



**COLORADO  
WATER CENTER**  
COLORADO STATE UNIVERSITY

COLORADO  
WATER CENTER  
**ANNUAL  
REPORT**  
FY19





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## WHO WE ARE

The Colorado Water Center (CoWC) is one of 54 Water Resources Research Institutes created by the Water Resources Act of 1964, which collectively form the National Institutes for Water Resources. As a division under CSU's Office of Engagement, the Center aims to connect all water expertise in Colorado's higher education system with research and education needs of Colorado's water managers and users, building on the rich water history at Colorado State University.

The CoWC leads interdisciplinary research, education, and outreach to address complex and evolving water-related challenges in Colorado and beyond. We do so by fostering collaboration between higher education and water stakeholders, synthesizing objective water knowledge to inform decision-making, and inspiring the next generation of water leaders.

## OUTREACH & TRANSFER

The CoWC collaborates with CSU Extension to house three water outreach specialists around the state and operates several websites with up-to-date water information that have become a consistent source of knowledge for water professionals and community members alike. Publications available on these sites include: research reports and Colorado Water, a newsletter containing information on current research, water faculty, outreach program updates, climate, water history, Colorado State Forest Service (CSFS) updates, CSU Faculty Grant Program updates, and water-related events and conferences, featuring different research in each issue. The CoWC outreach activities are conducted in conjunction with CSU Extension, the Colorado Agricultural Experiment Station, the CSFS, and the Colorado Climate Center (CCC). Our primary partners include water managers, water providers, and water agencies.

## TRAINING

One of the CoWC's primary missions is to facilitate the training and education of university students. To this end, the Center works with the U.S. Geological Survey and the Colorado Water Conservation Board to fund student interns and research grants and manages scholarships on behalf of students.

Student researchers work with faculty members and gain valuable water expertise as well as knowledge of the research process.

# TABLE OF CONTENTS

02 MESSAGE FROM THE DIRECTOR

03 NEW RESEARCH

05 FY19 RESEARCH HIGHLIGHTS

05 *Student Research*

08 *CWCB FY19 Projects*

14 *Faculty Grant Program*

22 CoWC STAFF UPDATES

30 YEAR IN REVIEW

30 *GRAD592*

30 *Newsletter and Reports*

32 *UYWCD Scholarship Recipient*

32 *Outreach & Engagement*

34 FY19 CoWC STAFF

35 CoWC ADVISORY BOARD

36 FINANCIAL &  
ACADEMIC SUMMARY

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## MESSAGE FROM THE DIRECTOR

The Colorado Water Center (CoWC) at CSU completed its rebranding efforts in 2019, blending the Colorado Water Institute and

the CSU Water Center into one unit to better serve its research, outreach, and training mission for Colorado through a variety of research projects and student training in cooperation with the Colorado Water Conservation Board (CWCB) and the U.S. Geological Survey (USGS). The Colorado Water Institute will do business as the CoWC, continuing to fulfill its statutory mission working with all of higher education in Colorado as part of a network of 54 university-based water centers and institutes across the nation serving under the federal Water Resources Research Act.

Significant efforts were dedicated in 2019 toward the development of the program and building plans for the new Water Building at the National Western, in partnership with Denver Water. One major component of the NW Water Center is a planned Western Water Policy Institute that CoWC will have a major role in helping to foster dialogue and study of water policy issues. 2019 also saw the implementation of the Irrigation Innovation Consortium (IIC), funded by the Foundation for Food and Agricultural Research Foundation (FFAR) and industry partners, including Northern Water. The IIC has a goal of promoting and enhancing water and energy efficiency in irrigation, ultimately creating greater resiliency in food and irrigated landscape systems.

Several of our outreach and education projects are highlighted in this annual report, including work in the Cache la Poudre, Arkansas, South Platte, and Colorado

River Basins, and the Ogallala Aquifer. The 2019 snow-pack brought much needed relief from the 2018 drought, allowing CSU Regional Extension Water Specialists to resume normal programs advancing water conservation and efficiency, water quality, and related research and training efforts. Work on climate smart agriculture initiatives continued under the leadership of Brad Udall and retired State Climatologist, Nolan Doesken. A significant change occurred for the Center this year when MaryLou Smith, CoWC Policy and Collaboration Specialist, retired in June after ten years of water policy related work, passing the torch for our Water Literate Leaders program, the Poudre Runs Through It collaborative, and the Regional Water Dialogue to Julie Kallenberger, CoWC Water Education Specialist. Angelique Giraud has recently joined our staff to assist Julie with the research and educational programs of the Center. Other significant changes at CSU include the retirement of CSU President Tony Frank and CSU Vice President Lou Swanson, both of whom were strong supporters of the Center and CSU's role in water research, outreach, and education.

Our 2019 Annual Report highlights several of the projects funded this past year through the CoWC with CWCB severance tax funds, as well as CSU and USGS funds. As CoWC director, I gratefully acknowledge the support from our state and federal partners and am pleased to report this year that the Center continues to benefit from a committed staff, excellent support from CSU upper administration, and the guidance of an outstanding advisory committee. More information on the CoWC can be found at [watercenter.colostate.edu](http://watercenter.colostate.edu).

*Reagan Waskom*  
Reagan Waskom



# NEW RESEARCH

## CWCB FY20 Projects

Investigating the Impact of Recharge Ponds, Pumping, and a Drought on Groundwater Levels and Return Flows in the Lasalle/Gilcrest Area during 2013-2018 (Year 2)  
*Ryan Bailey, Colorado State University*

Mineralogical and Microbiome Characterization of Aeolian Dust Deposited on Alpine Snowpack in the South San Juan Mountains Associated with Regional Climate Change  
*Rob Benson, Adams State University*

Streamflow Estimation in Colorado Ungauged Basins  
*Stephanie Kampf, Colorado State University*

Quantifying Impacts of Hydrological Parameter Uncertainty on Dam Safety Analysis  
*Jeffrey Niemann, Colorado State University*

Tools for Improving Knowledge of Reservoir Water Quality in the Front Range of Colorado  
*Matt Ross, Colorado State University*

Direct Measurements of Colorado Reservoir Evaporation: A Comparison Between Eddy Covariance and Class-A Pan Measurement, and Model Results  
*Peter Blanken, University of Colorado*

Exploring the Potential of Improved Soil Management Practices to Support Soil Health and Water Conservation in Irrigated Corn Systems of Eastern Colorado  
*Steven Fonte, Colorado State University*

Relationship Between Irrigation Return Flows, Riparian Vegetation Water Use, and Soluble Pollutant Removal in the Lower Arkansas River Basin  
*Ryan Morrison, Colorado State University*

## Externally Funded

Irrigation Innovation Consortium  
*Reagan Waskom, Colorado Water Center; Foundation for Food and Agriculture Research*

Multi-Environment Vertical Agricultural Technologies: Innovative Irrigation and Monitoring Solutions with Machine Learning Integration  
*Joshua Ken Craver, Colorado State University; Foundation for Food and Agriculture Research*

Next Generation Soil Moisture Technology for Improving Irrigation Management in Turfgrass and Landscape  
*Jay M Ham, Colorado State University; Foundation for Food and Agriculture Research*



Lysimeter Operations for Development of  
Colorado Crop Coefficients

*Alan Andales, Colorado State University;  
Colorado Division of Water Resources*

Satellite and UAS Imagery Use to Impliment Timely  
Irrigation Strategies

*José Chávez, Colorado State University;  
Foundation for Food and Agriculture Research*

#### USGS Student Research

Participatory Mapping of Colorado Watershed  
Ecosystem Services

*Luke Chamberlain & Kelly Jones;  
Colorado State University*

Quantifying Groundwater Recharge Below a Losing  
Stream Reach in the Denver Basin

*Kristen Cognac & Michael Ronayne;  
Colorado State University*

Floodplain Forest Establishment and Legacy Sediment  
within the Yampa River Basin, Northern Colorado

*John Kemper & Sara Rathburn;  
Colorado State University*

Snowmelt Modeling at Fine Scale for Mine Infiltration  
Estimation at Summitville

*Alison Kingston & Steven Fassnacht,  
Colorado State University*

Diel Signals in Hydrologic and Chemical Signals  
Along the North Saint Vrain

*Danielle Palm & Tim Covino; Colorado State University*

The Dynamic Nature of Snow Surface Roughness

*Jessica Sanow & Steven Fassnacht;  
Colorado State University*

Selecting Cost-Effective Water

Quality Management Practices Under Climate Change  
*Di Sheng & Jordan Sutter; Colorado State University*

## STAY UP-TO-DATE

Subscribe to our e-newsletter, *The Current*,  
or our print newsletter, *Colorado Water*, for  
updates on research, water-related news,  
jobs, funding, scholarships, and more!

**[watercenter.colostate.edu](http://watercenter.colostate.edu)**

#### USGS Internships

National Domain Water Budgets

NIWR-USGS Student Internship Program

*William Farmer*

#### CSU Faculty Grant Program

Kids Poetry on Water – Creating K-12 Curriculum

Integrating Water Science and Poetry

*Steven Fassnacht, Ecosystem Science & Sustainability*

The Current and Future State of Water Resources for  
the Colorado Rocky Mountains

*Kristen Rasmussen, Atmospheric Science*

Numerical Modeling of Evolving Recharge-Discharge  
Sources in a Multi-Aquifer System

*Michael Ronayne, Geosciences*

Development and Launch of a “Master Irrigator” Education  
and Training Program in Northeastern Colorado

*Amy Kremen, Soil & Crop Sciences*

Assessing Gene Flow of Invasive Brook Trout to

Restore a Meta-Population of Threatened Greenback  
Cutthroat Trout in the Upper Poudre River basin

*Yoichiro Kanno, Fish, Wildlife, & Conservation Biology*

Harnessing the Power of the Crowd to Monitor Urban  
Street Flooding

*Aditi Bhaskar, Civil & Environmental Engineering*

Hydrologic Drivers of Peatland Development and Carbon  
Accumulation in Western Washington

*John Hribljan, Forest & Rangeland Stewardship*



# STUDENT RESEARCH

## INVESTIGATING BI-DIRECTIONAL WATER EXCHANGES ACROSS INTACT AND DEGRADED FLOODPLAINS

*Alexander C. Brooks & Tim Covino,  
Colorado State University*

This study found that that water chemistry is a strong metric of seasonal dynamics in river-floodplain connectivity. Patterns in geochemical similarity, between the floodplain inflow and other sites in the complex, revealed three distinct patterns of connectivity: sites that were always connected to the inflow site, sites that had intermittent connectivity, and sites that had no evidence of connection to the main channel inflow to the floodplain.

Despite strong connections between the river and floodplain, the majority of water moving longitudinally through the river network did not remain in the floodplain complex for longer than several hours. This is corroborated by the tracer experiments which show that at high flow,  $97\% \pm 10\%$  of water from the inflow reached the outflow within 2.5 hours. During the low flow experiment,  $87\% \pm 10\%$  of flow at the inflow reached the outflow within 4 hours.

Despite the relatively low percentage of exchange, we did observe some water quality benefits of the floodplain as nitrate concentrations were consistently reduced by 10-20% over the reach. Reducing nitrate concentrations in streams can help prevent downstream water quality problems in reservoirs and drinking water.

Building on this preliminary work, we plan to explore how hydrologic connectivity controls important aspects of floodplain function, including growing season water availability to plants, dissolved oxygen and temperature in aquatic habitats, and retention and transformation of dissolved organic carbon. We expect this work will inform current and future restoration efforts that aim to restore functionality to the many degraded floodplains across the state.

*Alexander C Brooks (left) and Tim Covino (right).*

## DIRTY SNOW: TURNING QUALITATIVE ASSESSMENTS INTO QUANTITATIVE FACTORS FOR THE EFFECT OF DUST ON SNOW ALBEDO AND MELT RATE

Caroline Duncan & Steven Fassnacht, Colorado State University

The presence of light absorbing particulates on the surface of snowpack can greatly enhance melt due to decreased albedo, thus increasing absorption of short-wave radiation. In Southwestern Colorado, these light-absorbing particulates are present every winter in the form of dust on snow. This dust often comes from the Four Corners region, yet dust can be present in snowpack throughout the Western US from other global sources.

The main objective of this work is to evaluate the difference in radiative forcing caused by the presence of dust on snow at the Senator Beck Basin (SBB) study site, which is operated by the Center for Snow and Avalanche Studies. The water year 2013 was examined where the snowpack melted down to a dust layer on April 22. Over the next 27 days before the snowpack melted out, the observed midday average albedo was about 0.49, while modeled clean snow albedo was greater than 0.7. This resulted in a 122% increase in absorption of solar radiation.

Without the presence of dust on snow, melt would have taken almost twice as long. Ongoing work includes examining other years between 2005 and present, with different intensities of dust deposition in the winter.

## STREAMFLOW DEPLETION ON THE SOUTH PLATTE RIVER DUE TO GROUNDWATER PUMPING: ANALYSIS VIA FIELD WORK AND GROUNDWATER MODELING

Luke Flores & Ryan Bailey, Colorado State University

The interactions between streams and underlying alluviums are inherently intricate. While each system must be analyzed independently, this reach of the South Platte River exhibited behaviors indicative of a stream that is highly interactive with its alluvium.

Groundwater wells show that in close proximity to the stream, water levels between the two systems were nearly linearly related. Subsequently, pumping wells were able to reduce both stream stage and streamflow. At the same time, factors beyond pumping will always contribute to streamflow loss.

For the reach of this study, a highly variable upstream stream-flow contributed a highly variable stream width, which led to bank storage and resulting unsaturated zone flow. However consequential stream-aquifer studies for humans, animal, and biota often do not include such processes. It is our hope that this work serves to further encourage comprehensive stream-aquifer studies that do not exclusively rely on existing methods, and where researchers will be willing to use unique methodologies and models for their specific sites.

Drilling of observation well A in South Suburban Park, Littleton, Colorado.



Photo by Luke Flores





Photo by Thomas  
"Woody" Myers

## HISTORY OF SOUTH PLATTE RIVER RIPARIAN ECOSYSTEM AND CHANNEL CHANGE

Joshua Rogerson & Jessica Salo, University of Northern Colorado

Since the 1840s, water management has substantially altered the hydrology of the South Platte River in Colorado. Although the river experiences significant natural inter-annual flow variability, the altered annual flow regime is characterized by enhanced seasonal consistency of surface and ground water levels.

Today, the river supports a broad cottonwood-willow riparian forest that established from 1900-1930, in a pulse of channel narrowing that accompanied historic flow alterations. The status of this forest is not well understood. We developed and tested methods to assess historic riparian land cover change and channel movement on the South Platte River downstream of Greeley, Colorado. We digitized floodplain land cover on orthophotos taken at approximately 10 year intervals for a 30 km river segment located in Weld and Morgan counties, Colorado.

The analysis revealed that during low flow periods (1999 – 2006), the active channel constricted and there was a corresponding increase in riparian shrubs, herbs, and both dense and open forests. During times of high flow (2006 – 2015), an increase in active channel area, accompanied by decreases in riparian shrubs, herbs, and both dense and open forests, was observed. We found that studying the dynamics of the South Platte riparian ecosystem at the decadal scale reveals different relationships that can be captured over longer durations of time, and thus future research should focus on roughly decadal increments.

Understanding historic rates and patterns of South Platte River riparian land cover dynamics provides important context for informing management of this critical natural resource.







# CWCB FY19 PROJECTS

## STREAMFLOW PREDICTION IN COLORADO UNGAUGED BASINS

*Stephanie K. Kampf, Abby Eurich, John C. Hammond, & Aditi S. Bhaskar, Colorado State University  
Ben Livneh & Javier Cepeda, University of Colorado*

This report tested three different methods for predicting streamflow at ungauged basins in Colorado: the USGS regional regression equations, new empirical regression equations, and the Variable Infiltration Capacity (VIC) hydrologic model.

Streamflow data were compiled for 222 stations across the state, and these were converted to mean annual and mean monthly flows for two time periods: 1981-2018 and 2001-2018. The same streamflow metrics were extracted from daily simulations of streamflow in the VIC model. For the drainage area contributing to each watershed, variables related to topography, geology, and climate were computed. These were used as independent variables in new regression models that predict each of the streamflow metrics.

For each streamflow metric, all three model results were compared to observed streamflow for 1981-2018, 2001-2018, and for each decade from 1930-2010. Results show that all models have comparable performance for predicting mean annual discharge, with the strongest performance

from a new empirical model that incorporates mean annual snow persistence.

For mean monthly discharge, new empirical models have the most consistent performance across months and usually stronger performance than the USGS regression models. When the regression models were tested against observed flow from earlier decades, the new models performed best for mean annual flow and for snow-melt runoff months of April-June. The USGS regression models performed best for winter flows, and both the new regressions and USGS models had comparable performance for fall flows. While the uncalibrated VIC model was not as accurate as the regression models for streamflow prediction, it still performed relatively well, especially for mean annual flow. Because this simulates physical processes, it is useful for exploring causes for differences in streamflow patterns across the state.

Future work could expand on the uncalibrated VIC model results presented here and examine what model changes would be needed to improve streamflow predictions throughout the state.

## A REVIEW OF FLOODPLAINS AND FLOOD-INDUCED CHANGES IN FLOODPLAIN FORM AND FUNCTION

Ellen Wohl, Colorado State University

A floodplain is a relatively flat alluvial surface adjacent to the channel, inundated at least periodically by flows of the contemporary hydrologic regime, and composed of river-deposited sediment. This document reviews existing knowledge of floodplain storage capacity and changes associated with flooding. Storage capacity includes surface water, subsurface water in the hyporheic zone and groundwater, solutes, mineral sediment, and particulate organic matter.

The emphasis in this paper was on the range of channel and floodplain types present in Colorado. The paper demonstrated that diverse techniques exist for restoring floodplain form and function. Whether restoration focuses on enlarging a floodplain to a size closer to that present prior to human modifications, reconnecting the channel and floodplain, or restoring floodplain spatial heterogeneity, restoration can increase the ability of a floodplain to retain water, solutes, sediment, and particulate organic matter, and increase the resiliency of a river segment and the entire river network to natural and human disturbances. Options for floodplain restoration are likely to be constrained where rivers pass through urban areas or other densely used landscapes, but the entire floodplain length along a river does not need to be fully restored to regain 51 desirable ecosystem services.

River restoration sometimes focuses on the concept of river beads (Wohl et al., 2018), which are limited lengths of river where a broader range of restoration options exist. In urban areas, for example, portions of river held by public entities as natural areas or open space may be sites where

restoration of native floodplain vegetation and floodplain logjams can provide habitat, attenuation of downstream fluxes, and carbon storage, as well as recreational areas for people.

Our present understanding of river function does not allow us to quantitatively relate proportion of river length or area with restored floodplains to level of nutrient storage and uptake, for example (Bernhardt and Palmer, 2011), but this topic is an area of active research and we are likely to be able to start predicting such relationships within the next decade. In the meantime, understanding and management of rivers, and retention or restoration of floodplain storage, can be improved by conceptualizing of rivers as river corridors in which channels are intimately connected to their floodplains and the underlying hyporheic zone and as ecosystems that perform far more functions than simply conveying water downstream. Such conceptualizations can move us beyond simplistic expectations for a single, relatively homogeneous and uniform channel, and toward acceptance of the ‘messiness’ associated with channel and floodplain spatial heterogeneity and change through time, and the ecosystem services and river health that accompany such apparent messiness (Wohl, 2018).







Photo by Flickr  
User Unsettler

## SUCCESSIONAL TRAJECTORIES OF THE RIPARIAN FOREST ALONG THE SOUTH PLATTE RIVER

Cetan Christensen & Andrew Norton,  
Colorado State University  
Gabrielle Katz, Metropolitan State  
University of Denver

The ecological function of riparian ecosystems is dependent on the variability in stream flow. The flow regime, which includes the magnitude, frequency, duration, timing, and water flows in the river system, have major implications for the functioning of the river and the forest that surrounds it. For the ecological function of riparian systems to be maintained, the defining hydrologic conditions of the river system need to be maintained.

This study focused on the riparian forest on the South Platte River in Eastern Colorado. This research project gives us a better understanding of the composition of the riparian forest on the South Platte River, and enhances our understanding of historic forest establishment and regeneration patterns.

Ongoing work includes examining the correlation between river flow volumes and patterns and cottonwood, green ash and Siberian elm growth rates (using tree ring widths as a proxy measurement) and establishment dates.

Forests are valued as a natural resource, providing a variety of ecosystem services including wildlife habitat, recreation, and flood mitigation.

The persistence of a cottonwood forest on the South Platte River depends on dynamic processes of flooding, erosion and sediment deposition that create suitable conditions for seedling establishment and long term survival. However, we do not know if these conditions commonly exist within the study area. Future changes in flow amounts and timing due to additional diversions or climate change are likely

to alter forest trajectories as well.

Three sites were sampled in the summer of 2018, and four in summer 2019. A total of 243 cottonwood, 46 green ash, and 13 Siberian elm were sampled for tree ring analysis. At present all 2013 tree cores have been processed and analyzed. We are still processing those collected in 2019 with an anticipated completion date of December 2019.

Among the three sites from 2018 where we have completed age estimation, there is evidence for continuous establishment and little support for reduced recruitment in more recent years. There is evidence for recruitment in all 5-year increments indicating that recruitment has been temporally continuous, meaning this forest has been regenerating from the 1890s to present day. Preliminary analysis shows that the McClary site had the oldest Plains cottonwood trees, with establishment as early as the 1890s, and a significant pulse of establishment around 1920. At the Thrailkill and Colorado Land Commission sites, tree establishment was not identified until the 1930s, which may be attributed local disturbances that removed older stands, or due to later establishment at these sites than at the McClary site.

Thus while among all three of these sites there has been more or less continuous recruitment, there is evidence for significant heterogeneity between these three sites. Continuing work on this project will provide a more complete description of this forest as we process the remaining sites.

## INVESTIGATING MAJOR INFLUENCES ON GROUNDWATER LEVELS IN THE LASALLE/GILCREST AREA

Ryan T. Bailey & Chenda Deng,  
Colorado State University

The Gilcrest/LaSalle area is a 78-mile area located northeast of Denver. In recent years, the area has experienced high groundwater levels. The source of water for the aquifer includes infiltration and recharge from surface water irrigation, groundwater irrigation, and rainfall; pumping for agricultural use and infiltration from recharge ponds; canal seepage; groundwater lateral flow from surrounding areas; and upflux from the underlying bedrock aquifer.

The principal goal for this project was to assess the impact of these individual contributions on water table elevation fluctuation, through the use of a calibrated and tested MODFLOW model. Specific objectives were to:

1. Investigate reasons for high water table elevation in the area
2. Explore the effect of best-management practices (BMPs) on water table elevation
3. Monitor water table elevation fluctuations using network of existing observation wells

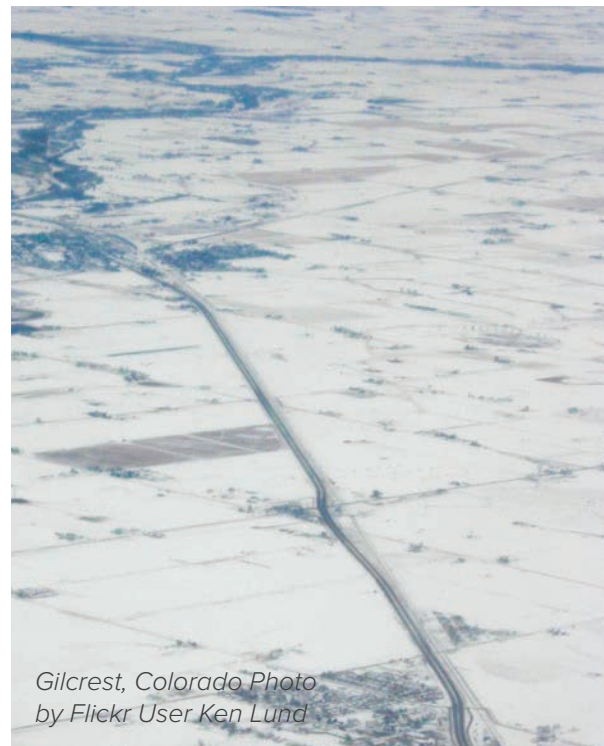
This project developed a new method to assess the impact of water budget components on the hydraulic head in waterlogged areas. Sensitivity analyses were applied to the LaSalle/Gilcrest MODFLOW model to quantify and rank the relative influence of groundwater sources and sinks on water table elevation, for the pre- and post-2006 periods. This was followed by an assessment of selected BMPs on water table elevation.

### RESULTS

#### Sensitivity Analysis

Before 2006, the order of influence on water table elevation was:

1. groundwater pumping
2. canal seepage
3. recharge from surface water irrigation



After 2006, the order of influence was:

1. recharge from surface water irrigation
2. canal seepage
3. groundwater pumping

Recharge from groundwater irrigation, precipitation, and recharge ponds did not have a strong influence on water table elevation. However, recharge pond implementation was not extensive during the model simulation period of 2000-2012.

#### BMPs

- Lining canals can result in an average water table decline of 4 feet, but up to 26 feet in some areas
- Conversion from surface water irrigation to groundwater irrigation can result in an average water table decline of 12 feet, but up to 55 feet in some areas
  - » A 20% conversion results in an average decline of 5 feet
  - » A 50% conversion results in an average decline of 10 feet
- Installing subsurface drains in the Gilcrest area, at a depth of 6 feet, results in an average water table decline of 0.4 feet, but up to 2 feet in some areas
- Lining canals + converting from surface water irrigation to groundwater irrigation can result in an average decline of 15 feet, but up to 60 feet in some areas



## USER-FRIENDLY WEB APPLICATION FOR WATER DATA STATISTICAL ANALYSIS AND VISUALIZATION

Panagiotis D. Oikonomou,  
Colorado State University



South Platte River

The state of Colorado has world-class water data in terms of availability compared with many other states, or countries. It has been a priority of the State to invest in water data, their availability and transparency, and to develop online tools that would inform about the status of the state's water resources, and possibly assist in water management decisions.

The South Platte Basin has an area of approximately 19,000 mi (Dennehy et al., 1993) and is located in northeast Colorado. The climate of the basin is semi-arid. The lower part of South Platte River Basin has undergone a huge transformation due to land reclamation, agricultural development, and population increase. It is an over-appropriated basin with multiple water needs and a large agricultural water demand. Hydroclimatic conditions, the anthropogenic interventions to satisfy water demands, along with the water legislative environment that governs the South Platte basin, are all adding to the system's complexity.

We developed a prototype web-based tool for Statistical Analysis and Visualization, using data selected

from the lower part of the South Platte Basin. The goal of the proposed online prototype tool is a proof of concept, and by expansion, it could advance the capabilities of the Colorado Decision Support System through the development of a user-friendly web application. Potential users of such a tool could vary, from state agency personnel to other stakeholders, and, even the general

public in order to have a quick and reliable trend analysis of the water data. This project explores the applicability of open source frameworks for scientific computing in order to develop a prototype trend analysis tool for water data in Colorado. It also establishes a robust framework for trend analysis.

The main idea behind this tool is to provide a user-friendly web application for statistical analysis and visualization to the end-user. It does not require any software knowledge. After the user selects their data, the available wells' identification names populate the stations' section of the form. At the same time, the wells' location is predicted on an interac-

tive map that provides an alternative for choosing which wells the user wishes to analyze.

Upon choosing the appropriate well, the user clicks to "Calculate Trend" to generate results. The tool then retrieves the available information for the well of interest, and ultimately results are shown in two tables: one offering an overview of water depth statistics and a count of missing observations; the other showing results of trend analysis and displaying the slope, and a probability value, with a 95% confidence level in the statistical outcome. Trend analysis from the tool also demonstrates the long-term behavior of the groundwater level and whether it is stable, rising, or decreasing.

The user has the option to store the produced graphs in three formats (pdf, svg, and png). At the same time the whole interface can be exported as a PDF via the browser's print option. This concise interface simplifies tracking, and provides the option to print out data for reporting on each location of interest.

[waterstats.watercenter.colostate.edu](http://waterstats.watercenter.colostate.edu)

# CSU FACULTY GRANT PROGRAM



## *WATER JUSTICE IN THE RIO GRANDE RIVER BASIN: FINDINGS FROM THE ENVIRONMENTAL JUSTICE RESEARCH TEAM*

*By Stephanie A. Malin & Melinda Laituri, Colorado State University*

The Rio Grande/Rio Bravo (Rio Grande-Bravo or RGB) River Basin flows 1,896 miles from its headwaters in the San Juan Mountains of Southern Colorado. It winds through New Mexico along the western border of Texas and four Mexican states, draining a total of 182,200 square miles. The region encompasses diverse ecosystems, ranging from mountainous alpine zones, to semi-arid rangelands and the high Chihuahuan desert, to the humid subtropics where the mouth empties into the Gulf of Mexico.

The populations and socio-economic fabrics of communities along the Rio Grande-Bravo River Basin

are equally diverse, given that the basin includes multiple U.S. and Mexican states. The Basin is also home to eighteen of the nineteen Tribal Pueblos of New Mexico (with only the Zuni outside the region) and four additional Tribal nations.

Water industries in the Basin include agriculture (water use estimated at 75% of available supplies), oil and gas, tourism and recreation, and commercial fishing. Although there are only four major urban centers along the mainstem of the Rio Grande, municipal water demand is expected to increase by 100% in the next fifty years and industrial water use will increase by 40%.



These physical and social characteristics are compounded by a changing climate, which has resulted in severely depleted waters.

These pressures set the context for an examination of competing demands for water through an environmental justice lens. We took a broad lens at the entire RGB Basin through our geospatial justice investigations, webinar, and mapping — and focused on specific issues and communities in northern New Mexico. Our approach to understanding the consequential geography of spatial justice is twofold:

1. developing a geospatial inventory of EJ stakeholders across the RGB Basin
2. creating a geospatial database of the RGB watershed.

After conducting our initial research and fieldwork, we held the New Mexico Tribal Environmental Justice Roundtable, which was attended by about 30 Pueblo/Tribal Environmental Professionals, who represented 10 of the 19 different Pueblos across New Mexico.

### KEY LESSONS LEARNED

People's health is affected in most of these cases of environmental injustice, and that this is a deeply held concern in the communities.

- Youth and women from Tribal communities play important roles in addressing environmental and climate injustice, and need to gain more influence.
- People's concerns over water quality and water scarcity intersect with almost every other experience of environmental injustice that was mentioned.
- Participants were particularly interested in the concepts of Distributive Justice (referring to placement of environmental "goods" like bike paths, public transit and public lands vs. "bads" like toxic waste storage), and Procedural Justice (referring to longer-term decision-making processes and specifically, who has a seat at the table when decisions are made).

### NEXT STEPS

The Center for Environmental Justice opens at CSU in 2019 and will provide new space for interdisciplinary research, policy, and engagement related to environmental justice and health. As one project, we'll be working on making these justice concepts useful for Pueblo and Tribal communities.



Photo by United States Department of Defense

## EVALUATION OF FLOODING VARIABILITY AND RISKS TO U.S. HOUSING STOCK

*Ryan Morrison, Ellison Carter, Kristen Rasmussen, & Brooke Anderson, Colorado State University*

Flooding is one of the most costly natural disasters in the U.S. Flooding events in the U.S. cause large economic and health burdens each year and are the nation's second-deadliest weather-related natural disasters, with national economic losses conservatively estimated to be at least \$50 billion annually. Strong climatological, meteorological, and changing land-use evidence indicates that the frequency and severity of flooding are intensifying in many regions and will continue to increase in the future. This research seeks to alleviate such negative impacts through understanding of geographic flooding trends.

Short-term mortality associated with flooding has been well documented and forms the basis for present-day estimates of health impacts associated with flooding. Long-term and cumulative health effects associated with flooding, on the other hand, are poorly understood. Yet, this information is greatly needed to develop a more comprehensive under-

standing of public health risk associated with flooding that would, in turn, improve future flood management and recovery response.

To build better flood management strategies, we need to understand both the population groups that may be disproportionately impacted by floods and characteristics of the floods that lead to more or fewer health risks. For instance, floods that occur rapidly (i.e., flash floods) cause different risks than floods that occur more slowly (slow-rise floods) and inundate homes for longer periods of time. Currently, there is no current database linking flooding type, population demographics, and susceptibility of population groups for floods of different sizes. Thus, in this work, we integrated mesoscale meteorological, hydrological, and housing data to estimate the spatial vulnerability of residential homes affected by different flood sizes.

## METHODS

Our approach included three phases of data collection and analysis:

1. Using historical records of precipitation and flooding to determine the frequency and type of flooding likely to occur in a region.
2. Gathering census information about housing stock (e.g. housing type by structure and age) to represent different population groups in a region.
3. Spatially analyzing the intersection of flooding

type and housing stock within flood inundation boundaries of different recurrence intervals. We used the Wabash River and Willamette River basins as study sites to compare distinct flooding characteristics driven by different hydroclimatic conditions.

## CONCLUSIONS

The frequency and spatial distribution of flood types varied in each basin. When housing stock attributes were spatially analyzed within flood boundaries for 20-, 50-, and 100-year events, we unsurprisingly found that more homes may be impacted by flooding during the 100-year event compared to smaller events. In addition, the spatial distribution of housing types impacted by different sized floods varied in each basin.

These findings highlight the need to examine more fundamental hydrometeorological processes of flooding across large spatial scales and to explore the disparate impacts of flooding on different demographic groups. In future work, we would like to expand this analysis nationally and establish a dataset of housing demographics and geospatial flood regime topology linking flood characteristics to recurrence interval and flooding extent. This research may be useful for national emergency response policies for flooding, and we expect it may also inform urban resiliency and health planning under climate change.

## ADDRESSING NON-SALMONID FISH PASSAGE IN SEMI-ARID REGIONS: CONVERGING PATHS, CONTINENTS APART

Christopher A. Myrick, Colorado State University

The ecological connectivity of rivers can be restored to some degree by well-designed fish passage structures. This project was designed to allow a Colorado fish passage researcher to interact and work with fish passage researchers from other semi-arid regions who specialize in the passage of non-salmonid fishes, to explore possible similarities between fish passage needs and approaches in Australia's Murray-Darling River system and those of Colorado's Eastern Plains.

## BACKGROUND – WHY BARRIERS TO FISH MIGRATION ARE A PROBLEM

Rivers worldwide provide important habitat for a wide variety of fish ranging in size from less than an ounce, to well over 100 pounds. A common thread between these and most other riverine fishes is that they rely on the ability to move freely between the habitats they need for spawning, feeding, or avoiding harsh environmental conditions such as droughts or floods.

The rivers that flow through semi-arid regions





serve another purpose – they provide water for agricultural and urban needs, for power generation, and, in some cases, for recreation. In order to manage the rivers for these purposes and to minimize loss of life and property during flood events, resource managers often rely upon the presence of instream structures such as dams or diversions. Unfortunately, these can serve as barriers to the migration of fishes and other aquatic organisms.

### METHODS AND RESULTS

As a Colorado Water Center Faculty Fellow, I traveled to Australia, and met and worked with global experts on this subject. Key observations from this exploration included:

- In Australia's Murray-Darling system, as in Colorado, nonnative fish species cause management problems for the environment and native fishes.
- Water demands often exceed water availability in both locations. This leads to tough decisions on who, or what, gets water during periods of low flow.
- There is a constant tension between the need to preserve native fishes, and the need to

provide the angling public with recreational fishing opportunities.

- The presence of large numbers of instream diversions, weirs, and dams poses an ongoing challenge to “reconnecting” the river to restore ecological connectivity. Efforts are underway in both regions to install effective fish passage structures where possible.
- While the Australians are clearly ahead when it comes to the design and installation of fishways for their nonsalmonid fishes, where we begin to achieve parity is in our ability to test new fishway designs under laboratory conditions.

### CONCLUSIONS AND NEXT STEPS

This opportunity allowed me to interact with leaders in the field, and to present our own research results on nonsalmonid fish passage. We've now forged new, strong collaborations and friendships, and established intercontinental lines of communication that should prove fruitful as we strive to improve the conservation and management of global freshwater fisheries. We are now working on details for hosting Dr. Matthew Gordos at CSU this winter.



*Sunset on the Murrumbidgee River, a native fish stronghold. Photo courtesy of Christopher Myrick*

## EFFECTS OF FOREST DISTURBANCE ON STREAMFLOW IN COLORADO

Abby Eurich, Tony Vorster, Paul Evangelista, Stephanie Kampf, & Brian Woodward, Colorado State University  
John Hammond, United States Geological Survey

Wildfires and bark beetle outbreaks alter the structure of forests, changing snow and vegetation patterns over large mountain landscapes and potentially influencing the timing and magnitude of streamflow in affected watersheds. Our team of forest ecologists and hydrologists set out to quantify the impact of forest changes on streamflow across Colorado.

Previous work has found mixed conclusions regarding the impacts of forest disturbance on streamflow. The effects can differ based on topography, climate, severity of the impact, precipitation in a given year, and whether the precipitation falls as snow or rain (Creeden et al, 2014; Biederman et al, 2015). To try to quantify these effects, we generated forest disturbance maps delineating severity and timing of bark beetle outbreaks (2001-2013), and summarized wildfire data (Monitoring Trends in Burn Severity, 1984-2015). For watersheds that have stream gages with complete annual records for the years of disturbance data (US Geologic Survey, Colorado Division of Water Resources), we analyzed the relationship between streamflow anomalies and disturbance type and severity, while controlling for climatic influences on streamflow.

### MAPPING & FINDINGS

We utilized Landsat 5 imagery to map lodgepole pine mortality from 2001 to 2013 across Colorado, Wyoming, Montana, and Idaho. We then merged these maps with the Aerial Detection Surveys to characterize the timing and cause of mortality at each mapped pixel.

We found that across these four states, Colorado had some of the most widespread and severe lodgepole pine mortality. These improved tree mortality maps present an opportunity to better investigate linkages between bark beetle outbreaks and streamflow.

Significant differences pre- and post- disturbance were found for some sites, showing both an increase and decrease in streamflow. Precipitation is a strong driver of annual streamflow variability. On a plot of annual streamflow vs. precipitation, if the streamflow

tends to plot higher in the years after disturbance than the years prior to disturbance, this indicates an effect of the disturbance causing streamflow to be higher, relative to the expected variation with precipitation. For fires, all watersheds with at least 15% of the area burned exhibited a significant change in total annual streamflow. So far, we have not found a similar threshold in the effect of beetle mortality. Fewer watersheds had significant streamflow response to beetle mortality than wildfire disturbance. This is likely because when trees die from beetle attack, they remain in-situ, and the surrounding vegetation is not impacted, sometimes even thriving with more resources and additional water available.

### CONTINUED RESEARCH

The site-specific nature of streamflow response to forest disturbance leaves questions about the main controls on streamflow response, and whether it can anticipate responses to future disturbance events.

We are continuing to explore these questions, and hope to understand why some watersheds respond differently from others — as well as whether there are clear predictive characteristics for their response.

Understanding how disturbance events in increasingly-stressed headwater ecosystems impact water supply is vital to land and water managers across Colorado. Continuation of this work will help to identify the most likely impacts to streamflow in these valuable and vulnerable landscapes.



*Bark Beetle impacts on Lodgepole Pine trees along the Onahu Creek trail. Photo courtesy of the National Park Service*





## THE HYDRO-SOCIAL CYCLE OF AN EXTREME CITY: TIJUANA, MEXICO

Ned Molder & Melinda Laituri, Colorado State University

According to the UN World Water Development Report (2018), by 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of freshwater and cities are growing by 60 million people each year.

Within this context, we examine extreme cities — urban environments on the bleeding edge of climate change, socio-economic inequality, and with limited access to basic resources. Using the hydro-social cycle, we study an extreme city, Tijuana, Mexico, located on the US-Mexico border. The hydro-social cycle is a framework to examine water from a holistic perspective. It is diagrammed to assess the existing water resource availability, the current water policy for water management, and the city context for demand and need. Extreme cities are characterized by stark inequality in residents' access to resources, as well as spatial differentiation by race, class, gender, and exposure to environmental harms. Extreme cities result from rapid population growth coupled with unplanned urban development and inadequate public infrastructure to serve marginal communities.

### WATER POLICY IN TIJUANA

Tijuana has a semi-arid climate with most of its approximately 9 inches of rain per year falling during the winter months. As a result, most of Tijuana's freshwater resources come from the Colorado River, through a network of canals and pipelines. Water allocation in cities such as Tijuana is managed by national and state policies. As a result, the local water issues associated with rapid growth in Tijuana are not accounted for in broader government water policies.

### METHODS

We utilized several data sources to diagram the hydro-

social cycle of domestic water distribution in Tijuana, and to seek answers to questions like:

- How is water distributed in Tijuana?
- How can the hydro-social cycle illuminate inequalities in water distribution?
- Where are the data gaps in water distribution, and how can these be filled to increase equitable water distribution?

### CONCLUSION

The results of this hydro-social analysis demonstrate both a lack of infrastructure data, and the ease with which residents not formally recognized by Tijuana's land tenure system are hidden from view in official water management plans.

Comisión Estatal de Servicios Públicos de Tijuana's (CESPT) management plan calls for 100% of residents to have access to water in the next few years. However, without accounting for recent population influx and regular displacement of uprooted individuals and families, this goal is unlikely to be met. Following this initial study, we recommend the following actions to improve water access to Tijuana's most vulnerable populations:

- Improve public data availability for water delivery infrastructure
- Expand public water delivery infrastructure to informal settlements
- Regulate CESPT reseller market to minimize cost increase to customers
- Facilitate the transition of informal settlements to formal land ownership
- Without significant reconsideration of the social, technological, and biophysical components of Tijuana's water system in a dialectical relationship, existing inequalities will remain

## WHO CHANGES THE RAIN?

Pat Keys, Kathy Galvin, & Randy Boone, Colorado State University

*"I DON'T ONLY LOOK AT WATER AS AN ACCESS ISSUE. I THINK IT'S REALLY IMPORTANT TO LOOK AT WHO'S MANAGING THE WATER AND WHO IS GETTING ACCESS, AND ENVIRONMENTAL JUSTICE ISSUES AROUND THAT. I THINK IT'S A HUGE TOPIC RIGHT NOW."*

*Dr. Colleen Vogel, Keynote Speaker at Water in Africa Symposium, 2019*

During 2018-2019, the Water Research Team (WRT) for "Who changes the rain?" developed new research directions, aimed to secure external funding, and hosted a symposium on Water in Africa. A key goal was to develop a new, interdisciplinary CSU-based team of scientists who would explore the coupled dynamics of how changes to landscapes (e.g. deforestation) can modify the atmospheric water cycle, and subsequently impact subsistence communities downwind.

The primary research question of this WRT was: What are the potential consequences that could result by achieving certain Sustainable Development Goals (SDGs) in Kenya? In this case, we were focused on SDG #15, regarding sustainability of "Life on Land" — and more specifically, whether changes to forest cover in Kenya might lead to unexpected changes in the atmospheric water cycle, including how much rain falls on both agricultural and rangelands, elsewhere in Kenya.

### WE EXPLORED:

- The social dynamics of how communities respond to changes in rainfall, and how drought can be understood from both satellite- and on-the-ground perspectives.
- Moisture recycling for all locations in Kenya.
- In addition, NASA selected a proposal from our team, to receive a three-year grant that will fund more detailed research. With this funding, we will be able to have further dialogue with stakeholders in Kenya, to co-develop land-use change scenarios and advance the modeling with remotely-sensed satellite data.

### SYMPOSIUM

In conjunction with funding from other CSU groups, we also hosted a 3-day symposium on the CSU

campus to highlight international keynote speakers, panel discussions, and more. Among the speakers was Ms. Munira Anyonge-Bashir, the Country Director for The Nature Conservancy. She was honored as the Dr. Norm Evans speaker for 2019, and presented on the ongoing water and sustainability work that The Nature Conservancy is conducting within Kenya. Ms. Anyonge-Bashir has been a key partner in the WRT's continuing NASA work, and is integral to facilitating the in-country workshops that will situate the research with local, stakeholder-driven priorities and concerns.

### NEXT STEPS

#### WE'RE NOW WORKING ON:

- Summarizing and disseminating the WRT's content, including insights from the Water in Africa symposium
- Continuing the coupled modeling work under the NASA grant
- Forging relationships between CSU and international partners, to advance the core focus of this WRT related to Sustainable Development Goal achievement





Munira Anyonge-Bashir, invited Keynote speaker at the Water in Africa Symposium and recipient of the Dr. Norm Evans Distinguished Speaker award, shares her experiences as the Kenya Country Director for The Nature Conservancy. Photo by Patrick Keys



Graphic recording of the Water in Africa Symposium panel on 'Water, Land, and Conservation'. Three such panels were produced and are available on the Africa Center website ([africacenter.colostate.edu/water-symposium](http://africacenter.colostate.edu/water-symposium)). Graphic by Heartwood Visuals.

# STAFF UPDATES

## COLORADO WATER CENTER IGNITING DIALOGUE FOR A NORTHERN COLORADO REGIONAL WATER VISION

*MaryLou Smith, Policy and Collaboration Specialist, Colorado Water Center*  
*Julie Kallenberger, Water Education Specialist, Colorado Water Center*

Water supplies in the Poudre and Thompson basins of Northern Colorado are under intense pressure as the region's population skyrockets. Our policy dialogue the past several years with regional agricultural, urban and environmental stakeholders has convinced us that without a clear vision about our water future, and leadership at high levels, we will not be able to sustain the desirable quality of life we presently experience.

### DEVELOP A NETWORK OF KEY LEADERS TO CRAFT AN ACTIONABLE STRATEGIC VISION FOR NORTHERN COLORADO WATER

Water Literate Leaders of Northern Colorado, now in its third year, is our effort to raise the level of dialogue about water to the top decision makers in the region. Dialogue starts with understanding, so key community leaders are offered a nine month course to become immersed in all things



*From left: Patrick McMeekin, Julie Pignataro, Kelly DiMartino, Ken Bennett, Corey Odell, Myles Baker, Nick Haws, Stacey Baumgarn, Jane Lopez, Mike Pruznick, and Ed Cannon. Not pictured: Jim Becklenberg, Sean Dougherty, Grant Houx, Jacki Marsh, Billy Mihelich, David Sislowski, and Manuel Sisneros.*

*Photo Courtesy of Ashley Marie Images*



water—water law and administration, domestic water providers and agricultural water users, business, recreation and environmental water concerns, economic growth, and water challenges and opportunities. Each class is made up of 20-24 members, which allows for exchange of ideas and diversity of views in a relationship rich environment. Class members are confronted with the need for tradeoffs if we are to continue providing for irrigated agriculture, open spaces and community buffers, high quality and affordable municipal water supplies, flat water and instream recreational opportunities, and the overall health of our rivers and ecosystems.

City and town managers, local councilmembers, mayors, influential business and real estate leaders, community activists and others in decision making positions populate the class.

### *Who are the* **WATER LITERATE LEADERS?**

A colloquium of current and emerging leaders from Northern Colorado's communities actively learning about Northern Colorado water from all angles including: agriculture, urban, environmental, recreation, and business via presentations, dialogue and field trips.

Congratulations to our 2018-19  
Graduates (pictured left)!

Learn more at  
[\*\*watercenter.colostate.edu/wll\*\*](http://watercenter.colostate.edu/wll)

### **CLASS MEMBER STATEMENTS**

*“Seeing the various people in the room each representing different interests made me wonder if there is a role for me in helping bring those interests together toward beneficial regional outcomes”*

*“Water is such a complex topic. I was relieved that this course came along just as I was elected to city council.”*

*“I am very interested in the creation of a regional water vision—to help Northern Colorado reach its potential.”*

### **FUELING A REGIONAL DIALOGUE**

Out of the first class of Water Literate Leaders, a regional dialogue has begun to coalesce. A few key players who are passionate about the need are exploring the potential for such efforts as connected water facilities, ag/municipal water partnerships for economic development, and common sustainable municipal landscape development code. One key leader said “A collaborative, cooperative and productive regional water dialogue would be very advantageous to the region and would contribute to a better future by maximizing use of available water resources. Sounds like it may be an interesting conversation. I look forward to it!”

Other notable collaborative efforts this past year include a successful year of convening the Poudre Runs Through It Study/Action Work Group and its annual Poudre River Forum, which attracted more than 325 citizens, water managers, and water professionals from around the basin. It was also another successful year for the CSU Water Sustainability Fellows Program for historically underrepresented students learning about water and working with north Denver high school students in a National Western Center Youth Water Project culminating in a water expo attracting 150 people to Argo Park in Globeville.

## SOUTHERN COLORADO

*Blake Osborn, Regional Water & Extension Specialist, Colorado Water Center & CSU Extension*

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### INTRODUCTION

The Colorado Water Center serves the state's Arkansas and Rio Grande river basins by working with local water users and water managers to develop new applied research projects, and to facilitate dialogue between the University and water users/managers. The CoWC interacts with many water professionals in the areas of environmental, agricultural, municipal, and recreational water use and management. Our science-based work provides these interested parties with information they need to manage water resources more efficiently and/or more economically.

### ACCOMPLISHMENTS IN 2018/19

#### LOWER ARKANSAS RIVER WATERSHED PLAN

The Lower Arkansas River Watershed Plan is now complete. We now begin the task of implementing the plan, which depends on local entities like the

conservation districts and NRCS, to help implement various aspects. The plan lays out actionable recommendations to change land management strategies into more water-quality-friendly Best Management Practices; lists possible funding assistance for these programs and technologies; and estimates the water quality benefits of implementing these practices at the watershed scale.

#### RIVERLAB

I am working to build RiverLAB, a research-based field laboratory intended to bring academic research of river restoration and fluvial processes to a semi-controlled environmental setting along the Arkansas River in Canon City, CO.

Institutions and universities (like CSU or the Bureau of Reclamation) want to create a new space at the intersection of these two ideas. RiverLAB is working with local stakeholders along the Arkansas River to create a dedicated river reach for outdoor experiments to be performed under "real-world" conditions. RiverLAB will be dedicated to academic research, but will also serve as an educational/outreach opportunity to bring more awareness to the field of river science and water management.



*Photo by Blake Osborn*



*THINKWATER FELLOWSHIP*

In 2017, I was awarded a national USDA ThinkWater Fellowship to learn and apply the principles of systems thinking to my work. This proved to be incredibly valuable, and this past year I applied — in cooperation with Water Education Colorado — to transition the fellowship into a new, federally funded program to train others in systems thinking. This program allowed us to advance our training in systems thinking and to apply the concept to the forthcoming Statewide Water Education Action Plan (SWEAP).

*UPPER ARKANSAS WATER BALANCE STUDY*

The Upper Arkansas Water Balance Study: Phase 2 is a collaboration between the Colorado Water Center, USGS, and the Upper Arkansas Water Conservancy District to better understand agricultural water use and the potential for irrigation scheduling in the upper Arkansas River valley. This project is now in year three and will be completed by spring of 2020.

## ONGOING IMPACTS OF CLIMATE CHANGE

*Brad Udall, Senior Water and Climate Research Scientist / Scholar, Colorado Water Center*

**INTRODUCTION**

My work at the Colorado Water Center continues to focus on the effects of climate change on the water resources of Colorado, and especially the Colorado River Basin. I have also worked on the impacts of climate change and adaptation options for agriculture through CSU's Climate Smart Agriculture initiative.

**CLIMATE SMART AGRICULTURE**

I finished developing three online courses for CSU's Climate Smart Agriculture effort: one on impacts and adaptation options for ag producers, and two on climate change myths. In February, I presented in Monte Vista at the Southern Rocky Mountain Ag Conference on Climate Smart Agriculture in general, and on CSU's efforts in this area.

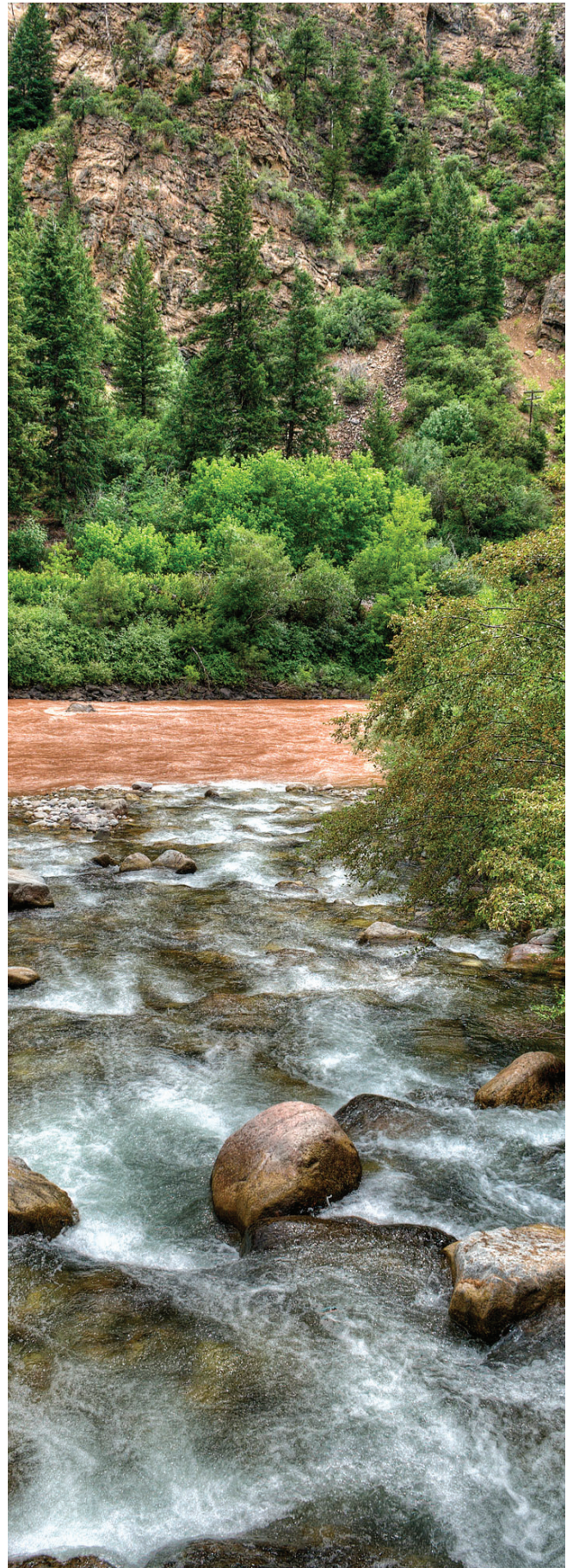


Photo by Flickr User D. Johnson

## COLORADO RIVER

In the last two years, I have published two peer-reviewed articles that have investigated how and why high temperatures are reducing the flows of the Colorado River (Udall and Overpeck, 2017 and Xiao, Udall and Lettenmaier, 2018). I continue to be involved in efforts to further explain why, where, and how this is occurring, and to disseminate this knowledge.

In February 2019, I testified in front of the US House Committee on Natural Resources subcommittee on Water, Oceans, and Wildlife regarding the ongoing impacts of climate change on the Colorado River Basin, the Drought Contingency Plan, and the upcoming renegotiations of the existing management guidelines. Along with colleagues from other western academic institutions, I assisted with publishing three publications on Colorado River water issues: one on tribal water rights, one on water risk in the basin, and one on why Lake Powell has been so low in recent years.

Additionally, I wrote a book chapter on climate change and water management in the American Southwest, and co-authored an article about the history and reliability of Reclamation's Colorado River natural flows (i.e. river flows unimpaired by human activities).

I have been working with scientists at Utah State University to investigate alternative management paradigms for the Colorado River. I have also been engaged with a broad group of stakeholders, organized by the University of Arizona, to investigate scenarios that might inform the renegotiations for the

Colorado River Interim Guidelines that are scheduled to begin in 2020.

I attended a number of scientific conferences — including one on flash drought, and the continuing efforts to understand how climate change is impacting the Colorado River Basin.

## OTHER EFFORTS

I assisted with Water Education Colorado's Spring 2019 Headwaters newsletter about the impacts of climate change on water supplies in Colorado. I presented a keynote address at the American Water Works Association annual meeting regarding the water-related results of the 2018 National Climate Assessment (which I previously co-authored).

At Colorado Mesa University, I presented a keynote address regarding the aridification of the American Southwest. I also presented at California's Irrigation Association, and at the Nevada Water Resource Association on climate change and the Colorado River.



## NORTHEASTERN COLORADO

*Joel Schneekloth, Regional Water Specialist, Colorado Water Center & CSU Extension*

Drought is always a risk in Colorado, with potential water limitations due to reduced snowpack as well as low precipitation during growing season. Combine this with issues of declining water levels in the Ogallala Aquifer region, plus the declining capacities for management strategies to maximize the economic return of water, and the risk becomes even greater. Another increasing issue for competition of water is urban growth in the Front Range of Colorado.

## WHAT CAN BE DONE

Management practices to enhance moisture

conservation and decrease irrigation needs will have an economic impact, thanks to reduced energy consumption during most growing seasons. This, in turn, has positive environmental effects by reducing pollutants. We've been researching:

## RESIDUE AND TILLAGE MANAGEMENT

Harvest of residue, or full tillage management, helps to improve the retention of residues on the soil surface, thereby increasing precipitation storage efficiency, and reducing evaporative losses. Additionally, tests involving leaving the residue in the field during the winter resulted





Cover crops emerging within the tillage/residue management study. Photo by Joel Schneekloth

in approximately two inches greater soil water storage, as compared to bare or harvested residue. Meanwhile, elimination of tillage prior to planting resulted in one inch less evaporation losses during the vegetative growth stage. This method of conservation can reduce irrigation needs, and could help preserve water supplies in the declining Ogallala Aquifer.

#### SOIL HEALTH

This issue is of increasing interest, due to its potential for either increasing yields or achieving water conservation. However, there is confusion on what soil health is, and its implications on water conservation. Our long-term tillage/residue management project involves integration of cover crops and soil amendments, to better understand the effects of water, yields, and soil quality. We are also studying the potential for residue (from either corn stalks or cover crops) to reduce weeds during the early growing season.

#### ENERGY CONSERVATION

In cooperation with the University of Nebraska, Kansas State University, and Electrical Power Research Institute, we are developing webinars and tools that will allow producers to conserve energy in irrigated agriculture, across the Tri-State region of the High Plains. Webinars were also developed to promote minimizing water and energy use through better irrigation management and irrigation pumping plant performance.

#### *COLORADO FARM SHOW*

We developed a one-day seminar on water issues specific to Northeast Colorado, with emphasis on conservation and water availability in the South Platte Basin.

#### *UNL TAPS PROGRAM/NORTHEAST JUNIOR COLLEGE*

The University of Nebraska Testing Ag Performance Solutions (UNL TAPS) program is an on-site, team competition on irrigated corn management and marketing. I helped advise a team from NJC on irrigation and nutrient management strategies, which they applied during the 2019 growing season.

#### *CENTRAL PLAINS IRRIGATION SHORT COURSE*

I have continued to work on developing the agenda for an irrigation education program, in conjunction with Kansas State University, the University of Nebraska, and the irrigation industry. Our goal is to improve

irrigation efficiency and economics within the Ogallala Aquifer regions of these three states.

#### *MASTER IRRIGATOR PROGRAM*

The groundwater management districts within the Republican basin have begun work on developing a four-day Master Irrigator Program for the region. University and industry representatives, along with producers, will come together to discuss and learn about irrigation and farm management strategies to conserve water, and minimize pumping, within the Ogallala Aquifer of Colorado.

#### *VIDEOS*

With the help of a summer intern, we spent five days filming producers in the Ogallala Aquifer region. Videos are currently being edited for release to the Ogallala CAP website to allow others to learn about management practices that promote effective use of water supplies.

## WESTERN COLORADO

*Perry Cabot, Research Scientist and Extension Specialist, Colorado Water Center & CSU Extension*

### INTRODUCTION

The Western Region of the Colorado Water Center serves the Colorado, Gunnison, Yampa/White and San Juan/Dolores basins, which deliver the majority of the water from or within the state. Water resources and irrigation research in the Western Region are dedicated to the optimal use of water in an area affected by competing agricultural, municipal, and industrial needs, as well as drought and climate variability, and shifting market demands.

### PURPOSE

Agriculture and food production is undergoing rapid change in Western Colorado. Over the next few decades, these changes will become irreversible, due to the confluence of population growth, water shortages, and climate change. With the majority of Colorado water rights held in agriculture, the food production sector faces challenges to increase the conservation and efficiency of water use in multiple ways.

### RESULTS

In partnership with CSU Extension and the CSU Agricultural Experiment Station, the Colorado



*Evaluating irrigation on different tillage regimes for furrow-irrigated corn in Fruita, Colorado. Photo by Perry Cabot*



Water Center has been working on evaluation, demonstration, and deployment of water-optimizing practices and technologies.

#### *SUB-SURFACE DRIP IRRIGATION SYSTEM*

The first phase of construction on a 5.5 ac research-level subsurface drip irrigation system was completed at the WCRC, including a primary control system, pumping and piping infrastructure, filtration and water delivery to 22 research plots. At full build-out, this system will allow for separate control and flow monitoring of 66 plots. The sub-surface driptape allows the plots to be managed using no-tillage and minimum-tillage practices. Currently, 16 plots are dedicated to research on the viability of interspersing grass varieties with alfalfa. Additional plots will be devoted to hemp research.

#### *AUTOMATED CHECK-STRUCTURE SYSTEM*

In partnership with Watch Technologies, two automated check structures were added to alfalfa fields at the WCRC. These devices communicate between canal check structures and in-field soil moisture levels to control water delivery. The affordable control system allows for

field tailwater to be significantly reduced by stopping the irrigation once optimal watering has occurred.

#### *CONSERVED CONSUMPTIVE USE EVALUATIONS*

Improved measurement and verification of consumptive use (CU) could reduce costs of monitoring and increase reliability of water-sharing programs. Research continued this year in both the Grand Valley and Upper Gunnison Region to evaluate CU on alfalfa and grass hayfields. We are comparing rates of water consumption based on field soil moisture monitoring, versus radiometric approaches with both the hand-held and satellite spectral signatures to provide more accurate, and near real-time conditions.

#### *COLLABORATION WITH WESTERN REGION AND TRI-RIVER AREA EXTENSION*

A strong collaboration exists between the Colorado Water Center and CSU Extension on the Western Slope. Efforts in this past year have been focused on:

- maintaining a Plant Select® landscape demonstration of varying irrigation rates
- demonstration of the viability and aesthetics of low-water-use turf
- a study of sweet corn quality based on irrigation

patterns, which provided farmers with input on optimal irrigation timing to improve sweetness of their crop

#### **IMPACT**

The CoWC program at WCRC-Fruita works with agricultural producers, industry partners, conservation and conservancy districts, interest groups, and other academic institutions. Engagement under this program supports the creation, evaluation, demonstration, and deployment of technologies that improve agricultural irrigation and water resources management.



*GRAD592*

## Colorado Water Center



# COLORADO WATER >>> CoWC's Bi-Monthly Newsletter

For an archive of newsletters, please visit [watercenter.colostate.edu/colorado-water-archive/](http://watercenter.colostate.edu/colorado-water-archive/)

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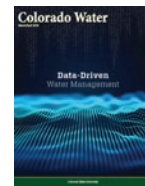
**V35, I4** Jul/Aug 2018  
Recreation & Tourism

**V35, I5** Sep/Oct 2018  
CSU Water Center Projects

**V35, I6** Nov/Dec 2018  
Irrigation Innovation Technology

**V36, I1** Jan/Feb 2019  
Environmental Justice

**V36, I2** Mar/Apr 2019  
Data-Driven Water Management



## PUBLISHED REPORTS

For an archive of publications, please visit [watercenter.colostate.edu/publications/](http://watercenter.colostate.edu/publications/)

Special Report 33

### **A Review of Floodplains and Flood-Induced Changes in Floodplain Form and Function**

By Ellen Wohl

Completion Report 238

### **River Adjustment and Flood Hazards on the Colorado Front Range**

By Joel Sholtes & Brian Bledsoe

Completion Report 237

### **Mountain Basin Hydrologic Study**

By Douglas D. Woolridge & Jeffrey D. Niemann

Completion Report 236

### **Bark Beetle Impacts on Remotely Sensed Evapotranspiration in the Colorado Rocky Mountains**

By John F. Knowles & Noah P. Molotch

Completion Report 235

### **Hydrologic and Water Quality Collection for Colorado's Upper Arkansas River Basin**

By Timothy K. Gates

Completion Report 233

### **Snow Depth Measurement via Time Lapse Photography and Automated Image Recognition**

By Kevin S.J. Brown & Steven Fassnacht



Photo by Chelsey Heiden

## MARISSA KARPACK

**Upper Yampa Water Conservancy District  
John Fetcher Scholarship 2018-2019 Recipient**

*By Melissa Mokry*

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

While at CSU, Karpack has been a graduate teaching assistant for undergraduate civil engineering courses. She was the 2017-2018 Walter Scott, Jr. Graduate Fellow and plans on pursuing a career in river engineering. More specifically, Karpack hopes to pursue hydraulic engineering, incorporating 2D and 3D numerical river modeling. Karpack has previously worked for Engineers Without Borders at CSU as a design engineer and as the International Projects Director during her undergraduate time at the University of Washington. The ultimate goal of her education and work experience is to develop effective long-term solutions to river and floodplain issues.

### RECIPIENT INFORMATION

**University**

Colorado  
State University

**Area of Interest**

Hydrology and hydraulics,  
emphasis on river and  
floodplain processes

**Major**

Masters of Science in  
Civil & Environmental  
Engineering

**Graduated**

May 2019

## 2018 SUBSURFACE WATER STORAGE SYMPOSIUM

Dating back to the mid-1800s, settlers in Colorado and the western US advanced visionary projects and legal frameworks that created sustainable water supplies for municipalities, agriculture, and industry. Today, settlers continue to arrive in Colorado, the diversity of our water needs has grown, and the need for visionary initiatives facilitating sustainable water supplies is as strong as ever. Following the Colorado Water Plan, solutions to water challenges will come in many forms.

In November of 2018, the Subsurface Water Storage Symposium brought water leaders together to identify challenges, share knowledge, and build collaborations that will enable the full potential of subsurface water storage. Participants explored water challenges confronting the western U.S., legal issues, and legislative support for the advancement of water storage initiatives. Technical aspects of subsurface water storage were also addressed, including new tools and knowledge for evaluating subsurface water storage projects and the status of a rapidly growing list of subsurface water storage projects in Colorado and the western U.S.



Photo by Catie Boehmer



# THE DR. NORM EVANS ENDOWMENT

## WATER IN AFRICA SYMPOSIUM: INNOVATION & CHALLENGES

The keynote for the 2019 Dr. Norm Evans Distinguished Lecture was Munira Anyonge. Anyonge is a wildlife conservation manager, community enterprise development specialist and a tourism development expert with over 20 years professional experience. She is skilled in project management, community mobilization and awareness creation, policy development and analysis, strategic planning and implementation. Her breadth of professional experience includes careers as a Tourism officer with the government of Kenya; Executive Assistant and Public Relations officer at the National Museums of Kenya; Community Development Specialist and USAID program Manager with Kenya Wildlife Service for over 10-years; She was among lead persons for the development of wildlife policy and legislation; Champion for Strategic plan development at Kenya Wildlife Service and the Head of the Community Enterprise development program at Kenya Wildlife Service. Munira is a highly recognized individual in the wildlife sector in Kenya. An accomplished manager, a facilitator of successful community wildlife development initiatives, including the Kenya Wildlife Conservancies Association (KWCA). Munira

is a passionate wildlife conservationist with several successful achievements including the Head of State Commendation (HSC) for her work in championing community benefits from wildlife conservation. She is fluent in English and Swahili.

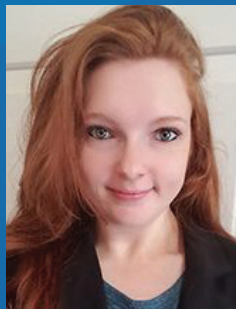
Munira has a Master of Business Administration (MBA), Tourism Development; BA in Business Studies; Professional skills in Protected Area Management-University of Montana, Missoula, USA, (2005); and Community Based Natural Resource-Management Rhodes University, South Africa, 2002.

More information on the Dr. Norm Evans Endowment and Munira's keynote address from this symposium are available to view online along with additional keynote addresses by Coleen Vogel and Line Gordon at [watercenter.colostate.edu/evans/](http://watercenter.colostate.edu/evans/)

Photo by Catie Boehmer



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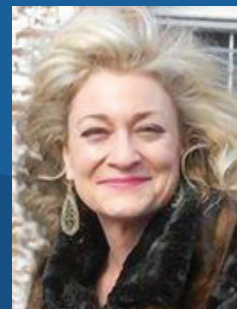
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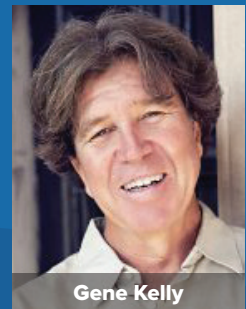
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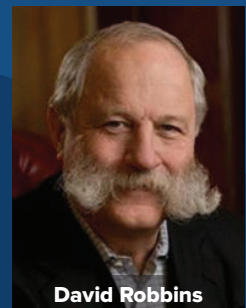
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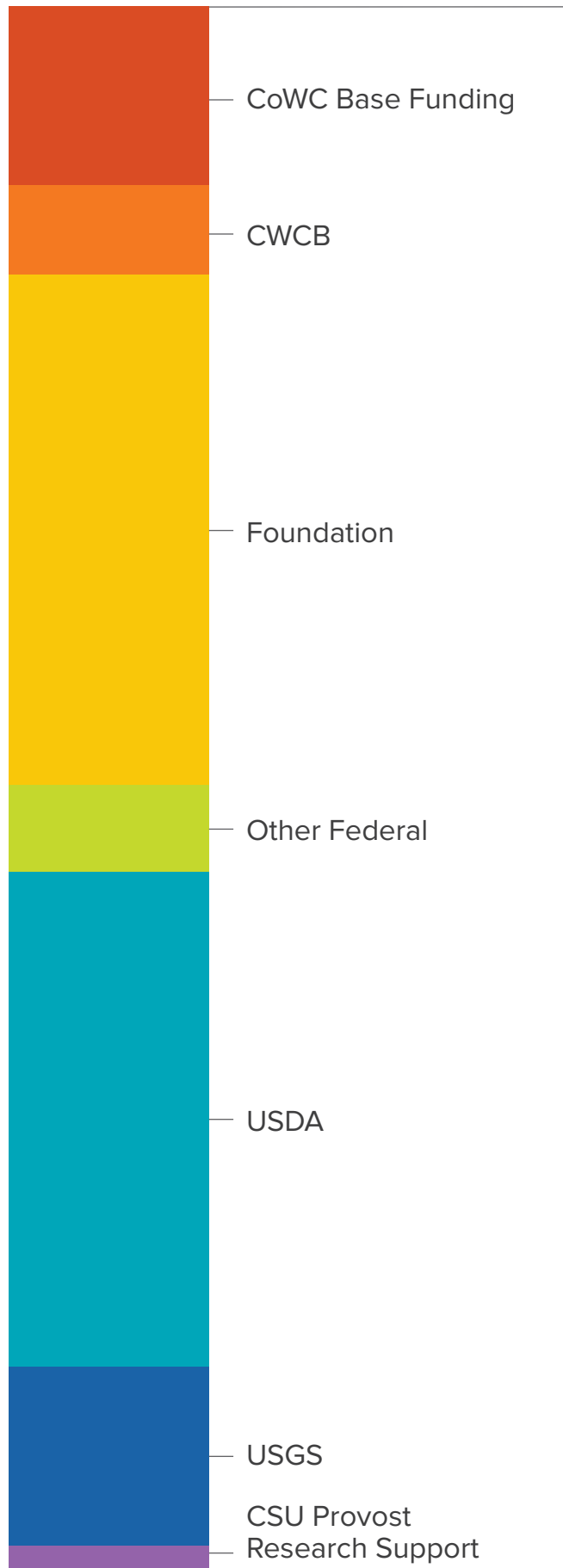
# FINANCIAL SUMMARY

Reporting Period: July 1, 2018 - June 30, 2019

In prior reports, this summary spanned multiple CSU Fiscal Years.

The reporting period has been updated to match CSU fiscal years, beginning this year with CSU FY19.





## SUMMARY BREAKDOWN

**CoWC Base Funding    \$ 661,972**

### CoWC RESEARCH FUNDING SOURCES

CWCB	\$ 342,044
Foundation	\$ 2,274,574
Other Federal	\$ 319,289
USDA	\$ 1,852,606
USGS	\$ 626,338
CSU Provost Research Support	* \$ 120,862
<b>Total</b>	<b>** \$ 5,535,713</b>

## ACTIVE PROJECT TYPE

Research	24
Education	2
Outreach	2
Internships	1
Training	9
<b>Total</b>	<b>38</b>

## STUDENT DEGREE LEVEL ON PROJECTS

Undergraduate	16
Masters	10
Ph.D.	13
<b>Total</b>	<b>39</b>

\* CSU Provost Research Support of \$120,862 is included in FY 19 CoWC Base Funding of \$661,972

\*\* Multiple research projects being conducted during a multi-year timeframe can cause overlap in funding.



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