



Proceedings

for

Scientific Impacts on a Historic Landscape

American Water Resources Association Montana Section 2020 Conference

Butte, Montana

October 5 - October 9, 2020

Virtual Presentations and Discussions

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Thanks to Planners and Sponsors

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*These abstracts were not edited and appear as submitted by the author, except for some changes in font and format.

THANKS TO ALL WHO MAKE THIS EVENT POSSIBLE!

The AWRA Officers

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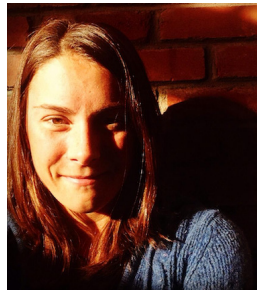
Montana Water Center

Wyatt Cross, Director, and Whitney Lonsdale, Assistant Director

And especially the conference presenters, student judges and volunteers.



Kim Snodgrass



Hannah Riedl



Jacqueline Knutson



Nancy Hystad

The Montana Section of the American Water Resources Association would like to thank our sponsors



MONDAY, OCTOBER 5, 2020

- 1:30 pm **WELCOME and ORIENTATION** to virtual meeting platform, MT AWRA Board
- 1:45 **TRAINING SESSION: Groundwater Information Center (GWIC)**, Luke Buckley, Montana Bureau of Mines and Geology
- 2:45 *Break/Networking*
- 2:50 **TRAINING SESSION: Accessing Surface Water Data**, Hannah Riedl, Montana Department of Environmental Quality (DEQ)
- 3:50 *Break/Networking*
- 4:00 **PANEL DISCUSSION: Workforce Development for University Students**, Moderator: Melissa Schaar, Montana Department of Natural Resources and Conservation; David Donohue, HydroSolutions; Madeline Gotkowitz, Montana Bureau of Mines and Geology; Nathan Korb, The Nature Conservancy; Laura Rennick, Montana Department of Natural Resources and Conservation; Joanna Thamke, MT-WY Science Center, U.S. Geological Survey
- 5:00 *Close of Monday session*

TUESDAY, OCTOBER 6, 2020

- 1:30 pm **WELCOME** with Introductions, Logistics, & Announcements - MT AWRA Board
- 1:45 **A message from the Montana Water Center**, Wyatt Cross, Director
- 1:55 **Legislative Update** - Jason Mohr, Research Analyst
- 2:15 **Scientific Impacts on a Historic Landscape**, Opening remarks, Kim Snodgrass, AWRA President
- 2:25 **The Urban Settlement and Development of Butte**, Julia Crain, Butte-Silver Bow Superfund: Special Projects Planner
- 2:45 *Break/Networking*
- 2:50 **Getting a Grip on Butte Groundwater Issues**, Nick Tucci, Haley & Aldrich, Senior Technical Specialist/Geochemist
- 3:35 **The Berkeley Pit lake may NOT be too big to fix!** Dr. Chris Gammons, Montana Technical University, Geological Engineering Department
- 4:20 **Q&A - Panel discussion** with Julia Crain, Nick Tucci, and Dr. Chris Gammons
- 5:00 *Close of Tuesday session*

WEDNESDAY, OCTOBER 7, 2020

- 1:00 pm **WELCOME** - start of the third day of virtual conference!
- 1:05 **A Brief History of Silver Bow Creek, Butte Mining and the Evolution of the Butte Water Company**, Pat Cunneen, Butte-Silver Bow Senior Operations Engineer
- 1:45 **Silver Bow Creek: 100 years as a copper mine — Can it be restored?** Joe Griffin, Hydrogeologist, Retired DEQ Manager
- 2:25 *Break/Networking*
- 2:35 **Silver Bow Creek Fisheries, Past Present,& Future**, Casey Hackathorn, Trout Unlimited, and Caleb Uerling, MT FWP Fisheries Biologist
- 3:35 **Managing Historic Mining Contamination in an Urban Environment**, Josh Bryson, Atlantic Richfield Liability Manager
- 4:05 **Q&A - Panel discussion** with Pat Cunneen, Joe Griffin, Casey Hackathorn, Caleb Uerling, and Josh Bryson
- 5:00 *Close of Wednesday session*

**THURSDAY & FRIDAY CONCURRENT TECHNICAL SESSIONS
SCHEDULE BEGINS NEXT PAGE**

TECHNICAL SESSIONS: ORAL PRESENTATIONS (Blue text indicates student presenters)

SESSION 1 (Concurrent)
COLLABORATION

SESSION 2 (Concurrent)
GEOCHEMISTRY

2:00 pm **Christine Sundnas.** Gallatin County Interactive Water Quality Mapper Demo.

2:00 pm **Kaitlin Perkins.** Characterizing Mine Waste Colloids in the Upper Clark Fork River to Better Understand Potential Exposure.

2:20 **Marco Maneta.** Hydro-economic Impacts of Agricultural Adaptation to Increasing Climatic Aridity.

2:20 **Lonnie Von Oesen and Spruce Schoenemann.** Lake Reconnaissance for Determining Potential Lake Cores with Carbonate for Retrieving Climate Records.

2:40 **Natalie Poremba & Erin Sexton.** Caring for Waters Across Borders.

2:40 **Kori Mooney.** Isolating Authigenic Carbonate in Lake Sediment Cores to Improve Climatic Interpretations: A Method Development Project.

3:00 BREAK

3:00 BREAK

HYDROLOGY

3:10 **Seth Siefkin.** Dams, Diversions, and Deliveries – Handling Streamflow Regulation in Flood Frequency.

3:10 **Curt Coover.** Parrot Tailings or Local Sources of Contamination to Silver Bow and Blacktail Creeks in Butte, Montana: Lines of Evidence.

GROUNDWATER

3:30 **Megan Conley.** Developing Small-Scale Denil Fishways for use in Headwater Streams.

3:30 **Gopal Krishan.** Aquifer Salinization in Punjab, Indian.

3:50 **Kathy Chase.** From Kalispell to Ekalaka: U.S. Geological Survey Flood-Related Work in Montana.

3:50 **Andrew Bobst.** An Overview of the Virginia City Groundwater Investigation.

4:10 BREAK

4:10 BREAK

THURSDAY, OCTOBER 8, 2020 (continued)

TECHNICAL SESSIONS: ORAL PRESENTATIONS (continued)

SESSION 1 (Concurrent)

HYDROLOGY *(continued)*

4:20 **Dan Armstrong.** Using Particle Image Velocimetry During Flood Events to Measure Stream Velocity and Discharge.

4:40 **Todd Myse.** A Canal Story: Working with a Local Canal Company to Investigate Groundwater/Surface-water Interaction and Gains and Losses in Farmers Canal, Gallatin County.

SESSION 2 (Concurrent)

GROUNDWATER

4:20 *No speaker scheduled*

4:40 *No speaker scheduled*

FRIDAY, OCTOBER 9, 2020

SESSION 3 (Concurrent)

MODELING

2:00 **Zach Lauffenburger.** Application of a Satellite-Driven Hydro-economic Model to Assess Climate Change Impacts On Montana's Water Resources, Agricultural Production, and Farm Revenues.

2:20 **Patrick Wurster.** Monitoring Crop Status in the Northern Great Plains Using the SMAP Level 4 Carbon Products.

SESSION 4 (Concurrent)

MANAGEMENT & RESTORATION

2:00 **Robert Sain.** Restoration of Elbow Coulee, Tributary to the Sun River.

2:20 **Mace Mangold.** Warm Springs Creek Restoration.

WATER QUALITY

2:40 **Kent Whiting.** Changes in Surface Water Chemistry of Silver Bow and Blacktail Creeks under Different Flow Regimes, Butte Priority Soils Operable Unit, Butte, Montana

3:00 BREAK

2:40 **Bruce Anderson.** Montana Stream Permitting Guide

3:00 BREAK

SESSION 3 (Concurrent)

WATER QUALITY *(continued)*

3:10 **Torie Haraldson.** Program Focus: The Gallatin Local Water Quality District's Surface Water Monitoring Network

3:30 **Sara Eldridge.** Cyanobacterial Bloom Distribution, Toxicity, and Associated Water-quality Conditions in Bighorn Canyon National Recreation Area: A USGS-NPS Partnership.

3:50 **Rachel Malison.** Launching Monitoring Montana Waters (M2W); A Flathead Lake Biological Station Initiative to Increase Local Capacity for Watershed Monitoring.

4:10 **Announcements - New Officer, Student Awards, Henderson Award, and Next Year's Location**

SESSION 4 (Concurrent)

MANAGEMENT & RESTORATION *(continued)*

3:10 **Joe Griffin.** Groundwater Contamination in Butte, Montana, and its Effect on Silver Bow Creek – the Tail End of the Story.

3:30 **Chuck Dalby.** Historic Conversion from Flood to Sprinkler Irrigation in Montana.

3:50 **Wyatt Cross.** Evaluating Irrigation Efficiency: Towards a Sustainable Water Future for Montana.

4:10 **Please join Session 3 for closing plenary.**

MONDAY TRAINING SESSIONS

TRAINING SESSION: GROUND WATER INFORMATION CENTER (GWIC)

LUKE BUCKLEY, Associate Professor and Data Scientist, Montana Bureau of Mines and Geology and Montana Technological University

Since 1994, Luke has been in charge of designing, developing, and administrating the MBMG Data Center. The Data Center is comprised of 63 enterprise databases and more than 40 web applications, connecting users around the world to Montana's natural-resources data. In addition to degrees in Geological Engineering (ASE), Mathematics (BS), and Technical Communications (MS), he has been a Microsoft Certified Information Technology Professional in Database Administration since 2007.

ABSTRACT:

The MBMG Ground Water Information Center (GWIC) has experienced tremendous growth in the past 30 years and forms the nucleus of the MBMG Data Center. In the early 1990s, the available information was limited to downloads of water-well data on floppy disk. As GWIC evolved to serve more data online, other datasets followed. Today, MBMG through its Data Center makes more than just groundwater data available (e.g., groundwater, surface water, geologic maps, publications, mining, etc.) in a variety of ways (e.g., browser, phone, web service, GIS). I will provide a guided tour through several of the ways during this one-hour training session, and by the end, we should have a better understanding of how to obtain groundwater, surface water, and geologic data through the MBMG Data Center.

TRAINING SESSION: ACCESSING SURFACE WATER DATA

HANNAH RIEDL, Water Quality Specialist, Montana Department of Environmental Quality

Hannah Riedl is a Water Quality Specialist with the Department of Environmental Quality Nonpoint Source Program, a position she's enjoyed since 2017. She works with local organizations to fund and implement voluntary water quality improvement projects. She also coordinates the State Harmful Algal Bloom Program and is one of your Montana AWRA board members. She has a B.S. in Restoration Ecology from the University of Montana, and an M.S. in Ecology from Colorado State University.

ABSTRACT:

MISSING: Clean Water Information Act Center mapper. **REWARD:** all the surface water data you desire. Some of you scrupulous AWRA members may have noticed that a major component of the Clean Water Information Act Center has disappeared from DEQ's webpage. But has it really? The Clean Water Information Act Center still serves information about streams and lakes impaired by pollution in Montana. We will learn how to access these records and associated citations. We will also dive into the EPA's Water Quality Portal and learn how to compile approved water quality data collected by local, state, and federal partners. Finally, we will learn how to access that Clean Water Information Act Center mapper.

WORKFORCE DEVELOPMENT FOR UNIVERSITY STUDENTS

ABSTRACT:

The session will be a workforce development discussion about preparing University students in water related fields for employment in Montana. The panel will consist of science leads and hiring managers from state agencies, non-profits, and industry. The goal is to provide insight to students, professors, and university program leads on how students can be well-prepared and more competitive for employment after graduation. With a big turnover in state agencies and industry due to retirement, this session will provide a candid discussion between hiring managers, students and professors about knowledge, skills, and abilities that both meet employers' needs and support excellence across the hydrologic fields in Montana. Students will have the opportunity to address the panel on specific areas of interest.

Moderator: MELISSA SCHAAR, Hydro-science Manager and a Groundwater Hydrologist for the Montana Department of Natural Resources and Conservation

Melissa has twenty years of experience working in academia, private industry, and state government in the fields of hydrogeology, geochemistry, engineering, water quality, and policy. She holds a Bachelor's in Earth Science from Montana State University and a Master's in Geological Engineering from Montana Tech.

DAVID DONOHUE, Senior Hydrogeologist, HydroSolutions, Inc

David Donohue is a senior hydrogeologist and the Helena office manager with HydroSolutions Inc, a hydrology and environmental engineering consulting firm with offices in Helena and Billings, Montana. He is a Licensed Professional Geologist with over 30 years of experience in the fields of natural resource, environmental, and water resource management, mining, water rights, geology and hydrogeology. He has an M.S. degree in Earth Sciences-Hydrogeology from Montana State University and a B.A. degree in Geology from the University of Montana.

MADLINE GOTKOWITZ, Hydrogeologist/Research Division Chief, MT Bureau of Mines and Geology

Madeline Gotkowitz has served as Research Division Chief since 2018 and coordinates Bureau investigations of Montana's geological, mineral, and water resources, and serves as Technical Editor of reports and publications. She received her Ph.D. from the University of Wisconsin-Madison (Environment and Resources, 2015), her M.S. from New Mexico Tech (Hydrology, 1993) and B.A. from Smith College (Environmental Science, 1991). Madeline's research interests span the fields of physical hydrogeology and contaminant fate and transport in groundwater.

NATHAN KORB, Freshwater Program Director, The Nature Conservancy

Nathan Korb leads the Montana chapter's innovative Freshwater Program aimed at accelerating the pace and scale of watershed protection, restoration, and improving the resilience of rivers to drought and climate change. He works closely with local communities to develop and implement measurable water conservation outcomes that benefit nature and people. He has been working to restore watersheds for native fish in the Missouri Headwaters since 1999 when he started as an intern for the Conservancy in the Centennial Valley. After graduating from Montana State University with a degree in Soil and Water Sciences, Nathan completed his Master's research on historical fire regimes in Douglas-fir forests of the Greater Yellowstone.

LAURA RENNICK, Deputy Administrator for the Water Resources Division, Montana Department of Natural Resources and Conservation.

Prior to her role with DNRC she worked for the Montana Department of Environmental Quality for 15 years in various roles in water management and administration and as the Chief of the Montana Energy Office. A love of Montana's rivers led her to a career focused on sustainable solutions for her home state of Montana and working with local stakeholders to develop and implement collaborative projects and solutions unique to the various needs across the Big Sky state. Laura has served as a board member for the National Association of State Energy Officials and is former Chair of the Board of Directors for the Montana Watershed Coordination Council. Laura holds a MS in Science and Engineering Management from Montana State University, BAs in French and Environmental Studies from Carroll College, and an AS in Business from the University of Montana.

JOANNA THAMKE, Hydrologist, WY-MT Water Science Center, U.S. Geological Survey

Joanna Thamke has been with the USGS in Helena, Montana for more than 30 years and has recently become the Associate Center Director for Studies of the Wyoming-Montana Water Science Center. The Studies Section of this Center includes a strong team of professional scientists dedicated to bringing national expertise to help understand Wyoming and Montana's water issues. Joanna started with the USGS's Iowa District in the mid-1980s and assisted with water-quality projects while completing her degree in geology at the University of Iowa. She transferred to Montana in 1988 and has led projects that focused on water quality, water availability, water use, and energy in the Williston Basin that have resulted in nearly 40 publications and several awards.

TUESDAY SPECIAL SPEAKERS

MONTANA WATER CENTER UPDATE

WYATT CROSS, Director, Montana Water Center

Wyatt Cross is the Director of the Montana Water Center, and a professor in the Department of Ecology and Montana State University. He's working to focus and grow the water center as the nexus between the Montana Universities and water resource professionals across the state. When he's not working on Water Center business, his research laboratory is focused on understanding how stream ecosystems respond to various human perturbations, including river regulation, climate change, and nutrient pollution.

LEGISLATIVE UPDATE

JASON MOHR, Research Analyst, Legislative Environmental Policy Office

Jason Mohr is a research analyst for the nonpartisan Montana Legislative Environmental Policy Office (LEPO). He also serves as staff for the Water Policy Interim Committee. Mr. Mohr has worked for the Montana Legislature for more than ten years. He has previously worked as a newspaper reporter and editor in Minnesota and Montana, and has degrees in chemistry and journalism.

TUESDAY FEATURED SPEAKER I

URBAN SETTLEMENT AND DEVELOPMENT OF BUTTE, MT

JULIA CRAIN

**Special Projects Planner, Butte-Silver Bow City County Government, Superfund
Butte, MT**

Julia loves cities and the stories they tell. After 10 years studying urban policy and planning in the Pacific Northwest, Julia returned to Butte and joined the staff of Butte-Silver Bow. As Superfund Data Administrator, she uses data to inform plans for department led cleanup, restoration, and infrastructure projects. Whether creating plans for mineyard rehabilitation, planting trees on the Butte Hill, or encouraging public involvement in environmental decision making, one thing is always at the forefront of her work - striving to do the best she can for her community.

ABSTRACT:

Cities are the indelible reflection of economic, social, and political forces. Butte's settlement began after unearthing gold and silver, but its rapid urban and industrial expansion is inextricably tied to the discovery of copper. What followed was the development of a place described in the early 20th century as "endlessly exciting." Learn more about Butte and how historic mining influenced its urban pattern and created the challenges we respond to today.

GETTING A GRIP ON BUTTE GROUNDWATER ISSUES

NICK TUCCI

Senior Technical Specialist/Geochemist, Haley & Aldrich
Butte, MT

Nick Tucci is a senior geochemist with over 15 years of experience working for a wide range of clients. He holds a specialized Master of Science degree from the Mine Waste Technology Program at Montana Tech University in Butte, MT. He is a leader in the environmental characterization, assessment, and remediation of large, complex, mining-impacted sites. He has developed and implemented multiple alternative investigative and remedial approaches to inorganic and organic contaminant sites which have decreased remediation timeframes, reduced life cycle costs, and streamlined the path to meet remedial goals.

ABSTRACT:

The Summit Valley alluvial and bedrock aquifers in Butte, Montana serves as host to some of the most pristine and mining-impacted groundwater (MIW) in Southwest Montana. The Southern portion of the valley is underlain by roughly 800 - 1,000 feet of unimpacted alluvial aquifer and continues to serve as a viable natural resource for domestic and industrial supply to this day.

Impacts from over a century of mining, milling, and concentrating practices on “America’s Richest Hill on Earth” have resulted in MIW that has degraded groundwater quality in the Northern portion of the alluvial aquifer known as the Upper Silver Bow Creek corridor. Impacts to the bedrock aquifer resulted from historic operations at the Berkeley Pit and approximately 10,000 miles of underground mine workings (MBMG, 2004). To protect human health and the environment from MIW, a robust and comprehensive remedy has been designed for groundwater. The remedy that has been defined as part of the Records of Decision and Consent Degrees between stakeholders for multiple Superfund operable units.

The purpose of this talk will be to provide an overview of the hydrogeologic setting of the Summit Valley alluvial and bedrock aquifers and provide historical context on Butte groundwater issues.

THE BERKELEY PIT LAKE MAY NOT BE TOO BIG TO FIX!

CHRIS GAMMONS, Ph.D.

**Professor, Department of Geological Engineering, Montana Technological University
Butte, MT**

Dr. Chris Gammons is a Professor in the Geological Engineering Department at Montana Tech. Formerly a hydrothermal geochemist, Dr. Gammons shifted his main research focus to environmental geochemistry when his family moved to Butte in 1997. He and his students have conducted field investigations of mining-influenced waters throughout western Montana, including the Butte-Upper Clark Fork Superfund Complex, with side trips to the famously acidic Rio Tinto, Spain, the mercury-contaminated headwaters of Lake Titicaca, Peru, and volcanically-acidified lakes and rivers in Patagonia, Argentina. Dr. Gammons teaches a wide variety of courses at Montana Tech including Mining Geology, Acid Rock Drainage, Hydrogeochemistry, Geology of Montana, and Isotope Geochemistry. Chris worked for 3 years as an exploration geologist with the Anaconda Minerals Company in the early 1980s, and he is equally well-versed in mining issues from the perspective of an economic geologist as well as an environmental geochemist.

ABSTRACT:

Since it first formed in the early 1980s by flooding of an open-pit copper mine in Butte, the acidic Berkeley Pit lake has been an icon for environmental damage related to resource extraction. However, this talk will describe recent (last 10 to 15 years) improvements in the water quality of the Berkeley Pit due to changes in how the mine waters are managed. These improvements include a rise in pH from 2.5 to > 4.0, a 30% decrease in total acidity of the water, precipitation of > 95% of the dissolved iron and arsenic as solids that settled to the bottom of the lake, and a shift from being permanently stratified and anoxic to being vertically mixed, with elevated dissolved oxygen through the water column. Updates to how the pit waters are being managed will be discussed, including the onset of long-term pumping to prevent a further rise in lake elevation, and discharge of treated mine water to Silver Bow Creek.

A BRIEF HISTORY OF SILVER BOW CREEK, BUTTE MINING AND THE EVOLUTION OF THE BUTTE WATER COMPANY

PAT CUNEEN

Senior Operations Engineer, Butte-Silver Bow City County Government
Butte, MT

Padraig Cunneen is a 4th generation Butte Irish kid—the youngest of 11 in his family. His great grandfather came from Avoca, Ireland to work as a shift foreman for Marcus Daly, first at the Alice Mine the 1880's, then at the Neversweat and Anaconda Mines. His father retired after 44 years with “the Company” when ARCO closed the Butte operations in 1981. That was the year Padraig graduated from Butte High, and his father told him: “Paddy me boy, mining in Butte is dead, ya better just go to the Tech.” At Montana Tech he earned a B.S. in Petroleum Engineering and an M.S. in Environmental Engineering. During his 35 years of engineering, Padraig has worked for the Montana Power Oil and Gas Division, ARCO Oil and Gas, Montana DEQ, Advanced Silicon Materials Inc., Montana Resources, the Montana Department of Justice and Butte-Silver Bow. He has worked with several wastewater and potable water treatment plants and distributions systems. Padraig and his wife Christine are raising five, 5th generation Butte Rats...

ABSTRACT:

Silver Bow Creek is a small stream that brought native peoples then placer miners to the Summit Valley in Southwestern Montana. Quartz miners later developed the rich ore veins on the Butte Hill. Silver Bow Creek was the main source of water for these early mining, milling, and smelting operations, but she never produced enough water to satisfy all her suitors. Some mining companies were quick to move their milling and smelting operations out of the valley, while others brought more water into the valley. After 150 years of evolution, Butte has produced some of the most interesting and sophisticated water systems in the country.

SILVER BOW CREEK: 100 YEARS AS A COPPER MINE — CAN IT BE RESTORED?

JOE GRIFFIN

Hydrogeologist, DEQ Retired

Butte, MT

Joe Griffin has spent the last 30 years evaluating the upper Clark Fork Superfund complex, as a consultant to Atlantic Richfield, a project manager for Montana DEQ, and now in retirement, as a Superfund gadabout.

ABSTRACT:

Silver Bow Creek, devastated by a hundred years of mining and ore processing, was devoid of all but the most metal tolerant life forms. But the first Earth Day in 1970 marked the inception of an environmental awareness that even infected the Anaconda Copper Mining Company. From the Companies early work to reduce metals discharging from the mine in the 1970s, through the Superfund cleanup era that extends to the present and beyond, the concentration of copper in the Creek has been reduced by over four orders of magnitude. Is that enough progress to meet Superfund's legal and enforceable measure of "clean enough" —Montana's water quality standards?

I will present the history of the cleanup and explore the practicable limits of meeting water quality standards. Finding practicable limits to restoring Silver Bow Creek's ecosystem is a complex endeavor that goes beyond Superfund and begs the question, "why is it taking so long?"

FISHERY HEALTH IN THE SILVER BOW CREEK WATERSHED: PAST, PRESENT AND FUTURE

CALEB UERLING

Upper Clark Fisheries Biologist, Montana Fish, Wildlife and Parks
Missoula, MT

Caleb Uerling is the Fisheries Biologist for the upper Clark Fork River watershed with Montana Fish, Wildlife and Parks. Caleb has been working in the upper Clark Fork for one year. Prior to working in the upper Clark Fork, Caleb worked as a fisheries technician in Missoula for three years. Caleb has a master's degree in Natural Resource Sciences from the University of Nebraska.

CASEY HACKATHORN

Restoration Specialist, Upper Clark Fork Program, Trout Unlimited
Missoula, MT

Casey Hackathorn is a restoration professional who collaborates with private landowners, agencies, local governments, and NGOs to develop and implement projects to restore and protect watersheds and their fisheries. Casey has led Trout Unlimited's Upper Clark Fork Program for the last nine years while working to reconnect tributaries, reclaim abandoned mine sites, conserve water, and restore riparian habitat for in western Montana. Prior to joining the TU team, Casey immersed himself in the rivers and mountains of Montana and across the West as an outfitter, guide, and wilderness instructor. Casey cut his teeth in project work as an Air Force officer while managing environmental cleanup projects at DoD facilities around the country. Casey holds a BS in civil engineering from the United States Air Force Academy.

ABSTRACT:

Silver Bow Creek was effectively fishless when remediation and restoration efforts began at a watershed-scale from Butte downstream more than two decades ago. Since then, fisheries have made a dramatic recovery in some reaches of Silver Bow Creek while continuing to suffer from lingering impairments in others. We explore the impacts of historical mining and smelting on Silver Bow Creek fisheries, the results of remediation and restoration activities to date on fish habitat, trout population trends in Silver Bow Creek over the last 20 years, and the challenges that remain to achieving a healthy aquatic ecosystem in the watershed.

MANAGING HISTORIC MINING CONTAMINATION IN AN URBAN ENVIRONMENT

JOSH BRYSON

**Liability Manager, Atlantic Richfield Company
Butte, MT**

Josh Bryson has worked at Atlantic Richfield Company for the past 2 ½ years advancing Consent Decree negotiations, improving public outreach and education, continuing remedial investigation and design, and providing uninterrupted operation and maintenance of remedial systems. Prior to his current role, Josh spent 10 years as a private consultant to Atlantic Richfield Company as a project manager and design engineer working to advance the final remedy for soils, surface water, and groundwater across multiple operable units in the Upper Clark Fork River Superfund Complex. He holds degrees in biology and environmental engineering, is a licensed professional engineer, and a certified project management professional. Josh lives in Butte with his wife Krista and three children – Maleese, Ava and Eli.

ABSTRACT:

Historic mining practices resulted in contamination of soils across the Butte hill and impact to surface water and groundwater at and below the Silver Bow Creek riparian corridor. Recently, the Butte Priority Soils Consent Decree was agreed to by all negotiating stakeholders and lodged with the US District Court for final review and entry. The final Superfund remedy for the Butte Priority Soils Operable Unit will address these remaining historic mining impacts, manage additional challenges that are unique to the Butte environment, and integrate the remedy into the Silver Bow Creek Conservation Area – a planned 160-acre park space that will transform the center of Butte.

**ABSTRACTS FOR ORAL AND POSTER PRESENTATIONS
LISTED IN ALPHABETICAL ORDER, BEGINNING ON NEXT PAGE**

Montana Stream Permitting Guide

Bruce Anderson, WGM Group

The Montana Stream Permitting Guide is a technical reference manual used statewide by Conservation Districts and other agencies to assist project applicants in developing well-considered stream and stream infrastructure projects. The guide addresses permitting requirements at the local, state and federal levels and is written in a pragmatic style accessible to laypersons and practicing professionals. The manual includes hundreds of example stream design projects and an introduction to fluvial geomorphology and channel process. Chapters include stream function and process, strategies to address river dynamics, bank stabilization using bioengineering and hard techniques, hydraulic structures for irrigation, and diversion, fish screens, and other topics related to assist with design and permitting of common stream projects. Bruce Anderson, Sr. Hydrologist at WGM Group originally authored the Montana Stream Permitting guide in 2001 and worked with DNRC to make comprehensive revisions to the 2020 update.

Using Particle Image Velocimetry During Flood Events to Measure Stream Velocity and Discharge

Daniel W Armstrong, U.S. Geological Survey

Bridge scour is the erosion of streambed material away from pier foundations and abutments and is the leading cause of bridge failure in the United States. Stream velocities and estimates of potential scour at bridges are necessary for design and maintenance; however, accessing the structure and manually measuring velocities can be impractical or unsafe. Using large scale particle image velocimetry to measure velocities allows engineers and hydrologists to obtain important measurements remotely and safely, especially during flood conditions when these measurements are needed the most. These measurements can provide a more accurate and low-cost picture of the forces acting on bridge foundations.

The U.S. Geological Survey in cooperation with the Montana Department of Transportation is exploring the use of video images to determine real-time, accurate measurements of stream velocity and estimate scour at bridges during flood events. Large-scale particle image velocimetry analyzes video recordings of the flow surface obtained from stationary cameras and tracks individual particles in the water between reference points on the bank. Using existing software packages, the user can analyze the video and determine two-dimensional surface flow velocities. These surface velocity data allow for estimations of the hydraulic forces encountered by bridge foundations, bank stabilization structures, and constructed channels.

Initial results from this method show accurate velocity profiles and, when combined with channel area measurements, accurate discharge measurements. Further research and testing will result in a better methodology and a better understanding of the strengths and limitations

of this approach. The potential uses for particle image velocimetry have just begun to be explored and the ability of this method to provide accurate, safe stream velocity measurements during flooding is promising.

Spatiotemporal patterns of ground water levels in the East Flathead Valley aquifer system: insights into recharge and groundwater use

James L Berglund¹, Dean Snyder¹, Andrew Bobst¹

¹Montana Bureau of Mines & Geology

Development in Montana's Flathead Valley is increasing the demand for water. The Montana Bureau of Mines and Geology is investigating groundwater resources in the East Flathead Valley (EFV), a region roughly bounded to the north by Columbia Falls, to the south by Echo Lake, to the west by the Flathead River, and to the east by the Swan Range. The EFV groundwater system consists of a complex package of unconsolidated glacial, lacustrine, and fluvial Quaternary sediments likely underlain by poorly cemented Tertiary sediments and Belt bedrock. Wells are generally completed within sand and gravel aquifers, including a near-surface layer (0-200 ft. below surface), an intermediate layer (250-400 ft. below surface), and a deep layer (500-1,500 ft. below surface). These sand and gravel layers are separated by silt and clay rich lacustrine sediments and glacial till. Groundwater recharge primarily occurs during the spring months as runoff from snowmelt infiltrates along the Swan Range mountain front. Groundwater withdrawals for irrigation are most intense during the dry late summer months. Water levels were measured monthly in approximately 80 domestic and irrigation wells throughout the EFV area, from August 2019 – September 2020. Wells range in depth from 40-1,122 feet (mean of 223 feet) and, with locations throughout the EFV, their hydrographs characterize groundwater response to processes near the Swan Range and towards the west and center of the valley. Groundwater levels showed distinct patterns that reflect highly seasonal recharge and withdrawal. One response is an asymmetric hydrograph, with peak water levels around August followed by a gradual decline before sharply rising around June. This pattern is attributed to short-duration, intense recharge from snow melt along the mountain front, resulting in a sharp rise in water levels. Water levels gradually decline until the onset of the following annual snowmelt event. A second pattern occurs as a "plateau," with water levels largely constant from September – June, punctuated by a sharp water level drop from June – September. This plateau-response hydrograph is attributed to well locations distal to infiltration of snowmelt, resulting in generally stable water levels through the year. Nearby pumping for irrigation during the later summer months, however, produces a sudden, short-duration drop in the hydrograph. Other wells display mixed patterns, such as a double peak, with two water level maxima occurring around November and June with declines in-between. This set of hydrographs from across the EFV captures the dynamic behavior of the aquifer system in response to the seasonality of recharge and pumping.

An overview of the Virginia City Groundwater Investigation

Andrew L Bobst¹, Tom Michalek², Jessie Mosolf¹

¹MBMG, ²MBMG/RESPEC

Virginia City is one of southwest Montana's oldest gold mining districts whose colorful history now draws over 300,000 tourists annually. Residents are concerned that growing tourism and development may affect the quality or quantity of water derived from the town's springs. Since the springs (Spring 1 and Spring 2) are the only developed municipal water sources, Virginia City planners and water operators are seeking reliable backup water sources that could meet peak demand if either of the springs became unusable. In 2017, the Ground Water Investigation Program at MBMG initiated a study to characterize the hydrogeology of local springs and identify potential supplemental water sources.

The geologic setting of Virginia City east of Alder Gulch comprises poorly consolidated Tertiary tuff deposits overlain by a series of mafic lava flows. These volcanic units are highly susceptible to mass wasting and a landslide complex approximately 2 miles across envelopes Virginia City. Here, blocks of indurated lavas have moved on a failure surface formed in the underlying tuff intervals. Several undeveloped springs occur at the contact between the lava flows and the underlying tuff. LiDAR data, geologic mapping, and drilling were used to map the landslide complex and investigate the hydrogeology of the associated springs.

Spring 1, the main source of water for Virginia City, typically provides over 200 gpm. Spring 1 is located on the side of the landslide complex where there is a small subsidiary landslide. This subsidiary landslide likely resulted from erosion and undercutting of the landslide complex by Daylight Creek. Spring 1 emits from the contact between blocks of lava flows and tuff entrained in the landslide complex. Wells installed adjacent to Spring 1 show that saturated groundwater (i.e. a water table) is present ~30 ft below the elevation of the spring (within the tuff), indicating that Spring 1 is a contact spring fed by infiltration and storage of water in the fractured lava flow units of the landslide complex.

Spring 2 is a supplemental source of water for Virginia City, and typically provides about 40 gpm. Located on the main scarp of the landslide, it emits at the contact between the lava-flow units and the underlying tuff. However, unlike Spring 1, the lava flow units appear to be in place at Spring 2, which results in a smaller source area, and shorter flow paths. As such, it also appears to be a contact spring fed by the infiltration and storage of water in the fractured lava flow deposits.

Potential supplemental sources of water in the Virginia City area that could meet peak demands without Spring 1 (the largest current source) include undeveloped springs, surface water from Daylight Creek or Alder Gulch, and alluvial groundwater. Developing additional springs and water conservation measures may be able to meet the future water demands. Surface water flows in Alder Gulch and the alluvial aquifer along Alder Gulch would likely be sufficient to meet

future water demand. Water rights, rights of way, water quality, and costs will affect development of these alternatives.

From Kalispell to Ekalaka: U.S. Geological Survey Flood-Related Work in Montana

Katherine J Chase, U.S. Geological Survey

The U.S. Geological Survey (USGS) is working with partners to assess flood risk for communities across Montana. These projects include peak-flow frequency analyses, online flood inundation maps, and development of regional regression equations. This work could not take place without the historic and ongoing collection of streamflow data by the USGS in cooperation with state, local, and federal agencies.

In cooperation with the Montana Department of Natural Resources and Conservation (DNRC), USGS hydrologists are calculating peak-flow frequencies (discharge values associated with annual exceedance probabilities from 50 – 0.2 percent) for selected USGS streamgages in several Montana river basins. Currently, we are calculating peak-flow frequencies for more than 80 streamgages in the Milk River Basin. These analyses are published online and eventually will be available through the USGS StreamStats application. The peak-flow frequencies are used for Federal Emergency Management Agency (FEMA) Flood Insurance Studies, design of hydraulic structures, and other applications.

In addition to peak-flow frequency analyses, the USGS partners with local communities to develop real-time, online flood inundation maps (FIMs). These FIMs show areas inundated by floods at observed and forecast stages at USGS streamgages. The USGS, the United States Army Corps of Engineers (USACE) and the National Weather Service (NWS) collaborated with local stakeholders in Flathead County to produce the first Montana FIM. The USACE built a one- and two-dimensional hydraulic model of the Flathead River from Columbia Falls to Kalispell and produced the inundation maps for several flood scenarios based on stages at the Columbia Falls USGS streamgage. The USGS collected water-surface elevations and velocities at multiple sites during the 2017 high-flow event to help calibrate the model and provided reviews of the model and maps. The NWS reviewed the FIM by comparing the inundated areas to data collected from 23 years of flood surveys along the Flathead River.

Finally, the USGS recently developed regression equations based on channel width in cooperation with the Montana Department of Transportation. These regression equations can be used to calculate peak-flow frequencies for ungaged locations using channel widths measured in the field or from aerial photographs. Channel-width measurement data have been published online, and the regression equations will be published in a USGS Scientific Investigations Report later this year.

These peak-flow data, maps and regression equations are crucial for effective planning and management of water resources and floodplains, to protect lives and property in flood-prone

areas, and for determination of actuarial flood insurance rates. They are based on 100-plus years of streamflow data collections efforts by many USGS hydrographers. We applaud their work and the support of our Montana colleagues.

Developing Small-Scale Denil Fishways for use in Headwater Streams

Megan Conley, Montana State University

Fluvial Arctic Grayling (*Thymallus arcticus*) is a species of concern in the state of Montana and resides predominately in the Big Hole River watershed in Southwest Montana. Hydraulic structures such as irrigation diversions are common in the Big Hole watershed and are essential for providing water diversion for agriculture but can be barriers to grayling and other fish. Denil fishways have been installed in irrigation diversions throughout the Big Hole River watershed to provide fish passage, with more structures planned in this watershed and others. The Denils are “simple” type in their configuration in terms of baffle size, shape and spacing. When water is in high demand by agriculture during the summer months, the Big Hole Denils may be partially or completely blocked to ensure that there is sufficient water for irrigation. This study was developed in order to test smaller (“scaled”) Denils that require less water for operation and, therefore, save water for irrigation during periods of low flow. Scaled Denil sizes were selected by analyzing predicted flowrates through a series of computer models. The model results led to the selection of a 0.75 scale and a 0.6 scale Denil (scaled from the “simple” Denil sizing). The scaled Denils were tested at the Bozeman Fish Technology Center during the summer of 2020. Two hundred and thirty grayling were tested for passage in the scaled fishways. For each of the two scaled fishways, three flow rates were tested and replicated four times for a total of 48 trials. Expected results include passage success rates for each combination of flowrate and scaled Denil size, participation rates for all trial combinations, and comparison and evaluation of each scaled Denil size for future trials. This presentation will include the study methods, preliminary results and future work.

Parrot Tailings or local sources of contamination to Silver Bow and Blacktail Creeks in Butte, Montana: lines of evidence

Curt Coover, PG¹, Kent S Whiting, PG¹

¹CDM Smith, Helena, Montana

Sources of metals loading to surface water in Silver Bow and Blacktail Creeks in Butte, Montana has been the subject of numerous investigations and reports. The Parrot Tailings, 1 mile from surface water, has been listed as a potential source. Based on sediment pore water sampling and geochemical modeling, the weight of evidence favors the local source over the distant source. The lines of evidence follow. (1) The impacts of metals to each of the stream reaches are different and correspond with known local primary wastes. (2) Shallow groundwater metals

concentrations are higher than for deeper wells in the same areas. This is evident in the Slag Canyon area. Given that the groundwater gradients are neutral to upward, if a distant source were responsible, then concentrations would increase with depth, not decrease, because of attenuation with distance from the source. (3) The fairly rapid response of the surface water metals concentrations to changes in surface water flow suggests a local source and not a distant one. (4) If the main groundwater contamination source were in the upper Silver Bow Creek area, the right bank pore water COC concentrations (closest to upper Silver Bow Creek) would have been consistently higher than the left bank, which was not the case. (5) Metals concentrations generally decrease with distance from a source area. If the source were in the upper Silver Bow Creek area, the most distant wells would have the lowest COC concentrations. COC concentrations in monitoring well AMW-13 are higher than the next upgradient well, BPS11-19A2 for example. (6) Metals concentrations in one pore water sample (PO209) were higher than in the nearby wells.

The chemistry of the water (low pH, very high iron, high ratio of copper to zinc) also suggests that the source of the metals is close by. The lines of evidence do not rule out any impacts by a distant source but strongly suggest the bulk of the observed metals in pore water and surface water can be explained by local groundwater impacted by near-stream primary sources; it is more likely that local sources along the stream banks are responsible for metals loading to surface water.

Evaluating Irrigation Efficiency: Towards a Sustainable Water Future for Montana

Wyatt F Cross¹, Whitney Lonsdale¹, Chuck Dalby², Sara Meloy³, Ann Schwend³

¹Montana Water Center, ²Kintla Enterprises, ³MT Department of Natural Resources and Conservation

Irrigated agriculture has been an important component of the culture and livelihoods of Montana residents since the mid 19th century. Irrigated agriculture also represents the largest consumptive use of water in Montana and can thus profoundly influence water supply and availability. Over the past 50 years, many producers across the West and in Montana have made changes to their irrigation practice and infrastructure in an effort to increase irrigation efficiency, effectively increasing the proportion of diverted water that is consumed by crops. Although these changes often reduce labor costs and may improve crop production and water quality, they have not necessarily led to water conservation. In 2019, the Montana Water Center convened a technical working group to discuss and synthesize information about irrigation efficiency, focusing at the intersection of hydrology, policy, economics, and aquatic ecology. The primary goals of this working group were to (a) clarify and summarize potential hydrologic responses to changes in irrigation technology and practice (i.e., a shift from flood to sprinkler irrigation or the lining of canals), (b) consider and clarify the relationships between policy and irrigation practice, and (c) discuss strategies in which irrigation management might help to balance increasing water demand with a variable and increasingly uncertain supply. In this talk, we give a brief overview of our process and key findings, and showcase our written product to be released in fall of 2020.

Historic Conversion from Flood to Sprinkler Irrigation in Montana

Chuck Dalby, Kintla Enterprises

As part of the Montana Water Center's effort to better understand effects of increased irrigation efficiency in Montana, the historic (1946-2019) conversion from flood to sprinkler irrigation was analyzed and mapped in a GIS. Comparison of historic Montana Water Resource Surveys (WRS) conducted between 1946 and 1971, and Montana Department of Revenue's 2019 Final Land Unit Classification (DORFLU2019), shows that between the mid-20th century and 2019, 420,000 acres (170,000 hectares)—21% of WRS mapped flood irrigated land was converted to sprinkler irrigation; of this 70% was converted to center pivot (290,000 ac—120,000 ha) and 30% was converted to other types of sprinkler irrigation (130,000 ac—51,000 ha). Most of the conversion (80%), from flood to sprinkler irrigation, has taken place in the headwater valleys of western Montana. About 2% (30,000 ac—12,000 ha) of the flood irrigated acres mapped at mid-century have been converted to urban and suburban uses—primarily housing, industrial, subdivision near population centers. In 2019, of the just over 2 million acres of irrigated agricultural land in Montana (DORFLU2019), 50% was irrigated by flood (gravity) systems, 36% by center pivot, and 14% by other sprinkler methods (DORFLU2019).

Cyanobacterial bloom distribution, toxicity, and associated water-quality conditions in Bighorn Canyon National Recreation Area: A USGS-NPS Partnership

Sara L Eldridge, U.S. Geological Survey

Bighorn Canyon National Recreation Area (BICA), between the Bighorn and Pryor mountains in southeast Montana and north central Wyoming, offers more than 120,000 acres of forests, mountains, deep canyons, high desert, and surface water to over 200,000 visitors each year who value the area for its vast and diverse fishing, boating, swimming and wildlife or scenic viewing opportunities. Recently, dense phytoplankton blooms were observed between July and September in BICA as a result, in part, of land use and upstream activities that enhance eutrophication. There is little data concerning the extent and severity of these blooms, and it is unknown whether they produce harmful cyanotoxins. Therefore, the USGS formed a partnership with the National Park Service in BICA to conduct a synoptic survey of water quality conditions, cyanotoxin occurrence, and phytoplankton bloom community composition across the park in 2019 and 2020 to determine how these blooms influence water quality, the potential environmental parameters that promote bloom development and toxicity, and the possible impacts of cyanotoxins and degraded water quality resulting from these blooms on humans and wildlife that inhabit or use BICA water resources.

Groundwater contamination in Butte, Montana, and its effect on Silver Bow Creek – the tail end of the story.

Joe Griffin, Montana Department of Environmental Quality, Retired, and Technical Advisory Committee Clark Fork Coalition

Over 100 years of mining and smelting in Butte, Montana has left a legacy of contaminated streams and groundwater that the Environmental Protection Agency began to address under the Superfund program in the late 1980s. The massive cleanup, which includes groundwater capture/treatment and stream restoration, has decreased copper concentrations in Silver Bow Creek by close to two orders of magnitude.

As stream contamination has tailed off, scientists are using a unique temporal cumulative gain-loss analysis to locate stream reaches that are still affected by more subtle contaminated groundwater inflow. The analysis is made possible by an intensive surface water monitoring program that has included collecting monthly water quality samples synoptically from seven stations since 2008.

The technique consists of calculating the difference in metal concentration between two stations that define a stream reach - the difference defines either a gain or loss of metals over the reach. By adding the gains or losses from successive monitoring events (cumulative gain-loss), and by comparing the relative slopes through time between reaches, managers have located problem reaches and focused additional groundwater capture or source material excavation along those areas.

The Gallatin Local Water Quality District's Surface Water Monitoring Network

Torie Haraldson, Gallatin Local Water Quality District

2020 marks the third year of data collection at the sixteen sites that make up GLWQD's Surface Water Monitoring Network. While the program is still young, there is much to discuss. Participants will take a tour of Network sites and learn about the challenges of site selection for long-term trend monitoring. Monitoring goals and methods and anticipated future work will also be discussed. Initial water quality results and outreach work will be highlighted, including publication of the first Watershed Health Summary – a non-technical synopsis of Network data, aimed at enhancing the layman's understanding of water quality in the Lower Gallatin Watershed.

Aquifer salinization in Punjab, India

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Groundwater resources in India are rapidly declining due to increasing dependency on groundwater use for irrigation and domestic purposes. Among all the states, Punjab is drawing the highest amount of groundwater in spite of a well-organized canal irrigation system which is unable to meet increasing demands of water. This has resulted in a decline in the water table in north-western, central, southern and south eastern parts of the state. On the other hand, in southwestern parts of Punjab, groundwater extraction is limited, which is resulting in water table rise further leading to groundwater salinity. The present study is taken with a view to assess groundwater salinity and its expansion.

Application of a Satellite-Driven Hydro-economic Model to Assess Climate Change Impacts on Montana's Water Resources, Agricultural Production, and Farm Revenues

Zachary H Lauffenburger¹, Marco Maneta¹

¹University of Montana

The increasing demand of water for agriculture and the uncertainties of climate change are posing challenges for farmers, water resource managers and policymakers. To anticipate increases in agricultural water demand at the end of the century, and to evaluate the regions most at risk of straining supplies, we used a satellite-driven integrated hydro-economic model that simulates how farmers allocate land and water resources. Our results quantify end-of-century Relative Concentration Pathway 8.5 (RCP8.5) climate change projection impacts on streamflows, agricultural land and water use, as well as on crop yields and farmers' net revenues. We compared end-of-century results with baseline hydrologic and economic scenarios that were calibrated from historic streamflows and satellite-data driven observations. Results show that without changes in water policy and basin management, agricultural adaptation will have a significant impact on streamflow quantities and timing. Our study illustrates the worst-case scenario impacts of climate change if there are no changes to policies aimed at the timing of water diversions, limiting water restrictions, or incentivising irrigation technology.

Launching Monitoring Montana Waters (M2W); A Flathead Lake Biological Station initiative to increase local capacity for watershed monitoring

Rachel L Malison¹, Erin K Sexton¹

¹Flathead Lake Biological Station, University of Montana

In response to the growing need for scientific and technical expertise in support of citizen-led watershed monitoring, the Flathead Lake Biological Station has initiated a new program called Monitoring Montana Waters (M2W). Founded in 1899, the Flathead Lake Biological Station (FLBS) is a world-renowned freshwater research and education facility, and is one of the oldest field research stations in the nation. The core mission of FLBS is to use science for the betterment of society and we do this in three primary ways: 1) by conducting cutting-edge ecological research, 2) by providing undergraduate, graduate and K-12 education programs, and 3) by providing outreach programs that help all make informed decisions about watersheds and water resources. The objective of M2W is to increase our capacity for supporting water quality monitoring efforts in Montana by providing scientific, technical and financial support to citizen-science watershed groups. Through M2W we will work to ensure that citizen groups are using legally defensible methodologies in all aspects of their monitoring efforts (e.g. sample collection, handling and chain of custody, instrumental calibrations and associated documentation). We offer assistance and consultation in designing monitoring plans and selecting analytes for study, as well as on the ground training in methodologies. Furthermore, small grants will help support the cost of sample analyses in the FLBS Freshwater Research Laboratory, and can also assist with start-up costs (e.g. purchasing equipment). We will provide guidance and support to citizen groups for water quality data analysis as needed. We hope our efforts will assist and amplify efforts to monitor Montana's waters as we engage collaboratively with relevant federal, state, tribal, local government agencies and watershed groups. We will ensure that samples collected and data generated meets accepted standards and maximizes utility and benefit to the waters of Montana. The focus of our program is lotic systems in Montana (i.e. rivers and streams), due to the highest data needs, although groups focused on lentic systems (i.e. lakes) will not be precluded from participation. Our overarching goal is to help better understand and protect the world-renowned waters of Montana by providing assistance for increased monitoring efforts.

Hydro-economic impacts of agricultural adaptation to increasing climatic aridity

Marco Maneta¹, Zachary Lauffenburger¹, John Kimball¹, Kelly Cobourn²

¹University of Montana, ²Virginia Tech

The agricultural system of the intermountain western U.S. is characterized by extensive farming and ranching, low product diversification, and prevalence of rainfed crops, which makes it very vulnerable to drought and long-term climate variability. Agriculture is a major component of the regional economy and of the livelihood of people in Montana; for this reason, it is

important to understand how farmers cope with reduced access to water. Common strategies involve increasing irrigation and reallocating land to priority crops, or fallowing land to mitigate impacts on farm revenues by reducing costs. Potential intensifications of water use in upstream counties, however, can have impacts on streamflows, limiting the options of downstream users.

Using results from a hydro-economic modeling and observation framework driven by satellite remote sensing we analyze the impacts of recent droughts on producer decision-making, and the mitigating effects and consequences of investing in more efficient irrigation technology. We use simulation results to analyze the most vulnerable and resilient counties and evaluate the extent to which increasing access to surface water to compensate for precipitation shortfalls results in stream depletion.

Warm Springs Creek Restoration

Mace Mangold, WGM Group

Mine waste from historic Anaconda Smelter operations impacted Warm Springs Creek for approximately 13 miles to the confluence with the Clark Fork. The restoration project was designed to mitigate overland flooding, remove contaminated floodplain and stream bank soils, and promote natural process and long-term channel function. The first phase of the project focused on a reach with split channels that threatened the Anaconda Deer-Lodge Airport during high-flow events. The design included a 2-D hydraulic model to compare existing versus proposed overland flood conditions, and a “field fitting” bank stabilization design that meshes natural substrate with existing mature vegetation to provide a reliably stable, yet naturally functioning channel design. Phase two remediated and restored approximately 13,000 linear feet of Lower Warm Springs Creek that contained buried and mixed mine tailings. Approximately, 70,000 cubic yards of contaminated soil were removed from streambanks and the adjacent floodplain. Channel restoration and stabilization methods were developed using a stable “reference reach,” which emulates natural conditions and materials found within the system. Hydrologic and hydraulic calculations were used to verify proposed stream material gradations and localized scour/shear stress. This case study will highlight project design considerations, site specific challenges, and follow up monitoring since 2014 on project success and limitations.

Isolating Authigenic Carbonate in Lake Sediment Cores to Improve Climatic Interpretations: A Method Development Project

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Holocene paleoclimate can be reconstructed by using the carbonate in lake sediment as a proxy for climate. Variations in lake water isotopic composition and secondarily water temperature determine the carbon and oxygen isotope composition found in the precipitated authigenic carbonate. Detrital carbonate can also be found in lake sediment, which is generally washed in from surrounding parent rock (e.g., limestone) and contains isotopic values representative of climate from millions of years ago. Because authigenic carbonate is a proxy for hydroclimate, high levels of detrital carbonate can overprint the in-situ isotope signals, which can easily be misinterpreted as climate signals. More depleted isotopic values typically indicate colder/wetter conditions while enriched isotopic values indicate warmer/dryer conditions.

A Canal Story: Working with a Local Canal Company to Investigate Groundwater/Surface-water Interaction and Gains and Losses in Farmers Canal, Gallatin County

Todd Myse, Montana Bureau of Mines and Geology

Farmers Canal, located in Gallatin County, Montana, is diverted from the east bank of the Gallatin River near Gallatin Gateway. The canal flows for about 11 miles to the northeast and terminates northwest of the Bozeman City limits. The canal was incorporated in 1890, at a time when the Gallatin Valley was primarily flood irrigated agricultural land. Since the 1970s, more efficient irrigation methods such as pivot and sprinkler have replaced flood irrigation. In addition, some land-use has changed from agricultural to residential, resulting in untraditional use of canal water such as irrigation for subdivisions. Changing land-use and irrigation practices have altered irrigation patterns and the timing of water use and demand. As a result, efficient operation requires an understanding of how the canal functions and its relation to groundwater.

Farmers Canal offers a unique opportunity to study how the canal functions and where it may be losing conveyed water or gaining groundwater. Each of the Canal's diversions have a Parshall flume, resulting in timely and efficient synoptic runs. The synoptic flow measurements provide a snapshot of canal conveyance efficiency both temporally and spatially. The upper canal is constructed within an embankment and the depth to groundwater ranges about 30 to 40 feet deep. Upper canal conveyance losses ranged from about 0.1 to 3.4 cfs/mile. A section in the upper canal was instrumented to provide continuous stage and discharge. In this section seepage amounts generally increased from the beginning of the irrigation season until about mid-July, then decreased thru mid-to-late August (most likely due to reduction in canal flow, sediment infilling, and vegetative growth). Seepage amounts increased again in late-August and

remained constant until the irrigation season ended. The lower canal has a different flow regime. The canal is mostly level with the ground surface and depth to groundwater ranges from 6 to 10 feet. For the lower canal, gains calculated ranged from about 0.7 to 2.1 cfs/mile.

Demands for water include ensuring adequate flow to meet the changing land use. Quantifying losing and gaining canal reaches provides information to help make informed management decisions.

Characterizing mine waste colloids in the Upper Clark Fork River to better understand potential exposure

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Mine waste is a global issue that has resulted in widespread contamination of rivers and streams with metals and metalloids. Assessing organismal exposure to these contaminants is typically done by measuring metal concentrations in the “dissolved” fraction, or that which passes through a 0.45 micrometer filter. Though the forms of metals in this fraction is thought to be free ions, it is well known that many of these contaminants can exist as nanoscale particles. These colloidal particles may be important in driving the exposure of aquatic organisms through both aquatic and dietary pathways, and the fate and transport of colloidal particles may differ from that of truly dissolved solutes. To better understand the forms of metals that organisms are exposed to in a contaminated river, samples were collected from the Upper Clark Fork River and its tributaries during baseflow. Using single particle inductively coupled plasma time of flight mass spectrometry (spICP-TOF-MS), we characterized the concentration, composition, size, and mass of colloidal particles. Our results reveal high concentrations of particles in the filtered fraction, with those particles containing the toxic elements arsenic, copper, lead, and zinc. This suggests that accounting for only free ions in filtered samples may not accurately assess the exposure of organisms to metal and metalloid contaminants. Moreover, this technique provides a sophisticated look at colloid facilitated transport, allowing for detailed examination of aquatic chemistry impacts on the movement of mine-derived contaminants.

Caring for Waters Across Borders

Natalie Poremba¹, Erin Sexton¹

¹Crown Managers Partnership

The Crown of the Continent (the Crown) is one of North America’s most iconic and wild landscapes. Nearly 18 million acres in size, the Crown stretches across the international border

between the United States and Canada. At the Crown's core is the world's first International Peace Park – Waterton-Glacier, and in Montana, the third largest wilderness area in the lower 48 states – the Bob Marshall Wilderness Complex. Waters that originate in the Crown spill in three different directions across the North American continent. As water travels to the Gulf of Mexico, the Pacific Ocean, or the Hudson Bay, it is used for drinking, recreating, agriculture, and wildlife habitat.

Although much of the Crown is in a natural, undeveloped state, its lands and waters are facing increasing pressures from urban and rural residential expansion, increased and diversified recreational use, the spread of invasive species, and climate change. Furthermore, the Crown is subdivided by borders: Tribes and First Nations, two countries, two provinces and one state, and private lands. Stressors and the resources they impact go beyond our human-made borders, and no single land management agency has the mandate or resources to tackle these large landscape scale issues alone.

Recognizing the need for large scale collaboration and management practices that reflect the reality of natural processes, the Crown Managers Partnership (CMP) was formed in 2001. The CMP is a voluntary partnership comprised of federal, state, provincial, tribal, and first nation land managers and universities in Montana, Alberta, and British Columbia. By collaborating on common issues and sharing resources and knowledge across borders, the CMP has worked to build ecological resilience in the Crown. Our priorities for protecting water resources in the Crown of the Continent include halting the spread of aquatic invasive species and restoring and protecting cold water salmonid populations. More recently, the CMP has prioritized assessing watershed integrity from a large landscape perspective, through a Landscape Conservation Design framework.

Restoration of Elbow Coulee, Tributary to the Sun River

Robert Sain, Kroenke Ranches

The Elbow Coulee Restoration and Enhancement Project is in progress at the Broken O Land and Livestock (Broken O) near Augusta, Montana. The Broken O that surrounds and contributes to over 50 miles of tributary streams and 26 miles of the Sun River, has a unique opportunity to improve fish passage, fish habitat and reduce sediment influence on the Sun River. The watershed goal for enhancement and restoration activity is to increase trout habitat and cold-water refuge by removing fish passage barriers and ensuring native flow to coulee tributaries of the Sun River. The objective for Elbow Coulee is to reconnect, enhance and restore 7.1 miles to its confluence with School Section Coulee and further downstream to the Sun River. To date, 21,120 linear feet (LF) of stream corridor have been preserved, and 8,831 LF have been enhanced, realigned, or restored.

A three phased initiative, phase two of Elbow Coulee addresses a unique set of problems that encompass irrigation point of diversion movement, channel re-alignment and enhancement of

riffle-pool complex. Construction was completed in 2019. A soup-to-nuts operation whereas the in-house restoration program planned, surveyed, designed, permitted, and performed construction on a 2,139-foot-long stream channel re-alignment. The realignment reconnects the stream to its floodplain and disconnects this section of the stream from an irrigation point of diversion. In addition, 2,760 LF of point fixes were made along the 2-mile phase. The design approach and challenges to consider for this type of project will be discussed.

Dams, Diversions, and Deliveries – Handling Streamflow Regulation in Flood Frequency Analysis

Seth Siefken, U.S. Geological Survey

Accurate estimates of flood frequency and magnitude are important information for understanding flood risk and informing water management decisions such as floodplain mapping and design of hydraulic structures. Flood frequency analysis at many locations is complicated by flow regulation from dams, large diversions, or delivery of water from inter-basin transfers. Regulation can alter the distribution of peak flows such that the data do not fit the log-Pearson Type III distribution commonly used for flood frequency analysis. Additionally, changes in regulation such as dam modification or altered water management practices can alter the peak flow distribution over time. USGS hydrologists recently faced multiple complex regulation issues while updating flood frequency analyses of selected streamgages in the Clark's Fork of the Yellowstone and Milk River watersheds in support of Montana DNRC flood-plain mapping studies. The Expected Moments Algorithm, which employs a generalized representation of peak flow data to fit a log-Pearson Type III distribution, was used for the analyses. The generalized representation allows peak flows to be represented as either intervals or discrete values which can be useful for analyzing regulated peak flow data. Research into the history of regulation at the analyzed streamgages identified several notable changes in regulation including one dam failure. The information was used to identify regulated and unregulated time periods at each streamgage and to inform the representation of peak flow data using the Expected Moments Algorithm. The updated analyses provide better representations of regulated and unregulated hydrology at the sites in question and should prove useful for informing water management decisions.

Gallatin County Interactive Water Quality Mapper Demo

Christine M Sundnas, Gallatin County GIS Department and Gallatin Local Water Quality District

The Gallatin Local Water Quality District (GLWQD) in partnership with the Gallatin County GIS Department has launched an online interactive mapper where citizens can view water information. This map was developed by the Gallatin County GIS Department and shows thousands of water quality results. It also shows the locations of long-term monitoring wells, controlled groundwater areas, groundwater equipotential contours, geology, and more. This

map is a great resource for citizens or professionals looking for water related information in their area of interest. This presentation will discuss history of the mapper, data sources, mapper limitations, use, and future upgrades.

Lake reconnaissance for determining potential lake cores with carbonate for retrieving climate records.

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Lake sediment cores hold records of past climatic information. Not all lakes are recorders of climate and several factors need to be met for a lake to be considered a good candidate. My research project was centered around finding lakes that contained carbonate sediments and were precipitation dominated, in order to determine how past hydroclimate and snowpack have varied in western Montana. Working with Dr. Schoenemann, we discovered many lakes that were good candidates, but in the end, we only cored three: Dickey Lake, Clearwater Lake, and Storm Lake. Before going out and coring a lake, we reviewed geological maps of the area surrounding each lake. The reason for this, is that for there to be enough carbonate in the lake, the surrounding rock needs to have an abundance of limestone. The chemical weathering of the limestone produces calcium and carbonate ions, which provide ample supply to produce authigenic calcite precipitated within the lake. After coring a candidate lake, we brought the cores back to the lab for analysis. To determine the presence of carbonate, we sectioned the top ~35-40 cm of the core into 0.5 cm intervals, then freeze-dried the samples in order to get percentage water weight, then baked them in a muffle furnace at three separate temperatures in order to determine the Loss On Ignition (LOI) and percentage carbonate within the sample. Dickey Lake showed the most promise for a full-core study because it had above 20 % carbonate during LOI. The final steps are to prepare sediment samples for measuring the carbonate isotopes and to compare them to the isotopic composition of the lake waters, which will help determine what time of year the carbonate is precipitating. Lastly, this will help us determine which type of lake systems are best at recording carbonate isotope variations and based on correlations with modern climate data, will assist in identifying future lakes to extract reliable climate records.

Changes in surface water chemistry of Silver Bow and Blacktail creeks under different flow regimes, Butte Priority Soils Operable Unit, Butte, Montana

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Surface water sampling within Silver Bow and Blacktail creeks, Butte Priority Soils Operable Unit, Butte, Montana, has shown that dissolved copper and arsenic concentrations tend to be higher at normal high flow relative to base flow, whereas the reverse is true for dissolved zinc. Prior to the current investigation, the best interpretation of the data was that arsenic and copper were derived from sediment sources, while zinc was derived from groundwater discharge to the stream. Potential sediment sources included sediment from storm water runoff, erosion of contaminated stream banks, and bed sediment derived from either or both of those sources. The theory would predict that metals derived from groundwater discharge under base-flow conditions would be mainly in the dissolved form, while metals derived under normal high-flow conditions would be mainly in the suspended form (measured as total recoverable). However, total recoverable metals, especially copper, are much higher than dissolved concentrations under base-flow conditions. The current investigation looked at potential geochemical processes to explain the apparent discrepancy, and also to explain diel changes in stream water quality observed by others.

Through a series of data collection efforts, including pore water analyses, sediment analyses, and batch desorption studies, and geochemical modeling, a new theory was developed. Copper and arsenic were found to be present within the sediment as sulfide minerals, while zinc was present within calcite. Under high-flow conditions, the sulfide minerals are scoured from the stream bed and suspended in solution, where the oxygenated surface water oxidizes and partially dissolves the fine-grained and amorphous sulfide minerals and releases the copper and arsenic. On the other hand, zinc-bearing calcite is formed under high-flow conditions because of the degassing of carbon dioxide from the pore water and the associated pH increase resulting in removal of zinc from solution. Under base-flow conditions, the zinc-bearing calcite becomes buried in the sediment where pH conditions are lower and some of the zinc-bearing calcite is redissolved. Under base-flow conditions, the dissolved copper and arsenic within the pore water are reprecipitated as sulfide in response to the action of sulfate-reducing bacteria within the organic-rich sediment. Under base-flow conditions, some of the fine copper sulfide particles are released to the water column with the flow of the discharging groundwater, accounting for the suspended copper measured as total recoverable concentrations under base-flow conditions.

Monitoring Crop Status in the Northern Great Plains Using the SMAP Level 4 Carbon Products.

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Agriculture in Montana accounts for approximately 80% of water consumption in the state. Agriculture is critical to the Montana's economy as it is the state's top industry. Crops account for approximately 1/3 of agricultural income, with wheat being the most important crop. While irrigated agriculture in Montana accounts for the majority of water consumption, wheat and barley are primarily rain-fed. Montana is prone to drought, which may result in yield reductions or even crop failure. Accurate monitoring of crop condition is critical to detect anomalies that may threaten the economic viability of agriculture and to understand how crops respond to climatic variability. While weekly crop condition reports are available for important crops produced in Montana through the National Agricultural Statistics Service (NASS), these reports are only available at the state-level. Montana is a relatively large area where climatic anomalies and the resulting impacts to crop condition often vary between regions. This heterogeneity in crop condition is not captured in the state-level crop condition reports. While county-level crop yield data is available through NASS, the reports are only available annually. Therefore, crop condition monitoring at the county-level and at weekly time scales are currently unavailable through NASS. Retrievals of soil moisture and vegetation information from satellite-based remote sensing products offer an opportunity for continuous and affordable crop condition monitoring at finer spatial and temporal scales than what is currently available. One such product, the SMAP Level-4 Carbon (L4C) product, provides daily gross primary production (GPP) estimates at a 9-km scale. The L4C is novel because it assimilates soil moisture estimates provided by NASA's Soil Moisture Active Passive (SMAP) satellite into a light use efficiency GPP model. This study compared weekly anomalies in accumulated GPP estimated by the L4C to anomalies calculated from a state-level weekly crop condition index (CCI) based on crop condition reports provided by NASS, and also to annual crop yield anomalies at the county-level. We focused on barley, spring wheat, corn, and soybeans cultivated in the continental United States from 2000 to 2018. We found that the L4C was particularly capable of monitoring the status of spring wheat in Montana. The Pearson-r correlation coefficient between GPP anomalies and the state-level spring wheat CCI anomalies was 0.6 three weeks after emergence, and 0.8 five weeks prior to harvest. Correlations between county-level spring wheat yields were highest in the counties of north-central and north-eastern Montana which are important spring wheat producing areas. In these counties, r-values greater than 0.6 were observed as soon as two weeks after emergence, and between 0.7 and 0.9 five weeks prior to harvest. We show that the L4C permits the evaluation and tracking of anomalies in crop status at higher spatial detail than metrics based on the state-level CCI or county-level crop yields for important wheat producing counties in Montana, and that the L4C GPP product can be used operationally to monitor crop condition with the potential to become an important tool to inform decision-making and research.