

Colorado Water

Newsletter of the Water Center of Colorado State University

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Theme: *Student Research*



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Front Cover: Jason Smith, James Cullis, and Joseph Vassios are the student researchers this month. (Photos courtesy of our authors.)

This Page: Snowmelt runoff fills a reservoir in the Rocky Mountains near Dillon, Colorado.
Photo courtesy of the Agricultural Research Service.

Editorial

by Reagan Waskom, Director, Colorado Water Institute

Colorado has lost several important water leaders over the past year. In this issue of *Colorado Water*, we mark the recent passing of Dick MacRavey, former director of the Colorado Water Congress, and someone who has been a friend to Colorado State University and water education. We've also recently lost Chips Barry, CEO of Denver Water; Ray Wright, President for the Rio Grande Water Conservation District; Doug Shriver, Chairman of the Rio Grande Water Users Association; and John Sayre, water attorney.

When leaders like these men are gone and we celebrate their lives and accomplishments, we tend to value them all the more for their scarcity. What I observe is that the combination of qualities these leaders possess seems rarer than their accomplishments, however significant they may be. Primarily, the combination of vision, drive and the ability to inspire others to follow their vision marks one as a leader. Courage, enthusiasm, competency and integrity are among the other traits commonly associated with leadership. But in the end, that rare combination of character and accomplishment is what makes us miss our leaders who have passed and yearn for new ones to take their place.

In the midst of the current water challenges we face in Colorado, it is common to hear folks bemoan the lack of great leaders, as though our contemporary problems could be resolved if the leaders of our past were here today. Would the presence of Delph Carpenter, Felix Sparks, Ben Eaton, Ed Taylor or Elwood Mead change the output of the CWCB, IBCC or Roundtables substantially today? Perhaps to some degree, but I submit that there are outstanding leaders sitting around those tables today wrestling with seemingly intractable issues in a very different milieu. Among the differences today is a much greater degree of transparency in which they must operate and significant diversity of values among those with access to power.

Are the characteristics of leadership innate or can we learn them? Here at the University, we like to think we are training some future leaders among the many who attend our classes. But in reality, the students who tend to be future leaders already exert significant leadership among their peers by the time they get to college. At best, we are lucky if we succeed in nurturing these emerging leaders by giving them opportunities to grow and perhaps a few significant challenges to test them. What we don't tell them



is that true leaders must forego many luxuries, in particular cynicism, pessimism, laziness and irresponsibility, and that the courage to make and stand behind difficult choices doesn't always lead to popularity.

This issue of *Colorado Water* features the reports of a few of our student water researchers working on projects funded partially through the Colorado Water Institute. Training students is a critical role for our universities – we provide future professionals to invigorate and backfill the water resources workforce. It is our hope that some of these students will become respected leaders in their chosen fields and will bring creativity and innovation to society's water-related problems. Their applied research projects expose students to a few of the challenges our current leaders face in resolving problems of water supply and water quality, but perhaps more importantly, student researchers are mentored by faculty advisors who take this role seriously. If in the process of their training we can help impart understanding to these students, then perhaps they will develop their own unique vision.

Dick MacRavey could often be heard at the Water Congress loudly quoting the proverb, "Where there is no vision, the people perish!" Dick understood that leadership requires vision, and he challenged the water community to make hard decisions and then fight for the cause. He knew that proactive strategies and the execution of those strategies determine Colorado's water future, one issue at a time.

Impact of Limited Irrigation on Four Common Shrub Species

Jason Smith, MS Candidate, Horticulture and Landscape Architecture, Colorado State University
Faculty Advisor: James Klett

Throughout much of Colorado, the demand for water increases while the available water supply decreases. As a result, it is increasingly more important to conserve water wherever possible. One way to conserve water is to plant low-water-use shrubs in the urban landscape. Unfortunately, little scientific research has been conducted on determining the water use of common plant species that are used in urban landscapes and distributed throughout nurseries and garden centers in the Rocky Mountain region. Most plant species' responses to limited irrigation are based solely upon opinion or visual observation, and as a result, a shrub water use study was conducted during the 2010 growing season at the W.D. Holly Plant Environmental Research Center at the Fort Collins Colorado State University campus (Figure 1).

The purpose of the study was to determine the growth response of four shrub species that are commonly marketed throughout Colorado nurseries and garden centers for planting in Colorado landscapes. The shrubs were subjected to progressively decreased amounts of irrigation based on the evapotranspiration (ET) of a short reference crop, and the resulting responses were assessed. The species that were tested were: *Cornus sericea* (redosier dogwood), *Hydrangea arborescens*, 'Annabelle' (Annabelle hydrangea), *Physocarpus opulifolius* 'Monlo' (Diablo® ninebark), and *Salix pupurea* (arctic blue willow); one cool-season grass was used as a control: *Poa pratensis* (Kentucky bluegrass).

The experiment consisted of two separate components. The first was an in-field component in which the shrubs and turf were planted in the ground. This in-field component tested all four species of shrubs and the turf using four separate treatments (0%, 25%, 50%, and 100% of ET of a short reference crop). The second part of the experiment was a lysimeter component, in which two of the species were grown in a pot-in-pot system and received 25%, 50%, or 100% of ET. Only the redosier dogwood and Annabelle hydrangea were tested in the lysimeter component due to space limitations. All plants (in both components) were planted during the 2008 growing season and were provided with 100% ET so that the shrubs could establish. In 2009 and 2010, irrigation treatments were implemented weekly, and the average amounts provided during 2010 are depicted in Table 1. Data collection included plant heights and widths, predawn leaf water potentials, daily water use (using the plants grown in the lysimeter component only), visual ratings, infrared temperatures (turf only), end of season sample leaf area, end of season sample leaf fresh and dry weights, and end of season whole above ground plant fresh and dry weights.

The Kentucky bluegrass in the in-field component responded as expected when irrigation amounts decreased; however, the shrubs did not follow such a predictable pattern. As irrigation amounts decreased for the Kentucky bluegrass, surface temperatures of the turf increased and overall visual appeal decreased. Interestingly, the tested



Figure 1. Shrub Water Study at Colorado State University

Courtesy of Jason Smith

Table 1. Mean Gallons of Water Applied per Week per Shrub

	0%	25%	50%	100%
In Field Trials (5/17/10 — 10/5/10)*	0	0.63	1.23	2.48
Lysimeter Trials (5/17/10 — 5/24/10)*	N/A	0.27	0.54	1.09
Lysimeter Trials (5/25/10 — 7/8/10)**	N/A	1.01	2.01	4.03
Lysimeter Trials (7/9/10 — 10/5/10)**	N/A	2.58	5.16	10.33

*Watering amounts calculated using estimated rooting area

**Watering amounts calculated using estimated leaf area

shrubs responded much differently than the control. The tested shrubs results showed that all species had good survival rates regardless of irrigation amounts received, and some species looked just as healthy visually in the lower watered treatments as they did in the higher watered treatments. The redosier dogwood shrubs that received 100% ET were wider, had less negative seasonal mean water potential readings (less stressed), had larger end of season sample leaf area, and had larger end of season whole plant biomass than the shrubs in the 0%, 25% and 50% treatments. Additionally the 100% treatment was slightly more visually appealing than the other treatments. However, the dogwoods in all treatments looked visually acceptable for landscape use. Treatments appear to have had no impact on the growth rate for the ninebark or the willow. However, more water did result in lower seasonal mean water potential readings (less stressed) for both species in the 100% category. The hydrangea was most affected by the varying watering amounts. The hydrangea's overall size, sample leaf area and sample leaf fresh/dry weights were greater in the 100% category than in any other treatment. However, the Annabelle hydrangea in the 100% treatment had higher pressure chamber readings (more stressed) than the other treatments. This counterintuitive result can be explained by the size differences. Since the hydrangea plants were larger and had more overall biomass in the 100% treatment, more transpiration occurred. More transpiration resulted in more water required to maintain the larger plants. Since the larger hydrangeas were more stressed, it is possible that

hydrangeas require more than 100% ET of a short reference crop to perform the best.

All in-field plants had a good survival rate, since all tested plants survived with the exception of one hydrangea replication in the 0% treatment. The ninebark, willow, and dogwood all looked acceptable for landscape use when receiving 0% ET. The hydrangeas appeared to look better with more water but they also grew in size, which further increased their water demand. However, the hydrangeas in the 0% treatment had an 80% survivability rate. If water becomes limited, all species should be able to survive and look quite acceptable for landscape use with the exception of the hydrangea. However, the hydrangea can probably survive a short period with little to no water and rebound when water becomes more readily available.

In the lysimeter component of the study, both the redosier dogwood and Annabelle hydrangea demonstrated that the more water provided, the better they grow. Treatments began on these two species in 2009 and Figure 2 is a representative photo of both species in each of the three treatments coming out of dormancy. As the plants were breaking dormancy in 2010, the plants receiving 100% ET came out of dormancy more quickly than any of their counterparts in the other treatments. In fact, all of the redosier dogwood replications in the 25% died back to the ground and broke dormancy by starting all of its new growth from the base of the plant. Thus, if these two shrub species go into dormancy in a stressed state, the plants will come out of dormancy more slowly the following season.



The watering amounts for the lysimeter plants not only affected the speed at which both plants broke dormancy, but also affected their growth habits. More water given to both potted redosier dogwoods and Annabelle hydrangeas resulted in larger plants. As irrigation amounts increased the height, width, and end of season entire above ground plant biomass also increased. Interestingly, end of season sample leaf area and sample leaf fresh/dry weights showed no significant differences among treatments for either species. However, as a result of the plants having a similar relationship with overall size and water use, data collected during dry down periods (periods where the plants were not watered and purposefully stressed to monitor the result) showed that the plants in the 100% treatment used water at a faster rate than the 50%, and the 50% used water at a faster rate than the 25%. Additionally, by the end of each dry down period, in general, the 100% redosier dogwoods had greater pressure chamber readings (more stressed) than their counterparts in the 25% treatment, and the 100% hydrangeas were equally stressed as the hydrangeas in the 25% treatment. Since the plants increased in size as watering amounts increased, more water was needed to maintain the larger plant sizes. Both species in each of the three treatments grew at a rate at which they could support themselves with the water supply provided to them.

The infield study results showed that more water given to dogwoods, ninebarks, and willows may affect some plant characteristics, but after two years of establishment, these three species appeared acceptable for landscape use with little to no additional water during normal precipitation years. Hydrangeas planted in the ground get larger with more water, and as they get larger, their demand for water also increases. However, hydrangeas may be able to survive a short period with no water and rebound when water becomes more available. In the lysimeter study, the potted dogwoods and hydrangeas displayed that they adjusted their growing habits to account for the water amounts provided to them. If more water is available, the plants will come out of dormancy at a faster rate and more seasonal growth will result.

Redosier Dogwood

Annabelle Hydrangea

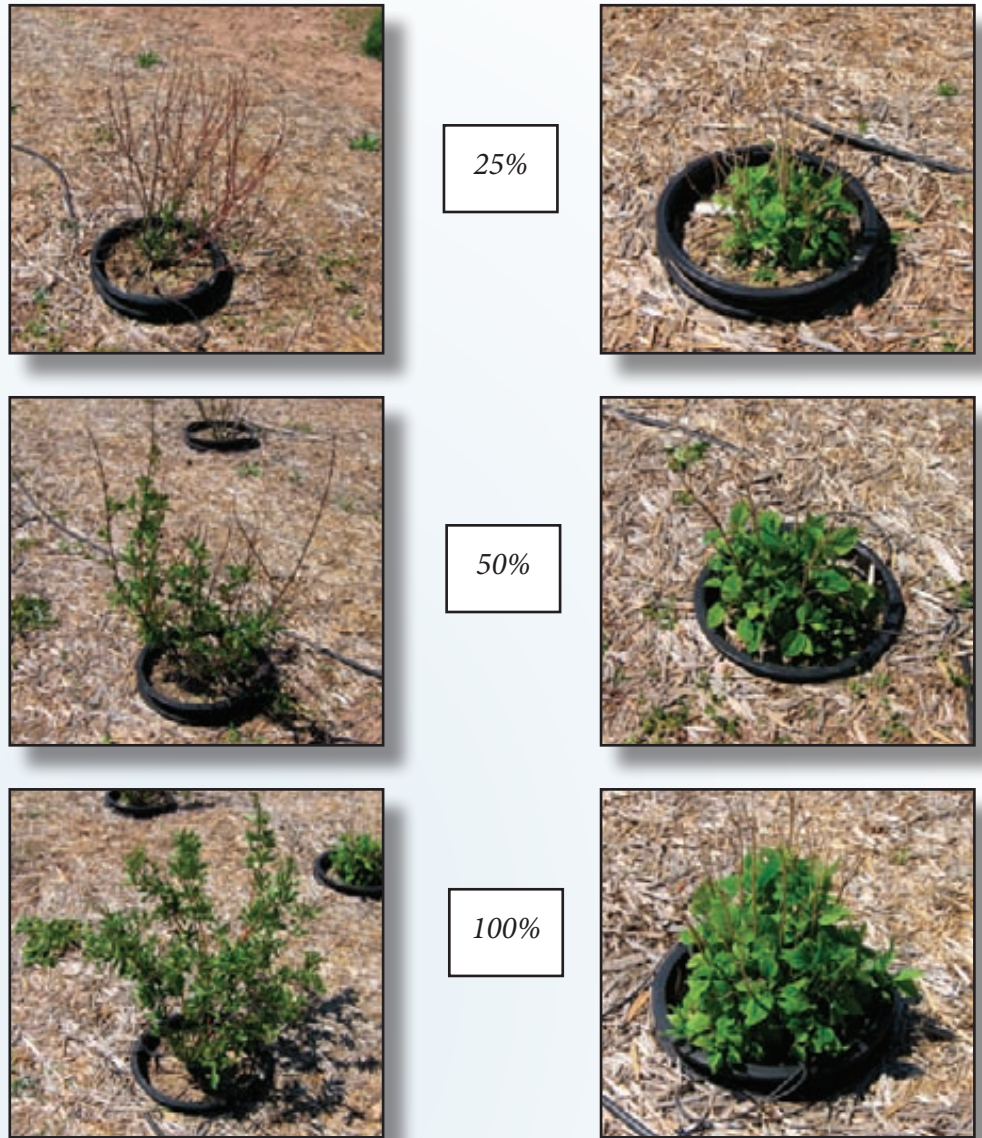


Figure 2. Redosier dogwood and Annabelle hydrangea coming out of dormancy (5/25/10)



James Klett, Dept. of Horticulture and Landscape Architecture, Jason Smith's faculty advisor, (left) and Jason Smith (right).

Shear Resistance of the Nuisance Diatom *Didymosphenia geminata*

James Cullis, PhD Candidate, Civil, Environmental and Architectural Engineering,
University of Colorado at Boulder
Faculty Sponsor: Diane McKnight

Shear Removal of Benthic Algae

The removal of benthic algae is important in maintaining the diversity and patch dynamics of stream ecosystems, since it opens up spaces for the growth of different species. Benthic algae is removed primarily during periods of increased bed shear stress (stress or force exerted by flowing water) resulting from flood events, but it can also be removed by abrasion from suspended particles or physically scoured when the bed material is disturbed under very high flow conditions. Diversity in the benthic algae community results not only from spatial and temporal variations in the disturbance metric (i.e., shear stress and potential for bed disturbance), but also in terms of variations in the resistance and resilience of different species or the same species under different conditions. These differences are due both to “inherent” properties, i.e., physical properties such as shape, size, texture, tensile strength, and attachment strength, and “conditional” properties, i.e., factors relating to the community and its environment such as age, occurrence of secondary structure, and acclimation to a given shear stress and/or resource conditions. Determining the response of specific types of benthic algae to increasing shear stress is therefore important in assessing the resilience of stream ecosystems to natural and anthropogenic alterations of the flow regime.

A Threat to the Sustainability of Stream Ecosystems

Didymosphenia geminata (didymo) is a mat-forming benthic diatom species that is increasing in significance as

a nuisance algal species in freshwater streams throughout the United States, Europe, Asia and New Zealand. Globally, it is acknowledged as the most harmful invasive species in lotic systems (flowing bodies of fresh water). Didymo can form thick mats that cover the stream bed. These mats significantly impact the aesthetic appeal of the stream, but also potentially impact the sustainability of stream ecosystems by blanketing the substrate, reducing diversity and altering the food web structure. These impacts then propagate through the community structure to impact economically valuable species, such as trout. The potential impacts on aesthetics and recreational fishing are concerning for tourism and local economies in the impacted areas. Despite these concerns, we still know very little about the factors controlling its growth and tendency to bloom. This hampers our potential to mitigate and manage this nuisance species.

Shear Removal Experiments

Didymo mats have been found in a wide range of hydraulic habitats, but appear most abundantly in areas of stable substrate or regulated flows downstream of lakes and reservoirs. These observations have led to the hypothesis that didymo mats are highly resistant to increasing shear stresses and that physical removal due to disturbance of the substrate under very high flow conditions is the primary mechanism for removal. Testing this hypothesis, and quantifying the shear removal rate, is therefore important in terms of improving our understanding of growth dynamics of this nuisance species and in considering potential mitigation measures.

To test this hypothesis we conducted a series of shear removal experiments in the research flume at the University of Colorado at Boulder. Rocks with significant didymo coverage were obtained from two study sites on Boulder Creek, Colorado and on two different sampling dates. The first site was the Rocky Knob site on Middle Boulder Creek and the second was on South Boulder Creek in Eldorado Canyon State Park. Both sites offer ideal habitat for didymo growth; cold, clear mountain streams with high light availability and very low nutrient concentrations. For each test, between six and eight rocks with didymo growth on them were removed from the stream and placed on a plastic tray for transport back to the laboratory (Figure 1).

The author (James Cullis, left) and his advisor (Prof. Diane McKnight, right) collecting algal samples for a related project on the significance of spatial and temporal variations of shear stress on the removal of benthic algae in the streams of the McMurdo Dry Valleys in Antarctica.





Figure 1. Pictures of didymo coverage in the stream at the Rocky Knob site in May 2010 (left) and rocks taken from the Eldorado Canyon site in south Boulder Creek in November 2010 on the plastic tray ready for transport back to the lab (right). Note the much higher didymo coverage for the May 2010 samples.

In the laboratory the sample trays were placed in the flume and subjected to increasing flow rates (Figure 2). A plankton net was placed at the end of the flume to collect any material removed (Figure 3). The samples were subjected to increasing flow rates for 30 minutes at each flow rate, and the net was removed after each flow rate. The content of the net was analyzed for ash-free-dry-mass (AFDM), chlorophyll-a (chl-a), and didymo cells density. The shear stress over the samples at each flow rate was estimated based on the extrapolation of the vertical velocity profile upstream of the sample using the “law of the wall” and averaged over the sample based on a horizontal Reynold’s stress profile at a level just above the tops of the rocks used in the sample.

Discussion of Results

The results of the tests are shown in Figure 4 in terms of the cumulative amount of material removed with increasing shear stress expressed per unit area of the sampling tray. The results suggest a linear cumulative removal function for all four tests and for all three biomass metrics. This is despite the differences in the total amount of biomass and the seasonal differences. Figure 5 suggests that the removal rates are a function of the total amount of biomass in the case of AFDM and didymo cell density, but not for chl-a. While the shear removal rate for AFDM appears to increase linearly with increasing biomass, the relationship for cell density appears to be limited at higher biomass. This may be a function of the fact that the growth of the mats themselves impacts the near bed hydraulics, reducing the potential to remove the well-attached and healthy cells

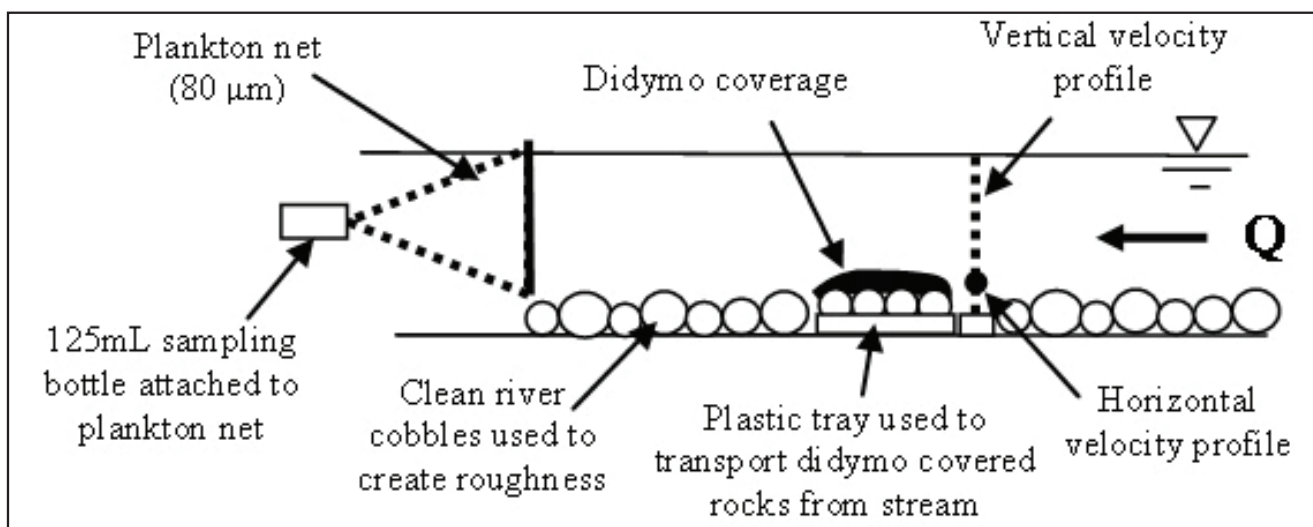
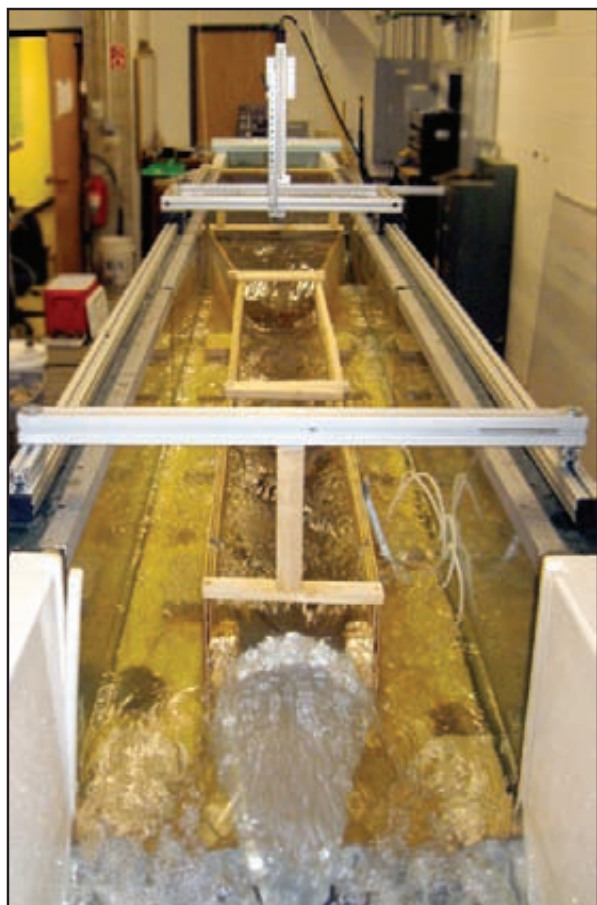


Figure 2. Experimental setup (not to scale).

Figure 3. Photograph of the setup for the shear removal experiments showing the flume running at its highest flow rate. The photograph shows the temporary contraction used to increase the shear stress over the samples, the ADV probed used to measure the velocity and turbulence profiles, and the plankton net used to collect the removed material at the end of the flume. The samples themselves cannot be seen under the flow of water, but are located in the middle of the straight portion of the temporary contraction.



with increasing shear stress, but can still remove biological material trapped within the mats. Alternatively, this may be a function of the better condition of the cells and the mats during the May samples, which represents the sample with the highest biomass.

The total percentage of the biomass removed during each of the tests is given in Table 1. There appears to be a marked difference in the response to increasing shear for the May sample compared to the November samples. The May sample was taken prior to spring runoff, which research has found is the peak period for didymo growth in Boulder Creek. The spring floods that followed in 2010 were very high and resulted in the almost complete removal of didymo from Boulder Creek. There was no significant recovery of Middle Boulder Creek during the summer, which is why the November samples had to be taken from a different site where there was persistent didymo growth. It is therefore likely that the condition of the mats was very different, with the May sample being much healthier and better conditioned, having been taken from the main flow areas. The November samples were taken at the end of a hard season for didymo growth and from areas that had not been exposed to elevated shears, which was why growth still occurred in these areas. Hence the November samples were less conditioned to the normally high shear environment of these rivers. This is reflected in the findings: almost 90% of the didymo cells were removed from the mats in the November samples while only 30% of the cells were removed from the May sample. The amount of AFDM and chl-a removed for the November samples is also higher, but not so significantly. This suggests that the didymo cells are more resilient to removal in May than in November, where the majority of didymo cells are either weakened or dead and/or located on the surface of the mat, and therefore preferentially removed with increasing shear stress.

Table 1. Total percentage of biomass removed during each test

(Maximum Average Shear stress $\approx 87 \text{ N/m}^2$)

Test	Date	AFDM	Chl-a	Didymo Cells
RK1	5/19/2010	18%	9%	33%
SBC1	11/9/2010	48%	48%	91%
SBC2	11/9/2010	27%	16%	93%
SBC3	11/9/2010	28%	21%	85%

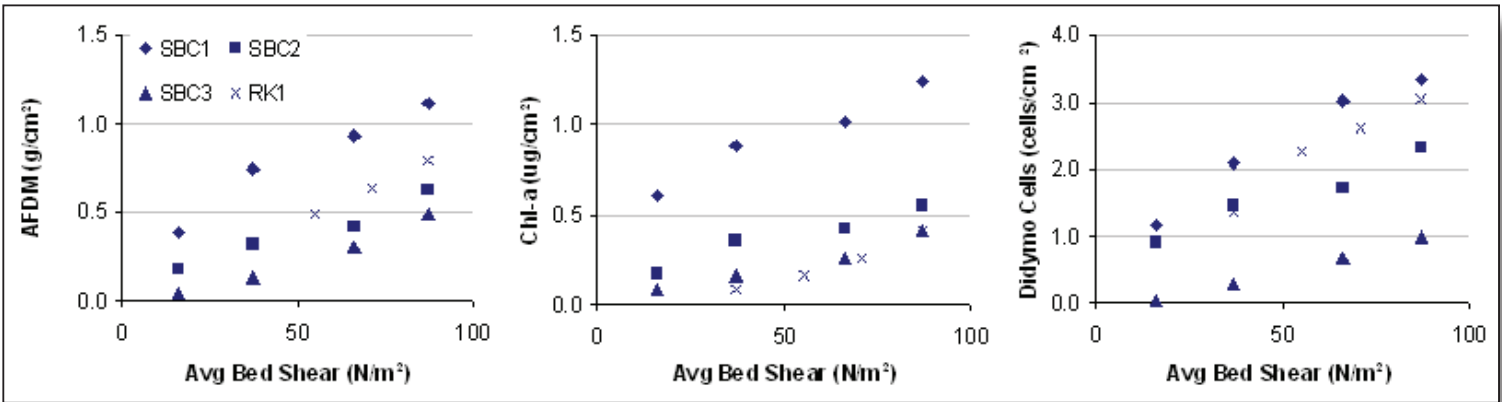


Figure 4. Cumulative amount of material removed from substrate with increasing average bed shear stress.

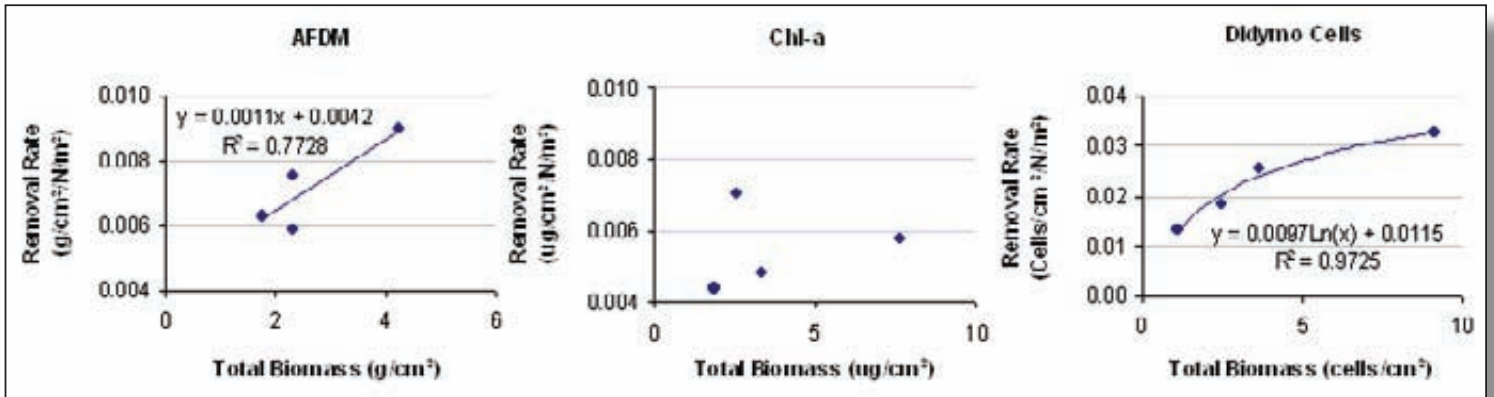


Figure 5. Relationship between removal rate due to increasing shear stress and the total amount of organic and inorganic material present on the substrate at the start of each test.

Conclusion

The above results are useful in improving our understanding of factors affecting the removal of didymo from impacted stream beds. Further tests, however, are required to augment the above data. These tests will be conducted in March 2011, when we anticipate that the didymo growth in Boulder Creek will have recovered from the high flows that resulted in very low coverage during the summer and fall of 2010. The laboratory studies described here complement the ongoing analysis of the hydrologic factors controlling the growth of didymo in Boulder Creek (See Cullis, J, 2010, "Hydrologic Control of the Nuisance Diatom, *Didymosphenia Geminata*" Colorado Water 27(3) pp 4-6). The ultimate objective is to combine the information from these and other studies into a conceptual model describing the growth dynamics of this nuisance species. Such a growth model could then be used to investigate the potential for future blooms, as well as to assess the threat of future altered flow regimes and the potential for mitigation measures, including the use of flushing flows.

Acknowledgements

Funding for this research is provided by the Colorado Water Institute (CWI) and the Boulder Creek Critical Zone Observatory (CZO). Laboratory facilities were provided by the Department of Civil, Environmental and Architectural Engineering (CEAE) at the University of Colorado and valuable support in using the flume was provided by Professor John Crimaldi.

For more information on the ecology and the potential impact of *Didymosphenia geminata* on stream ecosystems, go to the EPA website: www.epa.gov/region8/water/didymosphenia/ or contact the author (james.cullis@colorado.edu).

Paleohydrology of the Lower Colorado River Basin

Jeffrey Lukas, Associate Scientist, Western Water Assessment

Background and Goals of the Project

The State of Colorado draws a substantial portion of its water supply from the Colorado River. The reliability of this supply is a function of natural hydrologic variability, upon which anticipated changes in future climate will be superimposed. Thus, the range of this natural variability in the basin streamflows must be understood in order to obtain a robust estimate of the water supply risk and, consequently, devise effective management and planning strategies. Observed flow data that are limited in time (~100 years) cannot provide the full range of variability, even with stochastic models built on them. Paleohydrologic reconstructions of annual flow using tree rings, however, provide much longer (500-1000+ years) records of past natural variability, and thus a much richer sampling of potential flow sequences, including the severe and sustained droughts of greatest concern to water resource managers (see Figure 1 for an example). Such reconstructions are available for the Upper Colorado River basin flows at Lees Ferry, Ariz., but there is no equivalent dataset for the Lower Basin (Figure 2). The Colorado River District—which is responsible for the conservation, use, protection, and development of Colorado's apportionment of the Colorado

River—has acknowledged the need to include all of the Lower Basin in paleohydrologic reconstructions so as to develop a more robust assessment of the natural variability of the entire Colorado River Basin.

With funding from the Colorado Water Institute (CWI), the National Institute for Water Resources (NIWR), and the University of Colorado-National Oceanic and Atmospheric Administration (CU-NOAA) Western Water Assessment, as well as graduate student support from the CU Department of Civil and Environmental Engineering, in 2010 we began a project to fill in this need for the Lower Basin. The overall project objectives are to:

- Develop robust paleohydrologic reconstructions of the total Lower Colorado River Basin streamflow, commensurate with existing reconstructions of Upper Basin streamflow (e.g., Meko et al., 2007);
- Compare multiple reconstruction approaches to assess the robustness of each approach, and the sensitivity of the results to the chosen approach;
- Use the reconstructions in basin-wide water-balance modeling to assess the risks of the paleo-derived variability to Colorado River Basin water supplies.

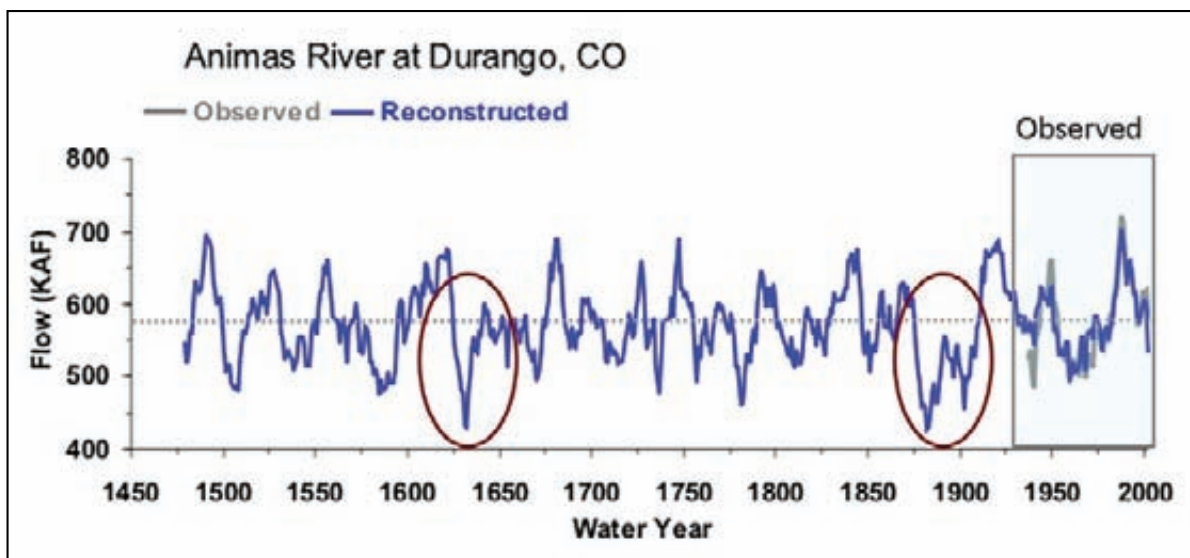


Figure 1. Paleohydrologic reconstruction, from tree rings, of the Animas River at Durango, CO, from 1470—2002. The 10-year running means of the observed and reconstructed flows are shown. The red ovals highlight sustained droughts which have no analog during the observed period, demonstrating the utility of reconstructions in capturing past hydrologic variability.



Figure 2. The Lower Colorado River Basin (shaded), showing the mainstem Colorado River, major tributaries, and important gauge locations (white squares).

Methods

The tasks and specific methods for the first year of the project are as follows:

1. Generate naturalized annual flow records for the Lower Basin for the historic period (~1906 onwards) to use as targets for the paleo reconstructions, for these two locations:

- The intervening flow on the mainstem Colorado River between Lees Ferry and Imperial Dam (“Imperial”)
- The flow for the Gila River (“Gila”) at the most downstream feasible point

Naturalized flow records—corrected for depletions, inter-basin transfers, and reservoir evaporation—must be used to calibrate with the tree-ring data. The U.S. Bureau of Reclamation (USBR) has a natural flow dataset for the mainstem Colorado and major tributaries (see Figure 3), but not all depletions have been corrected for. For the Gila River, relatively natural upstream gauge records (see Figure 3) will need to be corrected for the tributary inputs and significant diversions occurring downstream. The corrections will be made using a combination of historical

records of depletions and simple hydrologic modeling.

2. Compile all the available tree-ring chronologies within and adjacent to the Lower Basin. Long-lived, moisture-sensitive conifers are widespread in the Lower Basin and adjacent areas of Arizona, New Mexico, Utah, and Colorado. While dozens of site chronologies developed from such trees have been publicly archived, most end prior to 1990 and can’t be calibrated with the most recent streamflow data. Fortunately, two recent and ongoing projects at the University of Arizona have resulted in the collection of about 60 new chronologies, which will be recompiled by collaborators from the Laboratory of Tree-Ring Research at the university.

3. Generate and evaluate tree-ring reconstructions for Imperial and Gila using multiple methods:

- Non-parametric K-nearest-neighbor (KNN; *sensu* Gangopadhyay et al., 2009)
- Generalized Linear Model (GLM)
- Standard Multiple Linear Regression (MLR)
- Variant on MLR: Robust Loess smoothing

Paleohydrologic reconstructions have been generated using many different statistical approaches, all of which have particular strengths and weaknesses. Using several approaches will allow assessment of the uncertainty in the reconstructions that can be attributed to the methodology alone.

4. Use stochastic simulation on the observed and reconstructed flows to compute statistics on run length, deficits and surpluses, and run other diagnostics. These diagnostics will allow us to better understand the characteristics of hydrologic variability captured by the different reconstruction approaches relative to that contained in the observed record.

5. Preliminary system response analysis using reconstructions as input to the Rajagopalan et al. (2009) water-balance model of the Colorado River Basin. The water balance model is simple yet representative of the entire water resources system in the basin. We will work closely with the Colorado River District to perform exploratory analyses in using the long reconstructed streamflows to generate a rich variety of streamflow scenarios, which we will use to estimate the water supply risk in the basin under different climate and management scenarios.

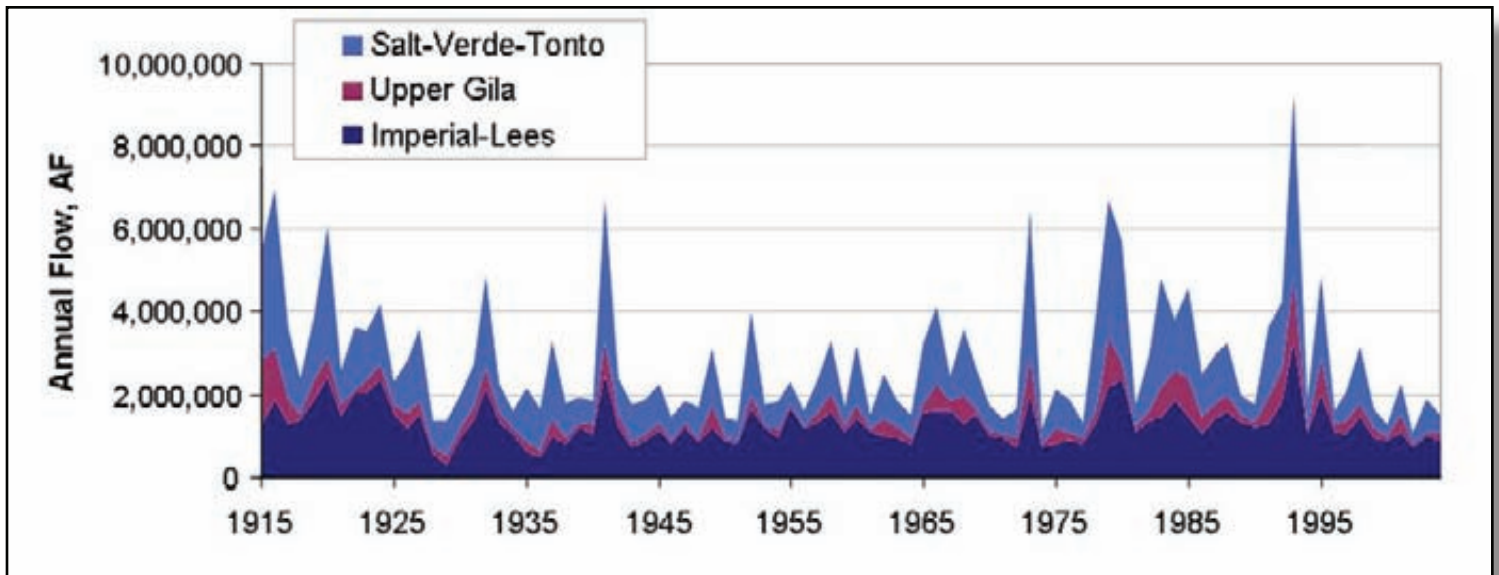


Figure 3. A rough approximation of total historical streamflows (1915-2004) for the Lower Colorado Basin can be made by summing the intervening flows between Lees Ferry and Imperial Dam (Imperial-Lees) on the mainstem and the gauged flows for upstream gauges in the Gila River Basin (Salt-Verde-Tonto and Upper Gila). See Figure 2 for gauge locations. These flow records are now being corrected for downstream depletions and inflows before being modeled with the tree-ring data.

Progress to Date

The project formally commenced with a project meeting in Boulder, Colo., in September 2010. The participants included all of the project personnel listed above as well as representatives from the USBR and the Colorado Water Conservation Board (CWCB). Presentations by the investigators covered both the proposed work plan and methods and past research projects on which this work will be based. The discussions during the meeting served to refine the work plan and methods.

Since the meeting, the bulk of the work has been carried out by Wade and Rajagopalan on task 1 above: *Generate naturalized annual flow records for the Lower Basin for the historic period.* Wade has conducted a literature review and data search to compile documentation of historic gauged flows and depletions, setting the stage for modeling the natural flows for Imperial and Gila. Rajagopalan has also been refining the software codes to implement portions of tasks 3 and 4, particularly those needed to use the KNN reconstruction approach.

At the September meeting, March 1, 2011 was set as the target date for the completion of tasks 1 and 2, and that date appears to be on track. The compilation of the naturalized flow records (the *predictands*) and the tree-ring data (*predictors*) will allow task 3 (generating the reconstructions) to proceed immediately, to be closely followed by tasks 4 and 5. Completion of all tasks is expected in July 2011.

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Project Personnel

PI: Balaji Rajagopalan, University of Colorado

CO-PIs: Jeffrey Lukas, Western Water Assessment; Jose Salas, Colorado State University. Other Investigators: Connie Woodhouse and David Meko, University of Arizona; Lisa Wade, University of Colorado (Rajagopalan MS student)

Collaborators: Dave Kanzer, Eric Kuhn, and John Currier, Colorado River District; Kiyomi Morino, University of Arizona; Joe Barsugli, University of Colorado

Alternatives for Sago Pondweed Control in Irrigation Canals

Joseph D. Vassios, PhD Candidate, Bioagricultural Sciences and Pest Management, Colorado State University
Faculty Advisor: Scott J. Nissen

Unlike other well-known nuisance plant species that are non-native, sago pondweed is a submersed perennial species that is native across much of the U.S., including Colorado. While it does not usually cause problems when present in lakes and ponds, sago pondweed is well-adapted to growing in canals. Adaptations include the ability to form belowground tubers, allowing sago pondweed to survive seasonal drawdowns. This ability to survive dry conditions, paired with a high growth rate corresponding with peak water demand, makes sago pondweed troublesome for irrigation districts in much of the Western U.S.

Traditionally, few options have been available for sago pondweed control in flowing water. The methods most commonly used in Colorado include in-season dredging to remove plant material and treatment with Magnacide[®] (acrolein, Alligare LLC). Magnacide[®] can provide aquatic weed control but is also toxic to aquatic invertebrates and vertebrates. In addition to aquatic toxicity, it can be hazardous to applicators. Due to safety concerns, Magnacide[®] applications in Colorado are usually made by a few highly-qualified applicators. Many chelated copper herbicides, including Clearigate[®] (Applied Biochemists), are available for in-season treatments and have been used with varying degrees of success depending on infestation density and water quality. In 2010 Cascade[®] (endothall, United Phosphorus Inc.) was labeled for use in flowing water, and it was widely used during summer 2010. Endothall was first labeled for aquatic use in 1960 and has been widely used for submersed aquatic plant control in lakes and ponds. While the use of this herbicide in irrigation systems is still new, it appears to provide good sago pondweed control.

As previously mentioned, Magnacide[®] can be hazardous to applicators and is listed as a restricted use pesticide. Those

handling this material must complete a training course and use personal protective equipment (PPE), including a full-face respirator. Other herbicides, such as Clearigate[®] and Cascade[®], are significantly less hazardous. These herbicides are not restricted use, and they require minimal PPE. The fact that these herbicides are not restricted use

allows them to be suitable for application by irrigation district personnel without additional training.

Cascade[®] applications are relatively straightforward. The herbicide is metered into the canal for a duration determined by a concentration/exposure time relationship. Herbicide applications are made using a small pump, and exposure times usually range from 8-24 hours. Herbicide concentration is determined using a “factor of 24” concept. For example, if the herbicide is applied at two parts per million (ppm), an exposure time of 12 hours would be required (two ppm x 12 hours = 24 ppm-hours). Following applications, injury symptoms will be

seen within one-two weeks, with plants turning brown and dropping to the bottom of the canal. Plants will continue to die back and in many cases, a single application will provide season-long control in Colorado canals. Photos in Figure 1 show sago pondweed control at zero days after treatment (DAT) and 28 DAT. While control with Cascade[®] is good, this herbicide does have its limitations. The formulation of endothall in Cascade[®] provides control of aquatic plants but will not control filamentous algae. Algae growth can be extensive on dense sago pondweed beds, and it often contributes to impeded canal flow as much as sago pondweed alone. In situations where algae are common, chelated coppers, such as Clearigate[®], may provide both aquatic plant and algae control.



Joseph Vassios and his advisor for the project, Scott Nissen



Figure 1. Sago pondweed control at 0 (top) and 28 days after treatment (bottom) following treatment with Cascade® herbicide.

From as early as 1971, evidence has suggested that the combination of endothall and copper could act synergistically to improve aquatic weed control. Our recent work has focused on evaluating the effectiveness of combination treatments containing endothall and chelated copper formulations for sago pondweed control in flowing water. This combination could be a solution for canals where both sago pondweed and algae are present. These combination treatments could reduce herbicide concentrations and exposure times, resulting in significant cost savings. In these studies we have evaluated treatments of Cascade® in combination with Clearigate®. These studies were carried out in the Weed Research Lab at Colorado State University using a flowing water system to simulated canal treatments.

Treatments included Cascade® alone (one and two ppm), Clearigate® alone (0.5 and one ppm) and Cascade® plus Clearigate®. Plants were exposed to these treatments for four, eight, and 12 hours. After the appropriate exposure times, canals were drained and refilled with clean water, and treated plants were allowed to grow under flowing water conditions for an additional 30 DAT. Plants were then harvested and dry biomass was determined.

The results of our greenhouse study provided good evidence for an interaction between Cascade® and the chelated copper formulation, Clearigate® (Figure 2). This interaction was highly significant when comparing the

reduction in sago pondweed biomass resulting from the four-hour exposure to one ppm Cascade® and one ppm Cascade® plus 0.5 ppm Clearigate®. The combination of one ppm Cascade® plus 0.5 ppm Clearigate® for four hours reduced sago pondweed biomass to a level equivalent to two ppm Cascade® for 12 hours.

The cost saving could be substantial for canal companies. To treat a 50 cubic feet per second canal with two ppm Cascade® for 12 hours would require 64 gallons of product; however, the combination treatment would require only 11 gallons of Cascade® and about 70 gallons of Clearigate® to achieve the same level of sago pondweed control. In addition, the combination treatment would control filamentous algae. While these results are encouraging, a significant amount of field validation will be required to determine if these combination treatments are commercially viable. One potential issue with this herbicide combination is that the two products may dissipate at different rates as they move down the canal.

Sago pondweed will continue to be a significant problem for many canal companies in Colorado for several reasons. Once established, sago pondweed produces tubers that allow an infestation to increase in density and survive when canals are de-watered during the winter. It can also reproduce from seed and from floating fragments that can root to start new infestations downstream. The recent registration of Cascade® provides canal operators with new opportunities to manage sago pondweed without a significant investment in equipment or applicator training. Funds provided by the Colorado Water Institute have provided the opportunity for us to explore new management options for canal operators. This summer we plan to validate our greenhouse results with full-scale field tests.

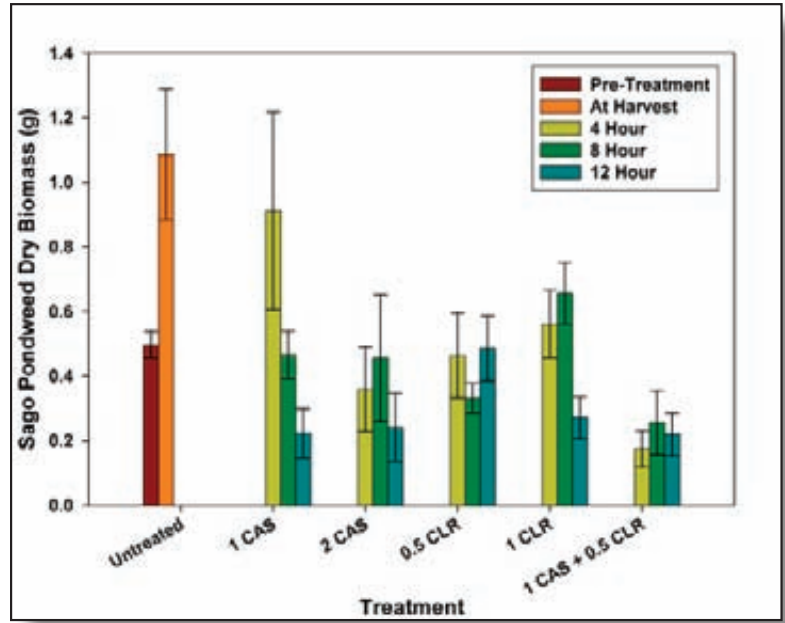


Figure 2. Average (± Standard Error) sago pondweed biomass 30 days after treatment following four, eight, and 12 hour exposure to listed treatments.

Exploring Hydropower in Colorado's Irrigation Canals

*Daniel Zimmerle, Department of Mechanical Engineering, Colorado State University
Lindsay George, Water Resources Engineer, Applegate Group, Inc.*

If you were to take a stroll along a few of the three million miles of irrigation canals that crisscross Colorado, you might encounter one of many flow control structures. They range from long chutes down hillsides, to cascades over concrete gates, to hidden restrictions rippling the water's surface. If you were in a poetic frame of mind, you might admire an interesting rapid or minor waterfall. But if you were in an energy frame of mind, you might wonder, "How much power could that generate?"

You wouldn't be the first. There has been long-standing interest in hydropower, and the flow in irrigation systems is no exception. Despite the interest, few small hydropower projects have been completed; virtually none in irrigation systems. Recently, however, interest in small hydropower, or "micro-hydro," has surged.

First, what *is* micro-hydro? Small hydropower plants in irrigation systems generally have two common characteristics – low "head" and low flow. Head refers to the change in height of the water over a short horizontal distance – think flow over a gate or down a chute. Flow is the water available for hydropower, which may differ from the total flow in some cases. It is important to remember that "low" in this context is relative to large conventional dams, often with hundreds of feet of head flowing thousands of cubic feet per second. A "low-head" hydro project may still have thirty or forty feet of head, although smaller heads are more common.

The forces driving interest in micro-hydro run the full range: policy to society to technology. Interest in renewable energy has increased dramatically in the last 10 years, and public pressure has led to renewable generation standards in many states, including Colorado. Utilities need renewables, and hydropower is an attractive choice. Hydropower is one of the most predictable renewables, suffering little of the transient off-again, on-again nature of many other resources. Since few sites remain to expand large hydropower, it is understandable that interest has turned toward smaller sites.

Permitting and regulations have long been the bane of new hydropower development. For small sites, permitting costs are disproportionately high, often killing economic viability. Last August, however, Colorado, acting through the Governor's Energy Office (GEO), signed a memorandum of understanding with the Federal Energy Regulatory Commission (FERC) to "Streamline and Simplify the Authorization of Small Scale Hydropower Projects." (www.ferc.gov/legal/maj-ord-reg/mou/mou-co.pdf). This trial

rule change promises to significantly lower barriers to small hydropower. The rule simplification is particularly targeted at existing structures and man-made waterways, like that ripple you spied in your local irrigation system.

Producing power is not sufficient. The power has to be connected to the grid, and someone has to purchase it. Twenty – even ten – years ago, the idea of integrating a small, remote, generator into the power grid was a novel idea, and often unwelcome. Today, with photovoltaic (PV) panels popping up on roofs and wind turbines sprouting from farms, the idea of integrating small sources has become almost commonplace. Utilities are now open to integrating these resources. Some are actively encouraging it. In effect, your neighbor's PV panel has blazed the way for your hydropower.

Big power plants are monitored 24-7 by trained operators. A small hydropower plant, nestled in a remote rural location, cannot afford that attention. Technology to the rescue! Today's inexpensive, powerful computers and ubiquitous communications can enable remote operation of small power plants. Your cell phone has both the muscle to control a small hydropower plant, and sufficient communications to connect it to your local utility's control center. New developments in power electronics – larger versions of the devices in your computer's "power brick" – have reduced the cost and complexity of connecting generators to the grid.

Adding all these forces together enables a significant push toward small hydropower development. Great, you say, but what makes a good hydropower project? Unfortunately, the answer is site-specific, but a few indicators of a good project include:

- A significant drop through an existing structure, pipe, or engineered waterway. Generally, it is not economical to harvest energy from the slow-moving flow between structures: the power density is simply too low.
- Predictable flow for a significant fraction of the year. Short seasons make it difficult to justify the capital investment. Senior water rights help, but are not strictly required.
- Nearby power distribution lines. Running a new feeder is expensive and can kill a project. A supportive local utility is also a big plus.

- Land or easements sufficient for the necessary support structures. Supportive neighbors also help.
- Patience. Recent developments have made small hydropower *easier*, but not necessarily *easy*. Would-be developers still face significant challenges bringing together permitting, interconnection, water rights and financing.

Public and private entities are pushing projects forward. Daniel Zimmerle from CSU's Engines and Energy Conversion Laboratory (eecl.colostate.edu/), and Lindsay George from Applegate Group (www.applegategroup.com/) have partnered to complete a survey of sites and technology for small hydropower development, sponsored by Advancing Colorado's Renewable Energy (ACRE) Program. One of their first discoveries is that many companies are developing and supplying turbines for small, low-head hydropower systems. A selection of technologies is covered in their interim report, available on the Colorado Department of Agriculture's project library. The team is also doing a statewide survey of irrigations systems. If you are a ditch operator, please return your survey. Lost yours? Never fear! Visit www.applegategroup.com/news/low-head-hydropower-survey-available or contact the author.

GEO recently launched its "Small Hydro Streamlined Federal Permitting Program." The program will assist developers that propose low-impact projects – projects that use existing infrastructure and do not increase stream diversions, fish passage, water quality or cultural resources. Apply to the program through RechargeColorado.com.

The future of small hydropower is still hard to predict, but it is increasingly likely that your next watt may come from the ditch next door.



This ditch is a good example of a Colorado irrigation canal with "micro-hydro" (small-scale hydropower) potential.

Photo by Lindsay George

Contact Daniel Zimmerle at 970-581-9945, dan.zimmerle@colostate.edu

THE COLORADO WATER WORKSHOP

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Adjoint Modeling to Quantify Stream Flow Changes Due to Pumping

Roseanna M. Neupauer, Associate Professor, University of Colorado

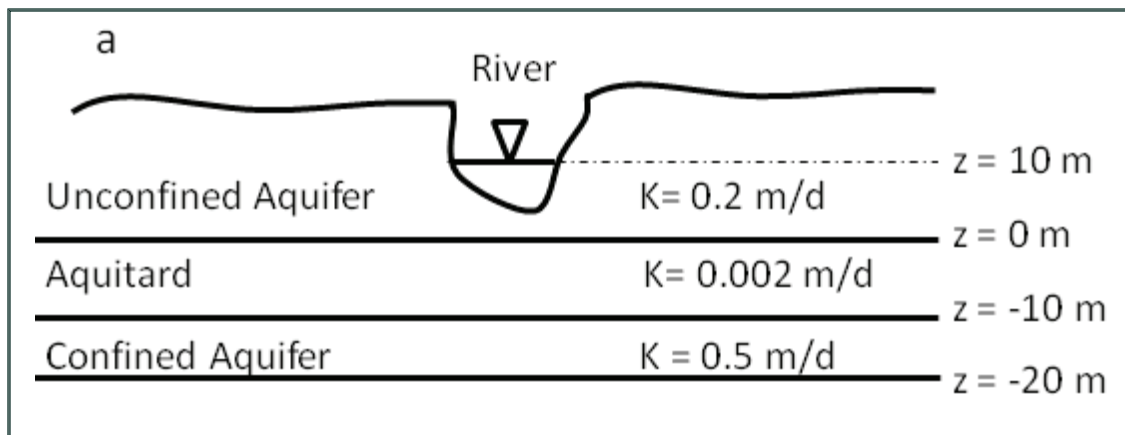
In Colorado, groundwater that is extracted from pumping wells is subject to water rights unless demonstrated to be non-tributary groundwater, which is defined as groundwater that, if extracted, will not deplete a stream by more than 1/10 of one percent of the annual withdrawal rate in any one year period within one hundred years. Groundwater modeling is typically used to determine whether or not groundwater can be considered as non-tributary. The approach is to first simulate conditions in the stream-aquifer system in the absence of pumping to quantify the stream flow rate under natural conditions, and then to simulate conditions with pumping for a 100-year period to quantify the stream flow rate when the well is pumped. If the depletion in the stream flow rate never exceeds 1/10 of one percent of the pumping rate, the groundwater that is withdrawn from the well is demonstrated to be non-tributary groundwater.

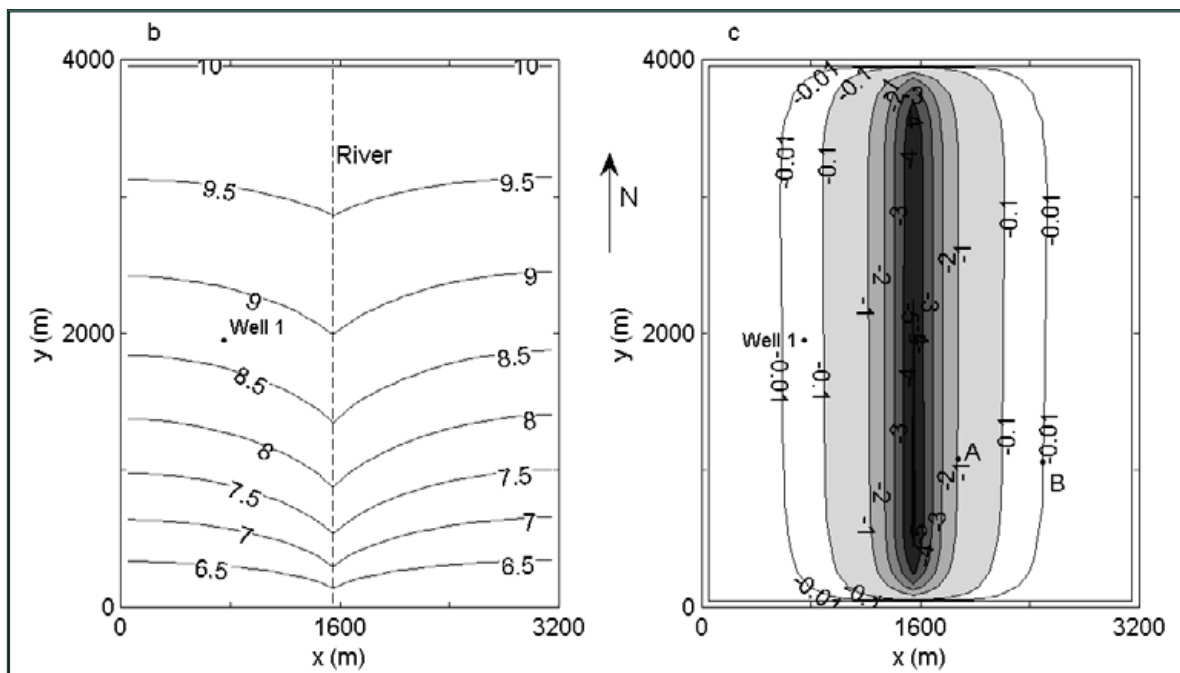
The approach described above is applicable if the pumping well under consideration is already in place or if the well location is already chosen. If the well location has not yet been chosen, it may be desirable to install the well where it will have little impact on stream flow, i.e., where it will pump non-tributary groundwater. For this situation, the modeling approach described above is inefficient,

because one simulation must be run for each potential well location. We are developing a new modeling approach that solves directly for the change in stream flow or stream volume due to pumping from a well at any location in an aquifer. With this approach, the model results will identify locations where a well can be installed to ensure that pumping has minimal impact on stream flow.

The model development is being conducted by Scott Griebeling, a graduate student in the Civil, Environmental, and Architectural Engineering Department at the University of Colorado, under the supervision of Roseanna Neupauer. Using adjoint theory on the governing equation for groundwater flow, we have developed the adjoint equations that describe changes in stream volume or stream flow rate as a function of time due to pumping at a well at any location in the aquifer. We have identified several scenarios for which these adjoint equations have the same form as the groundwater flow equations, and therefore can be solved with standard groundwater flow models, such as MODFLOW. We have also identified several scenarios for which these adjoint equations are similar but different from the groundwater flow equations, so we are developing approaches to use standard groundwater flow models to solve these adjoint equations.

Figure 1. Aquifer system used in the example. (a) Cross-sectional view. (b) Plan view. The northern and southern boundaries are constant head boundaries, and the east and west boundaries are no flow boundaries. The river stage and bottom elevation are 10 m and 5 m, respectively, along the entire river length. The contour lines represent head (in m) in the unconfined aquifer in the absence of pumping. (c) Stream depletion as a percentage of the pumping rate for a well installed at any location in the aquifer. Units are dimensionless.





Here we provide an example of the former scenario. We use the hypothetical aquifer system shown in Figure 1. The system is comprised of an unconfined aquifer, an aquitard (a bed of low permeability adjacent to an aquifer), and a confined aquifer, with a river running from north to south in the unconfined aquifer. The aquifers and aquitard are assumed to be homogeneous (hydraulic conductivity values shown in Figure 1a). Flow in this system was simulated using MODFLOW with the RIV package to simulate interaction between the river and the aquifer. The results show that in the absence of pumping, the flow rate of water from the river into the unconfined aquifer is approximately 4200 m³/yr. Using standard simulation methods, we also simulated flow in the system when Well 1 is pumped at a rate of 3650 m³/yr in the confined aquifer. When a well is pumped, head is lowered in the aquifers, and additional water is drawn out of the river. For example, results of the standard simulation show that after five years of pumping at Well 1, stream flow in the river is depleted by 1.24 m³/yr, or about 0.034% of the withdrawal rate.

We have found that we can use MODFLOW with the RIV package to solve directly for the stream depletion caused by pumping at any location in the aquifer. The only new assumption that must be made is that the change in head in the unconfined aquifer is small relative to the saturated thickness. Figure 1c shows a plot of stream depletion as a percentage of pumping rate for any location in the confined aquifer. The results are shown after five years of pumping. For example, if a well is installed at Point A in Figure 1c, approximately 1% of the water that is pumped in Year 5 will come from depletion of the river. This exceeds the criterion for non-tributary groundwater, so if a well were installed at Point A, it would pump tributary groundwater that would

be subject to water rights. Similarly, if a well were installed at Point B in Figure 1c, approximately 0.01% of the water that is pumped in Year 5 would come from depletion of the river; making this a candidate well location. As a verification of these results, note that the stream depletion due to pumping at Well 1 is approximately 0.034% of the pumping rate, which is equal to the value obtained from the standard simulation method.

A well installed near the river will cause more stream depletion than a well is installed farther away. For example, at (x,y)=(1600m, 2000m) in Figure 1c, which is near the river, stream depletion is approximately 5% of the pumping rate; however, at Well 1, which is farther away from the river, stream depletion is much lower.

The model results show essentially no stream depletion for a well near the northern or southern boundary. In the model, these boundaries are simulated as constant head boundaries, so they can provide an unlimited supply of water to the aquifer; therefore, a well near these boundaries will draw most of its water from outside of the model domain and relatively little from the river. If the constant head boundary is not physically realistic, the model results may not be meaningful near the boundary.

This example demonstrates that with a single simulation of MODFLOW, we can determine stream depletion for pumping at any location in the aquifer. The model results can be used to choose a well location that will minimize the impact of the well on surface water flows. The method has been developed and demonstrated for a single well in a confined aquifer. Additional work is being conducted to address other scenarios.

Six States Collaborate to Generate Nutrient Solutions

MaryLou Smith, Policy Collaboration Specialist, Colorado Water Institute

What drew watershed ecologists, corn and grain producers, wastewater treatment plant operators, university professors, and federal agency administrators to a six-state regional workshop in Salt Lake City, Utah from February 15-17, 2011?

A workshop on nutrients. Specifically, a workshop for Environmental Protection Agency (EPA) Region 8 states to roll up their sleeves to find solutions to the problem of nutrients degrading water quality, specifically phosphorous and nitrogen.

participants to generate specific and solid recommendations for EPA, the state water quality departments, and other agencies on the topic of setting numeric standards, regulating in other ways, or providing incentives to manage nutrients affecting water quality.

The committee wanted the workshop to be an opportunity for nutrient-interested players to listen and be heard, to hear and deliberate about the state of the science, and to consider practical approaches being attempted in waste water, drinking water, agricultural operations, and storm water, not only in the six states, but elsewhere.



Patrick Snyder, representing the South Dakota Department of Environment and Natural Resources, speaks during the panel discussing what states are doing already about nutrient levels. To his right: Steve Gunderson, Colorado Department of Public Health and the Environment; Walt Baker, Utah Division of Water Quality; and Mike Suplee, Limnologist from Helena, Montana.

Photo by Lindsey Knebel

Others included in the list of almost 200 participants were public works directors, state farm bureau representatives, the board chair of a sewer district, a livestock environment specialist, and a citizen's alliance river program director. The importance of this diversity is that workshop organizers sought a diverse group of stakeholders, academics, regulators, and administrators to work together to tackle a myriad of issues surrounding this complex topic.

CSU's Colorado Water Institute (CWI) was funded by Region 8 EPA to convene the workshop. More than 25 committee members from the six states of Colorado, Montana, North Dakota, South Dakota, Utah and Wyoming worked for six months to design a program to concentrate on a focused list of questions. The intent was to see if they could draw a diverse group of workshop

Were they successful?

On a scale of 1-5, the overall answer of workshop participants was a 4.5 – yes!

For details about their results, and a set of bold recommendations for the EPA and others, watch for an article in this newsletter's June/July 2011 issue, as well as a comprehensive, reader-friendly post-workshop report in May.

Walt Baker, director of the Utah Department of Water Quality, closed the workshop by saying that he was surprised, frankly, to see this diverse group of players on the same dance floor, but the result was that everyone came out of their siloes to really listen to one another. He suggested participants work to enact ideas generated—"let this be a spring board," he said.



Interagency Teams Fight Erosion Following Fourmile Canyon Fire

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

Fourmile Canyon Fire Teams Tackle a Watershed Emergency

Most wildfires – even exceptionally large, destructive ones like the Fourmile Canyon Fire – run their course in less than a few weeks. But it takes years to rebuild homes and lives, reforest hillsides, and stabilize steep slopes to prevent excessive erosion.

Flooding and erosion are top concerns in the aftermath of the Fourmile Canyon Fire, which burned more than 6,000 acres west of Boulder in September of 2010. The wildfire vaporized ground cover that normally would intercept rainfall and created water-repellent soils in severely burned areas. As a result, there is a significant risk for dangerous flooding, extreme erosion, and heavy sedimentation downstream that could endanger life, damage property, and degrade water quality. Recognizing this threat, state, federal, and Boulder County agencies have formed two interagency teams to ensure that actions are taken to stabilize and protect affected soils in the burn area before this season's first heavy rainstorms. The Fourmile Emergency Stabilization (FES) Team is helping mitigate runoff and erosion risks through widespread watershed rehabilitation operations, while the Fourmile Fire Rehabilitation Outreach Team simultaneously provides landowners impacted by the wildfire with ongoing information to address watershed threats.

“There will be impacts to the local watershed. It’s our goal to minimize those impacts,” said outreach team member Allen Owen, district forester for the Boulder District of the Colorado State Forest Service (CSFS).

Stabilization Team Formed to Rehabilitate Landscape

Last September, soon after the Fourmile Canyon Fire was controlled, the FES Team formed to write a report detailing the watershed emergency created by the fire and provide options to mitigate related problems. The team realized that it would be difficult to provide emergency stabilization across the entire burn area due to the land ownership pattern within the fire perimeter: two-thirds of the acreage burned by the fire is on a patchwork of privately owned land, and the remaining acreage is divided between the Bureau of Land Management (BLM), U.S. Forest Service (USFS), state, and county.

To communicate the importance of the FES Team’s cross-boundary rehabilitation efforts and provide information about rehabilitating individual properties, the Fourmile Fire Rehabilitation Outreach Team was formed. The outreach team, which includes several members of the FES Team, is composed of natural resource specialists from Boulder County, the Natural Resources Conservation Service (NRCS), CSFS, USFS, local conservation districts, and Colorado State University (CSU) Extension. The

Although many homes survived the Fourmile Canyon Fire, much of the surrounding vegetation burned.

Courtesy of CSFS

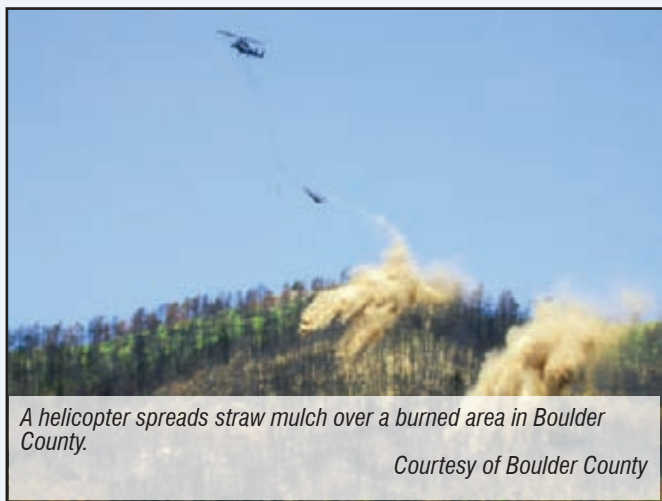
primary goal of the team is to provide education and outreach to area landowners about actions they can take to accelerate the recovery of the landscape, including cooperation on cross-boundary rehabilitation efforts. By reaching out to those impacted by the fire, the outreach team hopes to provide assistance to landowners and facilitate the recovery of a burn area that covers a mélange of different ownerships.

“We need to treat the burn area on a watershed scale to be effective,” Owen said. “Like the wildfire itself, future storm events won’t recognize property boundaries, so we need to work across them now.”

Short-Term Stabilization Requires Landowner Permission

Protecting the barren, water-repellent soils from the first intense rainstorms is the principal goal of the two interagency teams. During the first few spring and summer seasons following an intense wildfire, before native vegetation has returned, erosion is usually much more severe due to the sheer amount of exposed soil. If this problem is not addressed in the Fourmile burn area, heavy rains could wash massive loads of dirt and debris from recovering hillsides onto roads, over culvert openings, and into gulches that ultimately drain into Boulder Creek.

To mitigate watershed threats across the burn area, the FES Team is planning the widespread use of aerial mulching. The goal is to apply weed-free straw mulch by helicopter early this spring on 1,800 intensely burned acres with a slope of 20 degrees or more. Aerial application of mulch is probably the most effective way to reduce runoff and erosion because it addresses the entire landscape, allowing the mulch to take the place of grasses, pine needles, sticks, and other natural litter that existed before the fire. The mulch intercepts raindrops before they hit bare soil, slowing them down and preventing them from freeing soil particles to run downhill. The NRCS, Boulder County and other government funds will cover the \$2.2 million tab for broadcast seeding and aerial mulching operations.



A helicopter spreads straw mulch over a burned area in Boulder County.

Courtesy of Boulder County

Despite available funding, aerial mulching operations in the Fourmile burn area face a significant obstacle because the burned area straddles so many small, individually owned tracts of private land. To build consensus on aerial mulching plans and other soil stabilization operations, the teams held a series of community meetings over the fall and winter. At the meetings, landowners were asked to sign Emergency Watershed Protection Permits. The signed permits grant legal permission for watershed protection work that may directly impact more than 520 plots of private land, and also allow for the installation of sediment traps and sand bags. The teams hope to get 100-percent compliance.

“Getting everyone involved makes broad-scale stabilization measures possible,” Owen said. “The more stabilization we can do now, the less impact on water quality we’re going to have down the road.”



Straw bales were installed immediately after the fire to trap sediment. Courtesy of CSFS

Owen says the community meetings and a comprehensive set of frequently asked questions about land rehabilitation released by the outreach team have helped inform local landowners about risks and concerns in the burn area. Outreach team members also have provided advice about restoration measures, such as seeding, on-the-ground mulching, planting seedling trees, and safely removing dead trees. In addition, landowners are being encouraged to establish erosion barriers in the form of straw wattles or contour-felled logs – dead trees that are felled and anchored perpendicular to slopes to slow runoff and trap eroding soils.

Fire Chief Brett Haberstick of the burn area’s Sunshine Fire Protection District says the community meetings have done more than just provide technical rehabilitation information. “These meetings have been very valuable as gathering points for sharing stories and asking common questions,” Haberstick said. He says that some landowners may be leery of government agencies telling them how to care for their own land, but he thinks the community meetings are useful for rapidly building trust. “If we don’t do what is right now, the overall attempt to restore the landscape may be less effective in the future,” he said.

Boulder County plans to recruit volunteers and local fire protection districts like Haberstick's to help spread native seed along roadsides to reduce the risk of invasive weed colonization.

Seedling Trees – A Long-Term Erosion Solution

Although immediate soil stabilization measures will remain the primary concern for the next few years, the outreach team also is encouraging area landowners to think about long-term goals. Planting seedling trees is one of the best long-term solutions to rejuvenate burned forests and control erosion. As the trees grow, their spreading roots trap and retain soil, while their canopies intercept and disperse the energy of falling rain.

“Many plants will recover naturally after a wildfire,” said Randy Moench, manager of the CSFS Nursery in Fort Collins. “But planting seedling trees can accelerate regrowth and ensure that a variety of appropriate species recolonize a burned area, creating a healthier future forest.”

The CSFS Nursery has provided hundreds of thousands of inexpensive tree seedlings to reforest burned areas in the past, including part of the area burned by the 2002 Hayman Fire. To encourage replanting, the Longmont Conservation District, which distributes CSFS tree and shrub seedlings in Boulder County, is currently providing them at a reduced cost to those affected by the Fourmile Canyon Fire. Many species native to the area, such as ponderosa pine, Rocky Mountain juniper and Douglas-fir, are available for reforestation, soil retention and wildlife habitat improvement.

The conservation district is helping landowners order and obtain the CSFS seedlings, while CSFS, NRCS and CSU Extension personnel provide planting workshops, technical advice, and seedling survival tips.

Landowners Empowered by Team Efforts

“I’ve received numerous positive comments from landowners saying that these meetings are exactly what they need and that they are very impressed by the number of interagency staff in attendance,” said Garry Sanfaçon, Fourmile Canyon Fire recovery manager for Boulder County. “Clearly, this shows the dedication of Boulder County, the Colorado State Forest Service, the Natural Resources Conservation Service, CSU Extension and the other agencies involved to provide the best service to help affected landowners recover.”

Fire Chief Haberstick also has been impressed by how the outreach team has provided valuable information and outreach to landowners through multiple venues. “These landowners are confronted with a dizzying amount of decisions that need to be made in the wake of the fire. But the team has been able to respond quite well to the variety of their needs,” Haberstick said.

In the end, the combined efforts of the rehabilitation and outreach teams not only will benefit local landowners and ecosystems, but also those living downstream from the watershed. Which is important because, as Owen puts it, “It’s all downhill to Boulder.”

2011 Arkansas River Basin Forum

April 27- 28, 2011 — “Retaining. Rethinking. Restoring.”



Keynote Speaker:

Mr. John Stulp
Special Policy Advisor to the Governor on Water

Topics:

- Ecological restoration approaches and tools
- Nutrient discharge management
- Land use planning and flood control
- Emerging contaminants

The 2011 Arkansas River Basin Water Forum, hosted by the Fountain Creek Watershed, Flood Control, and Greenway District, will be held April 27-28 in south Colorado Springs at the Norris-Penrose Event Center (www.norrispenrose.com).

The Forum has been a focal point for highlighting current water issues in the Arkansas River Basin and in Colorado since its inception in 1995. Planners, presenters, and attendees represent a wide variety of organizations, agencies, and public citizenry working on water resources issues in the basin. As the basin contends with an array of restoration and resource management issues, the Forum theme this year is “Retaining. Rethinking. Restoring.”

Scholarships: The Forum sponsors are pleased to offer \$2000 in scholarships to outstanding graduate students. More information is available at our web site (www.arbwf.org/).

Registration prior to April 22 is \$45 for both days, \$25 for one day, and no charge for students. Please visit the Forum website at www.arbwf.org/ or contact Dr. Perry Cabot at (719) 549-2045 for more information.

Water Tables 2011: Support for the Water Resources Archive Continues to Increase

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

More than 200 people interested in water history came together on February 19 to attend the sixth annual Water Tables, the fundraiser held by the Colorado State University Libraries for the Water Resources Archive. Initial tallies indicate that the generosity of the event sponsors and attendees will provide nearly \$50,000 to support the Archive.

The theme of this year's event was "Western Water Law: Adapting to Our Changing Needs?" Twenty-three water experts, including one international and four out-of-state guests, hosted tables discussing relevant topics while a gourmet meal was served. Before the dinner, attendees had a chance to meet the hosts during a reception held in Morgan Library.

During his remarks at the reception, CSU Chancellor Joe Blake called the Water Resources Archive a "real treasure" for both CSU and the state. The archive preserves historical materials related to Colorado's water that might otherwise be lost or inaccessible.



Justice Greg Hobbs and CSU Chancellor Joe Blake enjoyed themselves at the event.

Photo by John Eisele

Also during the remarks at the reception, David Robbins and John Draper, opposing attorneys on the *Kansas v. Colorado* case concluded in 2009, talked about Arthur Littleworth, Special Master for the case. Mr. Littleworth donated all of his papers on the 25-year-long case to the Water Resources Archive, making his work and that of the two legal teams fully accessible to the public. The documentation on the Arkansas River available in the collection is an invaluable resource for historical research.

The archive exhibit, *Achieving a Lasting Peace? Reflecting on Conflicts, Courts and Compacts*, featured Mr. Littleworth's documents along with those of Delph Carpenter. Selected items traced the history of Arkansas River water law and litigation from the past 110 years, including the two *Kansas v. Colorado Supreme Court* cases and the Arkansas River Compact.

To kick off the dinner discussions about water law, Colorado Supreme Court Justice Greg Hobbs made some introductory remarks. He discussed the value of information that can be found in the archive as well as the importance of citing sources, referencing accusations of a political candidate's plagiarism of Hobbs' work during the 2010 campaign season.

Once remarks concluded, table discussions got underway. These included a discussion of "Australian water reform: what's in it for U.S.?" with Will Fargher, the general manager of the Water Markets and Efficiency Group, National Water Commission, Australia, as well as "Our water future: how do we get from the law what we need?"



The 23 table hosts for Water Tables 2011.

Photo by John Eisele



Archivist Patty Rettig (second from left) and her student assistants, Clarissa Trapp, Alan Barkley, and Jordan Deignan.
Photo by John Eisele

with Adam Schempp, director of the Western Water Program, Environmental Law Institute, Washington, D.C. Other hosts and topics included Heather Knight, Laramie Foothills Project Director, the Nature Conservancy of Colorado, discussing “Shared vision planning: engaging diverse interests in decision making”; Doug Kemper, Executive Director, Colorado Water Congress, discussing “Can water policy be both stable and flexible?”; and Eric Wilkinson, General Manager, Northern Colorado Water Conservancy District, discussing “Innovation, integration, and infrastructure: addressing Colorado’s future water needs.”

Discussions at dinner were lively and engaging. Many guests remarked on the value of the diverse perspectives

presented, whether from someone in a different profession, a different basin, or a different country. One guest called Water Tables one of the top five “must attend” water events in the state.

Thanks to the event sponsors, 33 graduate students were able to attend. This opportunity enables the next generation of water leaders to meet and talk with the current water leaders.

The Archive preserves materials critical for documenting the state’s water history. Funds raised for the event will go toward continuing to preserve and make accessible historical water documents and continuing outreach activities.

Gold sponsors of the event were the Colorado Water Conservation Board, CDM, Produced Water Development LLC, and Stewart Environmental Consultants, Inc.

Silver sponsors were AECOM, Applegate Group Inc., Aurora Water, Ayres Associates, Black and Veatch, Brown and Caldwell, City of Greeley, Colorado River Water Conservation District, Cache La Poudre Water Users Association, The Ferguson Group LLC, Fischer Brown Bartlett & Gunn PC, Leonard Rice Engineers Inc., Northern Colorado Water Conservancy District, Obermeyer Hydro Inc., Regensis Management Group LLC, Rio Grande Water Conservation District, Rubicon Systems America Inc., Dr. and Mrs. Robert Ward, and White & Jankowski LLP.

Bronze sponsors were Aqua Engineering Inc., Bratton Hill Wilderson & Lock LLC, Clear Water Solutions Inc., Colorado Corn, Deep Rock Water, Deer and Ault Consultants Inc., Hilton Fort Collins, Lawrence Jones Custer Grasmick LLP, The New Cache La Poudre Irrigating Company & The Cache La Poudre Reservoir Company, Odell Brewing Company, and Wright Water Engineers.

A Drought Early Warning System for the Upper Colorado River Basin

Nolan Doesken, Wendy Ryan, and Becky Smith

Colorado Climate Center, Department of Atmospheric Science, Colorado State University

Problematic drought in the West stirred the Western Governors Association to work closely with Congress in the late 1990s and early 2000s to improve drought policy and planning. The culmination came in 2006, when President Bush signed Public Law 109-430 – the National Integrated Drought Information System Act (NIDIS). The purpose of this legislation was to create “a dynamic and accessible drought information system that provides users with the ability to determine the potential impacts of drought and the associated risks they bring, and the decision support tools needed to better prepare for and mitigate the effects of drought.”

By 2007 the organizers of the NIDIS selected the Upper Colorado River Basin upstream from Lake Powell to the headwaters of the Colorado River in northern Colorado as the first Pilot Project for NIDIS (see Figure 1). The Colorado River was chosen for several reasons, including its propensity for drought, its important interstate compact, the management of Lakes Powell and Mead, the combination of federal and private resource issues, the large amount of transbasin diversions that move water out of the Colorado River Basin, and the projections that this basin could see reductions in water supplies if climate projects for the next several decades are realized.

The first “scoping” meeting for the Upper Colorado River Basin Pilot Project was held in late 2008 to narrow down the goals and needs of the basin and solicit stakeholder involvement. One of the practical goals was to develop a multiagency collaborative effort to improve drought monitoring and early warning for the basin and those adjacent areas (like the Colorado Front Range) who rely on water from the Upper Colorado River Basin.

In 2009, the Colorado Climate Center at Colorado State University was enlisted by the NIDIS Program Office to assist in this effort. We began by interviewing a wide range of interests to find out more about their needs and concerns related to drought. With the extreme drought of 2002 still fresh in many minds, and the perception that water officials were caught off guard by that drought, it was easy to solicit input on what people thought could and should be done better.

Some of the key points that came from those interviews with water users, providers and managers included the following

- Drought of one year or shorter duration was not much of a concern (except for causing wildfire). Drought of three year or longer duration is a much greater concern. Warnings for the severe multiyear drought periods would be greatly appreciated.
- Seasonal and annual climate and water supply forecasts are greatly appreciated but should be more accurate. Accurate forecasts out to two years with could greatly improve water management for drought situations. Ski resorts are particularly interested in November conditions, since November helps set the tone for the entire winter recreation season.
- Analogs are helpful to show what previous years are likely to be similar to the current year.
- It would be helpful if all the various sources of drought and water supply information could be contained in the same place and made accessible.
- The U.S. Drought Monitor weekly update maps are well known and popular. However, users tended to only trust them for other parts of the country and not their own immediate areas.
- It would be beneficial to have more frequent comprehensive water supply updates at critical times of the year.

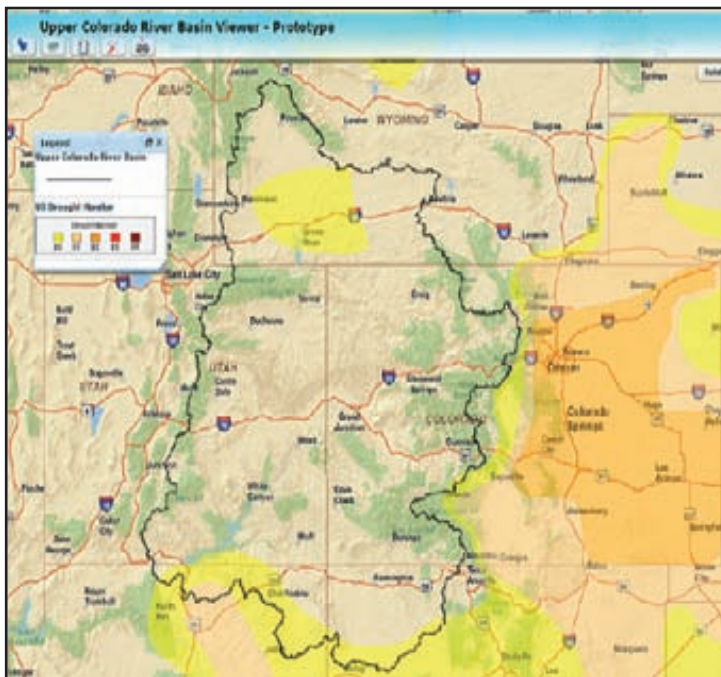


Figure 1. The Upper Colorado River Basin, outlined in black, with the yellow and orange highlighting showing the recent Drought Monitor, a measure of drought severity.

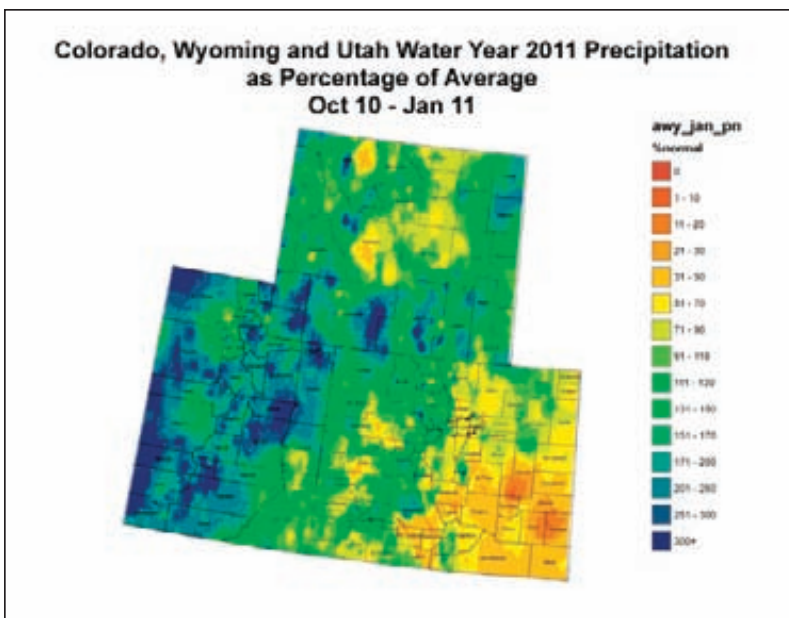
- Better projections of the current and next seasons' water demand on the Front Range would be useful.
- More Snowpack Telemetry (SNOTEL) stations should exist in sparsely monitored areas to collect snowpack information.
- More transects (segmented regions) should exist to show elevational distribution of snowpack.
- There is a keen interest in better understanding the magnitude and variation in snowpack sublimation.

Since 2009, efforts have begun to address some of these suggestions and concerns. Starting in 2010, the Colorado Climate Center introduced online "Webinars" specifically targeting current and projected water supplies in the Upper Colorado River Basin. These are condensed 20-minute assessments that look at recent precipitation, seasonal snowpack, streamflow, reservoir levels, soil moisture, anticipated water demand, and future weather and climate forecasts. These were held weekly from March through mid June followed by monthly or less frequent Webinars during the rest of the year. Hydrologists from the U.S. Geological Survey provide streamflow expertise; the National Weather Service provides weather expertise, and other content

experts help as needed. Through a collaborative process, the most up to date climate and water supply information is made readily available.

Last year, the Front Range had generous moisture and water supplies while the mountains and high valleys of the Upper Colorado were dry until spring storms arrived. This year has been quite different, with the mountains being pounded with heavy snows while Colorado's eastern plains remain extremely dry (see Figure 2).

The 2011 weekly UCRB Webinars are now underway and will be held every Tuesday morning through June. Narrative assessments are also prepared each week year-round and distributed electronically to all interested parties. These include a discussion of the local US Drought Monitor maps and recommendations for changes to the drought designations in Colorado, Wyoming, and Utah. Through intensive monitoring, we are supplementing the work of the Colorado Water Availability Task Force and providing the best available information to anticipate the next inevitable drought episode.



Interested in tracking water supply and drought conditions in the Upper Colorado River Basin?

Current and past water supply assessment reports are available online at ccc.atmos.colostate.edu/drought_webinar.php

If you would like to subscribe to receive this weekly assessment report and invitations to the Webinars by E-mail, please send an E-mail to Henry Reges: hreges@atmos.colostate.edu with "UCRB NIDIS Assessment List" in the subject line.

Figure 2. This precipitation map is an example of the information provided on the Colorado Climate Center website, which the general public may access.

Extension Specialists Focus on Water Under CWI

Lindsey A. Knebel, Editor, Colorado Water Institute

Perry Cabot, Joel Schneekloth, and Denis Reich are water outreach specialists at Colorado State University who work under Extension and, in 2010, began receiving direction from the Colorado Water Institute (CWI).

“It seemed logical to take the interest in water at CSU and blend it with Extension,” explains Cabot. Extension specialists conduct research and outreach in the field and connect information and research with local communities that might benefit from it.

“Water is a fairly technical and local subject, so local politics are involved,” says Cabot, and those local issues can’t always be dealt with from one location in the state – i.e., a university. “In order for the university to have a real relationship with water stakeholders, we have to be local.” He points to the Colorado Water Conservation Board’s model of having statewide input with members that represent all parts of Colorado – water outreach needs to have the same statewide presence, he says.

According to Schneekloth, one of the biggest changes the team experienced from the switchover is their ability to collaborate with each other on water topics in the state. “[Now] we can look at similarities between our regions that we can work on statewide,” says Schneekloth. He says that already, a few grants have been put in to look at statewide water issues thanks to their collaboration.

Cabot, Reich, and Schneekloth answer to different parts of the state – Schneekloth looks into water issues mainly in the High Plains and the South Platte, Reich looks into issues west of the Continental Divide (including the Colorado, San Juan, Gunnison, North Platte, and Yampa river basins), and Cabot takes on water issues in the Rio Grande and Arkansas river basins in southern Colorado. Their regions tend to overlap frequently, however, due to water transfers between basins and the difficulty of defining fixed basin boundaries.

The team also shares similar directives for their extension work. These fall into three general categories: supporting the efficient and optimal use of water, maintaining water quality, and promoting education.

Each of the three specialists exercises these directives to different lengths depending on the specific needs of their regions. Reich, for example, says that water quality is a major concern to stakeholders on the western slope of the state, where water is used in recreation and public lands. A large part of the concerns there, says Reich, are to protect wild and scenic river segments and endangered species. “Every stakeholder group is slightly different,” he says.

In Cabot’s region, efficient and optimal uses of water tend to be of import. Cabot explains the idea of a water gap in Colorado – the shortage between what water demand



Joel Schneekloth (left), Denis Reich (right) with furrow irrigated canola at the Western Colorado Research Center, Fruita, Colo.



will grow to in the future and how much water the state can supply. “We focus a lot on this gap,” says Cabot. Conservation is important, he says, and education is one of the methods he uses to promote the efficient use of water in places like agricultural and landscape irrigation, as well as K-12 groups.

Speaking at public events, promoting research, and conducting their own applied research projects are just part of the variety of job duties that Cabot, Reich, and Schneekloth perform as outreach specialists. Cabot explains that a typical week might consist of grant-writing, facilitating public meetings, attending water summits and roundtable discussions, conducting research, teaching a seminar, and talking over the phone about various research projects. All three also stay in touch with the CSU water community to share research ideas and results.

An important part of that day-to-day work, says Cabot, even in the age of new technologies that promote long-distance communication, is connecting face-to-face with stakeholders. “Nothing will ever substitute the face-to-face partnerships that Extension prides itself on,” says Cabot.

“We’re on the forefront of water issues,” says Schneekloth. “We have producers’, commodity groups’, and organizations’ ears, and we also have ears on what the issues are so we can bring them back to CSU.”

Reich also touts the advantages of getting to know stakeholder groups on a local level. Because of his local involvement, says Reich, he was able to connect a district in his region with a grant program he discovered. “I don’t think they would have otherwise known about that funding,” says Reich.

“It takes years to build that trust with local partners,” says Cabot. “Local endeavors, relationship-building, local politics – you can’t do this when you only interact with them once a year.”

Local, small-scale research is a key part of the team’s work in outreach. According to Cabot, all three have developed small research programs geared specifically towards local issues in their regions. Cabot is working on a biofuel project, for example, which is growing in popularity with agriculture because oil seeds require less water to produce, and they are valuable as a fuel source.

In addition to creating their own research projects, the team also serves as an “extension” of CSU research. “We have a lot of water research going on at the university,” says Cabot, “and unfortunately, we don’t have as much extension as we would like to get the results of our research out to the state. We are trying to cast a much larger net to bring more



Perry Cabot reports on an agricultural project in February, 2011 at the Seventh Annual Arkansas Valley Farm/Ranch/Water Symposium and Trade Show.

Photo by Bette McFarren

researchers into CSU water programs, recognizing that folks on campus don’t have the mobility to travel.”

Reich is working with CSU researchers to connect selenium research with stakeholders on the western slope. “Selenium inhibits the growth of certain fish populations when it is expelled from irrigated soils,” explains Reich. His work, then, is to translate the findings from CSU research to agencies working with the western slope’s water on a local level.

The switchover for Cabot, Reich, and Schneekloth to working under the Colorado Water Institute has been in effect for less than one year, but the arrangement has been successful thus far. “CSU Extension and CWI both have the role and responsibility to bring research-based information to bear on the water problems and decisions facing our state and our stakeholders,” says Reagan Waskom, CWI Director. “It only makes sense that we work together to increase our efficiency and impact.”

FY11 CWI Research Projects

Victor Sam

Master's Candidate, Civil and Environmental Engineering, Colorado State University

Study: The Efficacy of the Use of Moringa Oleifera Seeds to Remove Metabolites of Cyanobacteria from Drinking Water

Award Amount: \$4,980

Faculty Sponsor: Pinar Omur-Ozbek, Civil and Environmental Engineering, Colorado State University

The proposed work aims to study the occurrence and removal of the cyanobacterial metabolites microcystin-LR, geosmin and 2-MIB in source waters. Microcystins are potent hepatotoxins which can cause severe cases of gastroenteritis and hepato-enteritis (i.e., liver damage). Geosmin (*trans*-1,10-dimethyl-*trans*-9-decalol) and 2-MIB (2-methylisoborneol) are odorous compounds that cause earthy and musty odors in drinking water, respectively. Recently it was shown that microcystins usually co-occur with such taste-and-odor compounds. Since geosmin and 2-MIB can be detected by the human nose at very low concentrations, the surveillance of harmful toxins may be easily performed.

Currently, there is not a cost-effective and sustainable method to treat source water for these detrimental metabolites. That is why the moringa oleifera tree seed will be studied in this project for its ability to treat water. The moringa oleifera seed has already been used for many purposes in third world countries, serving as a source of food, medicine, and more recently an effective coagulant for water treatment. The seed, which is grown in most parts of the world, eliminates the addition of synthetic chemicals.

Evan Rambikur

Master of Science, Civil and Environmental Engineering (Irrigation and Drainage Engineering), Colorado State University

Study: Large Aperture Scintillometers for Evapotranspiration (ET) evaluation

Award Amount: \$4,740

Faculty Sponsor: José Chávez, Civil and Environmental Engineering, Colorado State University

Irrigation water management can be more effective and accurate when the crop consumptive use (CU), or evapotranspiration (ET), is known. This allows for more efficient irrigation. Research on different methods of evaluating ET is much-needed, therefore. Local estimates of ET can be made directly by precision-weighting lysimeters and Large Aperture Scintillometers (LAS, Kipp and Zonen, The Netherlands), coupled with the land surface energy balance (EB) equation.

At the Colorado State University (CSU) Arkansas Valley Research Center (AVRC) near Rocky Ford, Colorado, current efforts are being made to validate the use of LAS-EB systems to estimate ET over homogeneous crop surfaces using measured ET from a Large Weighing Lysimeter. LAS data were collected in the 2009 and 2010 growing seasons for alfalfa and corn crop surfaces. For the upcoming 2011 growing season, a network of four LAS-EB systems is proposed to be deployed in the Arkansas Valley over proposed alfalfa, corn, and native vegetation surfaces. The primary subject will be the performance of the LAS-EB systems. The objectives are to establish the accuracy of LAS units in obtaining vegetation ET rates over varying surfaces, and to present the results at local and national water related professional meetings.

Alia Khan

**Master of Science Candidate, Civil and Environmental Engineering (Water/Environmental),
University of Colorado at Boulder**

Study: Novel Technique for Evaluation of Dissolved Organic Material (DOM); research methodology and lab protocol development using a FluidImages FlowCAM® on lake water samples across the state of Colorado

Award Amount: \$4,500

Faculty Sponsor: Diana McKnight, Civil and Environmental Engineering, University of Colorado at Boulder

In recent years, increases in dissolved organic carbon (DOC) concentrations in surface waters have been documented in many northern temperate regions, and the affects of increasing DOC on aquatic ecosystems and drinking water quality are not yet fully understood. FlowCAMs® are becoming used more frequently by Water Treatment plants in order to monitor algal species, such as invasive ones that could cause harmful algal blooms. This novel instrument has extremely high capabilities, but our lab has no prior experience using it, and thus no existing methodology.

The aim of this study is to develop a research protocol for an instrument addition to our lab at INSTAAR; the Fluid Imaging Technologies FlowCAM®. FlowCAM® is a state-of-the-art instrument for rapid monitoring of particles in fluid. FlowCAM® automatically counts, images, and analyzes the cells in a discrete sample or a continuous flow. This provides instant, increased data collection by producing a digital image of each cell and then presents the data in an interactive scattergram.

Anne Maurer

Master's Candidate, Groundwater Engineering, Colorado State University

Study: Aquifer Storage and Recovery Optimization

Award Amount: \$5,000

Faculty Sponsor: Tom Sale, Civil and Environmental Engineering, Colorado State University

Increasing demands for water and finite resources are driving a need for more efficient water storage systems. An emerging strategy is aquifer storage and recovery (ASR). With ASR, seepage and evaporation loses can be minimized. Furthermore, peak capacities of key infrastructure elements such as surface water storage, water treatment plants, and pipelines can be reduced. Unfortunately, resolving necessary infrastructure, timing of aquifer storage and recovery is a complex process. Key factors governing infrastructure and operations include timing of water delivery, water quality, and timing of demands.

The purpose of the study will be to develop an optimization model that can be used to:

- Resolve appropriate infrastructure and operations for ASR.
- Develop feasibility level cost estimates.

Preliminary work has been completed in this effort with support from the Town of Castle Rock, Dr. Sale faculty startup funds, and a senior design project. Matching support for this project will be provided by the Town of Castle Rock.

FY11 CWI Research Projects

Umit Duru

PhD Candidate, Geomorphology, Colorado State University

Study: Variables Controlling Reservoir Sedimentation in the Colorado Front Range

Award Amount: \$5,000

Faculty Sponsor: Ellen Wohl, Geosciences, Colorado State University

The challenges of managing sediment issues in Front Range reservoirs are exemplified by recent sedimentation problems at Halligan (reservoir sediment release caused major downstream fish kill) and Strontia Springs (reduced water quality followed wild fire). Consequently, we need to develop a robust model of controls on reservoir sedimentation that can be used by managers. Although a few reservoirs have been studied in detail, only very limited work has been done on reservoir sedimentation throughout the Front Range. This study will be a unique and important study that can be used to improve reservoir management.

One challenge in understanding reservoir sedimentation is that sediment yield to a reservoir varies by location and time as sediment supply, storage, and mobilization from the contributing watershed change. This variability partly reflects regional characteristics such as lithology, rate of sediment generation, and mechanisms of sediment movement. The objective of this research is to evaluate the relative importance of parameters influencing sedimentation rate within and between reservoirs in the Front Range. The hypothesis going into the study is that reservoir sedimentation correlates most strongly with the magnitude (spatial extent, frequency) of disturbance that alters land cover (e.g., forest fire) because disturbance can mobilize large volumes of sediment from the watershed. Increased disturbance by forest fire results in more sedimentation in numerous sites across the Front Range. The alternate hypothesis, then, would be that reservoir sedimentation correlates most strongly with drainage area, relief, or elevation. The research will develop a GIS (geographic information system)-based statistical model to determine the factors most important for reservoir sedimentation in the Front Range.

Meagan Smith

Master's Candidate, Hydrologic Science and Engineering, Colorado State University

Study: Environmental Impacts of Ag-to-Urban Water Rights Transfers in the South Platte River Basin

Award Amount: \$5,000

Faculty Sponsor: Mazdak Arabi, Civil Engineering, Colorado State University

Previous research on ag-to-urban water transfers has focused primarily on the financial impacts associated with the reducing agricultural production. Little is known about the potential ecosystem impacts associated with transferring water out of agriculture. With this research, I will utilize Colorado Decision Support System water rights data in conjunction with geographic information system software and eRAMS to develop a model of the South Platte River Basin that relates the presence of incidental wetlands with specific water rights; taking into account hydrologic and geospatial properties, including soil type, irrigation practices, land use, and climate, to name a few. This model will allow the user to determine the location and estimate the extent of wetland impacts associated with the transfer of a specific agricultural water right and link the presence or absence of wetlands with things like land use change, climate change or wildlife habitat. Multiple ag-to-urban transfer scenarios will be developed and compared to baseline wetland data to investigate impacts on water quality, specifically nutrient capture (nitrogen, phosphorus, carbon). This research will provide not only a greater understanding of overall ecosystem impacts, but will allow a more complete valuation of all aspects of ag-to-urban water transfers, not just those associated with changes in production.

Principal Investigator: Balaji Rajagopalan

Civil, Environmental, and Architectural Engineering, University of Colorado at Boulder

Study: Paleohydrology of the Lower Colorado River

Award Amount: \$29,964

The State of Colorado draws a substantial portion of its water supply from the Colorado River. The reliability of this supply is a function of natural hydrologic variability, upon which anticipated changes in future climate will be superimposed. Thus, it is extremely important to understand the range of this natural variability in the basin streamflows to obtain a robust estimate of the water supply risk and consequently, devise effective management and planning strategies. Observed flow data that are limited in time (~100 years) cannot provide the full range of variability. Paleohydrologic reconstructions of annual flow using tree rings, however, provide much longer (500-1000+ years) records of past natural variability, and thus a much richer sampling of potential flow sequences, including severe and sustained droughts of greatest concern to water resource managers. Such reconstructions are available for the combined Upper Colorado River basin flows, but there is no equivalent dataset for the Lower Basin. In this research we propose to develop a paleohydrologic reconstruction of the total Lower Basin streamflow. We will use all the existing tree-ring data and naturalized streamflow records, with a suite of statistical methods. The reconstructions from the different methods will be combined to provide an "ensemble" of flows in each year, thus providing an effective characterization of the uncertainty. A rich variety of streamflow ensembles will be generated for the entire basin using this and existing reconstructions for the Upper Basin to explore the basin-wide water supply risk, focusing on implications for the water resources of the State of Colorado.

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Colorado Water Community Remembers Richard MacRavey

Lindsey A. Knebel, Editor, Colorado Water Institute



Richard D. “Dick” MacRavey, known as the Executive Director of the Colorado Water Congress (CWC) from 1980-2006, died at the age of 79 on Monday, February 28th, 2011. The current executive director of CWC, Doug Kemper, had the following remarks:

“Dick will be remembered for his tireless work in rescuing the Colorado Water Congress from financial difficulty. He built the foundation of the Water Congress that will serve as the base for all who follow him. His success in working with the legislature will stand as a permanent tribute to a man whose vision shall endure. The respect and relationship with the Colorado legislature that we enjoy is unique among non-profit organizations. Without his leadership, there would be no Colorado Water Congress today.”

In addition to directing the CWC, MacRavey served three years as Executive Director to the Larimer-Weld Council of Governments and seven years as Executive Director to the Colorado Municipal League. In 1970, he chaired the Colorado Good Government Committee for the promotion of the State Constitutional Amendments One, Two, and Three, all of which were approved. He served as a member of numerous committees and associations, including the National League of Cities Board of Directors, the American Society of Association Executives, the Colorado Society of Association Executives, the CWC, the American Water Works Association, and the Internal City Management Association, and he served on the boards of the Colorado Water PAC and the Colorado Water Education Foundation.

“Dick will always be remembered as the face of the Water Congress for so many years. He will be greatly missed by all,” said Joe Frank, CWC President.

“I believe Dick was one of the forces that created the opportunity for me to serve in this position,” said Secretary of the Interior and former Colorado Senator Ken Salazar. “He filled a strong mentorship role for me.”

MacRavey received the Wayne N. Aspinall Water Leader of the Year Award in 1999, and during his tenure as the CWC Executive Director, 350 of the 419 bills the CWC supported were enacted, and only one of the 123 bills the CWC opposed was enacted.

Gifts in Memory of Dick MacRavey

The Water Resources Archive will be honored to receive any memorial gifts on behalf of Dick MacRavey. Gifts should be made out to the CSU Foundation, noted for the Water Archive in memory of Dick MacRavey.

Send to: Andrea Lapsley,
Colorado State University Libraries
1019 Campus Delivery
Fort Collins, CO 80523

Faculty Profile: Lou Swanson

Lindsey A. Knebel, Editor, Colorado Water Institute

Since joining Colorado State University (CSU) in 1997, Lou Swanson has served as professor and chair of the Sociology Department, associate dean of the college of liberal arts, and (currently) the Vice President for Engagement. Swanson's current post is a new position for the university, which he explains is a result of President Tony Frank's mission to meet CSU's goals as Colorado's land grant university. These goals include teaching and learning, discovery and research, and outreach and engagement. "This office is one of the primary appointments for CSU's mission," says Swanson.

Swanson explains that as a result of his appointment, "we are more able to serve in a consistent way the water stakeholders of Colorado." His position also allows him to work with the state government, he says, and help fulfill Governor Hickenlooper's desire for a bottom-up style of government.

Besides connecting with state government, Swanson says he works closely with the deans of CSU's colleges, especially of colleges relating to sciences, resources, and business. He also oversees the Colorado Water Institute, CSU Extension, the Office of Community and Economic Development, Continuing Education, and the Bighorn Leadership Development Program, in no particular order, and he reports directly to President Frank.

Some examples of Swanson's recent work include representing CSU at the National Outreach Scholarship Conference (NOSC), a non-profit organization whose goal is to "build strong university-community partnerships anchored in the rigor of scholarship, and designed to help build community capacity," according

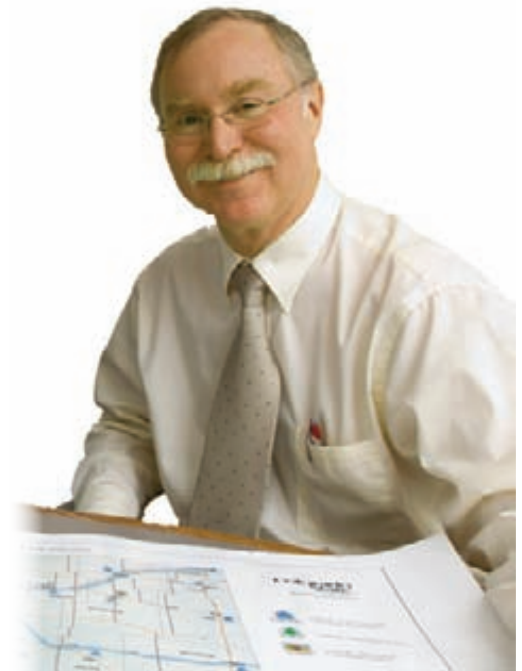
to their website. CSU is one of 15 universities involved in the NOSC.

Community engagement is a central idea for Swanson, who has a background in rural sociology – his bachelor's is in political science, followed by a master's in technology in international development and a doctorate in rural sociology. He served as a professor at the University of Kentucky in sociology before joining CSU, and he has co-authored six books on rural communities in the United States. Swanson also went to Tunisia from 1972-74 with the Peace Corps as a Resident Fellow at Resources for the Future – he helped construct wells and says he learned a great deal about how community and social structure are involved in natural resources. In 2009, Swanson was honored as an Outstanding Alumni in the College of Agricultural Sciences at Pennsylvania State University, where he obtained his doctorate. He has also served in the past as the president of the Rural Sociological Society.

Of his background, Swanson says that "rural sociology is interested in applying knowledge to the needs of people. I am continuing my interest and passion to connect talent with the needs of the state of Colorado."

Swanson says water is an important issue he deals with as part of his engagement directive. "Extension and community development in Colorado are all tied to water."

Swanson's office is currently involved with several new objectives – "we're



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transforming the engagement mission," he says. As of this January, for example, CSU Global Campus, a separate entity from CSU, is now an accredited university. Swanson is directly involved with a number of local initiatives, like President Frank's goal to expand Engagement into economic development. Swanson hopes this expansion will "enhance our capacity to help the people of Colorado as we strive to create new jobs."

"We're trying to make this office much more integrated – create more synergies for activity and hopefully increase our relevance."

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2011 UCOWR/NIWR CONFERENCE



Planning for Tomorrow's Water: Snowpack, Aquifers, and Reservoirs

Boulder, Colorado

July 11-14, 2011



The Universities Council on Water Resources announces the 2011 UCOWR / NIWR annual conference highlighting the vital role of water storage in planning for the water supplies of tomorrow. Water storage issues are at center stage and the opportunities for lively exchange abound. Providing reliable, sustainable, and secure water resources requires scientists and water managers to plan for the future. Water capture and storage is central to virtually every water system and water user who confronts the challenge of balancing water supplies and demands in a changing and uncertain environment. From lakes and reservoirs, to aquifers and groundwater, water storage and supply for many water systems also includes the accumulation and durability of snowpack. Snowpack helps to control the timing of vast quantities of available downstream water from the low periods of demand during winter to peak periods in the summer. As population and energy needs grow within a variable and possibly changing climate, it is increasingly challenging to ensure robust and resilient water supplies, adequate and secure infrastructure, and flexible and effective water use strategies. Everyone is a stakeholder where water storage is concerned and UCOWR and NIWR welcome you to participate!

Call for Abstracts for Posters

Posters will be displayed all day Tuesday, July 12 and Wednesday, July 13 at the Millennium Harvest House Boulder. Authors will be present on Wednesday from 6pm-7pm during the formal poster session, just prior to the UCOWR Awards Banquet.

We are currently accepting abstracts for poster presentations. Topics of interest include but are not limited to:

- Water supply planning and demand management
- Forecasting water supply and use
- Climate's role on water system reliability
- Adaptive management of water resources
- Water quality and protection of water supply
- Measuring and valuing snow, snowpack, and mountain runoff
- Groundwater recharge and management
- Distributed and small scale systems
- Water policy and economics
- Infrastructure needs and challenges
- International water issues
- Water conservation and education

Abstract Submissions

Poster abstracts are to be submitted online through May 31, 2011. The link is available at www.ucowr.org. Poster abstracts submitted prior to April 15, 2011 will be included in the conference proceedings.

Poster abstracts submitted between April 16, 2011 and May 31, 2011 will be eligible for presentation, but will not be included in the conference proceedings.

Poster dimensions are acceptable up to 48 inches tall by 96 inches wide.

Registration

Poster presenters must register for the conference or for their presentation only. If attending the conference, you can register online at through the link at www.ucowr.org, or via phone to 618.536.7571, or by faxing a completed registration form to 618.453.2671. If registering for the poster presentation only, please call 618.536.7571.

General Questions

Questions regarding posters? Please contact Rosie Gard at gardr@siu.edu or 618.536.7571 by June 30, 2011.

Water Research Awards

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

Culver, Denise R, Fish, Wildlife & Conservation Biology, USDA-USFS-Forest Research, Wetland Mapping and Survey for White River National Forest, \$52,500.00

Doesken, Nolan J, Atmospheric Science, Colorado State Water Conservation Board, Improvement of Lysimeter Operations and Consumptive Use Quantification in High-Altitude, Irrigated Meadows in the Yampa/White Basin, \$20,978.00

Doesken, Nolan J, Atmospheric Science, Colorado State Water Conservation Board, Monitoring Weather Conditions and their Effects on Evaporation Rates in Northeastern Colorado with the Colorado Agricultural Meteorological Network, \$20,000.00

Gates, Timothy K, Civil & Environmental Engineering, MWH Global, Assessment of the Impacts of the Arkansas Valley Conduit and Excess Capacity Master Contract on Ground Water, Return Flow and Solute Loads, and Crop Productivity in the Irrigated Stream-Aquifer System of Colorado's Lower Arkansas River Valley, \$24,438.00

Johnson, Brett Michael, Fish, Wildlife & Conservation Biology, DOI-NPS-National Park Service, Tracking Lake Trout Diet and Trophic Interactions in Blue Mesa Reservoir Using Stable Isotopes, \$10,000.00

Laituri, Melinda J, Natural Resource Ecology Lab, Environmental Defense Fund, Colorado River Basin Governance Geospatial Layer for Agricultural Water Users, \$38,457.00

Myrick, Christopher A, Fish, Wildlife & Conservation Biology, Great Plains Fish Habitat Partnership, Improving Fish Passage Structures for Great Plains Fishes - Great Plains Fish Habitat Partnership, \$30,841.00

Sanders, Thomas G, Civil & Environmental Engineering, DOI-NPS-National Park Service, Water Rights Activity Assessment, and Water Rights Records Research and Management in Protection of Water and Aquatic Resources of Units of the Nation, \$14,700.00

Winkelman, Dana, Cooperative Fish & Wildlife Research, DOI-USGS-Geological Survey, Population Level Effects of a Contaminant of Emerging Concern on a Great Plains Resident Species within EPA Region 8, \$18,868.00

For the article "Decision Support Systems for Efficient Irrigation Water Management in the Middle Rio Grande," published in the January/February 2011 issue, the authors Ramchand Oad and Luis Garcia wish to credit Kristoph Kinzli, Department of Environmental and Civil Engineering, Florida Gulf Coast University, for his joint authorship on the article.

Calendar

April

- 11 WQCC Meeting C; DPHE Sabin Room, Denver, CO**
Contact: Paul Frohardt, 303-692-3468
- 12 Nutrient Criteria Work Group; CDPHE Sabin Room, Denver, CO**
Contact: Paul Frohardt, 303-692-3468
- 13 Water Reuse Work Group; CDPHE Room C1D, Denver, CO**
Contact: Jenny Fifta 303-658-2154
- 17-22 Tamarisk Coalition Cataract Canyon Trip; Cataract Canyon**
www.oars.com
- 19 Permit Issues Forum; Brown & Caldwell**
Contact: Christine Johnston, 303-294-2224
- 22 2011 Annual Symposium The Art of the Deal: Colorado's Landmark Water Agreements; Mount Vernon Country Club, Golden, CO**
awracolorado.havoclite.com/events/
- 29 Interbasin Compact Committee Meeting; TBD Denver, CO**
- 29-1 Colorado Alliance for Environmental Education Teaching Outside the Box; Millennium Harvest House, Boulder, CO**
Teaching OUTSIDE the Box is an action-packed workshop that brings together the best in environmental education for a weekend of engaging presentations, networking, resource sharing, and more.
www.caee.org/development/conference

May

- 31 Wastewater Design Criteria Work Group; CDPHE, Denver, CO**
Contact: Connie O'Neill, 970-962-2785

June

- 1-30 Colorado Lake and Reservoir Management Association's Volunteer Lake Monitoring Program; Colorado Lakes**
Contact: Steve Lundt, slundt@mwr.dst.co.us
- 13-15 CFWE Colorado River Basin Tour; TBD**
CFWE's annual River Basin Tour will take you on an exciting journey from the headwaters to Grand Valley.
www.cfwe.org

July

- 11-14 2011 UCOWR/NIWR Conference; Boulder, CO**
Planning for tomorrow's water: Snowpack, aquifers, and reservoirs
www.ucowr.org
- 20-22 36th Annual Colorado Water Workshop; Western State College, Gunnison, CO**
Risk, opportunity, and leadership in a changing climate
www.western.edu/academics/water

August

- 23-25 Colorado Water Congress Summer Conference; Steamboat Springs, CO**
Summer Conference and Membership Meeting
www.cowatercongress.org

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Student researcher Joseph D. Vassios studied sago pondweed control with various herbicide treatments.

Courtesy of Joseph D. Vassios