated policy impact area, given a list of existing activities, what proportion of activity X will be lost if the policy option is implemented? Scope values vary from zero to 100 percent.
2. *Intensity of Loss*: How much will the lost future for X be missed? The meaning of a given scope value depends upon how many accessible futures for X remain (Figure 3). Intensity values for each choice opportunity,

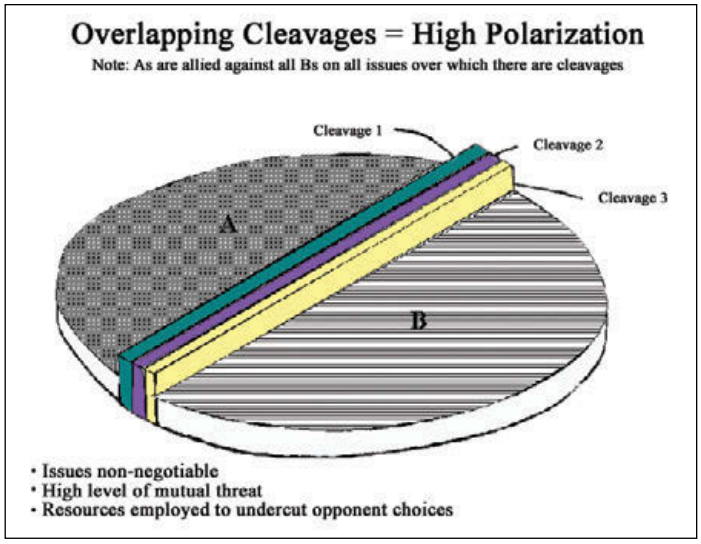


Figure 1. *Overlapping cleavages leads to high polarization among opposing groups.*

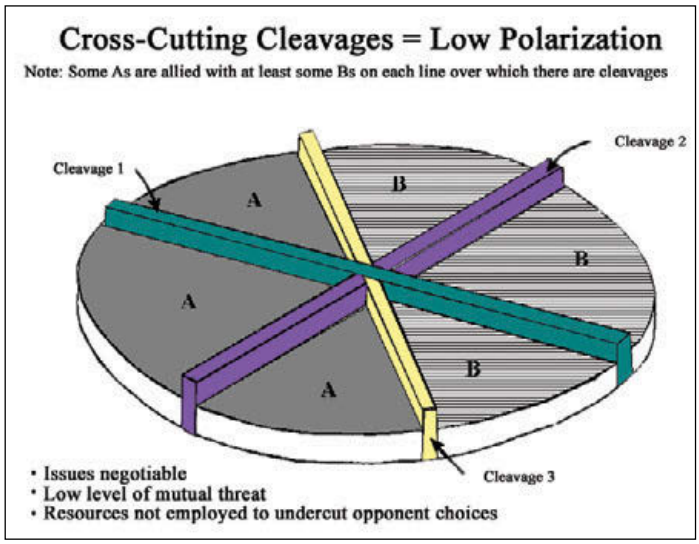


Figure 2. *Cross-cutting cleavages lead to low polarization among groups.*

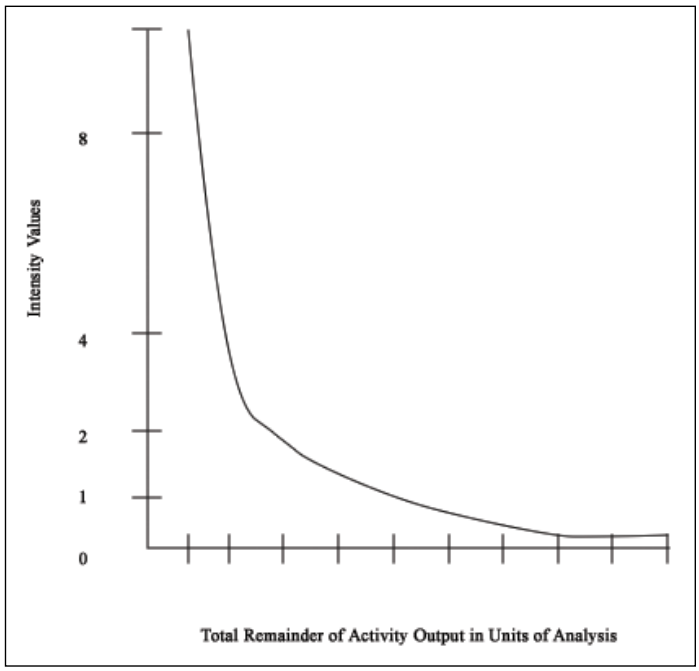


Figure 3. *Values increase as total remainder of activity in the analysis diminishes.*

suffering a non-zero scope of loss, increase exponentially as choice opportunities diminish.

A small scope of loss may earn a high intensity score by virtue of the fact that there are few other options for sustaining that activity. It is also possible that a high scope of loss value will be paired with a low intensity value because there are ample alternative places for the lost choice opportunity to be sustained.

3. *Duration of Loss*: How long, in calendar years, would it take to return the reduced choice opportunity for X to its present quantity and quality (if parties should wish to do so) given existing technology and financial resources? No crystal ball gazing is allowed.

Each proposed policy option will impose a unique pattern of losses to scope, intensity, and duration. Intensities of loss are heaviest weighted. Examination of scope, intensity, and duration values activity-by-activity and proposed policy-by-policy permits negotiators to view profiles of non-market costs, and thereby formulate better options to bring to negotiations.

Data

Informants familiar with the planning area make estimates following procedures described in Freeman's cited literature (available upon request). Individuals are subject to hidden fears or distorted or incomplete information; it is important that the estimation process minimize distorting factors and maximize information flow.

Although individuals of different persuasions can be expected to disagree greatly over what they prefer, they can be expected to arrive at reliable estimates of what will happen under each policy proposal whether or not they like that proposal. People are not asked to register their values; they focus their energies on estimating facts of conflict patterns and futures foregone.

Conclusion

Concepts and procedures advanced provide a practical method of assessing two strategic social dimensions that importantly impact prospects for negotiating solutions in challenging contexts—social conflict patterns and futures for activities foregone. Results can foster problem-solving discussion before and during negotiations. They can be integrated with traditional economic and technical analyses. They prepare participants for new or modified organizational regimes.

Please contact CWI for references: cwi@colostate.edu.

Upper Yampa Scholarship Announced

The Upper Yampa Water Conservancy District John Fetcher Scholarship provides financial assistance to a committed and talented student who is pursuing a water-related career in any major at a public university within the state of Colorado. Congratulations to this year's scholarship recipient, Taylor M. Baird.

- **University:** Colorado School of Mines
- **Anticipated Graduation:** May 2015
- **Major:** Environmental Engineering
- **Minor:** Humanitarian Engineering
- **Interests:** Water and wastewater treatment, Water reclamation and distribution, International development, Environmental health and safety

Taylor is currently a senior studying Environmental Engineering with a minor in Humanitarian Engineering at the Colorado School of Mines. She intends to pursue a master's degree in hydrological engineering from the Colorado School of Mines, then would like to become a Peace Corp volunteer. She hopes to lead a career in providing clean water to developing nations. She enjoys running and being outdoors when she has free time.

The Colorado Conservation Exchange

Robin Reid, Human Dimensions of Natural Resources, Center for Collaborative Conservation, Colorado State University
Heidi Huber-Stearns, PhD Candidate, Forest and Rangeland Stewardship, Colorado State University
Heather Knight, Laramie Foothills Project Director, The Nature Conservancy of Colorado
David Jessup, Conservation Practitioner, Co-Owner, Sylvan Dale Ranch
Jennifer Kovecses, Executive Director, Coalition of the Poudre River Watershed
Paige Lewis, Director of Forest Health and Fire Initiative, The Nature Conservancy of Colorado

The Colorado Conservation Exchange was formed to fund landowners and managers' efforts in providing ecosystem services, such as clean water, healthy soils, carbon storage, and wildlife habitat. The Exchange is currently focusing on wildfire risk reduction and the effects of agricultural best practices on water quality in the Big Thompson and Poudre watersheds. Activities so far have included an initial design phase and research into ecosystem service investments.

In the arid West, arguments over water are as common as spines on a cactus. Yet stakeholders in our watersheds—farmers, ranchers, utilities, and conservationists—are also exploring innovative ways to collaborate to enhance this vital natural resource for the benefit of all. Chief among these is the concept of payment for ecosystem services.

Ecosystem services are the benefits that we receive from nature. Healthy watersheds, for example, serve us by purifying water, providing fertile land to grow crops and pastures, and offering us opportunities for outdoor recreation and spiritual uplift. Unfortunately, the ecosystems that provide these services are under increasing risk of floods, wildfire, insect infestations, population growth, and climate change (Figure 1).

Figure 1. *Pick-up stuck in a Poudre gulch after floods.* Photo courtesy of City of Greeley Water and Sewer

New Economic Tools for Enhancing Our Watersheds

It's tempting to regard nature's benefits as free. But increasingly, we recognize that ecosystem services have economic value. Once we know their value, we can invest in those stewards in our watersheds who adopt the kind of best management practices that protect and enhance those services—and motivate them to do more. No-till cultivation, rotational grazing, erosion prevention, forest fire mitigation, and preventing nutrient runoff are examples of such practices.

Payments for ecosystem services may be thought of as investments in "natural infrastructure." No one thinks it unusual for a utility to invest in new water treatment facilities to keep drinking water pure. But why not invest in upstream practices that will purify water before it reaches the treatment plant? Creating wetlands, vegetating riversides, diverting nutrient runoff, and reducing sediment loads has improved water quality at less cost than investing in traditional treatment infrastructure in other parts of the country.

Investment in "natural infrastructure" creates a positive cycle, whereby more investment produces more benefits from nature, "eventually fueling both sustainable economic growth and ecological restoration" (www.ecosystemmarketplace.com).

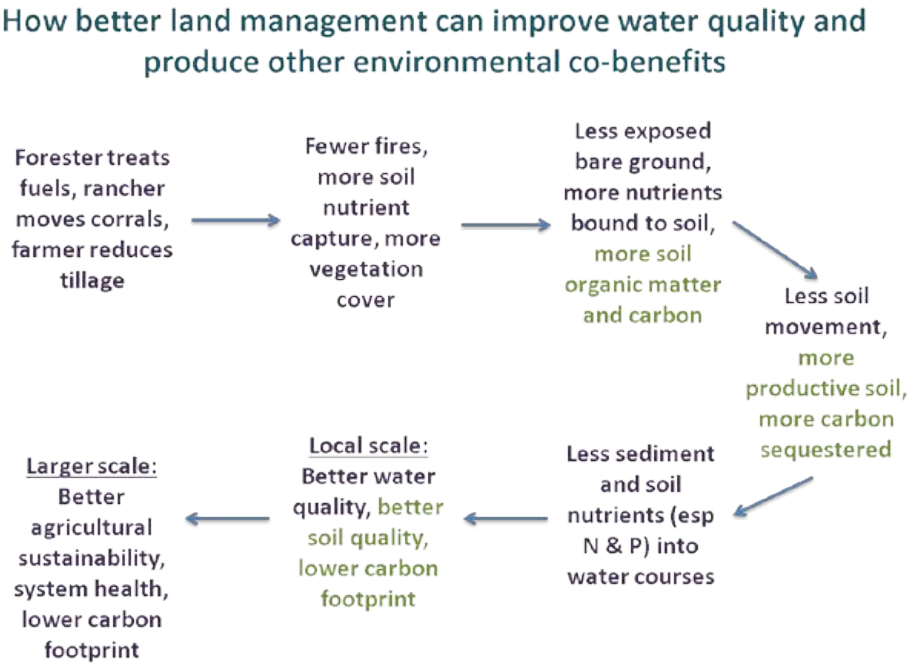


Figure 2. *How land management can affect water quality.* Graphic by Robin Reid

Figure 3. *Seven steps of an Exchange transaction.* Graphic by Robin Reid

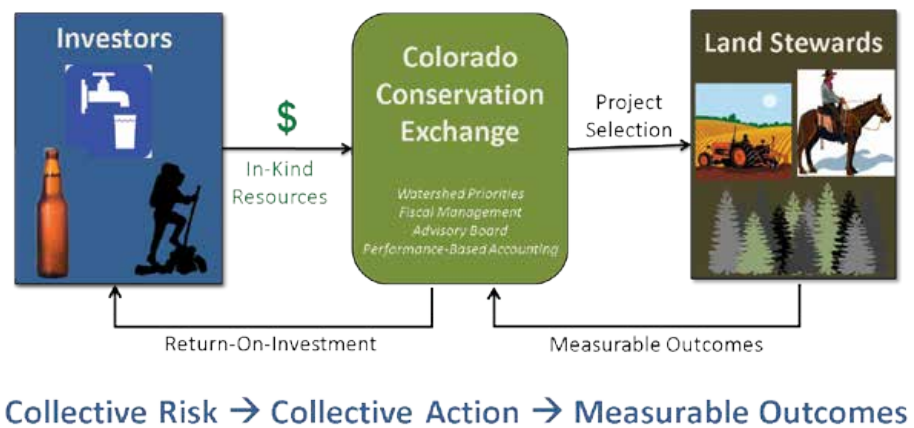


Figure 4. *How the Exchange works.* Graphic by Heidi Huber-Stearns

Who Pays?

In part, the same people who pay for traditional water quality infrastructure also help pay for natural infrastructure improvements. Utilities, breweries, urban residents, and downstream water users help land and water stewards finance practices that benefit them. But natural infrastructure also attracts investment dollars from people who would not normally pay for traditional water treatment facilities: outdoor recreation enthusiasts, environmental groups, universities, non-profit foundations, and ordinary citizens.

These diverse investors are part of the heart of the payment for ecosystem services concept. It expands the pool of investment capital to all those who cherish the health of their watershed.

The Colorado Conservation Exchange

In 2010, a group including members from Sylvan Dale Ranch, The Nature Conservancy, the Northern Colorado Food Incubator, CSU's Department of Human Dimensions of Natural Resources, and the Center for Collaborative Conservation started dreaming of bringing these new economic tools to northern Colorado, to better reward landowners and managers for providing us all with healthier ecosystem services into the future. After wide consultation with our local partners, The Colorado Conservation Exchange ("Exchange") was born (www.collaborativeconservation.org/colorado-conservation-exchange).

Today, the Exchange is a regional, community-led initiative where we can all support land and water stewards (public or private) who provide us with clean and abundant water, productive soils, carbon storage, wildlife habitat, and inspiring

open spaces (Figure 2). Initially, the Exchange is focusing on investments in wildfire risk reduction and agricultural best practices and their effects on water quality in the Cache la Poudre and Big Thompson Rivers.

How Will the Exchange Work?

The practical goal of the Exchange is to facilitate transactions between buyers and sellers of water quality credits. There are seven steps in a transaction (Figure 3), where investors (step 1) provide funds for land stewards to implement priority and confirmed conservation practices (steps 2-4) at the lowest cost with the greatest improvement in water quality (step 5). The innovation the Exchange brings is not so much in the payments themselves, but in providing an "environmental return" on their investment in a landowner's conservation practice (step 6), signified by a credit verifying that return (step 7).

So who might be some of the first participants in the Exchange? Let's say a local water utility, a brewery, and a local family invest in the Exchange. The Exchange would then allocate those resources where and how they will have the biggest impact on water quality in our watersheds, based on our best available science. In our watersheds, Exchange investments might fund a forest owner to replant a burn to reduce sedimentation or a farmer to replant riverine vegetation to block fertilizer run-off or a rancher to fence off valuable wetlands. This combined investment, through the Exchange, allows us to improve our watersheds faster and more effectively than one-off, individual transactions (Figure 4).

Where Are We Now?

The Exchange is currently in its design phase and will build a fully functioning Exchange next. During our design phase, we created the basic information and facilitated community collaboration that is critical to building the transactions described above.

Figure 5. *Water flow from livestock corrals to Big Thompson River on Sylvan Dale Ranch, before the Jessups built a new diversion to keep nutrients out of the river.* Photo by David Jessup

In 2011, we designed two pilot projects, at Sylvan Dale and Roberts Ranches, to quantify the return on investing in improved land conservation practices for water quality. David Jessup of Sylvan Dale diverted runoff from his cattle pens into a pasture in order to reduce nutrients flowing into the Big Thompson River (Figure 5). At Roberts Ranch, a large collaborative team, led by The Nature Conservancy and Wildlands Restoration Volunteers, used plants, wetlands, and rocks to reduce sediment flowing into local reservoirs near Livermore (Figure 6).

In 2013, the Exchange commissioned a study by the Center for Sustainable Economies and the World Resources Institute to understand if investments in our land and water quality ("green infrastructure") through the Exchange would be more cost effective than building additional water filtration at our public utilities ("gray infrastructure"). The study, titled A Preliminary Green-Gray Analysis for the Cache la Poudre and Big Thompson Watersheds of Colorado's Front Range, showed that investing in nature (green) was about half the cost of investing in construction (gray), for the same amount of water quality improvement.

Right now, we are creating a "Yellow Pages" of who is doing what in the Big Thompson and Poudre watersheds will provide information about those who study watersheds and water as well as those who try to improve our watersheds on the ground. Eventually, this will become an interactive, sortable, and updatable map online.

The Exchange now has an overall Working Group and teams for Science, Market Development, and Outreach/Fundraising, as well as a technical advisory team. Members include the Big Thompson River Restoration Coalition, Brendle Group, City of Fort Collins Utility, City of Greeley Water and Sewer, Coalition for the Poudre River Watershed, Colorado Natural Heritage Program,

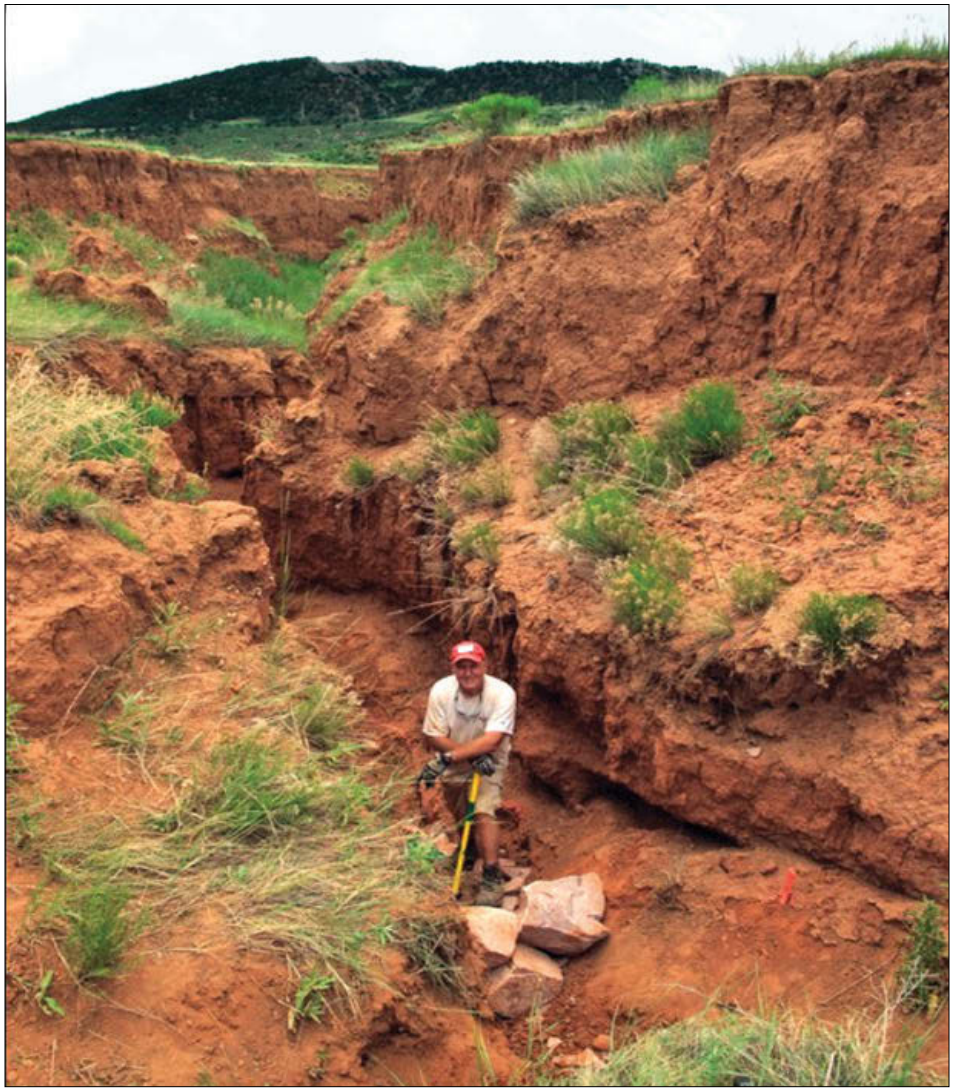


Figure 6. *Restoration of erosion at Roberts Ranch.* Photos by Wildlands Restoration Volunteers (above) and John Fielder (below)

Colorado State University, Community Foundation of Northern Colorado*, Ed Warner*, Environmental Incentives, Larimer County, Loveland Water and Power, Natural Resources Conservation Service, New Belgium Brewing Company*, Northern Colorado Water Conservancy District, Sylvan Dale Ranch*, The Nature Conservancy Colorado*, US Forest Service, Wildlands Restoration Volunteers, World Resources Institute and the Center for Collaborative Conservation* (* = collaboration and donor).

Other important collaborators are AltoTerra Services, Anheuser-Busch, Big Thompson Watershed Forum, CSU's Institute for Livestock and the Environment, Colorado Water Innovation Cluster, Colorado Water Institute, Environmental Defense Fund, Laramie Foothills Committee, Odell Brewing, Poudre River Trust, Poudre Runs Through It, Regenesis, and Roberts Ranch.

The Future of the Exchange

Members of the Exchange are currently raising funds to answer a generous challenge grant from Ed Warner, who recently also endowed the Center for Collaborative Conservation. Once funding is in place, the Exchange will finish the design phase and then launch it. Please join us and participate in building the Exchange!

The Center for Collaborative Conservation (CCC) at Colorado State University was founded to help accelerate collaborative efforts, train the next generation of collaborative leaders, and spread the word about great examples of collaborative innovation (www.collaborativeconservation.org).

Rep. Randy Fischer looks on as Governor John Hickenlooper signs HB 13-1044, an important water conservation bill authorizing the use of gray-water in Colorado. Rep. Fischer is joined by Senator John Kefalas; CSU President, Tony Frank; Professor Sybil Sharvelle, CSU's Urban Water Center; Rep. Joanne Ginal; and CSU System Chancellor, Michael Martin. Courtesy of Randy Fischer

Running the Legislative River

Thoughts from a Retiring Representative

Randy Fischer, State Representative, House District 53

This article offers observations based on my experience in the House of Representatives, where I have worked on water issues for eight years. I have focused on three potential barriers to crafting workable legislative solutions to complex problems: the legislative calendar, term limits, and partisanship.

Water issues inherently involve complexity, historical precedence, competing values and interests, emotion, and passion. Few issues are more important in determining Colorado's future economic and environmental sustainability than water, both in its quantity and quality. Despite considerable obstacles, the Colorado General Assembly has played a pivotal role in and made tremendous contributions to Colorado water policy over the years. Critical water planning efforts converge in 2014 and 2015 that will require the General Assembly to demonstrate wisdom and statesmanship to help secure Colorado's water future. Is the State Legislature prepared for the tasks that lie ahead?

As mentioned, potential barriers to crafting workable legislative solutions include the legislative calendar, term limits, and partisanship. I conclude with the hope that my successors in the General Assembly will continue to overcome these barriers and improve the deliberative process, especially on issues as fundamental to our state's success as water.

Finding an Eddy in the Legislative Flood

The artificial deadlines and time pressures of the annual legislative calendar create barriers to achieving the ideals of deliberative democracy, dialogue, and collaboration. As many as 700 bills may be introduced in each 120-day legislative session. The time available for giving meaningful consideration to each piece of legislation is unreasonably condensed. Legislators are sometimes motivated by a sense of urgency to get as much done in the 120-day legislative session as possible. The temptation to force legislation and forego adequate stakeholder deliberation is powerful. The alternative is to wait another year to run a particular piece of legislation. In a term-limited environment, the short time in office weighs heavily on legislators' thought processes such that a year seems like an eternity to wait for a better opportunity.

Navigating the Term Limit Shallows

In 1990, Colorado voters passed a constitutional amendment limiting legislators' terms to a total of eight years in each chamber. In my opinion, term limits create a knowledge and leadership vacuum which prevents the legislature from fully realizing its role as Colorado's democratically elected policy-making body. The learning curve on water policy issues is immense. Few legislators bring water expertise to office. Lobbyists readily fill the knowledge vacuum and may be sources of non-partisan water information. However, legislators must realize that lobbyists seldom check their clients' interests at their office doors.

Term limits, combined with the short length of the legislative session, prevent legislators from developing institutional memories, negatively impact the committee and House and Senate leadership structures, and deter lawmakers from tackling complex issues, such as water. As an example of the impact term limits have on committee leadership, the chairs of both the House and Senate Ag Committees are term limited in 2014 and will not be returning in 2015.

Paddling through Partisan Whitewater

The type of true dialogue and cooperation needed to resolve water issues often seems impossible in the politically charged atmosphere at the State Capitol. On social issues, partisanship and political debate often substitute for thoughtful dialogue in the State Legislature. Water issues, however, tend to transcend party politics, although geographic differences can be even more divisive. Some of the most rancorous water debates occur over issues such as trans-basin diversions, urban versus rural interests, or east slope versus west slope issues.

The Colorado General Assembly has exhibited moments of true statesmanship and often avoided partisan pitfalls to craft enlightened, progressive water policy. Past examples of inspired statesmanship in the water arena resulted in the Water Right Determination and Administration Act of 1969, which reformed and modernized the legal underpinnings of the Colorado Doctrine and House Bill 05-1177, the Water for the 21st Century Act, which established the basin roundtables and Interbasin Compact Committee.

A recent example of legislation that overcame partisan considerations included House Bill 12-1278, which directed the Colorado Water Institute to conduct a critically needed study of the South Platte alluvial aquifer. I was the prime sponsor of HB-1278 during a term in which I served in the minority party. It would have been easy for the majority party to make certain the bill never made it out of committee, but the issues raised in HB-1278 rose above partisan ideological differences. The ultimate passage of HB-1278 deserves recognition as an example of cooperation among traditional political adversaries. I will always be grateful to the members of the House Ag Committee for their statesmanship. Citizens came to the Committee, expressed their concerns, and made their case for legislative action. The committee took the time to listen to and understand the citizens' concerns and responded thoughtfully by authorizing the study.

Learning to Roll

Fortunately, antidotes exist for dealing with the calendar, term limits, and partisanship. Educational opportunities for legislators abound, and interim committee participation provides a more in-depth deliberative process for mitigating time constraints, delving into complex issues, and overcoming geographic and urban versus rural divisions.

Objective, non-partisan organizations, such as the Colorado Foundation for Water Education (CFWE), are critical for filling the water knowledge gap for citizens and legislators alike. CFWE plays a crucial role in providing real-world experiential learning opportunities about water from which I have personally benefited.

The Colorado Water Congress (CWC) State Affairs Committee's role in vetting water legislation is legendary. Legislators interested in water issues must inevitably stand and deliver their proposals before this committee of water experts and practitioners. The CWC's practice of setting up subcommittees to work with sponsors on their bills is an invaluable

collaborative process for ensuring the quality of draft legislation and for learning about water issues. This practice of setting up subcommittees is unique among organizations working at the Capitol. In addition, the CWC's educational seminars and conferences are invaluable sources of water education open to all legislators.

In 2001, the legislature created the Interim Water Resources Review Committee (WRRC). An appointment to the WRRC affords legislators with extraordinary opportunities to learn and gain valuable, in-depth water experience to partially mitigate the impacts of term limits and to counteract the compressed nature of the legislative session's time constraints. Unfortunately, the privilege of serving on the WRRC is limited to five representatives and five senators, only a tenth of the legislature. The 10 members of the WRRC become by default the legislature's water leaders. As chair, I have reached out to other legislators who are not official WRRC members to invite their participation in the 2014 meetings.

Conclusion

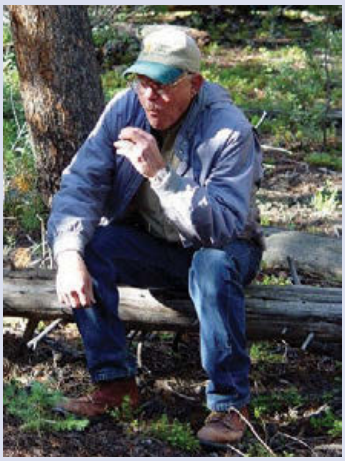
The "lay of the water" in Colorado is rapidly evolving. This is a time of great potential as multi-year water planning efforts converge. As I leave the House of Representatives due to term limits, I sincerely hope that the Colorado Legislature continues to demonstrate statesmanship and rises to the challenge of implementing the Interbasin Compact Committee and Colorado Water Plan recommendations. I hope the legislature continues to collaborate across party lines, build consensus, and engage in thoughtful dialogue on water issues. I hope that organizations such as CFWE, CWC, and Colorado Water Institute continue to exert their positive energies in helping legislators overcome the considerable barriers to crafting the forward-thinking public policies that Coloradans deserve and expect. Colorado's quality of life, vibrant economy, and healthy flowing rivers hang in the balance.

Representative Randy Fischer is a registered professional engineer who was born and raised in Fort Collins, Colorado. He represents the western half of Fort Collins in the Colorado House of Representatives where he has served for eight years. For the past three years, he has chaired the House Committee on Agriculture, Livestock, and Natural Resources. As chairman, he serves as an ex-officio member of the Interbasin Compact Committee and on the boards of the Colorado Water Institute and the Colorado Foundation for Water Education. He also serves in 2014 as the chairman of the legislature's Interim Water Resources Review Committee.

In Memory of Freeman Minson Smith

Modified from Warner College of Natural Resources Announcement

Freeman Minson Smith, Emeritus Professor of Watershed Science in Colorado State University's Warner College of Natural Resources, passed away of natural causes at 75 years of age on October 3, 2014 in San Mateo, California. Freeman left a lasting impression among colleagues, students, and friends and will be remembered and missed by many.



Freeman joined the watershed faculty in 1971 and retired from Colorado State University in 2005. He taught courses in Ecosystem and Watershed Modeling and represented Watershed Science in the college-wide Natural Resources Management courses for seniors. He also worked closely with the NSF-sponsored IBP Grassland Ecosystem Program.

Freeman enjoyed working with international graduate students. He organized and led the College International Forestry School, one of several international schools on campus during the 1980s and 1990s. In the late 1980s, Smith was selected to coordinate the Peace Corps Master's Program in Forestry and Natural Resources.

Freeman also enjoyed interacting with undergraduates. He taught Principles of Watershed Management and served as a member of the teaching team for the summer field course at CSU's Mountain Campus at Pingree Park (NR220) for many years.

Colleagues and friends describe Freeman as a kind, generous, patient, thoughtful, dedicated, congenial man of unwavering integrity. He was highly respected by students and faculty and recognized and appreciated as a mentor for new faculty. Freeman has been described as the "glue" behind key activities and a critical support person. He often stepped up to do things that others did not want to do, or did not have the time for. Freeman Smith will be missed much, by so many.

Water Court Settlement and Trial Process in Colorado

Daniel Brown, Attorney, Fischer, Brown, Bartlett & Gunn, PC

A majority of water court cases are settled before trial. This is partly due to the cost and nature of water court and the water court process, which involves a preliminary meeting with a water referee. During the process, engineers also meet to discuss the matters at hand and come to agreements if possible to aid in settlement.

Water court is considered by many water users as the worst possible environment in which to amicably and economically resolve water conflict. These folks view the process rather like sailing 'round the Horn—dangerous and unpredictable; an undertaking made only of sheer necessity where you are certain to emerge battered. This view has been reinforced by several recent, highly publicized cases, such as the East Cherry Creek Valley/ Farmers Reservoir and Irrigation Company/United Case 03CW403. This case involved more than 50 parties, untold pages of expert disclosures, countless hours of negotiation and preparation, weeks of trial, an appeal to the Supreme Court, and no doubt millions of dollars spent by the parties, and in the end, a disappointing result for the applicants. Even more routine water court cases often involve considerable time, expense, and uncertainty, and leave parties frustrated with the process even if successful.

So, given this sentiment, it may be surprising to learn that in Water Division No. 1 (South Platte Basin), generally considered to be the most contentious of the water divisions, a vast majority of the hundreds of cases are filed each year settle before ever making it onto the court docket and without a great deal of drama or fanfare. From the end of 2009 through June 2014, over 1,850 cases have resolved in Division No. 1, with fewer than 30 going to trial.

If the water court process is so hostile, why do so many water court cases settle? Does the high rate of settlement provide evidence to counter the notion that water court is a difficult place to resolve conflict? I believe the answer is yes in large measure, but there is more to the story.

The place to begin is to understand what "water court" is, and how the process works. "Water court" is not a special type of court or hearing; rather, the term "water court" is a way to refer to the District Court when it hears a case involving a water claim, or a "water matter." Water matters go before the "water judge," who is a district court judge appointed by the Supreme Court to hear water matters. So, it is important to remember that water court is like any other court proceeding, and therefore adversarial by its very nature.

What makes water court different is that it is governed by special statutes and court rules, in addition to the standard rules of civil procedure. These rules to a large degree have as their aim the resolution of water matters without need for trial. Most notably, water matters are typically first referred to a referee for initial investigation and initial case management. The "water referee" is a person appointed by the water judge who is qualified by training and experience to render expert opinions and decisions on complex water matters.

The water referee's job is to investigate all water court applications and consult with the Division Engineer at the outset of every case. To aid in this investigation, an applicant must provide specific information with the water court application. The referee may also require information to be provided and do his/her own independent investigation of the claims. All of this is unique to water applications and, unlike most other court cases, results in a prompt, expert, third-party review of the claims and factual assertions, and helps to identify and narrow issues for the parties at the outset.

Additionally, the rules require the water referee to actively manage cases to aid in settlement. The referee is supposed to issue a ruling within 63 days, but this deadline is routinely extended to up to a year, and then again for another six months if it appears the case is likely to resolve in that time. As a condition for remaining before the referee for this long, all parties must agree to waive their right to return the case to the water judge while it is before

the referee. The point is to allow the parties to work toward settlement in a less structured environment free from trial court rules and deadlines. It used to be that case management by the water referee was very informal, and cases could and did remain on the referee docket for years without any significant action taking place. With amendments to the water court rules that took effect in 2009, not only is a case limited to no more than 18 months before the water referee, but the referee has become much more active in managing cases. The result is earlier exchange of information and mandatory participation in status conferences so the referee can more closely monitor cases and push the parties to negotiate and resolve.

However, a ruling of the water referee can never be binding, because all parties have the right to "protest" a referee's ruling and send the matter to the water judge. As a result, the referee's authority and effectiveness are limited. The practical implication is that the potential exists for parties to abuse the process by delaying, stonewalling, or otherwise refusing to meaningfully negotiate without the threat of adverse consequence while a matter is before the referee. Still, the referee system produces results. Between the end of 2011 and the end of June 2014, over 900 cases were resolved, while only 155 cases were set for trial.

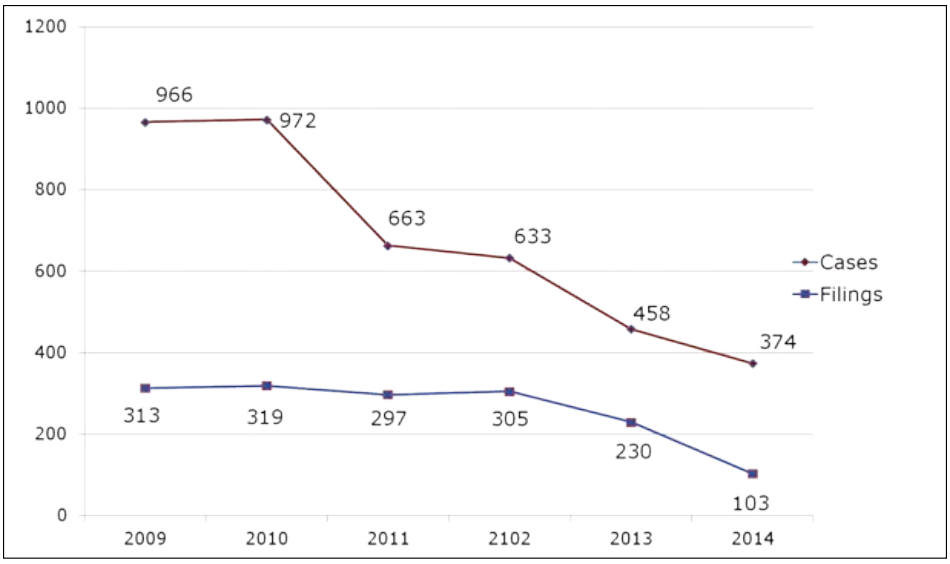
It is important to remember that water court is like any other court proceeding, and therefore adversarial by its very nature.

Of course, because the referee's findings and rulings are not binding, not all cases resolve before the referee. Cases that cannot be settled are "re-referred," at which point the matter goes to the water court to be set for trial. When this happens the case is "at issue," and thereafter the typical rules of civil procedure apply, including the disclosure, discovery, and expert opinion deadlines typical of all court cases. Still, the water court rules continue to encourage settlement. For instance, the 2009 revisions to the water court rules require a "meeting of experts" where the parties' engineers meet to discuss the issues in the case, and lawyers cannot be involved. This sort of meeting is unique to water court. The intent is to create a "space" where the experts can frankly debate and discuss differences of opinion free from the fear of prejudicing their clients' case. In so doing, it is hoped that the experts can come to a meeting of the minds and/or narrow disputed issues before trial and thereby aid the lawyers working toward settlement.

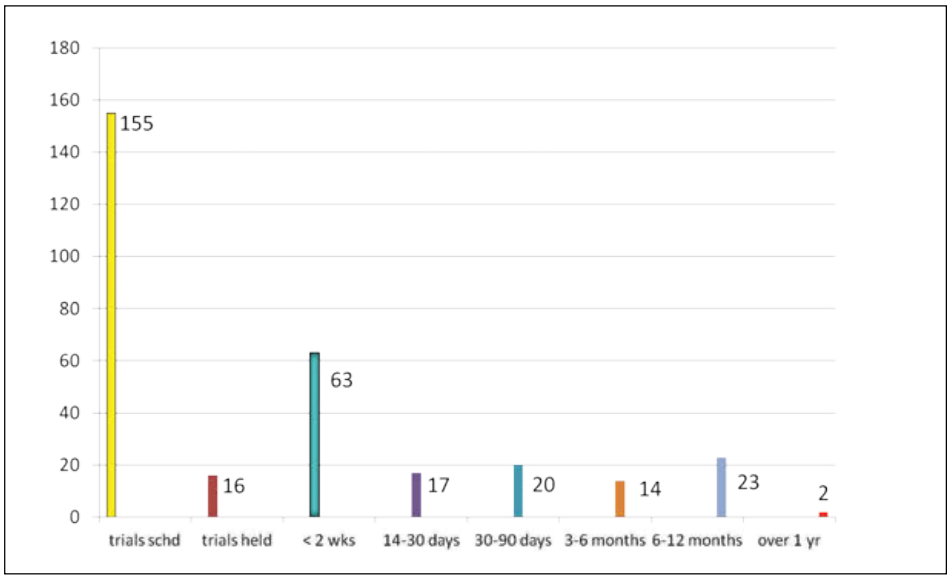
Even for cases that are set for trial (which are typically the more complicated and controversial), the vast majority settle. Of the 155 cases set for trial between 2011 and 2014, only 16 went to trial. However, it would be a mistake to attribute settlement in most of these cases to the special water court rules. As always when approaching trial, the major inducement to settle remains the risk and expense of trial. Interestingly for water cases, it seems an inordinate amount of settlement takes place immediately prior to trial. Of the 139 cases that were set for between 2011 and 2014 that settled, 80 (or 58 percent) settled within a month of trial, and 63 of these (or 48 percent) settled within two weeks of trial. My guess is that of these 63, half or more settled within a few day of trial.

There are a variety of reasons for this, human nature among them. However, I think the water court process aggravates the problem. In Division No. 1, it is typical for all but the simple cases to have from five to 15 parties. For highly-contested cases, 50 objectors or more is not unheard of. Most include at least one municipality, water district, or other water user that is routinely involved in water cases and is generally active, motivated, and

Photo by Jason Morrison



Graph 1. *Water Division No. 1 open cases and new filings*



Graph 2. *Water Division No. 1 trial settlement information: 2011-2014*

well-funded. The collective weight of such opposition can be extreme, particularly for the smaller/novice applicant. Merely managing a case with a large number of parties can strain many applicants' capabilities and resources, particularly close to trial, when most trial deadlines are looming. All the while, applicants are typically trying resolve issues with all of these parties, often seemingly all at once, while at the same time trying to prepare for trial.

Opposers, on the other hand, largely focus on only the applicant and usually the handful of issues of particular concern to them. The net effect can at times be something of a "mismatch" that, as a practical matter, can give opposers a lot of settlement leverage. When dealing with many opposers, applicants often have the distinct feeling they are being picked to death with demands being made by numerous parties, each with the ability to force the case to trial over any issue, or even just to compel the applicant to put on their case. This is not to say that applicants are always the victims. In some instances applicants, recognizing that they are not likely settle until very late in the game, essentially ignore certain issues and parties until close to trial. For small parties with a single issue to resolve, it can become financially burdensome to stay through the run-up to trial until an applicant is willing to deal with their issue. In the end, though, there is rarely anything malicious, devious, or improper going on—this is just how the trial process works. It is often only on the eve of trial that parties are willing to make the tough concessions necessary to resolve the case, even if they view such concessions as painful or unnecessary. The certainty of settlement is often preferable to a costly and uncertain trial.

So getting back to the question, does the high rate of settlement provide evidence to counter the notion that water court is a difficult place to resolve conflict? My response is yes, at least to the extent that any court process successfully resolves conflict. By and large, the complaints many have about water court are frustrations with an adversarial process. This is not to say that improvements can't or shouldn't be made to make the process quicker, cheaper, and fairer, particularly for the very simple cases (which should be kept simple) and for the highly contested cases (to "level the playing field" at least modestly for applicants). In my opinion the water court process could be improved by creating in the rules (1) meaningful deadlines with real consequence earlier in the process, including when the case is before the referee, and (2) methods of focusing the issues to those that are actually contested and limiting trial to these issues earlier in the process, thereby reducing the extent that opposers can use the trial to "leverage" settlement.

Thoughtfully Addressing Water Conflict

Joseph McMahon, Manager, Collaborative Processes LLC

This article suggests that those engaged in water conflicts of any kind consider two core issues: first, the importance of thoughtfully considering how to approach the conflict and how to select from among the conflict resolution options; second, to encourage parties to recognize the significant value of engaging water professionals or technical consultants in addressing water conflict.

Introduction

Working first as a consulting water engineer, and later as water lawyer and mediator, I had the opportunity to observe a wide variety of water conflicts. Water conflicts can arise at every level of conflict intensity, from merely having different ideas about how to undertake a water project to intensely fought water litigation. My professional movement from consultant and trial lawyer to mediator and facilitator has shown me the value of approaching conflict, including water conflict, thoughtfully. A great deal of expense and energy can be wasted, many times also resulting in suboptimal outcomes or resolutions.

Conflict and Water Conflict

As a base for this discussion, we could adopt the definition of conflict used by authors Carsten K. W. De Dreu and Michele J. Gelfand:

> Conflict is a process that begins when an individual or group perceives differences and opposition between itself and another individual or group about interests and resources, beliefs, values, or practices that matter to them.

In my experience, this generic definition applies to water conflict because, in many ways, water conflicts are like all other conflicts. The same psychology applies, and water conflicts go through the same four stages of conflict that other conflicts do (those being the stages of awareness, confrontation, negotiation, and transformation).

Water conflicts are like some other conflicts because water conflicts often involve "repeat players"—meaning you may confront the same opposing parties time and time again. Examples could be water users on the same stream system that compete for water, or land owners along a river floodplain who are all affected repeatedly by floods and droughts. Water conflicts also, like many others, can involve routine and low level conflict—as well as very intense litigation (or even violence).

Water conflict is unique because it is very personal. Water users and adjacent land owners feel very attached to their water—as strongly as to their home. In Africa, there is a saying that "if you touch my land or water, you touch my throat." This is true in the U.S. also.

Water conflict has not only intensity, but also a great variety. Water conflicts could include conflict over

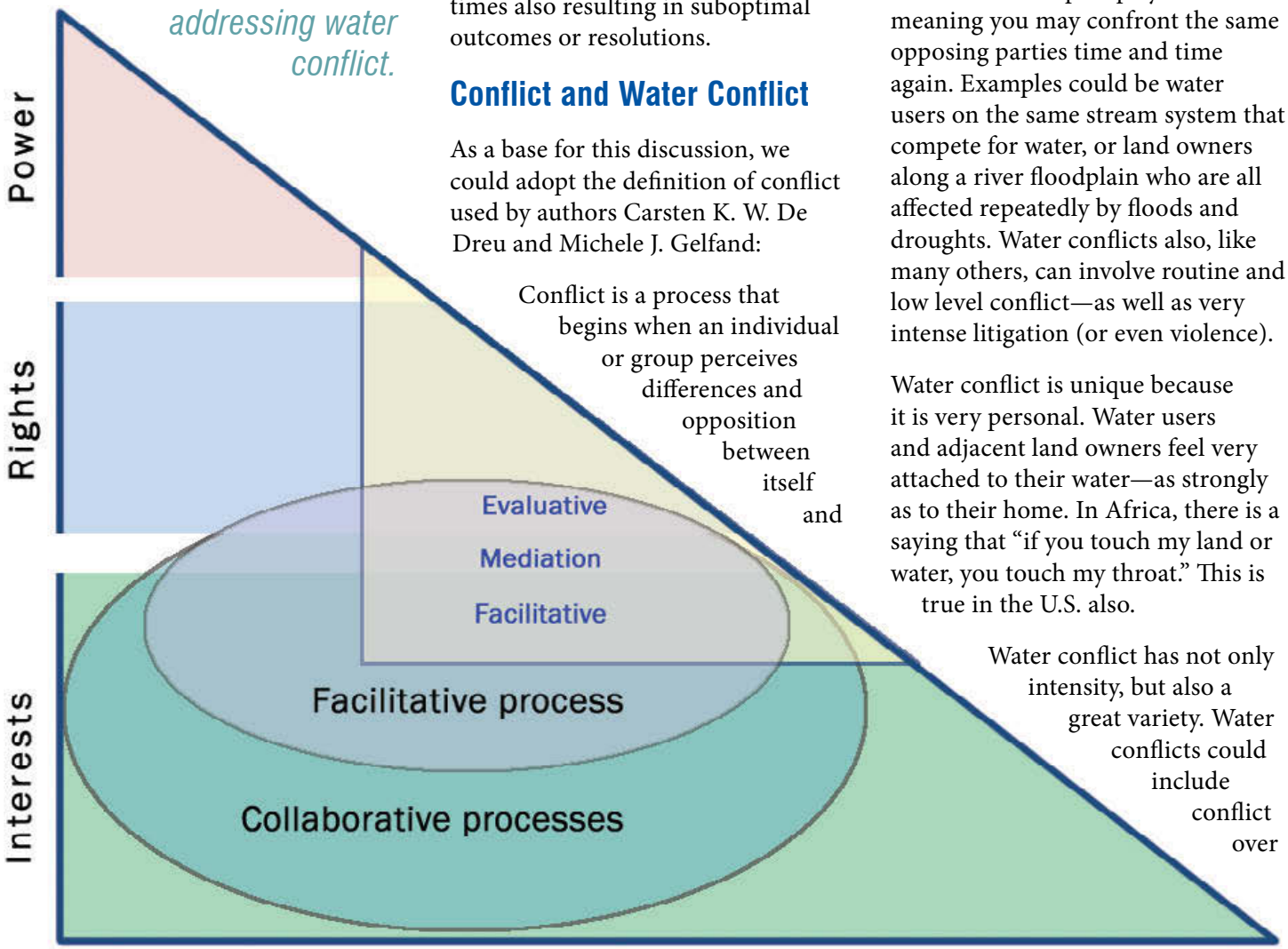


Figure 1. *The three approaches to conflict*

water rights, water administration, floodplains, basin plans, water boundaries, conjunctive use, water organizations, regulatory agencies, water conveyance, contamination, storm runoff, groundwater movement, endangered species, and so forth.

How Water Conflict Can Be Addressed

A fundamental concept of conflict developed by dispute resolution pioneers is that there are three fundamental approaches to conflict: one based on the power of a party to compel the opposing party to act (the "power based approach"), an approach based on the legal and equitable rights of the conflicting parties in which legal guidance is paramount (the "rights based approach"), and lastly an approach based on the real needs and interests of the conflicting parties where there is less emphasis on law and more work to balance each party's needs with those of the others (the "interest based approach").

These three approaches are very different. Power is easy to understand—the more powerful party forces the other less powerful party to comply. The "rights" based approach tends to work more in law and equity. Example: water litigation is a rights based approach as would be a mediation based in looking at litigation risk and benefit.

The unique approach—interest based—is a collaborative process in which parties explain their needs and the stakeholders (often with the assistance of a mediator or facilitator) meet to (a) understand the needs/interests of each other and (b) fashion resolutions and plans that adequately meet the interests of all involved.

Although both power and rights based approaches may be forced on a party (such as litigation in which participation is essentially required or the court orders a settlement conference), the interest based approach is voluntary. As noted in Figure 1, interest based approaches not only seek action (an outcome), but also work to improve relationships and transform conflict from destructive to productive.

Core Consideration #1: Thoughtfully Choosing How to Approach the Conflict

Because emotion often runs high in water conflicts, decisions claimed by parties to be rational are in fact made emotionally. This can result in a rush to the court before the conflict has been thoughtfully assessed. The move to litigation is not irreversible, but the change in course from a rights or power based approach in court to a productive interest based process is difficult. In many instances, if the parties assessed the real causes of the conflict and engaged in communications with opposing parties aimed at resolution, they could avoid a lengthy trip down the "litigation path." I strongly recommend interest based approaches as a starting point for water conflict, resorting to rights based approaches only if absolutely needed. Common steps include:

Step 1: Assess the conflict by asking: Who are the real parties? Who needs to be involved? What is the dispute about? What triggered the dispute? What can be done to avoid conflict escalation? What are the bona fide interests of each party involved? What are the disputes (such as technical, relational, regulatory, personality, and so forth)?

Step 2: Consider how an interest based approach can be undertaken: Who should participate? What are the key topics? What information is needed for such a discussion? What expertise is needed to assess the data and consider options for resolution? Should such a process use a mediator or facilitator? What would an interest based process include? What topics and in what order?

Step 3: Work to convene the interest based process. Decide who to invite and do so. Make early ministerial concessions to get things started (such as travel to their location or office). Let all parties play a role in planning and adjusting the process.

Core Consideration #2: Recognize the Value of Engaging Water Professionals or Technical Consultants in Addressing Water Conflict

An underutilized approach to addressing water conflict is that of convening professionals and consultants from opposing parties to clarify the zones of dispute. In conflicts involving technical matters, there is almost always some level of misunderstanding. As such, there is both real conflict (reasonable judgments differ) and unnecessary conflict (based on misunderstanding each other's technical position). A convening of technical experts or consultants can begin the process where emotion and distrust is somewhat reduced, allowing trust to build slowly.

The water professional or consultant often brings more of an unbiased and science based perspective to a conflict. The water professional, even though aligned with a party, can present information that is evidence rather than positional based. When professionally presented, the water professional is often in an excellent

position to explain his party's needs and interests in a rational way, making them more believable to others. The hope is that, when water professionals work together as a group searching for agreement and clarifying disagreement, the discussion focuses on the science rather than *my science* and *your science*.

Having facilitated a number of such working groups, I note some examples:

- Hydrogeologists confer to assess evidence about preferential pathways below a landfill and how differing views could be accommodated by a well-considered groundwater monitoring system.
- Surface water hydrologists confer to consider how to make periodic releases of reservoir water for endangered species while avoiding flooding newly planted fields.
- Hydrogeologists confer about differing data interpretations on underlying geology at a barrel fill site.
- Geotechnical experts confer to assess how to manage stormwater at an environmental remediation site.
- Remediation experts consult to determine why they differ on remediation cost estimates.
- Consultants bring in geochemists to assist in assessing the likelihood of formation of clay lenses in underlying materials.
- Senior executives have their respective financial consultants (in-house or engaged) review disputed records of transactions to help executives negotiate a settlement based on key rather than all disputes.

Conclusion

Thoughtful conflict assessments ensure that parties do not rush to the wrong method of addressing conflict. At some early point, engaging productively with opposing parties can head off expensive litigation or prolonged conflict. Where suitable (and it often is), parties should use water professionals as resources to narrow conflict, define where professional judgments are aligned and where they differ, and help senior management/boards understand the salience of such. Water professionals can not only narrow and clarify conflict but also serve a valuable role in exploring paths to conflict management and resolution.

Using Public Deliberation to Address Colorado's Big Problems

An Interview with Martín Carcasson

Lindsey Middleton, Editor, Colorado Water Institute
MaryLou Smith, Policy and Collaboration Specialist, Colorado Water Institute

Wicked Problems

The democratic process often relies on rational discourse, expert opinion, or the use of activism to affect change. Such practices can become counterproductive in solving what scholars have coined "wicked problems."

Water in Northern Colorado is an example that CSU professor Martín Carcasson often uses to illustrate the concept. Those with a vested interest in Colorado's water value a particular aspect of water—the agricultural producer wants to ensure his or her water rights; the angler wants waterways to be healthy for fish. These values are often separated in to what Carcasson calls boxes.

"Most arguments are within one box," he says, "and that's the problem. The conversation we need to have is about the tension between the boxes."

Inherently, wicked problems cannot be "solved" in the sense of reaching a single, encompassing conclusion, which is something the public desires. Rather, in this case, the goal becomes using public deliberation as a means of working through disagreements between vested groups and fostering a broader understanding of the problem. The public, stakeholders, or other parties of interest must come together to take on the wicked problem itself rather than continue struggling against each other.

This process is known as deliberative democracy, a concept that Carcasson has worked to bring to the CSU Department of Communication Studies.

CSU's Center for Public Deliberation

Carcasson came to CSU in 2003, and for his first two years with the department, he maintained a traditional teaching style related to debate and argumentation. His work to that point had focused on researching and critiquing political discourse related to big issues like poverty, education, and the environment. But he began to realize that most of his academic work involved writing about why current approaches weren't sufficient. Carcasson says he reached a turning point when he was asked to write a paper about President Clinton's second term race initiative, which involved dialogue and deliberation.

"At the time, I'm teaching argumentation and debate classes, and I get exposed to material focused on dialogue and deliberation," says Carcasson. "And I realize, this is better than debate. This is what we need to be teaching."

Carcasson was able to transition a course at CSU called Rhetoric and Argumentation into what he called Public Argumentation. Initially, the class would involve research, evidence-building, and then two debates which required each student to research and argue both sides of the same issue over the semester. The students, many of whom had initially chosen topics because they felt strongly one way or the other, often left the semester confused and unmotivated about their topic. Carcasson believed this happened because the debate model required students to focus completely on either supporting or attacking a specific proposal, leaving no one to explore or work through potential middle ground.

In the reworked class, after the debate portion, the students would now put together a deliberative document in which they would present three "approaches" (not solutions) to the problem, including arguments for and against each and limitations. Their role is to provide a clear map of the issue for the community, essentially laying out the choices the community needs to make, and the various consequences of those choices.

The class now focused on how the students can collaborate to support improved community decision making. Carcasson introduced ideas like, *What do you do if you find a piece of evidence that supports the other side?* "If the goal is to be competitive," explains Carcasson, "you hide the evidence. But if the goal is to collaborate and make better decisions, you present your evidence to the opposing side."

Carcasson initially ran into complications when he decided to develop an advanced course to expand on the concepts from Public Argumentation. The goal was for students to research a topic, develop materials, receive some training as facilitators, and run a public event to engage the issue in the local community. The class, though, was open enrollment, meaning not all the students felt passionate enough to put in the effort required, and it became

CPD Student Associates Jack Becker and Mar Parsaye facilitate a table discussion during the Poudre Runs Through It deliberation session at Timberline Church in Fort Collins in April, 2011.

clear that one semester was too limiting to equip students and make the events possible.

"I remember thinking, that class did not work like I planned. But if I had just those dedicated students and more time with them…" says Carcasson. "That's where the idea for the [Center for Public Deliberation] was born."

Carcasson was also working with the National Issues Forum (NIF), and on their website, he had come across the NIF network. The network includes centers and institutes in each state mainly based out of universities that use the NIF materials to do training and run public dialogues. Starting such a center, he found, would involve training and a three-year startup grant, and would also require an advisory board from off campus.

After going through the training process and making plans for the center, Carcasson began making calls to fill an advisory board. Carcasson had envisioned following through with his original plans for the Public Deliberation course—the class would pick a topic, study it, and put on a public event. His plan changed when one of his calls to a school district communications director resulted in a request to help run an upcoming meeting. The students helped with that event, which went very well, and then Carcasson was approached for another project regarding district grade configuration—the question of whether to move sixth grade students to junior high and eighth graders to high school in Fort Collins schools. The center ran six nights of meetings with over 600 people, all conducted by the students, and based on materials developed by Carcasson and other planners. Over the years since the center was developed in 2005, only two of their events were based on topics selected by the center. The main resource for events has been the result of outside groups approaching for help. In Carcasson's opinion, this clearly demonstrates that the CPD was filling a critical void in the community. "It is clear many people were starving for genuine conversation and engagement," he says.

Carcasson generally works with around 30 students —15 incoming students take a facilitation training course during their first semester with the program, and those students are required to take one credit hour of practicum their second semester, which entails 40 clock hours. This setup allows Carcasson to have experienced students available each semester. Having such a large group of trained facilitators also allows Carcasson to avoid typical public processes that rely on having participants speaking one at a time into a microphone and typically talking past one another. At CPD events, participants can be split into small groups with two trained students at each table—one to facilitate a unique process designed for that topic, and one to record notes.

"Instead of a place for people to express their opinions, it's a place for two things—for them to react to information framed for discussion,

Poudre Runs Through It dialogue participants facilitated by Center for Public Deliberation students, April 2011, Drake Centre, Fort Collins. Photo by Stephen Smith

Poudre Runs Through It dialogue participants facilitated by Center for Public Deliberation students, April 2011, Drake Centre, Fort Collins. Photo by Stephen Smith

and for them to interact with people they normally wouldn't interact with." Having students trained for this process was important, Carcasson adds. "We train facilitators to help people talk to each other—we want to get away from a collection of individual opinions."

Carcasson describes this as a "win-win-win-win" scenario. CSU students gain direct facilitation experience, including conflict management, collaboration, and tackling tough issues. The university gains credit for an outreach program that provides a public service. The community benefits through the use of a free service of process design and trained facilitators, where the expense of hiring an outside firm can be prohibitive. The fourth benefit, says Carcasson, is for himself—the program is a platform through which he can research deliberative democracy.

The Center for Public Deliberation was the first NIF center formatted with a dedicated coursework and such a depth of student participation, so Carcasson's responsibilities have also included developing training materials for other centers. He has also trained 13 Extension agents in the facilitation process.

Applying Deliberative Democracy to Colorado Water Issues

There are many issues in Colorado that could fall under the label of wicked problems. The state is currently working on developing a Colorado Water Plan, which will address how to fill a projected gap between future water supply and demand caused by growing population, drought, and climate change. Water shortages are anticipated to affect agricultural producers and municipalities, tourism and recreation water use, industry, and the environment.

In moving forward with this plan, roundtables are convening to propose a plan for their basins. From a deliberative democracy standpoint, Carcasson believes that such meetings, as well as future communications to the public, should not portray the Colorado Water Plan as an all-encompassing solution that solves the various problems with water in Colorado. This approach conveys to the public that the problem is already solved by experts, and does not encourage public participation. Rather, the plan should present the reasoning behind various options for addressing certain tensions, giving the public the chance to express their opinion about the tensions and how they might best be approached.

Recent Publications

Factors affecting temporal variability of arsenic in groundwater used for drinking water supply in the United States- Science of the Total Environment, DOI: 10.1016/j.scitotenv.2014.02.057; Ayotte, Joseph D.; Belaval, Marcel; Olson, Scott A.; Burow, Karen R.; Flanagan, Sarah M.; Hinkle, Stephen R.; Lindsey, Bruce D.

The USGS National Streamflow Information Program and the importance of preserving long-term streamgages – USGS Fact Sheet: 2014-3026; Hodgkins, Glenn A.; Norris, J. Michael; Lent, Robert M.

Status and understanding of groundwater quality in the South Coast Interior groundwater basins, 2008: California GAMA Priority Basin Project - USGS Scientific Investigations Report: 2014-5023; Parsons, Mary C.; Kulongoski, Justin T.; Belitz, Kenneth

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Groundwater quality in the South Coast Interior Basins, California - USGS Fact Sheet: 2013-3088; Parsons, Marcy C.; Belitz, Kenneth

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Two graphical user interfaces for managing and analyzing MODFLOW groundwater-model scenarios - USGS Techniques and Methods: 6-A50; Banta, Edward R.

Long-term soil monitoring at U.S. Geological Survey reference watersheds - USGS Fact Sheet: 2014-3002; McHale, Michael R.; Siemion, Jason; Lawrence, Gregory B.; Mast, M. Alisa

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Contaminants of emerging concern in ambient groundwater in urbanized areas of Minnesota, 2009-12 - USGS Scientific Investigations Report: 2014-5096; Erickson, Melinda L.; Langer, Susan K.; Roth, Jason L.; Kroening, Sharon E.

Water quality at a biosolids-application area near Deer Trail, Colorado, 1993-1999 - USGS Scientific Investigations Report: 2013-5074; Yager, Tracy J. B.

Water quality and algal community dynamics of three deepwater lakes in Minnesota utilizing CE-QUAL-W2 models USGS Scientific Investigations Report: 2014-5066; Smith, Erik A.; Kiesling, Richard L.; Galloway, Joel M.; Ziegeweid, Jeffrey R.

A screening tool for delineating subregions of steady recharge within groundwater models Journal Article; Dickinson, Jesse E.; Ferré, T. P. A.; Bakker, Mark; Crompton, Becky

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Spatial and stratigraphic distribution of water in oil shale of the Green River Formation using Fischer assay, Piceance Basin, northwestern Colorado USGS Scientific Investigations Report: 2013-5241; Johnson, Ronald C.; Mercier, Tracey J.; Brownfield, Michael E.

Characterization of salinity loads and selenium loads in the Smith Fork Creek region of the Lower Gunnison River Basin, western Colorado, 2008-2009 USGS Scientific Investigations Report: 2014-5101; Richards, Rodney J.; Linard, Joshua I.; Hobza, Christopher M.

Mobilization of selenium from the Mancos Shale and associated soils in the lower Uncompahgre River Basin, Colorado Journal Article; Mast, M. Alisa; Mills, Taylor J.; Paschke, Suzanne S.; Keith, Gabrielle; Linard, Joshua I.

Geospatial database of estimates of groundwater discharge to streams in the Upper Colorado River Basin USGS Data Series: 851; Garcia, Adriana; Masbruch, Melissa D.; Susong, David D.

WaterQualityWatch and water-quality information bookmark USGS General Information Product: 157; Wilde, Franceska D.

Floods, Communication, and Climate Change

Exploring the Role of Media Use and Interpersonal Discussion in Connecting Water-Related Extreme Weather Events to Perceptions About Climate Change

PI: Ashley Anderson, Journalism and Technical Communication, Colorado State University

A growing body of scholarship is investigating how extreme weather events shape people's perceptions of climate change. These weather events are tangible and local experiences that make climate change more personal rather than an abstract and distant concept. As a result, climate change communication efforts have successfully used local television weathercasters to raise awareness about climate change during extreme weather events. Less studied is how people talk about climate change in the context of extreme weather events. Also not as highly studied is how people use social media to discuss these issues, even though online media platforms such as Facebook are highly used by opinion leaders to discuss climate change and energy issues. In this project, Anderson examined the broad research question: How does communication use during the September 2013 flood event in Colorado play a role in how people perceive, discuss, and seek out information about climate change?

Discussion of Climate Change in Social Media During the Flood Event

To investigate how opinion leaders discuss the issue of climate change in the context of the flood event in social media communication, Anderson collected all Twitter posts that mentioned the event in the two months surrounding the event. Tweets were examined for categories of information, expressing several findings:

- The majority of tweets regarding the issue either portrayed a stance that climate change is connected to the flood event, or posed a question as to whether there is a connection between climate change and the flood event. Few posts denied the connection between the two.
- Many of the posts used sarcasm to convey contempt for or mock climate change deniers, or individuals who do not believe in the existence of climate change.
- Most of the individuals who used Twitter to communicate about the issue of climate change related to the flood event considered themselves to be opinion leaders in at least one issue area.

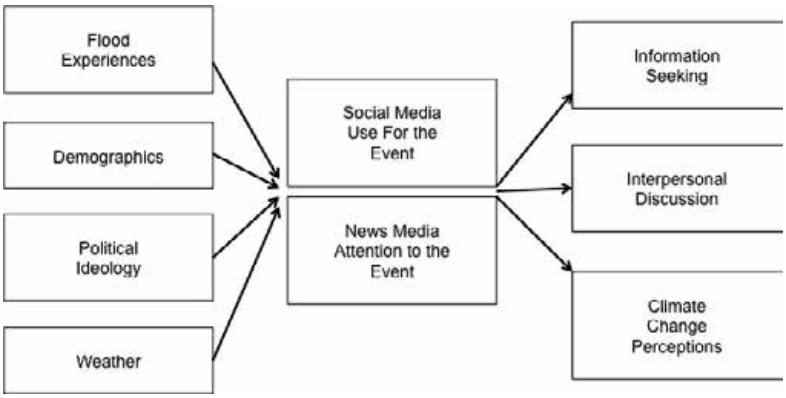


Figure 1. *Predicting climate change engagement outcomes with a survey of Coloradans.*

Perceptions of Climate Change

Perceptions of climate change in Colorado were analyzed prior to the flood event. Several of the perceptions reported in the initial event were compared to those same perceptions following the event. It was found that the percentage of people associating at least some influence of climate change with flooding of rivers and lakes increased from 69% to 79.8% after the 2013 flood.

Reported Communication Use During the Flood Event

Individuals reported utilizing a variety of communication modes during the flooding event:

- Read about it in a news media source (89.4%)
- Read about it in social media sources (51.9%)
- Discussed personal experiences with the flooding event with family/friends (61.4%)
- Discussed news media stories with family/friends (73.7%)
- Shared personal experiences on social media (31.0%)
- Shared information from news media sources on social media (18.5%)

Impacts of Communication During the Flood on Actions Related to Climate Change

The survey data are being used to test an outcome prediction model (Figure 1).

Conclusions

Several conclusions can be made about the strategic communication of climate change based on this study:

- Coloradans were more likely to hold the perception that climate change influences flooding after the historic flood event in September 2013, suggesting that individuals make the connection between major weather events and climate change.
- Extreme weather events are most likely to draw a mental connection to climate change among audiences when the event is more recent.
- While most individuals did not create posts about the event in their social media feeds, the majority did read about the event in social media. This provides evidence of a set of opinion leaders who use social media sources to communicate about the issue. In addition, several of these social media users also consider themselves to be an activist or advocates on an issue. This feeling of efficacy is an important precursor to other important beliefs and climate change action.

Understanding who these individuals are provides an understanding of how they may be discussing climate change and extreme events in other areas of their lives.

For more information, contact Ashley Anderson at ashley.a.anderson@colostate.edu.

Storage and Markets

The Interaction of Inter- and Intra-Temporal Water Allocation in a Changing Climate

PI: Dale Manning, Agricultural and Resource Economics, Colorado State University
Collaborators: Alex Maas, PhD student, Agricultural and Resource Economics, Colorado State University; Andre Dozier, PhD student, Civil and Environmental Engineering, Colorado State University

Introduction

Water represents an important scarce natural resource in many arid parts of the world, including the Southwestern U.S., where five of the eight fastest growing states are located. Yet water resource managers in this area predict large shortages over the next 100 years. In Colorado, only 80 percent of projected demand will be met by the year 2050, even if currently planned supply and conservation projects are successful, and annual expected shortfalls may exceed 500,000 acre-ft for Colorado alone. Much of the Southwest will suffer similar constraints, and water managers will increasingly be faced with difficult allocation and investment decisions. The solution to water scarcity has traditionally been to build more storage and increase supply, but in the 1980s, this "expansionary" approach became prohibitively expensive. As such, solutions to water scarcity include a host of supply-side and demand-side projects, but the success of these projects depends on the institutional agreements within which they are enacted. This project investigates the value of increased storage and optimal reservoir release under a variety of allocation institutions—namely, allocation using a competitive market and Prior Appropriation Doctrine (PAD).

Project Overview

This project uses a dynamic water allocation model to examine the extent to which water storage capacity affects the optimal use of water over time. Inefficiencies are included in the model to capture the value losses associated with varying levels of restrictions in trade. The model is calibrated to the Colorado-Big Thompson (C-BT) water market with two user types and solved using stochastic dynamic programming to examine the additional value of water through the use of trade and storage. Two hypothetical no-trade cases represent the allocation of water through the PAD—one where no reallocation has occurred and one with moderate reallocation. The gains from allowing trade are then evaluated under alternative storage capacity scenarios to compare the value of increased inter-temporal efficiency with the gains from trade across users. Finally, the results are applied to a climate change scenario to investigate the role of storage capacity and markets in adapting to changes in the distribution of water availability.

Currently, a large body of literature explores the optimal use of scarce water resources, but little work exists investigating the specific interactions of storage and markets. The C-BT system, being one of the most studied water projects in the country, provides an excellent case study for analyzing storage and markets because it is highly important to the agro-economy of northern Colorado, has ownership and lease information readily available, and has low transaction costs associated with leasing or selling shares in C-BT water. This means that the baseline calibration is to a functioning market. The no-trade scenario represents the constructed counterfactual. This differs from most situations in the Southwest in which only inefficient

allocations are observed and efficient allocations have to be estimated.

Results

Initial results indicate that trade is highly valuable in the C-BT system, whereas inter-annual storage is not. The average simulated present value of water usage over the next 50 years is $707 million dollars with efficient leasing markets. Restricted trade scenarios meant to mimic PAD are estimate to be 96.5% and 72.9% of that value. By comparison, changes in storage have very small effects on present value estimates. In the worst case scenario, when trade is restricted such that 85% of water use is designated to agriculture (consistent with current water use in Colorado), deadweight loss is large. The results also suggest that liberalized water markets may help ameliorate potential losses under predicted changes in climate and water availability. The same is not true for additional inter-storage, which has a small effect on value under reduced inflow scenarios.

For more information, contact Dale Manning at dale.manning@colostate.edu.

Andre Dozier, Alex Maas, and Dale Manning looking at a physical model of the Colorado Big Thompson Project during a visit to Northern Water.
Courtesy of Dale Manning

Drought Stress Adaptation in Winter Wheat through Soil Microbial Interactions and Root Architecture

PI: Patrick Byrne, Soil and Crop Sciences, Colorado State University
Co-PIs: Mary Stromberger, Soil and Crop Sciences, Matt Wallenstein, Ecosystem Science and Sustainability, and Tiffany Weir, Food Science and Human Nutrition, Colorado State University; Dan Manter, USDA-ARS Soil-Plant-Nutrient Research Unit

Project Objectives

1. *Correlate winter wheat responses to water stress under field conditions with bacterial abundance, genetic diversity, and activity of ACC+ bacteria in the rhizosphere.*

   The group measured the bacterial genetic diversity, bacterial abundance based on number of 16S gene copies, and ACC deaminase activity associated with 12 wheat cultivars, grown under irrigated and dryland conditions and collected at mid-grain filling in summer 2013.

2. *Identify variation among wheat genotypes in root exudate chemical profiles, and effects of ACC+ bacterial inoculation on root architecture and above-ground growth and water status, under water-stressed and non-stressed conditions.*

   The researchers grew seven wheat varieties that differ in their drought response under well-watered and moisture stress conditions. Seeds were inoculated with a consortium of ACC+ bacteria or with sterile physiological saline (as a control). Seeds were grown for five weeks, after which daily irrigation was stopped for half of the plants. Four weeks later, plants were evaluated for leaf relative water content, biomass, and root traits.

   In the same experiment, exudates were extracted from roots that grew into buried syringes. These samples are pending analysis at the Proteomics and Metabolomics Facility at CSU.

3. *Quantify the increase in drought tolerance of drought susceptible wheat cultivars grown in the presence of ACC+ bacteria and root exudates of drought tolerant cultivars.*

   The team conducted a greenhouse root tube study with two plants grown in each tube. The paired plants were either of the same cultivar (RonL, Byrd, and OK06318) or one plant each of Byrd and RonL or Byrd and OK06318. Half the tubes were well-watered throughout the study and half were drought stressed. Within each moisture treatment, half

the seedlings were inoculated with ACC+ bacteria, and half were soaked in physiological saline. At harvest, plants were evaluated for root biomass in top, middle, and bottom sections of the tube, length of longest root, above ground biomass, seed weight, seed number, and average kernel weight.

Results and Conclusions

1. ACC deaminase activity was correlated with bacterial abundance, but not with genetic diversity of bacterial rhizosphere community, and not with drought susceptibility of wheat cultivars. This last relationship needs to be tested with a larger number of replications and number of cultivars.
2. The cultivar RonL showed the largest increase in deep root biomass in response to inoculation with ACC+ bacteria. This is consistent with previous studies that have shown RonL to be responsive to these bacteria.
3. ACC+ inoculated plants showed increases in leaf relative water content, indicating that they were better able to acquire or conserve water compared to non-inoculated plants.
4. Metabolomic analysis was able to discriminate between the root exudate compositions of four winter wheat cultivars.
5. Improved performance for ACC+ inoculated plants in dry conditions was clearly demonstrated for above ground biomass and seed weight of RonL grown to maturity.
6. The above ground biomass and seed weight of Byrd improved when grown in the presence of RonL, under dry conditions and inoculated with ACC+ bacteria. This supports the hypothesis that root exudates of certain cultivars can improve the performance of other cultivars by enhancing ACC+ bacteria in the rhizosphere.

Proposal

Information gained in this project was incorporated as preliminary data in a proposal to USDA's Agricultural and Food Research Initiative (AFRI) entitled Root-Microbial Interactions to Enhance Wheat Productivity under Drought Stress.

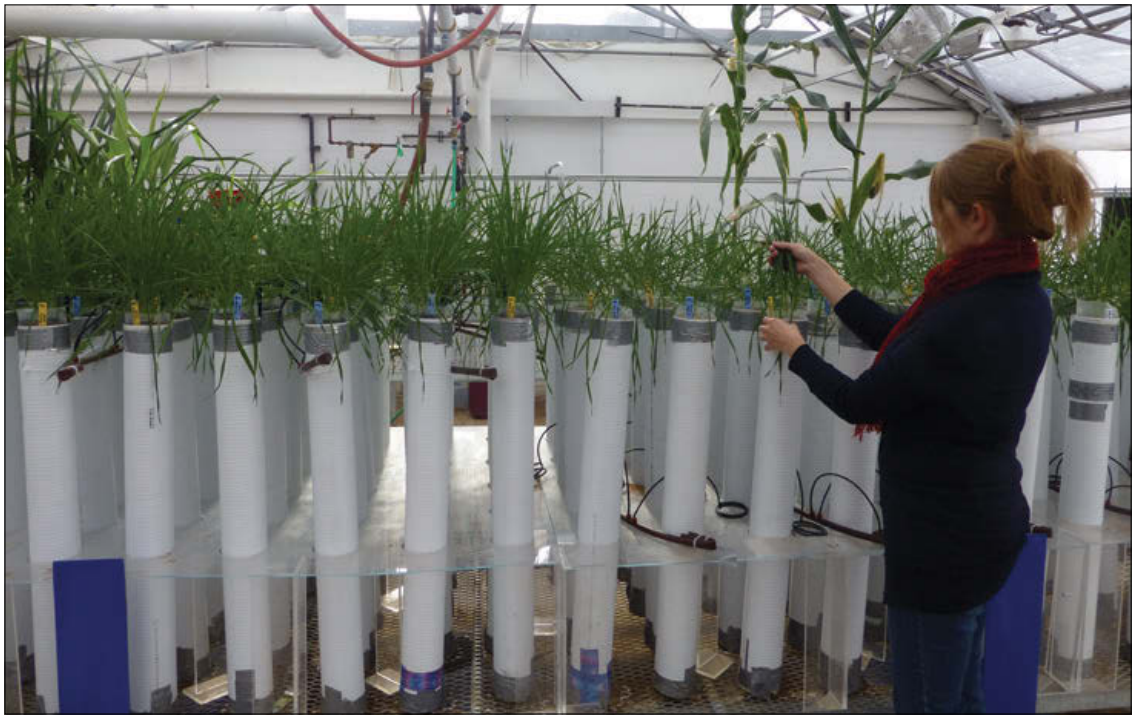
Outreach Activities

Project presented at the Rocky Mountain Agribusiness Association meeting, the CSU Interdisciplinary Water Seminar, and the CSU-USDA Central Great Plains Research Station Field Day in Akron, Colorado.

Byrne, Stromberger, and Weir wrote an article about this project for the 2014 CSU Crops Testing Winter Wheat Report 'Making Better Decisions'.

The greenhouse experiments were featured in tours given to participants in the Biofuels Research Tour and to students in the course Plant Breeding for Drought Tolerance.

For more information, contact Patrick Byrne at patrick.byrne@colostate.edu.



Mary Stromberger observes drought-stressed wheat plants growing in plastic tubes in CSU's University Greenhouses. The plants to the left of the photo were well-watered throughout the experiment. Half the plants were inoculated with ACC+ bacteria and half were non-inoculated.
Courtesy of Pat Byrne

Exploring the Water-Energy Nexus at CSU

Hydrologic Fate and Transport of Chemicals Used in Oil & Gas Development

PI: Michael Gooseff, Civil and Environmental Engineering, Colorado State University
Co-PIs and Other Collaborators: Jens Blotevogel, Civil and Environmental Engineering, Thomas Borch, Soil and Crop Sciences, Alicia Shogbon, PhD student, Civil and Environmental Engineering, and Molly McLaughlin, Master's Student, Civil and Environmental Engineering, Colorado State University

Overview

The goals of this project included: 1) the development of novel methods to analyze concentrations of chemicals used in hydraulic fracturing fluids (for oil and gas development), 2) the transport of a select suite of two of these chemicals in simple porous media systems (laboratory experiments), and 3) to enhance engagement of the CSU and broader community in discussion of the water-energy nexus. Gooseff's research team developed a new collaborative research group to work toward these goals.

Project Activities and Results

1. Enhancing Engagement of the CSU Community on Water-Energy Nexus Issues

The team took advantage of several venues in which to contribute their scientific understanding of the water-energy nexus issues:

- A substantial presentation to the Governor of Colorado's Agricultural Forum
- A presentation that included research findings from this project at the University Consortium Special Meeting on Upstream Unconventional Gas Development in Calgary, Canada
- Participation in a panel discussion of hydraulic fracturing sponsored by CSU Student Sustainability Center and the Sustainable Remediation Forum (SURF)

2. Development of Novel Techniques to Analyze Hydraulic Fracturing Fluid Components

There are potentially hundreds of different components of fluids used in hydraulic fracturing processes, and each has a specific role. The exact mixture of compounds is specific to different operators and place-based context. There are four commonly used compounds (in fairly high proportions) in most fracturing fluid mixtures: polyacrylamide, glutaraldehyde (as a biocide), didecyldimethylammonium bromide (also a biocide), and polyethylene glycols (as surfactants). These compounds do not have simple 'off-the-shelf' analytical techniques used to quantify their concentration in solution, so the team needed to develop these techniques and characterize the fundamental properties of these chemicals in different concentrations to be able to analyze samples from laboratory column studies and predict their transport and fate in porous media.

2.1 Polyacrylamide Analysis

Non-ionic, granular polyacrylamide (PAM) was used in this experiment. The product is 99% pure. Additionally, the team used Nalco ASP900, a friction reducer commonly used in slickwater fracturing which is 15-20% anionic PAM. The remainder of the solution is composed of ammonium sulfate and proprietary stabilizers. To simulate different fracturing fluid mixes, solutions of various concentrations of PAM or ASP900 in NaCl were prepared.

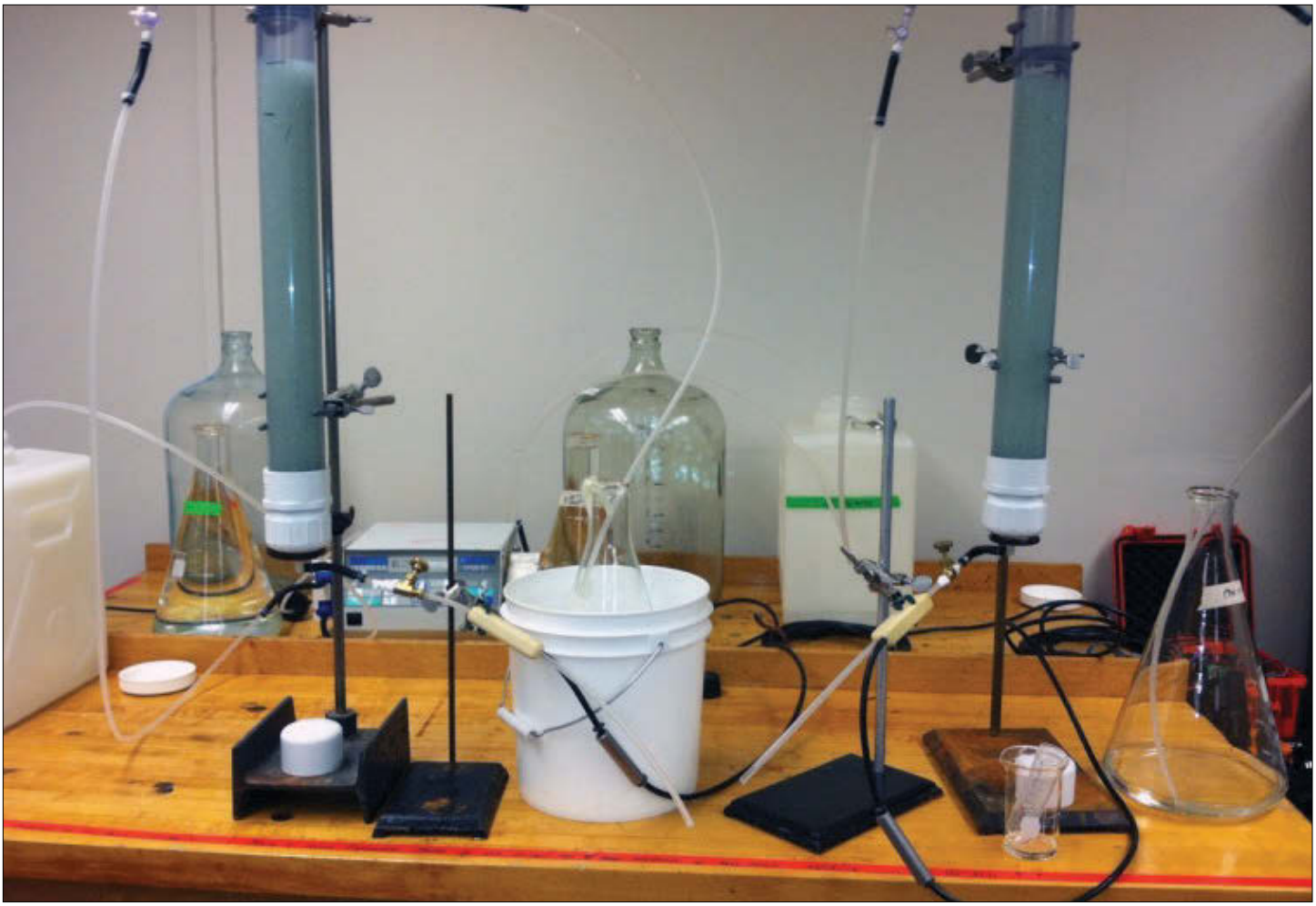
Viscosity measurements were taken for each solution. For both ASP900 and aqueous PAM, a linear relationship exists between viscosity and concentration.

A spectrophotometer was used to measure the absorbance spectrum of PAM and ASP900 in a sodium chloride solution. This information was used to optimize the detection of PAM on the HPLC/DAD.

Size exclusion chromatography: an HPLC/DAD was used to develop a method for PAM analysis. As expected, there is a linear relationship between peak area and PAM concentration. A method for ASP900 analysis is currently being developed.

2.2 Biocide Analysis

The HPLC/DAD was also used to develop a method for analysis of glutaraldehyde after derivatization with dinitrophenylhydrazine. An LC-TOF/MS was used to develop a method for analysis of didecyldimethylammonium bromide (DDAB). DDAB is a quaternary ammonium compound, a class of biocides commonly in hydraulic fracturing.



Column set up on laboratory bench in the Engineering Research Center. Courtesy of Mike Gooseff

2.3 Surfactant Analysis

The LC-TOF/MS was also used to develop a method for analysis of polyethylene glycols (PEGs). PEGs are commonly used surfactants in hydraulic fracturing chemical packages.

3. Column Studies to Quantify Transport and Fate in Porous Media

The columns are made of polyacrylic pipe material and screened at the bottom. In order to simulate constant head conditions and vary the flow rates, three sample ports at either side of the column were added. Each column was filled with glass beads. Our stock solutions will include 5 g/L NaCl solution to be used as a tracer (modifying the EC of the solution), and then two different solutions with fracturing fluids: one with PAM, and one with PAM and DDAB. These will be run for three different PAM concentrations and three different flow rates.

Solution is pumped from glass carboys into one of the column's three side ports at three different elevations and overflows from the respective outlet 180 degrees from the inlet port. This is done in order to change head conditions across the experimental media. The effluent passes through an electrical conductivity probe that is connected to a data logger for high temporal resolution data collection. Samples are then collected at the outflow of tubes leading from these probes. The stock solutions include 5 g/L NaCl solution to be used as a conservative tracer (modifying the EC of the solution), and then two different solutions with fracturing fluids: one with PAM, and one with PAM and glutaraldehyde. These will be run for three different PAM concentrations and three different flow rates.

Because NaCl strongly contributes to the electrical conductivity of DI water, the team can monitor electrical conductivity at high temporal resolution to gain dense breakthrough curves of conservative solute transport. These conservative injections will serve as a baseline to observe the possible change that will occur with PAM injection and expected retardation.

For more information, contact Michael Gooseff at mgooseff@engr.colostate.edu.

Developing Scholarly Excellence Across the Aquatic-Terrestrial Interface

Understanding the Hydro-bio-geo-chemistry of Extreme Events

PI: Ed Hall, Natural Resource Ecology Laboratory, NREL
Co-PIs and Other Collaborators: Claudia Boot, Research Scientist, NREL, Francesca Cotrufo, Soil and Crop Sciences, CSU, Peter Nelson, Civil and Environmental Engineering, CSU, Tim Covino, Ecosystem Science and Sustainability, CSU, Mazdak Arabi, Civil and Environmental Engineering, CSU, Stephanie Kampf, Ecosystem Science and Sustainability, CSU, Michael Lefsky, Ecosystem Science and Sustainability, CSU, Lee MacDonald, Research Scientist, NREL, Sara Rathburn, Geosciences, CSU, Sandra Ryan-Burkett, USDA Forest Service, Michelle Haddix, Research Associate, NREL, Chuck Rhodes, Codie Wilson, FGT Predoctoral, Civil and Environmental Engineering, CSU, Dan Brogan, Master's Student, Civil and Environmental Engineering, CSU, Sarah Schmeer, Master's Student, Ecosystem Science and Sustainability, CSU, Aaron Havel, Master's Student, Civil and Environmental Engineering, CSU

Overview

This new research team created an active and mobile collaborative working group that bridged the physical and biological sciences for water-related research. This group proposed to link large data sets on the High Park Fire in the Cache La Poudre (CLP) Watershed from two previously funded NSF RAPID awards. The goal of that synthesis was to determine the production, transport, and fate of black carbon in the CLP watershed.

Dan Brogan working in the field with the HBGC working group. Courtesy of Dan Brogan

Project Activities

The group held a one-day symposium bringing together the participants of the NSF RAPID proposals to collate and advance the understanding of the effects of the High Park Fire on black carbon dynamics within the CLP watershed. This included the synthesis of data from the High Park Fire RAPID project for black carbon contents in plant litter, soils at two depths, riverbank sediment layers, and particulate and dissolved organic carbon in main stem Poudre River water. In addition, the group collected new data on black carbon contents of surface sediment, deposition layers, and additional particulate organic carbon over five dates from the South Fork of the Poudre River. The publication containing these data is currently being written and slated for submission to Nature Geoscience in October. This publication will be the largest synthesis on how wildfire produces black carbon and the first to address how physical processes impact the fate of black carbon in time and space. This will be of interest to a wide range of researchers as it defines for the first time: a) the physical variables and environmental drivers that contribute to the transport of black carbon in a montane watershed, b) the spatial and temporal resolution required for predicting movement at the watershed scale, and c) the impact of retention versus export of black carbon on an ecosystem. Given the increasingly recognized significance of black carbon to the global carbon cycle and the predicted increase of wildfires, this will make a unique contribution to the scientific literature with important management implications for a wide range of watersheds.

The data synthesized from this effort will be made publically available as a curated database. The synthesis visualization tools and relational database management system (RDBMS) afford researchers the opportunity to access data and information about the data efficiently. Data packages will be archived within the Colorado State University institutional repository (CSU IR) to meet open access expectations of publishers and research sponsors. Metadata and data tables will be compressed and ingested into the CSU IR Digitool system and associated with the Water Archives Collection.

Outreach Activities and Additional Collaborations

In addition to the above synthesis project, the group has created a public face for research at the intersection of the physical and biological sciences in water related science at CSU. Currently this face exists as a webpage: (http://ibis.colostate.edu/cwis438/websites/hbg/Index.php?WebSiteID=6). The page is still a work in progress but will

grow to include links to products as they develop and additional collaborators as they arrive. The interaction among these researchers has led to several other collaborations and projects, including:

1. A second manuscript defining the need for a cross-disciplinary approach to studying both the evolution of watersheds and their response to extreme events such as floods or fire.
2. In June 2014 members of the hydro-bio-geo-chemistry (HBGC) group Covino, Hall, and Wohl submitted a proposal to NSF Hydrology to study the effects of active and legacy beaver dams on the hydrology, geomorphology, and biogeochemistry of watersheds along the Colorado Front Range.
3. PIs Hall, Kampf, and Covino are in the process of organizing a special session for the fall meeting of the American Geophysical Union, "Feedbacks among geomorphology, hydrology, and biology across terrestrial and aquatic ecosystems."
4. PI Kampf is leading a new effort on coordinated monitoring within the CLP watershed with many members of the HBGC working group. This has resulted in additional funding from the City of Fort Collins and synthesis work with the newly formed non-profit Coalition for the Poudre River Watershed.

For more information, contact Ed Hall at ed.hall@colostate.edu.

Evaluation of Cost-Effective Approaches for Nutrient Removal in Urban Stormwater and Wastewater

City of Fort Collins Case Study

PI: Sybil Sharvelle, Civil and Environmental Engineering, Colorado State University
Co-PIs and Other Collaborators: Chris Olson, Civil and Environmental Engineering, and Sarah Breidt, Master's Student, Civil and Environmental Engineering, Colorado State University

Overview

To respond to pending regulation in Colorado that will specify more stringent effluent nitrogen and phosphorus standards from urban watersheds, this study aims to compare existing and potential nutrient treatment efficiency from wastewater and stormwater sources. Currently, the burden of nutrient removal is placed solely on wastewater dischargers; however, the use of stormwater controls to reduce urban nonpoint discharges of pollutants has become more common and cost-effective in recent decades. This analysis examined Fort Collins, whose primary treatment center is the Drake Water Reclamation Facility (DWRF), as a case-study to evaluate nutrient removal technologies from both sectors. Average annual nutrient removals and 20-year lifecycle costs were determined for all alternatives.

Project Activities

Currently, DWRF utilizes the modified Bardenpho process to remove both nitrogen and phosphorus. Alternative treatments were modeled in BioWin® as sidestream nutrient removal processes and integrated with the existing biological nutrient removal at DWRF. These technologies are:

- Anaerobic Ammonium Oxidation (ANAMMOX)
- Centrate and RAS Reaeration Basin (CaRRB)
- Struvite Precipitation
- Selective Adsorption
- Ammonia Stripping
- Electrodialysis

Additional nutrient removal to centrate (sidestream fluid) relieves pressure to mainstream nutrient removal and has the potential to lower operating costs while achieving equal or better effluent water quality. Impacts to the mainstream process were determined by varying mainstream BNR efficiency through the recycle mixed liquor (RML) flow rate between

Bioretention cell treating stormwater from library parking lot in Fort Collins. Courtesy of Chris Olson

one and 20 million gallons per day per pump. Approximately 1,500 stormwater control measures (SCMs) are implemented in Fort Collins at present; however, not all provide water quality treatment. Two alternative stormwater scenarios were evaluated using the Simple Method and include 1) retrofitting all existing flood control basins (no treatment) to extended detention basins, and 2) implementing bioretention ponds to treat runoff from all currently untreated impervious area.

Results

Existing wastewater and stormwater annual nutrient loads are in the same order of magnitude, indicating the potential for stormwater nutrient abatement and trading to be a cost-effective alternative to wastewater controls. Wastewater treatment for all modeled technologies shows a removal efficiency between 40 and 90 percent removal from baseline (influent) concentrations and a treatment efficiency between 16 and 55 percent from existing discharges. Modeling of stormwater treatment alternatives indicated an achievable removal of 20 to 35 percent from existing nutrient loads. For both nitrogen and phosphorus, it was found that stormwater controls incur a greater unit removal cost due to lower removal efficiencies; phosphorus costs-per-pound removed were five and 400 percent larger for retrofitted EBDs and bioretention ponds, respectively. Nitrogen removal efficiencies were greater than most wastewater sidestream processes in both stormwater scenarios. These findings indicate that nutrient trading is likely to be an advantageous option for city planners on the basis of cost-efficiency. Results will be presented to the City of Fort Collins and also disseminated to other utilities in Colorado that may benefit from findings. This project has also led to an update of the CSU Urban Water Center website. The draft updated version is housed at http://erams.com/urbanwatercenter/ until it is finalized to be posted at http://urbanwater.colostate.edu.

Conclusion

Wastewater and stormwater annual nutrient loads into Fort Collins surface waters are of the same magnitude for both nitrogen and phosphorus. While treatment efficiency for wastewater processes involving sidestream treatment is greater if compared to baseline (influent) concentrations, the additional treatment provides comparative removal efficiency to stormwater controls when analyzed against existing nutrient discharges. It may be advantageous for municipalities to consider upgrading existing flood control SCMs to ones that capture and treat the water quality control volume; this stormwater alternative was the more cost-effective of the two considered and is similar to unit costs of wastewater processes. In addition, stormwater controls remove phosphorus and nitrogen simultaneously, while wastewater technologies normally are efficient at removing only one. Additional research into the value of the combined treatment, market incentives for nutrient recycling from wastewater are needed to further characterize cost-effective urban nutrient removal possibilities.

For more information, contact Sybil Sharvelle at sybil.sharvelle@colostate.edu.

Characterizing Biological Pollutants in Agricultural Runoff at Colorado Dairies

PI: Sheryl Magzamen, Environmental and Radiological Health Sciences (ERHS), Colorado State University
Co-PIs and Other Investigators: Stephen Reynolds, ERHS; Joshua Schaeffer, Postdoctoral Fellow, ERHS; Thomas Borch, Soil and Crop Sciences; Robert Young, Postdoctoral Fellow, Soil and Crop Sciences; Amanda Van Dyke-Gonnerman, PhD student, ERHS; and Jessy Tryon, ERHS, Colorado State University

Overview

To assess potential effects on the watershed and general ecosystem health, this research team conducted preliminary studies in exposure assessment and sequence-based analysis of microbial communities to characterize biological pollutants (bacteria, antibiotics, antibiotic resistant genes in agricultural runoff) at three dairies in Colorado. They sampled a spatially heterogeneous array of sites over two seasons to assess primary pollutants and sources. The focus on biological contaminants is a first step in elucidating the broader spectrum of water-borne contaminants involved in agricultural operations.

Activities During Grant Period

Sampling: Field campaigns were conducted in February and March 2014. At each location, three samples were collected: approximately 850ml for the pharmaceuticals analysis, conducted with liquid chromatography-mass spectrometry (LC-MS); approximately 250ml for the Routine Package analysis (pH, conductivity, Ca, Mg, Na, K, B, Cl, Carbonates, Bicarbonates,

Left Photo: *Project postdoc Robert Young prepares samples for liquid chromatography-mass spectroscopy.*

Right Photo: *Project postdoc Josh Schaeffer collects samples during a field campaign.*

Sulfates, Nitrates), dissolved oxygen and total organic carbon; and approximately 10ml for 16S microbial community analysis and antimicrobial genetic testing.

Selection of pharmaceuticals for analysis: After consultation with Noa Roman-Muniz, Associate Professor in Animal Sciences and CSU Extension Dairy Specialist, and Craig McConnel, Assistant Professor of Clinical Sciences in CVMBS, the team focused on three antibiotics that are commonly used on dairies: *Ceftiofur* (a cephalosporin commonly used for the treatment of mastitis in dairy cattle), *Oxytetracycline* (a broad spectrum antibiotic), and *Penicillin*.

Outputs

Data analysis, water quality indicators: One of the primary interests in conducting the water quality analysis is to understand how indicators vary within farms and between farms, which was performed using ANOVA. The statistical analysis indicates that there were actually significant differences by dairy for several of the water quality indicators (pH, electrical conductivity, calcium, boron, hardness and dissolved oxygen), and no significant differences by sampling location. This may be a function of limited number of samples for each location.

Data analysis, pharmaceuticals analysis: Calibration curves for detection of the three pharmaceutical compounds were conducted in May 2014. Methods development for the LC-MS/MS analysis is completed. Sample extraction and analysis will be completed during summer 2014.

Data analysis, microbial community analysis: The microbial analysis has been included with a larger set of samples from Schaeffer's Pilot grant with the High Plains Intermountain Center for Agricultural Health and Safety (HICAHS) under a cost sharing measure.

Data analysis, antimicrobial resistant genes: Results from Bifeng Gao's lab at the University of Colorado are pending.

Additional Funding

As the microbial community analysis requires large amounts of memory and storage, Schaeffer, Magzamen, and Chloe Stenkamp-Strahm, a DVM/PhD student in ERHS, obtained funding from the Amazon Elastic Compute Cloud to conduct data analysis and store data. The CVMBS IT department now has dedicated four work stations with ample memory storage and processing speed to conduct such analyses.

Members of the research team were awarded a CVMBS College Research Council award to investigate the transmission of *E. coli* O157:H7 at a dairy site included in this study. As part of the efforts to understand transmission dynamics, environmental samples including water samples will be collected.

Given the intersecting interests of several researchers on campus in One Health and the connections between animal health and environmental quality, Magzamen's team has developed the Collaborative Health Research on the Microbiome and the Environment (CHROME) project, under the auspices of HICAHS (http://csu-cvmbs.colostate.edu/academics/erhs/agricultural-health-and-safety/Pages/microbiome.aspx.) This forum will allow researchers to pool data and resources and create interdisciplinary grant proposals to investigate microbial community dynamics on animal, human, and ecosystem health.

For more information, contact Sheryl Magzamen at sheryl.magzamen@colostate.edu.

Water Research Awards

Colorado State University (July 16, 2014 to September 15, 2014)

Bailey, Ryan T, Civil & Environmental Engineering, Colorado Water Conservation Board, Modeling the Influence of Conjunctive Water Use on Flow Regimes in the South Platte River Basin Using the South Platte, $50,000

Baker, Daniel W, Civil & Environmental Engineering, DOD-ARMY-Corps of Engineers, Web-Based Guidance and Toolbox for Urban Stream Systems, $50,644

Clements, William H, Fish, Wildlife & Conservation Biology, Colorado Division of Parks and Wildlife, Evaluating Restoration Effectiveness in the Arkansas River, $53,955

Denning, A. Scott, Atmospheric Science, National Aeronautics & Space Administration, The Tropical Terrestrial Tipping Point: Drought Stress and Resilience in Moist Tropical Forests, $127,905

Gage, Edward A, Forest & Rangeland Stewardship, DOD-ARMY-Corps of Engineers, Testing Methods for Determining the Frequency of a Species Wetland Rating, $175,000

Goemans, Christopher G, Agricultural & Resource Economics, USDA-USFS-Rocky Mountain Research Station - CO, General Equilibrium Model of Ecosystem Services, $41,735

Grunau, Lee, Colorado Natural Heritage Program, DOI-BLM-Bureau of Land Management, Statewide Climate Change Vulnerability Assessment, $26,920

Henry, Charles S, Chemistry, Access Sensor Technologies, LLC, Detection of Toxic Metals in Water, $43,235

Hooten, Mevin B, Cooperative Fish & Wildlife Research, Colorado Division of Parks and Wildlife, Optimal Plains Fish Monitoring, $75,780

Liu, Jiangguo, Mathematics, National Science Foundation, Developing Novel Conservative Methods for Flow and Transport, $119,999

Manning, Dale T, Agricultural & Resource Economics, USDA-USFS-Rocky Mountain Research Station - CO, Modeling Forest Ecosystem Services and Demand for Water in Large Landscapes, $55,840

McKay, John K, Bioagricultural Sciences & Pest Management, USDA-Agricultural Research Service, The Role of Root System Architecture in Drought Tolerance, $23,144

Nelson, Peter A, Civil & Environmental Engineering, American Chemical Society, Modeling Stratigraphic Feedbacks in Fluvial Morphodynamics, $100,000

Nelson, Peter A, Civil & Environmental Engineering, National Science Foundation, Investigating the Effects of Sediment Supply, Width Variation, and Unsteady Flow on Riffle-Pool Dynamics, $82,377

Poff, N. LeRoy, Biology, DOI-USGS-Geological Survey, Climate Change, Biological Invasion, and Water Management in Western Riparian Forests, $114,990

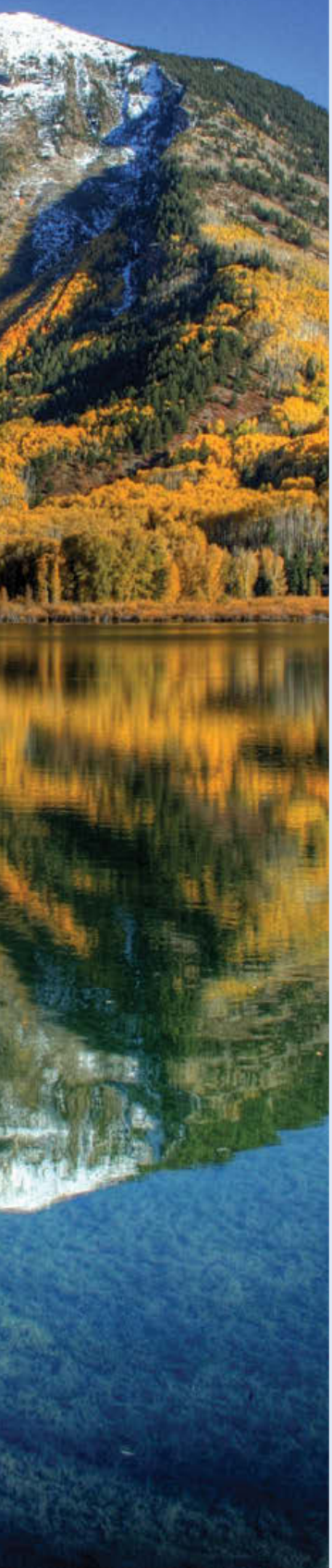
Thornton, Christopher I, Civil & Environmental Engineering, Obermeyer Hydro, Inc., High-Head Hydro Turbine CFD Study, $162,253

Waskom, Reagan M, Colorado Water Institute, Conservation International, Global Water Adaptation, $15,621

Waskom, Reagan M, Colorado Water Institute, DOI-USGS-Geological Survey, Application of Remotely Sensed Data for Improved Regional and National Hydrologic Simulations, $60,000

Winkelman, Dana, Cooperative Fish & Wildlife Research, Colorado Division of Parks and Wildlife, Distribution and Impacts of Gill Lice in Colorado, $21,012

Winkelman, Dana, Cooperative Fish & Wildlife Research, Colorado Division of Parks and Wildlife, Whirling Disease Resistant Rainbow Trout Introductions, $38,117



Calendar

January

8-10 **CWWCA Annual Conference; Denver, CO**
http://bit.ly/1rOPYmE

28-30 **Colorado Water Congress Annual Conference; Denver, CO**
The Colorado Water Congress is the premier water industry event in the state, attracting 500+ attendees that convene for networking and collaboration on the important water issues of the day.
www.cowatercongress.org/

29 **CSU Water Table 2015; Denver, CO**
This years topic, *Partnering the Waters,* will bring together over twenty water leaders from Colorado and beyond to host table discussions on a mix of historical lessons, professional experiences and potential future needs, all related to partnerships.
http://lib.colostate.edu/archives/water/water-tables/2015/

February

1-3 **2015 Industrial and Commercial Water Reuse Conference; Austin, TX**
Water recycling is emerging as a key strategy in competitiveness, corporate social responsibility, and compliance.
www.watereuse.org/industrial-commercial-2015

10-12 **Tamarisk Coalition's 12th Annual Conference; Albuquerque, NM**
Come learn about the latest advancements, from riparian restoration case studies, success stories, regional riparian management initiatives and challenges of funding, planning, and implementing riparian restoration, to exploring novel tools, techniques, and research.
www.tamariskcoalition.org/about-us/events/2015-conference

March

30-1 **2015 AWRA Spring Specialty Conference; Los Angeles, CA**
Water for Urban Areas: Managing Risks and Building Resiliency
www.awra.org/meetings/LosAngeles2015/

April

13-15 **2015 Federal Water Issues Conference; Washington, D.C.**
National Water Resources Association presents Federal Water Issues
www.nwra.org/upcoming-conferences-workshops.html

13-16 **Colorado Rural Water Association's 34th Annual Conference & Exhibition; Denver, CO**
The conference covers a wide range of programs with multi-simultaneous sessions including water, wastewater, source water, groundwater, and management certification topics.
http://bit.ly/1I52WBw

August

16-18 **2015 UCOWR/NIWR/CUASHI Conference; Las Vegas, NV**
Water is Not for Gambling: Utilizing Science to Reduce Uncertainty
http://ucowr.org/conferences

19-21 **Colorado Water Congress Summer Conference; Vail, CO**
The high-energy Summer Conference is packed with great topical content. It's a don't-miss event for those who wish to stay informed about water issues in Colorado while engaging in numerous professional development activities.
www.cowatercongress.org/cwc_events/Summer_Conference.aspx

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Poudre Runs Through It dialogue participants facilitated by Center for Public Deliberation students, at the Drake Centre in Fort Collins, Colorado. Photo by Stephen Smith