

Colorado Water

Colorado
State
University

Newsletter of the Water Center of Colorado State University

January/February 2012 – Volume 29, Issue 1

Theme: South Platte



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

Highlights

- 2** **Managed groundwater recharge on the Lower South Platte River**
Erin Donnelly
- 5** **Water as a Crop: Are South Platte Farmers Willing to Participate In Innovative Leasing Arrangements?**
James Pritchett, Chris Goemans and Jennifer Thorvaldson
- 10** **Elwood Mead's Role in Founding CSU's and USDA's Fort Collins Irrigation Programs**
Patricia J. Rettig and Robert C. Ward
- 17** **Fred Anderson, 83, former state senator, helped change Colorado water laws**

In Every Issue

- 1** **Editorial**
- 14** **Water Outreach Update**
Demonstrating Conservation Tillage Techniques for Surface Irrigated Fields in Northern Colorado
Erik Wardle
- 18** **CSFS**
CSFS Releases First Colorado Forest Road Field Handbook
Ryan Lockwood
- 20** **Water Resources Archive**
Water Tables 2012 Will Celebrate Western Water Organizations
Patricia J. Rettig
- 22** **Climate**
Figuring out Colorado's Precipitation Patterns
Nolan Doesken
- 24** **History**
History of the Cache la Poudre Gaging Station Near the Canyon Mouth and the Colorado Meter
Tom Cech
- 28** **Meeting Briefs**
Colorado Water Congress Holds Annual Convention
- 30** **Faculty Profile: Eugene Kelly**
Lindsey A. Knebel
- 32** **Water Research Awards**
- 33** **Calendar**

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

Published by: Colorado Water Institute
Colorado State University
Fort Collins, CO 80523-1033

Phone: 970-491-6308
Fax: 970-491-1636
Email: cwi@colostate.edu

Director: *Reagan M. Waskom*
Assistant to the Director: *Nancy J. Grice*

Editor: *Lindsey A. Knebel*
Design: *Jena J. Thompson*

Water Resources Specialists:
Perry Cabot, Denis Reich and Joel Schneekloth

Research Associates:
Faith Sternlieb and Julie Kallenberger

Policy & Collaboration Specialist:
MaryLou Smith

Nonpoint Source Outreach Coordinator:
Loretta Lohman

Front Cover: Chatfield Reservoir near Littleton, Colorado, is filled by the South Platte River. Photo by Thaddeus Roan

This Page: Winter scene of Lake Agnes in the Colorado State Forest near Cameron Pass. Photo by Sean Streich

Editorial

by Reagan Waskom, Director, Colorado Water Institute

Is it finally time for a state water plan for Colorado? Virtually all of our neighboring states—Wyoming, Utah, New Mexico, Oklahoma, Texas and Kansas—have a document called a water plan. The purpose of such a plan is to outline choices and pathways that may help avoid future water crises. Governor Hickenlooper recently challenged the Colorado water community to develop a state water plan by 2016.

Former CWCB Executive Director Bill McDonald said at this year's Colorado Water Congress annual convention that a Colorado water policy has always been in place, if not a plan for water development. In Colorado, state level water planning has been difficult historically because of conflicts between the West Slope, where most of the water is, and the Front Range, where the majority of the economic activity occurs and water demands exceed supply.

Since 1956, there have been various documents in place to guide Colorado water management, but they mostly boiled down to determining how much available water exists in the Colorado River for development. Colorado Water Resources, published in 1956, was a small document that covered water needs and potential projects to meet those needs. Of the 1956, 1974, and 1978 state water documents, only the 1974 document was actually called a water plan. The 1993 Metropolitan Water Supply Investigation was initiated following the Two Forks veto to find a new path forward for Denver area water needs.

The Statewide Water Supply Initiative (SWSI), first published by the CWCB in 2004 and updated in 2010, set about to analyze Colorado water supply and future needs on a basin-by-basin approach. SWSI 2010 brought Basin Roundtable findings together with the previous SWSI study to look at needs and a portfolio of strategies to address the gap. Conservation, reuse, storage, infrastructure, and weather modification are all under consideration, but unlike other states' water plans, SWSI has no implementation guidelines—that is left to water providers.

The Interbasin Compact Committee (IBCC) formed in 2005 to deal with water issues between basins, has been working to develop a strategy for meeting water needs that would avoid drying up 500,000 to 700,000 acres of farmland in the next 40 years. A combination of conservation, new projects, and temporary transfers are recommended to minimize the irrigated farmland taken



out of production. The latest proposal by the CWCB would also evaluate risk in future water projects.

Very few state governments actually build and manage projects—states tend to be programmatic and policy focused rather than builders of water infrastructure. Municipalities, water districts, the Army Corps of Engineers, and the U.S. Bureau of Reclamation are the traditional builders of water infrastructure. Colorado water enthusiasts will recall the 2003 Referendum A, which would have allowed the Colorado Water Conservation Board to borrow up to \$2 billion for public and private water projects by issuing bonds. Former Gov. Owens and a few other prominent West Slope political figures supported Referendum A on the 2003 ballot, where it was soundly defeated, failing to win a majority in a single county only a year after one of the most serious droughts in modern memory. In the end, Ref A contributed only to the end of several political careers.

Speaking specifically about war planning, General Dwight Eisenhower reportedly said, “Plans are worthless, planning is everything.” Colorado may not have a document called a state water plan, but it does have a robust planning process to facilitate local solutions through the CWCB, the IBCC, and Basin Roundtables. Planning for future water demand and supply management must include the flexibility to deal with future needs and problems we cannot envision yet. To wheel excess water effectively when available, and limited water when we must, Colorado needs modern infrastructure and flexible institutional arrangements. Regardless of future climate and population trends, we know that Colorado streamflows will inevitably vary from extreme lows to extreme highs—and this hydrologic uncertainty is what we must plan for.

Managed groundwater recharge on the Lower South Platte River

Erin Donnelly, MS Candidate, Watershed Science Program, Colorado State University

Faculty Advisor: John D. Stednick

Introduction

Increased pressures and demands on water resources in the South Platte River Basin have raised environmental concerns. With the current tendency to move waters from downstream agricultural uses to municipal uses along the Colorado Front Range, hydrologic modification has become of interest, including habitat improvements for potentially threatened or endangered aquatic species (Cech, 1987; 1990; Baron et al., 1998). The presence of four federally threatened or endangered aquatic species, the interior least tern, piping plover, whooping crane, and pallid sturgeon, on the Platte River in Nebraska prompted the state of Colorado to enter into a Three States Agreement with the states of Nebraska and Wyoming and the U.S. Department of Interior to implement recovery efforts for these species and their associated habitats. The chronology of the scientific and social dynamics was recently documented (Freeman, 2010). Several state threatened and endangered minnow species are also listed on the lower South Platte River in Colorado, including the brassy, plains, and suckermouth minnows, northern redbelly dace, and common shiner (CDOW, 2010).

The Three States Agreement is to meet or reduce shortages to U.S. Fish and Wildlife Service (USFWS) “target flows” and provide additional habitat for endangered species in the Lexington to Chapman, Nebraska reach of the Platte River. The reduction in shortages to target flows is realized in part by: (1) operating Kingsley Dam and related facilities in Nebraska to store a portion of the inflows to Lake McConaughy as well as water available from upstream projects in an environmental account that is managed by the USFWS, (2) using Pathfinder Reservoir in Wyoming to store water in another water account to be similarly managed, and (3) operating the Tamarack Project in Colorado (which utilizes excess flows when available for groundwater recharge, which return to the river at times when flow shortages are more likely).

The Tamarack Ranch State Wildlife Area (TRSWA) near Crook, Colorado is used as a recharge facility and currently consists of seven high capacity groundwater wells and pipelines and two recharge ponds. The project operates in a complex hydrogeologic and ecological system. This project has been organized and undertaken by a non-profit organization, the South Platte Lower River Group, Inc. (SPLRG).

SPLRG is a coalition of water users and State of Colorado agencies formed to protect existing agricultural and municipal water uses while increasing annual streamflow during critical periods.

Under the Three States Agreement, Colorado must increase flows in the South Platte at the Colorado-Nebraska border by 10,000 acre-feet between April and September. Current annual capacity of this managed groundwater recharge project is 5,670 acre-feet with a future design capacity of 9,720 acre-feet. The goal of augmentation is to enable junior groundwater appropriators to withdraw water from alluvial aquifers during high demand periods without harming senior surface water rights holders to provide adequate water quantity in the right place and at the right time. This is a significant amount of water in a semi-arid region, and increasing municipal water needs, along with severe drought, has brought more scrutiny to the operation and effects of such systems. Understanding the interaction between surface and groundwater has direct impacts on irrigated agriculture, wildlife habitat, and municipal water project development.

Water resources monitoring at Tamarack has been intermittent over the past 10 years. We have previously measured water quality and water levels in the alluvium, wetlands, sloughs, and river (Kazbekov, 2001; Watt, 2003; Beckman, 2007), determined hydrologic flow paths with groundwater model (Halsted and Flory, 2003; Beckman, 2007), imaged the subsurface heterogeneities and former river channels using seismic reflection (Poceta, 2007), and measured changes in gravity with and without pumping (Gehman, et al., 2009). Groundwater modeling work found that early idealizations of the stream-aquifer connection might overestimate the connection between the aquifer and stream hydrology, such as the significance of a lower permeability streambed (Hurr and Schneider, 1973; Halstead and Flory, 2003).

Flow augmentation projects utilizing managed groundwater recharge serve as a management tool for the conjunctive use of groundwater and surface water (Warner et al., 1986; 1994). There are limited sources for this water, and the added amount can have effects on water quality, water quantity, and aquatic habitat. The goal of this project is to determine the effects of managed groundwater recharge on South Platte River streamflows and as related to aquatic

habitat, to continue monitoring water quality changes and determine hydrogeophysical properties of the river alluvium as it relates to hydraulic connectivity.

Approach

There are very little field data collected to measure streamflow accretion due to groundwater recharge. Yet, thousands of wells use augmentation plans to replace water pumped from the alluvial groundwater in the South Platte River Basin. This study will determine if streamflow increases are quantifiable and improve the technical foundation for projects designed to restore wildlife habitat and maintain irrigated agriculture relying on alluvial groundwater.

The South Platte River is the major water supply for northeastern Colorado (Strange and others, 1999). The river originates in Park County Colorado, where it flows east through Denver and then northeast into Nebraska into the Platte River. The river system follows a snowmelt hydrograph, meaning peak runoff occurs in late spring. However, the largest water demand occurs during the summer growing season when the river naturally runs low (Beckman, 2007). As a result, the South Platte River Basin has become a complex system of canals, transbasin diversions, and other hydrologic modifications that have been described as an elaborate plumbing system (Strange and others, 1999).

Flow regulation affects riparian (Johnson 1994) and aquatic species, often adversely (Kinzel and others, 2009). The South Platte River was historically a wide braided channel with sparse vegetation and a highly mobile floodplain (Kinzel and others, 2009). Various anthropogenic influences, most notably reduced peak and annual flows, have altered vegetative and aquatic species composition and hydrologic processes. Over the past century the channel transformed from a braided into a meandering, anastomosed, and narrowed plan form (Kinzel, 1999). The disappearance of scouring flows has allowed vegetation to encroach along channel banks and sand bars that had stabilized the floodplain (Figure 1). These changes in channel morphology have severely decreased habitat availability for native aquatic species (Warner, 1987).

The Tamarack Project began in 1997. The TRSWA is state-owned land within the South Platte River Basin located in Logan County near Crook, Colorado, approximately 30 miles northeast of Sterling, Colorado (Figure 2). The

Figure 1. A lack of scouring flows allows vegetation to thrive closer to the river.
Courtesy of John Stednick



project utilizes wells to pump unappropriated or “excess” water from the alluvium adjacent to the South Platte River during winter and early spring months into a recharge pond located approximately 4000 feet away from the river. The return flow to the river is estimated to take between 60 and 120 days (Miller and others, 2007). This process allows Colorado meet state compact requirements without harming senior water rights holders.

The effectiveness of artificial recharge systems depends largely on the nature of the groundwater-surface water interaction. This interaction is influenced by geology, climate, and topography. The geology of the TRSWA is composed of eolian sands and alluvial sands and gravels. Because of the porous nature of the subsurface, the groundwater-surface water system at the TRSWA is highly responsive, meaning that a change in one system will quickly produce a change in the other.

To evaluate the effects of managed groundwater recharge on surface water volume at Tamarack, the hydrologic environment must be characterized and quantified. The research at Tamarack will determine if a managed artificial recharge project produces a measureable increase in streamflow in the South Platte River during critical low flow periods. This will be evaluated by streamflow measurements, water table elevation measurements with a matrix of nested piezometers, and a fluorescein tracer study (Figure 3) to quantify flow paths of groundwater moving from the recharge pond to the river. The results can ultimately be used to develop more efficient augmentation

Figure 2. The Tamarack Ranch State Wildlife Area (TRSWA) near Crook in eastern Colorado.

Courtesy of John Stednick



projects used for multiple consumptive uses and habitat enhancement.

Literature Cited

Baron, J. S. M.D. Hartman, T.G. Kittel, L.E. Band, D.S. Ojima, and R.B. Lammers. 1998. Effects of land cover, water redistribution, and temperature on ecosystem processes in the South Platte Basin. *Ecological Applications* 8(4):1037-1051.

Beckman NA. 2007. Quantifying groundwater and surface water mixing at a conjunctive use site [CSU Theses/Dissertations]. p. ix, 170 pp.

Cech, T.V. 1987. Conjunctive use of surface and ground water in the South Platte River Basin: a case study of the central Colorado water conservancy district. In: Fairchild DM, editor. *Ground water quality and agricultural practices*. Chelsea (MI): Lewis Publishers, Inc. p 47-55.

Cech, T.V. 1990. Ground water management in the South Platte Basin of Colorado. *Water Well Journal*, June 1990:52-54.
Freeman, D. 2010. Implementing the Endangered Species Act on the Platte Basin Water Commons. University Press of Colorado.

Colorado Division of Wildlife (CDOW). 2010. Report: Native Fish. Available: <http://wildlife.state.co.us/Education/TeacherResources/ColoradoWildlifeCompany/Pages/CWCFall92NativeFish.aspx>.

Figure 3. This fluorescein tracer study uses a greenish-yellow fluorescent dye to determine flow rate.

Courtesy of John Stednick



Gehman, C. L., D. L. Harry, W. E. Sanford, J. D. Stednick, and N. A. Beckman. 2009. Estimating specific yield and storage change in an unconfined aquifer using temporal gravity surveys, *Water Resour. Res.*, 45, W00D21, doi:10.1029/2007WR006096.

Halstead, M. and V. Flory. 2003. Tamarack Modeling Project (Draft Report and Technical Memorandums), Division of Wildlife, Colorado Department of Natural Resources, Denver Colorado.

Hurr, R.T., P.A. Schneider, Jr. 1973. Hydrogeologic characteristics of the valley-fill aquifer in the Julesburg reach of the South Platte River valley, Colorado. U.S. Geological Survey Open-File Report 73-125. 2p.

Johnson WC. 1994. Woodland expansion on the Platte River Nebraska--Patterns and causes. *Ecological Monographs* 64(1):45-84.

Kazbekov, J. 2001. Hydrogeology and water chemistry at the Tamarack Recharge Project, Colorado. MS Thesis. Department of Earth Resources. Colorado State University, Fort Collins, CO. 35 p.

Kinzel PJ, Nelson JM, Heckman AK. 2009. Response of sandhill cranes (*Grus canadensis*) riverine roosting habitat to changes in stage and sandbar morphology. *River Research and Applications* 25(2):135-152.

Miller CD, Durnford D, Halstead MR, Altenhofen J, Flory V. 2007. Stream depletion in alluvial valleys using the SDF semianalytical model. *Ground Water* 45(4):506-514.

Poceta, J. 2005. Electrical resistivity imaging of aeolian and alluvial sediments along the South Platte River, Northeastern Colorado. Master of Science Thesis Department of Geosciences, Colorado State University, Fort Collins, CO. 64pp.

Strange EM, Fausch KD, Covich AP. 1999. Sustaining ecosystem services in human-dominated watersheds: Biohydrology and ecosystem processes in the South Platte River Basin. *Environmental Management* 24(1):39-54.

US Bureau of Reclamation and US Fish and Wildlife Service. 2006. Platte River Recovery Implementation Program. Final Environmental Impact Statement. 99 pp.

Watt, J. 2003. Water quality changes at a streamflow augmentation project, lower South Platte River, Colorado. MS Thesis. Department of Earth Resources. Colorado State University, Fort Collins, CO. 88 p.

Warner, J.W., D.K. Sunada, A. Hartwell. 1986. Recharge as augmentation in the South Platte River basin. Fort Collins (CO): Colorado Water Resources Research Institute Groundwater Technical Report No. 13. 116 p.

Warner, J.W., J. Altenhofen, J. Odor, B Welch. 1994. Recharge as augmentation in the South Platte River basin. Fort Collins (CO): Colorado Water Resources Research Institute Groundwater Technical Report No. 21. 119 p.



From a limited irrigation study conducted by James Pritchett and others.

Courtesy of James Pritchett

Water as a Crop: Are South Platte Farmers Willing to Participate In Innovative Leasing Arrangements?

James Pritchett and Chris Goemans, Department of Agriculture and Resource Economics, Colorado State University

Colorado State University
COLORADO AGRICULTURAL EXPERIMENT STATION

Jennifer Thorvaldson, Regional Economist, MIG Inc.

Introduction

A portion of the agricultural water rights in the South Platte will be reallocated to municipal households as population increases in a basin where water rights are fully appropriated. Indeed, the Colorado Water Conservation Board's Statewide Water Supply Initiative (2010) forecasts that as many 267,000 acres of irrigated land will be fallowed by 2050 as Colorado's population doubles. The dry-up represents approximately 32 percent of irrigated land in the basin.

Water transfers between agricultural users and municipal buyers are voluntary and presumably mutually beneficial; otherwise, they would not occur. Conventional practice is to fallow agricultural land once irrigation water has been sold and a change of use case has been successfully completed in water court. Alternatively, the municipal purchaser may retain water in irrigated cropping for later removal. The end result is a decrease in irrigation activity

that is permanent and, due to the economies of scale involved in water transactions, tends to be clustered in an area in which few economic alternatives exist.

The localized decrease in irrigated cropping and the subsequent third-party impacts to the rural regional economy and local government revenues are of particular concern to stakeholders. Indeed, the Colorado Water Conservation Board began its Alternatives to Agriculture Transfer program in order to encourage and develop alternatives to so-called 'buy and dry' water transfers. The grants program has funded feasibility projects such as the Super Ditch in the Arkansas River Basin, the Lower South Platte Water Cooperative, and a consumptive use savings project of the Parker Water and Sanitation District (CWCB, 2011).

In these programs, farmers temporarily cease irrigating as part of a lease agreement. Leasing can be rotated among producers to avoid the clusters of permanent fallowing.

In this way, the water asset is still retained locally, which may mitigate undesirable impacts relative to 'buy and dry' transactions. These programs are consistent with the preferences of Colorado municipal households, who are less likely to encourage acquiring water from farmers to meet city needs (Thorvaldson et al, 2010).

Innovative leasing arrangements, such as rotational fallowing, are gaining interest as a potential alternative to traditional 'buy and dry' transactions. Yet many unknowns need be resolved before leasing arrangements become a practical means for meeting municipal water needs. Among these unknowns are whether farmers are willing to participate in these leases, the cost of these leases, and the amount of water that can be secured via a lease.

The purpose of this article is to provide insight into these questions using information from a 2007 mail survey of irrigated farmers in the South Platte Basin. The central theme is to answer the question, "Are rotational fallowing programs feasible from a farmer's standpoint?"

Feasibility is multi-faceted, involving compensation, farmer preferences, and profitability. The contributions of this article include uncovering the barriers to farmer participation, which is of practical importance to groups interested in developing water sharing arrangements, suggesting the amount of water that might be released in a leasing program, and the relative costs of providing lease arrangements.

Survey of South Platte Farmers

A 2007 mail survey was used to elicit the preferences and opinions of South Platte farmers. The timing of the survey is notable in two respects—it occurred just after a significant number of wells ceased pumping in the South Platte due to changing the application of well augmentation rules, but before the Alternatives to Agriculture Transfer program was initiated. In the former case, farmers with groundwater wells may have been unwilling to respond to a survey amidst the controversial application of recent court rulings. In the latter case, South Platte farmers may have been unaware of innovative leasing examples that are currently piloted in Colorado.

A questionnaire was designed and, prior to mailing, was reviewed by an advisory committee of farmers, field extension personnel, university extension specialists, water conservancy district employees, and municipal water provider representatives. Recommendations from these experts were incorporated into the questionnaire. The questionnaire's two main sections are i) farmer and farm operation characteristics, including irrigation water source,

prevailing crop rotation, and financial demographics; and ii) attitudes about leasing arrangements, including willingness to participate, compensation, and contract provisions.

The questionnaire was mailed to South Platte Basin farmers, who reported more than fifty irrigated acres in the 2002 Census of Agriculture. Mailing began during the first week of September 2007 using procedures outlined by Dillman (2007) with a postcard reminder mailed ten days later, and a second survey mailing twenty-one days after the initial mailing. Of the 1,731 successful mailings, 329 (19 percent) were returned and could be used in the analysis. The response rate is meager, but the farm demographics of returned surveys are not significantly different from those reported in the 2007 Census of Agriculture. An exception is the size category of survey respondents. The survey tended to over sample farmers of 1,000 acres or more relative to the 2002 Census of Agriculture.

The Decision to Enter Fallowing Programs

One study objective is identifying the willingness of farmers to participate in lease-fallow programs. When asked about their agreement with the statement "I am willing to incorporate a fallow period into my crop rotation if I am compensated enough," over 63 percent of respondents signaled agreement. A majority of respondents felt that these agreements would be beneficial to rural communities, and only seven percent reported an intention to sell water in the next five years.

Farmers rarely embark on new enterprises if these opportunities are not perceived to be profitable. Thus, survey respondents were asked their perceptions of the profitability of lease-fallow programs or leasing in general. Likewise, profitability might be constrained by the farm's capital structure, debt obligations, irrigation water system and sources, and current crop mix. Demographic characteristics such as age, education, and future plans for the farm influence the decision to lease. Not all of these factors influence decisions equally, and understanding the factors that motivate a leasing decision indicate the barriers to wide spread participation.

Using standard techniques (Zhou, 2008; McDowell, 2003) statistically significant factors in predicting a positive willingness to sign fallow-lease arrangements were identified and are listed below in descending order of influence:

- Working with Third Parties – Respondents signaled agreement with the statement "I am willing to work through another organization (e.g., farmer owned cooperative) when signing lease arrangements." If respondents were willing to work

with a third party, they were more likely to be willing to lease their water.

- Reducing Risk – Respondents who agreed with the statement “Water leases would reduce the financial risk of my farming operation” were more likely to enter into fallowing arrangements.
- Education – Those reporting more years of formal education were more likely to sign leases.
- Experience – Respondents who reported more experience in farming responded more favorably to fallow-lease arrangements. The impact of experience increased with years, but the effect increased at a decreasing rate.
- Irrigated Acres – Survey responses of more irrigated acres tended to signal a greater willingness to sign lease-fallow arrangements, but this had a small impact on the decision to lease
- The statistically significant factors indicating a negative willingness to sign fallow-lease arrangements are:
 - No-till – Respondents who practiced conservation tillage or no tillage were less supportive of lease-fallow arrangements.
 - Urban Proximity – Respondents whose farming operation was near a large urban area were less likely to sign a lease. Farmers on the urban-rural fringe may be better positioned to sell, rather than lease, their water rights.
 - Ditch Company – The more a farmer’s water was supplied by a ditch company, the less likely the respondent would sign a fallow lease.
 - Ground Water – the greater the reliance on groundwater as a supply source, the less likely a positive response to fallow-leasing.

Fallow-Leases: What Price Paid to Farmers?

A viable lease market will depend critically on prices paid to farmers, and if this cost is more than cities are willing to pay. In an open-ended question, respondents were asked to indicate the minimum price per acre needed to forgo irrigation for one year. Their responses are summarized in the histogram in Figure 1. Price intervals are displayed along the horizontal axis, and the percentage of respondents categorized in the interval is measured on the vertical axis.

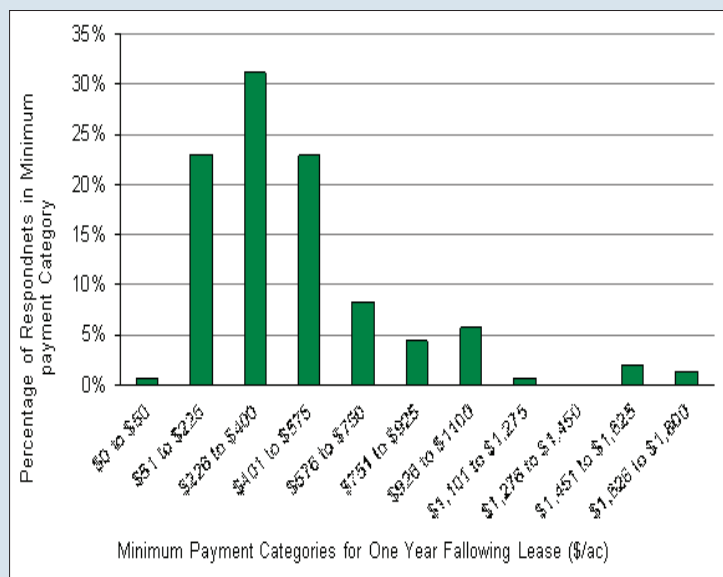


Figure 1. Minimum Lease Payments Sought by Respondents to Forego One Year's Irrigation (\$/acre)

Many respondents (77 percent) fall into an interval between \$225 and \$575 per acre. Assuming that 1.5 acre-feet of consumptive use (CU) is available to lease, a cumulative willingness to lease can be defined for lease rates (\$/acre-foot of CU). Figure 2 displays this cumulative approach with nearly 50 percent of survey respondents willing to lease at \$500 per acre-foot or less.

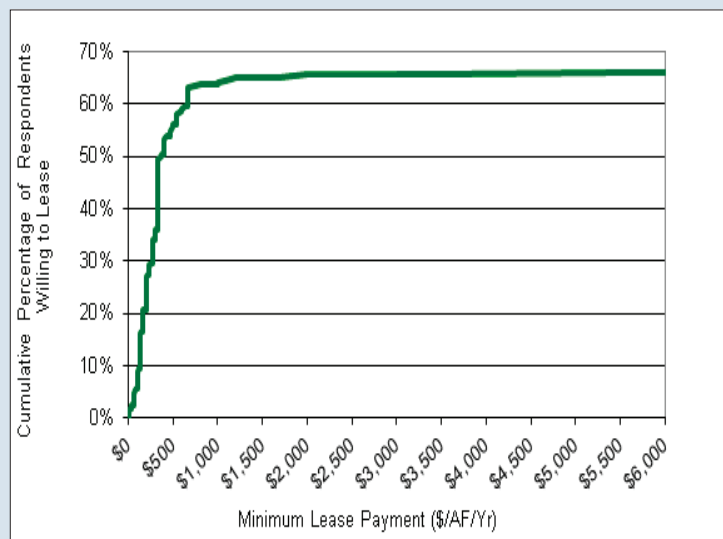


Figure 2. Respondents' Cumulative Willingness to Lease (% of all Responses) with Corresponding Stated Minimum Annual Lease Payments (\$/AF of CU)

Figure 3 relates the survey respondents' supply of CU at various annual lease payments, assuming that 1.5 acre-feet of CU is available to each respondent per irrigated acre. As an example, an average lease payment of \$400 per acre-foot of CU garners roughly 37,000 acre-feet of CU, a significant potential from leasing arrangements.

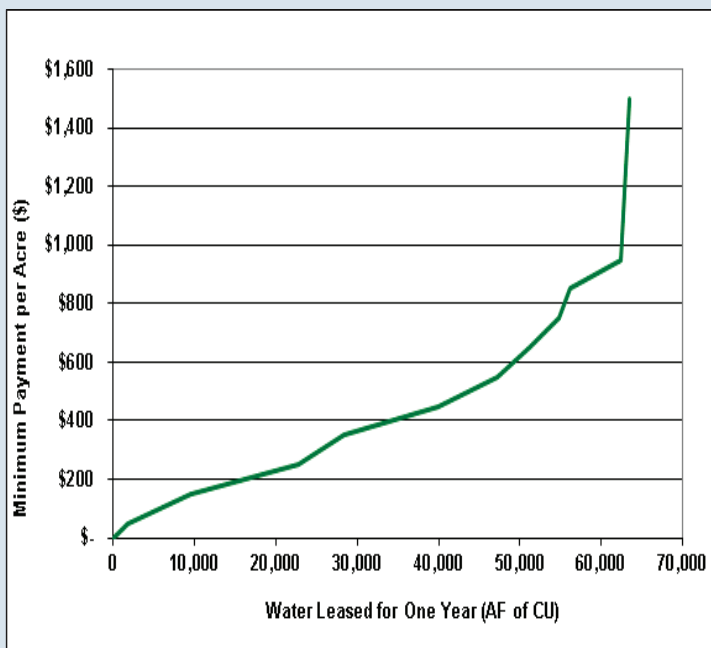


Figure 3. Respondents' Supplied Acre-Feet of CU via Lease at Minimum Payment Levels (\$/AF of CU)

Will the participating farmers cease all farming operations during their lease period? Survey respondents are not likely to do so, which represents an advantage of rotational fallowing over 'buy and dry' practices. On average, respondents were willing to fallow 59 percent of their irrigated land, for an average 200 acres per farm. A more detailed illustration of these responses is provided in Figure 4.

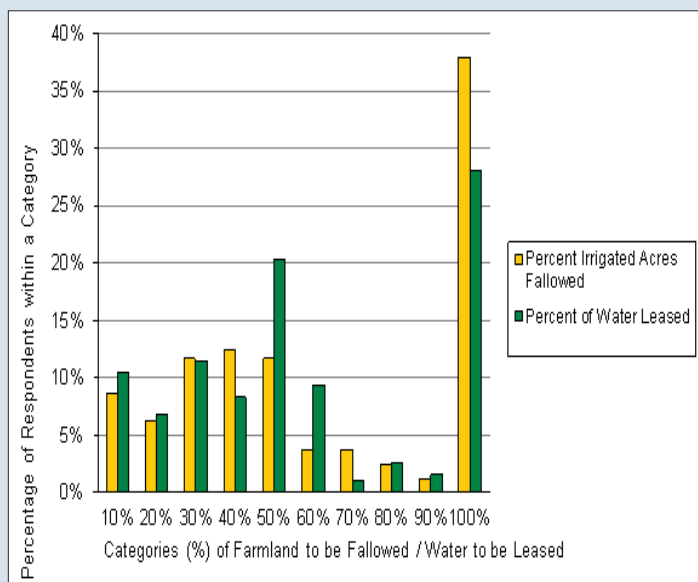


Figure 4. Percent of Irrigated Acres Fallowed and Water Supplies Committed to an Annual Lease

Figure 4's horizontal axis contains intervals of the proportion of land fallowed and water leased by respondents, while the vertical axis is the percent of respondents in each category. As an example, about 10 percent of respondents indicate they would lease 10 percent of their irrigation water (furthest left green bar), and 8 percent of respondents will fallow 10 percent of their irrigated cropland (furthest left yellow bar).

Examining Figure 4, respondents can be categorized as belonging to two groups—one committing all land and water to a lease, and another group continuing operations. Leasing from the former group may reduce transactions costs, but may do little to prevent the regional economic base from shrinking. The second group consists of those willing to commit half of their holdings or less to a leasing arrangement. Respondents in this category plan to stay in farming, which will help to avoid the 'hot spot' problem of clustered areas taken out of irrigation; however, they could be problematic in reducing transactions costs for leasing arrangements since it may cost more to collect, treat, and transport water from many small sources than from a few large sources.

Concluding Remarks

Innovative leasing arrangements are a potential means for meeting the future water needs of urban households in Colorado. It is unclear if these leases will be successful due to many unknown factors. Among these unknowns is whether farmers are willing to participate in the leases, the cost of the leases, and the amount of water than can be secured via a lease.

This study is based on a 2007 mail survey of South Platte irrigated farmers, and respondents' answers to the questionnaire indicate a willingness to participate in lease arrangements. Respondents generally have a favorable view of the impact that leases will have for farmers and rural communities, and many are willing to participate in a fallow-lease program at reasonable prices. Based on these responses, leases appear to have the potential to serve as a substitute for a subset of permanent water transfers and fulfill a portion of municipalities' needs. Leases of this type may mitigate the third party effects of 'buy and dry' transfers from agriculture water right holders to municipalities.

Notes, Limitations, and Future Opportunities

A contemporary survey of farmers with a greater response rate will improve the accuracy of results. The statistical model in this analysis is based on a maximum likelihood (ML) approach. The consistency and asymptotic efficiency properties of ML rely on large sample sizes, so the results reported here should be interpreted with caution. The inclusion of more detailed lease data would also prove useful and will become more feasible as water leases become more common. For instance, the payment that farmers require in exchange for leasing their water and the payment municipalities are willing to make for that water will vary according to a variety of factors. One of which is the level of priority of the water right being leased, since in a dry year a relatively junior right may not be satisfied in its entirety, if at all. However, as noted by McCrea and Niemi, (2007), even information about hypothetical future transactions can be useful in lowering the costs of negotiating an agreement by a leaser and lessee.

A leasing market may prove to be too “thin” if the water made available by farmers is of relatively junior priority, and municipal water providers instead seek scarcer, senior water rights (Colby, 1998). Fortunately, just over half of all willing leasers agreed to lease their senior water rights while keeping their junior rights, if suitably compensated. Other challenges related to water leasing that were not addressed here include verifying the actual use of water and monitoring its quality after it is transferred (Doherty, 2010). Leases will require adjudication of changes in the location and use of the water (Nichols, 2010).

Please contact James Pritchett, james.pritchett@colostate.edu, 970-491-5496, with questions about this article.

Acknowledgements

The authors gratefully acknowledge the financial support of the Parker Water and Sanitation District, the Colorado Water Conservation Board's Alternatives to Ag Transfer grants program, the Colorado Water Institute and the CSU Agriculture Experiment Station for this research.

References

- Colby, B.G. 1998. Negotiated Transactions as Conflict Resolution Mechanisms: Water Bargaining in the U.S. West. in *Markets for Water Potential and Performance*, edited by K.W. Easter, M.W. Rosegrant, and A. Dinar, Norwell, MA: Kluwer Academic Publishers.
- Colorado Water Conservation Board, Alternatives to Agriculture Transfer Grants Program. 2011
- <http://cwcb.state.co.us/LoansGrants/alternative-agricultural-water-transfer-methods-grants/Pages/main.aspx>. Accessed November 30, 2011.
- Dillman, D. 2007 *Mail and Internet Surveys: Tailored Design Method*. (2nd Ed). Hoboken, NJ: John Wiley & Sons.
- Doherty, T. 2010. CWCB's Alternative Agricultural Water Transfer Methods (ATM) Grant Program. *Colorado Water*, 27(1): 2-4, January/February.
- McDowell, A. 2003. From the help desk: Hurdle Models. *The Stata Journal*, 3(2): 178-184.
- McCrea, M.E. and E. Niemi. 2007. Technical Report on Market-Based Reallocation of Water Resources Alternative: A Component of the Yakima River Basin Storage Feasibility Study. Ecology Publication Number 07-11-044.
- Nichols, P.D. 2010. The Lower Arkansas Valley Super Ditch Company, Inc. *Colorado Water*, 27(1): 5-7, January/February.
- Statewide Water Supply Initiative. 2010. Executive Summary. Colorado Water Conservation Board. Colorado Department of Natural Resources. Available at: <http://cwcb.state.co.us/water-management/water-supply-planning/Pages/SWSI2010.aspx> Accessed November 26, 2011.
- Thorvaldson, J., J. Pritchett and C. Goemans. 2010. “Western Households’ Water Knowledge, Preferences, and Willingness to Pay” *Canadian Journal of Agricultural Economics*, 58 : 497-514.
- Zhou, S., T. Herzfeld, T. Glauben, Y. Zhang, and B. Hu. 2008. Factors Affecting Chinese Farmers’ Decisions to Adopt a Water-Saving Technology. *Canadian Journal of Agricultural Economics*, 56: 51-61.

Elwood Mead's Role in Founding CSU's and USDA's Fort Collins Irrigation Programs

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

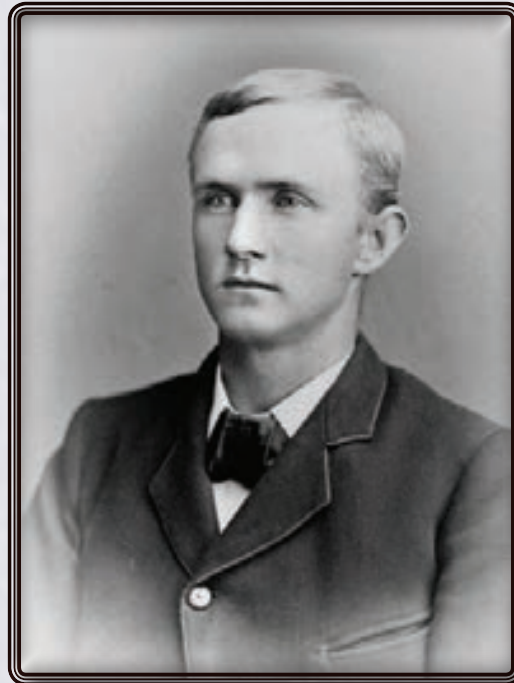
Robert C. Ward, Emeritus Director, Colorado Water Resources Research Institute, and Emeritus Professor, Civil and Environmental Engineering, Colorado State University

The U.S. Department of Agriculture's (USDA) Fort Collins Irrigation Investigations group and Colorado Agricultural College's initial water programs are, today, represented by the USDA Agricultural Research Service's (ARS) Water Management Research Unit and Colorado State University's Civil and Environmental Engineering Department's water programs. Since the beginning of these two irrigation organizations in the late 1800s, each, separately and together, has constructed a rich and continuous tradition of contributions to water research, education, and outreach. The end of 2011 presents an opportunity to reflect upon the history of these two highly inter-related water programs, as it was 100 years ago that the USDA's Fort Collins Irrigation Investigations group was officially organized.

Why consider the origins of both organizations together? The roots of each have a common beginning in one man—Elwood Mead. Colorado Agricultural College provided Mead with initial knowledge, experience, and insight in western water management that matured into a public service career, which included time with the USDA. At the same time, Mead put the college in Fort Collins on a path to excellence in water resources that continues to this day. At what is today Colorado State University, in the 1880s, Mead served as the first professor of irrigation engineering in the United States. At the USDA between 1899 and 1907, Mead fostered creation of the national Irrigation Investigations network where USDA irrigation investigators would cooperate with the agricultural colleges and experiment stations throughout the nation "...to gather and disseminate information primarily of interest to the small irrigator" (Kluger, 1992, page 28). This organizational effort on the part of Mead led, in 1911, to the formal creation of an irrigation investigations unit in

Fort Collins associated closely with Colorado Agricultural College's Agricultural Experiment Station.

Mead (1858-1936) was born and raised in Switzerland County, Indiana, growing up on the family farm. In 1878, he entered Purdue University, where he earned a degree in agriculture and science. While at Purdue he studied under Dr. Charles Lee Ingersoll in the School of Agriculture, who was particularly interested in a stronger connection between the theoretical and the practical—i.e., a closer link between the classroom and the farm (Kluger, 1992).



Elwood Mead in the 1880s.
 Courtesy of Archives and Special Collections, Colorado State University Libraries.

Mead graduated in June 1882 and spent seven months as an assistant engineer with the Army Corps of Engineers in Indianapolis. During this time, Ingersoll became the second president of Colorado Agricultural College in Fort Collins. Mead married Florence S. Chase on December 20, 1882, and then departed for Fort Collins where Ingersoll had persuaded him to accept a position as professor of mathematics and physics (Kluger, 1992).

The newlyweds arrived in Fort Collins to find a town with a population of just over 2,000 and an entirely unfamiliar landscape. Mead was intrigued by the many irrigation ditches he saw. To pursue this interest, he soon began assisting state engineer E. S. Nettleton, newly appointed as the second such officeholder in April 1883, with water distribution monitoring in the Fort Collins area (Kluger, 1992).

Quoting Kluger (1992) regarding Mead's introduction to western water issues:

"Mead's only official contact with these regulations was as a part-time watershed engineer in Larimer

County. At the same time, he was also assisting President Ingersoll and Professors A. E. Blount and James Cassidy in the organization of an agricultural experiment station for the community. These two activities complemented one another, as this locale essentially was devoted to irrigated farming. This stirred Mead's interest in the whole issue of water rights in arid areas, and came to occupy increasing amounts of his time away from his teaching duties. His primary responsibility, however, was in the classroom."

At the fledgling college, the small faculty had to teach a variety of courses; Mead's included mathematics and physics. A portion of the physics course included instruction on the measurement and flow of water for irrigation, but Mead must have wished for more. In his annual report for 1883, he duly reported on his classes, but also encouraged the college to progress toward irrigation instruction (Mead, 1883):

"While it is not yet desirable that we institute any systematic course of instruction in engineering, it is highly important that our students have a knowledge of such engineering subjects as have a direct bearing on the subject of irrigation. From the character of the agriculture of this state, the obligation resting on this college to furnish some such instruction is peculiarly great, and its worth to our students and the state at large of corresponding value. Every farmer in Colorado has to apply some of the principles of engineering in the construction and management of his irrigating canals. The subject of the measurement and distribution of water is of great and constantly increasing moment, and it is in the highest degree important that our students be informed as to the principles which govern its flow."

Mead returned east sometime in 1884, but by July 1885, returned to Colorado because of his health (Fort Collins Courier, July 2, 1885). He resumed work with the state engineer, and when Colorado Agricultural College's board created a chair of physics and irrigation early in 1886, Mead was elected to fill it beginning in fall 1886 (SBA annual report, 1885/86, p. 14). This was the first such position in the country (Kluger, 1992).

Mead's background in agriculture, engineering, teaching, and law provided the basis for the rest of his highly successful career. During his summers he oversaw irrigation activities in the South Platte River Valley while serving as an assistant State Engineer, a task that refined his understanding of the benefits and shortcomings of Colorado's water management system. In 1887, he wrote the college's first bulletin, titled "Report of Experimental Work in the Department of Physics and Engineering,"

about experiments related to irrigation, meteorology, and the duty of water, in particular. The same year, the federal government passed the Hatch Act, establishing agricultural experiment stations at land-grant colleges. Colorado Agricultural College established theirs in 1888, with both Ingersoll and Mead involved (Fort Collins Courier, March 1, 1888).

All of these activities served to make Mead known widely as an authority on irrigation and water rights. When Wyoming established a territorial engineer position in 1888, they offered Mead the job, which he accepted. When statehood was achieved in 1890, he used his knowledge to help write the water sections of Wyoming's constitution. As State Engineer, he then established the procedures by which the water-related portions of the new constitution would be implemented.

During his 11 years in Wyoming, Mead steadily increased his involvement in western and national water concerns and issues, furthering his national reputation and contacts. He was particularly active with the Wyoming congressional delegation in pursuing legislation that would, in his mind, enhance economic development in Wyoming and the West through irrigation.

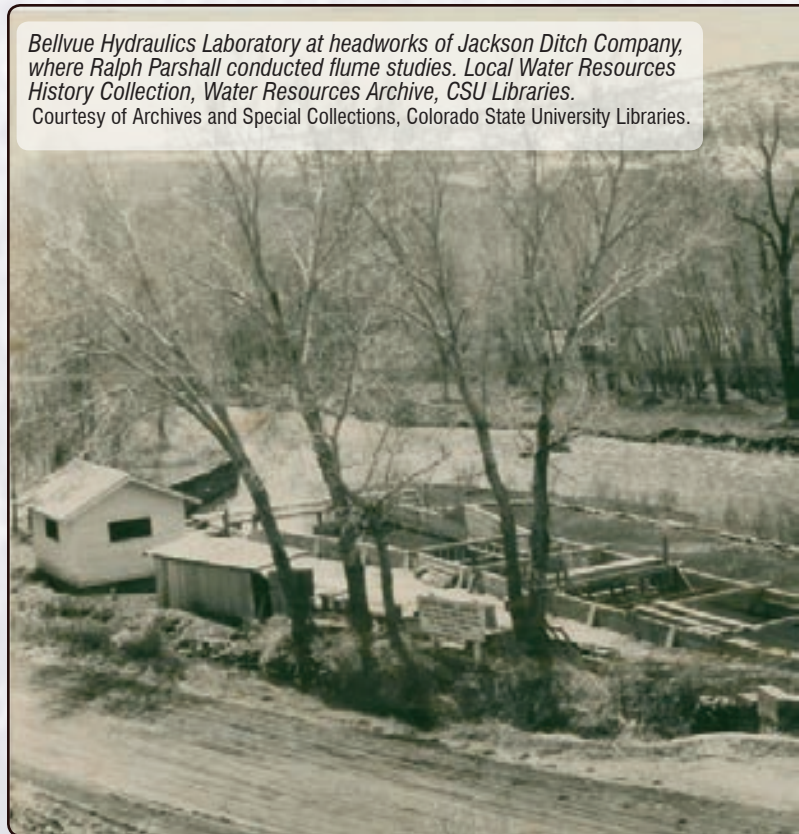
In 1897, Florence Mead died, leaving Mead with three children under age seven. About this time he began to realize he had exhausted professional opportunities in Wyoming, and further advancement of the benefits of reclamation in the West would probably have to occur at the federal level. To be a part of such action at that level, Mead began to seek new opportunities. In 1898, he began working on some irrigation studies for the USDA. After legislation passed authorizing the USDA Office of Experiment Stations to engage in irrigation investigations, Mead resigned as Wyoming state engineer (Kluger, 1992) and was appointed head of USDA irrigation investigations in 1899.

Before 1902, there had been recognition that the federal government was moving toward a larger role in reclamation in the West. The Agriculture and Interior departments each had their own ideas of how this role should evolve; thus they both sought to be the lead agency for whatever federal program emerged from the impending legislation. Creation of an irrigation investigations arm of the USDA, led by Mead, was part of the bureaucratic maneuverings leading up to passage of the Reclamation Act in 1902. Proponents of a limited federal role supported the irrigation approach with Mead at the head (Kluger, 1992, pages 27-28).

As head of irrigation investigations, Mead's main focus, as it had been through most of his career, was on the

application of water to land at the farm level. He remained close to the farmers by setting up initial headquarters for the investigations at Cheyenne, with a branch established later at Berkeley. Also, right from the beginning, Mead “established a series of observing points all over the country where irrigation is practiced” (Colorado Transcript, September 6, 1899). Inevitably Fort Collins, site of the state’s land-grant college and experiment station, was chosen as an observing point.

Thus, Mead set in motion establishment of irrigation investigation ‘units’ at agricultural colleges—an action that led, in 1911, to formal establishment of such a unit at Colorado Agricultural College in Fort Collins. Interestingly, but for Mead’s replacement at the college, the unit might have been established sooner. Louis G. Carpenter, hired by Ingersoll when Mead left, had known Ingersoll when they were both at Michigan Agricultural College. Carpenter took over Mead’s teaching in 1888, and in 1899 became the director of the Experiment Station. Letters among the USDA files in the National Archives make it clear that Carpenter’s departure from the college in late 1910 opened the door for an irrigation investigations unit to finally be established in Fort Collins.



Bellvue Hydraulics Laboratory at headworks of Jackson Ditch Company, where Ralph Parshall conducted flume studies. Local Water Resources History Collection, Water Resources Archive, CSU Libraries. Courtesy of Archives and Special Collections, Colorado State University Libraries.

la Poudre River, resulting in the development of a flume that revolutionized practical water flow measurement in the administration of water rights not only in the West, but around the world (Poudre Heritage Alliance, 2002, page 8).

By 1911 when the Fort Collins unit was formally established, Mead had been in Australia for four years trying to implement most of his ideas about reclamation. Upon his permanent return to the United States in 1915, Mead assumed the position of professor of rural institutions, University of California, Berkeley, 1915-1923, and chairman of the State Land Settlement Board of California, 1917-1923. In 1924, Mead returned to federal service as the Commissioner of Reclamation, United States Department of the Interior, until his death in 1936 (Hansen, 1977).

During the lead up to construction of Boulder Dam, and under Mead’s leadership, the Bureau of Reclamation stationed a Boulder Dam design team in Fort Collins to use the Irrigation Investigations Unit’s Hydraulics Laboratory to conduct studies. The Hydraulic Laboratory was constructed beginning in 1912 under the direction of Ralph Parshall, then a professor at the college, and Victor Cone, director of the USDA Irrigation Investigations Unit, which had offices on campus (Hansen, 1977). The USDA Hydraulics Laboratory was located where the north end of the Lory Student Center sits today. The reservoir created by Boulder, later Hoover, Dam was named for Mead.

Elwood Mead, while being a very quick study in irrigation engineering during the 1880s, put Colorado Agricultural College on a path toward water education, research, and



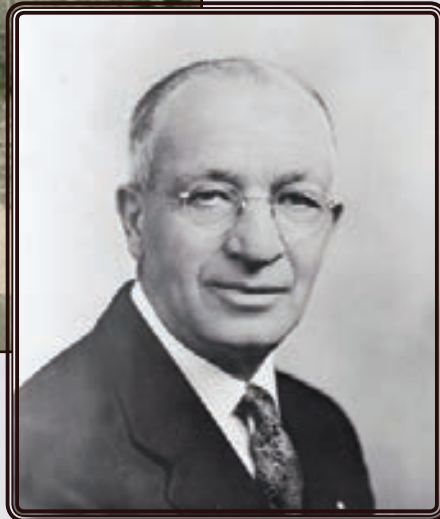
Civil and Irrigation Engineering building on CSU’s campus, c. 1911, where the USDA had offices. University Historic Photographs Collection, CSU Libraries.

Courtesy of Archives and Special Collections, Colorado State University Libraries

The man brought in to be the first director of the irrigation investigations unit in Fort Collins was Victor M. Cone. Cone had been employed by the USDA since 1906, previously based in California. Under Cone, the Fort Collins USDA irrigation investigations staff addressed a number of key topics in their formative years, including water flow measurement, defining return flows, the duty of water, and quantifying evapotranspiration. In particular, between 1919 and 1926, USDA irrigation investigator Ralph Parshall conducted studies on a site located near the Jackson Ditch’s main diversionary headworks on the Cache



Right: Ralph Parshall, 1942. Parshall Collection, Water Resources Archive, CSU Libraries. Courtesy of Archives and Special Collections, Colorado State University Libraries.



that led to formation, in 1911, of an irrigation investigations unit in Fort Collins, in close association with the Agricultural Experiment Station at Colorado Agricultural College.

From this brief overview of Elwood Mead's early career, we see how the origins of what is today the USDA ARS Water Management Research Unit and the water programs in Colorado State University's Civil and Environmental Engineering Department are very closely connected. These programs, while undergoing a number of name changes over the years, have collaborated in highly productive ways, including educating a large number of future irrigation engineers.

A full version of this article is available through the USDA ARS Water Research Management Unit's website: <http://www.ars.usda.gov/npa/ftcollins/wmr>.

References

Colorado. State Board of Agriculture. 1886. Report of the Secretary of the State Board of Agriculture of the State of Colorado.

Hansen, James E. 1977. Democracy's College in the Centennial State: A History of Colorado State University. Colorado State University, Fort Collins, Colorado.

Kluger, James R. 1992. Turning on Water with a Shovel: The Career of Elwood Mead. University of New Mexico Press, Albuquerque, 218 pages.

Mead, Elwood. 1883. Annual Report of the Department of Mathematics and Engineering, Colorado State Agricultural College. Fort Collins Courier (Fort Collins, Larimer County, Colorado), December 20, page 8.

Poudre Heritage Alliance. 2002. Irrigation and Water-Related Structures in the Cache la Poudre River Corridor. Draft Report (unpublished) coordinated by Susan Boyle, National Park Service, Estes Park, Colorado, 92 pages.

United States. Department of Agriculture. 1911. Annual Report of the Office of Experiment Stations for the year ended June 30, 1910. Washington: Government Printing Office.

Newspapers

Colorado Transcript (Golden, Jefferson County)
September 6, 1899, page 1.

Fort Collins Courier (Fort Collins, Larimer County)
July 2, 1885, page 1.
March 1, 1888, page 1.

outreach that is widely respected around the world today. The college instituted irrigation engineering as a distinct area of study in 1889 (one of four that existed at the time). What Mead began in the 1880s was firmly entrenched on campus by Louis G. Carpenter, who joined the college as Mead's replacement in 1888.

Mead was also a quick study in the politics of irrigation law and policy, which led him to involvement in national irrigation politics from 1899-1907. During this time he established the foundation of irrigation investigations



The USDA's Hydraulic Laboratory on CSU's campus. Courtesy of Archives and Special Collections, Colorado State University Libraries.

Demonstrating Conservation Tillage Techniques for Surface Irrigated Fields in Northern Colorado

Extension Erik Wardle and Troy Bauder, Water Quality Program, Department of Soil and Crop Sciences, Colorado State University

Introduction

Professionals that work in academia and other public sector institutions are tasked with meeting the needs of the citizens we serve. Professors, researchers, and Extension personal at Colorado State University are continually looking for ways to increase the positive impacts of our work. While some research certainly necessitates an in-house approach, collaboration and cooperation with organizations outside of the university system is equally important. These partnerships enhance the impact of research and outreach activities, integrating scarce resources to accomplish more with less. An excellent example of this type of collaborative project is currently taking place along the Northern Front range of Colorado (Figure 1).

During the summer of 2010, a group of agencies and individuals interested in conservation tillage¹ decided to pursue funding to solidify an ongoing demonstration project intended to promote these practices in the area. The strength of this project comes from the locally driven interest in conservation tillage under furrow² irrigation and the strong collaboration among participating entities.

The project planning and advisory committee consists of Colorado State University faculty and staff from Soil and Crop and Bio-agricultural Sciences and Pest Management Departments, the director and staff of the Agricultural Research Development and Education Center (ARDEC), and an Extension water specialist. Government entities represented in the project include NRCS field office staff and a senior Agricultural Research Service scientist. Other public sector participants include the Fort Collins and Big Thompson Conservation districts. Key to the success of this project are the multiple producer participants who were the driving force behind the continuation work being conducted. In addition, representatives from the tillage implement industry and seed companies have been important to this process. After funding was secured for the work, the scope and focus of the project was set by the group at a meeting in fall of 2010. The focus of the project is the evaluation and demonstration of conservation tillage practices under furrow irrigation. Outreach and promotion of these practices is being done with online data sharing, photo and video production, conference presentations and field days.

Figure 1. Project planning and advisory committee meeting fall 2010.

Photo by Erik Wardle



1. Conservation tillage is defined by the Natural Resources Conservation Service as any practice that leaves at least 30 percent crop residue cover on the soil surface.
2. Furrow irrigation refers to surface flood irrigation where each crop row is irrigated by running water down a small ditch created to move water through the field.

Background photo by Bill Cotton

The Problem

Although viewed as an outdated irrigation practice by some, furrow irrigation continues very important to Colorado agriculture. Conversion to more efficient irrigation systems is restricted by cost, land suitability, and efficiency rules in the Arkansas Basin. According to the 2008 Farm and Ranch Irrigation Survey, over 1.5 million acres of cropland are irrigated with surface methods in Colorado. While center pivot sprinkler irrigation is expanding, there is still significant acreage under surface irrigation that could use improved tillage methods. Conservation tillage is fairly common in the eastern part of the state but is much less prevalent along the Front Range, especially under furrow irrigation. Traditional practices in furrow irrigation involve multiple energy-consuming tillage operations intended to loosen soil, bury residue, smooth and level soil surfaces, and create a suitable seedbed. However, these systems leave the bare soil surface vulnerable to wind and water erosion during seasonal periods where weather conditions are often most conducive to soil loss before the crop canopy is developed. Tradition and legitimate concerns regarding furrow irrigation performance help continue these outdated practices. Residue can cause furrow 'dams' during irrigation, slowing water movement down the rows and affecting irrigation uniformity. Cool spring soil temperatures in undisturbed ground can limit early season plant growth and slow stand establishment. Disease and insect pest concerns in some crops have also limited widespread adoption of conservation tillage practices.

Recent developments in planting and tillage system technologies are offering more options for alleviating cool spring soil temperatures and successfully dealing with crop residue during planting and irrigation. These tillage systems, coupled with more accurate and economical Global Positioning Systems (GPS) are gaining widespread acceptance in certain parts of the Western Great Plains and Colorado, but are much less common in the Northern Front Range.

Conservation tillage in furrow irrigation is not only possible, but offers many agronomic, economic and environmental benefits. First, the benefits of soil moisture preservation with increased crop residue in many environments and cropping systems are well known and have been documented for many years. One benefit of this soil moisture preservation is that early season irrigations can often be avoided, conserving water and reducing energy demands of pumping wells. Soil erosion prevention from both wind and water with increased residue is also

a proven benefit. Erosion reduction from conservation tillage in a furrow irrigation system occurs not only prior to the irrigation season, but also during furrow irrigation by decreasing irrigation-induced sediment and increasing water infiltration into the soil.

Sediment from irrigation water runoff can contribute to water quality degradation by transporting nutrients (nitrogen and phosphorus), adsorbed pesticides, and potentially selenium to surface water bodies. As such, the Colorado Phosphorus Risk Assessment lists residue and tillage management as a Best Management Practice appropriate to decrease the relative potential for off-site P movement for sites with high P runoff potential. In Colorado, as in other areas of the United States, an excessive amount of nutrients in surface water can cause excessive algae blooms which reduce sunlight penetration and available oxygen, resulting in fish kills. Irrigation induced erosion reduction with conservation tillage, and its associated decreases in nutrient transport to surface water bodies, may be one tool to help alleviate nutrient problems in the South Platte River and meet the coming nutrient standards.

Project Field Work and Outreach

The goal of this project is to evaluate and promote conservation tillage on furrow irrigated fields as a practice that is environmentally and economically sustainable. In order to accomplish these goals, our team has a number of on-going field and outreach activities. At ARDEC, we have a replicated field scale demonstration and research site that shows conventional tillage, and two conservation practices, minimum-tillage and strip-tillage³ (Figures 2 and 3). This site is being intensively monitored for crop health, soil moisture, irrigation efficiencies, and runoff water quality parameters. In addition, all activities at ARDEC are being recorded to help develop a detailed farm budget for these systems. This information will be used to assess the capacity of these systems to produce high yields, improve soil health, save fuel and labor and improve a producer's bottom line. Our cooperating producers in the area are innovative farmers that are practicing conservation tillage on a production scale. In addition to the ARDEC site, documenting on-farm practices that local growers are finding to be successful is enriching the outcomes of this project.

This is the first year of the project, and initial results continue to be processed and made available through the project webpage, conservationtillage.colostate.edu. A field day held in July of this year was well attended and provided

3. Conventional tillage refers to the utilization of multiple common local tillage operations leaving no residue on the soil surface; minimum-tillage means only tillage operations deemed absolutely necessary are done with most of the soil surface left undisturbed; strip-tillage is a practice where a narrow band of soil is disturbed in order to create a prepared seedbed.



Figure 2. **Left:** *Minimum-tillage plot (left) next to conventionally plowed plot at field demonstration site.*

Figure 3. **Right:** *Strip-tillage field, named for the prepared strips of soil and the undisturbed residue on the rest of the field. The seed will be planted directly into those prepared strips.*

Photos by Erik Wardle



an opportunity for producers, government staff, and industry representatives to share experiences and ideas on conservation tillage. The primary benefit of this project is an increased understanding of the possibilities of conservation tillage under furrow irrigated cropping systems within Colorado. The objective is that an increased understanding will lead to greater experimentation with, and adoption of, tillage practices that conserve soil and water resources and reduce energy demands. Complementary outreach materials on the subject will include updated electronic and hard copy materials that will be available to help producers make educated decisions regarding adoption of these practices. This work will also add to the body of knowledge on the impacts of conservation tillage on irrigation runoff water quantity and quality, particularly nutrients and sediment.

Background photo by Bill Cotton

The Value of Collaboration

Drawing upon experience and expertise of producers and private and public sector technical experts has enriched project planning and will certainly enhance its outcomes. It is important to note that although adoption of conservation tillage is not as wide spread as would be desirable in the Northern Front Range, numerous innovative farmers in the area are making these practices work for them. Working closely with these producers has brought technical expertise and ensures that the information produced by the project will fill a need to help other farmers make key management decisions. Our private sector partners have also been invaluable to the productivity and ongoing success of the project. In an era of limited resources, collaboration among private and public sector colleagues is increasingly important to maximize the impact of research and demonstration work in our state.

**32nd Annual
American Geophysical Union**

**Colorado
State
University**

HYDROLOGY DAYS

March 21 - March 23, 2012

Cherokee Park Room

Colorado State University

Hydrology Days Award Lecturer:

Michael Celia

Professor

Department of Civil and Environmental Engineering
Princeton University

**For more information and/or to submit abstracts, go to:
www.hydrologydays.colostate.edu**

Fred Anderson, 83, former state senator, helped change Colorado water laws

Reagan Waskom, Director, Colorado Water Institute

Former state senator Fred Anderson, who was well known for his legislative work on Colorado water, died on December 22, 2011 doing what he loved, moving water (shoveling snow). Fred, known to his friends as Freddie, was 83 and still engaged in water. In fact, three weeks prior to his passing he stood up at the Colorado Ag Water Summit and strongly admonished us to get on with the work of untangling the groundwater problems in the South Platte. Fred was a beloved member of the Colorado Water Institute's advisory board for many years, helping to guide water research and researchers through the maze and pitfalls of water politics.

Senator Anderson is widely credited as the legislative father of Colorado's pioneering Instream Flow Program. Anderson carried the bill in the state legislature that permitted the concept of beneficial use for the environment, also known as the Instream Flow law. In 1973, beneficial use for the environment was a new concept in Colorado water law that



Senator Fred Anderson

was eventually tested in Colorado Supreme Court, which ruled in favor of this new beneficial use. Fred made sure the Colorado Water Conservation Board would be the sole custodian of the program. After leaving the legislature, he worked closely with Senator Martha Ezzard on the 1986 legislation that provided for the CWCB to supplement its junior instream flow rights by allowing the Board to accept donations or leases of senior water rights for instream flow purposes. Today over 8,500 miles of Colorado streams are protected by instream flow water rights held by the CWCB.

Fred Anderson served sixteen years in the state Senate, eight of those as Senate President. Among his greatest achievements was helping to integrate ground and surface water management through the 1969 Water Rights Determination and Administration Act, which introduced the concept of augmentation plans to replace out of priority depletions caused by the pumping of tributary groundwater. The State Engineer was given the responsibility of jointly administering surface and

tributary groundwater within the priority system. Prior to leaving the legislature Senator Anderson was the primary sponsor or co-sponsor of virtually every significant piece of water legislation. After leaving the Senate, Fred was very active in water legislation for the Northern District and the Colorado Water Congress from 1982 to 1996 when he retired. Fred was also instrumental in crafting Senate Bill 5, enacted in 1985, which resolved a number of questions concerning allocation of Denver Basin groundwater. Fred once indicated to me that the 1969 Act and Senate Bill 5 were the result of hard won compromises, but that he never thought at the time that the bills would be the final

word on these complex management issues.

At CSU, we should also recognize that Senator Anderson was the driving force on the state legislature behind the building of present day veterinary hospital at Colorado State University. The previous Vet Hospital was in the Glover Building west of the Oval on main campus. A new facility was desperately needed, yet some of the powers in the legislature in the mid-1970s were

not favorably disposed towards CSU and wanted to deny the requested funding for a new Vet medicine center. Joe Shoemaker crafted a compromise to remodel the existing building rather than build a new hospital. Fred engineered a field trip for some of the Joint Budget Committee members to visit campus where they saw students cutting through the Glover Hospital while animal surgery and recovery was underway, creating a chaotic and cramped atmosphere. It is not clear whether this was staged or not, but Fred was able to convince his fellow legislators of the need to fund the building of a separate facility on Drake Road south of the main campus in order to elevate CSU Vet Science programs to the next level.

Senator Anderson grew up as a fourth generation farmer near Loveland and served in the U.S. Army during the Korean War. Loveland was his home for all of his 83 years and he served the Loveland community in many capacities. He was a tough negotiator, a good man and a great friend to CSU. Thanks, Freddie!



Photo by Kyle Thompson



CSFS Releases First Colorado Forest Road Field Handbook

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

The Colorado State Forest Service (CSFS) recently released the first-ever Colorado Forest Road Field Handbook to provide private landowners and state land managers information on how to properly build and maintain forest roads. The purpose of the free 142-page handbook is to protect water quality, fish and wildlife habitat, and forest ecosystems by helping to ensure that forest roads are constructed and maintained according to accepted best management practices.

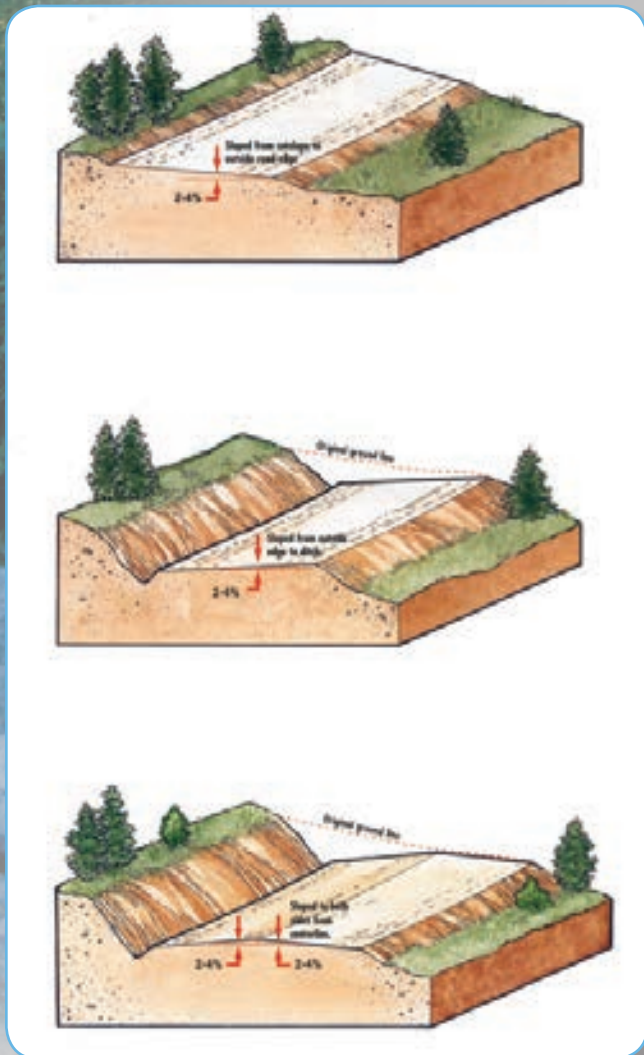


The new 6x8-1/2" handbook is tabbed and printed in full color.

Due to vegetation and soil disturbance, forest roads can lead to degraded water quality and may produce up to 90 percent of the sediment generated by forest activities. Many private and state forest roads are already in existence, so the primary focus of this publication is to assist landowners in the management of these in-place roads.

Left: The handbook contains many color photographs to illustrate subjects like culvert sizing.

Photo by R.M. Edwards



Illustrated schematics highlight topics such as road surface geometries.

The full-color CSFS forest road handbook provides on-the-ground guidelines and illustrations on proper road design, location, inspection, maintenance, and repair to help landowners protect local water supplies and minimize erosion. The handbook also can help save landowners thousands of dollars on maintenance costs over time through proper design and placement of forest roads. Forest owners may have as little as \$1,000 or as much as \$100,000 or more per mile invested in their current road systems.

“This handbook will ensure well-designed forest roads that are built in the best possible locations to minimize impacts on the surrounding environment,” said Rich

Edwards, CSFS assistant staff forester and chief editor of the handbook.

Personnel from the CSFS, U.S. Forest Service Rocky Mountain Region, Natural Resources Conservation Service, and other natural resources agencies reviewed and provided comment on the handbook. The handbook provides contact information for technical assistance from these and many other relevant agencies and organizations, and includes a section on contracts for easements, road construction, and general forestry operations.

“We wanted to get as much district and interagency input as possible to make this relevant to forests throughout Colorado,” Edwards said.

The major topics covered in the handbook, each delineated by a tabbed section, include:

- Road surface
- Road location
- Cross-drainage structures
- Stream crossings
- Inspection/maintenance/repair
- Wet-weather operations
- Contact information for assistance

Private forest roads allow landowners access to timber harvesting operations and forest management activities, and provide crucial access for fire protection, recreation, and search-and-rescue operations. The CSFS road guidelines are directed primarily at private landowners extending or maintaining roads in forested watersheds, but also will be useful to loggers, road construction contractors, and professional foresters. The CSFS also encourages anyone who works in or owns forestland to utilize the forest road handbook when designing stream crossings, such as bridges and culverts.

Forest road figures and guidelines were largely borrowed from a similar handbook created by the Oregon State University Extension Service, but were tailored to Colorado’s distinct climate, forest types, soils and topography. Funding for publication was provided through a grant from the Colorado Department of Public Health and Environment, Water Quality Control Division.

For more information about the Colorado Forest Road Field Handbook or to obtain a free copy, contact a local CSFS district office or visit www.csfs.colostate.edu to locate the nearest district office.

Water Tables 2012 Will Celebrate Western Water Organizations

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

“One man cannot build or administer a water system; one farm cannot pay the expenses of its maintenance. There is, then, at the threshold of life in an arid region a fundamental necessity for co-operation; for organization; for the association of men.”

Stated in 1898 by leading irrigation advocate William E. Smythe, this concept of the need in the arid west for cooperation, organization, and association has come to fruition time and again over the past century. The Water Resources Archive will celebrate this history of western water organizations during its next Water Tables event on Saturday, February 18, 2012.

Water Tables 2012, the seventh annual fundraiser for the Water Resources Archive, will be held on the Colorado State University main campus in Fort Collins. Reservations will be accepted beginning in January. The sit-down dinner will feature at least twenty water professionals and historians as table hosts, with each table focusing on a different organization that has played a role in western water development.

Perhaps it is fitting that one of the oldest organizations to be represented at Water Tables has its origins in irrigation research. As settlers moved west, they dug irrigation ditches to make the vast lands into productive farms. Soon a need for reliable information about the water supply and successful irrigation practices became apparent. The U.S. Department of Agriculture began its irrigation investigations in 1898, and the branch in Fort Collins, now known as the Water Management Research Unit, was established in 1911. Long-time unit employees Gordon Kruse and Harold Duke will serve as table co-hosts.

Several organizations with lengthy and fascinating histories will be celebrating their 75th anniversaries in 2012. Among them is Northern Water, formed following passage in 1937 of landmark state legislation authorizing creation of conservancy districts. Historian Daniel Tyler will host a table discussing Northern Water’s history. Tables are also planned to celebrate the histories of complementary organizations formed in 1937: the Colorado River Water Conservation District and the Colorado Water Conservation Board.



Water Tables 2011 table host Tom Cech and wife Grace examine some historic documents.
Photo by CSU Photography, courtesy of the CSU Water Resources Archive.



Water Tables 2011 table host Jeris Danielson chats with guests.
 Photo by CSU Photography, courtesy of the CSU Water Resources Archive.

These organizations, and the event's overall theme, were chosen to coincide with the statewide Water 2012 celebration, as well as the tenth anniversary of the Water Resources Archive. Water 2012 arose with the recognition of the forthcoming 75th anniversaries as mentioned, but

is going beyond to celebrate Colorado's water, its uses, its value, and its history.

Join the Water Resources Archive February 18 to learn about long-standing historic water organizations, as well as emerging ones. Some of the newer organizations to be represented include the Colorado Foundation for Water Education, table hosted by executive director Nicole Seltzer, and the Colorado Water Trust, table hosted by executive director Amy Beatie.

The need in the arid west for cooperation, organization, and association will always continue. Learning the lessons of the past will help future endeavors succeed. The Water Tables reception gives everyone a chance to mingle and network with all the hosts and guests while the dinner provides time for focused discussion and learning opportunities. It will be a night not to miss.

Proceeds from Water Tables support the Water Resources Archive, which works to preserve, promote, and make available records of Colorado's water history. The complete list of table hosts and organizations will be posted on the Water Tables website in January. For more information about the Water Resources Archive, see <http://lib.colostate.edu/archives/water/> or call (970) 491-1844.

Earn a Water-Focused M.E. from an Industry Leader

Colorado State University is one of the only institutions that offers an online graduate degree in civil engineering with a focus on:

- Water control and measurement
- Physical and engineering hydrology
- Water resources planning, management, and systems analysis
- Environmental monitoring
- Geographic information systems (GIS)
- Infrastructure management and security
- Linear programming and network flows

For more information about this degree and our other Water Resource programs, visit

CSUWaterPrograms.com



Figuring out Colorado's Precipitation Patterns



Nolan Doesken, State Climatologist, Colorado Climate Center

Life would be so much easier for water providers, managers, and users if our precipitation patterns here in Colorado (and anywhere in the world, for that matter) were just a bit more consistent and predictable. Don't get your hopes up, though. That probably won't happen anytime soon.



A SnoTel site from Hourglass Reservoir near Pingree Park.

Photo by Wendy Ryan

Climatologists have been measuring and tracking precipitation patterns in Colorado for over 120 years with a few individual weather stations (like downtown Denver) dating back even to the early 1870s. These data are of great interest and value and have taught us large amounts about our state and our climate. For example, we know that average annual precipitation is least in the middle of the San Luis Valley with only seven to eight inches (rain and melted snow) per year. The Grand Junction-Delta area of western Colorado is only slightly wetter (nine to ten inches). Colorado's Eastern Plains are a bit wetter, averaging 14 – 18 inches of precipitation annually except less in the immediate Arkansas Valley from Pueblo downstream to Las Animas. Eastern Colorado precipitation increases closer to the Kansas border headed east and closer to the foothills of the Rocky Mountains headed west.

Where precipitation patterns get really interesting and complicated is in the mountains themselves. Precipitation increases with elevation fairly universally here, but more dramatically in some parts of the state than others and at some times of the year more so than others. Winter, for example, is when the most dramatic topographic variations in precipitation are often seen. Many of the historic weather stations are in mountain valleys where most of the people live. Most of these valleys, including places like Walden, Granby, Dillon, Glenwood Springs, Aspen,

Leadville, Salida, Gunnison, Montrose, and Durango, average between 10 and 20 inches of moisture per year, which qualifies many to be called “semi-arid” by climatologists. Meanwhile, the mountains just a few miles away may be in the 20-40 inch range or even higher.

There are only a few parts of the state where annual precipitation exceeds 40, but those areas are very important for Colorado's water supplies. Portions of the San Juan Mountains of southwestern Colorado, the Elk Range in central Colorado near Marble and Crested Butte, and the Gore Range near Vail and the mountains just east of Steamboat Springs from Rabbit Ears Pass northward are some of Colorado's wettest areas on average. In fact, the automated weather station and snow measurement site called “Tower” near Buffalo Pass northeast of Steamboat Springs measured a whopping 82.9 inches of precipitation during the 2011 Water Year (October 2010 – Sept 2011).

But here's the rub. We may have a good handle on what to expect based on historic data and computed averages, but the fact is that no two years are ever the same. The seasonal as well as geospatial distribution of precipitation are incredibly variable from year to year. It is possible, and even common, for precipitation to vary by a factor of two

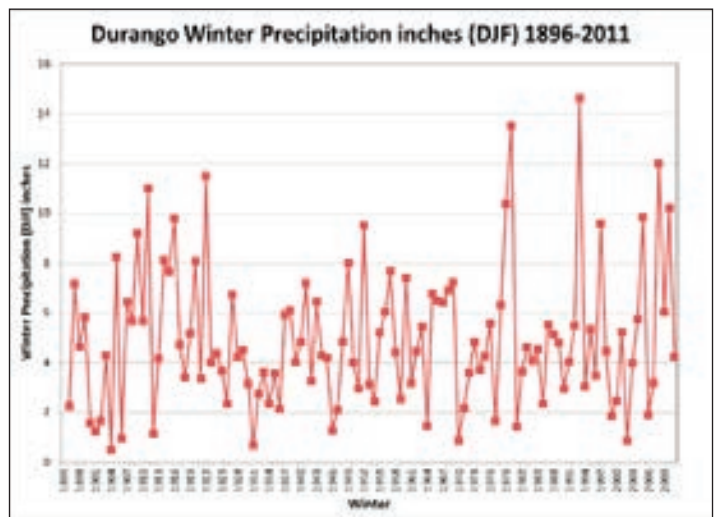


Figure 1. This time series of winter precipitation from Durango shows how winter precipitation in inches varies greatly from year to year.

or greater from one year to the next (Figure 1). Not only does precipitation vary season to season and year to year; we also see large difference from north to south and east to west. Historical data have shown that northern Colorado

and southern Colorado are often out of phase (one area can be unusually wet while the other is dry). West to east variations in precipitation anomalies are also common. That is a lot of variation, considering that we humans like a very steady and reliable water supply from one year to the next. It's much easier to live and conduct business that way. But that is not how our climate system works.

Like it or not, climate variability is a fact of life—with or without the additional challenges of Colorado-style topography. We only need to look at our current winter in context with the previous two water years to quickly get an idea of the challenges we are up against. Think back to the 2010 water year (Oct 2009-Sep 2010). Southwestern Colorado got hammered with furious back to back to back snowstorms in December, January, and February, while the headwaters of the Colorado River in northern Colorado limped along with winter snowfall barely half the historic average. (Figure 2). Then, as concerns over avalanches and potential spring floods grew in southern Colorado and opposite concerns about possible water shortages were taking root in the Upper Colorado River Basin, the weather patterns did an about face. In a matter of a few weeks, the storms shut off over southern Colorado. Northern Colorado then took its turn in the storm track and ended up with a normal snowpack and a large surge of June snowmelt and runoff when temperature and rainfall patterns converged. The very next winter (2010-2011) followed a nearly opposite course with a persistent storm track delivering snow all winter and spring to Colorado's northern and central mountains, while leaving southern and eastern Colorado with warm, windy, and dry weather. Several storms from April to June bailed out northeastern Colorado. Both the Colorado River and the South Platte watersheds ended up with a year with very abundant water supplies while the Rio Grande and tributaries to the Arkansas River in southern Colorado experienced a year of extreme drought.

Then our current winter and the beginning of our Colorado year-of-water celebration came (Water 2012, www.water2012.org). There was concern that it could be a drier year in the Colorado mountains with this being the second consecutive La Niña year (cooler than average sea surface temperatures near the equator in the eastern Pacific Ocean). However, the lack of December and early January snowfall across much of the western U.S.—especially from California, Nevada, and Utah eastward into northern and

Colorado Water Year 2011 Precipitation as Percentage of Normal (Oct 10 - Feb 11)

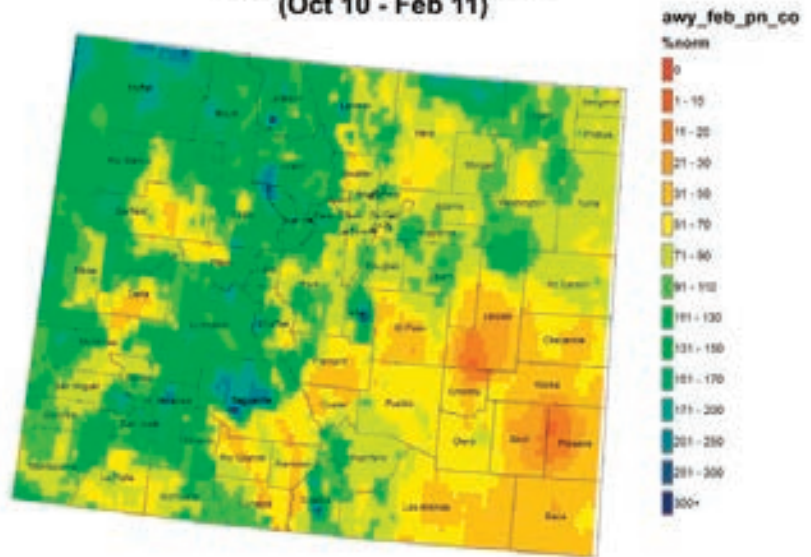


Figure 2. October 2010-February 2011 precipitation as a percent of the average for Colorado.

central Colorado—soon became alarming, with some areas receiving less than 25 percent of the average early winter snowfall.

We wish we knew what was coming next. Good forecasts are in high demand. Most likely, weather patterns will change. But even with the best available forecast technology, along with global perspectives on important climate phenomenon such as the El Niño Southern Oscillation (ENSO, <http://www.esrl.noaa.gov/psd/ens/mei/>), we still have only limited insight on weather patterns and subsequent water supplies weeks to months in advance. That is why we rely so heavily on water supply forecasts based on current snowpack. The snow that has already fallen remains the best indicator of what water we'll have at the end of the season.

The Colorado Climate Center continues to track climate and water supply conditions very closely. Webinars are held each Tuesday morning at 10 a.m. from mid-winter to early summer sponsored by the National Integrated Drought Information System. You may register to attend any of these webinars at this address: http://ccc.atmos.colostate.edu/drought_webinar_registration.php

If you would like to receive e-mail reminders and short weekly water supply status reports from the Colorado Climate Center, please contact Henry Reges at hreges@atmos.colostate.edu or call (970) 491-8545.

Background photo by Kyle Thompson

History of the Cache la Poudre Gaging Station Near the Canyon Mouth and the Colorado Meter

Dick Stenzel, Senior Water Resource Engineer, Applegate Group Inc.

Tom Cech, Director, One World One Water Center for Urban Water Education and Stewardship, Metropolitan State College of Denver

In 1881, the Colorado General Assembly created three water divisions—the South Platte, Arkansas, and Rio Grande—and also created the Office of State Engineer, to be appointed by the governor for a two-year term. The State Engineer's primary task was to make careful measurements and calculations of the maximum and minimum flow in cubic feet per second of water in each stream from which water shall be drawn for irrigation, according to the Report of the Special Committee of the United States Senate on Irrigation and Reclamation of Arid Lands. In 1881, Eugene K. Stimson was appointed by Governor Fredrick W. Pitkin, and served a two-year term from June 1881 - April 1883. Stimson installed Colorado's first streamflow gaging station on June 20, 1881 in the canyon of the Cache la Poudre River, approximately one and a half miles above the mouth of the canyon, northwest of Fort Collins. Stimson originally hired an assistant, who worked for him for several weeks until it was determined that there was no money in the budget for an assistant. Stimson was then forced to check the flows of the Cache la Poudre daily, and then ride 30 miles on horseback to the Big Thompson River at a location

west of Loveland at the canyon mouth to install another gaging station.

The Cache la Poudre station was operated from June 20, 1881, through August 5, 1881. Later that August, Stimson began making measurements on the Big Thompson River and continued until September 20, 1881. During most of this time, his office was a tent with a portable drafting table. Stimson had limited time to accomplish the other activities required of the State Engineer. In 1882, Stimson did not monitor either gaging station, and instead he spent his time inspecting measuring flumes that he required to be constructed on irrigation ditches that had decrees in the Cache la Poudre River, and making flow measurements in the flumes to develop rating tables for them.

In 1883, E. S. Nettleton (Figure 1) was appointed State Engineer of Colorado and held the office for four years. Irrigation engineering was undeveloped in the U.S. in the 1870s, and the Union Colony canals were among the first largest irrigation systems in the country. During that period, Nettleton oversaw construction of the Greely

The Cache la Poudre gaging structure, the first permanent gaging station in Colorado, as it looked in 1900.

Courtesy of Dick Stenzel

Number Three and Number Two Irrigation Canals. State Engineer Nettleton brought with him a significant background in irrigation ditch construction and established himself as a leader in irrigation engineering.

On May 4, 1883, Nettleton re-established the gaging station on the Cache la Poudre. However, it was discontinued again on July 4, 1883 because he was concerned about its condition. When the flows of the river declined in the fall of 1883, an inspection and re-measurement of cross-sections of the original flumes in the river channels was made. The channel at the gaging station had changed dramatically, such that it impaired the accuracy of computations made during the first part of the year, and reduced them to the level of approximations. Nettleton made a proposition to the ditch owners of the Cache la Poudre River Basin: If they furnished the necessary funds, he (as State Engineer) would build a gaging station and permanent measuring flume where a continuous self-recording gauge could be installed. This would provide trustworthy ratings of flows at all river stages. With this more accurate data, the Water Commissioner of the district could divide the waters equitably at all stages. The ditch companies promptly responded to Nettleton's proposition, and assessed themselves, according to the size of their ditches. They raised the money to construct the measuring flume and gauge house for about \$1,650. In the fall of 1883, boulders were removed from the riverbed by blasting, and the channel prepared for a wooden flume. A flume eight feet high, 32 feet deep, and 103 feet wide was constructed and completed in November, ready for use during the following irrigation season.

The Cache la Poudre gage was then re-established on March 13, 1884, and a continuous recorder was installed. An eight by 10 foot instrument house was constructed on the riverbank adjacent to the flume, and a continuous self-recording system was installed. The self-recording apparatus consisted of a stand-pipe, connected to the flume by a horizontal pipe, level with the flume floor. A galvanized-iron hollow cylinder, having conical ends, floated on the water in the stand-pipe, and was connected by a metal line with the self-recording device, which was located on a table placed above the stand-pipe. This device consisted of a cylinder turned by a clock, so that one revolution of

the cylinder was made each week. A sheet of profile paper was wound on the cylinder, and thick lines divided the paper into seven equal parts, each part representing a day of the week. These columns were subdivided into twelve equal parts, each representing two hours. A pencil was held to the cylinder by a small weight, and the pencil was connected to the float in such a manner that the rise and fall of the float caused a proportional horizontal motion of the pencil. Prior to installation of the recording device, the river at the location of the gaging station as installed by Stimson had been rated, but required local observers to make tri-daily observations of the height of water on a staff gage located on the riverbank.



Figure 1. E.S. Nettleton, Second State Engineer of Colorado, invented Colorado Meter and improved gaging station on Poudre River.

Courtesy of Dick Stenzel

After the wooden measuring flume was installed, observations were made to determine the velocity of the current at 10-foot intervals across the river, beginning five feet from the north side of the new measuring flume. One assistant stood in a boat, which was held in position by a head line sliding on a ferry cable attached to both shores. A current meter was placed in the water with the counting gear disconnected. Another assistant with a stopwatch, gave a signal, and at the same instant the counting gear of the meter was engaged. The assistant using the current meter began to lower the meter slowly from the water surface to the bottom of the river channel. The meter was then pulled back up to the surface, and the operation was repeated two or three times with as nearly a uniform motion as possible. This method

provided the average river velocity at a given point, with a usual observation time of 100 seconds, at which time the counting gear of the meter was disengaged and the stopwatch stopped at the same instant.

The measurement of time that elapsed and the number of revolutions of the meter were both recorded, and at least two observations were taken at each point. When the work at one point was satisfactorily completed, the assistant on shore moved the boat ten feet towards the south side of the flume, and the operations were repeated every ten feet across the stream. In this meticulous manner, they ascertained the average velocity of the stream. They repeated operations when the river stage changed by one foot, either higher or lower. Five stream gagings were made using this same procedure between the lowest and highest stages of water. This provided the data needed for computing the

discharge of the river at the gaging station at various stages in the river, and eventually a rating table at the gaging station was developed.

Initially, these measurements were made with an eight-vaned, double-pivoted, Fteley current meter, manufactured by Messrs. Buff & Berger of Boston. The instrument even came with an electronic registering apparatus. It soon became apparent that this instrument was entirely too delicate for use in the Cache la Poudre River.

As a result, Nettleton designed and invented the Colorado Current Meter in 1885. Nettleton stated:

The main object in designing this instrument, was to make it self-clearing, the great defect of the Fteley meter being its liability to error from clogging with grass, weeds, etc., which, at times, would vitiate many hours' work, and make the readings so diverse that doubts would arise as to the value of a whole day's work. A secondary object was to reduce the speed of revolution, the high speed of the Fteley instrument necessitating expensive jeweled bearings and a delicacy of construction, incompatible with the rough work which is required to be done.

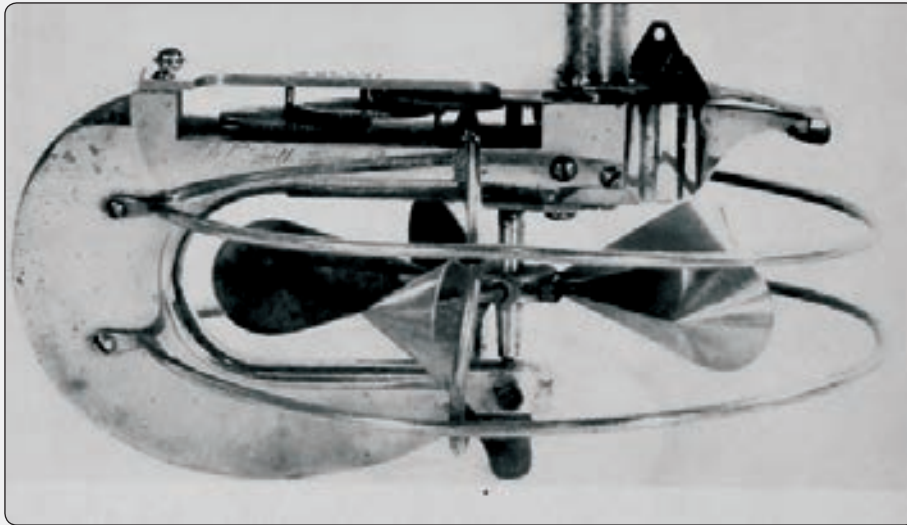


Figure 2. E.S. Nettleton's Colorado Meter.

Three Colorado Meters were made for Nettleton by W. E. Scott & Co. of Denver, one of which is housed today at the Smithsonian Museum in Washington, D.C. (Figure 2). Nettleton described the meter as:

acting on the same general principle as the "anemometer," or wind-gauge, the principal change being in the shape and number of the cups. It has five vanes or cups revolving horizontally on an axle, having bearings at the open end of a C-shaped metal frame, the cups passing between the sides of the C. On the upper arm of the frame is affixed a set of counting gears, so arranged, that they can be instantly thrown into, or out of connection, with the vanes, by means of a spring, and a cord passing up the metal rod, by which the instrument is held in the desired position in

the water. The shape of the cups is such that floating weeds, etc., will not be retained longer than about three-eighths of a revolution.

The meters were each rated separately by moving them at known velocities through still water. This had the same effect as holding the meter in running water. Therefore, by determining the number of revolutions made by the meter, in a given time, at each velocity, a rating table could be developed for the meter. Nettleton rated the meters at the reservoir that existed at that time at the Denver Water Company.

The general public was fascinated with this new device for measuring water. When State Engineer Nettleton came to measure the flow of the Greeley Canal Number 3, the Greeley Tribune had the following description of the device:

The instrument, which measures the velocity of the water, was about as large as the butter end of a churn dasher....with this improved system...after much toil and calculation, one may almost say that the very drops of heaven are called down and numbered and sent out to fill the land with corn and flowers.

Courtesy of Dick Stenzel

A few years later, the vertical walls of the wooden flume located at the Cache la Poudre streamflow gaging station was replaced with masonry walls, and the fairly smooth riverbed was used for the floor of the flume. Unfortunately, Chambers Lake Dam failed on June 9, 1891, and the resulting flood destroyed the recorder shelter. By that time, the State Agricultural College (today's Colorado State University) was operating the station, and soon after, the flood professor L. G. Carpenter reinstalled the weekly recorder at the station. These records were so important to local ditch companies that they had a single 12-mile wire installed from the Cache la Poudre gaging station to Professor Carpenter's office at the college, where a receiving instrument was placed. Although that long-distance streamflow recorder proved to be unsuccessful (and was later discarded), it is believed to have been the first installation in the U.S. of a long-distance recorder

at a gaging station. The photo on page 24 shows the gaging station structure in 1900. On November 30, 1909, the State Engineer took over operation of the station and installed a Bristol gage in a timber shelter and erected a cableway that was used during high flows. The site and gage datum have remained relatively unchanged since 1881, and has remained in continuous use. As such, it is believed to be the first river station in the U.S. where a recorder was installed, and also has the longest record of history. The photo at right shows the current gaging station structure as it looks today.

The Cache la Poudre gaging structure as it looks today.

Photo by Dick Stenzel

Evapotranspiration Workshop

USDA-Natural Resource Research Center,
Building D, Fort Collins, CO

March 21, 8:30 a.m. - 4:30 p.m.

Topics:

Recent Trends in Evapotranspiration Calculations and Data

Case Study:

Estimating Historic Consumptive Use

Luncheon Speaker:

Marvin Jensen, "Use of Supporting Data in Estimating and Confirming ET Estimates"

Cost:

\$200 (all profits go to support CoAgMet weather station network)

Registration:

To register, please visit <http://col.st/zT7ZFc>

Contact Tom Trout for further information, Thomas.Trout@ars.usda.gov

Colorado Water Congress Holds Annual Convention

Reagan Waskom, Director, Colorado Water Institute

The Colorado Water Congress held its 54th Annual Convention at Denver Tech Center on Jan. 25-27, 2012. The conference theme was, “The Year of Water Celebration - Our Stories, Our Work, Our Vision.” Workshops on the Colorado River, water quality, water conservation and water projects were among the concurrent sessions held on Wednesday, capped with a reception with the newly formed POND committee (Professionals Outreach, Networking and Development), which is designed to promote networking opportunities among water professionals.

The Thursday morning general session, moderated by Floyd Ciruli, opened with a video welcome by Gov. Hickenlooper declaring 2012 the Year of Water for Colorado. This year celebrates the 75th anniversary of the Colorado Water Conservation Board (CWCB), the Northern Colorado Water Conservancy District, and the Colorado River Water Conservation District. Parker Water and the Frypan-Arkansas project celebrate their 50th anniversary of water delivery. Gov. Hickenlooper’s Special Advisor for Water, John Stulp, read a proclamation declaring the 2012 Year of Water a year of action and celebration of water in Colorado. Floyd Ciruli offered that we might be at one of those moments in history where Colorado is posed to make significant progress in water management. The issues of the mid-1930s that spawned the CWCB and Conservancy Districts are still with us today: transbasin projects pitting East slope against West, Ag vs. cities, groundwater vs. surface water, interstate disputes, basin of origin mitigation, Colorado River entitlement,

conservation vs. new infrastructure, and a focus on jobs. Patty Limerick, CU History professor, provided an opening talk on historic context of 1937, the New Deal, and the history of the Denver Water Board. She noted that a tremendous potential exists in 2012 for Colorado to do things in a different way that still respects tradition.

Supreme Court Justice Greg Hobbs led a session featuring water authors and the 2012 book list. Craig Childs, author of *House of Rain*, discussed the indigenous search for water in the arid southwest and how it shaped the indigenous civilization. Anasazi, Hohokam, and others all lived around water and small wet places, until prolonged drought came to the southwest, forcing them to leave for more hospitable places. John Waterman, author of *Colorado River: Flowing Through Conflict*, discussed his raft trip down the river from source to the sea and what he observed. And finally, Steve Maxwell, author of *Future of Water*, offered a business and finance perspective on water. Maxwell noted several key trends to watch: water shortages already prevalent in many areas of the world and climate and population growth portend more of the same; failing infrastructure and the unfortunate propensity to require infrastructure catastrophe before systems are upgraded; privatization—using private capital to solve public problems; and the surge of investor interest in water sector. Maxwell stated that technology will not solve the problems without major change in price, behavior, and policy. Public understanding is weak, and many problems could be more easily addressed with a more knowledgeable public.

(Left to right): Frank Jaeger, Parker Water & Sanitation District; Eric Wilkinson, Northern Colorado Water Conservancy District; Eric Kuhn, Colorado River Water Conservation District; Joe Frank, Lower South Platte Water Conservancy District; Jim Broderick, Southeastern Colorado Water Conservancy District; Travis Smith, Rio Grande River; and Jennifer Gimbel, Colorado Water Conservation Board.

Photo by Carla Quezada



Mike Gibson, manager of the San Luis Valley Water Conservancy District, took over the duties of president of the Colorado Water Congress. Gibson noted that the issue that he plans to promote is getting more young people to take an interest in water as a career path. At the closing luncheon, the CWC also paid tribute to the late state Sen. Fred Anderson, who died at the age of 83 while shoveling snow on Dec. 23.

The highlight of the annual convention was the Wayne N. Aspinall water leader of the year award. David Robbins, president and co-founder of the Denver law firm of Hill & Robbins and Chair of the Colorado Water Institute Advisory Board, was recognized as the newest Aspinall leader. Robbins is widely known for his work defending the Rio Grande Water Conservation District against attempts to remove water from the San Luis Valley via pipelines in the 1980s and 1990s. He subsequently worked with Congress to write legislation for the Great Sand Dunes National Park, further protecting the San Luis Valley's water against future



John Stulp, Water Advisor to Governor Hickenlooper, reads the Governor's proclamation of the 2012 Year of Water.

Photo by Carla Quezada

transfers. In his acceptance speech Robbins noted, "We should not give away a drop of water that this state needs, we owe it to future generations."



Colorado Water 2012



Celebrate Colorado water in 2012! There are many ways to be involved. Join the Colorado Water 2012 movement, use the Colorado Water 2012 logo in your organization's promotions and events in 2012, join one of the seven committees planning statewide activities, or publicize your local activities on the Water 2012 online calendar. Stay tuned for more opportunities to get involved!

The goals of Colorado Water 2012 are to:

Increase support for management and protection of Colorado's water and waterways

Showcase exemplary models of cooperation and collaboration among Colorado water users

Motivate Coloradans to become proactive participants in Colorado's water future

Raise awareness about water as a valuable and limited resource

Connect Coloradans to existing and new opportunities to learn about water

For more information, or to be added to the email list, contact Nona Shipman, OSM/VISTA Colorado Water 2012 Coordinator at water2012@cfwe.org or 304-377-4433 or visit www.Water2012.org.

Eugene Kelly

Lindsey A. Knebel, Editor, Colorado Water Institute

Eugene Kelly, with CSU as a faculty member since 1989, was appointed in 2011 as the new head of the Department of Soil and Crop Sciences. Kelly says in his new position, he's still engaged scientifically with his own research interests, but most of his efforts now involve coordinating and promoting the activities and talents of others.

Kelly's goals in the new position include training the next generation of environmental/agricultural scientists and the next generation of farmers. "The planet is changing rapidly, so their careers are going to look different in ten years," says Kelly, and they are going to need the knowledge and skills to adapt.

Kelly moved to Colorado from his home state of New York to earn his first bachelor's degree at CSU in Forest and Range Management. It only took one suggestion from a professor at the time to introduce him to soil sciences, and Kelly says after taking a couple of classes in the department, he was hooked.

Kelly went on to earn a master's degree in Agronomy from CSU and doctorate in Soil Science at the University of California. Both his master's thesis and Ph.D. dissertation were focused on the pedology of soils within grassland ecosystems. Pedology, he says, is simply the study of the origin and evolution of soils.

As part of his doctorate work, Kelly wanted to assess the use of soils as indicators of ancient climates, and to accomplish this, he needed to study grassland soils that had never been cultivated. The idea was based on a discovery in his master's thesis work that humans in general, and cultivation specifically, dramatically alter soils. Kelly's solution was to test abandoned pioneer gravesites, areas considered sacred and left undisturbed. "The sites still provide essential baseline data for many other studies we conducted in this region over the last 25 years," he says.

Kelly's local research includes studying areas of the South Platte watershed, which Kelly says incorporate many kinds of land use, from natural to agricultural to urban, where he and others on his team developed models assessing the vulnerability of these ecosystems to climate change.

"My perspective," he says, "is more of a long term pedological perspective—what's going to happen to the Earth's surface, and how will that affect how we use it?" Kelly says that overall, the ecosystems in the drier

portions of the Great Plains are surprisingly resilient, but he wonders what will happen once they are pushed outside the known limits.

Kelly's interest in global change led him to become involved with CSU's new School of Global and Environmental Sustainability (SoGES)—he was one of the faculty members involved with the creation of the white paper that guided the school's development, and was later brought into an associate directing role. He helped create the school's minor, which he describes as "an added value to the other colleges across campus," rather than a competing degree. Kelly also administers grants and moderates the Managing the Planet Panel Series for SoGES.

"This is a perfect discipline for me," says Kelly. "I drifted into Pedology as an activity that involved more of the things that interest me; Chemistry, Physics, Biology, Geology, and Ecology. Pedology simultaneously challenges one intellectually, physically and brings you to the field in some of the most beautiful and interesting places imaginable."


"I'm fortunate in that I've been in a scientific discipline that requires you to think broadly," says Kelly, mentioning his varied and interdisciplinary training and interests. "I do believe that will help me in my position as department head."



Eugene Kelly
Department Head

Department of Soil and Crop Sciences
Colorado State University

Plant Sciences C-19
Fort Collins, CO 80523-1170
Phone: (970) 491-6881
Eugene.Kelly@colostate.edu



Alaska Geochemical Database (AGDB)-Geochemical data for rock, sediment, soil, mineral, and concentrate sample media; 2011; DS; 637; Granitto, Matthew; Bailey, Elizabeth A.; Schmidt, Jeanine M.; Shew, Nora B.; Gamble, Bruce M.; Labay, Keith A.

In-place oil shale resources underlying Federal lands in the Green River and Washakie Basins, southwestern Wyoming; 2011; SIR; 2011-3113; Mercier, Tracey J.; Johnson, Ronald C.; Brownfield, Michael E.

Proceedings of the third USGS modeling conference, June 7-11, 2010, Broomfield, Colorado-Understanding and predicting for a changing world; 2011; SIR; 2011-5147; Edited by: Brady, Shailaja R.

Applying remote sensing to invasive species science—A tamarisk example; 2011; FS; 2011-3109; Morisette, Jeffrey T.

Groundwater recharge in Wisconsin--Annual estimates for 1970-99 using streamflow data; 2011; FS; 2009-3092; Gebert, Warren A.; Walker, John F.; Hunt, Randall J.

Hydrogeologic setting and simulation of groundwater flow near the Canterbury and Leadville Mine Drainage Tunnels, Leadville, Colorado; 2011; SIR; 2011-5085; Wellman, Tristan P. ; Paschke, Suzanne S. ; Minsley, Burke ; Dupree, Jean A.

Thermal mapping of Hawaiian volcanoes with ASTER satellite data; 2011; SIR; 2011-5110; Patrick, Matthew R.; Witzke, Coral-Nadine

Internships, Employment Opportunities, and Research Grants; 2011; GIP; 114;

Department of Interior Climate Science Centers; 2011; FS; 2011-3025; Jones, Sonya A

Biostratigraphic data from Upper Cretaceous formations-eastern Wyoming, central Colorado, and northeastern New Mexico; 2011; SIM; 3175; Merewether, E. A.; Cobban, W. A.; Obradovich, J. D.

How to build and teach with QuakeCaster, an earthquake demonstration and exploration tool; 2011; OFR; 2011-1158; Linton, Kelsey; Stein, Ross S.

Aeolian and fluvial processes in dryland regions: the need for integrated studies; 2011; Article; Journal; Ecohydrology; Belnap, Jayne ; Munson, Seth M.; Field, Jason P.

CRvolution 2—Origin and evolution of the Colorado River system, workshop abstracts; 2011; OFR; 2011-1210; Edited by: Beard, L. Sue; Karlstrom, Karl E.; Young, Richard A.; Billingsley, Goerge H.

Assessment of undiscovered oil and gas resources of the Devonian Marcellus Shale of the Appalachian Basin Province; 2011; FS; 2011-3092; Coleman, James L.; Milici, Robert C.; Cook, Troy A.; Charpentier, Ronald R.; Kirshbaum, Mark; Klett, Timothy R.; Pollastro, Richard M.; Schenk, Christopher J.

The future of rare earth elements—will these high-tech industry elements continue in short supply?; 2011; OFR; 2011-1189; Long, Keith R.

Carbonatite and alkaline intrusion-related rare earth element deposits—A deposit model; 2011; OFR; 2011-1256; Verplanck, Philip L.; Van Gosen, Bradley S.

Water Research Awards

Colorado State University (September 16, 2011 to January 15, 2012)

- Anderson, David G**, Colorado Natural Heritage Program, NatureServe, Climate Change Vulnerability Assessments for Colorado Plant Species, \$22,750
- Beavers, Andrew M**, CEMML, AECOM, Prescribed Fire Effects for USFWS National Wildlife Refuges Wet Meadows & Marshlands (Pacific Islands) Dry ..., \$10,504
- Brummer, Renate L**, CIRA, DOC-NOAA-Natl Oceanic & Atmospheric Admn Improvements in Statistical Tropical Cyclone Forecast Models, \$43,000
- Carlson, Kenneth H**, Civil & Environmental Engineering, Noble Energy, Inc., Noble Energy and Colorado State University Power Intensity Study, \$125,000
- Chavez, Jose L**, Civil & Environmental Engineering, Regenes Management Group, Crop Water Stress Index and Evapotranspiration Monitoring using Remote Sensing Techniques, \$120,227
- Clements, William H**, Fish, Wildlife & Conservation Biology, International Copper Association, The Use of Stream Microcosms & Field Experiments to Quantify Remediation Success in Mining Contaminated Streams, \$25,000
- Cox, Amanda L**, Civil & Environmental Engineering, Urban Drainage & Flood Control District, Detention Pond Outlet Structure Model, \$36,346
- Fiege, Mark T**, History, FRICO-Farmers Reservoir and Irrigation C, FRICO History Project: Phase 2 (Narrative History of FRICO), \$50,000
- Garcia, Luis**, Civil & Environmental Engineering, USDA-ARS-Agricultural Research Service, Spatial Data and Implementation Tools for Distributed Watershed Modeling Addressing NRCS Resource Concerns, \$326,350
- Garcia, Luis**, Civil & Environmental Engineering, USDA-ARS-Agricultural Research Service, Module Development for OMS (Object Management System), \$97,600
- Hawkins, John A**, Fish, Wildlife & Conservation Biology, DOI-Bureau of Reclamation, Monitoring of Potential Colorado Pikeminnow Entrainment in the Maybell Canal, Yampa River, Colorado, \$2,853
- Johnson, Jerry J**, Soil & Crop Sciences, Colorado Sorghum Producers, Getting Sorghum Going in Colorado, \$15,500
- Lemly, Joanna**, Colorado Natural Heritage Program, EPA-Environmental Protection Agency, CSU 2010 WPDG: Lower South Platte River Basinwide Wetland Profile, \$115,801
- Loomis, John B**, Agric & Resource Economics, USDA-FSA-Farm Service Agency, Economic Assessment of CRP on Outdoor Recreation, \$200,000
- MacDonald, Lee H**, Ecosystem Science and Sustainability, USDA-USFS-Rocky Mtn. Rsrch Station – CO, Evaluating & Predicting Postfire Logging Effects on Erosion, \$6,080
- Miller, Steven D**, CIRA, Calif. Inst. of Tech/Jet Propulsion Lab, CloudSat DPC (CIRA), \$90,348
- Myrick, Christopher A**, Fish, Wildlife & Conservation Biology, DOI-BLM-Bureau of Land Management, Are Western Sucker Swimming Performances Interchangeable? Comparing the Swimming Performances of Five Sucker..., \$60,000
- Noon, Barry R**, Fish, Wildlife & Conservation Biology, Exxon Mobil Corporation, 2010 Exxon Mobil: Lek-Based Monitoring of Greater Sage-Grouse Sage Grouse, \$86,616
- Qian, Yaling**, Horticulture & Landscape Arch, University of Colorado, Growing Switchgrass as an Energy Crop in Colorado, \$36,000
- Rondeau, Renee**, Colorado Natural Heritage Program, The Nature Conservancy, USFWS Climate Change Resilience Model in Gunnison Basin, \$10,500
- Sanford William E**, Geosciences, Regenes Management Group, Task 3: Quantifying Changes in Irrigation Return Flow Due to Limited Irrigation & Other Crop Optimizing Techniques, \$77,792
- Schubert, Wayne H**, CIRA, DOC-NOAA-Natl Oceanic & Atmospheric Admn Tropical Cyclone Model Diagnostics and Product Development, \$220,000
- Stephens, Graeme L**, Atmospheric Science, Calif. Inst. of Tech/Jet Propulsion Lab, CloudSat Science, \$48,574
- Theobald, David M**, Fish, Wildlife & Conservation Biology, DOI-USFWS-Fish & Wildlife Service Vulnerability, Resilience & Connectivity of Natural Landscapes & Riparian Habitat in the Southern Rockies ..., \$91,028
- Venayagamoorthy, Subhas K**, Civil & Environmental Engineering, DOD-NAVY-ONR-Office of Naval Research, Dynamics and Modeling of Turbulent Mixing in Oceanic Flows, \$49,868
- Waskom, Reagan M**, Colorado Water Institute, Colorado Water Conservation Board, CWCB/CWI Cooperative Intern Program, \$6,792
- Waskom, Reagan M**, Colorado Water Institute, DOI-USGS-Geological Survey, Water Quality Impacts of The Mountain Pine Beetle Infestation in the Rocky Mountain West..FY11 104G Water Resources Com., \$140,162
- Waskom, Reagan M**, Colorado Water Institute, Walton Family Foundation*, Exploratory Water Sharing Field Trips and Corollary Work, \$159,799
- Whittier, Jack C**, Animal Sciences, University of Wyoming, Tri-State Ranch Management Practicum Beginning Rancher Education and Development Program, \$85,193
- Wilson Kenneth R**, Fish, Wildlife & Conservation Biology, Exxon Mobil Corporation, 2010 Exxon Mobil: Piceance Basin Wildlife and Habitat Studies, \$33,650
- Wittemyer, George**, Fish, Wildlife & Conservation Biology, Exxon Mobil Corporation, 2010 Exxon Mobil: Mule Deer Movement Behavior in Response to Natural Gas Resource Extraction, \$114,264

Calendar

February

- 18 Water Tables 2012**
A fundraiser for the Water Resources Archive at Colorado State University. The event will celebrate more than 20 western water organizations through engaging dinner conversation with prominent water professionals. [Lib.colostate.edu/water](http://lib.colostate.edu/water)
- 23-24 DARCA 10th Annual**
The presentations will include discussions on the recent United/FRICO change case, administrative issues, and how to keep the next generation on the farm. Darca.org
- 2/27 - 3/1 Second National Flood Workshop**
This includes the meteorological and hydrological conditions observed before, during, and after flood events, technological advancements being made in remote field data acquisition and flood modeling, and regulations and requirements in flood mitigation and floodplain management. www.wxresearch.com/nfw/

March

- 1 Statewide Roundtable Summit**
John Stulp and Jennifer Gimbel will be speaking on the Colorado Water for the 21st Century Process, risk management and other topics. <http://cwcb.state.co.us/about-us/about-the-ibcc-brts/>
- 1-2 Rocky Mountain Land Institute 21st Annual Land Use Conference**
12th National Severe Weather Workshop Topics will include lessons learned from the events of the recent past in the hopes of identifying partnerships and progress that will lead to better prepared communities and the ultimate goal of a Weather Ready Nation. www.norman.noaa.gov/nsww/
- 14-15 Colorado Division of Water Resources “Irrigationists Symposium”**
Topics will include Water Accounting, Dam Safety, and Irrigation History and Issues in the South Platte Basin. For more information email: brent.schantz@state.co.us
- 18-21 AWWA Sustainable Water Management Conference**
This conference seeks to combine technical presentations with in-depth discussions on legal, regulatory, and legislative matters facing water utilities today. www.awwa.org/Conferences
- 21-23 CSU Hydrology Days (CSU/AGU) 23rd Annual Hydrology Days**
The 32nd Annual Hydrology Days, Held on the Colorado State University Campus. <http://hydrologydays.colostate.edu/>
- 22 World Water Day**
International World Water Day is held annually on 22 March as a means of focusing attention on the importance of freshwater and advocating for the sustainable management of freshwater resources. www.unwater.org/worldwaterday/about.html
- 26-28 American Water Resources Association – Spring Specialty Conf. GIS & Water Res. VII**
Topics have been broken into 8 tracks: Executive Track, Water Quality/Environmental, Flood Risk, Hydrologic Model Integration, Water Data Integration, National Hydrography Dataset, LiDAR, Climate Change. www.awra.org/meetings/Spring2012/

April

- 16-18 National Hydropower Association Annual Conference**
2012's unprecedented event will include more than 20 sessions and over 100 speakers and will offer unrivaled opportunities for hydro professionals. www.nationalhydroconference.com/
- 25-28 Arkansas River Basin Water Forum**
The Arkansas River Basin Water Forum serves as a conduit for information about the Arkansas River Basin in Colorado, and for issues related to water allocation and management.

Colorado State University

The Water Center of Colorado State University
1033 Campus Delivery
Fort Collins, Colorado 80523-1033

NONPROFIT
ORGANIZATION
U.S. POSTAGE
PAID
Fort Collins, Colorado 80523
Permit Number 19

ATTENTION SUBSCRIBERS

Please help us keep our distribution list up to date. If you prefer to receive the newsletter electronically or have a name/address change, please visit our web site and click on *Subscriptions*.

COLORADO WATER ONLINE

Visit the CWI web site to access a PDF version of our current newsletter. To download past issues of our newsletter, click on *Newsletter Archives*.

VISIT OUR WEB SITES

Colorado Water Institute
www.cwi.colostate.edu

CSU Water Center
www.watercenter.colostate.edu



The Speer Blvd. Bridge at Confluence Park in Denver, Colorado, reflects onto the South Platte River just after sunset.

Photo by Thaddeus Roan