# PROCEEDINGS

**for**

# Science, Policy and Communication: The role of science in a changing world

**American Water Resources Association Montana Section 2017 Conference**

**October 18 - October 20, 2017**
**Great Northern Hotel -- Helena, Montana**

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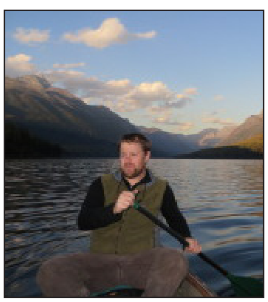
***These abstracts were not edited and appear as submitted by the author, except for some changes in font and format.**

## THANKS TO ALL WHO MAKE THIS EVENT POSSIBLE!

- **The AWRA Officers**
  Aaron Fiaschetti, President -- Montana DNRC
  Emilie Erich Hoffman, Vice President -- Montana DEQ
  Melissa Schaar, Treasurer -- Montana DEQ
  Nancy Hystad, Executive Secretary -- Montana State University

- **Montana Water Center, Meeting Coordination**
  Whitney Lonsdale

**And especially the conference presenters, field trip leaders, moderators, student judges and volunteers.**



*Aaron Fiaschetti*

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## WEDNESDAY, OCTOBER 18, 2017

**REGISTRATION**

9:30 am – 7:00 pm REGISTRATION
Preconference registration available at http://www.montanaawra.org/

**WORKSHOP, FIELD TRIP and HYDROPHILE RUN**

10:00 am - 12:00 pm **Workshop: Science and Public Collaboration**
*Led by Susan Gilbertz, Oriental Ltd. Room*

1:00 pm – 5:00 pm **Field Trip: Canyon Ferry - Present, Past**
*Led by Melissa Schaar, MT DEQ and AWRA Treasurer*
*Bus leaves Great Northern Hotel promptly at 1 pm, returns at 5 pm*

5:40 pm – 7:00 pm **Hydrophile 5k Run/Walk**
*Meet at field trip bus drop off location at 5:40 or 301 S. Park at 5:50 for shuttle. Run finishes at Blackfoot Brewery.*

**Dinner on your own**

## THURSDAY, OCTOBER 19, 2017

**REGISTRATION** ***Western Star/Empire Builder Combined Rooms***

7:30 am REGISTRATION
Gather for Coffee and Conversation with Colleagues

**OPENING DAY PLENARY SESSION**

8:00 am WELCOME WITH INTRODUCTIONS, LOGISTICS AND ANNOUNCEMENTS
Aaron Fiaschetti -- *AWRA Montana Section President*

8:15 A MESSAGE FROM THE MONTANA WATER CENTER
Andrew Wilcox -- *Montana Water Center, Associate Director*

8:30 KEYNOTE SPEAKER 2: Tom Livers -- Montana Department of Environmental Quality
Title: *Observations and Perspectives on Science and Public Policy Development*

9:00 *BREAK*

9:30 KEYNOTE SPEAKER 2: Dr. Robert Lackey -- Oregon State University
Title: *Practitioner's Guide to Identifying Advocacy Masquerading as Science*

10:30 Special Speaker: Jason Mohr, *Research Analyst - Legislative Update*

11:00 Break for conversation and networking

11:30 Lunch in the Oriental Ltd. Room - provided to all registered conference attendees

## ORAL PRESENTATIONS (Red text indicates student presenters)

### SESSION 1 (Concurrent) *Western Star Room*
### SURFACE WATER

Moderator: Christina Eggensperger -- *Montana Tech*

12:40 pm Katherine Chase. *Estimating Daily Streamflow Where No Streamgages Exist In Montana and Across the United States.*

1:00 Justin Martin. *Applied paleohydrologic information for improved water management in the Upper Missouri Basin.*

1:20 Hong-yi Li. *Understanding Water-Energy-Ecology Nexus from an Integrated Earth-Human System Perspective.*

1:40 Larry Dolan. *Missouri Headwaters Impact Assessment and Basin Study.*

2:00 Chuck Parrett. *The Big Flood on Tenmile Creek--Not That One; the BIG One.*

2:20 Chris Gammons. *Macrophyte beds influence diurnal streamflow patterns in late summer*

2:40 *BREAK & POSTER SET UP*

### SESSION 2 (Concurrent) *Empire Builder Room*
### SCIENCE, POLICY AND COMMUNICATION

Moderator: Joanna Thamke -- *USGS*

12:40 pm Michael Downey. *The Flash Drought of 2017 - What Happened and What It Means Looking Forward.*

1:00 Ron Spoon. *Integration of Water Resource Data and Assessments of Fishery Health: Does Drought Impact Montana's Fishery Resource?*

1:20 Eric Trum. *Linking Knowledge with Action: the role of locally based conservation organizations.*

1:40 Mike Koopal. *Aquatic Invasive Species (AIS) Risk Management at a Local Level: The Whitefish AIS Management Program.*

2:00 Melissa Schaar. *Harmful Algal Blooms (HABs): A Montana Lesson in Communication.*

2:20 Micaela Young. *Blackfeet Nation Agriculture Resource Management Plan: Water Policies and Procedures*

2:40 *BREAK & POSTER SET UP*

### SESSION 3 (Concurrent) *Western Star Room*
### FORESTRY

Moderator: Lauren Alleman -- *Montana Aquatic Resources Services, Bozeman*

3:00 pm Brian Sugden. *Estimated Sediment Delivery Reduction with Forestry Best Management (BMP) Road Upgrades in Western Montana.*

3:20 Meryl Storb. *Quantifying the timing of key hydrologic thresholds in mountain sreams and evaluation of changes in threshold timing over the past century.*

### SESSION 4 (Concurrent) *Empire Builder Room*
### GROUND WATER

Moderator: Attila Folnagy -- *Department of Natural Resources and Conservation, Helena*

3:00 pm John LaFave. *Montana in the National Ground-water Monitoring Network.*

3:20 Katie Luther. *GWUDISW: No, it's not a French Cheese.*

3:40 Willis Weight. *Numerical Groundwater Flow Model of the Middle and Lower Flathead Valley, Kalispell, Montana.*

4:00 James Swierc. *Ground Water Depletion in Helena Area Aquifers*

3:40 Amy Jensen. *Overview of USDA Forest Service National Best Management Practices Program and Status of Monitoring Efforts.*

4:00 Robert Livesay. *Effect of bedrock permeability on saturated soil flow response and streamflow generation across two semi-arid headwater catchments.*

4:20 Jeff Schmalenberg. *Instream Turbidity Effects of Various Forest Management Activities in Western Montana*

4:20 Florence Miller. *Strontium and uranium isotopes suggest changing water storage and groundwater exchange along a mountain stream (Hyalite Canyon, Montana)*

4:40 Payton Gardner. *Exploring Topographic and Lithologic Controls of Bedrock Recharge on Hillslopes*

## POSTER SESSION

***Oriental Ltd. Room***

5:00 – 7:00 pm AWRA 2017 POSTER PRESENTATIONS

1. Barry Adams. *Establishment of a baseline groundwater-quality monitoring program in an area of current and proposed energy development on the Blackfeet Reservation, Montana.*
2. Kelsey Anderson. *Development and Application of a Centralized Water Monitoring Resource Website.*
3. Leah Bellus. *Understanding Strategies to Increase Volunteer Retention for the Gallatin Stream Teams Program.*
4. Matt Berzel. *Tracking potential leakage of tailings-lake water into background groundwater in Butte, Montana, using geochemical and stable isotope tracers.*
5. Melissa Brickl. *Surficial Depressions and their Surface Water Inflows and Outflows: Windows into the Shallow Aquifer along the East Flathead Valley.*
6. Camela Carstarphen. *Groundwater Quality of the Intermontane Basins, Gallatin and Madison Counties, Southwest Montana.*
7. DeAnn Dutton. *Estimated Water Use in Montana in 2015.*
8. Christine Eggensperger. *Membrane Distillation Increases Copper Sulfate Concentration in Contaminated Waste Streams Prior to Further Enrichment.*
9. Derek Goble. *Groundwater stream-water interaction study using 222Rn, CFC's and SF6 in a uranium contaminated aquifer near Riverton, Wyoming.*
10. Torie Haraldson. *Water Quality of the East Gallatin River in Bozeman, Montana.*
11. Christine Miller. *Gallatin County Public Water Supply Nitrate .*
12. Charles Shama. *Mountain Front Recharge in a semi-arid climate; Southwest Montana.*
13. Shanny Span Gion. *Investigation of hydrology and water quality in the Lame Deer Creek watershed, Northern Cheyenne Indian Reservation, Montana.*
14. Isabellah von Trapp. *A multiple tracer approach to separating soil water from groundwater in a headwater catchment.*
15. Ian Cavigli. *Putting Landowners and Managers in the Driver's Seat: The Montana Conservation Menu.*
16. Jennifer McBroom. *Helena Valley re-watering/ restoration project on Prickly Pear Creek.*
17. Caelan Simeone. *An examination of drought-induced hydraulic stress in conifer forests using a coupled ecohydrologic model.*
18. Samuel Box. *Impacts of vegetation growth on reach-scale flood hydraulics in a sand-bed river and the implications for vegetation-morphology coevolution.*

## THURSDAY, OCTOBER 17, 2017 (continued)

19. Jessica Simkins. *Hydroelectric Pumped Storage and Fish Diversion in Montana.*

20. Jessica Makus. *Ranching for Rivers.*

21. Megan Moore. *Public Perceptions of Natural Water Storage in Montana.*

22. Chris Gammons. *Macrophyte beds influence diurnal streamflow patterns in late summer.*

### SOCIAL HOUR AND BANQUET

5:00 - 7:00 pm SOCIAL HOUR, Oriental Ltd. Room

7:00 BANQUET (extra cost, must be registered), Western Star and Empire Builder Rooms

7:40 Special Speaker: Water Legend Induction

8:10 Photo Contest

(Closing Comments and Announcements)

## FRIDAY, OCTOBER 20, 2017

7:30 am Gather for Coffee and Conversation with Colleagues

### SESSION 5 (Concurrent) RESTORATION — *Western Star Room*

Moderator: Brian Sugden -- *Weyerhauser Company, Kalispell*

8:00 am Lauren Alleman. *Compensatory Mitigation for Streams & Wetlands in Montana with In-Lieu Fee.*

8:20 Bruce Anderson. *Stream Permitting Guide, a pragmatic approach to project design.*

8:40 Amy Chadwick. *Can We Use Low-Cost Restoration Techniques to Improve the Resilience of Water Supply Watersheds to Climate Change? (Preliminary Results and Lessons Learned).*

9:00 Andrew Bobst. *Effects of Beaver Mimicry Restoration on Stream Flows, Riparian Groundwater Levels, and Water Temperatures.*

9:20 Christine Brissette. *Stream restoration effects on storage and baseflow generation, Ninemile Creek, MT.*

### SESSION 6 (Concurrent) WATER QUALITY — *Empire Builder Room*

Moderator: Tammy Swinney -- *Gallatin Local Water Quality District*

8:00 am Christoper Ellison. *Evolution of Yellowstone River Sediment Monitoring in the Great Plains Region of the Upper Missouri River Basin.*

8:20 Stephan Warnat. *Microfluidic Systems in Environmental Monitoring.*

8:40 Katie Holsinger. *The Gallatin Microplastics Initiative: Engaging Outdoor Recreation Citizen Scientists in Watershed Monitoring of Microplastics to Affect Change.*

9:00 Kyle Flynn. *Clear as mud?: Evaluating turbidity in the Beaverhead River and Clark Canyon Reservoir.*

9:20 Thomas Henderson. *Mine Reclamation Activities Improve Water Quality in Yellowstone's Soda Butte Creek.*

9:40 Kristin Richardson. *LWD Reintroduction in Cedar Creek: Going Big for Bull Trout Strongholds!*

10:00 *BREAK*

**SESSION 7 (Concurrent)** ***Western Star Room*** **WATER DATA SYSTEMS AND INFORMATION**

Moderator: John LaFave -- *Montana Bureau of Mines and Geology; Montana Water Center*

10:20 am Maya Daurio. *The Foundation for the Water Information System: A Discussion of Hydrography Dataset Editing in the Musselshell Watershed.*

10:40 Troy Blandford. *Towards an improved Water Information System: Linking information to Montana's statewide hydrography dataset.*

11:00 William George. *Climate Change Impacts on the Hydrological Processes of Silver Bow Creek, MT.*

11:20 Jim Beck. *The Importance of Water Rights*

11:40 Luke Buckley. *User-Centered Design: Best practices to effectively deliver Montana surface water data*

12:00 Michael Pipp. *FACTS: MT DEQ's Web-Based Water Discharge Permitting System*

9:40 Elizabeth Meredith. *Characterizing water resources around oil and gas development*

10:00 *BREAK*

**SESSION 8 (Concurrent)** ***Empire Builder Room*** **MODELS, WATER QUALITY AND GEOCHEMISTRY**

Moderator: Chris Kelley -- *Montana Dept of Agriculture*

10:20 am Wondmagegn Yigzaw. *Representing Reservoir Stratification in Land Surface and Earth System Models.*

10:40 Roy Sando. *Annual PRObability of Streamflow PERmanence (PROSPER) in the Pacific Northwest, 2004-2016.*

11:00 Liping Jiang. *Cisco refuge lake study in Minnesota lakes using constant survival limits.*

11:20 Adam Sigler. *Soil architecture versus management as controls on nitrate leaching.*

11:40 Christina Eggensperger. *Membrane Distillation Increases Copper Sulfate Concentration in Contaminated Waste Streams Prior to Further Enrichment.*

12:00 Guta Abeshu. *Catchment-scale water-carbon coupling across the contiguous United States: A data-based analysis.*

**CLOSING PLENARY** ***Western Star Room***

12:30 pm CLOSING PLENARY

Announcements - New Officer, Student Awards, Next Year's Location

1:00 pm ADJOURN

**MT GROUNDWATER CHARACTERIZATION COMMITTEE MEETING** ***Location To Be Announced***

1:00 pm Ground Water Assessment Program Steering Committee Meeting

## KEYNOTE SPEAKER

**Tom Livers**

Director, Montana Department of Environmental Quality
1520 E. 6th Avenue
Helena, MT 59601
Phone: (406) 444-6815; Email: TLivers@mt.gov

Tom Livers was appointed director of the Montana Department of Environmental Quality in November 2014 by Governor Steve Bullock. He served as the department's deputy director for 12 years. Prior to that he headed the department's Technical & Financial Assistance Bureau, and the Conservation & Renewable Enegy Bureau at the Montana Department of Natural Resources & Conservation. He spearheaded development of the Drinking Water State Revolving Fund and the State Buildings Energy Conservation Bond Program, and served as the State of Montana's incident commander on the Silvertip oil spill in 2011.

**Abstract:** ***Observations and Perspectives on Science and Public Policy Development***
Science is an important factor in many public policy decisions, but seldom is the sole driver. Livers will offer his observations and perspectives on the interplay of science, economics, and other factors in public policy development.

## KEYNOTE SPEAKER

**Robert T. Lackey, Ph.D.**

Professor, Department of Fisheries and Wildlife
Oregon State University, Corvallis, Oregon 97331
Phone: (541) 737-0569 (office); (541) 602-5904 (cell)
Email: Robert.Lackey@oregonstate.edu

Dr. Bob Lackey is professor of fisheries science at Oregon State University. In 2008 he retired after 27 years with the Environmental Protection Agency's national research laboratory in Corvallis where he served as Deputy Director, Associate Director for Science, and in other senior leadership positions. Since his very first fisheries and wildlife job mucking out raceways in a California trout hatchery, he has worked on an assortment of environmental and natural resource issues from various positions in government and academia. His professional assignments involved diverse and politically contentious issues, but mostly he has operated at the interface between science and policy. He has published over 100 articles in scientific journals and is a fellow of the American Fisheries Society and the American Institute of Fishery Research Biologists. Dr. Lackey has long been an educator, having taught at five North American universities and currently teaches a graduate course in ecological policy at Oregon State University. Canadian by birth, he is now a U.S.-Canadian dual-citizen living in Corvallis, Oregon.

**Abstract:** ***Water Resource Management and Science: A Practitioner's Guide to Identifying Advocacy Masquerading as Science***
Policy advocacy by scientists and journalists (particularly "advocacy masquerading as science") is commonplace. Nowadays, many people expect that the scientific information they read or hear is infused with hidden policy preferences. Worse, other readers and listeners are unaware of the inherent policy bias in some scientific information. Using such "science" (i.e., advocacy or normative science) in policy deliberations is not merely policy advocacy, but it is stealth advocacy. Scientific information must remain a cornerstone of public policy decisions about water resource and other natural resource issues, but I offer cautionary guidance to scientists: become involved with policy issues and deliberations, but play the proper role.

## SPECIAL SPEAKER

**Jason Mohr**

Research Analyst, Legislative Environmental Policy Office
Room 171, State Capitol
Helena, MT 59620-1704
Phone: (406) 444-1640
Email: JMohr@mt.gov

Jason Mohr has been a research analyst with the Legislative Environmental Policy Office since 2009. He previously worked as a performance auditor and journalist. Jason grew up in Colorado; he has earned degrees in chemistry and journalism.

**Abstract:** ***Legislative Update***

## WORKSHOP FACILITATOR

**Susan Gilbertz**

Professor of Geography and Environmental Studies
Montana State University Billings
Phone: (406) 657-2183
Email: sgilbertz@msubillings.edu

**Background**: Susan grew up on a cattle and bison ranch in northeastern Wyoming. She attended small, rural schools through the 8th grade and graduated high school in Gillette.

**Education and Research**:
She earned bachelors and master's degrees in communication from the University of Wyoming. Later she earned her Ph.D. in Geography from Texas A&M University, and in 2003 she joined the faculty at Montana State University Billings. She studies how individuals become attached to particular places and how those attachments influence environmental philosophies and actions. As the principle investigator for the project, "The Yellowstone River Cultural Inventory" she oversaw scores of interviews with people living near the Yellowstone River. Two hundred of those recorded interviews are now archived with the Western Heritage Center of Billings, MT, an affiliate of the Smithsonian Institution. Now, as a senior research professor, she is working with colleagues who study the interfaces between water availability, water quality, public participation in governing shared resources and risk perceptions. Her teaching and research interests have taken her to China, Indonesia, Italy, France, Germany, Luxembourg and Oman.

**Workshop Abstract**: ***Science and Public Collaboration***
Based on detailed analyses of over 10 years of collaborative efforts in the Yellowstone River valley, this workshop reviews how and why citizen groups "sideline" science in their deliberations. Attendees will engage in actively strategizing and critiquing how to keep science as a central component in collaborative processes. The workshop exercises will result in a set of recommendations and guidelines that will later be made available to the group.

### Estimating Daily Streamflow Where No Streamgages Exist In Montana and Across the United States

*Katherine Chase, USGS WY-MT Water Science Center, 3162 Bozeman Ave, Helena, MT 59601, kchase@usgs.gov.*

Data from streamgages help engineers, water resources managers, scientists, and others to better understand water availability and ecological characteristics of streams and watersheds. Annual, seasonal, and monthly streamflow statistics can be calculated from USGS streamgage data; these statistics can be related to basin and stream channel characteristics to develop regression equations to estimate streamflow statistics at locations without streamgages. However, at locations without streamgages, estimates of daily streamflow are essential for understanding historical streamflow variability and for calculating streamflow statistics for which regression equations have not been computed. Daily streamflow at locations without streamgages is generally more difficult to estimate than annual, seasonal, and monthly statistics. The U.S. Geological Survey's (USGS's) Water Availability and Use Science Program (WAUSP) is developing new water accounting tools and assessing water availability at regional and national scales, with the goal of helping to build decision support capacity for water management agencies and other natural resource managers. One of these new tools, the USGS National Hydrologic Model (NHM), provides long-term historical and future estimates of the hydrologic cycle at a daily time step across the continental United States. This presentation will focus on methods and data being used to develop, calibrate, and evaluate the USGS NHM and to estimate daily streamflows where no streamgages exist. Other components of the hydrologic cycle that can be simulated using the USGS NHM, as well as USGS portals that serve observed and simulated streamflow data, also will be discussed.

### Applied paleohydrologic information for improved water management in the Upper Missouri Basin

*Justin Martin, U.S. Geological Survey, U.S. Geological Survey, 2327 University Way (Suite 2), Bozeman, MT 59715, justinmartin@usgs.gov. Additional authors: Gregory T. Pederson (USGS), Connie A. Woodhouse (Univ of AZ), Marketa MacGuire (USBR), Jordan Lanini (USBR), Daniel Broman (USBR), Patrick Erger (USBR), Larry Dolan (DNRC), Subhrendu Gangopadhyay (USBR), Gerald Benock (USBR).*

The Upper Missouri River Basin (UMRB) is the only major watershed in the western U.S. for which hydrologic reconstructions from tree rings have not been systematically generated. This knowledge gap is critical given that the region is facing an array of water resource issues that are challenged by climate change and natural hydrologic variability, and has experienced both severe floods and droughts in the recent past. Providing a longer context for understanding past flow variability is critical for anticipating and managing future water supplies. Here we present recent progress in a collaborative research project with the U.S. Bureau of Reclamation (USBR) and Montana Department of Natural Resources and Conservation (DNRC) that seeks to address this data and knowledge gap. Working with stakeholders and water managers, we co-designed research objectives; identifying 21 major UMRB gages that allow for characterizing historical natural streamflow in the basin, and targeting information that would span changes in streamflow over the past 1200 years. Reconstructions were statistically disaggregated to daily flows and routed through the USBR and DNRC constructed RiverWare operations model to test current operational rules against the sequence of historic flood and drought events. In conjunction with future hydrologic scenarios, information generated from this study is intended to help guide operational improvements and assess water management options for adapting to severe drought and flood conditions. Strengths and limitations of this effort will be discussed along with lessons learned for future work.

### Understanding Water-Energy-Ecology Nexus from an Integrated Earth-Human System Perspective

*Hong-yi Li, Montana State University, 334 Leon Johnson Hall, Bozeman, MT 59715, (406) 457-5929, hongyi.li@montana.edu.*

Both Earth and human systems exert notable controls on streamflow and stream temperature that influence energy production and ecosystem health. An integrated water model representing river processes and reservoir regulations has been developed and coupled to a land surface model and an integrated assessment model of energy, land, water, and socioeconomics to investigate the energy-water-ecology nexus in the context of climate change and water management. Simulations driven by two climate change projections following the RCP 4.5 and RCP 8.5 radiative forcing scenarios, with and without water management, are analyzed to evaluate the individual and combined effects of climate change and water management on streamflow and stream temperature in the U.S. The simulations revealed important impacts of climate change and water management on hydrological droughts. The simulations also revealed the dynamics of competition between changes in water demand and water availability in the RCP 4.5 and RCP 8.5 scenarios that influence streamflow and stream temperature, with important consequences to thermoelectricity production and future survival of juvenile Salmon. The integrated water model is being implemented to the Accelerated Climate Modeling for Energy (ACME), a coupled Earth System Model, to enable future investigations of the energy-water-ecology nexus in the integrated Earth-Human system.

**Missouri Headwaters Impact Assessment and Basin Study**
*Larry Dolan, Montana Department of Natural Resources and Conservation, 1424 9th Avenue, Helena, MT 59620, (406) 444-6627, ldolan@mt.gov. Additional Authors: James Heffner (DNRC), Marketa McGuire (USBR), Jordan Lanini (USBR), Daniel Broman (USBR).*
The Montana Department of Natural Resources and Conservation (DNRC) and U.S. Bureau of Reclamation (Reclamation) are working collaboratively on the Upper Missouri Basin Impacts Assessment (UMBIA) and subsequent Missouri Headwaters Basin Study (Basin Study) which encompass the entire Missouri and Musselshell River watersheds upstream of Fort Peck Reservoir. We are conducting these studies through the Department of the Interior WaterSMART Program in which federal water and science agencies work together with state and local water managers to plan for a range of future water supplies and to take action to secure water resources for the communities, economies, and ecosystems that they support. In addition to understanding future change, we also seek to understand historical variability in the basin's water resources over the past 1100 years through collaborations with U.S. Geological Survey researchers, who are developing the first hydrologic reconstructions from tree rings for this region. For the UMBIA, we have developed a RiverWare operations model to test current rules for river operation as well as water uses under hydrologic conditions over the instrumental historical record, the paleo record based on tree rings, and projected future conditions. In the Basin Study, we are building on this information and working with basin stakeholders to identify and evaluate potential adaptation strategies to enhance Reclamation's ability to deliver water, to provide for hydropower generation, recreational benefits, fish and wildlife habitat, water quality, water-dependent ecological resiliency, and flood control management throughout the system. We will provide context for the two ongoing studies and discuss preliminary findings.

**The Big Flood on Tenmile Creek--Not That One; the BIG One**
*Chuck Parrett, Retired USGS, 5235 Creekside Lane, Helena, MT 59601, (916) 813-1663, chuckparrett@yahoo.com. Additional Authors: Mike Cannon (Retired USGS), Jim Hull (Retired USGS)*
Tenmile Creek is a mountain stream that rises on the eastern flank of the Continental Divide about 18 miles southwest of Helena, Montana. From its headwaters to a narrow gorge about one-half mile upstream from the Tenmile Water Treatment Plant near Highway 12, the stream flows about 12 miles through steep, forested mountains. Downstream from the narrow gorge, the stream gradient decreases and the stream valley widens. The drainage area for Tenmile Creek at the water treatment plant is about 53 square miles. Though small in size, Tenmile Creek supplies about half of the municipal water supply for Helena. Because of its importance as a source of municipal water, Tenmile Creek has had a USGS streamflow gage in operation (station 06062500) downstream from Rimini (drainage area of 33 square miles) for 100 years (1915-94; 1997-2016).
The long period of flow record at station 06062500 shows that annual peaks are fairly stable from year to year, with 90 percent of all peaks ranging between 73 cfs and 403 cfs. Nevertheless, an extraordinarily large peak

flow occurred in 1981 that caused extensive property damage and widespread flooding in the Helena valley. The 1981 flood peak of 3,270 cfs was more than 3 times larger than the second largest peak in the record and was such a large outlier that determining its exceedance probability from a log Pearson 3 analysis of 100 years record is speculative. The 1981 flood peak at a discontinued stream gage on Tenmile Creek near Helena (station 06063000; drainage area of 100 square miles) was calculated to be 3,770 cfs. While the 1981 flood peak is by far the largest peak in the last 100 years, there is evidence of a larger flood that occurred probably 10-15,000 years ago when a glacier covered much of the upper Tenmile drainage area above the gage (station 06062500). This flood deposited numerous granitic boulders on the margins of the narrow stream valley just upstream from the gorge near the Tenmile Creek water treatment plant. To estimate the magnitude of this flood, we surveyed elevations of the tops of the deposited granitic boulders and assumed that the flood depths had to be about the same elevations as the boulder tops. We then surveyed a stream cross section and made minor adjustments to the cross section where it appeared that some infilling from a small, ephemeral tributary and some small irrigation ditch construction had occurred. We then assumed that the large flood flow would likely have been critical on this steep stream reach and used a critical-flow equation to calculate the flood discharge. Our calculation showed that the glacial flood discharge was about 7-8,000 cubic feet per second. This estimated flood discharge from thousands of years ago, though more than twice as large as the 1981 flood peak, suggests that the recurrence interval of the 1981 flood may have been significantly greater than 500 years.

### Macrophyte beds influence diurnal streamflow patterns in late summer

*Chris Gammons, Montana Tech, cgammons@mtech.edu. Additional authors: Robert Rader*

Depending on the time of year, many streams in Montana show diurnal streamflow patterns. In late spring and early summer, rivers that drain mountainous areas may swell late in the day due to melting snow and ice. In late summer, evapotranspiration by riparian vegetation (willows, cottonwoods) can intercept shallow groundwater on its way to the river, causing a reduction in streamflow during the day. Other diurnal patterns are human-caused, e.g., timed irrigation withdrawals or releases of treated municipal wastewater. Aquatic plants are another, often-overlooked factor that can influence diurnal streamflow patterns. We present the results of diurnal streamflow measurements at the mouth of Blacktail Creek, in Butte, Montana (USGS gaging station #12323240), collected in the first week of August 2016 and August 2017. During both of these time periods, diurnal changes in streamflow were exceeding 100%: that is, flow more than doubled between early morning and late afternoon. However, based on our own streamflow measurements with a Marsh-McBirney meter, the actual magnitudes of the flow cycles were much less, and we observed considerable hysteresis in the 24-h stage-discharge rating curve. These observations are explained as follows. During the day, photosynthesis caused an abundant crop of aquatic macrophytes (river buttercup and other species) to "inflate". The greater cross-sectional area of vegetation caused the river velocity to slow down and its stage to increase. In the evening, in response to a decrease in sunlight, the macrophyte beds "deflated", releasing much of the stored water and resulting in maximum measured flows near midnight. Drainage of the stream continued all night, with the lowest stages and streamflows recorded near 8 AM. The cycle repeated the next day, and so on. Although the influence of macrophytes is probably negligible at most gaging stations, we have noted impacts of vegetation on streamflow patterns at other streams in southwest Montana, including the Big Hole River at Mudd Creek (reported in a 2009 Geological Society of America presentation by David Nimick of the USGS), and Silver Bow Creek below Warm Springs Ponds. The implications of this phenomenon to monitoring of streamflow, stream chemistry, and contaminant loads are discussed.

## SESSION 2 SCIENCE, POLICY AND COMMUNICATION

### The Flash Drought of 2017 – What Happened and What It Means Looking Forward

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Much of Montana experienced record drought conditions this summer. Numerous weather stations in northeast Montana, some with more than 100 years of record, documented the driest conditions ever in June, July and August. Many crops in eastern Montana failed to germinate at all and for those that did many were harvested for hay because summer precipitation was too low to produce a grain crop. In the west, the big story was a wildfire season that burned over 1.1 million acres and ranks as the third highest in acres burned behind the 3 million in 1910 and 1.3 million in 1988. Interestingly, these events are set in the backdrop of a high and in some cases record snow pack and exceptional soil moisture headed into last spring. The drought of 2017 is exceptional because the indicators that we use to evaluate hydrologic and agronomic conditions failed to alert us to the situation until it was well upon us. It is not that the experts read the data incorrectly or fell asleep at the wheel. The problem was that a combination of factors mostly related to precipitation timing and temperature combined to create conditions that deteriorated much more quickly than most of us, including our predicative models, could ever have guessed. 2017 has illustrated what many of our climate scientists have warned about for years. The issue of precipitation timing and its effect upon the landscape. Most of the predictive climate models for Montana indicate that we are likely to get quite a bit warmer and a bit wetter in the future. That does not sound so bad until we consider the effect of precipitation timing in the context of that scenario. A large percentage of Montana's precipitation comes as snow in the high elevations and as rain in April, May, June, and July. 2017 saw a shift in that precipitation to October, December, January and February. As the water year goes, amounts accumulated in 2017 were mostly average. However, due to a shift in precipitation timing, Montana experienced record drought and the worst fire season in 30 years. The implications for Montana's landscape considering this phenomenon are at best concerning and at worst downright alarming.

**Integration of Water Resource Data and Assessments of Fishery Health: Does Drought Impact Montana's Fishery Resource?**

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Fisheries management in Montana is extensively based on fishery monitoring conducted by Montana Department of Fish, Wildlife & Parks. Decision-makers and the general public understand that healthy fisheries probably need a healthy water supply. However, when water becomes limited, how do fisheries managers provide information on how much water is needed for fishery protection? Fishery and streamflow data is presented for twelve major river systems in Montana. Fisheries can respond relatively quickly to changes in their environment, including low streamflow during drought. However, many other variables impact fisheries response creating a challenge to isolate fisheries response to water conditions. Modeling fish/flow relationships can be difficult. This paper explores methods to communicate water needs that attempt to satisfy both technical professionals and the general public. A simple approach to presenting the relationship between drought and fisheries response is displayed by observing two major droughts in the last 35 years. Improved understanding of fish/flow dynamics regarding Montana's rivers and stream is needed to implement projects that protect existing water uses while ensuring the long term health of aquatic life. Current constraints in balancing water management decisions are explored in this presentation, and improved communication regarding fishery issues is intended to improve future decisions regarding allocation of Montana's water resource.

**Linking Knowledge with Action: the role of locally based conservation organizations**

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The key to linking knowledge with action is having information and solutions that are salient, credible, and legitimate. Scientists, policy makers, and resource managers have traditionally focused on increasing the credibility of the science. However, without local buy in and relevance (salience) or a fair process that involves the necessary people (legitimacy) it is harder to translate the knowledge into action. Credible science has an obvious role to play in improving water quality restoring more natural stream and riparian conditions across the state. DEQ conducts water quality assessments, identifies causes and sources of impairment, and provides technical and financial support for addressing these issues. In a state as large as Montana, DEQ and other agencies rely on local conservation organizations (watershed groups, conservation districts, etc.) to implement projects that are scientifically credible but also have local buy in. I will focus on the role of local conservation organizations in working with scientists, agencies, and resource managers to increase the local salience and legitimacy of their work to increase use.

**Aquatic Invasive Species (AIS) Risk Management at a Local Level: The Whitefish AIS Management Program**

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Whitefish Lake is a highly prized recreational waterbody located at the headwaters of the Columbia Basin and provides municipal drinking water to the residents of Whitefish. An Aquatic Invasive Species (AIS) infestation in Whitefish Lake could impact the local economy, affect water quality and native aquatic species, jeopardize municipal drinking water infrastructure, and increase the potential for infestations in downstream waterbodies via drift. Since 2013, the Whitefish Lake Institute (WLI) has recommended a local AIS Management Program to the City of Whitefish to prevent the introduction and spread of AIS to local lakes. Each year, the City of Whitefish has approved the program and has provided a funding commitment. The program focuses on early detection monitoring for dreissenid mussels and Eurasian watermilfoil (EWM) via microscopy and/or eDNA analysis, early detection macrophyte surveys, control and eradication of EWM in Beaver Lake, a watercraft inspection and decontamination program, and an annual program report. In 2017, the watercraft inspection program was amplified based on the Montana FWP announcement in late 2016 that zebra mussels were found east of the Continental Divide. The City of Whitefish passed an Ordinance requiring watercraft to be inspected prior to launch in Whitefish Lake and signed an MOU with the state of Montana for program operations Watercraft inspection stations were expanded at the only two major access points; City Beach and Whitefish Lake State Park. The staffed inspection season at the stations now run from May 1-September 30 with an on-line self-certification for non-motorized hand launched vessels, and for all watercraft during the non-staffed season. Due to congestion and traffic patterns issues at the major access points, the program expedites the inspection process by offering exit seals to watercraft users as they leave the lake. Users can then re-enter Whitefish Lake without the need for an inspection if they have an intact seal. A decontamination station at an off-site location was established for high risk watercraft that are defined through an approved algorithm. Other funding partners for the Whitefish AIS program include Montana DNRC, Montana FWP, the Whitefish Community Foundation, and private donors. WLI also coordinates AIS early detection monitoring on over 40 lakes in four northwest Montana counties via the Northwest Montana Lakes Volunteer Monitoring Network, a partnership with Montana FWP.

**Harmful Algal Blooms (HABs): A Montana Lesson in Communication**

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Harmful algal blooms (HABs) occur when indigenous cyanobacteria in the water multiply quickly to form visible colonies or blooms. These blooms sometimes produce potent cyanotoxins that pose serious health risks to humans and animals. Until recently, Montana has not experienced a sizeable number of HABs, thus has not allocated resources to a HAB program. The reality is that standing bodies of water exposed to sun, e.g., lakes, reservoirs, stockponds, and roadside ditches have the potential to develop HABs in Montana. Due to changing climatic conditions, HABs are increasingly likely throughout much of the state as well as the country.

**Blackfeet Nation Agriculture Resource Management Plan (ARMP): Water Policies and Procedures**

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An abundance of surface water runs through the Blackfeet Reservation from tributaries originating on the east face of the Continental Divide in Glacier National Park and the Rocky Mountain Front. The largest watercourses include the Milk River, Cut Bank Creek, Saint Mary River, Two Medicine River, and the Marias River. There are also vast networks of smaller streams distributed throughout the reservation, most of which are part of the Missouri River drainage system. The rivers provide a year round source of water for irrigation, livestock, and domestic needs. For over 30 years, the Blackfeet Tribe worked to establish jurisdiction and control of water resources on and throughout the Blackfeet reservation. One of the most important developments, the passage of the Blackfeet Water Rights Compact, came to pass when President Obama signed the bill into law on December 16, 2016. The Compact provides for federal approval of the Compact as well as $422 million (in addition to a state contribution of $49 million) in funding for water-related projects on the Reservation. Complementary to the Compact is the Agriculture Resource Management Plan (ARMP), also developed by the Tribe in consultation with Northern Engineering. The ARMP provides for a comprehensive inventory of all available tribal resources including lands, waters, infrastructure, and built environments to aid in planning for the future management of these resources as well as initiate tribal economic development. Changes in legislation facilitated comprehensive planning efforts which in turn calls for changes in policies and procedures and potentially, related laws. The Tribe has elected to utilize an integrated human-ecological approach, or Integrated Water Resources Management (IWRM) process to develop water policies and procedures and for future projects funded by the Compact. Successful IWRM approaches cited to date, especially those employed on tribal lands typically rely on a combination of Western science and Traditional Ecological Knowledge (TEK) to accomplish their goals. The combination of these perspectives has proven to be a powerful mechanism for resource management in the 21st century. Similarly, the Tribe will adopt and implement a modified IWRM framework to accomplish their objectives. Given this proposed approach, key personnel with an appreciation for combined perspectives will develop and test policies, procedures, and projects against the principles of IWRM at the fore, which are: (1) Manage water sustainably; (2) Coordination is required for integration; (3) Encourage public participation; (4) Resources are connected; (5) Reclaim indigenous space. The practice of policy review and development is relatively well established (although typically managed through top-down approaches) and standards for this common practice will be modified by principles of IWRM and guidelines for reclaiming indigenous spaces. After all, the implementation of the Blackfeet Water Rights Compact is a decolonizing process as the Tribe reclaims not only geographic space, but also intellectual and political space. As part of my doctoral dissertation, this project will (1) evaluate the manner in which the Blackfeet Tribe modifies the principles and practices of IWRM to suit their own purposes, (2) reclaims indigenous spaces, both geographic and intellectual, and (3) develops projects under a modified IWRM that reflects their values and objectives. This will be accomplished through an action research process whereby as a member of the Blackfeet Tribe Interdisciplinary Water Planning Team, I will engage directly in the process of IWRM development and implementation. Through a Deleuzian analytical framework (A Thousand Plateaus: Capitalism and Schizophrenia, Gilles Deleuze and Felix Guattari) I will observe the process, conduct qualitative interviews, and map the micropolitical coding and recoding of indigenous spaces. Outcomes, which include an analysis of the projected efficacy of a modified IWRM on tribal lands, will be submitted as a co-written article with the Tribe to the American Water Resources Association, Water Resources Impact journal.

## SESSION 3 FORESTRY

### Estimated Sediment Delivery Reduction with Forestry Best Management (BMP) Road Upgrades in Western Montana

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Biennial state monitoring demonstrates that forestry Best Management Practices (BMPs) are widely applied across Montana. However, many roads in use today were constructed prior to state BMPs being formally adopted in 1989. Over the nearly 30 years that BMPs have been in place, Montana landowners have been progressively upgrading these old "legacy" roads to BMP standards. This commonly includes adding regular road surface drainage that disconnects roads from streams, and routes runoff into filtration areas. Other key BMPs include using road closure to increase roadbed vegetation, adding gravel surfacing, and use of supplemental filtration techniques (e.g., slash filter windrows) near streams. To reduce cost, and be a source of funds, BMP upgrade work is often dovetailed with nearby forest management operations. In some cases, roads that are stream-adjacent or pose other environmental risks that cannot be fully mitigated "in-place" with BMPs have been decommissioned. Numerous sediment TMDLs developed by Montana DEQ in forested watersheds over the past decade have set reduction targets for forest roads. However, few studies in this region are available to help evaluate the watershed-scale sediment reduction benefits with road BMP upgrading. This presentation summarizes a study to estimate reduction in sediment delivery reduction from road surface erosion with road BMP upgrades on Weyerhaeuser (formerly Plum Creek) lands in western Montana since the mid-1990. Ten watersheds had baseline inventories in the mid-1990s that were used to populate the Washington Road Sediment Model (WARSEM). These watersheds were then re-inventoried and modeled using WARSEM in 2005 and 2010 after BMP upgrades had been completed. An additional 22 watersheds in western Montana were inventoried and modeled after BMP upgrades had been completed. Key findings of this work are that estimated mean sediment delivery was reduced by 46% with BMP upgrades. Furthermore, the estimated delivery rates with BMPs are in place may represent less than five percent of background sediment loading rates in these watersheds. This work also found that the majority of estimated watershed-scale delivery occurred at a minority of stream crossings, which implies that on-the-ground surveys are needed to identify and prioritize BMP upgrading or maintenance needs. This study has several important limitations and sources of uncertainty that are also discussed.

**Quantifying the timing of key hydrologic thresholds in mountain streams and evaluation of changes in threshold timing over the past century**

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Climate change appears to be shifting the timing and type of precipitation in parts of the intermountain west. This shift is leading to a greater fraction of annual precipitation falling as rain at high elevations, which reduces storage in snowpack and shifts the timing of snowmelt to earlier in the spring. Shifts in runoff timing have potential implications to water resource management and stream ecosystem functions. For example, earlier snowmelt may lengthen the algal growing season, altering the annual budgets of aquatic biogeochemical processing. Several studies have suggested that snowpack is decreasing and runoff is occurring earlier; most have attributed these alterations to temperature changes and not shifting precipitation regimes. However, detecting trends in hydrographs is inherently difficult because these time series demonstrate variability at multiple frequencies that have potential to confound interpretation of trends in seasonal thresholds. We used the "significant zero crossings" (SiZer) approach to evaluate hydrologic hydrograph models with respect to time. SiZer generates a range of models with increasing levels (bandwidths) of smoothing, providing a robust assessment of the potential range of statistical interpretations for temporal trends of hydrograph inflections. SiZer analysis impacts the interpretation of trends by smoothing the noise in the data generated by conventional analysis of multimodal hydrographs. We applied SiZer to quantify timing of peak flow and start of the baseflow recession in annual hydrographs for several USGS gauges in montane regions of western Montana. This enabled us to evaluate trends in timing for hydrologic thresholds across the period of record for individual gauges. Our preliminary analysis for the Gallatin River suggests no clear evidence that the timing of hydrologic thresholds is changing from 1930 - 2016. However, the timing of hydrologic thresholds may be confounded by variability in the total snowpack volume from year to year. Decadal-scale trends in timing of spring snowmelt drivers may be shifting to earlier in the year once the variability in total annual discharge is accounted for. This study provides an objective perspective on how high-elevation watersheds are responding to climate dynamics, and has implications to understanding an important causal link between climate change and metabolic biogeochemistry in mountain headwaters.

**Overview of USDA Forest Service National Best Management Practices Program and Status**

**of Monitoring Efforts**

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The Forest Service has a long history of working with States and partners to carry out Best Management Practices (BMP) programs, including agreements with the U.S. Environmental Protection Agency and many States to use and monitor BMPs. These programs, however, are not standardized to allow efficient cross-regional application, evaluation, or reporting. The Forest Service's National BMP Program was developed to enable the agency to readily document compliance with the nonpoint source management strategy initially at regional and national scales, and eventually at the state and specific National Forest scale. This presentation summarizes the Forest Service's National BMP monitoring efforts and highlights several initial "lessons learned." Although Forestry BMPs have been monitored in Montana for over 25 years, the Montana BMP Field Review process is confined to only evaluating the effectiveness of BMPs during timber harvest operations. While the Forest Service actively participates in the state review processes, the Forest Service also undertakes or authorizes many activities that extend beyond forestry, such as recreation, fire, and mineral development. The Forest Service's National BMP monitoring efforts now provide standardized monitoring of BMP use and effectiveness on these other activities and many others, including instream restoration activities, range/grazing, road decommissioning, and water uses and developments. Potentially the most valuable result of the Forest Service's National BMP monitoring efforts is the establishment of requirements to engage and communicate with fellow staff in other program areas. Trained specialists from several resource areas are required to go into the field, review a project, and discuss what could have been done better at that site in order to complete the monitoring forms. They are also asked to brainstorm what changes could be made to improve processes within the program or on future projects for the benefit of protecting water quality. These standard, required questions established a protected space to verbalize and discuss potential areas and methods for improving water quality protection. While these facilitated discussions will never be scored or tracked in databases, they are critical to the success of nonpoint source management on National Forest System lands.

**Effect of bedrock permeability on saturated soil flow response and streamflow generation across two semi-arid headwater catchments**

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This study investigated the relative influence of local topography and subsurface lithology on hillslope saturated soil flow and streamflow response in two snowmelt dominated semi-arid catchments. We selected two adjacent catchments of differing lithology (Cretaceous granite and Precambrian meta-silt/sandstone) in Lubrecht Experimental Forest, MT and measured saturated soil flow, stream discharge and bedrock hydraulic properties during the 2017 water year. We utilized a network of 91 instrumented soil wells (< 1.5m in depth) installed across various landscape positions to monitor saturated soil flow in our two study catchments. We used rotary drilling techniques to collect 3 in-situ measurements of bedrock hydraulic parameters per catchment and recorded streamflow hydrographs for each catchments stream network. Preliminary results show that topographic metrics accurately predict the spatio-temporal occurrence of saturated soil flow across our study catchments. This presentation will discuss the hydrologic response of each catchment and link findings to our measurements of bedrock permeability. Findings from this study broaden our understanding of the connection between saturated soil zones and recharge to bedrock groundwater systems in semi-arid headwater basins.

**Instream Turbidity Effects of Various Forest Management Activities in Western Montana**

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The Montana Department of Natural Resources and Conservation, Forest Management Bureau has monitored continuous instream turbidity levels below various forest management activities for the past 8 years. The objective of these monitoring projects was to document; 1.) the magnitude and spatial extent of instream turbidity events associated with forest management projects, 2.) the effectiveness of timber sale mitigations and Best Management Practices (BMPs) and 3.) to inform adaptive management. The forest management activities that were monitored with continuous, instream turbidity sondes include; 1.) culvert removal, 2.) stream emulation culvert installations, 3.) fish passage barrier installation, 4.) temporary and permanent bridge installations and removals, 5.) channel restoration, and 6.) riparian buffer effectiveness following regeneration harvest and prescribed burning on steep slopes. Concentration-duration-frequency analysis was performed to describe the magnitude of instream turbidity events directly below project activities and, at some monitoring locations, the spatial extent downstream. Monitoring results have largely validated project level environmental effects assessments that forecast impacts to water quality that result from instream construction activities, such as culvert replacement. Impacts to water quality were found for very short durations and typically returned to background levels within 24 hours of instream activities. The spatial extent of downstream water quality impacts were localized at the reach scale and rapidly diminish as sediment plumes translate downstream. Results also demonstrate that timber sale mitigation measures, riparian buffers and BMPs are highly effective at mitigating effects to instream turbidity during timber harvest and instream construction activities. These findings have refined DNRC practices during instream construction activities and advised resource specialists in the design of timber sale mitigation measures, resulting in the reduction of water quality impacts during road-stream crossing construction. Future monitoring efforts hope to document annual turbidity signals at various watershed scales and management histories.

## SESSION 4 GROUND WATER

### Montana in the National Ground-Water Monitoring Network

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The Framework for the National Ground-Water Monitoring Network (NGWMN) calls for the use of existing state and local groundwater monitoring programs (SOGW, 2013). The Montana Bureau of Mines and Geology (MBMG) maintains a statewide groundwater monitoring network that collects water-level and water-quality data from Montana's principal aquifers—including the heavily-developed Intermontane Basins aquifers and the less-intensively-developed, but widely-used Alluvial, Lower Tertiary, Upper Cretaceous, Lower Cretaceous, and Paleozoic aquifers. Montana's network design is based on aquifer extents and development, and provides current data about long-term trends in groundwater storage and quality. The MBMG shares data through its Ground Water Information Center (GWIC) website (http:// mbmggwic.mtech.edu/), and web mapping applications. Data also are available through web services hosted on ESRI's ArcGIS Server or Geoserver. The MBMG selected its NGWMN wells based on the Framework Document and "Tip Sheet" guidance available from the NGWMN web page (http://cida.usgs.gov/ngwmn/learnmore.jsp ). Candidate wells had at least five years of water-level record and a monitoring frequency of at least quarterly. Other criteria included the aquifer extent, groundwater development, flow system position, and monitoring well density. The selection process identified 227 wells for inclusion in the NGWMN. Each well's hydrograph was evaluated against local hydrogeologic and land-use data to assign it to a Background, Suspected Changes, or Documented Changes subnetwork. Most wells show little-to-no anthropogenic influence and became part of the Background Subnetwork. Hydrographs with anthropogenic signals (Documented Changes subnetwork) showed: Seasonal irrigation recharge—mostly from the irrigated alluvial aquifers; seasonal irrigation withdrawals—mostly from the irrigated intermontane basins and buried glacial aquifers; long-term depletion—locally from the upper Cretaceous Fox Hills-Hell Creek aquifer system in eastern Montana. Data from Montana NGWMN wells are available through the NGWMN Data Portal (https://cida. usgs.gov/ngwmn/).

### GWUDISW: No, it's not a French Cheese

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The GWUDISW (groundwater under the direct influence of surface water) Rule was created by EPA as part of the Surface Water Treatment Rule in 1996. With more than 2200 public water systems in Montana, and an ever changing number of public drinking water sources (approaching 3000 at times), the process of determining the water-origin status of every active public water source in the state has been a long one. In the last four years the status of more than 1000 sources has been finalized, and six sources have been determined to be under the influence of surface water (four springs and two wells). One of the sources recently determined to be GWUDISW (in 2014) was Chico Hot Springs' cold water spring. Since the determination, the staff at Chico Hot Springs has done an outstanding job of responding to the newly revealed public health risk. They provided bottled water and purchased ice for the duration of the time required to install a surface water treatment plant, which was done in record time. This presentation will describe the GWUDISW Rule, the source at Chico Hot Springs, the situation that led to the GWUDISW determination, the new treatment plant, and some details about the process they went through.

**Numerical Groundwater Flow Model of the Middle and Lower Flathead Valley, Kalispell, Montana**

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An application was prepared for a proposed production well that would be used for a water-bottling plant in Kalispell Montana was given the status of preliminary determination to grant in January 2016. This provided the opportunity for concerned parties to object. Water For Flatheads Future (WFFF) was an objector to the proposed project based upon the well's potential impacts to the Shallow aquifer and connections with surface-water rights. The dispute was whether the production well was completed in the Deep Kalispell aquifer, or stratigraphically somewhere else. The MBMG has been doing extensive research in the area including drilling and preparing a geologic model. They have identified a Shallow aquifer, Confining Unit, an aerially limited intermediate aquifer, an Upper Deep aquifer, and Deep aquifer. My work shows the production well to be located within the upper part of the Upper Deep aquifer. Two geologic models were created during the construction of the numerical groundwater flow model: 1) a multi-layered model (MLM), of 20 or so layers; and 2) a simplified Layer Model (SLM), consisting of 8-layers. Over 1000 cross-sections were interpreted from more than 220 GWIC well logs. The MLM could not be converted into a numerical model at this time, as it pushed the limits of the GMS 10.2 software; however, the SLM was successfully converted into a numerical groundwater flow model, that appears to capture the groundwater flow system and serves as a useful tool. This presentation will articulate the conceptual and numerical model and provide examples of applications showing impacts to the Shallow aquifer and connections with the surface-water system. This will be of interest to anyone working in the Kalispell area.

**Ground Water Depletion in Helena Area Aquifers**

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Groundwater represents the primary potable water source in the Helena Valley and surrounding area. There are 3 general aquifer types developed as local water sources, comprising: 1. The high yield Helena Valley Aquifer; 2. Relatively fine-grained Tertiary basin-fill deposits, and 3. Fracture flow systems in bedrock outside the valley. Concerns over water levels and depletion have occurred since the drought of 2000-2001, when falling water levels resulted in the designation of a temporary controlled ground water area in the northern part of the Helena Valley. Subsequent studies showed that ground water availability was linked to local precipitation and streamflow patterns. At this time, the Lewis & Clark Water Quality Protection District expanded their monthly ground water level monitoring program to current levels, with monthly readings in over 120 area wells. Continuous water level monitoring pressure transducers at 31 locations around the area supplement the monthly measurements. Comparison of water levels with surface water runoff, irrigation patterns and precipitation characterizes the impact of different recharge sources to groundwater. A local potentiometric surface map reflects April 2011 conditions. Well hydrographs show several areas where water level elevations are inconsistent with regional patterns, showing depressions within the water table surface. These depressions coincide with changes in the water table surface as compared to the modeled groundwater surface presented in a 1992 USGS Report (Briar & Madison). Based on the water level hydrographs, two general types of depletion occur in the Helena area. For this study, depletion represents seasonally declining water levels which correlate with reduction in storage and available ground water for development. The assumed cause is from pumping ; however, irrigation methods have changed over time, with less flood irrigation, and this change may reduce the amount of irrigation water which reaches the water table. The first depletion type is considered long term, and reflects rates as slow as 1 foot/year or more, but with long term trends showing that yearly water level highs are declining over time. This this type of depletion reflects pumping from DNRC "exempt" wells where ground water availability is limited due to a lack of recharge. As a result, this type of depletion appears to represent declines in available storage in the local aquifer. Multiple "exempt" wells in the same aquifer show the combined effects of such pumping, with water levels declining at a rate of approximately 10 feet/year in a subdivision along the eastern margin of the Helena Valley. The second type of depletion is considered more short term, with more immediate effects. This depletion reflects pumping from public water supply wells which reflect relatively high rates of depletion; however, there is less data available to characterize these problems. At locations in the North Hills and the Southeast Valley, drawdown levels show depletion of more than 100 feet with apparent depletion rates exceeding 20 feet/year. These conditions reduce yields in some water supply wells, and may potentially cause "exempt" wells to go dry with landowners responsible for replacement.

**Strontium and uranium isotopes suggest changing water storage and groundwater exchange along a mountain stream (Hyalite Canyon, Montana)**

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The Rocky Mountain west is characterized by steep mountainous stream systems. Water storage and groundwater exchange during base flow conditions are important, but marginally understood features of mountain stream systems. Mountain stream, soil, and groundwater interconnectivity significantly influence stream discharge, solute composition, water quality, and alluvial-aquifer recharge; yet tracers of these connections have not been adequately developed. The objective of this project is to evaluate water storage and flow dynamics in soils, aquifers, and streams of the Upper Gallatin Watershed. A better understanding of hydrologic storage in mountain systems is critical to guide water management decisions, in light of changing precipitation patterns and the dependence of ecosystems and municipal/agricultural communities on late summer flows. As a case study for understanding the exchange between ground water and a mountain stream system, Hyalite Creek and its tributaries were longitudinally sampled four times in 2016 (February, May, July, August) and twice in 2017 (February, May). To address our objective, we are using strontium (Sr) and uranium (U) isotopic compositions as natural tracers of water-rock interaction. Longitudinally in Hyalite Canyon 87Sr/86Sr ratios reflect rock sources, that increase in age and Rb/Sr content from Tertiary volcanic rocks in the headwaters to Cretaceous to Cambrian age sedimentary rocks in mid-reaches and Archean gneiss in the lower reaches. In contrast, the 234U/238U Activity Ratio (UAR) is a function of water-rock interaction and reflects contact time and hydrochemical processes along a water flow-path. Together, UAR and 87Sr/86Sr data provide a powerful geochemical tool allowing evaluation of transitions in sources and ages of streamflow generation along watersheds with diverse bedrock. Concentrations of Sr and U and the Ca/Sr ratio increased downstream along Hyalite Canyon due to influxes from tributaries draining more soluble sedimentary rock units including secondary carbonates. Streamflow in Upper Hyalite Canyon has low 87Sr/86Sr values (~0.7085-0.7089), typical of the volcanic and sedimentary lithologic units it drains, and low UAR values (~1.5–1.7), consistent with relatively short flow path water (runoff and soil water). A transition in the mid-reaches of Hyalite Creek showed an unpredicted increase in UAR up to ~3 with no change in 87Sr/86Sr values. Increased UAR coincides with the lower extent of glaciation in the canyon, and is hypothesized to result from groundwater inputs having longer flow paths through glacial till or an expanding catchment area. A coupled increase in 87Sr/86Sr values (~0.7098-0.7120) and decrease in UAR (~1.7-2.1) in the lower reaches of Hyalite Creek suggest greater inputs of water from localized flow through Archean gneiss with high 87Sr/86Sr values. Within the lower canyon, these changes in isotopic composition occur with minimal change in discharge volume or solute concentration, suggesting that concurrent gains and losses of water of similar magnitude in the lower, steeper reaches of Hyalite Creek may be causing water and solute turnover. Isotopic data provided novel insight to the character of water storage and base flow generation along Hyalite Canyon, which serves as an input to the valley groundwater system and constitutes a large fraction of the Bozeman municipal water supply.

### Exploring Topographic and Lithologic Controls of Bedrock Recharge on Hillslopes

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Deep bedrock recharge controls groundwater dynamics in upland watersheds, determining how the watershed responds to climatic forcing, whether the watershed acts as carbon source or sink and plays a large role in water geochemical and nutrient cycles. Here, the relationship of soil, lithology, topography and bedrock recharge are explored using full Richards equation modeling of soil and deep-bedrock groundwater on hillslopes. Saturated and unsaturated flow in the shallow soil and underlying deep-bedrock are simulated on hillslopes using the high-performance computational software PFLOTRAN. The effect of topographic and lithologic characteristics in mediating groundwater recharge are explored using the fully coupled hillslope model. Topographic characteristics investigated include slope angle and hillslope length. Lithologic controls considered include the contrast between soil and bedrock saturated conductivity and capillary pressure parameters. Simulation results are used to identify basic relationships of location and volume of groundwater recharge, and partitioning between vertical recharge and slope-parallel soil flow as a function of hillslope characteristics. In addition, the effect of hillslope characteristics on subsurface residence time distributions is identified. These basic relationships are used to understand where and when deep-groundwater recharge occurs, constrain the relative volume of deep groundwater circulation in upland catchments, and how to use stream residence time distributions to identify contribution of deep-bedrock groundwater to streamflow. The results inform conceptual models of streamflow generation, deep groundwater recharge, and the groundwater dynamics in upland catchments across a variety spatial scales and locations.

## SESSION 5 RESTORATION

### Compensatory Mitigation for Streams & Wetlands in Montana with In-Lieu Fee

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Under Section 404 of the Clean Water Act Section and Section 10 of the Rivers and Harbors Act, unavoidable impacts to streams and wetlands must be compensated to ensure no net loss of ecological function. One option for compensatory mitigation is In-Lieu Fee (ILF). ILF is one of three choices for stream and wetland mitigation (in addition to mitigation banks and permittee-responsible mitigation). Montana Aquatic Resources Services (MARS) is a 501c3 non-profit organization that is approved to sell advance stream and wetland credits to permittees for unavoidable impacts to aquatic resources across the state's 16 Service Areas, which are based on watershed boundaries. MARS bundles credit sales together and then works with partners like land trusts and non-profits to identify projects that address the highest needs in the watershed where the impact(s) occurred. MARS is required to establish perpetual site protection through conservation easements or acquisition, monitor project performance, and grant endowments for long-term management. To date, MARS has made 9 credit sales in 8 of the state's 16 watershed districts. A novel form of ILF mitigation is MARS' Channel Migration Easement (CME) Program, which protects river migration corridors from channelization, bank stabilization, or actions that prevent it from natural erosional and depositional processes. CMEs can be funded through ILF credit sales or through federal and state grants. MARS has piloted two CME's along the middle and lower Yellowstone River with The Nature Conservancy and Montana Land Reliance. This model can be translated to other large river systems across the state and around the country.

**Stream Permitting Guide, a pragmatic approach to project design**

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During the process of developing a stream restoration policy, the interagency workgroup identified the Montana Stream Permitting: A Guide for Conservation District Supervisors and Others (Guide) as a key resource but one that required an update to better reflect the current state of restoration science and emphasize the need for limiting hardened structures. The Guide was published in 2001 to assist conservation districts and agencies in reviewing stream projects. It has served as a useful tool for CD supervisors and others reviewing 310 permit projects. The Guide will be updated based on scientific advancements and regulatory process changes. While the content will continue to serve conservation district supervisors and other permitting entities, the updates will also help inform landowners and the general public interested in stream management and restoration.

**Can We Use Low-Cost Restoration Techniques to Improve the Resilience of Water Supply Watersheds to Climate Change? (Preliminary Results and Lessons Learned)**

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Climate change models predict increasing drought for much of Montana, listing earlier runoff, reduced snowpack, longer growing seasons, and increased plant growth among the primary causes. Adding to the potential effects of reduced water supply, changes to Montana's headwater streams, such as extirpation of beaver, fire suppression, removal of large woody debris, riparian area degradation, and ensuing channel incision, have reduced the capacity of headwater systems to store water naturally. The Blacktail/Basin Creek watershed, one of the water supply watersheds to Butte, Montana, supported multiple beaver pond complexes within the last thirty years, but now exhibits signs of reduced water storage, with stream channels cutting down through beaver pond sediments and lodgepole pine starting to colonize the lower floodplain as wetlands convert to uplands. With funding from Natural Resource Damage Program (NRDP) and a Climate Adaptation Grant from Wildlife Conservation Society, we have been building a network of wet meadow restoration and monitoring sites in the headwaters of the watershed to test the efficacy of low-cost restoration placed over a large area to improve groundwater storage and moderate high and low stream flow levels. The low-cost restoration approach primarily uses mimic beaver dams and similar post-and-brush structures to slow water and elevate streams, with the goal of re-establishing water pooling and floodplain connectivity. Monitoring and restoration sites have been established from 2015 to 2017; this presentation provides preliminary monitoring results and lessons related to restoration and monitoring techniques.

**Effects of Beaver Mimicry Restoration on Stream Flows, Riparian Groundwater Levels, and Water Temperatures**

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Beaver-mimicry restoration (BMR) seeks to simulate the effects of beaver activity on stream ecosystems and has become a popular approach to aggrade incised streams and reconnect stream channels to riparian systems. Proponents of BMR suggest that it will improve stream and riparian habitat, improve water quality, reduce stream temperatures in the summer, increase water storage in wetlands and shallow alluvial aquifers, and increase late-summer stream flows. However, the effects of BMR on seasonal dynamics of natural water storage have yet to be tested directly, and the specific hydrologic mechanisms that would promote higher and cooler late summer flows remain poorly understood. Our objective was to monitor stream flows, groundwater levels, and water temperatures before and after restoration at paired restored and control sites, in order to better understand the hydrologic mechanisms behind the perceived benefits of BMR on streams.

We expect that the most obvious effects from BMR will be evident in groundwater level changes and in stream temperature changes. Changes in stream flow due to smaller scale BMR are anticipated to be subtler and more difficult to measure. BMR projects were conducted on Long Creek and Alkali Creek in the headwaters of the Beaverhead River in southwest Montana during August and October of 2016, respectively. We began monitoring these sites in August 2015 and April 2016. Groundwater monitoring, surface-water monitoring, and remote sensing are being used on treated and untreated portions of the streams, before and after restoration. We plan to continue monitoring these sites through November 2018. Initial results indicate that elevated groundwater levels in the riparian system responded quickly to restoration, even at long distances from the installations. Preliminary numerical modeling suggests that groundwater elevations near the stream will remain elevated through the summer in response to increased stream stage; however increased groundwater discharge to the stream due to spring time recharge away from the stream will likely recede to pre-treatment levels prior to the end of the summer. Statistical models of the relationship between air and water temperatures will be used to assess how changes in stream temperature signals responded to the restoration. Taken together, groundwater level measurements, stream flow measurements, and distributed temperatures measurements will provide a more complete perspective on the role of BMR in altering the stream-riparian hydrosystem.

**Stream restoration effects on storage and baseflow generation, Ninemile Creek, MT**

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Stream restoration is increasingly being considered as a climate change mitigation tool, altering the storage and exchange capacities of streams and their adjacent alluvial aquifers. While previous studies have monitored the effect of restoration on exchange processes, few have used field data to link these effects to seasonal patterns of storage and streamflow. Our project monitored the impact of restoration lead by Trout Unlimited on Ninemile Creek after extensive placer mining in the mid-1800's. Using a combination of topographic and morphologic surveys, well transects, piezometers and chemical tracers, we monitored hydraulic exchange processes across multiple spatial scales and at six flow stages. We then used synoptic Radon-222 surveys and discharge measurements to estimate reach-scale alluvial aquifer recharge and discharge throughout the 2016 hydrograph recession. We found that restoration resulted in a longer period of alluvial aquifer recharge (storage) early in the season, and higher volumetric groundwater discharge at baseflow. While our results highlight the effect of site-specific factors such as substrate, they also suggest that restoration can enhance the storage and exchange processes that lead to increased late-season, in-stream flows. Our work is a important step in understanding the impact of restoration on streamflow, and presents a suite of methods that can be transferred to other basins for similar evaluations.

**LWD Reintroduction in Cedar Creek: Going Big for Bull Trout Strongholds!**

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Providing suitable habitat for native aquatic species is central to watershed restoration goals. Threatened and sensitive aquatic species such as bull trout and cutthroat trout have experienced severe habitat losses and range shrinkage during the last century in many western landscapes. Construction of stream-adjacent roads and associated loss of riparian cover has lessened the complexity of habitat within streams by delaying or precluding recruitment of large woody debris (LWD). Documentation has shown that streamside roads typically contain fewer pieces of wood complexes than reference streams, as well as create problematic conditions during flooding because of decreasing floodplain capacity. In addition, cold-water species are facing increasing challenges as hydrologic regimes shift in response to climate change, which in the northwest, show that stream temperatures are rising and base flows may be lowering. Restoring functionality and complexity to streams can assist ecosystems to be more resilient in the future when faced with legacy road placement and climate change. Enhancing floodplains by relocating streamside roads and reintroducing LWD can be a key to restoring this functionality. Results of restoration include more complex channel networks such as pools and off-channel habitat, increased water storage, and providing the benefits of shade and diversity of a riparian plant community. Such a restoration project was completed in 2015 in western Montana on the Lolo National Forest through a partnership with Trout Unlimited. Two miles of stream-adjacent road was relocated away from Cedar Creek, an important cold-water bull trout tributary to the middle Clark Fork River. Cedar Creek is projected to continue to be a bull trout stronghold, so work is focused here. By separating the stream and the road, a newly created floodplain was established which was infused with ample large wood for roughness and complexity, riparian planting, and high-flow off-channel habitat. Within the stream, over 100 LWD structures were installed, creating pools and complex habitat. Since completion of Phase I, annual monitoring has revealed beaver activity, floodplain activation at bankfull flows, substrate sorting, favorable scouring, and in many locations, has caused increases in the local water table. Stay tuned, as Cedar Creek Phase II is expected to be implemented in 2018, resulting in about 0.2 miles more of similar restoration.

## SESSION 6 WATER QUALITY

### Evolution of Yellowstone River Sediment Monitoring in the Great Plains Region of the Upper Missouri River Basin

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The U.S. Geological Survey streamgage on the Yellowstone River near the city of Sidney (06329500) is Montana's only long-term sediment-monitoring site. Measurements of suspended-sediment concentrations (SSCs) near Sidney support the U.S. Army Corps of Engineers management plan for Lake Sakakawea on the Missouri River. For 40 years (1972 through 2012), near-daily SSC samples were collected by a contracted observer from the local area using a manned cableway during the open water season. In 2013, daily observer sampling was replaced with turbidity monitoring to begin a new era of sediment monitoring. After 4 years and 3 field trial assessments of various turbidity sensors, SSC data are once again being generated using turbidity as a surrogate for SSC. Both streamflow and turbidity were evaluated for estimating SSC and calculating sediment loads. The relation between SSC and streamflow was marginally significant (coefficient of determination [r2]: 0.18) and the relation was fragmented and populated with an inordinately high proportion of outliers. Close inspection of outliers indicated that samples were associated with episodic pulses of high concentrations of suspended sediment originating from upstream tributaries such as the Powder River that demonstrated the potential to generate SSC in excess of 20,000 milligrams per liter. At the Sidney monitoring site, SSC peaked prior to, simultaneously, and after the streamflow peak, with occasional multiple sediment peaks observed. Turbidity was superior to streamflow for predicting SSC, with a strong coefficient of determination of 0.92. Notable gaps in the data were observed and are attributed to episodic high SSC concentrations that exceeded the detection capabilities of the turbidity sensor. Hydroacoustic technology, an innovative application, is currently being evaluated as a logical next-step in long-term replacement of turbidity monitoring to provide reliable, continuous, real-time measures of SSC.

### Microfluidic Systems in Environmental Monitoring

*Stephan Warnat, Montana State University, Mechanical and Industrial Engineering, 220 Roberts Hall, PO Box 173800, Bozeman, MT 59717, langlois_warnat@hotmail.de.*
This presentation discusses challenges and advantages of microfluidics and Micro-Electromechancial Systms (MEMS) in environmental monitoring. The ability to observe and measure aquatic properties allow the prediction and understanding of changes in the entire ecosystem. A high spatial and temporal resolution of the measured properties defines the quality of these interpretations. Sampling is often a limiting factor in this process and is currently done in two ways: 1) Skilled personal collect samples at a defined space and time and analyse these samples sub-sequentially in the laboratory; 2) Sensor platforms are deployed into the water body and measure properties remotely. Both approaches can not guarantee a high spatial and temporal resolution. Manual water sampling is limited by personal and laboratory availability. Remote measuring

platforms are equipped with macroscopically fabricated sensors which increase device costs and reduce the number of possible platforms. MEMS and microfluidic devices can overcome these limitations. MEMS are microscopic devices and become part of our daily life: cell phones are equipped with accelerometer, gyroscopes and magnetometers; tire pressure sensors and air bag sensors are required in every new automobile; biomedical applications utilizing miniaturized flow and pressure sensors and analytic devices (Lab-on-Chip). These miniaturized systems have also advantages for water monitoring platforms: 1) Fabrication is economic feasible for mass production, which allows a cheap installation on many monitor systems to increase spatial and temporal resolution; 2) Power consumption is very low which allows continues measurement; 3) Small device size allow parallel measurements and therefore an increase of measurement throughput and 4) Device sensitivity is higher compared to conventional sensors of the same price class. This presentation shows an initial concept to develop such a microfluidic/MEMS system for environmental monitoring and discusses the following aspects: Sensor miniaturization advantages and examples; device integration in environmental monitoring platforms; sensor examples and challenges; material challenges; measuring cell viability.

**The Gallatin Microplastics Initiative: Engaging Outdoor Recreation Citizen Scientists in Watershed Monitoring of Microplastics to Affect Change**

*Katie Holsinger, Adventure Scientists, 237 E Main St, Bozeman, MT 59715, (406) 924-9209, katie@adventurescientists.org. Additional authors: Stan Jones, DNRC RWRCC.*

Since 2013, the Bozeman-based conservation organization Adventure Scientists has worked to expose the alarming numbers of microplastics entering our waterways worldwide. Microplastics, or tiny pieces of plastic, pose detrimental effects to environmental and human health when they enter natural systems. In light of the ubiquitous presence of this pollutant uncovered in our global study, and with a desire to engage on this topic in our own back yard, we launched the Gallatin Microplastics Initiative in 2015. To understand the breadth and depth of the problem in the Gallatin watershed, we assembled a team of adventure scientists--capable outdoors women and men committed to conservation--and trained them as microplastics sample-collectors. These volunteers head to 70 critical points on the Gallatin and its tributaries once each season on foot, bike, boat, skis, and snowshoes to collect water samples. Our partner scientist, Abby Barrows, analyzes these samples for the quantity and type of microplastic particles: information essential to knowing the severity of the problem, and that may offer insight on how to address it. We have just concluded two years of our study, and preliminary data show 62% of samples collected in our Gallatin Initiative contain microplastic pollution. Successfully engaging our team of reoccurring citizen science volunteers has set this project apart from other monitoring efforts. We measure this success through days volunteered to conservation, conservation changes made, and the likelihood of the volunteer to pursue a career in conservation following their experience with Adventure Scientists. We consider our volunteers a vital component to our overall goal of understanding and addressing the microplastics problem for their role in collecting data, disseminating results through their personal and professional channels, and, through the experience we provide, becoming community leaders in conservation. Our project was conceptualized by a team of local and national water experts, collectively called the Gallatin Microplastics Coalition. The members of this coalition are committed to using the results of our study in their individual spheres of water work, thus addressing this emerging environmental issue through multiple avenues and with science-backed decision making.

**Clear as mud?: Evaluating turbidity in the Beaverhead River and Clark Canyon Reservoir**

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Elevated turbidity has been reported in the Beaverhead River downstream of Clark Canyon Reservoir near Dillon, MT the last three summers. Conditions have been so poor that fishing and recreational uses have been impacted, in turn influencing the revenues of local guides, outfitters, and businesses; not to mention the recreational experience of local fishermen and women. In 2015, the Department of Fish, Wildlife and Parks (FWP) implemented an initial monitoring program to characterize river and reservoir conditions.

The Department of Environmental Quality (DEQ) expanded upon this effort in 2016. As expected, the cause and source of the turbidity is complex as the Beaverhead River is a tailwater of Clark Canyon Reservoir, and turbidity could either be generated autochthonously within the reservoir by geochemical, physical, or biological phenomena, allochthonously from tributaries, or within the river itself. Furthermore, to the Agency's knowledge, high turbidity had not been reported until 2014. This talk will cover the 2016 limnological investigation of both the Beaverhead River and Clark Canyon Reservoir. An emphasis will be placed on identifying the material composition of the turbidity, its relationship to lacustrine bed sediment, and characterizing reservoir conditions including destratification, mixing, and lake stability. Details will provide some understanding of reservoir operation, inlet/outlet effects, dead pool storage declines, and lake mixing process including seiche, surface waves, and convective mixing as related to resuspension of benthic sediments. Finally, the presentation will provide a very basic overview of ongoing efforts this summer by the Bureau of Reclamation including use of an uplooking acoustic Doppler, sediment traps, and a more spatially robust monitoring network.

**Mine Reclamation Activities Improve Water Quality in Yellowstone's Soda Butte Creek**

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Nearly 25 years ago, researchers described a layer of unusual bright orange-red sediments on the floodplains of lower reaches of Soda Butte Creek just upstream of the confluence with the Lamar River inside Yellowstone National Park. These discolored sediments were traced nearly 15 miles upstream and outside Yellowstone to the abandoned McLaren Mill and Tailings Impoundment located near Cooke City, Montana. Abandoned in the 1950s, the mill was gone but the failing tailings impoundment remained covering the Soda Butte Creek channel. Sediments immediately downstream of the McLaren site were enriched with heavy metals, and the iron-rich orange waters seeping from the base of the tailings impoundment were shown to be toxic to fish and zooplankton. The segment of Soda Butte Creek below the McLaren site and downstream to the Montana-Wyoming border today represents the only Clean Water Act-impaired water body entering Yellowstone National Park. In 2014, the DEQ Abandoned Mine Lands Program completed the McLaren Tailings Reclamation Project, culminating five years of reclamation work. This reclamation effort included the excavation of approximately one half million tons of contaminated tailings, pumping and treatment of over one hundred million gallons of contaminated water, and reconstruction of approximately 1,800 feet of Soda Butte Creek and Miller Creek stream channels. In 2015, National Park Service and DEQ scientists initiated studies of water quality in Soda Butte Creek to document water quality immediately downstream of the reclaimed tailings site to mirror previous water quality studies that began a decade prior to reclamation. Investigation results indicate significant improvements in water quality. Where iron exceeded the water quality standard in 20 out of the 31 samples collected before the reclamation project, no exceedances of iron were documented from the eleven samples collected between June 2015 and June 2016. Pre-reclamation copper exceedances of the DEQ water quality standard occurred in 8 of the 31 samples. In contrast, only a single copper exceedance was documented in 2015 and 2016 following reclamation. Pre-reclamation manganese concentrations exceeded the U.S. EPA National Secondary Maximum Contaminant Level (SMCL) in 14 of the 31 samples collected from 2000 through 2010. None of the 11 post-reclamation samples contained manganese above the SMCL. The bright orange stream sediments that conspicuously marked the contamination in Soda Butte Creek prior to reclamation are gone. These changes are a striking visual indicator of the improvements in ecological condition resulting from the reclamation of the McLaren site. The collaboration between the DEQ and the NPS was critical to the planning and execution of the McLaren Tailings Reclamation Project and this collaboration also made possible the post-reclamation characterization of water quality in upper Soda Butte Creek watershed. This data supports the quantification of water quality improvements and a formal assessment of post-reclamation water quality of this 303(d)-listed stream. The reclamation represent major milestones to Yellowstone National Park, and the will support Yellowstone native cutthroat trout conservation efforts and safeguard downstream aquatic and riparian habitats from the legacy of mining in this region.

**Characterizing water resources around oil and gas development**

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Montana citizens are concerned about the risks to their water resources from enhanced oil recovery techniques and the resulting increased oil and gas activity. The increased level of development is seen by some as increasing the risk of water supplies being contaminated by oil-field brines. In response to these concerns, the Montana Bureau of Mines and Geology worked with the Montana Department of Environmental Quality, the Montana Department of Natural Resources, the US Department of Fish and Wildlife Service, and local Conservation Districts to sample groundwater throughout the eastern counties. Coupled with the Montana Department of Environmental Quality's surface water sampling program, the beginnings of a comprehensive picture of the current condition of the water resources around energy development has developed. Groundwater sampling in areas of known brine contamination in Sheridan County illustrates what contaminated water can look like: high salinity, high chloride, high radiochemistry, and the presence of organic constituents. Groundwater sampling outside known contaminated areas has shown that, individually, these qualities can also occur naturally. High chloride to salinity ratios and the presence of ethane is found naturally in deep (>1000 ft) wells completed in the Fox Hills/Hell Creek aquifer. Groundwater analyses found light hydrocarbons in Fort Union Formation wells. Therefore, the combination of more than one indicator is key to identifying the presence of brine contamination. A combination of factors (salinity, chloride, and radiochemistry) were used to determine one surface-water sampling site in northeastern Montana exhibits the presence of contaminated groundwater – despite the lack of detectable organic constituents, including methane. Elevated levels of alpha radiation in some streams demands further investigation to determine if it represents mobilization of contamination from historic drill cuttings and/or brine storage or reflects the natural variability in radiochemistry. Based on the range of measured values in surface and groundwater, alpha radiation, more so than beta, appears to be a better indicator of contamination because the high alpha radiation values associated with brines are more easily distinguished from baseline. Water resource sampling such as this is imperative to protecting both the individual water users from degradation of their resources and the oil and gas industry from inappropriate attribution of naturally occurring conditions to development activities. Expanding efforts to understand the natural variability of eastern Montana's water resources, especially of characteristics generally associated with brines, will protect and aid in the orderly development of Montana's resources.

## SESSION 7 WATER DATA SYSTEMS AND INFORMATION

**The Foundation for the Water Information System: A Discussion of Hydrography Dataset Editing in the Musselshell Watershed**

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The Montana Hydrography Dataset is a connected network of surface water information for the state. Recently, the Montana State Library (MSL) utilized LiDAR and Montana Natural Heritage Program wetland mapping to update streams, waterbodies, and the Musselshell River in the Musselshell watershed using a variety of USGS tools as well as customized workflows developed by MSL GIS staff. This presentation will provide an overview of this work and of the ways that accurate, up-to-date surface water information provides the backbone for water-related analysis, modeling, and data discovery. This presentation is a companion to another AWRA presentation, entitled, "Towards an improved Water Information System: Linking information to Montana's statewide hydrography dataset."

**Towards an improved Water Information System: Linking information to Montana's statewide hydrography dataset**

*Troy Blandford, Montana State Library, 1515 E. 6th Ave, Helena, MT 59620, (406) 444-7930, Tblandford@mt.gov.*

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Multiple local, tribal, state, and federal agencies generate, use, and distribute water data. The amount and variety of water information and knowing where to find it can be daunting tasks. The goals of the Montana Water Information System (WIS) are to facilitate water data discovery and access and to increase data sharing opportunities. This presentation will demonstrate the long-term vision to restructure the WIS from a website-based discovery hub to one driven more by a spatial database, the Montana Hydrography Dataset. National tools for linking data to the statewide hydrography dataset and the advantages of network-linked data will be discussed. This presentation is a companion to another AWRA presentation, entitled, "The foundation for the Water Information System: A Discussion of Hydrography Dataset Editing in the Musselshell Watershed" direction, and opportunities for involvement.

**Climate Change Impacts on the Hydrological Processes of Silver Bow Creek, MT**

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Climate change is expected to alter temperature and precipitation regimes across the globe and have a varying effect on local hydrological processes. For Silver Bow Creek (SBC), a headwater of the Clark Fork River in western Montana, the magnitude, duration, and frequency of spring runoff and summer base flow are all dependent on snow accumulation and melt. Headwater hydrology is directly influenced by climate change and mountain streams will likely experience earlier snowmelt, increased spring flows, and decreased summer flows. As a matter of point, the Montana State Water Plan acknowledges such effects in coarse scale-modeling of large river basins. To alleviate water stress during summer, they also identify the need for retaining high spring flow through natural systems such as wetlands and ponds to be redistributed in drier months. To evaluate this consideration in headwater streams like SBC, the process-based hydrological model Soil and Water Assessment Tool (SWAT) was used to evaluate the effects of climate change on SBC spring runoff and summer base flows. SWAT is a continuous time simulation model that allows the user to predict surface water discharge, sediment loading, and stream nutrient content from user specified meteorological forcing functions. The SBC model was developed using 1/3 arc second DEM, SSURGO soil database, Montana land cover framework, and observed weather data. The model was then calibrated to daily USGS flow data. Calibrated SWAT model and projected future downscaled climate change data were used to model SBC future stream flows. The results from the model were then used to make qualitative inferences about changes in surface water quality due to climate change. This presentation covers model development, effect of climate change on SBC spring runoff and summer base flow, and potential impacts in surface water quality due to climate change. Conclusions drawn from this study could help land managers prepare for projected climate change water management scenarios.

**The importance of Water Rights in Montana**

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Understanding the relationship between Land and Water is more important than ever for many in Montana. Statewide adjudication of over 200,000 water rights has been ongoing since 1982 and is not expected to be complete until 2028.In addition, the Second Decree has recently begun where over 90,000 previously examined water rights will under go a re examination process. Being able to quickly and efficiently determine the status of water rights is more important than ever. Water rights research is important for: Evaluating water rights, wells, ditches, and land features involved in proposed projects; Scoping potential projects with clients, members of the public, permit or program applicants, and other staff; Due diligence research for land acquisitions, exchanges and other transactions.

**User-Centered Design: Best practices to effectively deliver Montana surface water data**

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User-Centered Design (UCD) is an iterative process that allows designers and developers to create useful

products. Using a combination of brainstorming, in-person interviews, usability testing, and design evaluation, The Montana Bureau of Mines and Geology (MBMG) is building a web portal to deliver Montana's Surface Water Assessment and Monitoring Program (SWAMP) Data in an efficient manner. Data from the MBMG and the Department of Natural Resources and Conservation (DNRC) are currently being collected and stored. The MBMG has more than 100 surface-water monitoring sites in its Ground Water Information Center (GWIC) database. In addition, the DNRC has stream stage (feet), discharge (cfs), and water temperature (degrees C) data for 34 real-time stations and more than 150 seasonally downloaded stations across Montana. Working together with the Water Management Bureau and Information Technology staff at DNRC, a database was developed to import an automatic data feed from Aquatic Informatics' AQUARIUS software. The surface-water data are imported into the system every 30 minutes using a combination of the AQUARIUS API, FTP, Microsoft SQL Server Integration Services, and some custom software. The SWAMP database and website are recent additions to the MBMG Data Center at http://mbmg.mtech.edu/datacenter Watershed"direction, and opportunities for involvement.

**FACTS: MT DEQ's Web-Based Water Discharge Permitting System**

*Michael Pipp, MT DEQ, (406) 444-7424, mpipp@mt.gov.*

Montana DEQ is developing a web-based system to facilitate water discharge permit applications and management under the Montana Pollution Discharge Elimination System (MPDES). The new system, named "FACTS" for "Fees, Application, Compliance, and Tracking System" is a two-part system with an external component for businesses and organizations to develop, submit, and pay for permit coverage applications and an internal component for DEQ permit writers, data managers, and compliance inspectors to manage permit development, issuance, and implementation (i.e., permit compliance). A business or organization can manage multiple facilities and associated permits and representatives for each facility, if different. Individuals can be associated with multiple organizations to serve as a permit application preparer. The system will provide on-line communication between DEQ permit writers and an organization's facility contacts to facilitate the permit application process. This presentation focuses on the external system developed for organizations seeking MPDES permit coverage.

## SESSION 8 MODELS, WATER QUALITY AND GEOCHEMISTRY

**Representing Reservoir Stratification in Land Surface and Earth System Models**

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A one-dimensional reservoir stratification modeling has been developed as part of Model for Scale Adaptive River Transport (MOSART), which is the river transport model used in the Accelerated Climate Modeling for Energy (ACME) and Community Earth System Model (CESM). Reservoirs play an important role in modulating the dynamic water, energy and biogeochemical cycles in the riverine system through nutrient sequestration and stratification. However, most earth system models include lake models that assume a simplified geometry featuring a constant depth and a constant surface area. As reservoir geometry has important effects on thermal stratification, we developed a new algorithm for deriving generic, stratified area-elevation-storage relationships that are applicable at regional and global scales using data from Global Reservoir and Dam database (GRanD). This new reservoir geometry dataset is then used to support the development of a reservoir stratification module within MOSART. The mixing of layers (energy and mass) in the reservoir is driven by eddy diffusion, vertical advection, and reservoir inflow and outflow. Upstream inflow into a reservoir is treated as an additional source/sink of energy, while downstream outflow represented a sink. Hourly atmospheric forcing from North American Land Assimilation System (NLDAS) Phase II and simulated daily runoff by ACME land component are used as inputs for the model over the contiguous United States for simulations between 2001-2010. The model is validated using selected observed temperature profile data in a number of reservoirs that are subject to various levels of regulation. The reservoir stratification module completes the representation of riverine mass and heat transfer in earth system models, which is a major step towards quantitative understanding of human influences on the terrestrial hydrological, ecological and biogeochemical cycles.

**Annual PRObability of Streamflow PERmanence (PROSPER) in the Pacific Northwest, 2004-2016**

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The dynamic spatiotemporal pattern of stream channel wetting and drying, broadly defined here as flow permanence, is a fundamental determinant of longitudinal hydrological connectivity, both along mountain headwater streams and to the downstream river network. Extensive field efforts and successful stewardship programs that report flow permanence at locations throughout the western US have resulted in substantial progress in flow permanence classification (e.g., ephemeral, intermittent, perennial) of the river network. Despite this progress, methods for accurately classifying flow permanence, predicting near-term flow permanence, and determining inter-annual variability for streams lacking specific field-based knowledge have not been developed. Such methods are necessary for predicting flow permanence characteristics in mountain headwater areas where field data cannot be easily collected. Further, we are unable to predict near-term (e.g., within the current year) flow permanence conditions that capture the inter-annual variability of stream drying patterns. To address this, the USGS has developed the PRObability of Streamflow PERmanence (PROSPER) tool. The PROSPER tool is a geographic information system (GIS)- based tool that provides annual predictions on flow permanence conditions at 30-meter resolution for any unregulated and non-major stream channel in the Pacific Northwest region of the Unites States. The PROSPER tool was developed using random forest classification models that incorporated flow permanence field observations and a suite of GIS-derived climatic and physiographic variables that influence hydrological conditions. Specifically, the tool predicts the probability that a given 30-m grid cell of stream channel remains wet or goes dry based on antecedent climate conditions (e.g. snow water equivalent, precipitation, minimum temperature, and evapotranspiration) for monthly and annual periods associated with the upstream basin of each cell. The predicted probabilities of flow permanence output by the PROSPER tool will be made publicly available through the USGS StreamStats platform (https://water.usgs.gov/osw/streamstats/).

**Cisco refuge lake study in Minnesota lakes using constant survival limits**

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Cisco Corgenous artedi is a common cold-water fish species found in lakes of several northern states which physiologically requires cold, well-oxygenated water to survive, grow, and reproduce. A refuge lake can provide cisco habitat not only under the past climate conditions but also under the future warmer climate scenarios. Temperature (T) and dissolved oxygen (DO) as the most significant water quality parameters affecting survival of cisco in lakes were simulated using a one-dimensional lake water quality model MINLAKE2012 and were used to project cisco survival and lethal conditions in 620 cisco lakes in Minnesota under past (1961-2008) and MIROC 3.2 future climate scenarios. A fish habitat simulation model FishHabitat2013 using simulated T and DO profiles as inputs was developed to determine lethal conditions of cisco using oxythermal habitat approach, which defines an upper boundary for T and a lower boundary for DO, i.e., lethal temperature (LT) and DO survival limit (DOLethal). The "lethal conditions" for a fish species in a lake are where temperature is above and/or DO is below the survival limits. The FishHabitat2013 used a lethal temperature of 22.1 oC and DO survival limit of 3 mg/L that were determined through model validation and sensitivity analysis. Twenty-three

Minnesota lakes that had observations of cisco mortality or survival in the unusually warm summer of 2006 were used for model validation. Cisco lethal conditions in 12 shallow and 16 medium-depth regional lakes and 30 virtual deep lakes were then simulated under past (1961-2008) and MIROC3.2 future climate scenarios. Isopleths of total number of years with cisco kill and average cisco kill days for the years with kill using lake geometry ratio and Secchi depth as x and y axes were generated to understand climate impacts on 620 cisco lakes. Under future MIROC 3.2 climate scenario, shallow cisco lakes are projected to have cisco kill in almost every year with on average more 30 kill days; medium-depth lakes are projected to have 25–47 years with cisco kill and on average 12–70 kill days. Therefore, shallow and medium-depth lakes are not good candidates as cisco refuge lakes. Only relatively eutrophic deep lakes (Secchi depth < 2 m) in northern and mid-latitude Minnesota and many southern lakes have 5 or more years with cisco kill, and all other deep lakes are potential refuge lakes.

**Soil architecture versus management as controls on nitrate leaching**

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Leaching of nitrate from cultivated soils can reduce crop yield and threaten the quality of underlying groundwater. Water flux through a soil profile interacts with the available nitrate pool to determine nitrate leaching rates. In dryland annual cultivation systems, deep percolation rates and the size of the soil nitrate pool are dynamic over time and are controlled by weather, soil characteristics, and cropping system management. Understanding the interaction among these three primary controls can inform decisions about where and how to focus nitrate leaching reduction efforts. In the Judith River Watershed of central Montana, gravel terraces are capped with variable thickness of fine textured materials (mainly loess) and have weathered to form soils with variable moisture storage capacity. The predominant land use on these terraces is annual cultivation of wheat and barley, with summer fallow (absence of crop for a full year) in the crop rotation every three to four years. Over a six-year period, we measured soil water nitrate concentrations in lysimeters installed in privately managed fields under different cropping management with variable thickness of fine textured material in soils. We hypothesize that soil architecture (primarily thickness of fine textured material) determines maximum soil moisture storage capacity and that soils with larger storage capacity have greater nitrate production through mineralization of organic matter, more nitrate loss through denitrification, and decreased loss through leaching. Overprinted on the maximum capacity of soils to store moisture is the effect of cropping system management, determining when plants are present to dry the soil. Drier soils have higher capacity to store water, while wet soils are primed to facilitate deep percolation during future precipitation events. We predict that the greatest vulnerability to leaching occurs in soils with limited thickness of fines and in management systems that incorporate summer fallow. Preliminary results suggest that our lysimeter record is consistent with this prediction.

**Membrane Distillation Increases Copper Sulfate Concentration in Contaminated Waste Streams Prior to Further Enrichment**

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Economic extraction of metals from contaminated waste streams is of particular interest in Butte, Montana where past mining efforts have resulted in several waste streams containing dissolved valuable. Current methods of extraction can be suitable but become less appealing as operational costs increase over time. This research was a combined effort at creating a new method for extraction with presumed decreased operational costs due to the nature of its continuous "recycled" contaminant stream. A continuous-flow metal recovery reactor was built to selectively extract copper from waste streams using modified magnetic nanoparticles.

Copper ions adsorb onto the magnetic nanoparticles and are subsequently desorbed for further processing. However, subsequent processing requires a higher concentration than can be obtained in the reactor. Thus, this research evaluated a direct contact membrane distillation (DCMD) process that concentrates copper sulfate. DCMD uses a temperature differential between hot feed reservoir and cold distillate streams. Contaminants are removed via stream contact with a hydrophobic micro-porous membrane. Volatile water molecules pass through the membrane as water vapor, leaving behind copper sulfate. Often, contact between the membrane and waste stream causes contamination of membrane pores and decreased water production flow rates. However, DCMD experiments in this research show very little flux decline during operation, indicating this process is viable for the concentrations necessary. After DCMD experiments, membrane scale characterization was conducted. Liquid entry pressure testing, water-in-air contact angle measurements, x-ray diffraction classification, and scanning electron microscopic imaging showed changes in porosity and hydrophobicity. Both membrane samples showed a significant decrease in liquid entry pressure (from 40 pounds per square inch (psi) for a clean membrane to roughly 30 psi for membranes that underwent experimentation with the copper sulfate stream). Water-in-air contact angle measurements showed only a significant decrease in one of the membranes used for experimentation. Distillate samples taken during experimentation were tested to discern mineral composition and content. Infrared couple plasma (ICP) analysis revealed a three-fold increase in copper concentration from beginning to end of experimentation.

**Catchment-scale water-carbon coupling across the contiguous United States: A data-based analysis**

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Catchment wetness is a key link between climate fluctuation and vegetation dynamics, regulating the carbon exchange between terrestrial ecosystems and the atmosphere. Here, we examine the influence of intra-annual variation of wetness (water available to vegetation) on Gross Primary Productivity (GPP) at the catchment scale, using 375 pristine catchments across the contiguous United States. Data employed includes hydro-metrological data from CAMELS datasets, phenological data from USGS, GPP and ET data from MODIS. Monthly catchment wetness (W) was estimated using two approaches, i) W as a linear function of evapotranspiration, catchment storage dynamics and base flow, and ii) an analytical solution based on the classic Budyko framework. The results show the existence of a monthly hysteresis between W and GPP at intra-annual scale, which is largely controlled by the competition between the availability of energy (incoming solar radiation) and water (W). The orientation (northeast/southeast) of W-GPP hysteresis curve depends on the lag between W and GPP intra-annual peaks, which is then controlled by precipitation and solar radiation. The directions of the hysteresis curves, i.e., clock-wise and anti-clock-wise, are governed by catchment storage characteristics: if storage release rate is slower than wetting rate, then hysteresis curve follows clock-wise pattern and vice versa. Based on the inter-links between W and GPP, we then introduced catchment water use efficiency (CWUE) index as a ratio of GPP to W in order to depict vegetation use efficiency in terms of water that is available to them. The CWUE is well correlated with the traditional ecosystem water use efficiency with R2 of 0.62 during the vegetation growing period. We employed the Budyko equation to identify climatic and hydrologic controls on the elasticity of CWUE standard deviation ratio (SDR), which is defined as the ratio between the standard deviation of W and GPP. SDR was found to be controlled by the variance of ET, PET, storage dynamics and surface runoff. These findings will help to understand the interactions between the catchment-scale water and carbon cycles, for example, improving the prediction of droughts based on the water demand from vegetation.

**Establishment of a baseline groundwater-quality monitoring program in an area of current and proposed energy development on the Blackfeet Reservation, Montana**

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Oil and gas exploration and development has occurred on the Blackfeet Reservation in northwestern Montana for several decades. Current and proposed energy development includes the use of hydraulic fracturing to reach and extract oil in the area. In response to potential groundwater-quality effects from energy development, the Blackfeet Environmental Office (BEO) has developed a groundwater-quality monitoring program. The addition of groundwater-quality data to their existing surface-water monitoring program will help the Blackfeet Tribe assess the overall water-quality conditions of the Reservation. The U.S. Geological Survey has assisted the BEO throughout the project development and data-collection efforts. The BEO groundwater-quality monitoring program is specifically focused on the most populated watershed within the Blackfeet Reservation: the 1,008 square-mile Cut Bank Creek watershed, which includes historic, current, and proposed energy development. Data collection consists of sampling groundwater at 30 domestic and stock wells, with one-half of the wells completed in surficial deposits and one-half completed in bedrock. Samples are being analyzed for an extensive set of constituents that include field parameters, major ions, trace elements, nutrients, volatile organic compounds, gas range organics (gross measurement of organics in the C6 to C10 range), and diesel range organics (gross measurement of organics in the C10 to C28 range). The water-quality data will be stored in the U.S. Environmental Protection Agency's Water Quality Exchange (WQX) Portal.

**Development and Application of a Centralized Water Monitoring Resource Website**

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The declining quality and growing pressure on global water resources has underlined a need for a variety of water stakeholders to be involved in the decision-making process of watershed management. This involvement often requires collaboration as a means of promoting efficient and responsive environmental governance and, as groups experience diminishing capacity and budgets, the need for information sharing as a means of leveraging these partnerships increases. Moreover, at the 2015 AWRA panel on the 'intersection between science and management', audience discussion led to a panel suggestion for the formation of an information sharing platform about who is collecting what types of data, and at which locations in the state. The creation of a centralized monitoring website for Montana is important as access to reliable water quality monitoring information is needed in making informed watershed management decisions. Many different groups of varying capacity conduct water monitoring across Montana's expansive geography, creating a need for a centralized platform that enables information to be easily accessible and affordable. Internet-based technologies have improved the ways in which information can be exchanged, shared, and consumed at a low cost. Further, digital based technologies allow for geographically disparate groups to connect and interact to a greater degree than before by providing a platform for participation and communication. Thus, to meet the need stated by Montana water professionals and to capitalize on the possible benefits associated with internet-based technologies, MWCC, the Montana Department of Environmental Quality (DEQ), and the Montana Department of Natural Resources and Conservation (DNRC) have partnered together in order to create an online water monitoring resource website that describes water monitoring programs active in the State of Montana. The website will include a directory of programs as well as an interactive map. The website is intended to be a coordinated central location to direct users to pertinent information about water monitoring entities in order to increase awareness of statewide activities as well as facilitate the opportunity for coordination and information sharing. Having the water monitoring directory and map hosted on MWCC's website is within the scope of the organization's mission to facilitate collaborative conservation efforts while providing a more formalized network which promotes information sharing and safeguards against a project becoming too dependent on

any one individual. The presentation will give an overview of the website development, a tour of both webpages, and the maintenance plans associated with both webpages.

**Understanding Strategies to Increase Volunteer Retention for the Gallatin Stream Teams Program**

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Much of the productive work and services provided by community organizations and non-profits would not be possible without the time and talent contributed by volunteers. Given their importance, non-profits have devoted considerable attention to identifying, recruiting, and managing volunteers. However, far less attention has focused on how to sustain a stable volunteer base by retaining these individuals. The motivation to join an organization can be very different from the motivation to stay. Volunteers often leave when the task(s) becomes redundant, boring, or their 'term' of commitment is over. Volunteer retention is a useful measure of volunteer satisfaction since unhappy or bored volunteers will simply leave. Therefore, low rates of turnover can be interpreted as a positive indicator. Non-profit organizations across Montana seek to engage volunteers in helping their communities improve the quality of life; assisting in conservation and preservation projects for the benefit of the people and the natural environment. Therefore, it is essential to understand effective volunteer recruitment and management practices that will help retain volunteers from one year to the next. In the Gallatin Watershed, Gallatin Stream Teams is a program of citizen scientists devoting time and skills to monitoring local urban streams for the Gallatin Local Water Quality District and the Greater Gallatin Watershed Council. Since 2008, the program has been challenged by low volunteer return rates. This evaluation will examine the obstacles to retaining volunteers, and the strategies that could increase retention.

**Tracking potential leakage of tailings-lake water into background groundwater in Butte, Montana, using geochemical and stable isotope tracers**

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This study was conducted to identify environmental tracers using water chemistry and stable isotopes in the Moulton Road area adjacent to the Yankee Doodle tailings impoundment north of Butte, Montana. The water level of the tailings lake is being raised as tailings slurry is pumped up to the impoundment, and numerous residential wells are located in close proximity. Although it has an alkaline pH (> 9), the water in the tailings lake is much higher in some chemical constituents than the wells and some of these constituents could be used as tracers to determine if lake water is migrating out of the impoundment due to the rising level. Tracers examined in this study include the O- and H-isotopic composition of water and the concentration and S- and O-isotopic compositions of dissolved sulfate. Although water in the tailings lake is partly evaporated, the contrast between the isotopic signature of the lake and the groundwater wells is relatively small, making it a less powerful tracer. On the other hand, sulfate concentrations are more than an order of magnitude higher in the lake than in the groundwater. Whereas the S-isotope compositions of dissolved sulfate in lake and groundwater samples are similar, the O-isotope compositions of sulfate for the two end members are very different (-2.8 and -14.0 ‰, respectively). A conservative mass balance model was used to predict changes in the concentration and isotopic composition of sulfate in background groundwater as water sourced from the tailings lake is mixed in. As little as 5% mixing of lake water is enough to cause a substantial shift in the d18O of dissolved sulfate in a long-term groundwater monitoring well. This study also reports new data on the geochemistry of the active tailings slurry, the shallow sediment in the tailings lake, and the shallow sediment pore water of the lake. Acid-base accounting tests show that the solid fraction of the tailings slurry is net acidic, and will generate acid leachate if allowed to completely oxidize. The shallow sediment in the lake is also net acidic, but has somewhat higher neutralization potential compared to the slurry due to precipitation of calcite in the lake. Results from sediment pore water samplers (peepers) and piezometers show very little change in the chemistry of the pore water as the sediment is buried, at least to a depth of 8 feet. Vertical gradients in the pore waters are directed upwards, consistent with an increase in pore-water pressure as the tailings sediments consolidate. Based on the results of this study it is recommended that d18O-sulfate should be added to the list of analytes obtained from long-term monitoring wells in the Moulton Road area. This parameter is the most powerful tracer of potential mixing of lake water and background groundwater.

**Surficial Depressions and their Surface Water Inflows and Outflows: Windows into the Shallow Aquifer along the East Flathead Valley**

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Numerous surficial depressions (eg., glacial potholes or kettle lakes) and their surface water inflows and outflows on the east side of the Flathead Valley are windows into the shallow aquifer. Water-level and water quality data suggest that the shallow aquifer east of the Flathead River is hydraulically connected and an important recharge source to the Flathead Valley Deep Aquifer (LaFave et al., 2004). This poster will provide a brief overview of a DNRC watershed investigation for the East Flathead Valley which encompasses the streams that are the inflows (Mooring Creek and Hemler Creek) and outflow (Blaine Creek) to Blaine Lake. The objective of this watershed investigation is to identify stream reaches that are hydraulically connected to groundwater by comparing the groundwater elevations to streambed elevations. Preliminary results of groundwater data and streamflow data for Mooring Creek and Blaine Creek will be presented. Streamflow gages, shallow piezometers, and monitoring wells are strategically located to identify hydraulically connected stream reaches and their data will be used to support decisions related to new water right permit applications. DNRC intends to collect and disseminate surface water and groundwater data to the Surface Water Assessment and Monitoring Program and Groundwater Information Center, respectively.

**Groundwater Quality of the Intermontane Basins, Gallatin and Madison Counties, Southwest Montana**

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Samples from 20 springs and 298 wells were collected in Gallatin and Madison counties between January 2008 through December 2012 by the Montana Bureau of Mines and Geology's (MBMG) Ground Water Assessment Program. Sample sites were chosen to obtain representative data from all the water-bearing geologic units and areas of groundwater development. The geologic units were broadly grouped into shallow and deep unconsolidated basin-fill in the intermontane valleys, and structurally deformed sedimentary, igneous, and metamorphic fractured bedrock in the mountainous areas. In general, water quality was very good. The median TDS for all samples was 364 mg/L; the median for basin-fill aquifers was 370 mg/L and 354 mg/L for bedrock aquifers. There was little variation of TDS among the basins; the median for the was Gallatin 380 mg/L, Upper Madison 280 mg/L, Lower Madison 430 mg/L, and Jefferson 430 mg/L. Most groundwater was a Calcium-Bicarbonate-type water (236 samples), 61samples were a Sodium-Bicarbonate water-type (12 samples were Calcium-Sulfate and 9 samples were Sodium-Sulfate water-type). Arsenic was detected at concentrations above the Maximum Concentration Level (MCL) of 10 µg/L in the Lower Madison basin, but not in the other basins. Median arsenic concentrations in the Lower Madison ranged from a low in bedrock aquifers of 2 µg/L, to 8 µg/L in Tertiary basin-fill aquifers, to 19 µg/L in Quaternary basin-fill aquifers (five samples were above the MCL). Median concentrations in Upper Madison aquifers ranged from 0.62 µg/L in bedrock, to 0 .8 µg/L in Tertiary basin-fill aquifers and 2.0 µg/L in Quaternary basin-fill aquifers. Nitrate concentrations were generally low, medians ranged from 0.38 mg/L in bedrock aquifers to 0.60 mg/L in basin-fill aquifers. Three sites in the Gallatin Valley/Big Sky area had nitrate values above the 10 mg/L MCL. Radon was detected above the 4,000 pCi/L action level at five sites (seven percent) in the upper and lower Madison valley. Tritium results indicate that most of the water was "modern" (98 percent of Tritium concentrations are between .8 and 15 Tritium Units). Deuterium and oxygen-18 values plot along the Global Water Meteoric Line (GWML), indicating a common recharge source. All data presented can be retrieved from the Montana Ground Water Information

Center (GWIC), http: www.mbmggwic.edu.

**Estimated Water Use in Montana in 2015**

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The U.S. Geological Survey (USGS) has compiled estimates of water use in the United States at 5-year intervals since 1950. As part of these efforts, county-level estimated use of water in Montana for 2015 was compiled for eight categories of use—irrigation, public supply, self-supplied domestic, livestock, thermoelectric power, self-supplied industrial, mining, and aquaculture. In 2015, preliminary estimates indicate that the citizens of Montana withdrew about 10,600 million gallons of water per day (Mgal/d) from Montana's streams and aquifers for these eight categories of use. Estimates of withdrawals from surface water totaled about 9,740 Mgal/d (about 92 percent of total) and withdrawals from groundwater totaled about 860 Mgal/d (about 8 percent of total). In 2015, about 2.5 million acres in Montana were irrigated based on an ArcGIS irrigated land coverage provided by the Montana Department of Natural Resources and Conservation (DNRC). Irrigation water use was estimated by using consumptive-use values based on actual evapotranspiration (ET) depths derived from remotely-sensed satellite data provided by the USGS National Water Use Information Project (NWUIP). The consumptive-use estimates were combined with irrigation efficiencies and transmission-loss estimates to calculate irrigation withdrawals for the for the 2015 growing season (April through September). Preliminary estimates indicate that irrigation accounted for about 10,180 Mgal/d or about 96 percent of total withdrawals for all uses. Surface water was the source of about 93 percent of irrigation withdrawals and groundwater provided about 7 percent. Not all water withdrawn for irrigation was consumed by plants; much of the water withdrawn eventually discharged back to streams as irrigation return flow. Water-use estimates for the remaining seven categories were based on a variety of sources and calculations. In general, publically-available metered or reported withdrawal information is very limited for the state of Montana. As a result, withdrawal estimates are often based on the interpretation of a limited amount of reported data that are in turn used to estimate withdrawals for other facilities or areas. For example, calculated per-capita water-use estimates from a set of public-supply systems with reported withdrawals were used to calculate public-supply water use in other areas of similar climatic conditions. In addition, the USGS NWUIP provides national data sets for some categories such as livestock, aquaculture, mining, and thermoelectric. Preliminary estimates for 2015 Montana withdrawals for public supply were about 150 Mgal/d, self-supplied domestic withdrawals were about 30 Mgal/d, withdrawals for livestock were about 40 Mgal/d, withdrawals for thermoelectric power generation were about 80 Mgal/d, self-supplied industrial withdrawals were about 10 Mgal/d, withdrawals for mining were about 40 Mgal/d and withdrawals for aquaculture were about 70 Mgal/d. Surface water was the dominant source for most uses, groundwater was the primary source for self-supplied domestic and self-supplied industrial water uses.

**Membrane Distillation Increases Copper Sulfate Concentration in Contaminated Waste Streams Prior to Further Enrichment**

*Christina Eggensperger, Montana Tech, 1300 W Park St, c/o Environmental Engineering Department, Butte, MT 59701, ceggensperger@mtech.edu. Additional authors: Dr. Katherine R. Zodrow, Montana Tech; Dr. Jerome P. Downey, Montana Tech.*

Economic extraction of metals from contaminated waste streams is of particular interest in Butte, Montana where past mining efforts have resulted in several waste streams containing dissolved valuable. Current methods of extraction can be suitable but become less appealing as operational costs increase over time. This research was a combined effort at creating a new method for extraction with presumed decreased operational costs due to the nature of its continuous "recycled" contaminant stream. A continuous-flow metal recovery reactor was built to selectively extract copper from waste streams using modified magnetic nanoparticles. Copper ions adsorb onto the magnetic nanoparticles and are subsequently desorbed for further processing. However, subsequent processing requires a higher concentration than can be obtained in the reactor. Thus, this research evaluated a direct contact membrane distillation (DCMD) process that concentrates copper sulfate. DCMD uses a temperature differential between hot feed reservoir and cold distillate streams. Contaminants are removed via stream contact with a hydrophobic micro-porous membrane. Volatile water molecules pass through the membrane as water vapor, leaving behind copper sulfate. Often, contact between the membrane and waste stream causes contamination of membrane pores and decreased water production flow rates. However, DCMD experiments in this research show very little flux decline during operation, indicating this process is viable for the concentrations necessary. After DCMD experiments, membrane scale characterization was conducted. Liquid entry pressure testing, water-in-air contact angle measurements, x-ray diffraction classification, and scanning electron microscopic imaging showed changes in porosity and hydrophobicity. Both membrane samples showed a significant decrease in liquid entry pressure (from 40 pounds per square inch (psi) for a clean membrane to roughly 30 psi for membranes that underwent experimentation with the copper sulfate stream). Water-in-air contact angle measurements showed only a significant decrease in one of the membranes used for experimentation. Distillate samples taken during experimentation were tested to discern mineral composition and content. Infrared couple plasma (ICP) analysis revealed a three-fold increase in copper concentration from beginning to end of experimentation.

**Groundwater stream-water interaction study using 222Rn, CFC's and SF6 in a uranium contaminated aquifer near Riverton, Wyoming**

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We use environmental tracers: CFC's, SF6, and 222Rn measured in stream water to determine volume and mean age of groundwater discharging to the Little Wind River, near Riverton, Wyoming. Samples of 222Rn were collected every 200 m along a 2 km reach, surrounding a known groundwater discharge zone. Nearby groundwater wells, in-stream piezometers and seepage meters were sampled for 222Rn, CFC's and SF6. Tracer concentrations measured in groundwater and in-stream piezometers were used to estimate the mean age of the subsurface system. High resolution 222Rn samples were used to determine the location and volume of groundwater inflow using a model of instream transport that includes radioactive decay and gas exchange with the atmosphere. The age of groundwater entering the stream was then estimated from in-stream measured CFC and SF6 concentrations using a new coupled stream transport and lumped-parameter groundwater age model. Ages derived from in-stream measurements were then compared to the age of subsurface water measured in piezometers, seepage meters, and groundwater wells. We then assess the ability of groundwater age inferred from in-stream samples to provide constraint on the age of the subsurface discharge to the stream. The ability to assess groundwater age from in-stream samples can provide a convenient method to constrain the regional distribution of groundwater circulation rates when groundwater sampling is challenging or wells are not in place.

**Water Quality of the East Gallatin River in Bozeman, Montana**

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In 2013, the City of Bozeman began preliminary water quality monitoring and modeling efforts to understand nutrient inputs to the East Gallatin River. The Gallatin Local Water Quality District led four years of water quality data collection for these efforts. The 2014-2016 field seasons produced a comprehensive dataset from 9 main stem sites and 13 tributaries, while 2017 efforts focused on areas predicted by modeling to be responsive to nutrient inputs. It includes results from nutrient and water chemistry grab sampling, chlorophyll and macroinvertebrate sampling, and discharge and physical parameter measurements. Periods of continuous measurement of water temperature, specific conductivity, pH, dissolved oxygen, and turbidity were also collected at several locations. Project data will be summarized, presenting and evaluating trends rather than the results of mechanistic modeling.

**Nitrate Levels in Gallatin County Public Water Supply**

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Public water systems, or supplies (PWS), provide water to many residents of Gallatin County. They are regulated by the U.S. EPA and Montana DEQ to ensure a safe drinking water supply for human consumption. PWS water quality testing data is publically available information that consists of frequent measurements of nitrate+nitrite levels in the water (sampled at least yearly) as well as other analytes. Because of the annual sampling requirement at a minimum frequency, these data sets provide the most comprehensive understanding of nitrate levels available. We reviewed PWS nitrate data for Gallatin County and found that nitrate+nitrite levels are steadily increasing in several PWS, many of which are near the City of Belgrade. Nitrate has negative health effects as a stand-alone contaminant but can also be an indicator analyte for other water quality issues, such as the presence of pesticides, or pathogens and pharmaceuticals. This presentation will explore the land use and nitrate trends in the area near Belgrade where numerous PWS are showing an increase in nitrate+nitrite levels.

**Mountain Front Recharge in a semi-arid climate; Southwest Montana**

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Groundwater recharge to regional valley benches originates largely from adjacent Mountain Front Recharge (MFR). As streams exit the mountain block, stream water recharges the regional groundwater. Groundwater flow paths at stream valleys where groundwater flow focuses through narrow valleys contributes significantly towards MFR. The Madison Valley in Southwest Montana is a semi-arid mediterranean climate that receives 12.5in annual valley precipitation. In this study, we compare two drainages looking at focused groundwater flow at the mountain-valley transition. We are i) calculating the amount of groundwater recharge that is occurring from the losing section of the two streams, and ii) targeting focused underflow below two different streams exiting a mountain canyon into a larger valley. This study will characterize groundwater surface-water interactions along Daylight Creek and along North Meadow Creek. The focus is on creating a physical mass balance recharge estimate from the losing stream sections near the mountain-valley transition. Daylight Creek that runs through Virginia City, MT is within a small highland pass watershed with peak elevations of 6,800ft and does not receive much precipitation or significant snowfall. North Meadow Creek is located west of McAllister. The watershed reaches elevations up to 10,000ft and receives significant snowfall averaging 19.4in snow water equivalent. To help answer valley recharge i) we will utilize a physical mass balance equation,
$P = ET + R + G$, where P is precipitation; ET is evapotranspiration; R is surface runoff and G is groundwater. Methods used to answer focused underflow ii) is the installation of shallow wells (6-9ft) which are instrumented with pressure transducers and temperature loggers set vertically in wells. Staff gauges measure surface runoff and will help characterize vertical groundwater movement between the stream and shallow streambed sediments underneath. From April through June, the smaller Daylight Creek is showing a signal of a losing stream. The larger North Meadow Creek however has three unique zones. The upper mountainous zone is showing a strong signal of a gaining stream. The middle zone is showing a transitional signal from a gaining stream to a losing stream, and the lower valley zone is showing a strong signal of a losing stream. Sub-surface flow from mountains is important in groundwater source protection, regional development planning, and water rights disputes for regional basin-fill aquifers. Understanding how MFR varies spatially from small watersheds (Daylight Creek) to large watersheds (North Meadow Creek) will provide information for larger regional basin wide groundwater studies.

**Investigation of hydrology and water quality in the Lame Deer Creek watershed, Northern Cheyenne Indian Reservation, Montana**

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The Northern Cheyenne Department of Environmental Protection and Natural Resources (NCDEPNR) and the U.S. Geological Survey (USGS) have recently initiated an assessment of the hydrology and water quality in the Lame Deer Creek watershed to improve information availability for resource-management decisions by the NCDEPNR. The Lame Deer Creek watershed in southeastern Montana encompasses about 82 square miles and is home to approximately 2,000 residents including the community of Lame Deer. Lame Deer is the tribal and government headquarters of the Northern Cheyenne Indian Reservation and is the regional location of educational, commercial, and medical facilities. Despite the social and political importance of Lame Deer, there is limited information available regarding local groundwater resources, surface-water dynamics, groundwater-surface water interaction, and water quality within the Lame Deer Creek watershed. Understanding the influence of sewage lagoons and private waste-water systems (septic systems) in the watershed on drinking water and the aquatic environment is of particular interest. The NCDEPNR and USGS plan to assess the surface-water and groundwater resources within the Lame Deer Creek watershed with an emphasis on the occurrence of water-quality constituents of human-health concern including trace metals, nutrients, and a variety of constituents commonly found in waste water. This assessment will provide systematic information about groundwater and surface-water resources, their interaction, and overall water quality. An added benefit will be the establishment of surface-water and groundwater sites that could be utilized by the NCDEPNR as a foundation for a long-term streamflow, groundwater-level, and water-quality monitoring network. 2017 project activities included the inventory of existing wells, selection of stream sites, area-wide synoptic groundwater-level and streamflow measurements, and the generation of a preliminary potentiometric-surface map.

**Using multiple environmental tracers to investigate the relative role of soil and deep groundwater in stream water generation for a snow-dominated headwater catchment**

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In this study, we investigate seasonal fluctuation of environmental tracers in stream flow, soil water, and deep bedrock groundwater to constrain the role of deep bedrock groundwater in streamflow generation for a mountainous headwater catchment. Synoptic measurements of stream discharge, 222Rn, conductivity and major ion concentrations were measured throughout the water year over a 5 km reach of Cap Wallace Creek in the Lubrecht Experimental Forest, Montana, U.S.A. with the intention of understanding groundwater – surface water interactions across spatial and temporal scales. Stage measurements were continually recorded at seven stilling well locations along the reach. Discharge measurements and water samples were taken at these sites frequently throughout the winter, spring, summer, and fall of 2017. Stage and environmental tracer concentrations from shallow soil and groundwater wells in contributing hillslopes were also monitored during this time. Environmental tracer content is used to constrain stream transport models used for calculating groundwater and shallow soil discharge to the stream. Analysis of the resulting hydrographs and environmental tracer data show: 1) a consistent longitudinal profile in streamflow and locations of hillslope contribution throughout the year, and 2) a seasonal variation in stream chemistry in which tracer concentrations are highest during baseflow and become dilute during spring melt. These stream results are compared to the sampled concentration of tracers in soil and groundwater wells finished on contributing hillslopes to infer the relative role of bedrock and soil flow in streamflow generation. These results have implications for understanding the processes controlling seasonal watershed response to snowmelt and for understanding headwater response to changing climatic conditions and shifting demands for water resources.

**Putting Landowners and Managers in the Driver's Seat: The Montana Conservation Menu**

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The Montana Conservation Menu is a website designed to help landowners and land managers in Montana find assistance programs for implementation of conservation practices. Populated with a wide array of technical and financial assistance programs offered by state and federal agencies, non-profits, and conservation partnerships, the conservation menu serves as a one-stop shop for landowners searching for support for on-the-ground conservation practices on their property. The website provides landowners with an intuitive interface to search by program type, agency, conservation objective, and tags relevant to the issues each landowner aims to address. Once landowners have narrowed the field of available programs, they can choose the program that best fits their needs. The website gives program details, contact information, and links to each program's website for further information and/or application materials. The website also contains a feature that allows visitors to the website to suggest additional programs not already present within the list, which are then vetted and appended to the site. With the assistance of the Montana Conservation Menu, landowners can easily find programs designed to aid their conservation aims and, vice versa, conservation organizations can effectively reach willing landowners to put their expertise and resources to work.

**Helena Valley re-watering/restoration project on Prickly Pear Creek**

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Prickly Pear Creek, the largest perennial stream located in the Helena Valley, has historically faced with numerous water quality impairments due to chronic de-watering, and thermal modification from surface water irrigation diversions. Due to these conditions, in 2008, the MT Water Trust developed and coordinated an agreement between the Prickly Pear Water Users and the Helena Valley Irrigation District, which allowed for full flow restoration of the stream system through what is termed "source switching". Stream restoration work is successful due to programs like mentioned above that has led to stream restoration work involving landowners along Prickly Pear Creek that have little or no riparian vegetation present with eroding banks due to grazing by livestock and other land practices, lowered water table that has led to stream channel incising and restricted access to the channel's historic floodplain. Stream construction will occur in fall of 2017 to address these issues. The goal of the restoration project is the reestablishment of natural stream channel function, channel point bars, and sloped stream banks, adding flood capacity within the stream channel and stream riparian woody vegetation which could significantly reduce sediment loads to the creek. BMP implementation by willing landowners has been a successful method of addressing problem sites by the WQPD and previous grant projects. Opportunities with funding to work with and educate landowners on stream reaches that are classified as "I" due to the dewatering and on impaired listed streams is beneficial to implementing volunteer TMDL reductions as recommended in the water shed TMDL document and other beneficial outcomes.

**An examination of drought-induced hydraulic stress in conifer forests using a coupled ecohydrologic model**

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Recent studies indicate that increases in drought stress due to climate change will increase forest mortality across the western U.S. Although ecohydrologic models used to study regional hydrologic stress response in forests have made rapid advances in recent years, they often incorporate simplified descriptions of the local hydrology, do not implement an explicit description of plant hydraulics, and do not permit to study the tradeoffs between frequency, intensity, and accumulation of hydrologic stress in vegetation. We use the spatially-distributed, mechanistic ecohydrologic model Ech2o, which effectively captures spatial variations in both hydrology, energy exchanges, and regional climate to simulate high-resolution tree hydraulics, estimating soil and leaf water potential, tree effective water conductance, and percent loss of conductivity in the xylem (PLC) at 250 meter resolution and sub-daily timestep across a topographically complex landscape. Tree hydraulics are simulated assuming a diffusive process in the soil-tree-atmosphere continuum. We use PLC to develop a vegetation dynamic stress index that scales plant-level processes to the landscape scale, and that takes into account the temporal accumulation of instantaneous hydraulic stress, growing season length, frequency and duration of drought periods, and plant drought tolerance. The resulting index is interpreted as the probability of drought induced tree mortality in a given location during the simulated period. We apply this index to regions of Northern Idaho and Western Montana. Results show that drought stress is highly spatially variable, sensitive to local-scale hydrologic and atmospheric conditions, and responsive to the recovery rate from individual hydraulic stress episodes.

**Impacts of vegetation growth on reach-scale flood hydraulics in a sand-bed river and the implications for vegetation-morphology coevolution**

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Vegetation alters flood hydraulics and geomorphic response, yet quantifying and predicting such responses across spatial and temporal scales remains challenging. Plant- and patch-scale studies consistently show that vegetation increases local hydraulic variability, yet reach-scale hydrodynamic models often assume vegetation has a spatially homogeneous effect on hydraulics. Using Nays2DH in iRIC (International River Interface Cooperative), we model the effect of spatially heterogeneous vegetation on a series of floods with varying antecedent vegetation conditions in a sand-bed river in western Arizona, taking advantage of over a decade of data on a system that experienced substantial geomorphic, hydrologic, and ecosystem changes. We show that pioneer woody seedlings (Tamarix, Populus, Salix) and cattail (Typha) increase local hydraulic variability, including velocity and bed shear stress, along individual cross sections, predominantly by decreasing velocity in zones of vegetation establishment and growth and increasing velocity in unvegetated areas, with analogous effects on shear stress. This was especially prominent in a study reach where vegetation growth contributed to thalweg incision relative to a vegetated bar. Evaluation of these results in the context of observed geomorphic response to floods elucidates mechanisms by which vegetation and channel morphology coevolve at a reach scale. By quantifying the influence of spatially heterogeneous vegetation on reach-scale hydraulics, we demonstrate that plant- and patch-scale research on vegetation hydraulics is applicable to ecogeomorphology at the reach scale.

**Hydroelectric Pumped Storage and Fish Diversion in Montana**

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Pumped storage is a way to take advantage of Montana's hydraulic resources by storing energy like a large capacity battery. This proposed project is located in Meagher County, MT and has the potential to create 400 megawatts of energy. The pumped storage station is a closed loop system which includes an upper and lower reservoir. When energy is in high demand the water is released from the upper reservoir to the lower reservoir, thus generating energy. At times of low demand the system takes advantage of the excess energy on the grid and uses it to pump the lower reservoir water to the upper reservoir. By doing this, this system becomes profitable by buying back energy when costs are low (typically at night) and selling when rates are high. This clean and sustainable system will provide stable energy to the grid and has the potential to stabilize other forms of green energy such as wind and solar. The hydroelectric pumped storage station will require a large volume of water to initially fill the reservoirs as well as periodically to account for water losses. To satisfy this need, a water diversion has been designed to supply the adequate volume of water, remove aquatic life or debris prior to diversion, and maintain the health of the water source. In order to meet the above requirements, a Farmers Screen will be installed off of the nearby Cottonwood Creek. A Farmers Screen is a horizontal fish screen that utilizes a weir wall system to divert the necessary volume of water from the source creek to the reservoirs while filtering out natural debris and aquatic life, safely returning both to the parent stream.

**Ranching for Rivers**

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Ranching for Rivers is a new approach to managing livestock within riparian areas for improvement of native riparian vegetation, fisheries and wildlife habitat, and water quality and quantity enhancements. This approach promotes the development of "riparian pastures" as an alternative to complete exclusion of the riparian area to livestock. Riparian pastures, which are relatively small pastures adjacent to a waterbody that can still be grazed for a portion of the year, offer a number of operational benefits for the rancher as well as numerous natural resource benefits. Together, these benefits are resulting in simple, commonsense projects that are furthering conservation goals along waterways, while also satisfying ranchers' needs as managers of livestock operations and stewards of the land. Coordinated by the Soil and Water Conservation Districts of Montana, in partnership with the Missouri River Conservation District Council, the program provides up to 50% cost-share for ranchers to create riparian pastures on their land. Funding can be used for fencing, developing off-stream watering sources, water gaps, or similar infrastructure. A pilot program was launched in 2016 that funded five projects in the Missouri River basin with over eight miles of streambank protected. Together, these projects reduced sediment by an average of 793 tons/year for each mile of streambank protected, resulting in a total sediment reduction of 6,651 tons/year. Starting in fall 2017, SWCDM expanded this program to landowners located in areas with a DEQ-accepted Watershed Restoration Plan. In addition to the riparian pasture cost-share, participants will be provided with the services of a certified range specialist to customize a grazing plan to maximize the benefits of the riparian pasture.

**Public Perceptions of Natural Water Storage in Montana**

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Drought in Montana has the potential to impact the natural environment and human communities, with specific repercussions for agricultural communities. Water storage to mitigate drought is one of the top concerns for most water managers and landowners throughout the state (DNRC 2015, State Water Plan). Traditional management practices and plans fall short due to their assumptions that future conditions will remain predictable (Milly et at., 2008). Montana must seek out avenues other than traditional infrastructure, such as reservoirs, to store and supply water. The concept of nature-based solutions, specifically, natural water storage systems, has come forth as a potential strategy to raise water tables, provide alternate storage methods and slow spring runoff, resulting in later season flows (Hafen & Macfarlane, 2016; Pollock et al., 2014). This research examines the adoption of these new strategies in the context of changing climate in southwestern Montana. Previous research has identified the benefits of natural water storage for ecological communities, but has not

# END OF PROCEEDINGS