# Proceedings

for

# Groundwater Uncovered

American Water Resources Association Montana Section 2019 Conference

October 9 - October 11, 2019
Rock Creek Resort-- Red Lodge, Montana

Contents



*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
  Melissa Schaar, President -- Montana DNRC
  Kim Snodgrass, Vice President -- Water and Environmental Technologies
  Hannah Riedl, Treasurer -- Montana DEQ
  Nancy Hystad, Executive Secretary -- Montana State University

- Montana Water Center
  Wyatt Cross, Director, and Whitney Lonsdale, Assistant Director

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

Melissa Schaar

Kim Snodgrass

Hannah Riedl

Nancy Hystad

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

DEQ
Montana Department of Environmental Quality

MONTANA University System
WATER CENTER

MONTANA DNRC

WET
Water & Environmental TECHNOLOGIES

Celebrating 20 years
HydroSolutions
est. 1999

Gallatin Local Water Quality District

MISSOULA VALLEY
water quality district

ENERGY LABORATORIES

## WEDNESDAY, OCTOBER 9, 2019

### REGISTRATION

10:00 am – 12:00 pm REGISTRATION
Preconference registration available through the MT AWRA website

### FIELD TRIP and HYDROPHILE RUN

1:00 pm – 5:00 pm Groundwater in Action, Revised Plan
Presentations, Conference Room, Rock Creek Resort

4:30 pm – 5:00 pm Hydrophile 5k Run/Walk - Carpool and meet at Red Lodge Ales

5:00 pm – 7:00 pm Montana AWRA Community night at Red Lodge Ales

## THURSDAY, OCTOBER 10, 2019

### REGISTRATION

7:30 am REGISTRATION, COFFEE, BREAKFAST AND CONVERSATION

### OPENING DAY PLENARY SESSION

8:00 am WELCOME WITH INTRODUCTIONS, LOGISTICS AND ANNOUNCEMENTS
Melissa Schaar -- AWRA Montana Section President

8:10 A MESSAGE FROM THE MONTANA WATER CENTER
Wyatt Cross -- Montana Water Center, Director

8:20 KEYNOTE SPEAKER 1: Alfonso Rivera, Ph.D., Chief Hydrogeologist, Geological Survey of Canada
Title: Issues and challenges for the assessment and management of transboundary aquifers at the global scale

9:20 KEYNOTE SPEAKER 2: Joanna Thamke, Supervisory Hydrologist, Montana-Wyoming Science Center, United States Geological Survey
Title: Assessing groundwater at a national scale from the USGS perspective

9:50 KEYNOTE SPEAKER 3: John LaFave, Hydrogeologist, Groundwater Assessment Program Manager, Montana Bureau of Mines and Geology
Title: Assessing groundwater at a state scale from the MBMG perspective

10:20 BREAK

10:40 Special Speaker: Jason Mohr, Research Analyst - Legislative Update

11:00 PANEL DISCUSSION: West Billings Aquifer -- Land use change and consequences to groundwater resources

12:00 Water Legend Presentation: Congratulations to Joanna Thamke!

12:30 LUNCH - Provided to all conference attendees

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

SESSION 1 (Concurrent)
**GROUNDWATER/SURFACE WATER INTERACTION**

Moderator: Elliot Barnhart

1:30 pm ***Kimberly Bolhuis.*** Controls on magnitude and spatio-temporal distribution of bedrock infiltration in a semi-arid, mountainous catchment.

1:50 ***Evan Norman.*** Quantifying Groundwater and Surface Water Interactions in Low-Impact Stream Restoration Environments.

2:10 ***Jeremy Crowley.*** Insights into seasonal geothermal spring and river interactions using unmanned aerial vehicle photogrammetry and thermal data, LaDuke Hot Springs, MT.

2:30 ***Payton Gardner.*** Using Synoptic River Surveys to Characterize Groundwater Systems.

2:50 ***Ali Gebril.*** Application of Geophysical Methods in Hydrogeologic Studies to Investigate Late-summer Dewatering in Lolo Creek, Southwest Missoula, Montana.

3:10 BREAK

SESSION 2 (Concurrent)
**WATER QUALITY**

Moderator: Christine Sudnas

1:30 pm ***Mark Petersen.*** Variability in range cattle water quality and precipitation in the Northern Great Plains over 10 years.

1:50 ***Sara Eldridge.*** Cyanobacterial bloom distribution, toxicity, and associated water-quality conditions in Bighorn Canyon National Recreation Area: A USGS-NPS Partnership.

2:10 ***Miranda Margetts.*** Montana's first wastewater based epidemiology investigation.

2:30 ***Meryl Storb.*** Using diel and seasonal variation in dissolved metabolites and conservative tracers to explore the influence of nutrient loading on stream ecosystem function.

2:50 ***Elizabeth Mohr.*** Simulation and Experimental Investigation of Linked Elemental Cycling in Freshwater Ecosystems.

3:10 BREAK

SESSION 3 (Concurrent)
**HYDROLOGY**

Moderator: Katherine Zodrow

3:30 pm ***Haley Tupen.*** Hydraulic and Hydrologic Characteristics and Resulting Fish Passage at the Huntley Diversion Dam Nature-like Fish Bypass.

SESSION 4 (Concurrent)
**MANAGEMENT & RESTORATION**

Moderator: James Rose

3:30 pm ***Tera Ryan.*** Saline seeps: how land-use management connects to both their development AND reclamation.

TECHNICAL SESSIONS: ORAL PRESENTATIONS *(continued)*

SESSION 3 (Concurrent)
**HYDROLOGY** *(continued)*

| | |
|---|---|
| 3:50 | ***Abaye Abebe.*** How do variations in the sources of recharge influence the general nature of groundwater storage in intermountain basin aquifer? |
| 4:10 | ***Mike Roberts.*** Water Distribution Foot Soldiers: What Water Commissioners Can Do For You. |
| 4:30 | ***Ronald Breitmeyer.*** Immediate Post-wildfire Soil Hydrologic Changes in a Sagebrush Steppe Ecosystem. |
| 4:50 | ***Chuck Parrett.*** Are Increasing Temperatures in Montana Affecting High and Low Streamflows? |
| 5:10 | BREAK & POSTER SET UP |

SESSION 4 (Concurrent)
**MANAGEMENT & RESTORATION** *(continued)*

| | |
|---|---|
| 3:50 | ***Andy Bobst.*** Changes in Riparian Evapotranspiration following Beaver-Mimicry Stream Restoration. |
| 4:10 | ***Kimberly Bray.*** Primary controls on nutrient use: ecosystem metabolism and disturbance in a small headwater stream, western Montana. |
| 4:30 | ***S. Katie Fogg.*** Shading Beyond the Channel: Effects of Vegetative Shade on Hyporheic Water Temperatures in the Broader Floodplain. |
| 4:50 | ***Ginette Abdo.*** The Effects of Changing Land Use on Water Resources – Agriculture to Residential Expansion. |
| 5:10 | BREAK & POSTER SET UP |

6:00 - 9:00 PM **POSTER SESSION and EVENING SOCIAL:** Heavy hors d'oeuvres and Photo Contest

7:00 PM **HENDERSON AWARD PRESENTATION**

## AWRA 2019 POSTER PRESENTATIONS

***Brianna Whitehead.*** Quantifying a Parafluvial Soil Response to Beaver Mimicry Restoration.

***Sarah Khalid.*** Simulating Energy and Water Dynamics for a Temperate Urban Microclimate Using a Fully Distributed Eco-Hydrological Model.

***Lauren Werner and Rebecca Tseng.*** Wastewater Analysis Identified Drug-Use Trends for a Montana Community on Independence Day 2019.

***Megan Guinn.*** Development and Hydraulics Testing of a Modified Denil Fishway.

***Cullen Cunningham.*** Occurrence and removal of drugs of abuse in wastewater processes.

***Kaitlin Perkins.*** Examining the Abundance and Composition of Submicron Particles in a Mine-waste Contaminated Intermountain West River.

***Jordan Jimmie.*** Modeling Hydrologic Impacts of Water Rights Quantification and Settlement on the Flathead Indian Irrigation Project.

***Allison Kelly.*** Pesticides Enhance Bacterial Growth and May Exacerbate Reverse Osmosis Biofouling

***Caleb Lockyer.*** Investigation of spatial and temporal distributions of metals in a stormwater retention pond after storm events.

## AWRA 2019 POSTER PRESENTATIONS *(continued)*

***Matthew McGlennon.*** In-situ groundwater monitoring using micro-fabricated sensors: Advantages and challenges.

***Zachary Lauffenburger.*** Calibration of Hydrologic Component of the Hydro-Economics of Agriculture Model.

***Holly Nesbitt.*** Hydro-social and socio-hydrological modeling: Challenges with data, scale, and perspective.

***Kendra Allen.*** The Beaver Project: Natural Water Storage and Climate Adaptation in Blackfeet Nation.

***Kevin Hyde.*** The Montana Mesonet: Near Real-time Climate Data for Decision Support.

***Jennifer Muscha.*** Livestock water quality varies across 10 years (2009-2018) in Eastern Montana.

***Spruce Schoenemann.*** Precipitation Isotope Ratios and Tree-ring based Snowpack Relationships to inform Paleoclimate Reconstructions from Lake Sediment δ18O.

***Bill Kleindl.*** Floodplain Ecological Assessment Across Temporal and Spatial Scales: Does the Portfolio Effect Apply to Rapid Assessment Tools?

***Lacey Gunther.*** Cottonwood Restoration in the Upper Missouri River Breaks National Monument.

***James Berglund.*** You Con-duit! Modeling conduit flow and geometry using high-resolution temperature monitoring and dye tracing

***Zach Lenning.*** Research and conservation seed increase at The Bridger Plant Materials Center.

***Anthony Sammartano.*** Restoration focused on Community Educational Opportunities.

***Claudia Macfarlane.*** Macroinvertebrate and Water Quality Education Program in the Ruby Valley.

***Liz Shull.*** Cultivating Lasting Conservation Change through Shared Values and Collaboration.

***Natalie Poremba.*** Aquatic Invasive Species Education and Monitoring in the Flathead Valley.

***Mitchell Hoffman.*** Musselshell Cooperative Weed Management Area.

***Ryan Schaner.*** Inventorying Headcuts on Mesic Sites Adjacent to Sage Grouse Leks on the Matador Ranch.

***Julia Nave.*** How Can a Water Fund Work in Montana?

***McKenzie Schessl.*** Clearwater Resource Council: Protecting the Natural Resources and Rural Lifestyle of the Clearwater Watershed.

***Meg Desmond.*** Holistic Planning and Grazing Management.

***Emilie Lahneman.*** The Bitter Root Water Forum: Building Community around a River.

***Caroline Provost.*** From Headwaters to Flat-water, Montana's Birds Call Water-based habitats Home.

***Zane Ashford.*** Gallatin Watershed Council: Preserve & Restore.

***Grant Flaming.*** Upper Overwhich Creek Fish Removal Project.

***Lauren Odom.*** Lake County Junior Conservationist Education Program.

***Valerie Bednarski.*** Upper Gallatin Nuisance Algae Investigation.

***Stuart Ellsworth.*** Configuration of StreamPro Acoustic Doppler Current Profiler (ACDP) to Measure Streamflow in Montana's Rivers for a Wide Range of Conditions.

***Haley Gamertsfelder.*** Mapping the Spread of Lepidium latifolium (Perennial Pepperweed) and Iris pseudacorus (Yellow Flag Iris) on the Clark Fork and Bitterroot Rivers in Missoula County.

***Shawn Kuzara.*** Groundwater Recharge in Flood to Pivot Irrigation Conversions.

***Mark Werley.*** Utilizing ArcGIS Online to Create Interactive Tools and Stories for the Charles M. Russel Community Working Group.

***Lauren Herbine.*** Developing field protocol for characterizing stable isotope composition of winter recharge water to a western basin: A collaboration of BSWC, UM, USFS, MBMG, in the Lolo Basin.

## FRIDAY, OCTOBER 11, 2019

7:30 am GATHER FOR COFFEE, BREAKFAST AND CONVERSATION WITH COLLEAGUES

TECHNICAL SESSIONS: ORAL PRESENTATIONS

SESSION 5 (Concurrent)
### MODELING

Moderator: David Donohue

8:00 am ***Paul Hegedus.*** Combining data intensive precision agriculture and transport modeling to limit nitrate loss to groundwater from conventional dryland wheat farming.

8:20 ***Patrick Wurster.*** Validation of the SMAP Level 4 Carbon Product using a continuous crop condition survey index.

8:40 ***Christine Sundnas.*** Gallatin County Interactive Water Quality Mapper Demos.

9:00 ***David Ketchum.*** High Resolution Irrigated Lands Mapping in the Western United States.

9:20 ***Willis Weight.*** Numerical Groundwater Flow Model of the Kalispell Valley, Kalsipell Montana.

9:40 ***Attila Folnagy.*** Montana's Groundwater Modeling Portal: Usefulness for Water Users.

10:00 BREAK

SESSION 5 (Concurrent)
### ECOLOGY, CLIMATE & COLLABORATION

Moderator: Payton Gardner

8:00 am ***Robert Ray.*** Strategically Implementing Montana's Nonpoint Source Management Plan.

8:20 ***Zach Hoylman.*** An evaluation of gridded drought indices to enhance the Upper Missouri Drought Early Warning System.

8:40 ***Luke Buckley.*** Data Center Evolution: Building a Water Communication System through Collaboration and Networking.

9:00 ***Heather Nold.*** Low Head Dam Feasibility Study for the Sourdough Watershed.

9:20 ***Kelsey Jencso.*** Enhancing the Upper Missouri River Basin Drought Early Warning System.

9:40 ***Brett Marshall.*** Macroinvertebrate Bioassessment Study Designs: A Critical Examination of Four Assumptions Leading to their Misuse.

10:00 BREAK

TECHNICAL SESSIONS: ORAL PRESENTATIONS *(continued next page)*

SESSION 7 (Concurrent)
**GROUNDWATER**

Moderator: Robert Ray

| | |
|---|---|
| 10:20 | ***David Donohue.*** The Importance of Perfecting Your Water Reservation - Now is the Perfect Time. |
| 10:40 | ***John Reiten.*** The Tale of Two Aquifers: A Study in Aquifer Sustainability. |
| 11:00 | ***Kevin Chandler.*** Great View, But Where's the Water? |
| 11:20 | ***Elliot Barnhart.*** Small Injection of Organic Nutrients in a Subsurface Coal Bed Stimulates Microbial Gas Production. |
| 11:40 | ***James Swierc.*** Groundwater in the Northeastern Helena Valley, Lewis & Clark County, Montana. |
| 12:00 | ***Katherine Zodrow.*** Pesticides in Groundwater Impact Bacterial Growth and Biofilm Formation. |
| 12:20 | BREAK |

SESSION 8 (Concurrent)
**HYDROGEOCHEMISTRY**

Moderator: Willis Weight

| | |
|---|---|
| 10:20 | ***Camela Carstarphen.*** Montana's Precipitation Isotope Network (MTPIN): data and a year's worth of lessons Montana Bureau of Mines and Geology's (MBMG) Ground Water Assessment Program (GWAP). |
| 10:40 | ***James Rose.*** Assessing the increase of nitrate and chloride in groundwater at Meadow Village, Big Sky, MT. |
| 11:00 | ***Joe Griffin.*** Cumulative gain-loss analysis – a technique used to locate stream reaches where metal contaminated groundwater inflow is degrading water quality in Silver Bow and Blacktail Creeks within the Butte Superfund Site. |
| 11:20 | ***Adam Sigler.*** Denitrification Patterns Across a Dryland Agroecosystem in the Northern Great Plain. |
| 11:40 | ***Joe Naughton.*** Practical implications of the Biotic Ligand Model as a water quality standard. |
| 12:00 | ***Ben Colman.*** Colloidal and truly dissolved metal(loid)s in wastewater lagoons and their removal with floating treatment wetlands. |
| 12:20 | BREAK |

12:30 CLOSING PLENARY: Announcements - New Officer, Student Awards, Next Year's Location

ADJOURN

## ISSUES AND CHALLENGES FOR THE ASSESSMENT AND MANAGEMENT OF TRANSBOUNDARY AQUIFERS AT THE GLOBAL SCALE

***Alfonso Rivera***, Geological Survey of Canada

A great number of transboundary water systems of the world, including transboundary aquifers (TBAs), support the socioeconomic development and wellbeing of an important part of the world's population. At present, nearly 600 TBAs have been defined in the Americas, Africa, Asia, and Europe. Transboundary water issues abound and are complicated by lack of adequate governance and shared management. Of upmost importance to resolve those issues are the background assessments, legally-binding agreements and by the fact that in many cases institutional asymmetries do not allow for a standardised knowledge.

We present a critical look at the transboundary aquifer issues, based on the analysis of identified TBAs, and discuss what is working and what it is not to illustrate the most important steps and lessons learned, as well as the good practices needed for water management in the transboundary context.

Our analysis of the current state of knowledge of TBAs in four continents shows that information on most transboundary aquifers remains limited. Given important aspects related to incomplete or contradictory knowledge on TBAs, the large number of stakeholders and opinions involved, scarce legal agreements, and the interconnected nature of these problems with other problems, lead us to conclude that groundwater science alone cannot solve transboundary groundwater issues.

Issues that still need to be addressed are: hydrogeological understanding of the transboundary systems, clear and unambiguous delineation of TBAs, indicators of cooperation, data harmonization and information sharing and management, and water use conflicts or impacts of global changes in the systems. Addressing these issues requires a concerted effort of all stakeholders involved to establish a satisfactory balance between scientific knowledge and efficient management and protection of transboundary waters.

***Alfonso Rivera is the chief hydrogeologist of the Geological Survey of Canada. He has served as both research manager and research scientist. Alfonso is the author and editor of the book "Canada's Groundwater Resources" published in 2014. He is adjunct professor at the University of Quebec-INRS, Canada, and member of the Académie de l'eau, France. When he is not working as a hydrogeologist, he travels to exotic places for scuba diving, his other passion.***

## KEYNOTE SPEAKER 2

### ASSESSING GROUNDWATER AT A NATIONAL SCALE FROM THE U.S. GEOLOGICAL SURVEY PERSPECTIVE

***Joanna Thamke***, U.S. Geological Survey, Montana-Wyoming Science Center

Groundwater is among the Nation's most important resources. It provides drinking water to more than 140 million residents, or nearly half of our Nation's population. It is the primary source of drinking water for almost all of our rural population, as well as for some of our largest metropolitan areas. More than 50 billion gallons of groundwater are used daily in support of our Nation's agricultural economy. Groundwater can play a crucial role in sustaining streamflow, particularly during droughts and other low-flow periods. It also plays an integral role in maintaining the health of riparian, aquatic, and wetland ecosystems.

Established by an Act of Congress 140 years ago, the U.S. Geological Survey (USGS) has been the Nation's principal source of information about its natural resources. In 1896, Congress included an annual appropriation to the USGS for 'the investigation of underground currents and artesian wells in arid and semiarid sections' that began in earnest the Nation's groundwater research. Since then, the USGS has provided groundwater information that includes: more than 10,000 groundwater-related publications, dozens of open-source groundwater modeling software, groundwater educational products, a National Groundwater Monitoring Network, Groundwater Watch and Climate Response Network websites, and a National Groundwater Atlas.

The first USGS groundwater assessment was completed by O.E. Meinzer (1923) who has been called the 'father of groundwater hydrology'. Meinzer's publication was followed by several decades of USGS State-by-State summaries on groundwater resources, summary appraisals for 21 regions of the Nation in the 1970s, the Regional Aquifer-System Analysis Program which evaluated 25 of the Nation's most important regional groundwater systems, and ongoing groundwater research with International, Federal, Tribal, State, and local agencies. The USGS has identified more than 60 Principal Aquifers and nearly 70 Secondary Hydrogeologic Regions for the Nation. Most recently, 22 USGS Regional Groundwater Availability Studies have been conducted as part of the National Water Census. Moving forward, the USGS will be conducting Integrated Water Availability Assessments that will collectively comprise a multi-extent, stakeholder driven, near real-time census and seasonal prediction of water availability for both human and ecological uses at regional and national extents.

***Joanna Thamke has been a hydrogeologist with the U.S. Geological Survey since the mid-1980s and has spent most of her career in Helena, Montana. Joanna enjoyed being the Montana American Water Resources Association President during 1999-2000. She is the Section Chief for the very skilled Groundwater and Surface Water Section of the Wyoming-Montana Water Science Center. She also leads several USGS project teams that focus on water quality, water availability, water use, and energy in the Williston Basin.***

## ASSESSING GROUNDWATER AT THE STATE SCALE FROM THE MONTANA BUREAU OF MINES AND GEOLOGY PERSPECTIVE

***John LaFave***, Montana Bureau of Mines and Geology

Since its inception 100 years ago, the Montana Bureau of Mine and Geology has played a vital role in evaluating the state's groundwater resources. Initially created as the Montana State Bureau of Mines and Metallurgy to "promote the development of mineral resources…" the name was changed in 1929 to the Montana Bureau of Mines and Geology (MBMG) to reflect the expanding role as the state's geological survey. Following the name change, groundwater research became a core part of MBMG's mission.

Throughout the decades, groundwater research at MBMG has been marked by distinguished hydrogeologists, novel programs, and inter-agency collaborations. During the dustbowl years of 1930's, Eugene Perry described available and potential groundwater resources throughout eastern Montana. During the 1950's and 60's, Sid Groff, chief of the newly formed Groundwater and Minerals division, oversaw the "Cooperative Program" with the US Geological Survey (USGS), to "study the source, movement, quality and quantity of groundwater" in several western river basins. During the 1970's and 80's Wayne Van Voast, working in southeast Montana, pioneered the field of coal hydrology and initiated a monitoring program (that continues to this day) to assess the effects of coal mining on groundwater resources. In the 1970's, Marvin Miller gained international recognition for his work on assessing and remediating saline seeps in the Great Plains; John Sonderegger and Bob Bergantino, with assistance from US Department of Energy and Montana Department of Natural Resources, characterized Montana's geothermal resources and their potential for economic development. In the 1980's, water-quality and reclamation issues at legacy mines, including the EPA Superfund designation in the upper Clark Fork basin, gave rise to the MBMG Environmental Hydrology program. The1980's also saw MBMG assist the Montana Department of Agriculture in developing a state-wide ag-chemical groundwater monitoring network. In the 1990's, the state legislature established the Ground Water Assessment Program at the MBMG to systematically assess Montana's groundwater resources; Tom Patton oversaw the development of a comprehensive state-wide groundwater monitoring network, the digitization of water-well records, and the creation of the Ground Water Information Center—which now serves as Montana's official repository for groundwater information. Additionally, Tom worked on the USGS-led pilot program to establish a national groundwater monitoring network. In 2009, the legislature established the Ground Water Investigations program to provide detailed groundwater information in areas of current and anticipated development.

Today, 230,000 wells withdraw about 200 Mgal/day from Montana's 10 principal aquifers. The MBMG's ongoing monitoring, investigation, interpretation, and dissemination of groundwater data ensures that those with a vested interest in groundwater development, protection, and management can make decisions based on long-term, high-quality information.

***John LaFave has 26 years of experience as a hydrogeologist with the Montana Bureau of Mines and currently serves as the program manager for the Montana Groundwater Assessment Program. He has a BS in Geology from the University of Wisconsin and an MA is Geology from the University of Texas. His research interests include all aspects of groundwater resource assessment, groundwater quality, and isotope hydrology.***

## LAND USE CHANGE AND GROUNDWATER AVAILABILITY IN BILLINGS AREA

West of Billings and east of Laurel, land use is undergoing steady change from agricultural to residential housing. Most of the construction is located in areas beyond Billings municipal services and these new homes rely on the shallow alluvial aquifer for potable water. The Montana Bureau of Mines and Geology has identified agricultural irrigation as the primary source of aquifer recharge, and as land conversion to residential development continues, reductions in aquifer recharge may alter groundwater availability and quality.

***Monica Plecker, AICP, Planning Division Manager, City of Billings and Yellowstone County***
***Kevin Chandler, Hydrogeologist, Montana Bureau of Mines and Geology***
***Dr. Mark Ellison, Manager, Billings Regional Office of the Water Resources Division***
***David Mumford, P.E., Public Works Director, City of Billings***

***Monica Plecker is the Planning Division Manager for the City of Billings and Yellowstone County. Specifically, the Division is part of the Planning and Community Services Department and she is responsible for overseeing daily operations related to current, long-range and transportation planning in Billings, Broadview and Yellowstone County. Monica graduated with a degree from James Madison University in Harrisonburg, Virginia. She has experience as both a public and private sector planner. Monica is a member of the American Institute of Certified Planners and is serving her second term as member of the Board of Director's for the Montana Association of Planners (MAP). She also represents the Roberts district for the Carbon County Conservation District.***

***Kevin Chandler, M.S. Geosciences, began working as a Hydrogeologist with Montana Bureau of Mines and Geology in October of 2009 and has developed groundwater–flow models of West Billings, the Ash Creek Mine-Decker Mine areas, buried valley aquifers in Medicine Lake and Sidney, and the Fox Hills/Hell Creek Aquifer in eastern Montana. Kevin is currently working on two groundwater projects in Richland County, modeling the West Crane Buried Valley aquifer and Fox Hills/Hell Creek aquifer flowing well remediation.***

***Mark Ellison was raised in Missoula and graduated from the University of Montana. He received a PhD in Geology from Northwestern University in Evanston, Illinois in 1987. Mark worked in the oil industry and as a teacher until coming to the DNRC in 2013 as a hydrologist. He is currently the manager of the Billings Regional Office of the Water Resources Division.***

## SPECIAL SPEAKERS

### MONTANA WATER CENTER UPDATE

*Wyatt Cross*, Director, Montana Water Center

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

### LEGISLATIVE UPDATE

*Jason Mohr*, Research Analyst, Legislative Environmental Policy Office

***Jason Mohr is a research analyst for the nonpartisan Montana Legislative Environmental Policy Office (LEPO). He also serves as staff for the Water Policy Interim Committee. Mr. Mohr has worked for the Montana Legislature for 10 ½ years. He has previously worked as a newspaper reporter and editor in Minnesota and Montana, and has degrees in chemistry and journalism.***

## WATER LEGEND

### JOANNA THAMKE, Hydrogeologist, Wyoming-Montana Water Science Center, U.S. Geologial Survery

***Joanna has been a respected Hydrologist with USGS for 35 years. She moved to Helena, MT in 1988, and has been working at the Wyoming-Montana Water Science Center for 31 years. She has served as a mentor for most of the present hydrologic staff at the USGS setting a high standard for professionalism. She is the Section Chief for the Groundwater and Surface Water Section. The diversity of her projects includes various aspects of water quality and quantity as they relate to energy development, mining, public water supply, and agriculture. Her current work focuses on water quality, water availability, water use, and energy in the Williston and Powder River Basins. Her work in the Williston and Powder River basins has yielded a wealth of groundwater information and has increased our understanding of this critical resource in the region.***

***Joanna has also been very proactive in conducting studies answering transboundary groundwater questions. As an example of this, she has been studying the brine contamination related to historic oil and gas activities, and nitrates related to agriculture on the Fort Peck Indian Reservation since 1989, making her the foremost expert on the issues in that area. Joanna has completed studies and investigations that provide a blueprint of practical field methodologies for future studies.***

***Joanna is held in the highest regard as a professional Hydrogeologist, and in the Helena community in general. Joanna "sets the gold standard" for conduct, work ethic and professional excellence. She is a consummate professional that is sought out by coworkers as well as professionals outside USGS because of her unparalleled professional opinion on water-resource quality and quantity issues in Montana. In addition to the excellence in scientific contributions Joanna strives for, what is arguably more remarkable about her is the value she places on people. Joanna is regarded as a mentor and role model. She has an open-door policy which gives her a reputation for dropping whatever she is doing and focusing on the individual coming to her for guidance.***

***Joanna was a Montana AWRA board member from 1997-2000. She is extremely generous with her time outside her professional life, serving as a board member of World Montana since 2015, President of Helena Public Montessori Parents, Inc, and the Helena Rotary Club's Youth Exchange Counselor and International Committee member. World Montana assists in changing the image of the United States one person, one friend at a time and to bring the world – its people and cultures, problems and triumphs, customs and cuisines, philosophies and religions into the great state of Montana.***

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

**ORAL PRESENTATION ABSTRACTS**

*(listed in alphabetical order by first author's last name)*

## The effects of changing land use on water resources – agriculture to residential expansion

Ginette Abdo[1]

[1]Montana Bureau of Mines and Geology

Increasing demand for water supply due to subdivision growth and residential expansion can result in increased groundwater drawdown and decreased stream flow (stream depletion). This raises concerns with water right holders, land owners, and adjacent surface-water users. Subdivision water needs are typically supplied by either one or more centralized public supply wells (PWS), or individual private wells.

The Montana Bureau of Mines and Geology, Ground Water Investigation Program (GWIP) has investigated the effects of subdivision growth in several project areas; these studies have a common goal of characterizing the magnitude of changes to the groundwater and surface water systems. We have used numerical groundwater flow modeling to interpret field data and to predict future hydrogeologic responses. This presentation is a compilation of multiple studies.

Taken together, results from these projects suggest that domestic consumption is a small portion of the overall groundwater budget. Groundwater and surface water response to pumping depends on aquifer properties, pumping rates and distances to surface water. These principals are well known in the literature and were applied to GWIP project areas in Montana through numerical models.

Modeling results of hypothetical subdivisions, mainly in southwestern Montana watersheds, suggest that the magnitude of stream depletion can be small enough that it is often within measurement error. However, since stream depletion is proportional to the pumping rate, as residential development continues the effects on stream flow will increase. The timing of when stream depletion occurs is important in management and planning. These studies also indicate that in most settings, the removal of irrigation recharge as land use changes to residential development has a larger effect on the hydrologic system than increases in pumping from residential wells.

## How do variations in the sources of recharge influence the general nature of groundwater storage in intermountain basin aquifer?

Abaye G Abebe[1], Robert A Payn[1], Stephanie A Ewing[1], Payton W Gardner[2]

[1]Montana state university, [2]University of Montana

Informed management decisions regarding sustainable water use during dry seasons in the western US require an improved understanding of the general nature of groundwater storage in intermountain basins. The goal of this study is to explore the fundamentals of how the abundance and behavior of groundwater in basin aquifers depends on sources of water originating from adjacent mountains and from local precipitation. Here, we consider variations in four recharge pathways to intermountain basin aquifers: (1) mountain front stream recharge (MFSR), (2) mountain front block recharge (MFBR), (3) recharge from local precipitation (LPR), and (4)

recharge from irrigation infrastructure (IIR). MFSR is sourced by streambed infiltration, mainly in proximity to the mountain front. MFBR is sourced by subsurface transfer from the adjacent mountain-blocks. LPR is distributed across the surface of the basin floor. IIR combines infiltration from canal leakage and any excess field applications that are not consumed by evapotranspiration. We are building a collection of parsimonious groundwater models (using MODFLOW) to understand the relative influence of these recharge sources on groundwater storage, outflow from the aquifer, potentiometric surface, and aquifer flow vector fields relative to streams and rivers within the basin. The model is driven by seasonally (monthly time scale) transient conditions to simulate the aquifer dynamics due to seasonal variations of typical snowmelt driven hydrologic regimes. Sensitivity analyses allow exploration of how the change in model parameter values controlling each recharge mechanism affects the response of the aquifer to different recharge scenarios. Initial modeling scenarios demonstrate that the hydraulic conductivity of stream beds controlling MFSR and the lower boundary condition controlling drainage from the model have a strong influence on groundwater storage and the general nature of the flow vector field in the simulated intermountain basin aquifers. Higher conductivity at the lower boundary and lower conductivity in the stream beds lead to losing stream conditions across the intermountain basin. Lower conductivity at the lower boundary and higher conductivity in the stream beds lead to a progression from losing to gaining conditions in streams across the basin from the mountain front. Further sensitivity analyses explore how these patterns and the resulting water balances are influenced by scenarios where the intermountain basin aquifers are more connected vs. less connected from MFBR and how they may be influenced by the enhancement of divergent flow at the mountain front via irrigation infrastructure. Exploration of these fundamental patterns contributes a theoretical benchmark for understanding the potential for groundwater storage in intermountain basins to augment dry-season stream flow and water resource availability.

**Small injection of organic nutrients in a subsurface coal bed stimulates microbial gas production**

Elliott Barnhart[1], Leslie Ruppert[1], Arthur Clark[1], Edwin Weeks[1], George Platt[2], Hannah Schweitzer[2], Heidi Smith[2], William Orem[1], Shuhei Ono[3], Matthew Fields[2]

[1]USGS, [2]Montana State University, [3]Massachusetts Institute of Technology

The subsurface groundwater biosphere represents a large fraction of Earth's biomass but little is known about the in situ activity of this important microbial ecosystem. Subsurface microorganisms have generated substantial quantities of coalbed methane (CBM) in many subsurface coal beds and laboratory experiments indicate that CBM can be enhanced with relatively small additions of organic nutrients. The potential for enhancing microbial communities to produce additional CBM with organic nutrients has not been demonstrated in situ. Here, we compared temporal variations of gas concentrations measured by a down-well Pro-Oceanus total dissolved gas probe (Mini TDGP) over two years to those calculated based on isotherm analysis from cores obtained from a well in the Flowers-Goodale coal bed in the Powder River Basin, MT, USA. The Mini TDGP then measured a down-well gas rise from approximately 25% to 50% saturated over four months following a small (200 L) injection of 0.1% yeast extract and 0.45% deuterated water. Down-well water, gas and microbial samples were collected just before and after this injection with a subsurface environment sampler (SES) that maintained in situ pressure upon retrieval. The coal slurry and water from the SES were analyzed to determine the microbial and geochemical shifts that occurred, and the gas was analyzed for isotopic changes and rare isotopologues to characterize the origin of the methane. These down-well results suggest in situ microbial communities can be stimulated to produce

additional methane in subsurface coal beds, and the methods tested and developed in this study could be used to determine the activity of microbial communities in other subsurface environments.

**Changes in riparian evapotranspiration following beaver-mimicry stream restoration**

Andrew L Bobst[1], Robert A Payn[2], Robert W Pal[3]

[1]MBMG, [2]MSU-LRES, [3]Montana Tech - Biological Sciences

Beaver mimicry stream restoration (BMR) attempts to restore stream ecosystems by simulating the effects of beaver activity. Objectives for BMR projects often include increasing both the extent of the riparian plant community and late-summer stream flows. We expect that shallower groundwater tables from BMR will manifest in more robust riparian plant communities and subsequently in higher actual evapotranspiration (ETa). This effect results in a potential tradeoff between BMR goals, since enhanced ETa can decrease the amount of water available to supplement late-summer stream flows. This project evaluates this tradeoff at two headwaters streams in southwest Montana.

High resolution drone imagery provides an opportunity to investigate and quantify the mechanisms controlling ETa. We evaluated pre (2016) and post (2017-2018) treatment vegetation indexes (NDVI) collected from drone imagery. NDVI values can be used to estimate ETa based on relationships with potential ET (ETo) values calculated at nearby weather stations. Piezometers installed in 2015 and 2016 provide a record of depth to groundwater (DTW) throughout the sites over the 4 year period. ETa/ETo values were calculated for a 1 m buffer around each piezometer. ETa/ETo decreases as DTW increases. Below a DTW value of 0.8 m the slope of this relationship is about -0.09/m, and about -0.38/m when DTW is greater than 0.8 m. DTW appears to provide a first order control on ETa; however, considerable variation in ETa/ETo remains after removing that explained by DTW.

Both of our sites exhibited increases in riparian evapotranspiration after restoration. At Long Creek, the treatment areas showed an average increase in ETa/ETo values of 0.13, while the control areas increased by 0.07. Applied across the 17.3 treated hectares (42.6 acres) a 0.06 increase results in an additional 5,800 m3/yr (4.7 acre-ft/yr) of water consumed by plants in the treated areas. This equates to an average of 0.37 L/s (0.013 cfs; 5.8 gpm) more water being used by plants over the growing season (April to September). At Alkali Creek, ETa/ETo values increased by 0.06 in the treatment area, while the control showed no change. This increase results in an additional 2,740 m3/yr (2.2 acre-ft/yr) of water consumed by plants over the 7.26 treated hectares (17.9 acres), or an average increase in plant water use during the growing season of 0.17 L/s (0.006 cfs; 2.7 gpm).

Our results show that ETa likely increases due to BMR, and those increases appear to be largely driven by changes in groundwater elevations; however, the residual variation in the DTW to ETa/ETo relationship suggests that other variables (e.g. plant type, % leaf area) may be important to predicting ETa. The growing season ETa increases at both sites were about 0.02 L/s per treated hectare (0.0003 cfs/acre).

**Controls on magnitude and spatio-temporal distribution of bedrock infiltration in a semi-arid, mountainous catchment**

Kimberly K Bolhuis[1], W. Payton Gardner[1]

[1]University of Montana, Geosciences

Mountains in arid and semi-arid regions receive a disproportionately large amount of precipitation compared to their bounding valley aquifers due to orographic effects; however, little is known about how much and where mountain precipitation infiltrates into bedrock. Many conceptual and numerical hydrologic models treat the bedrock as an impermeable barrier relative to the soil mantle, partitioning flow on the hillslope and in the catchment into shallow subsurface and surface flow only. Recent research has illuminated dynamic interactions between soil and bedrock reservoirs on research hillslopes around the world, and has shown that bedrock permeability is a major control on the volume of bedrock groundwater recharge and watershed response dynamics. This study focuses on: 1) constraining the surface conditions (e.g. degree of antecedent moisture and potential evapotranspiration) and landscape position most conducive to deep percolation and recharge to the bedrock groundwater system and 2) the applicability of current methods used to estimate recharge across variations in landscape position and lithology in mountainous watersheds. Recharge and hydrologic connection at the hillslope scale is evaluated using observations of water table dynamics in nested soil and bedrock wells across a variation in landscape position. Bedrock permeability is estimated from slug tests, core samples, and outcrop fracture mapping. Stable water isotopic and geochemical samples of precipitation, soil and bedrock groundwater, and stream water are used to evaluate the recharge flux and magnitude to the mountain block at the hillslope and watershed scale. Well hydrographs and discharge observations in two watersheds underlain by bedrock of differing permeabilities are used to evaluate the response of the watershed to deep infiltration from snowmelt and storm events. The watershed with more permeable bedrock showed a slow and subdued response to precipitation inputs, while the catchment with less permeable bedrock exhibited a more rapid and flashy response to precipitation inputs. Observation wells screened below the soil-bedrock interface exhibited a hydraulic response to snowmelt. The observed 2H and 18O values for bedrock groundwater and for baseflow are similar. The bedrock groundwater and baseflow isotopic values are heavier compared to depth-integrated snowpack isotope values. These results indicate the potentially active role of bedrock groundwater in upland catchments. This research expands the current knowledge of the seasonality, magnitude of, and controls on recharge to the bedrock reservoir in mountainous terrain in a semi-arid climate, indicating the importance of understanding the key role that bedrock plays in partitioning and transmitting flow through the mountain block.

**Primary controls on nutrient use: ecosystem metabolism and disturbance in a small headwater stream, western Montana**

Kimberly K Bray[1], H. Maurice Valett[1]

[1]University of Montana

Ecosystem metabolism and disturbance can alter nutrient retention in aquatic systems. Nitrate concentrations followed consistent diel swings in Miller Creek of western MT in 2019 with minima occurring during the day and maxima at night. Research addressing the interacting determinants of nitrate retention was conducted with a single-station method from June to October of 2019. Fine-scale temporal measurements collected from a suite of in-situ sensors placed in the stream revealed

significant daily trends. Generalized linear models were used to determine the relative roles of physiochemical characteristics and stream metabolism on daily changes in nitrate retention. Instream experimentation and mesocosm incubations were used to investigate how interaction between reduced sediment stability and metabolism change nitrate retention at a whole-system scale over multiple seasons.

**Immediate post-wildfire soil hydrologic changes in a sagebrush steppe ecosystem**

Ronald J Breitmeyer[1], Riley Cromie[2], Allison Cramer[2], Kyle O'connor[2]

[1]Montana Bureau of Mines and Geology, [2]University of Nevada, Reno

Wildfire impacts hundreds of thousands of acres of delicate ecosystems every year in the western United States. In particular, sagebrush steppe ecosystems are slow to recover in the post-wildfire environment potentially exposing what are often thin layers of soil to erosion and ultimately loss of substrate for reestablishment of native vegetation. Additionally, fire impacts to soils may alter hydrologic properties of soils affecting long-term soil water storage and infiltration dynamics ultimately impacting groundwater recharge in fire impacted areas. An immediate post-fire snapshot of soil hydrology in a sagebrush steppe ecosystem was collected in the Perry Canyon watershed in Washoe County, Nevada. In August 2018, the area was burned in the approximately 70,000-acre Perry Fire. Hydrologic analysis included collection of semi-undisturbed core samples from six sampling sites within Perry Canyon for laboratory soil water characteristic curve (SWCC) and unsaturated hydraulic conductivity (K_θ) analysis. Soils at each site in the watershed were collected in burned and unburned areas located ~1-2 m apart. In-situ mini-disc infiltration tests for field-saturated hydraulic conductivity (K_fs) were also collected at the time of sampling. The SWCC for soils in burned areas generally exhibited a lower air-entry suction and higher rate of loss of water content with increase of suction relative to soils sampled from unburned areas. The relative hydraulic conductivity (K_θ/K_s) tended to be higher at equivalent levels of saturation for soils sampled in burned areas versus those sampled in unburned areas. Saturated hydraulic conductivity (K_s) from laboratory tests generally suggested higher (K_s) for soils in unburned areas. Trends in K_fs were inconsistent with burned areas exhibiting higher K_fs (relative to unburned areas) at some sites and vis-a-versa at other sites. The post-fire snapshot presented in this study indicates that wildfire in this environment has altered hydrologic properties of soils that affect infiltration and potentially groundwater recharge. The magnitude of those effects and longer-term evolution of the soil hydrology is subject to ongoing investigation.

**Data center evolution: building a water communication system through collaboration and networking**

Luke Buckley[1]

[1]Montana Technological University - MBMG

The Montana Bureau of Mines and Geology's (MBMG) Data Center is evolving to expand data dissemination through collaboration and networking. Streamlined discovery of and access to Montana's water-resource information can greatly enhance research projects. Collaboration among data users requires that data be visible, discoverable, and retrievable. Recognizing that not all data collectors in Montana can provide data to a wide audience, MBMG offers collaboration opportunities through the online section of the Data Center.

The MBMG works with several National, State, and local agencies to promote data collection and sharing efforts. Groundwater scientists are familiar with the Ground Water Information Center (GWIC)—the state's repository for water-well logs and groundwater data. Since 2014, MBMG and DNRC have collaborated to build a statewide, real-time, surface-water-monitoring network (SWAMP). We continue to expand the network by working with local water quality districts to collect and deliver locally collected data (Gallatin and Lewis and Clark). In 2018, the Montana Climate Office (MCO), Montana Department of Agriculture (MDA), and MBMG collaborated to harvest groundwater-level data at MDA-Mesonet stations. MCO stores and delivers the atmospheric and soil moisture data, and MBMG will store and deliver the water level and temperature data through the Data Center.

Currently, MBMG's Data Center provides raw data to consumers through more than 40 websites, applications, and services. Websites like GWIC and SWAMP support direct contact with the users through either a browser or mobile device. MBMG delivers real-time access to other websites through a series of water-related web services, such as the Natural Resource Information System's (NRIS) Digital Atlas and the United States Geologic Survey's (USGS) National Ground Water Monitoring Network (NGWMN). During FY2019, more than 450,000 visitors interacted with the MBMG's web presence, generating 29 million hits and downloading more than 11.6 billion pieces of data.

**Montana's precipitation isotope network (MTPIN): data and a year's worth of lessons Montana Bureau of Mines and Geology's (MBMG) Ground Water Assessment Program (GWAP)**

Camela A Carstarphen[1], Jacqualine Timmer[2]

[1]Montana Tech, Montana Bureau of Mines and Geology, [2]Montana Bureau of Mines and Geology

The Montana Bureau of Mines and Geology developed a pilot network to collect monthly precipitation samples for stable isotope analysis from eight sites in southwest and western Montana (the Lolo, Upper Clark Fork, Lower Blackfoot, and Upper Missouri Watersheds). October 2019 marks the completion of the first year of monthly composite sample collection at all 8 sites. Characterizing the natural stable isotope variations (18O/16O and 2H/1H) in precipitation supports identification of groundwater recharge sources. Isotope analysis of groundwater and surface-water is fairly common; however, the isotopic composition of Montana's precipitation is not well documented. The pilot program objectives include documenting the spatial and temporal variation in isotopic composition of precipitation, establishing sampling and handling protocols, and evaluating the utility and feasibility of long-term network operation. Each site consists of a precipitation sampler paired with a climate station, such as a Montana Climate Office Mesonet station, or a Natural Resources Conservation Services (NRCS) snow telemetry (SNOTEL) site. Precipitation is collected with the International Atomic Energy Agency's Global Network of Isotopes in Precipitation (IAEA's GNIP) recommended sampler. Monthly composite samples are collected and decanted into 20 ml HDPE conical capped bottles with no headspace for analysis at MBMG's Analytical Lab using cavity ring-down spectroscopy. Data are available through the MBMG Ground Water Information Center (GWIC) website and are included in the Global Network of Isotopes in Precipitation database. Data from three basins (Lolo, lower Blackfoot, and Upper Missouri) include groundwater and surface water sampling sites. In addition to stable water isotope analysis, samples for tritium analysis are collected bi-annually at four of the sites. To date, only Lolo basin has a full year of data collection. A weighted local meteoric water line (LMWL) using high elevation data plots on the Global Meteoric Water Line (GMWL), $\delta D = 8.23\ \delta O18 - 12.20$ ($r2 = 1.0$). A weighted LMWL

using lower elevation data is similar to the published LMWL of Gammons, 2005: δD = 7.33 δO18 – 9.16 (r2=1.0). October composite samples collected from three sites in 2018 have tritium concentrations lower than reported global values: Lolo Pass Site - 4.0 tritium units (TU's), Macdonald Pass Site - 7.3 TU's, and Lubrecht Site – 3.7 (TU's).

**Great view, but where's the water?**

Kevin M Chandler[1]

[1]Montana Bureau of Mines and Geology

Scenic views of limestone palisades, rolling hills of aspens and pines, and clear running streams draw people to the Beartooth Mountains. When looking for groundwater resources, mountain front recharge (MFR) is often assumed to replenish the aquifers along mountain fronts and beyond. But as the case with all recharge, geologic structure and material types control groundwater movement, not necessarily proximity to mountains. The Beartooth mountain front from Big Timber to Wyoming is one of the most geologically complex areas in Montana. Mountain streams provide nearly constant recharge to the alluvial aquifers, and the majority of wells in Stillwater and Carbon counties are completed in shallow alluvium. Although the alluvial aquifers produce ample high-quality water, they overlie less than 10 percent of the land area. The bedrock aquifers are increasingly being explored for domestic and stock water sources. Water-level fluctuations observed in bedrock wells and spring discharges from the bedrock aquifers do not indicate connection to mountain recharge sources. The hydrogeologic setting of the Beartooth Mountain front will be compared to other mountain front settings to explain the lack of MFR observed in aquifers north of the Beartooth Mountains.

**Colloidal and truly dissolved metal(loid)s in wastewater lagoons and their removal with floating treatment wetlands**

Benjamin P Colman[1], Lauren Sullivan[1]

[1]University of Montana

Climate change is predicted to cause continuing declines in late-season streamflow, thus increasing the relative contribution of wastewater effluent to surface water flows. Wastewater effluent represents a critical point source of metal and metalloid contamination to aquatic ecosystems and wastewater lagoons are as the most common wastewater treatment system in the rural United States. Although the fraction of total wastewater metals and metalloids in "dissolved" forms (defined here as < 450 nm) likely drives the potential for negative effects on receiving waters, this broad operational definition lumps truly dissolved solutes (<1 nm) with small colloids and nanomaterials (1-450 nm; hereafter colloids). This size distinction may be important as colloidal particles and truly dissolved solutes differ in their interactions with aquatic organisms and likely would require different strategies for their removal from wastewater. One potential tool for improving metal(loid) removal in wastewater lagoons is floating treatment wetlands, which consist of hydroponically grown plants on floating mats. This study examined the distribution of metal(loid)s between truly dissolved and small colloidal size fractions in six wastewater lagoon systems. Additionally, the efficacy of floating treatment wetlands in removing metal(loids) and influencing the distribution of contaminants among truly dissolved and small colloidal size ranges was examined. In this survey of six lagoons, it was found that iron, lead, copper, manganese, and

zinc were most abundant as small colloidal particles while aluminum, arsenic, and chromium were found mostly as truly dissolved solutes. The FTWs were especially effective at removing those metal(loid)s that were abundant in colloidal forms, suggesting a potential role for FTWs in enhancing wastewater lagoon efficiency for some metal(loid) contaminants.

**Insights into seasonal geothermal spring and river interactions using unmanned aerial vehicle photogrammetry and thermal data, LaDuke Hot Springs, MT**

Jeremy Crowley[1], Alan English[1], Raja Nagisetty Nagisetty[2], Jesse Bunker[2]

[1]Montana Bureau of Mines and Geology, [2]Montana Technological University

Using temperature as a tracer of GWSW interaction in large, dynamic river systems is challenging because the groundwater temperature signal is typically small compared to the surface water signal. Seasonal studies of GWSW interactions have also been hindered by the timing of contrast in temperature between the groundwater and surface water, which limits the optimal periods of study to the summer and winter. Geothermal groundwater systems have a very high temperature and contrast compared to surface water, providing an opportunity to investigate temporal variation in GWSW interaction over an entire annual cycle. This study used forward looking infrared (FLIR) from an unmanned aerial vehicle (UAV) platform, stream and groundwater discharge, and precipitation to evaluate the seasonality and spatial distribution of GWSW interaction of a small geothermal feature in southwest Montana. LaDuke hot springs is a series of geothermal springs that discharge into the Yellowstone River about five miles northwest of Gardiner.

Field data collection and UAV flights were conducted approximately every 2 months from September 2018 to September 2019. UAV 3D photogrammetry models were successfully developed throughout the year, even when up to 1.5m of snow was present in the area of interest. The 3D models were used to determine accurate river elevation in the study area. Preliminary findings indicate that some of the springs remain in fixed locations throughout the year, while others appear to migrate up and down slope based on river stage. FLIR thermal mosaic model development was most successful during periods of low to moderate river discharge. During period of high river discharge, thermal mosaic models were difficult to develop because pixel uniformity contributed to the lack of key point discrimination in the river. The differential between upstream and downstream synoptic-streamflow measurements was not large enough to determine the magnitude of the geothermal spring discharge. The geothermal features are only present on the east bank of the Yellowstone, potentially due to proximity to faults and/or a clay layer which dips to the west.

**The importance of perfecting your water reservation - now is the perfect time**

David Donohue[1], Lucas Osborne[1], David Baldwin[1]

[1]HydroSolutions Inc

Thirty-three municipal, forty conservation district, and ten State and Federal water reservations have been granted in Montana. The Department of Natural Resources and Conservation (DNRC) recently completed a 10-year review of existing state water reservations as directed by the 2015 Montana Legislature. Each water reservation holder submitted a report which provided information on how the objectives of the reservation are being met. This information was used by DNRC to evaluate the continuing need for each reservation. Most water reservations in Montana are

associated with three Final Orders issued by DNRC: 1) Yellowstone, 2) Upper Missouri, and 3) Lower Missouri Final Orders. Water reservation uses created through these Final Orders include maintaining instream flow for fisheries, municipal, irrigation, and multi-purpose uses (chiefly large storage reservoirs). Municipal, irrigation, and multi-purpose reservations were all required to submit a response to the DNRC request for information. In most cases, DNRC found that the actual volume used to date has been considerably less than expected.

Only the Upper Missouri municipal reservations have a perfection date attached to the reservation, which is December 31, 2025. In the Upper Missouri, several municipalities have moved ahead with developing water reservations, either with scoping, planning, and designing, or with actual use of the water. The City of Helena has drilled two test holes and installed one production well to evaluate the availability of water in the deep alluvial aquifer within the reservation boundary. In addition, the City continues to tap into the water reservation with applications to change the points of diversion within the place of use for selected irrigation projects. The City of Great Falls has perfected most of its surface water reservation through change applications for parkland irrigation and industrial use.

The City of Shelby submitted applications to change the place of use and point of diversion for each of the City's municipal water rights and reservation. The City requested the water right changes to meet current municipal demands from portions of the City that have grown outside of its historic boundaries. Additionally, the City has obtained multiple water use agreements to distribute water to outlying communities. The water right and water reservation changes are part of an interim solution to provide reliable potable water to local communities prior to completion of the North Central Montana Regional Water Authority pipeline project.

Inventive and progressive policies by some municipalities show that numerous opportunities to develop and perfect water reservations are available. End users will greatly benefit from access to reliable and sufficient water supplies. Moving forward with planning, design, and actual use of the water is critical to ensuring the reservation is not withdrawn for lack of use in the future. But, the 2025 deadline means that some water reservation holders must initiate actions quickly.

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

Sara L Eldridge[1]

[1]US GEOLOGICAL SURVEY

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

possible impacts of cyanotoxins and degraded water quality resulting from these blooms on humans and wildlife that inhabit or use BICA water resources.

**Shading beyond the channel: effects of vegetative shade on hyporheic water temperatures in the broader floodplain**

S. Katie Fogg[1], Geoffrey C Poole[1], Ann Marie Reinhold[1], Scott J O'daniel[2], Byron Amerson[1]

[1]Montana State University, [2]Confederated Tribes of the Umatilla Indian Reservation

In 2011, Meacham Creek (Umatilla Basin, Oregon, USA) underwent a restoration effort reconnecting the stream channel to its historic floodplain – with the intent of increasing hyporheic exchange to cool summertime stream temperatures. In response to the restoration, we measured an immediate increase in water level of the alluvial aquifer and a subsequent increase in summertime stream temperatures. Additionally, simulation modeling of the restored stream suggests that hyporheic exchange rate and heat transfer to the aquifer increased. Because much of the floodplain vegetation was removed for heavy equipment access, we hypothesized that loss of shade in the stream corridor warmed channel temperatures directly via two mechanisms: (1) increased solar radiation on the stream surface, and (2) increased heat conduction into the hyporheic zone through exposed floodplain sediments. We examined the potential effects of reduced floodplain shade on hyporheic water temperatures using a groundwater heat budget model, with and without floodplain shade. Model results showed floodplain shade had little affect on hyporheic water temperatures of short flow paths but large effects on hyporheic temperatures of longer flow paths, especially during the summer months. Where hyporheic zones extend laterally from the channel, management of floodplain shade, in addition to streamside shade, may have important implications for channel water temperature dynamics.

**Montana's groundwater modeling portal: usefulness for water users**

Attila J Folnagy[1], Melissa Schaar[2]

[1]MT DNRC, [2]MT DNRC

A new groundwater development requires analysis by Department of Natural Resources and Conservation (DNRC) of impacts to senior groundwater and surface water users. This pilot project examines the potential for a groundwater modeling web application to provide the DNRC and water users with a better understanding of the impacts of a proposed well. The two models uploaded into the web application and discussed in this talk are for the West Billings and Flathead Valley Aquifers. These locations are representative areas of Montana where DNRC receives many groundwater permit applications. This web application runs the MODFLOW groundwater modeling software that simulates groundwater flow in the aquifer (s) as well as surface water conditions. Modeling with MODFLOW requires a specific skill set that most users don't have. Thus, the web application provides a user-friendly platform where a user can input the information about a proposed well and generate drawdown and stream depletion results for potential projects. This will provide the user with the knowledge of potential impacts of the proposed well prior to applying for a permit. The ultimate goal of this pilot project is to benefit future groundwater permit applicants with an understanding of potential impacts prior to drilling a well. The web application will assist the DNRC and water users who have proposed groundwater projects during the pre-application phase of the permitting process. An important component of the pilot project is that the web application will be

used by DNRC staff for demonstration and discussion purposes to determine its usefulness to DNRC and water users. If this groundwater model web application pilot study is successful, then DNRC will pursue additional funding for uploading additional groundwater models and making the groundwater modeling web application available for public use.

**Using synoptic river surveys to characterize groundwater systems**

Payton Gardner[1]

[1]University of Montana

Here, I demonstrate the utility of synoptic stream water surveys as a convenient means to interrogate properties of the surround local to regional groundwater system. Synoptic sampling of stream chemistry has long been used as a powerful methodology for estimating the volume and location of groundwater discharge to streams over a variety of spatial scales. The principal behind the technique is to find a suitable tracer that is present in the groundwater system at a known concentration, and then infer the amount of groundwater in surface water from the concentration of the tracer in the surface water and mass balance calculations. However, in many cases the concentration of the tracer in groundwater is not uniform, nor well known and may encode information on the groundwater system discharging to the stream, such as the groundwater residence time, provenance, quality, and chemical evolution. In fact, in many cases, it is the tracer concentration or distribution of concentrations in groundwater system feeding the stream that we are interested in. However, regional scale sampling of the groundwater system is often difficult and limited by the location and amount of groundwater wells. Here, we flip the paradigm of stream tracer surveys, by using stream discharge and chemistry to estimate the tracer concentration and infer properties of groundwater feeding the stream. Groundwater discharge to the stream can be estimated using one set of environmental tracers, applied tracers, synoptic stream gauging or other methods. The concentration of a tracer of interest in the groundwater can then be estimated using the estimated groundwater discharge and the observed river chemistry. In this paradigm, the stream becomes an easily accessible location to sample to the flow weighted average concentration of tracer in groundwater system discharging to the stream. We use this methodology to infer properties such as the magmatic isotopic composition, age distribution, and quality of the surrounding local to regional groundwater systems discharging to the stream. In this talk, I will develop the theory behind the method and demonstrate its application in several groundwater systems of local to regional scale.

**Application of geophysical methods in hydrogeologic studies to investigate late-summer dewatering in Lolo Creek, Southwest Missoula, Montana**

Ali Gebril[1]

[1]Montana Bureau of Mines and Geology

Lolo Creek, a perennial major tributary to the Bitterroot River, in some years, has become intermittent in the lower reaches in late summer months. Finding reasons for late summer dewatering has led to geophysical and hydrogeologic studies by the Montana Bureau of Mines and Geology to understand the cause and effect relationship between surface water and groundwater uses, and stream flow. Lithology from boring logs, stream flow and groundwater level measurements, LiDAR and survey data, and geophysical information helped to construct a

conceptual model for Lolo Creek study area. Geophysical measurements including Electrical Resistivity Tomography (ERT), Spontaneous Potential (SP), and Multichannel Analysis of Surface Waves (MASW) were useful to 1) delineate the saturated zones, 2) estimate depths to bedrock, 3) locate fractured bedrock zones, and 4) identify a geologic fault near the town of Lolo. In addition, we developed an empirical relationship between saturated zones hydraulic conductivities and electrical resistivity based on a field scale investigation. This relationship provided estimates of hydraulic conductivities at other locations where aquifer properties were lacking, providing reasonable estimates of initial aquifer hydraulic conductivities in the study area.
Information obtained from geophysics studies are valuable to confirm hydrogeologic framework and the conceptual model. A sound conceptual model is vital to build a robust groundwater flow models intended to use as an investigation tool to study Lolo Creek late-summer dewatering. The results of this investigation would be useful to for water management decisions and restoration efforts in the Lolo Creek watershed.

**Cumulative gain-loss analysis – a technique used to locate stream reaches where metal contaminated groundwater inflow is degrading water quality in Silver Bow and Blacktail Creeks within the Butte Superfund Site.**

Joe Griffin[1]

[1]Montana Department of Environmental Quality - Retired also Technical Advisory Committee Clark Fork Coalition

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

The program is now at a point that the effect of contaminated groundwater discharging to Blacktail and Silver Bow Creeks is subtle but evident, and in need of additional environmental management. The robust surface water monitoring program for the site, synoptic sampling 10 to 12 times per year at seven instream stations, has proven invaluable, enabling the technical team to locate stream reaches that still require additional groundwater capture or source material excavation.

A unique form of cumulative gain-loss temporal trend analysis is being used to locate reaches that are affected by metal contaminated groundwater inflow. For instance, the difference in total recoverable copper concentration between any two stations will show either a gain or loss of copper over the reach. By adding the gains or losses from successive monitoring events (cumulative gain-loss), and by comparing the relative slopes through time between reaches, managers are locating problem reaches and focusing additional groundwater capture or source material excavation along those areas.

This type of trend analysis also records those times when engineered remedy features have affected and improved in-stream water quality. In the near past, natures stream engineers – beavers – have also affected groundwater-stream interaction and water quality by building dams and ponding water.

**Combining data intensive precision agriculture and transport modeling to limit nitrate loss to groundwater from conventional dryland wheat farming**

Paul B Hegedus[1], Stephanie A Ewing[1], Robert A Payn[1], Bruce D Maxwell[1], W. Adam Sigler[1]

[1]Montana State University

Inefficient uses of nitrogen (N) fertilizer can lead to detrimental effects on groundwater quality in agricultural regions. Here we use measures of nitrate in soil water to constrain a vertical solute transport model examining soil N use efficiency in agricultural soils. We present model sensitivity analyses in the context of conventional dryland wheat production in the Judith River Watershed (JRW) of central Montana, where up to 25% of private wells sampled have exceeded the EPA standard for nitrate in drinking water. Our goal is to incorporate a mechanistic model of solute transport through soils into a data-intensive precision agriculture approach that utilizes the vast stream of data available from farms to optimize N fertilizer applications based on maximizing producer profits and maximizing agronomic N efficiency. More specifically, we aim to use the water and solute transport model to identify key soil parameters and patterns of conditions (management, weather) that can be used to predict N fertilizer inefficiencies and design fertilizer prescriptions that maximize efficiency of N use. Inefficient uses of N are defined as any fate of N that does not result in increased productivity (yield or protein content) and subsequent economic net return. The model was parameterized based on soil data collected in the JRW, and we performed sensitivity analyses to evaluate N dynamics under various scenarios of soil attributes, crop management (cropped vs fallow), and weather. Results from these sensitivity analyses provide insight into circumstances that produce the largest agronomic and economic N use inefficiencies and allow better understanding of how competing processes (i.e. leaching and denitrification) dictate N loss. These efforts highlight where and when "perfect storms" of N use inefficiencies could occur, and aid in developing management recommendations that reduce the potential for those episodes of inefficiency to degrade groundwater quality. Ultimately, data-intensive precision agriculture provides a basis for management decisions that both save on application costs and reduce nutrient loading to water resources.

**An evaluation of gridded drought indices to enhance the Upper Missouri Drought Early Warning System**

Zachary H Hoylman[1], Kelsey Jencso[1], Zachary Holden[2], Michael Downey[3], Troy Blandford[4], Kyle Bocinsky[1], Kevin Hyde[1]

[1]Montana Climate Office, [2]USFS, [3]Montana DNRC, [4]Montana State Library

Early detection of drought can be crucial to mitigating its impacts on Montana's economy, through changes to the management of our surface water resources, agriculture, livestock production and outdoor recreation. Due to complex land-atmosphere interactions, drought impacts our water resources in different ways due to differences in antecedent conditions and the intensity of a particular event. Previous work has focused on development of gridded indices (e.g. PDSI, SPEI, SPI, Deficit, etc.) that attempt to capture the various physical drivers of drought. However, it is often a challenge to know when during the season to use a specific index and which time scales (from days to months) best describe different forms of drought. Here, we leverage soil moisture data from the Montana Mesonet and from Snow Telemetry (SNOTEL) stations across the western U.S. (285 stations) to evaluate common gridded drought indices and the time scales for each that are the most robust descriptors of soil moisture, a key drought indicator in semi-arid landscapes. Initial

results suggest that indices such as the Standardized Precipitation Evapotranspiration Index have the greatest correlation (r up to 0.8) with soil moisture at ~90-day timescales. Generally, time scales increased with soil depth, ranging from 80 to 200 days for 2in to 36in depths respectively. We found that the greatest correlations occurred during the summer and fall months when soil moisture was more responsive to atmospheric demand and precipitation is primarily rain dominated. There was also spatial variability in the optimal timescales across Montana, likely due to different soil properties, topography and vegetation conditions. These results provide important information for drought management task forces, such as the Montana Drought and Water Supply Committee, to provide early warning of developing drought conditions and inform the appropriate application of commonly available drought metrics.

**Enhancing the Upper Missouri River Basin Drought Early Warning System**

Kelsey Jencso[1], Zachary Hoylman[2], Zack Holden[3], Michael Downey[4], Troy Blandford[5], Kevin Hyde[2], Kyle Bocinsky[2]

[1]University of Montana - Montana Climate Office, [2]Montana Climate Office, [3]United States Forest Service, [4]Department of Natural Resources and Conservation, [5]Montana State Library

The Montana Climate Office, Montana Department of Natural Resources & Conservation, United States Forest Service and Montana State Library have partnered to further develop the Upper Missouri River Basin (UMRB) Drought Early Warning System under NOAA NIDIS and Public Law 113-86. This presentation will focus on the progress of key tasks in this two-year project: 1) Collect, assess and integrate information on the key indicators of drought in the Upper Missouri River Basin (UMRB) and drought impacts in order to make usable, reliable and timely forecasts of drought. 2) Continue ongoing research and monitoring activities related to predicting drought in its varying durations and magnitudes across the UMRB. 3) Provide timely drought information and products from watershed to regional scales across the UMRB. This project utilizes new and existing partner networks to optimize the expertise of a wide range of federal, tribal, state, local and academic partners in order to make climate and drought science readily available, easily understandable and usable. Our aim is to improve the capacity of stakeholders to better monitor, forecast, plan for and cope with the impacts of drought in the Upper Missouri River Basin.

**High resolution irrigated lands mapping in the Western United States**

David G Ketchum[1], Kelsey Jencso[2], Justin Huntington[3]

[1]Montana Department of Natural Resources and Conservation, [2]University of Montana, [3]Desert Research Institute

The sustainable management of water resources in the Western US depends on improved understanding of the impact of human activities on the hydrological cycle, the most significant of which is our use of water for irrigation. We built annual, 30 m resolution irrigation maps for years 1986 -2017 using Google Earth Engine for the 11 conterminous United States. Our map classifies lands into four classes: irrigated agriculture, rainfed or unirrigated agriculture, uncultivated land, and wetlands. We used 80,000 point samples from 11 western states over 28 years to extract Landsat, climate, meteorology, and terrain data to train a Random Forest classifier. Our classifier has an overall accuracy of 95.3%, with higher accuracy for our target classification of irrigated lands. We found that most variance in our classification is controlled by Landsat optical green and

red bands, and terrain. Our model is most effective in arid locations where the contrast between unirrigated and irrigated lands is high. Our model shows poor results in areas where the spectral difference between forest, range, wetlands, and irrigated lands is low, especially in cold, wet, high altitude areas such as the Big Hole in Montana. This work illustrates the need for the use of modern object segmentation approaches now in common use in the field of computer vision that could improve our ability to increase the accuracy of irrigated lands mapping.

**Hydrologic consequences and benefits of intensifying agricultural water diversions**

Marco Maneta[1], Kimball John[1], Lauffenburger Zachary[1], Cobourn Kelly[2]

[1]University of Montana, [2]Virginia Tech

The agricultural system of the intermountain western U.S. is characterized by extensive farming and ranching, low product diversification, and prevalence of rainfed crops, which makes it very vulnerable to drought and long-term climate variability. Agriculture is a major component of the regional economy and of the livelihoods of people in states like Montana, for this, it is important to understand how farmers cope with drought. Common strategies involve increasing agricultural water demand and reallocating land to priority crops or to fallow to decrease impacts on farm revenues. Potential intensifications of water use in upstream counties, however, can have impacts on streamflows, limiting the options of downstream users. The 2012 drought that affected the U.S. Midwest but that only impacted the southern half of Montana is an excellent case study to analyze how farmers adapt in the short term to drought conditions. We present results from a hydro-economic modeling and observation framework driven by satellite remote sensing to simulate the hydrologic and county-scale agroeconomic impacts of the 2012 drought. We use simulation results to analyze the most vulnerable and resilient counties and evaluate the extent to which increasing access to surface water to compensate for precipitation shortfalls result in stream depletion.

**Montana's first wastewater-based epidemiology investigation**

Miranda L Margetts[1], Deborah E Keil[1]

[1]Montana State University

Drug abuse continues to be a public health problem. Current methods for monitoring community drug use include self-reporting population surveys, emergency department visits, drug treatment admissions, or fatal overdoses. Data from these approaches are not available rapidly and may require months to years to compile. Montana, by virtue of its reduced population and large geographic size experiences an added data burden. Due to rural populations, county-level estimates based on small sample sizes are suppressed. To provide near real-time monitoring of drug use, we have measured sewage drug biomarkers to estimate drug consumption at the community level. Results from our recent NIH-funded project demonstrate the feasibility of wastewater analysis for illicit and prescription drugs in two Montanan communities. At each location, we undertook weekly sampling over a 3-month period in Spring of 2019. Our pre-treatment influent measures indicate clear differences between drug consumption behaviors across these communities. Preliminary examination of wastewater effluent at these two sites further demonstrates that opioid removal within a typical treatment facility varies by specific compound and most persist with the potential to enter surface waters. This study is the first example of 'wastewater based epidemiology' in Montana and the translation of our data for both public and environmental health endeavors has

been recognized for its 'near real time' surveillance capabilities. We anticipate sustaining this work through our lab and expanding to include additional locations.

**Macroinvertebrate bioassessment study designs: a critical examination of four assumptions leading to their misuse**

Brett Marshall[1]

[1]River Continuum Concepts, Inc.

Macroinvertebrate studies have become commonplace since the acceptance and promotion of rapid bioassessment protocols. Certain assumptions are implicit to the use of these protocols whenever they are used to detect change. We examined four inter-related aspects of bioassessment sampling designs that may preclude their use (senu stricto) to describe change: (1) aspects of design, (2) assumption of variance homogeneity, (3) assumption of taxonomic completeness, (4) assumption of standard unit effort. The misuses of bioassessment designs arise from a failure to understand the limitations of the original study design. These misuses include (1) inappropriate use and definition of reference criteria (e.g., "best-value" reference criteria), (2) misunderstanding the allocation of bioassessment statistical replication, and (3) use of the design when an alternative design should be used. These misuses are often rationalized by the assumptions that (1) the bioassessment design "homogenizes variance" sufficiently that it can be assumed to be zero, and (2) the samples are "taxonomically complete." We collected 5 replicate composite bioassessment samples using the Wyoming bioassessment field methods from five important locations in rivers of Sublette County Wyoming. We examined the variance from large composite samples and compared them to individual (non-composited) Surber samples. Not only was the variance significantly different from zero, but it was not reduced when compared with non-composited samples. Similarly, we compared taxa richness of electronically composited individual Surber samples with standard bioassessment field-composited samples and found that data from field composites only represented about half of the species represented in individual samples. Rarefaction analysis indicated that our results predicted this outcome from composite samples and that earlier investigators misinterpreted their rarefaction results by projecting the asymptote beyond the level of effort of their study. Therefore, the assumptions used to support the use of non-replicated sampling designs (homogeneity and taxonomic completeness) were not supported by our studies. This will seem counterintuitive to many investigators because a sample collected from a larger area should, in theory, contain more species than smaller samples. However, the assumption that field area corresponds to a standard unit effort also appears to be invalid in our studies. This is because one of the ubiquitous cost-reducing procedures used to facilitate large-scale (national) studies was the use of fixed-count subsamples. We found that the density of the dominant taxon had a huge influence on the proportion of the sample used to attain the subsample target. It did not matter that composite samples were comprised of 8, 0.1-m2 samples when some samples were only subsampled to <1% to attain the subsample target. The amount of sample used in single samples to attain the subsample target ranged from 0.3% to 100%, effectively canceling the field unit effort. Although acceptable for bioassessments, this is the reason why the assumptions that would allow bioassessments to defensibly describe change, without replication, are not valid. Moreover, our subsampling model suggests it is much more effective to collect several smaller replicates than to use composite samples to describe spatial or temporal changes in benthic community structure.

**Simulation and experimental investigation of linked elemental cycling in freshwater ecosystems**

Elizabeth J Mohr[1], Ann Marie Reinhold[1], Geoffrey C Poole[1]

[1]Montana State University

Biotic removal of carbon and nutrients in streams determines the capacity of a stream to maintain high water quality in the face of excess anthropogenic carbon and nutrient sources. Yet scientists and managers alike lack a robust mechanistic theory to predict rates of biotic removal to inform management of water quality in the face of increasing carbon and nutrient loading and in the context of global climate disruption. We believe the concept of the "individual elemental cycle" (e.g., the nitrogen cycle or the carbon cycle) limits our ability to develop such a theory. Therefore, we have developed the capacity to automatically generate simulation models of dynamic "biogeochemical webs," consisting of multiple linked elemental cycles. The models incorporate multiple classes of microorganisms defined by the metabolic pathways they employ (e.g., aerobic heterotrophs, denitrifiers, nitrifiers, methanogens) and simulate the associated rearrangement of each element found in metabolic reactants to form metabolic end products while conforming to constraints such as mass balance, energy balance, stoichiometry, and thermodynamics. To assess the accuracy and efficacy of our modeling approach, we compared our model results to observations from a set of biogeochemical mesocosm experiments. We filled the mesocosms (10-liter carboys) with stream water and gravel and amended them with two stable isotope tracers: either 13C-enriched CH3COONa and 15N-enriched NaNO3 or 13C-enriched NaHCO3 and 15N-enriched NH4Cl. The mesocosms were incubated in the dark with no headspace and sampled periodically for 7 days. Comparing resulting experimental data with model output allows us to iteratively refine the conceptual model on which our simulation model is built, revealing details about the dominant metabolic pathways and biophysical constraints governing the behavior of biogeochemical webs. As our conceptual models are refined, we expect to identify the rules of life that explain observed variation in carbon and nutrient uptake in stream ecosystems.

**Practical implications of the Biotic Ligand Model as a water quality standard**

Joe P Naughton[1]

[1]RESPEC Inc.

The Biotic Ligand Model (BLM) has been recommended by EPA as a copper standard since 2007 although few states have thus far adopted it. Although more realistic than prior hardness-based standards, the BLM requires a much greater set of field data, has greater quality control demands, and is more computationally complex. To evaluate the practical consequences of adopting the BLM as a standard in Montana, the relative restrictiveness of the EPA's hardness-based and BLM-based standards were compared for samples collected throughout the upper Clark Fork River basin. Streams within the basin have a variety of chemical regimes and also a variety of environmental stressors including metal contamination, nutrient enrichment, chronic dewatering, and an array of physical habitat disturbances. Overall, restrictiveness was similar between each standard (when comparing dissolved concentrations) but there were stark seasonal and spatial differences. The BLM-standards were typically more lenient in nutrient-enriched waters and were more restrictive during low flow periods. The BLM was highly sensitive to dissolved organic carbon (DOC) concentrations which are difficult to measure accurately. Interestingly, inputs of cold, clean water

from mountain tributaries had little net effect on BLM-predicted toxicity in the mainstem river because dilution of copper was offset by dilution of DOC.

**Low head dam feasibility study for the Sourdough Watershed**

Heather Nold[1]

[1]Montana State University

According to Headwaters Economics, a local research nonprofit, the Gallatin County's population grew three times the rate of the rest of Montana in the last 15 years, straining the limited water resources available in the City of Bozeman. While the infrastructure once suited the community, the high quality of life in Bozeman has attracted tourists, recreationalists, academia, and entrepreneurs to settle in the valley encroaching on limited resources and once open space. Nestled in the valley of Gallatin, the Madison, and Bridger Range, Bozeman is perched at the headwaters of the Missouri river. It allows the community to enjoy incredible water quality. However, 80% of municipal water is sourced from local snowpack. Climatic trends predict that the snowpack will be melting earlier in the season in addition to being variably present. If growth models and per capita uses of water in the valley continue, the City Bozeman expects a water shortage within the next 20 years. In order to ensure future health of the aquifer and local waterways, the City of Bozeman is considering water storage solutions and water conservation due to the high risks posed by a local water shortage. While traditional water storage infrastructures such as dams have frequently been employed by municipalities, the engineering community has been shifting paradigms in recent years. The dam impacts of sedimentation, fish barriers, and lack of floodplain connectivity, has generated interest in innovative technologies to retain water for municipal uses. Beaver dam analogs, renowned for their ability to promote groundwater recharge and propagate wetlands are researched as stream restoration techniques in channelized reaches. The beaver dam analogs or constructed low head dam structures inundate small portions of the watershed, storing water. Through analysis of digital elevation models in the Sourdough Watershed in GIS programs, the water storage capacity of several of beaver analog dams can be determined. Conducting geospatial and hydrologic analysis indicates that low head dams may be a feasible infrastructure opportunity to improve municipal water storage resiliency for the City of Bozeman. In addition to the evaluation of technical criteria, research will be conducted to review compatibility of beaver analog dams to existing water supply infrastructure, maintenance costs of the analog dams, and the capital investment required per acre-ft of water supply. If determined economically and technically feasible the watershed will be enabled with the restorative qualities of beaver analog dams while reaping the benefits of water storage.

**Quantifying groundwater and surface water interactions in low-impact stream restoration environments**

Evan Norman[1], Glenn Shaw[1], Amy Chadwick[2], Marvin Speece[1], Mohamed Khalil[1]

[1]Montana Technological University, [2]Great West Engineering

Surface and groundwater storage, flow, and exchange rates pre and post stream restoration has been an important topic in high divide regions for several years. Improved monitoring regimes have aided in quantifying restoration methods in a variety of watershed networks. In this study, a robust dataset collected over the previous four summers following restoration in 2016 and 2018

will quantify short and long-term impacts of beaver-mimicry structures in the alpine setting of the Blacktail Creek Watershed south of Butte, Montana in addition to in-depth site characterization. The questions for this study are: i) How much surface and groundwater flow attenuates after stream restoration? ii) Does river restoration result in enhanced late season baseflows? and iii) How do the groundwater and surface water interactions vary within the stream reach following restoration? These research questions are important for understanding ecosystem functions as a result of restoration. Field work consists of monitoring both surface water flows and groundwater levels, assessment of hydraulic conductivity, surveying monitoring well and staff gage locations and geophysical characterization of aquifer dimensions and lithology. Surface water flows were used in a water balance and spatial temperature and specific conductivity variations were used to assess groundwater and surface water interactions. Sieve analysis on shallow (0-5') saturated and unsaturated soils were analyzed to characterize soil types and to provide estimates of hydraulic conductivity (K). Slug tests were performed on 1" and ¾"piezometers using pressure transducers and manual water levels collection. AQTESOLV software analyzed hydraulic conductivity values across various spatial areas throughout the site region. Vertical variations of temperature were used in piezometers and surface water to estimate groundwater and surface water interactions in both restored and non-restored sites. MODFLOW 2000 was used to compare pre and post restoration groundwater flow rates and groundwater and surface water interactions. Drone flights across a treatment and control reach output a digital surface model to characterize the surface of the groundwater flow models. Seismic and resistivity surveys performed by Montana Tech Geophysical Engineering Department estimated a depth to bedrock, aquifer lithology and flow direction. Groundwater levels, hydraulic gradients, hydraulic conductivity, stream flows and surveys assisted in building a conceptual model in GMS and MODFLOW numerical modeling software. This oral presentation will review conclusions of site responses during monitoring years 2016-2019 and the preliminary groundwater modeling efforts describing impacts of beaver-mimicry structures and natural geomorphic features.

**Are increasing temperatures in Montana affecting high and low streamflows**

Charles Parrett[1]

[1]Retired USGS

Average annual temperatures throughout Montana are increasing. Monthly temperatures generally show the same pattern as the annual temperatures, with the most dramatic increases (as indicated by LOESS curve plots) occurring from about 1970 to 2018. Changes in Montana precipitation are much less significant than changes in temperature. For example, average annual temperature in Montana has increased about 4 degrees F since 1950, but average annual precipitation, the principal driver of annual streamflow, has stayed virtually constant. Temperature increases are expected to have the greatest effect on late summer streamflow when temperatures and evaporation are high and flows are already low due to depleted snowmelt runoff. High flows, which occur mostly in May and June, are the result of a complex interplay of both snowmelt and large May-June precipitation. Increasing temperature is likely to affect the timing of snowmelt, but otherwise is likely to play a much smaller role in producing changes in high streamflow.

To examine whether increasing temperatures have had discernible effects on high and low streamflows, data from 15 long-term streamflow gauging stations were examined. The selected stations all arise in mountainous terrain, and average and high streamflows have a substantial snowmelt runoff component. The high flow characteristic examined for trends was annual peak

flow, and the low flow characteristic selected was mean August flow. Six of the sites drain areas east of the Continental Divide, 8 sites drain areas west of the Divide, and 1 site, arising in Glacier National Park, drains into the Hudson Bay basin. All sites had at least 50 years of essentially continuous streamflow record.

A linear regression relating the selected high and low flow characteristics to the 1970 to 2018 flow period was used to determine whether the characteristics showed a trend for the same period that showed the sharpest increase in either annual or August temperature. The total period of available flow record was also examined for trend. To ensure that trend slopes were not unduly affected by the first few flow values, the beginning periods for the trend analyses were changed slightly when the first several flows were either substantially above or below the long-term median flow. The non-parametric Sens slope estimator for trend was also used at several sites, but the results generally were the same as for the use of linear regression.

Trend tests for annual peak flow indicated 9 sites with a decrease in annual peak discharge for the 1970 to 2018 period and 6 sites with a slight increase. One of the negative trends was statistically significant (p-value less than 0.05). Trend tests for mean August flow showed that all 15 sites had decreases for the 1970 to 2018 period, and that decreases were statistically significant at 6 of the sites. On this basis, there appears to be little connection between increasing temperatures and high flows, but a strong connection between increasing temperatures and mean August streamflow.

**Variability in range cattle water quality and precipitation in the Northern Great Plains over 10 years**

Mark K Petersen[1], Jennifer M Muscha[2], Kurt Reinhart[3]

[1]USDA-ARS Fort Keogh Livestock and Range Research Laboratory, [2]USDA-ARS Fort Keogh LARRL, [3]USDA-ARS Fort Keogh

In semi-arid to arid environments, livestock water is a highly valued necessary input that is scarce and utilized when quality may compromise animal well-being and productivity. Knowledge of the breadth in mineral solute content from year to year and factors that alter solute content would be valuable to managers to avoid forced cattle use of high solute poor-quality water. In 2015, Petersen et.al. reported variability of the concentrations of nine dissolved minerals over 5-years in stock water. That report showed water quality is highly variable within and between years, sources and locations, with no indication as to the cause of inconsistency. An association between the pattern of precipitation and water solute concentration was hypothesized as contributing to water quality variability. The objective of this study was to determine the relationship between relative precipitation patterns as above, below or intermediate in the previous 1, 3, 6 and 12 months and mineral solute concentrations found in four sources (pumped ground water, catchment reservoir, springs and surface flowing water), in three geographical locations (North, Southeast, and Southwest) at the 22,500 ha USDA-ARS Fort Keogh Livestock and Range Research Laboratory located near Miles City, MT. Up to 45 water samples were collected for analysis twice yearly to determine mineral content in the greatest precipitation months (May or June) and in a lower precipitation month (September) from 2009-2018. Samples were analyzed for concentrations of Na, Ca, Mg, pH, NO3N, SO4, TDS, Fe, Mn, Cl, and Fl (Midwest Laboratories, Omaha, NE). Data were analyzed as a completely randomized 4×10×3×4×2 factorial arrangement of treatments (precipitation pattern, year, location, source and season) using the MIXED procedure of SAS (SAS Institute, Cary, NC) with location × water source × year × season as the experimental unit.

Significance was determined at P≤0.05. Precipitation classes or measurement interval did not affect concentrations of chloride, fluoride, manganese, or nitrate. Precipitation 6 and 1 month prior to sampling interacted with sources to affect Ca and Mg concentrations. Ground and reservoir water had lower concentrations of Ca and Mg than spring and surface flowing water, regardless of precipitation amount. Precipitation 12, 6, and 1 month prior to sampling interacted with sources to affect Na, SO4, and TDS. TDS levels were higher in ground water than spring and reservoir water regardless of precipitation year. Surface flowing water had intermediate TDS levels, dependent on precipitation year. In general, area North of Yellowstone River has lower levels of Na and TDS. Application of these results by mangers to assess water quality hazards for range livestock will require knowledge of the interactions of solute concentrations in stock water sources with precipitation frequency to roughly forecast the potential of reduced animal productivity or in the case of sulfur intoxication possibly sudden death. Because instances of low water quality are difficult to predict, water quality should be monitored prior to livestock access in semi-arid or arid environments. Managers can then detect stock water with unacceptable concentrations of dissolved solutes and implement practices intended to avoid and/or minimize consumption of it.

**Strategically implementing Montana's nonpoint source management plan**

Robert Ray[1], Hannah Riedl[1]

[1]MT Department of Environmental Quality

Montana is the 4th largest state and has the lowest population per square mile in the contiguous nation. With a limited tax base and funding to address nonpoint source (NPS) pollution, the NPS program recently implemented a three-tiered system to more effectively apply resources and demonstrate success. The tiering tailors NPS technical and financial assistance to the needs and capacity of individual watersheds. This presentation will discuss the strategy and provide an update on its implementation over the past year.

**The tale of two aquifers: a study in aquifer sustainability**

Jon C Reiten[1]

[1]Montana Bureau of Mines and Geology

The Fox Hills-Hell Creek aquifer and glacial buried valley aquifers are important sources for municipal, domestic, stock, and irrigation water supplies in eastern Montana. The Fox Hills-Hell Creek sandstone forms a regional aquifer underlying about 1/3 of the state. The recently discovered West Crane aquifer underlies slopes above and west of the Yellowstone River in Richland County. This aquifer is within a 1-1.5 mi wide buried valley extending from Fox Creek to Burns Creek. Aquifer sustainability refers to water levels that allow long-term water availability to wells completed in an aquifer. Long-term hydrographs from monitoring wells show contrasting conditions in these aquifers. Water-level trends demonstrate aquifer sustainability. Hydrographs from Fox Hills-Hell Creek aquifer wells in the Sidney area display declining trends ranging from 0.3 to 4 ft/yr for the past 30-40 yr. In contrast, hydrographs from wells in the West Crane aquifer fluctuate in response to recharge events and water use. The Fox Hills-Hell Creek aquifer is being depleted in eastern Montana and western North Dakota because the discharge is greater than the recharge. At many locations, wells that flowed when constructed no longer flow. Funding through the DNRC Reclamation Develop Grant Program has been approved to address uncontrolled flows

that contribute to the problem. At the current discharge rate, the aquifer is not a sustainable resource. The West Crane aquifer is a new resource developed by local producers to irrigate land previously used as pasture or for dryland crops. Since 2011, water use has expanded to 12 center pivot systems. An ongoing Groundwater Investigation Program (GWIP) project provides data enhancing our understanding of the aquifer hydrogeology. Initial water-level trends indicate seasonal drawdown directly associated with irrigation pumping followed by water-level recovery until the next irrigation season. Water-level monitoring and water-use monitoring are critical elements of managing this resource. Data collected through GWIP will serve as a starting point for developing and managing this renewable resource as a sustainable water supply for irrigation.

**Water distribution foot soldiers: what water commissioners can do for you**

Mike J Roberts[1]

[1]DNRC

Annual water shortages, high demands on water, and subsequent conflicts amongst water users has led to the need on many streams in Montana for qualified and objective third-party individuals to measure and distribute water legally and accurately. These folks, District Court appointed water commissioners on decreed streams, are the front lines of water distribution in Montana. Who exactly are these intrepid men and women, how are they trained, and what gives them the authority to deliver privately held water rights? More importantly, can data collected from these distributions be useful to water resource practitioners conducting water right, instream flow, and hydrologic investigations? As the number of enforceable decrees increases, and early and late season water shortages become more unpredictable, an understanding of the role of water commissioners becomes even more important to water management in many basins in Montana.

**Assessing the increase of nitrate and chloride in groundwater at Meadow Village, Big Sky, MT**

James Rose[1]

[1]Montana Bureau of Mines and Geology

The resort community of Big Sky is concentrated in the West Fork of the Gallatin River Watershed. The water shed is drained by the North Fork, Middle Fork, and South Fork of the West Fork. The West Fork and mainstem of the Gallatin River are designated Blue-Ribbon trout streams. However, as the local population grows, nitrate and chloride concentrations, indicators of sewage effluent, are increasingly detected in surface water and groundwater samples. Although concentrations do not exceed drinking water standards, data indicate detrimental changes to the river environment.

In 2007 The Gallatin River Task Force observed algae in the Middle Fork downstream of Meadow Village and the Meadow Village Golf Course. The golf course was irrigated with treated sewage effluent from the local water treatment plant. In 2014 algae began to appear in the South Fork near Meadow Village. In 2018 there was an unprecedented algae bloom that extended from the Meadow Village area, into the mainstem of the Gallatin River and continued for several miles downstream. The algae growth was attributed to nutrient loading from an unknown source.

Surface water and groundwater sampling in 2014 and 2015 throughout Big Sky by the Montana Bureau of Mines and Geology, and the Gallatin Water Quality District showed the highest concentrations of nitrate and chloride were associated with the Meadow Village Aquifer. Elevated nitrate and chloride values also occurred upgradient and outside of the golf course area. Three springs flowing from the aquifer into the South Fork, and two wells upgradient from the golf course showed the highest nitrate or chloride concentrations sampled at Big Sky. The algal blooms appear where the three springs discharge into the South Fork.

Since 1970 nitrate concentrations in groundwater at Meadow Village have shown a modest increase ranging from an average 0.5 mg/l to 2.0 mg/L. However, concentrations of chloride have increased 10-fold in groundwater (2.1 mg/l to 27.6 mg/L) and in surface water samples (1.5 mg/L to 12.7 mg/L). The presence of chloride suggests a more widespread impact than the nitrate results alone.

Conditions at Big Sky suggest the primary source of elevated chloride and nitrate in water is from septic and sewage effluent. The concentration of chloride and nitrate in groundwater and surface water appear to increase proportional to the amount of development that has occurred.

**Saline seeps: how land-use management connects to both their development AND reclamation**

Tera O Ryan[1], Scott Brown[2]

[1]Montana Salinity Control Association, [2]Montana Salinity Control Association

Among the conditions required for the development of dryland saline seeps in Montana, surface land use management is the only one susceptible to the influence of a single person. Nobody can change where inland seas formed millions of years ago – developing into the bedrock that is the primary source of salts in saline seeps. Nor can one person alone affect how much rain will fall each summer. Although one could argue that climate change contributes to precipitation timing, location and quantity, that process is more of a global community effort, while this presentation focuses on the actions of an individual. A single agricultural producer can change their land use management practices and have a measurable result on a saline seep - either in its development and expansion, or in its reduction and eventual reclamation. This presentation will explain how saline seeps develop as a result of either naturally occurring conditions, or through anthropogenic influences. Reclamation methods of the latter will be described, with examples of both common and unique sites in Montana.

**Denitrification patterns across a dryland agroecosystem in the Northern Great Plains**

W. Adam Sigler[1], Stephanie A Ewing[2], Scott D Wankel[3], Clain A Jones[2], Sam J Leuthold[4], Jack Brookshire[2], Robert A Payn[2]

[1]Montana State University, [2]Land Resources & Environmental Sciences, Montana State University, [3]Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, [4]Plant and Soil Sciences, University of Kentucky

Nitrogen loss from cultivated soils threatens the economic and environmental sustainability of agriculture. Nitrate accumulated from fertilization or mineralization/nitrification of soil organic matter (SOM) may be lost from soils to denitrification, producing the greenhouse gas N2O. Nitrate accumulated in soils and not taken up by crops is also subject to leaching loss, which can degrade water quality and is subject to denitrification downstream. Here we use patterns in the isotopic compositions of nitrate and water to characterize the influence of nitrogen loss to denitrification within soils, groundwater, and streams (process domains) of a non-irrigated agroecosystem in the northern Great Plains. Within a relatively simple conceptual framework of water and dissolved organic carbon (DOC) availability, the isotopic character of nitrate shows a remarkably clear influence of denitrification across process domains, expressed as positive correlation between δ15N and δ18O in nitrate. The apparent δ15N fractionation factor (ε) with decreasing nitrate concentration – interpreted as further evidence of denitrification - is lowest in soils, where it may be suppressed by heterogeneous water and carbon distribution in the soil environment as well as by inmixing of nitrate from fertilization and mineralization/nitrification of SOM in-situ. Even so, a clear denitrification signal was observed during fallow (no crop growing) periods in soils with architecture characterized by thicker fine textured surface horizons. The clearest denitrification signals and largest ε occurred at riparian sites where saturation limits oxygen supply, DOC is abundant, and in-situ nitrate sources are minimal compared to inputs from incoming groundwater. This study reveals how soil water content and groundwater recharge, affected by crop rotation, influence landscape scale patterns of denitrification. Understanding these controls on patterns in denitrification will be critical for managing the role of agricultural ecosystems in the global N cycle and the climate system.

**Using diel and seasonal variation in dissolved metabolites and conservative tracers to explore the influence of nutrient loading on stream ecosystem function**

Meryl B Storb[1], Robert A Payn[1], Juliana D'andrilli[1]

[1]Montana State University

Measurements of stream nutrient concentrations sampled exclusively during daylight hours provide a limited perspective on potential variation in daily cycles of aquatic ecosystem function. Likewise, daytime sampling bias may mask the contributions of nighttime periods of chronic loading, due to the potential for lower daytime nutrient concentrations during periods of higher demand by primary production. Our objective is to determine how chronic anthropogenic N loading influences diel variation in nutrient demand within an alpine stream ecosystem. Our approach evaluates the metabolic regime of two stream reaches with contrasting N loads, over an algal growing season, by measuring diel variation in concentrations of inorganic dissolved metabolites, conservative tracers and continuous whole-stream metabolism estimates. The study area is the West Fork of the Gallatin River watershed, encompassing the Big Sky resort area (southwest Montana), which is likely to exhibit changes in stream metabolic character caused by climate

change and extensive land use change and development. In this study area, stream ecosystems are commonly nutrient limited under natural conditions. Therefore, development and land use change in recent decades allows comparison between two similar stream reaches with contrasting histories of N loading and limitation due to the application of treated wastewater as golf course irrigation between the two reaches. Temporal variation in nitrate concentrations demonstrate larger diel amplitudes in the downstream reach that is subject to higher N loading. When combined with diel patterns in conservative tracer and dissolved oxygen concentrations, diel variation in nitrate concentrations provide evidence of how chronic nutrient loads appear to influence nutrient demand via alteration of the stream metabolic regime. Continued examination of diel and seasonal cycles in metabolic behavior and inorganic nutrient concentrations in this setting will provide more detailed insight into the mechanisms by which stream metabolic regimes are influenced by anthropogenic nutrient loading. Likewise, diel variation in nutrient concentrations have implications for water quality management decisions that are often overlooked by conventional regulatory sampling practices (i.e. TMDL development).

**Gallatin County Interactive Water Quality Mapper Demo**

Christine M Sundnas[1], Gallatin County Gis Department[1]

[1]Gallatin Local Water Quality District

The Gallatin Local Water Quality District (GLWQD) in partnership with the Gallatin County GIS Department has launched an online interactive mapper where citizens can view water information. This map was developed by the Gallatin County GIS Department and shows thousands of water quality results. It also shows the locations of long-term monitoring wells, controlled groundwater areas, groundwater equipotential contours, geology, and more. This map is a great resource for citizens or professionals looking for water related information in their area of interest. This presentation will discuss history of the mapper, data sources, mapper limitations, use, and future upgrades.

**Groundwater in the Northeastern Helena Valley, Lewis & Clark County, Montana**

James Swierc[1]

[1]Lewis & Clark Water Quality Protection District

Local residents have long expressed concerns over the long-term availability and sustainability of groundwater resources in the northern part of the Helena Valley, the North Hills. This has resulted in the establishment of two temporary controlled groundwater areas, and two studies published by the Montana Bureau of Mines and Geology (MBMG) in 2006 and 2012. These studies focused on areas with the most development, centered in the western part or the area. Recent suburban growth and development in the eastern part of area has resulted in additional concerns over groundwater resources. In response to the citizen concerns, during Fall 2018, the Lewis & Clark Water Quality Protection District (LCWQPD) implemented a groundwater level monitoring program, coupled with water quality and water isotope sampling from selected wells.

This presentation will present recent and historic data results and discuss constraints to the conceptual hydrologic model of groundwater resources in the area. A review of well logs shows that the local aquifer is dominated by clay-rich layers, with local coarse-grained seams providing local

yields. Argillite bedrock is present along the western part of the area, and beneath the clay-rich layers within the study area. A major fault is present along the northern part of the area, with bedrock exposed at the surface north of the fault. Major ion water quality data for the area will be presented, showing local differences in major ion composition related to recharge mechanisms and local aquifer geology. Water isotope data will be presented as constraints to local recharge. Finally, water level hydrographs from the 2018-2019 for select wells will be reviewed and compared with data for the same wells from the previous 2006 and 2012 MBMG studies.

Preliminary data results suggest that the depth to available ground water increases to the north and northeast in the area, especially in the area north of the Helena Valley fault. Yields from wells installed into the clay-rich layers generally have limited yields, while wells installed into bedrock show more consistent yields. A review of reported static water levels from wells in MBMG-GWIC database suggests that the groundwater divide in the northern part of the study area is located south of the surface drainage divide, reflecting the complexity of groundwater movement in the area.

**The National Drinking Water Advisory Council**

Jeffrey Tiberi[1]

[1]EPA's National Drinking Water Advisory Council

I was recently appointed to this position and would like to hear from your group what they see as the most important drinking water issues in Montana.

**Hydraulic and hydrologic characteristics and resulting fish passage at the Huntley Diversion Dam Nature-like Fish Bypass**

Haley N Tupen[1]

[1]Montana State University

Nature-like fish bypasses utilize low channel slopes and diverse velocities to provide passage to a wide variety of fish species. The nature-like fishway at the Huntley Diversion Dam near Billings, Montana was constructed in the 1990s, but was suspected to be impassable due to high water velocities and a steep bed slope. This structure was reconfigured in 2015, but its efficacy has not yet been evaluated. Furthermore, no major studies have yet been performed to evaluate the efficacy of nature-like fishways for non-salmonid fish in the United States. This study will characterize the hydraulic and hydrologic characteristics throughout this fishway and determine if the structure is passable by a variety of Yellowstone River species, including burbot (Lota lota), sauger (Sander canadensis), and channel catfish (Ictalurus punctatus). Flow rates within the bypass were determined using both direct and indirect means, including the USGS Midsection Method, the Slope-Area Method, and the Float Method. Water stage measurements were measured on-site using survey equipment and temporary staff gages. U20L Onset HOBO data loggers were installed at multiple points throughout the bypass to determine water levels, temperatures, and pressures relative to a barometric gage. Topographic data of the site was collected using a Trimble GPS, and this data will be used to generate 1, 2, and 3-D models of the channel. Model results will be compared with species-specific swimming capabilities from literature, and attraction flow at the

bypass-river confluence will be evaluated. Preliminary results of the hydraulic models and comparison to species-specific swimming capabilities will be presented.

**Numerical groundwater flow model of the Kalispell Valley, Kalispell, Montana**

Willis D Weight[1]

[1]WDW Writing Consulting & Planning INC

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.

**Validation of the SMAP Level 4 Carbon Product using a continuous crop condition survey index**

Patrick M Wurster[1], Santiago Beguer´Ia[2], John S Kimball[1], Colin Brust[3], Marco Maneta[3]

[1]University of Montana, [2]Estación Experimental de Aula Dei – Consejo Superior de Investigaciones Científicas, [3]Univeristy of Montana

Gross primary production (GPP) is a useful metric for understanding the coupling between carbon and water cycles, and also mass/energy transfers between the land surface and atmosphere. Further, accurate estimates of cropland GPP can be integrated into crop production models, thus having implications to improving farm management practices and food security. Satellite-based models have been developed to monitor the GPP of several plant function types (PFT). However, validation of these models has been generally limited to areas where CO2 eddy flux measurement towers are present. Here, we validated operational GPP estimates provided by the NASA Soil Moisture Active Passive (SMAP) mission Level 4 Carbon (L4C) Product using a crop condition survey index (CCSI) for cereal and broadleaf PFTs in the conterminous United States at the state scale. The L4C daily GPP record is derived globally using a light use efficiency (LUE) model driven

by MODIS (Moderate Resolution Imaging Spectroradiometer) vegetation and SMAP derived root zone soil moisture observations, and also daily surface meteorology inputs (i.e., solar radiation, vapor pressure deficit, temperature) from the NASA GMAO forward processing (FP) system. The CCSI is a continuous representation of weekly crop condition surveys conducted at the field scale by farmers and provided by the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS). The advantages of using the CCSI to validate the L4C are the two data sets are independent, and the CCSI is available at a high temporal resolution (weekly). Cereal PFTs were represented by barley, spring wheat and winter wheat, and broadleaf PFTs were represented by corn, cotton, and soybeans. We found a relatively strong correlation between the CCSI and L4C in states with high production and yields of the selected PFTs. We also found that the correlation between the CCSI and L4C improves as the phenology progresses, with the highest correlations being observed in the mature stage (e.g., r2: 0.67 for corn in Kansas). However, lower correlations were observed for earlier phenological stages (e.g., r2: 0.44 for silking corn in Kansas). This work highlights the potential for identifying the advent of crop stressing events based on daily GPP values from operational satellite driven models.

**Pesticides in groundwater impact bacterial growth and biofilm formation**

Katherine R Zodrow[1], Allison Kelly[1], Emily Vincent[1], Alexis Icenogle[1], Brian St. Clair[1]

[1]Montana Technological University

In rural agricultural areas, pesticides and fertilizers can contaminate shallow groundwater, negatively impacting human health. To negate these human health impacts, small point-of-use reverse osmosis (RO) systems may be installed in the home. However, little is known about the influence of pesticides and fertilizers on RO membrane biofouling, which is the main cause of membrane and system replacement. To explore the influence of pesticides on RO biofouling, we chose three pesticides found previously in the groundwater of the Judith River Basin in Montana—triasulfuron, chlorosulfuron, and metsulfuron methyl. Bacterial growth and biofilm formation of the model organism Escherichia coli (E. coli) and the RO membrane biofilm-initiating species Sphingomonas wittichii (S. wittichii) were observed in a solution with each pesticide. While bacteria in a high nutrient media (Tryptic Soy Broth) showed no changes in growth in the presence of the pesticides, growth was increased when pesticides were added to minimal M9 media, indicating that the bacteria will feed on the pesticide when other, more attractive, food sources are not available. Likewise, some increases in bacterial growth were observed in the presence of nitrate (fertilizer). However, biofilm formation under stagnant conditions did not change significantly in the presence of either pesticides or fertilizers. Regardless, higher bacteria load in the feed water of RO systems may lead to increased membrane biofouling, increasing the cost of these systems and their efficiency.

**POSTER PRESENTATION ABSTRACTS**

*(listed in alphabetical order by first author's last name)*

## The Beaver Project: natural water storage and climate adaptation in Blackfeet Nation

Kendra Allen[1]

[1]BSWC/Center for Large Landscape Conservation & Blackfeet Fish & Wildlife Department

Increasing natural water storage and riparian habitat has been prioritized in the Blackfeet Nation Climate Adaptation Planning process as a way to build resilience to the impacts of climate change.

In July 2019, the Blackfeet Community College Native Science Field Center and Montana Conservation Corps Piikani Lands Crew participated with the Ksik Stakii or "Beaver" Project to engage in hands-on field experience focused on highlighting connections between beaver, natural water storage, and climate change preparedness. To protect water and riparian areas in a warming, drying climate, students and local community members worked with natural resource experts to build twelve, semi-permeable mimic dams (called beaver dam analogs or BDAs) in a process that mimics beaver dam-building behavior. Made of willow, sod, pine, and rocks, the dams will slow water flow over time and increase natural water storage to encourage more water release in late summer when stream levels are low. The dams will also encourage riparian vegetation growth on a local home-owners land, where they were constructed.

Ksik Stakii is the word for beaver in the Piikani language. Much of the Ksik Stakii Project is focused on collectively exploring innovative adaptation techniques and supporting conversations about the critical roles of beaver and water protection in a warming climate. The Ksik Stakii Project is a collaborative effort between the Blackfeet Community College, Blackfeet Fish and Wildlife Department, Blackfeet Environmental Office, Blackfeet Agriculture Resource Management Planning Team, and the Center for Large Landscape Conservation. At its core, the project seeks to honor Blackfeet leadership in protecting beaver and to foster discussions between students, elders, natural resource managers, producers, and community members about the importance of beaver to Blackfeet way of life.

We believe this project will be a model for the region and will demonstrate that climate change adaptation can be an affordable and fun activity that brings people together, advancing science education, environmental stewardship, and climate resilience.

**Gallatin Watershed Council: Preserve & Restore**

Zane Ashford[1]

[1]Gallatin Watershed Council

Gallatin Watershed Council (GWC) works with local volunteers, landowners, and community partners to bring water quality monitoring, stream restoration, and watershed education to the Gallatin Valley with the goal of improving water quality for all. This summer GWC launched its Gallatin Watershed Stewards Program, a mission to harness the power of collaborative community action in order to preserve the resources of the Lower Gallatin Watershed. This grassroots movement aims to inspire each individual to become a Watershed Steward by actively engaging in preserving the Gallatin's water resources through conservation efforts, educational workshops, and volunteer events. This summer, Gallatin Watershed Stewards monitored water quality and quantity at 16 sites across the watershed through Gallatin Stream Teams, cleaned up over a ton of trash and invasive weeds from the Gallatin and East Gallatin Rivers, and participated in volunteer planting events to assist restoration efforts across the Valley.

In addition to community engagement, GWC is working toward delisting impaired streams across the watershed through implementation of the Lower Gallatin Watershed Restoration Plan (LGWRP). Over the past year, GWC has assisted in restoring over 2 miles of streams in the Lower Gallatin through collaborative restoration projects with private landowners, nonprofit partners, and private consultants. GWC teamed up with Trout Unlimited and Gaia Resources to reduce sediment loading into Dry Creek, a stream that's been listed as impaired for sediment and nutrients since 1992. This 1.83-mile riparian enhancement project is critical for achieving sediment and nutrient reduction goals listed in the LGWRP. GWC engaged over 25 volunteers through the Gallatin Watershed Stewards program to assist with willow planting and support the revegetation aspect of this project, providing the community an opportunity to get involved in conservation efforts in the watershed. Other restoration efforts focused on the East Gallatin River with support from the Montana Watershed Coordination Council Watershed Fund.

GWC's mission is to preserve and restore the water resources of the Lower Gallatin Watershed. Through collaborative partnerships, community education, restoration efforts, and individual empowerment, GWC brings together the Gallatin Valley's diverse interests and work towards purposeful usage and stewardship of a healthy Gallatin Watershed, today and tomorrow.

## Upper Gallatin Nuisance Algae Investigation

Valerie R Bednarski[1]

[1]BSWC/Gallatin River Task Force

The Gallatin River Task Force began collecting routine water quality data in the Upper Gallatin River Watershed in 2000. This data is used to assess and track long-term health of the river system, plan for restoration projects, and identify and monitor unforeseen events. In late July and early August of 2018, an unprecedented algae bloom was observed and documented at sites on the South Fork, West Fork, Taylor Fork, and mainstem Gallatin River. Excess algae can negatively impact fish and aquatic insect populations as well as the quality of recreation experience on the river. Factors that influence algae growth include nitrogen and phosphorus concentrations, water temperature, hardness, pH, water velocity, and clarity. Although the primary drivers of the algae bloom are unknown, Task Force data did provide insight into conditions that could explain nuisance algae growth in the West Fork and in the Gallatin mainstem downstream of its confluence. Elevated levels of nitrogen above the state Montana standards were some of the highest ever documented in the West Fork of the Gallatin River (West Fork).

In addition to elevated nitrogen concentrations, average weekly water temperature during the last week of July at the West Fork streamflow station was the highest ever recorded since installing the temperature sensor in late 2009. This week aligned with the beginning of the 2018 algae bloom and suggests that water temperature, in addition to elevated nitrogen, may have been an important factor that contributed to increased algae growth in the West Fork and the Gallatin downstream from the confluence.

## You Con-duit! Modeling conduit flow and geometry using high-resolution temperature monitoring and dye tracing

James Berglund[1], Laura Toran[2]

[1]Montana Bureau of Mines & Geology, [2]Temple University

While simulating groundwater flow in porous aquifers can often challenging, the presence of voids within the rock, such as solutionally-widened conduits in limestone (karst) or fractured crystalline rock, pose additional challenges when producing accurate in hydrological models. Conduits and fractures dominate local flow, yet there is often much uncertainty as to their geometry, location, and interconnectivity with the surrounding matrix. These systems therefore require special modeling considerations and approaches to appropriately characterize groundwater flow. Temperature monitoring and dye tracing provided a better understanding of conduit geometry on water temperature and solute transport. The combination of a non-reactive (dye) and reactive (temperature) tracer resulted in a useful dual calibration approach for characterizing flow within the conduit. A model was constructed using FEFLOW, a finite element flow and transport code that can incorporate fracturs and conduits, along with both mass and heat transport. The study site is a 750-meter long karst conduit connecting a sinking stream and a spring within the

folded Valley and Ridge Province of the northern Appalachian Mountains in central Pennsylvania. A dye trace between the stream and spring showed 65% of the water entering the stream reached the spring, while the spring's flow was 5-10x greater than the sinking stream, indicating additional inflow from the surrounding rock matrix. The timing and shape of the breakthrough curve provided information on dye loss and recovery to the surrounding rock matrix. Data from high-resolution temperature loggers installed in both the stream and spring indicated that as the water travels from the sinking stream to the spring its temperature was buffered by reacting with the surrounding rock. A greater degree of buffering indicates a greater degree of water rock interaction, which is controlled by the size and geometry of the conduit along with seasonal variations in sink and spring flow. The temperature and dye trace data was then compared to several hypothetical conduit geometry scenarios using FEFLOW. Varying conduit geometries and flow parameters determined a forked conduit close to the sink most closely resembling observed data. A sensitivity analysis indicated that conduit geometry, and conduit conductivity exerted the most control on temperature and dye trace breakthrough curves. This approach provides a better understanding on the nature of conduit flow through both observation and modeling.

**Challenges to Integrating Water Rights into a Hydroeconomic Model of Montana**

Anna Crockett[1]

[1]University of Montana

The uncertainty of climate change, manifesting in shifts in the quantity and timing of water flows, puts stress on coupled social-ecological systems, particularly in the arid Western United States. Along with climate, governance of water also plays a role in the distribution and timing of current and future water supplies. There is a need to link climate change predictions with information detailing the legal system for allocating water in Montana to better understand future water allocation challenges and to support current planning efforts. This research seeks to address this need through a case study analysis of instream flow policies in Montana aimed at determining the spatial and temporal strain on instream flows given future climate scenarios. We explore whether instream flow policies, either in their current or modified form, can serve to balance water use between agriculture and aquatic species habitat protection given uncertainty of future availability and timing of water. We approach this problem through a streamflow and policy analysis, mainly, through integrating data from the Montana Water Rights Database into a spatially-explicit hydroeconomic model recently developed at the University of Montana. This poster presents the challenges associated with the Montana Water Rights Database as a data source, including the meaningful aggregation of water rights data into a hydroeconomic model. Specifically, I will highlight (1) the difficulties of working with the database itself – a large, complex database constantly in flux due to statewide adjudications; (2) the process of determining how to cull and refine the data to include only information pertinent to the model; and (3) the challenges associated with translating data to the model itself, such as developing a relational stream network coupled with water rights information. Integrating

water rights data into a hydroeconomic model will allow the model to represent not only physical, but also legal thresholds of water availability and produce more accurate, meaningful results of water availability for statewide planning and management.

## Occurrence and removal of drugs of abuse in wastewater processes

Cullen Cunningham[1], Tammy Jones-Lepp[2], Nicholas R Bishop[2], Miranda Margetts[1], Otto Stein[1], Ellen Lauchnor[1], Deborah Keil[1], Jordan Sykes[1]

[1]Montana State University, [2]Independent Contractor - Montana State University

The impacts of wastewater discharge on water resources have long been investigated, however there is currently limited knowledge of the prevalence and impact of certain trace organic contaminants in wastewater, such as pharmaceuticals. This study investigated the influent and effluent loadings, as well as the removal efficiency by two mechanical, aerobic activated sludge treatment processes. Wastewater samples were collected weekly from the two communities over a 12-week period and analyzed for concentration of 62 drugs and metabolites using Liquid Chromatography – Mass Spectrometry analysis. We report how specific treatment steps influenced overall drug removal in one of the wastewater treatment plants. A series of grab samples were collected from several locations along the treatment process to evaluate the impact of solids separation, biological treatment, and ultraviolet disinfection. A broad range of treatment efficacies were observed, ranging from no removal to complete removal of select prescription and illicit drugs. We also observed substantial variability in removal of a given drug between the plants, though the fundamental design of the wastewater treatment processes is similar. The grab samples taken from the intermediate process locations indicated that the biological component of wastewater treatment is the most significant source of removal for the drugs of interest. Future studies involving more communities, particularly those featuring wastewater treatment approaches apart from activated sludge treatment, will also provide new insight into the treatment response of these drugs. The detection of some drugs and metabolites in the wastewater effluent of both plants indicates that the compounds have potential to remain recalcitrant through wastewater treatment and enter receiving waters. More research is needed to better understand effective degradation and removal mechanisms for these compounds, as well as their impact on aquatic life and ecosystems.

## Holistic Planning and Grazing Management

Meg E Desmond[1]

[1]Blackfeet Agriculture Resource Management Plan

The Blackfeet Nation Agriculture Resource Management Plan (ARMP) was established in 2016 in response to the American Indian Agriculture Resource Management Act of 1993 (AIARMA). The Federal law called on Tribes to develop a strategy for managing their agriculture resources. When completed, the United States Departments of the Interior and Agriculture shall manage agriculture resources consistent with each Tribes ARMP. The Blackfeet Nation is the first Tribe to develop an ARMP completely in house. While most Tribes contract out these plans, the Blackfeet Nation saw the opportunity to integrate traditional ecological knowledge and community priorities into a binding policy. Using holistic planning methodologies, the Blackfeet ARMP has addressed the expansive reach of agriculture, acknowledging the system as a whole. The mission statement of the ARMP determines that "By 2028, we envision the Blackfeet Nation fully engaged, informed, and actively involved in the development of holistic agriculture resource management for the economy, the environment, and the health of the people, land, flora, fauna, and water. Together, we will work to embrace our natural laws, values, and relationships based on respect, trust, and healing. The ARMP will provide a means for establishing reciprocal partnerships among producers, businesses, and landowners to increase international access and availability of quality Blackfeet agriculture products. Our Blackfeet youth will have mentoring opportunities to learn from elders, producers, and leaders to contribute their voice to a quality Blackfeet way of life." Completing the ARMP set a new precedent for Tribal Nations. By making plans in house, collaborating with community members, using high quality data, recognizing both traditional and modern land use and livelihoods, engaging in diverse reciprocal partnerships, ensuring adequate implementational abilities, and understanding the dynamic nature of a comprehensive plan, the Blackfeet Nation has not only created a practical tool for agricultural management, but developed a translational methodology for holistic planning. This revolutionary mindset has connected disparate components of conservation efforts and united the Blackfeet Nation in a desire to implement this progressive strategy. Due to the authority derived from AIARMA, the Blackfeet Nation has the opportunity to use the ARMP to drive changes in grazing habits by utilizing free market incentives to influence changes in grazing management. We are working towards utilizing soil health as a threshold for determining and appraising land value that will encourage producers to prioritize regenerative grazing practices, upholding the health of the ecosystem as well as increasing the value of their products, thereby granting them access to niche markets. Blackfeet producers that engage in conservation management will have priority access to our proposed Beef/Bison Processing Facility and its high-quality market. Adjusting stocking rates and incorporating ecosystem health into land appraisal and valuation processes will provide opportunity to integrate climate adaptation objectives into the language of grazing management. The ARMP team's inventive grazing management strategies are a tangible example of holistic planning. New practices would see the collision of economic growth, climate adaptation, market specialization, human health, policy improvement, and soil health.

**Configuration of StreamPro Acoustic Doppler Current Profiler (ACDP) to measure streamflow in Montana's rivers for a wide range of conditions.**

Stuart Ellsworth[1], Tanner Traxler[1]

[1]RESPEC

RESPEC's monitoring group routinely measures streamflow to support watershed monitoring and restoration projects, which require flow measurements be taken for a range of stream sizes and conditions. The traditional single-point area/velocity method of measuring streamflow using a wading staff and pressure sensor (e.g. Marsh McBirney) at discrete intervals in the channel is severely limited by the conditions often encountered by our field teams, particularly during peak runoff on large river systems. This has resulted in missed measurements in quarterly monitoring events when safety considerations do not allow for wading the channel. To address this limitation, our monitoring group has employed the use of Teledyne RD Instruments' StreamPro Acoustic Doppler Current Profiler (ACDP) to measure stream velocity and channel dimensions more safely and efficiently, along with the accompanying WinRiver software package to process these measurements in real-time.

The ADCP uses Doppler radar technology to take instantaneous measurements of velocity and depth in the channel directly beneath the instrument; a "boat" is used to float the instrument as slowly/steadily as possible to achieve the most accurate measurements across channel transect. The data is transmitted to a field laptop/tablet using a Bluetooth signal, and the channel velocity/ dimension measurements are graphically displayed in real-time with the WinRiver software package. A minimum of three transects with a measurement precision of >5% are required to calculate streamflow. Transects are typically complete in a matter of minutes allowing for multiple replicates and improved measurement precision compared to traditional methods; and, the StreamPro ADCP can be configured to accommodate depths ranging from 0.1 to 6 meters.

This has allowed our team to safely measure streamflow in large river systems (e.g. Clark Fork, Madison, and Gallatin rivers) during spring melt and peak runoff conditions from bridges, when the presence of ice and high, turbulent flows do not allow for safe access to the channels, as well as during low flow conditions in smaller headwater streams (Silver Bow Creek, Blacktail Creek, Mill-Willow Creek, and Jack Creek) where the presence of algae and shallow water limit the use of traditional measurement tools. Our team began using the StreamPro ADCP during the 2018 summer field season, which allowed for calibration of the instrument to better handle summer low flow conditions. Initial sites locations were paired with USGS stream gauge locations to verify instrument accuracy. At ungauged locations, measurements were also taken using traditional methods for comparison. With the advent of the 2019 field season, the instrument's configuration was modified (using weights and a larger boat) to accommodate the high, turbulent flows that characterize peak runoff on Montana's large rivers. StreamPro ADCP data comparisons to traditional methods and instrument calibration/modification techniques for a range of stream conditions will be presented.

**Upper Overwhich Creek Fish Removal Project**

Grant Flaming[1]

[1]BSWC / Trout Unlimited / USFS Region 1

In the headwaters of the West Fork of the Bitterroot River, a stronghold for genetically pure Westslope cutthroat trout, upper Overwhich Creek supports a population of non-native Yellowstone cutthroat trout. Located upstream of a high waterfall, this system was actually fishless until Yellowstone cutthroats were stocked many years ago. In recent years, these non-native trout have been moving downstream over the waterfall and hybridizing with native Westslope cutthroats. Montana Fish, Wildlife, & Parks and Bitterroot National Forest are working together to remove these non-native fish from upper Overwhich Creek by treating the stream with piscicide.

This informational poster will explore project timeline and scope, how rotenone (the piscicide) works, how it is applied to the stream, the use of sentinal fish, methods for preventing collateral damage, and project results.

**Mapping the Spread of Lepidium latifolium (Perennial Pepperweed) and Iris pseudacorus (Yellow Flag Iris) on the Clark Fork and Bitterroot Rivers in Missoula County**

Haley Gamertsfelder[1]

[1]Missoula County Weed District- Big Sky Watershed Corps

Haley Gamertsfelder, Big Sky Watershed Corps Missoula County Weed District and Montana Biological Control Coordination Project. American Water Resources Association Poster Abstract Submission

Mapping the Spread of Lepidium latifolium (Perennial Pepperweed) and Iris pseudacorus (Yellow Flag Iris) on the Clark Fork in Bitterroot Rivers in Missoula County.

The Missoula County Weed District started as a traditional weed district common in Montana. Spraying acres of right of way off of the major roads and encouraging landowners to spray their state listed weeds. As Missoula grew, the needs of the county changed. Mindsets shifted away from spraying, there was more opposition to herbicides being used in the county. For this, the Missoula County Weed District adopted more holistic approaches to weed management, focusing their efforts on the newest weed invaders of the county and implementing the Montana Biological Control Coordination Project (MT BC.) They increased education and outreach through their multiple school programs and increased landowner incentives for controlling weeds on their own properties, leaving the management decisions up to the private land owner. In recent years the weed district has started on a large feat, to inventory, map and treat the new invader category noxious weeds growing in the high water zones along the Bitterroot and Clark Forks rivers in Missoula county.

The current concerns are the showy Yellow Flag Iris (Iris pseudacorus) and less conspicuous but equal parts heinous, Perennial Pepperweed (Lepidium latifolium.) This project is run by the weed prevention coordinator and carried out by multiple staff members and seasonal employees. On the maiden voyage for this project the weed district dropped points for each individual plant or infestation they came across. The next year they revisited those points and treated them with glyphosate, a popular tested aquatic herbicide. In the years since they have floated equipped with maps created in ArcMaps showing the previous routes taken to monitor past infestations and treat those that were still healthy. With new technology to help better track the spread of weeds, we are able to get a slight hold on this ever-growing problem, while taking into consideration the dynamics of riverine systems. This is an ongoing project that will be carefully executed each year as the war on weeds is shaped further by human interaction, climate change, and the unpredictability of life.

**Development and Hydraulics Testing of a Modified Denil Fishway**

Megan N Guinn[1]

[1]Montana State University Eco-Hydraulics Research Group

Optimizing fish passage around man-made stream barriers, for example dams or small irrigation diversions, is a priority of the Ecohydraulics group in the MSU Department of Civil Engineering. One focus is on smaller streams where water flows are low and make traditional fishways (sometimes called fish ladders) ineffective. The goal of this research project was to design, fabricate, and test a new fishway. The prototype is a modification of the traditional Denil fish ladder. The new fishway is smaller, lighter, and fabricated from commonly available materials. A small fishway is desirable in small streams where the total stream flow may not be enough to support the fishway flow in addition to the barrier function. A lighter fishway would be easier to install and maintain. Using common material to construct the fishway will reduce the cost. The new fishway was designed in CAD (Solidworks and Fushion 360). A prototype was built using the dimensions from the CAD model. As of this writing the prototype is undergoing hydraulic testing to assess water velocities and water surface profiles. The hydraulic observations was contrasted against published values for traditional fishways and current knowledge of fish swimming capability and it has proven to be a promising approach and should be further developed and tested in a wider experimental design. The end product could enhance fish mobility and habitat access in basins where the traditional Denil fishway is ineffective.

## Cottonwood Restoration in the Upper Missouri River Breaks National Monument

Lacey Gunther[1]

[1]Friends of the Missouri Breaks Monument

Over the last 200 years, the Missouri River has been extensively dammed and developed. What was once a dynamic and highly variable floodplain has been constrained and hardened, and natural flow regimes have been heavily modified by dams and reservoirs (Johnson et al, 2014). In addition, land conversions like forest clearing to make way for agricultural cropland and reservoir filling has led to a 47% decline in forest and shrubland vegetation from 1892 to 2006 (Dixon et al, 2010).

These anthropogenic changes have all had major impacts on the recruitment and survival of plains cottonwood (Populus deltoides) along the Missouri River. Approximately 62% of cottonwood trees are over 50 years old, and only 14% have been established in the last 25 years (Dixon et al, 2010). Cottonwoods are a critical tree species along the Missouri River. They provide habitat for wildlife, help stabilize stream banks, provide windbreaks and shade, and can improve water quality by trapping sediment and filtering runoff high in nutrients.

Over 600 cottonwood saplings have been planted throughout the UMRBNM since 2013, and they were inventoried and assessed for the first time during summer 2019. Data collected during the summer field season will be analyzed to assess growth rates, determine future planting sites, and see if there are any factors that inhibit or encourage cottonwood growth.

## Developing field protocol for characterizing stable isotope composition of winter recharge water to a western basin: A collaboration of Big Sky Watershed Corps, University of Montana, United States Forest Service and the Montana Bureau of Mines and Geology in the Lolo Basin

Lauren Herbine[1], Camela Carstarphen Carstarphen[2], Payton Gardner[3], David Callery[4], Jacqualine Timmer[2]

[1]Big Sky Watershed Corps, [2]Montana Bureau of Mines and Geology, [3]University of Montana, [4]United States Forest Service

Characterizing the natural stable isotope variations (18O/16O and 2H/1H) in precipitation supports identification of groundwater recharge sources. Isotopic analysis of groundwater and surface-water is fairly common, but the isotopic composition of Montana's precipitation is not well documented. In many of our western intermontane basins, meltwater from snowpack feeds surface water and provides groundwater recharge. However, the isotopic composition of winter precipitation may change as the snowpack accumulates and is subjected to variations in temperature and potential evaporative conditions. The Montana Bureau of Mines and Geology developed a pilot network to collect year-round, monthly precipitation samples for stable isotope analysis from eight sites in

southwest and western Montana (the Lolo, Upper Clark Fork, Lower Blackfoot, and Upper Missouri Watersheds). The pilot program objectives include documenting the spatial and temporal variation in isotopic composition of precipitation, establishing sampling and handling protocols, and evaluating the utility and feasibility of long-term network operation. Each site consists of a precipitation sampler (developed by the International Atomic Energy Agency's Global Network of Isotopes in Precipitation) paired with a climate station (either a Montana Climate Office Mesonet station, or a Natural Resources Conservation Services (NRCS) snow telemetry (SNOTEL) site). Winter collection at three high elevation sites compared the sampler (designed to reduce or eliminate post-precipitation condensation and evaporation) to established winter protocol (5-gallon HDPE bucket). At Lolo Pass during winter sampling events we collected samples from the precipitation sampler and a complete composite sample of the snowpack. Excavation of a snow pit in March at one high elevation site allowed us to sample from discrete layers within the snowpack to assess change in isotopic composition prior to spring snow melt. Data indicate that the late December snowpack lost depth, increased in density and became lighter compared to November and December's snowfall. However, samples from this portion of the snowpack collected in March indicate the snow became isotopically heavier during January ($\delta^2H$ = -115 ‰, $\delta^{18}O$ = -15.9 ‰). Isotopically light precipitation collected in February ($\delta^2H$ = -152 ‰, $\delta^{18}O$ = -19.8 ‰) increased snowpack depth from 1.4 m to 2.2 m. The February snowfall showed little isotopic change when sampled from the snow pit in March. The composite snowpack signature for February represents a mix of the early isotopically heavier part of the buried snowpack and the lighter values from February precipitation. Warming temperatures and isotopically heavier precipitation give March, April and May snowpack compositions heavier signatures (March: $\delta^2H$ = -152‰, $\delta^{18}O$ = -20.3 ‰; April: $\delta^2H$ = -139 ‰, $\delta^{18}O$ = -18.3 ‰; May: $\delta^2H$ = -131‰, $\delta^{18}O$ = -17.6 ‰). Groundwater isotopic signatures from the fractured bedrock resemble the March snowpack while surface water and alluvial aquifer signatures resemble May's snowpack signature. This implies that characterizing the stable isotopic composition of winter recharge waters could be accomplished by collecting a late winter and a mid-spring composite snowpack sample.

**Assessing Cottonwood Health on the Upper Missouri River Breaks National Monument**

Victoria Hill[1]

[1]Big Sky Watershed Corps/Friends of the Missouri Breaks Monument

In 2001, President Clinton designated 149 miles of the Wild and Scenic Missouri River and 500,000 acres of the Northern Great Plains of central Montana as the Upper Missouri River Breaks National Monument for its "spectacular array of biological, geological, and historical objects of interest" (Proclamation 7398). Plains cottonwood (Populus deltoides) are integral to all three of those components. Cottonwoods are an essential aspect of the Missouri River ecosystem, providing nesting habitat for many important bird species, such as the bald eagle. Cottonwoods stabilize the riverbank and complete the iconic landscape of

the White Cliffs section of the Monument. Native American tribes that lived along the riparian area used cottonwoods in their medicines, as canoes, and as sacred poles in ceremonies (Northern State University). However, cottonwood regeneration is threatened by altered flow regimes, invasive species, and cattle grazing. Dams above and below the Monument have halted flooding that cottonwoods depend on for seedling establishment. Only fourteen percent of the cottonwoods along the Missouri River have been established in the last 25 years, and 62% are over 50 years old (Dixon et al., 2010). The nonprofit Friends of the Missouri Breaks Monument has planted 645 trees since 2013 to promote cottonwood reestablishment in areas of the Monument where they will likely not replenish naturally. Of the eight planting locations on the Monument, some sites have a higher survival rate than others. In May 2019 the Friends began conducting a cottonwood mortality assessment of all trees planted since 2013. This assessment recorded the quantitative parameters of tree height, diameter at base height (DBH), and caliper, and qualitative parameters of crown density, tree vigor, and presence of pests and invasive plants. Assessing the health of planted trees at these locations will help the Friends determine where to plant trees in the future for the highest likelihood of survival, and help protect the wonders of the Monument for generations to come.

**Musselshell Cooperative Weed Management Area**

Mitchell Hoffman[1]

[1]BSWC/MRCDC,PCCD,MWC

Weeds and invasive plant species are a very different beast in eastern Montana than in the west. In the west most land is public, and it becomes a public issue to tackle these threats. This means that everyone can easily understand their stake in the issue and everyone feels they have a share in the solution. In the east most land is not only private, but working agricultural land. It's too easy to get in the mindset that if you've taken care of the weeds on your land or in your county, that your job is done. Unfortunately, even after over 100 years of homesteading weeds still haven't gotten the memo about property lines. All too often, after spending many long hours, considerable amounts of money, weed seeds blow in from the neighbors' house and you're back to square one. This was the primary driver in setting up the Musselshell Cooperative Weed Management Area. The CWMA has the goal of bring stakeholders, including state and federal agencies, private landowners, and NGOs to the table to better tackle weeds and other invasive species throughout the region. By working together, we are better able to leverage our funds to tackle large scale weed management projects. We are also able to share information about species distribution, site follow-up, and what is working and what's not. For my poster I would like to highlight this cooperation, where we've come from, and where we're going.

**The Montana Mesonet: Near Real-time climate Data for Decision Support**

Kevin D Hyde[1]

[1]Montana Climate Office

The Montana Mesonet is a partner-driven system of networked climate observation stations developed through the Montana Climate Office located at The University of Montana. The closely spaced stations monitor weather, soil moisture, and (optionally) vegetation response. Near real-time data are transmitted by cellular signals for viewing on-line through the Montana Climate Office (MCO). The purpose of the MT Mesonet is to support adaptive management of farms, rangeland, water resources, and natural ecosystems; with the aim of building resilient and sustainable agricultural, economic, and ecological systems.

Each MT Mesonet station is configured with a surface weather package, a soil moisture array, and a solar-powered data logger/transmitter unit. Atmospheric data support calculation of evapotranspiration and other meteorological derivatives. The soil probe array monitors factors supporting plant growth. Volumetric water content measures soil response to precipitation and vegetation, temperature monitors subsurface response to surface temperature trends, and electrical conductivity is sensitive to agricultural inputs and changes to biogeochemical processes.

The vertical soil sensor profile monitors trends with depth and potential recharge. Soil data support decisions about crop timing, stocking levels, available water, irrigation efficiency, and drought potential. The optional NDVI sensor pair monitors relative vegetation greenness, a commonly used indicator of productivity, where local NVDI provides means for future calibration of broad-scale satellite images of vegetation response, water stress, and drought indicators. Initiated in 2016, the network now numbers over 68 stations statewide. Partners include: Private ranches and farms, County, State, Federal, and Tribal agencies and entities, units of The Montana University System, and community and not-for-profit groups. Support from the National Mesonet Program enables transfer of data from the Montana Mesonet to support federal needs for meteorological data. Support from the National Interagency Drought Information System empowers collaboration with the Governor's Drought and Water Supply Committee to actively develop, new applications for monitoring drought. Through partnership with the Montana Department of Agriculture, the Montana Bureau of Mines and Geology, and the Montana State Library, existing groundwater monitoring wells, previously requiring site visits for direct data download, are being capped with Mesonet Stations. The data transfer structures are currently being built to move well data through the data cloud to the MCO IT infrastructure and into the MT Ground Water Information Center (GWIC). Thereafter, as resources permit, data will then be served and archived by the MT State Library.

**Modeling Hydrologic Impacts of Water Rights Quantification and Settlement on the Flathead Indian Irrigation Project**

Jordan A Jimmie[1], Brian Chaffin[1]

[1]University of Montana, Department of Society and Conservation

The Confederated Salish and Kootenai Tribes (CSKT) of the Flathead Reservation are a federally-recognized group of tribes (Kootenai, Salish, and Pend d'Oreille) located in western Montana. On the reservation lies the expansive Flathead Indian Irrigation Project (FIIP), which supplies irrigation water to approximately 127,000 acres of tribal and non-tribal agricultural land. The 1904 Flathead Allotment Act opened "surplus" land to non-native homesteaders without tribal consent, creating the land ownership fragmentation observed on the reservation today. This legacy, combined with historically unquantified tribal reserved water rights and the antiquated state of the FIIP infrastructure, including water losses from unlined earthen canals, aged dams, and inefficient diversion points, make the FIIP extremely difficult to manage. In 2015, the CSKT, State of Montana (MT), and U.S. Federal Government completed decades of negotiation that ultimately quantified CSKT reserved water rights in a state-tribal Compact—these quantifications are now codified in MT state law and will be enforceable as early as 2025. The parties also negotiated terms of the CSKT water rights settlement (Settlement) that resolves any future tribal water claims, allocates substantial federal funding aimed at rehabilitating and modernizing FIIP infrastructure, and provides adequate water to protect culturally-significant, endangered bull trout (Salvelinus confluentus). The Settlement awaits U.S. Congressional and CSKT membership approval to become law and be eligible for federal appropriation. The goal of this research project is to determine potential spatial variability in flow regimes currently and under enforced Compact allocations prior to or in the absence of FIIP rehabilitation. We approach these questions by employing the ArcGIS version of the Soil and Water Assessment Tool (SWAT) to demonstrate how the Compact provisions will impact both tribal and non-tribal lands, as well actually and potential bull trout habitat. Quantifying reserved water rights of federally-recognized tribal nations is vital for the enhancement of tribal sovereignty over water resources, economic development, natural resource management, and cultural and traditional practices. As with many tribes located in prior appropriation states, the CSKT have not had legally-enforceable water rights to allocate to other uses such as environmental flows for endangered species habitat until the recent Compact. Modeling contemporary FIIP flow conveyance regimes is critical for better management of the watershed, tribal and non-tribal irrigated agriculture, and endangered fish species habitat in the absence of an approved federal settlement and necessary FIIP improvements.

**Pesticides Enhance Bacterial Growth and May Exacerbate Reverse Osmosis Biofouling**

Allison Kelly[1], Emily Vincent[1]

[1]Montana Technological University

Bacterial interaction is important mainly in regards to groundwater contamination in agricultural settings and for bacterial clogging of reverse osmosis filtration systems. We investigated bacterial growth and biofilm formation of Escherichia coli (E. coli) and Sphingomonas wittichii (S. wittichii) These strains of bacteria were used each for their unique contributions to this project, E. coli is considered a model organism, known for its fast growth rate, and S. wittichii is more abundant in Montana water, so it is more of a representation of the systems we are exploring. Both strains of bacteria were grown in trypic soy broth (TSB) and minimal media, M9. The bacteria were treated with pesticides (chlorosulfuron, triasulfuron, and methylsulfuron) and nitrate. A Growth Assay was performed with both bacteria treated with pesticides in TSB and M9 media. A two-fold dilution was performed for the pesticides starting at 100 mg/L and ending at 0.187 mg/L; the same was done with the nitrates, except with a starting concentration of 50 mg/L. Growth curves were performed by recording the absorbance of each well in a 96-well plate reader every hour for a 24-hour period for E. coli and a 72 hour period for S. wittichii. After the MIC assay was performed, a biofilm assay was performed also using the 96-well plate reader to determine the extent of biofilm formation in each well. There was no significant trend observed for biofilm formation for S. wittichii and E. coli when treated with pesticides or nitrates; however, the growth of E. coli increased with increasing pesticide concentration in minimal media, suggesting E. coli can digest and utilize pesticides when in a limited resource environment.

**Simulating Energy and Water Dynamics for a Temperate Urban Microclimate Using a Fully Distributed Eco-Hydrological Model**

Sarah Khalid[1], Marco P Maneta[1], Zack Holden[2], Chris Soulsby[3]

[1]University of Montana, [2]US Forest Service, [3]North Rivers Institute, University of Aberdeen

The western U.S and other regions of the World are experiencing drier summers and longer periods of consecutive days without wetting rain. Less frequent summer storms reduce the moisture available to dissipate heat, increasing the amount of energy available to heat the ground and the air. This reapportion of the energy balance is especially acute in urban environments because of low surface albedo and relatively low thermal capacity of asphalt and concrete. To investigate the impact of summer storms and urban irrigation on the energy balance and thermal comfort in urban environments we use a fully distributed ecohydrological model to simulate the urban microclimate of Missoula, MT, a typical temperate, mid-latitude town in the inter-mountain western US. We conduct simulations during a wet and a dry summer and evaluate the fluctuations of surface temperatures attributed to summers storms. The driving hypothesis is that less frequent summer storms

and less urban irrigation reduce the dissipation of available energy as latent heat, effectively increasing surface temperatures and decreasing thermal comfort in urban environments more significantly than the expected regional increase in air temperature associated with climate change. The goals of this study are 1) to determine to what extent timing and duration of summer precipitation and urban irrigation helps dissipate heat; 2) to evaluate urban thermal impacts induced by longer dry periods during summers; and 3) to quantify the role that different land covers and water plays on the reapportion of the energy balance and on ameliorating localized heat islands. A comparison of turbulent heat flux partitioning between wet and dry years during preliminary model runs show considerable differences between the two, modulated strongly by the presence of water. Additionally, in situ measurements at two sites representing the built and the non-built urban environment show substantial variation in net radiation consistent with albedo and shallow soil temperature differences.

**Floodplain Ecological Assessment Across Temporal and Spatial Scales: Does the Portfolio Effect Apply to Rapid Assessment Tools?**

William J Kleindl[1], Paul Stoy[1]

[1]Montana State University

Riparian systems of the American West are a shifting mosaic driven by fluvial and fire disturbances and recovery. These disturbance and recovery patterns are influenced by landscape patches shaped by silviculture, agriculture, development, and preservation management decisions. Together these create a system with dynamic elements that operate at a wide range of spatiotemporal scales. Although there are well-established ecological assessment models that measure the extent of anthropogenic impact on ecological condition and services, these tools are generally temporally static, site-specific, and do not account for natural disturbance dynamics. Here we developed 34-years of Landsat thematic maps within the Flathead River system in MT, USA and BC, CA (~59000 ha). We established multiple reaches based on geomorphic characteristics (n=43: 290-7660 ha) and three silviculture, preservation and agriculture/urban dominated management zones (n=3: 14660-25575 ha). From these, we mapped structural attributes and created qualitative models that measure riverine ecological functions and services. We further examine how these relationships change across time and spatial scales from reach to management zone to watershed. From these, we pursue two research approaches: 1) The Portfolio Theory address control that spatiotemporal patterning of disturbance has on ecological variation at different spatial scales. However, multimetric indices (MMI) commonly used in ecological assessment already reduces the amplitude of individual system attributes effect within an index and our early results suggest this affects the portfolio. Therefore, we ask, are reach-based MMIs scalable within a portfolio? 2) Portfolio Theory is based on the idea that emergent properties of aggregated systems are less volatile than their components. Its application is compelling in systems where volatility is driven by natural (e.g. fluvial) or anthropogenic (e.g. logging/recovery) processes. However, it has been established that as systems harden through anthropogenic influence

(e.g. ag/urban), they become simplified as our early results indicate. Here we ask, is the portfolio effect an efficient management tool in human-dominated systems?

## Groundwater Recharge in Flood to Pivot Irrigation Conversions

Shawn L Kuzara[1]

[1]Montana Bureau of Mines and Geology

The long-term hydrologic ramifications of converting from flood to pivot irrigation are becoming apparent to Montana's water resource managers. In 2019, the Montana Water Center hosted a series of discussions about the science and policy surrounding irrigation methods, and the State Water Plan recognizes the significance of understanding the possible consequences of this conversion.

The economic and conservation benefits of pivot irrigation are convincing many Montana irrigators to install sprinkler irrigation systems. Such systems allow for more precise management of water and soil, and they require less operator time. For malt-barley and sugar beet growers in southcentral Montana there is specific pressure from retailers to demonstrate water conservation. However, rural residents rely on irrigation-recharged shallow aquifers for domestic water. Reduced aquifer recharge is a consequence of more efficient irrigation and may reduce groundwater supplies and, in some locations, baseflow to streams.

The Montana Bureau of Mines and Geology (MBMG), in cooperation with Carbon, Big Horn, and Yellowstone Conservation Districts, the USDA Natural Resources and Conservation Service, Montana Department of Natural Resources and Conservation (DNRC), and private landowners, are monitoring irrigated fields that were historically flood irrigated but are - or will be - converted to pivot irrigation. We expect to use these data to assess the field characteristics (depth to the water table, landscape position, and geology) that affect groundwater availability. This information may be useful to anticipate and potentially mitigate effects of pivot installation on shallow groundwater systems.

Future work includes monitoring the quality and quantity of recharge from flood and pivot irrigated fields along the Clarks Fork of the Yellowstone River. Information regarding where fields might be converted to sprinkler irrigation with the least impact to groundwater supplies will be provided directly to irrigators through an educational outreach program. This work to improve understanding of important field characteristics for recharge and provide outreach to irrigators is funded by the DNRC Renewable Resources Grant and Loan Program.

**The Bitter Root Water Forum: Building Community around a River**

Emilie Lahneman[1]

[1]BSWC/Bitter Root Water Forum

In 1993, a group of Bitterroot residents came together to learn more about water resources in the Bitterroot Valley. They understood that water was the lifeblood of their community, and they wanted to form a group that would promote the protection and restoration of our water resources, and help inform citizens of the many facets that support a healthy, functioning watershed. Sharing information about the importance of a healthy watershed through educational "forums" was how the Bitter Root Water Forum got its start. Now, BRWF works to ensure clean water for this and future generations through a twofold approach of conservation education and on the ground restoration. BRWF's conservation education programs provide quality information on issues of watershed health to both youth and adults. Youth education programs led by the Big Sky Watershed Corps (BSWC) member provide easy and reliable access to conservation education both in schools and in the field through partnerships with the US Forest Service, Department of Natural Resources and Conservation, Fish Wildlife and Parks, Soil and Water Conservation Districts of Montana, Future Farmers of America, Trout Unlimited, and more. Adult education programs connect community members with opportunities to learn more about watershed issues and include irrigation tours, continuing education courses for Realtors, field tours of successful conservation projects, consultations for landowners interested in restoration projects, and public informational forums on watershed issues of importance. BRWF's restoration projects aim to improve stream health and rebuild healthy riparian areas. Projects are accomplished by working with streamside landowners and engaging an active team of volunteers. Notable projects include sediment reduction on Threemile and Rye Creeks through road improvement measures, and sediment and temperature and reduction projects on the East Fork of the Bitterroot River, Miller Creek, and Cameron Creek through streamside revegetation and fencing. Through a thriving volunteer base, the Water Forum is able to monitor and maintain all existing restoration projects, resulting in a high survival rate for riparian plantings, and a strong sense of community around these projects. Community involvement in a shared resource, the Bitterroot River, is the driving force behind these goals. The Water Forum's mission of "Bringing the community together to protect, enhance, and restore the watershed we ALL rely on" would not be possible without the constant time and support the community gives to our cause. With this support, the Water Forum has grown from a small group of concerned grandmothers to three full time staff, a Big Sky Watershed Corps member, and a large volunteer base dedicated to our River's community. With more restoration projects, education programs, and community events planned for the coming year, the Water Forum and surrounding community are very excited to see what the future holds for the Bitterroot River.

**Calibration of Hydrologic Component of the Hydro-Economics of Agriculture Model**

Zachary H Lauffenbuger[1], Marco Maneta[1], Colin Brust[1]

[1]University of Montana

Climate change continues to lead to significant changes in hydrologic systems, such as earlier spring peak discharge and longer, hotter dry periods. It is imperative to adapt to those changes to offset any negative effects, which include lack of river water available for agricultural uses and heat stress to crops. Agriculture has a long history of adapting to climate variability, but ongoing and substantial changes in climate are presenting new challenges for farmers. In an effort to aid policy makers and natural resource managers an integrated hydro-economic model was developed which simulates hydrologic conditions across Montana, coupled with an economic model of farmers' decision making. The objective of the work package presented here is the calibration of the hydrologic component of the model. An accurate calibration of the hydrologic conditions across Montana will allow for the analysis of climate change scenarios impact on discharge timing and magnitude, and the effects of shifting hydrographs on water resource use and economic effects that result. The hydrologic model is a modified HBV rainfall-runoff model coupled with the Muskingum-Cunge method for river routing. In total there are 13 parameters which govern snowpack, discharge, stream routing, and groundwater and soil moisture quantities. The model domain was divided into 330 subbasins on a watershed spatial scale. Because most subbasins are ungaged, subbasins were grouped into 5 clusters based on 17 subbasin characteristics using K-Means. The hypothesis being that subbasins with similar physiographic characteristics, e.g. mean elevation, mean percent clay, etc., will have similar discharge response, soil and groundwater residence times, and overall parameterization. The 13 parameters were calibrated for select subbasins from each cluster that contain a USGS gaging station using brute-force Monte Carlo (MC) simulation runs and the best parameter set for each cluster was then applied to all subbasins for each cluster. Brute force MC was the chosen method because it permits trivial massive parallelization for sampling a wide range of parameter sets to determine parameter sensitivity, correlation, and scenario analysis. Discharge results show good model fit for calibrated subbasins, Kling-Gutpa Efficiency scores between 0.42-0.66, and Nash-Sutcliffe Efficiency scores between 0.45-0.60. Ungaged, unimpaired subbasins produce mixed model fits across clusters, which indicates that this K-Means clustering method for parameterization of ungaged basins needs refinement. Experimentation on which suite of subbasin characteristics and the number of clusters is currently being conducted.

## Research and conservation seed increase at The Bridger Plant Materials Center

Zach Lenning[1]

[1]BSWC - The Bridger Plant Materials Center

My term with the Big Sky Watershed Corps serving at the Bridger Plant Materials Center has been very busy and productive so far. A large part of my work here has included research on establishment of conservation species and the use of new species as pollinator habitat and cover cropping. The first study that I have been working on is investigating the effects of planting depth on small seeded conservation species and how soil types will affect the emergence rate of these species. The second study is an evaluation of the forb Lacey Phacelia and legume Austrian Winter Pea for use in Montana and Wyoming as cover crops. This study also looks at the interactions of these plants at variable planting depths. I have also been participating in the Native Pollinator Monitoring project that is lead by Casey Delphia PhD at MSU. The project involved placing bee traps around plants that were in bloom and collecting the specimens to be sent to Bozeman for identification. In partnership with the National Park Service we also produce seed for use in highway construction projects in YNP, GTNP and GNP. The process involves collection of seed from wild sources in the park to maintain the genetic integrity of flora in the parks, and I was lucky enough to spend time in Yellowstone and Glacier collecting seed for use in future projects. The majority of other work performed at the BPMC has revolved around production of conservation seed and has included planting, cultivating, fertilizing and spraying pesticides, harvesting and seed cleaning.

## Investigation of spatial and temporal distributions of metals in a stormwater retention pond after storm events

Caleb Lockyer[1], Liping Jiang[1], Joe Griffen[1]

[1]Montana Tech

In Butte, Montana retention ponds were constructed to mitigate sediment transport during storm events due to the environmentally toxic particulates that accumulated from historic mining activities. In 1983 Silver Bow Creek was designated a superfund site as a result of flow from the mining area contributing contaminants to the watershed. As groundwater and stormwater shed water off the Butte hill, the constituent flow is burdened with elevated concentrations of metals. These flows can have levels of zinc and copper that regularly exceed acute water quality standards in Montana. The largest drainage basin in the historic Butte city center covers approximately 674 acres. An end-of-the-pipe, retention pond was constructed in 1997 to capture flow from drainage basin. The retention pond, named CB8, was designed for the 10-year, 24 hr storm event with an original construction volume of 23 acre-feet. The pond increases in depth from the inlet to outlet structure, approximately .5 meter to 1.5 meters when full. Throughout the summer and fall of 2019, monitoring of the retention pond was conducted to investigate the hydrologic performances of the retention pond in accordance with storm events. Multiparameter data

sondes (Hydrolab HL4 & YSI EXO2) were deployed throughout the study period of July through September, 2019. Locations for the deployment of these sondes where selected near the centroid, inlet, and outlet of the pond. Data collected from the sondes displayed diel cycles influencing temperature, pH, and dissolved oxygen. To investigate column stability or stratification in the pond, a cross sectional transect was established to record turbidity, specific conductance, pH, temperature, and dissolved oxygen. Results from monitoring sites along the transect exhibited stratification in the pond despite relatively shallow depths. These results indicated that surface and depth samples of metals concentrations could be influenced by these trends. To correlate vertical stratification and diel cycles in water chemistry with the distribution of metals concentrations, samples were collected at 6 sites along the longitudinal transect. Depth samples were collected near the centroid and at the outlet of the pond. Samples were collected before storm events during a period of dry weather, and again 0-24 hr, and 48-96 hr after storm events. Analytes from these samples included TSS, DOC, Cu, Zn, Pb, As, Fe, and Cd. Analysis of the pond samples were designed to be used in the Biotic Ligand Model (BLM) for copper toxicity and the hardness-based criteria for metals used by Montana DEQ and the EPA. Associating diel cycles of field parameters, column stratification patterns, and concentrations of heavy metals will provide valuable information to gage the bioavailability of copper and how it is distributed throughout the pond after a storm event. Data collected from this study will be used to analyze the temporal hydrologic efficiencies of the pond after a storm event, and to propose design strategies for future stormwater treatment at this site.

**Macroinvertebrate and Water Quality Education Program in the Ruby Valley**

Claudia Macfarlane[1]

[1]Ruby Valley Conservation District

In 2018, the Ruby Valley Conservation District (RVCD) won a Water Quality Education Mini Grant from the Soil and Water Conservation Districts of Montana (SWCDM) to provide nonpoint source and water quality education programs to rural schools in the Ruby Valley. This program addressed the following nonpoint source and water quality issues in the Lower Ruby Watershed: sedimentation and riparian health. The Macroinvertebrate and Water Quality Education Program consists of classroom sessions educating students on topics including: watershed and riparian health, sources of pollution, water quality parameters and macroinvertebrates as bioindicators. After classroom education, classes participate in field sampling of benthic macroinvertebrates and in situ water quality parameters including Temperature, DO, pH, and turbidity. RVCD believes educating students about the benefits of healthy watersheds will help to grow the next generation of stewards. Over 72 students from Kindergarten through 10th grade have had the opportunity to sample either the Ruby River or Clear Creek for a total of 15.5 hours of education for students in the Ruby Valley as of August 2019.

Partnering with Twin Bridges High School and the Ruby Habitat Foundation, in the spring of 2019 students participated in water quality monitoring and macroinvertebrate sampling

on Clear Creek associated with pre restoration stream conditions, with the hopes to continue the program to document post restoration changes. Clear Creek is a side braid of the Ruby River and is listed as impaired for sediment in the 2006 TMDL and Water Quality Restoration Plan for the Ruby River. A 2012 Riparian Assessment of Clear Creek found that 53% of reaches were Sustainable at Risk and 47% were poor or Not Sustainable. The Ruby River is listed as impaired for sediment and temperature in the 2006 TMDL and Water Quality Restoration Plan for the Ruby River. With education being the primary goal of the program, during field activities students gained the ability to analyze the relationship between aquatic macroinvertebrate populations and water quality and the ability to describe the connection between land-use practices and water quality. RVCD administers Big Sky Watershed Corp's Watershed Awareness Survey to classes after completion of the entire program. The Watershed Awareness Survey measures a participant's change in behavior or intention to change a behavior with regard to conservation-based practices. Individual beneficiaries will report change in behavior or intention to change a behavior with regard to conservation-based practices rated as a 4 or 5 on a 5-point scale. Programs where surveys were not administered, due to time or age constraints, were evaluated through a discussion with the teacher and students. Currently 60% (9/15) of beneficiaries reported a change from 4 to 5, with teachers and students verbally confirming their increased understanding of watersheds and water quality. Sampling and education will continue throughout the fall, and will become a regular program of RVCD.

## In-situ groundwater monitoring using micro-fabricated sensors: Advantages and challenges

Matthew Mcglennen[1], Markus Dieser[1], Matthew Fields[2], Christine Forman[3], Stephan Warnat[1]

[1]Montana State University, Center for Biofilm Engineering, Mechanical Engineering,
[2]Montana State University, Center for Biofilm Engineering, Microbiology & Immunology,
[3]Montana State University, Center for Biofilm Engineering, Chemical and Biological Engineering

The recent increase of artificially recharging natural aquifers via managed aquifer recharge (MAR) to meet the global demand for freshwater concerns. Recharging the aquifer with different sourced water influences microbial abundance, which can significantly change groundwater quality and consequently, human health. Other groundwater parameters such as pH, electrical conductivity, and temperature are anticipated to vary with the increase in microbe concentration. However, a correlation between microbial density and hydro-chemical parameters is not established. The lack of long-term in-situ measurements in aquifers hinders modeling this correlation and improved MAR technologies. The current state of the art is to pump groundwater for measurements to the surface or -at best- collect downhole, water or core samples and transport them to the laboratory for analysis. This decreases the temporal and spatial data resolution necessary to predict dynamic changes in subsurface sediment systems. What is lacking are deployable sensor platforms that operate reliably in the groundwater environment for an extended time (6 to 12 month), and studies

on the correlation between microbial activity and the given hydro-geochemical parameters. Micro-fabricated sensors, or Micro-Electrochemical Systems (MEMS), have the potential to overcome the challenge in deploying in-situ groundwater sensors. These microscopic devices rely on well-established semiconductor fabrication processes, and have the ability to measure pH, temperature, conductivity, and microbial density. Their small physical dimensions also enable in-situ integration of redundant multi-sensor platforms in one groundwater well, which counteracts possible sensor degradation and enables long-term system deployment. We will show in this poster our current progress in the system development, and first results on the measurement of microbial concentrations in water samples using micro-fabricated sensors.

**Livestock water quality varies across 10 years (2009-2018) in Eastern Montana**

Jennifer M Muscha[1], Mark K Petersen[1], Kurt Reinart[1]

[1]USDA-ARS Fort Keogh Livestock and Range Research Laboratory

Concentrated dissolved minerals in naturally occurring water accessible to livestock grazing semi-arid landscapes can negatively influence animal productivity and well-being. Twelve indicators of water quality (Ca, Cl, F, Fe, Mg, Mn, Na, Nitrate-N, pH, SO4, total dissolved solids (TDS) and temperature) were sampled from four sources (pumped ground water, catchment reservoir, springs and surface flowing water) and in three geographical locations (North, Southeast, and Southwest of Yellowstone River) accessed by livestock over 10 years from 2009 through 2018 at the 22,257 ha USDA-ARS Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana to estimate variation. Up to 45 water samples were collected for analysis twice yearly in the greatest precipitation months (May or June) and in a lower precipitation month (September). Precipitation amounts in each year were 257, 439, 492, 156, 435, 338, 216, 369, 161, 467 mm from 2009, 2010 ,2011, 2012, 2013, 2014, 2015, 2016, 2017, and 2018, respectively, compared with the 30-year average of 316 mm. Data were analyzed as a completely randomized 10×3×4×2 factorial arrangement of treatments with year × location × source × season as the experimental unit using the MIXED procedure of SAS (SAS Institute, Cary, NC). Significance was determined at $P \leq 0.05$. A year by source interaction ($P < 0.05$) was found for Ca, Fe, Mg, Na, Mg, SO4, TDS, and temperature. Highest levels of Na, SO4, and TDS were found in flowing surface water in 2011. Ca levels were highest in spring water in 2011, 2014, 2017 and 2018 and in flowing surface water in 2012. Fe and Mg levels were highest in 2012 in flowing surface water. A year by season interaction ($P < 0.05$) was found for Ca, Fe, Na, SO4, TDS, and temperature. Highest levels of Na, SO4, and TDS were found in 2011 in September. Ca and Fe levels were highest in 2012 in May. A source by location interaction ($P < 0.05$) was found for Ca, Cl, F, Fe, Mg, nitrate-N, pH, Na, SO4, and TDS. Increased levels of Fe, Na, SO4, and TDS were found in flowing surface water in the Southeast location. Spring water in the Southeast location contained the highest levels of Ca and Mg. A year by location interaction ($P < 0.05$) was found for Ca, Mg, Na, SO4, TDS, and temperature. A source by season interaction ($P < 0.05$) was significant for Ca, Fe, pH, and temperature. A season by location interaction was significant for Ca, Na, and TDS. SO4 levels are generally

higher in the dry season. Higher and then lower precipitation in 2011 followed by below average precipitation in 2012 and below average precipitation in 2015 was associated with elevated mineral concentrations. Average concentrations of Ca, Cl, Mg, nitrate-N, pH and TDS levels across sources did not exceed the upper maximum intake level for beef cattle. In contrast, concentrations of F, Fe, Mn, Na, and SO4 exceeded upper levels for beef cattle, implicating these minerals may negatively impact range beef cattle performance.

**How Can a Water Fund Work in Montana?**

Julia Nave[1], Sierra Harris[2], Karen Filipovich[1]

[1]BSWC/The Nature Conservancy, [2]The Nature Conservancy

Water funds are a framework that bring together water users, providers, and communities to collectively plan for and invest in a secure water future. Stakeholders convene to identify conservation and restoration activities in their watershed that will protect their water supply, water quality, and recreational opportunities. The group then secures new sources of long-term sustainable funding to pay for the activities identified. Funded activities could include those that increase natural water storage, advance water conservation, restore degraded riparian areas, or improve irrigation and farming practices.

Traditionally, water funds were established to enable downstream water users– like businesses, cities, and utilities– to invest in upstream land management to improve water quality and quantity. However, water funds can be tailored to address unique challenges, priorities, and geographic areas. Since The Nature Conservancy developed the first water fund in Quito, Ecuador in 2000, they have adapted the model to create over 40 water funds around the world. Two North American water funds, the Rio Grande Water Fund and the Minnesota Headwaters Fund, serve as prime examples of the ways the water fund framework is customized to address diverse water security challenges.

The Nature Conservancy in Montana has been exploring how the water fund model may be applied to address water security within our state given a changing climate and growing population. A pilot project in the Upper Gallatin is in the early development stages in partnership with the Gallatin River Task Force. A water fund would support locally led efforts to address water scarcity challenges in the Big Sky area. This approach shows great promise in the Big Sky area due to the willingness of partners, commitment of previously engaged stakeholders, and the urgency to address water security challenges in this headwaters community. Water funds may eventually provide solutions across a broader Montana landscape and evaluating the potential to scale or replicate our successes in Big Sky will be an important part of the process.

## Hydro-social and socio-hydrological modeling: Challenges with data, scale, and perspective

Holly K Nesbitt[1]

[1]University of Montana

The fields of hydro-sociology and socio-hydrology have emerged in recognition of the need to treat human-water systems as integrated and complex, yet researchers in these fields continue to face substantial challenges integrating hydrological and human dimensions in both theory and practice, and specifically in coupled modeling efforts. To understand the current state of hydro-social/socio-hydrological modeling research, challenges, and future opportunities, we performed a literature review. As a group of social scientists and hydrologists, we used a keyword search in Google Scholar, followed by a snowball method to review 71 papers. Results indicated several key challenges to meaningful, integrated social-hydrologic modeling, including: vastly different data types; information loss through aggregation; spatial and temporal misalignment between social and hydrologic systems; difficulty incorporating feedbacks between social and hydrological data types in a coupled system; and a proliferation of either hydrologic- or social-centric models that lack theoretical underpinnings of social and hydrologic disciplines respectively. This review is intended to strengthen and inform modeling efforts from both biophysical and social perspectives and to support interdisciplinary teams as we try to answer increasingly complex questions about water and society in the face of global change.

## Lake County Junior Conservationist Education Program

Lauren N Odom[1]

[1]BSWC / Lake County Conservation District

In 2018, Lake County Conservation District (LCCD) was awarded funding from the Lower Flathead Valley Community Foundation (LFVCF). This award was used to fund the pilot year of the Lake County Junior Conservationist Program. This program focused on the following areas of conservation and sustainable agriculture in Lake County: Introduction to conservation, soil conservation, wildlife conservation, water conservation, and plant agriculture. Additionally, this program was designed to expand on Lake County Conservation District's Annual 4th Grade Agriculture Days event. This event occurs in May and acted as the animal agriculture portion of the Junior Conservationist Program, as well as the final lesson of the Junior Conservationist curriculum. After completing the curriculum students were able to participate in a Recap Relay and Graduation, in which they were given the title "Junior Conservationist." The Lake County Junior Conservationist Program is a 7-month program providing one-hour lessons delivered to four separate classes of fourth graders. This program provides a total of 13 hours of supplemental conservation education for every student participating in all lessons and 4th Grade Agriculture Days. Over 80 students participated in the Junior Conservationist Program and 65 students graduated as "Junior Conservationists." Lake County Conservation District

partnered with Ronan Middle School for the pilot year of the program. The Wildlife Conservation lesson was delivered in partnership with the Confederated Salish and Kootenai Tribes. These partners both acknowledged the low availability of conservation education in current in school curriculum as a key issue that needed to be addressed and where both eager to partner to amend this issue. Education was the primary goal of the program, especially focusing on introducing conservation related vocabulary and introducing stewardship principles. LCCD administers a Conservation Education Assessment Survey to every class on the first lesson and then again after the graduation from the program. The Conservation Education Assessment Survey measures the student's ability to recall vocabulary from throughout the program, expand on why they think that conservation is important and what they want to conserve, and self-assess their perceived change in knowledge level. Students rank their own knowledge level on a 5-point scale. At the end of the program 40% of beneficiaries reported their knowledge level was at a 4 ( I know a lot about conservation covered in these lessons) or a 5 ( I know everything about conservation covered in these lessons) 43% of students reported their knowledge level was at a 3 ( I know some of the conservation covered in these lessons. Additionally, despite students not being warned that they would be resurveyed, 60% of students increased their score from test 1 to test 2 and the amount of 100% Scores went from 3 to 13. Lastly, the overall grade average of all classes on the surveys increased 14%. The program was considered successful and LCCD hopes to either expand this program to other schools utilizing their BSWC Member or create a lesson kit that can be sent to teachers throughout the district.

**Examining the Abundance and Composition of Submicron Particles in a Mine-waste Contaminated Intermountain West River**

Kaitlin Perkins[1], Manuel Montano[2], Ben Colman[1]

[1]University of Montana, [2]Western Washington University

Metals and metalloids have historically been thought to enter aquatic food webs in the "dissolved" fraction, operationally defined as anything passing through a filter of a given size (e.g., 700 nm). This definition of dissolved may be inaccurate because it lumps small, submicron particles (colloids) with truly dissolved solutes (< 1 nm). For elements like iron, the iron itself may not be toxic, but colloidal iron may serve sorb toxic metal(loid)s and serve as vectors for metal(loid) accumulation in organisms. The goal of this study was to examine the elemental composition of submicron particles along 200 km of the mine-waste contaminated Clark Fork River. We collected water samples during base flow and characterized the elemental composition of individual particles under 1000 nm. We found that there were more particles consisting of single metal(loid)s than particles consisting of multiple metal(loid)s at all sites. There was a greater overall mass concentration of particles at upstream sites than downstream, which is likely driven by dilution from tributaries with lower particle concentrations. Iron and manganese were the most abundant metals in both single and multiple metal(loid) particles, and had sizes in the lower end of the colloidal size range. Lead, zinc, cadmium, and copper were sometimes

found associated with iron particles, suggesting that iron may indeed be serving as a vector. These data begin to illuminate the potential importance of colloids in both the transport of contaminants and in driving metal(loid) exposure to organisms.

**Aquatic Invasive Species Education and Monitoring in the Flathead Valley**

Natalie Poremba[1]

[1]BSWC/Crown Managers Partnership

Aquatic invasive species (AIS) cause damage to the environment, economy, and human health. The best approach to tackling AIS is to ensure that they do not spread at all. This can be achieved by individual recreators following clean, drain, dry protocol and stopping at inspection stations - goals which can be fostered through outreach and education. In partnership with Flathead Lake Biological Station (FLBS), Confederated Salish and Kootenai Tribes (CSKT), and the Flathead Lakers, I developed educational AIS maps and delivered AIS curriculum to 7th graders throughout the Flathead Valley. The material was intended to empower young residents and recreators to take ownership and responsibility for the care of their local water bodies. The next best tactic in managing AIS is monitoring lakes, rivers, and streams to ensure that if AIS do enter the system, they are detected early on. This allows managers the chance to eradicate populations before they become firmly established or spread further. Throughout the summer with scientists and managers from FLBS and CSKT, I sampled 30 sites on Flathead Lake to monitor for invasive zebra and quagga mussels. We conducted 100m tows using fine mesh nets, and collected samples from both shoreline and boat. The samples were sent to two different labs - a genetics lab which looked for environmental DNA and a microscopy lab which looked for the microscopic, larval form of the mussels, veligers. Big Sky Watershed Corps afforded me the opportunity to combat AIS on two fronts: education and monitoring.

**From Headwaters to Flat-water, Montana's Birds Call Water-based habitats Home**

Caroline Provost[1]

[1]BSWC/Montana Audubon

Whether surveying along Montana's major rivers, like the Madison and Missouri River Important Bird Areas, or open-water habitats like Ninepipe National Wildlife Refuge, or the arid prairie pothole region surrounding Glasgow, Montana's water-based habitats prove to be a magnet for breeding birds. With over 50% of our breeding birds reliant on water-based habitats in some way, Montana Audubon focuses a large portion of our annual inventory and monitoring efforts in these habitats. During just this past survey season we have worked with the Montana University Bird Ecology lab to conduct point-counts on breeding birds along the Madison and Missouri Rivers, worked to conduct colonial waterbird surveys for species of concern at four western Montana sites, and worked to inventory the breeding habitat of the Black Swift, a headwater's species reliant on

perennial waterfalls. These surveys helped us measure both the diversity and abundance of species, many of which are state species of concern, at key sites throughout the state. A key purpose in our efforts are to help the state, through the work of the Montana Natural Heritage Program, assess the conservation status of our many avian Species of Concern and Species of Greatest Inventory Need.

Fortunately, for Montana Audubon, and the species we are looking to survey, there is a lot of work we can achieve in just one summer of survey effort. This work is summarized here, and highlights efforts to survey sites along the Madison and Missouri River Important Bird Areas for all bird species using point counts, and survey for noxious weeds using a central and sub-plot measuring strategy, efforts to survey colonial waterbirds for long-term trend analysis at Ninepipe National Wildlife Refuge, Brown's Lake, Helena Valley Regulating Reservoir, and Lake Helena, and efforts to locate the little-known and elusive Black Swift. These surveys take us from the bottom-land cotton-wood gallery forests of our wide rivers, to the churning waters of our glacier-fed mountains in northwestern Montana, and reveal a few secrets along the way.

**Restoration Focused on Community Educational Opportunities.**

Anthony T Sammartano[1]

[1]Montana Audubon Center

When the land the Montana Audubon Center operates on was first purchased, the goal was for the development of a public use area where those interested in natural sciences could visit, learn and experience a part of the natural world with local experts. After 20 years of immense volunteer restoration effort and 10 years of programming, the Montana Audubon Center has achieved this goal and has become one of the best places in Billings to be outside and learn about all aspects of nature. Restoration efforts continue to this day as the landscape matures alongside a growing community landscape in the Yellowstone County/Greater Billings. This growth has been bringing new individuals out to the Montana Audubon Center and the surrounding property as folks discover new and fun things to do with their families around Billings. My goal while serving with the Montana Audubon Center has been to recruit some of these new faces along with current Billings' residents into participating in any number of the activities that the Montana Audubon Center offers, with my area of focus being restoration. The landscape is treated as an ecotone garden, with various plant communities not endemic to the Yellowstone River floodplain scattered across the property, and this garden needs consistent tending. Numerous visitors experiencing what the Montana Audubon Center offers ask if there are ways they can volunteer to help and the Volunteer Coordinator and myself do our best to find opportunities to meet their service desires and also to help to teach or provide learning opportunities in areas these individuals desire. By investing in our local community, we are fostering a growing community of passionate folks who love what the Montana Audubon Center provides and are willing to volunteer more of their time to help keep this place beautiful and assist the staff as our popularity forces us grow.

**Inventorying Headcuts on Mesic Sites Adjacent to Sage Grouse Leks on the Matador Ranch**

Ryan Schaner[1]

[1]Big Sky Watershed Corps/The Nature Conservancy

Sage grouse (Centrocercus urophasianus) are an endangered North American bird requiring large intact grasslands with varying sagebrush cover. Mesic sites are areas with adequate year-round soil moisture retention. Mesic areas are prime areas for insect habitat and insect production. Sage-grouse broods depend upon the overall health and production of mesic sites for food and cover. The Nature Conservancy's (TNC) Matador Ranch has two active sage-grouse leks within its 60,000 acres. A lek is an area where sage grouse congregate in the spring to mate. As part of an effort to manage for sage grouse and improve, their habitat TNC has initiated an inventory of mesic sites in important sage grouse habitat. A 2-mile radius from the center of the lek was surveyed for headcuts or gullies. A headcut is a type of erosion that has a channel depth of minimum one foot and the head of the gullies is undercutting upslope. All headcuts surveyed within the two-mile buffer were measured in cubic feet and a GPS point was taken for future referencing. Other landscape features documented during surveying were sheet erosion areas, mass-wasting sites and wetland depressions. Sheet erosion is the gradual removal of soil in thin areas by overland flow or splash erosion. Rocky glacial till was the most common area documented as sheet erosion. Mass wasting sites are areas of downward movement of soil and rock induced by gravity. The most common mass wasting surveyed were hill slumps. Wetland depressions are inland aquatic ecosystem with closed or near closed elevation contours and a central area of greatest depth. These features are important to illustrate because there appeared to be a correlation between number of headcuts and overall area of sheet erosion or wetland depressions. The previously described landscape features and headcuts were mapped via ArcGIS to illustrate in detail the landscape. Lek SG11-52 surveying was completed with a total of 351 headcuts and 27 mass-wasting sites across 2,552 acres of land. Sheet erosion was a prominent landscape feature within SG11-52's buffer. One headcut was present per 7.27 acres of surveyed land. Lek SG11-53 is currently being surveyed and comparing numbers will be ready soon. A historic mesic resources layer provided by the Sage Grouse Initiative (SGI) was added for final illustrating. The purpose of creating a detailed illustration is of TNC to begin long-term remediation work on the headcuts surveyed. A headcut class ranking system was used during surveying to assist in prioritizing future remediation work. Mesic resources were also separately monitored on the Matador Ranch. A photo riparian monitoring project was conducted on the Matador Ranch. Photos were taken at specific locations bearing a specified azimuth degree. Photos from 2001 were compared to photos from 2019 and any visual changes were recorded.

**Clearwater Resource Council: Protecting the Natural Resources and Rural Lifestyle of the Clearwater Watershed**

McKenzie C Schessl[1]

[1]BSWC/Clearwater Resource Council

The water quality of the Clearwater River Basin has been a concern for several decades. In the Clearwater, the lakes and rivers are the center of the community. They provide water for the community members, scenic vistas and diverse wildlife; they are the center of the local economy and a way of life. The condition of the surrounding watershed is directly influenced by the activities within it, but there has been very little research about the condition of the watershed since earlier work in the 1970s and 80s. In 2009 a critical analysis was conducted, inventorying the lakes, streams, and current knowledge about the basin in order to create a watershed plan. The Adopt-a-Lake program was initiated in 2009; the purpose of the program is to collect secchi depth and temperature measurements which are indicative of the amount of algae production in the lakes and overall water quality. For stream health, CRC, with the help of trained "citizen-scientist" volunteers, monitors the nitrogen, phosphorus and turbidity levels of 27 streams in and around the Clearwater basin. In 2011, the Seeley-Swan High School joined with CRC to initiate the "Students in Action Morrell Creek Water Monitoring Project" and "Riparian Classroom" to engage students in real world science relevant to their community. The objectives include development of high-quality information on stream flows and nutrients that directly influence our lakes. The biggest threat to Montana waters are the Dreissenid mussels. To prevent an infestation, early detection is key. CRC monitors the six major lakes for the Dreissenid mussels and aquatic invasive plants four times each summer. After analysis, individual lakes show year-to-year variability in depth and temperature means, but there have been no consistent declines or improvements in conditions through the period of monitoring. We found multiple streams that did not exceed regulatory standards but should be of concern because of elevated concentrations of Total P, Total N, or both. More work is needed to resolve the unknown sources of nutrients and that could mean refocusing work on and around the lakes and larger tributaries immediately upstream. No positive samples have been detected within the Clearwater Basin for Dreissenid mussels. CRC's efforts monitoring the Clearwater Valley lakes and streams have shown that students and volunteers can collect high quality information at limited cost with the additional benefit of engaging and educating the community in natural resource issues.

## Precipitation Isotope Ratios and Tree-ring based Snowpack Relationships to inform Paleoclimate Reconstructions from Lake Sediment δ18O

Spruce W Schoenemann[1], Justin Martin[2], Gregory T Pederson[2], David Mcwethy[3]

[1]University of Montana Western, [2]U.S. Geological Survey, Northern Rocky Mountain Science Center, [3]Department of Earth Sciences, Montana State University

Rocky Mountain snowpack over the recent 30-40 years has shown an unprecedented decline, yet extended observations of snowpack are few. To date, tree-ring based reconstructions of April 1 Snow Water Equivalent (SWE) in the Northern Rocky Mountains have extended the temporal history of snowpack changes to ~1200 A.D. In combination with carbonate isotope lake sediments, there is potential for extending winter season hydroclimate relationships through the Holocene epoch, providing a long-term record of snowpack and climate variability that integrates internal dynamics to orbital-scale forcings. Here we present a preliminary reconstruction of Northern Rockies snowpack dynamics spanning ~2200 years based on δ18O measurements of sediment carbonates collected from Foy Lake in northwest Montana. We explore the calibration of lake sediment δ18O to annually resolved snowpack and temperature reconstructions from tree rings and assess potential sources of error, as well as techniques to quantify such error in this novel climate reconstruction approach. To investigate possible climatic drivers of the reconstructed decadal δ18O/snowpack variability, we employ HYSPLIT air parcel back-trajectories to identify modern dominant seasonal moisture source regions and ENSO-related shifts in the storm tracks, along with comparison to other proxy reconstructions. Given the availability of suitable lake sediment records, such reconstructions could provide a unique insight on the mid-Holocene (~8–5 ka) climatic optimum when temperatures were analogous to the present-day, and may help anticipate snow derived water availability in a warmer future.

## Cultivating Lasting Conservation Change through Shared Values and Collaboration

Liz Shull[1]

[1]BSWC/Wildlife Conservation Society

Throughout my AmeriCorps term with the Wildlife Conservation Society's Community Partnerships team, I have learned the importance of the roles that partnerships and collaborative efforts play in creating the lasting conservation of water, land, and wildlife. Some of the projects that I have spent the past ten months working on are our Summer Wildlife Speaker Series and our Bear Smart Big Sky Initiative. The Summer Wildlife Speaker Series is an 8-part series with events the occur all across Southwest Montana. Each event focuses specifically on a particular wildlife species that calls Montana home. Some of our species highlighted this summer were mountain lion, big horn sheep, wolverine, owls, pronghorn and more. Each event creates a connection between communities and wildlife through education, conversation and calls to action.

Another project that I have been involved with is the growth of our Bear Smart Big Sky work. The mountain community of Big Sky, Montana has grown 21 percent over the past

five years. Rapid development and tourism can be great for a community economically, but usually comes at a cost to natural resources. A dramatic increase in the population of Big Sky can be largely attributed to both the recreational and geographical values make Madison and Gallatin counties a desirable place to live in and visit. On any given day, residents and visitors alike can hike, mountain bike, ski, fish, golf, and rest, all in the convenience of their own backyard. Just as Big Sky is growing, bears are also beginning to expand outside of the Greater Yellowstone Ecosystem (GYE) boundaries moving into inhabited locations. From 1990-1994, there were a recorded 26 female grizzly bears with cubs in the GYE. Between 2010-2014, that number nearly doubled to 57 sows with cubs. Not surprisingly, we have seen a significant increase in human-bear conflict resulting in relocation or the lethal removal of bears, within the Big Sky area. Between 1994-2002, 11 bears were relocated and 4 were lethally removed due to conflicts in Big Sky. These numbers detrimentally increased to 68 bears relocated and 20 lethally removed between 2003-2018.

Bear Smart Big Sky was initiated in 2013 to reduce trends in bear relocation and removal due to human conflict in communities that share the land with bears and other wildlife. Through education, outreach, and strategic partnerships, Bear Smart Big Sky works to 1) reduce the availability of anthropogenic attractants such as garbage and bbq, 2) increase community awareness about how to live and recreate safely in bear country and 3) establish regulations and incentives to reduce bear attractants on the land. Through the dedicated and collaborative work of our Bear Smart Big Sky Council, Big Sky has begun to see a reduction in the number of bears relocated and lethally removed amidst a rapidly growing human population.

**Wastewater Analysis Identified Drug-Use Trends for a Montana Community on Independence Day 2019**

Rebecca Tseng[1], Lauren J Warner[1], Deborah Keil[1], Cullen Cunningham[1], T. Jones-Lepp[2], Nicholas R Bishop[2], Miranda Margetts[2], Otto Stein[1], Ellen Lauchnor[1]

[1]Montana State University, [2]Independent Contractor - Montana State University

Water epidemiology studies of pharmaceutical and illicit drugs can provide a more accurate representation of drug usage within a community. By studying both the influent and effluent flows of a wastewater treatment plant, we can monitor collective community drug use and environmental impact of drugs that escape wastewater treatment, respectively. Our group posed the question to see whether Independence Day, July 4th 2019, would coincide with increased drug usage in a Montana community, population 40,000. We gathered a 24-hour composite sample of influent wastewater on July 3, 4, 5 and 6, 2019. Approximately 1L influent samples were filtered using a Millipore 0.22 micron pore filter to remove any solids within the wastewater matrix. This filtered wastewater was acidified to a pH of 2. The sample proceeded through solid phase extraction and liquid chromatography tandem mass spectrometry for identification and quantification of more than 50 drugs and metabolites. The drugs that showed an increased concentration in the

community wastewater influent during this period included, and weren't limited to, ketamine, cocaine, MDMA, ritalin, and methamphetamine.

## Utilizing ArcGIS Online to Create Interactive Tools and Stories for the Charles M. Russel Community Working Group

Mark Werley[1]

[1]Big Sky Watershed Corps

Construction on Fort Peck Dam started in 1933, at the time it was the largest earthen dam in the world and it created Fort Peck Lake, the fifth largest man-made lake in the US with more coastline than all of California. A considerable amount of water is held in the reservoir and in the water poor land of northeast Montana where you find water you find an area teeming with wildlife. This inspired the creation of the Charles M. Russel National Wildlife Refuge, an area extending out and surrounding the entirety of the lake into the six counties touching the refuge. Those are Phillips, Valley, McCone, Garfield, Petroleum, and Fergus where the primary driver of the economy is farming and ranching. The long history of producers in the region means there is a long history of working lands conservation. Ranching on grasslands requires a healthy prairie system and likely is a major factor as to why the refuge has such fantastic herds of elk, deer, and antelope as well as the rare grassland bird species that are declining in other parts of the country. Several forces in recent history have meant the decline of ranching and the populations and economies of the region. While the price of land increases and the sale price of cattle decrease, more and more land is necessary to support herds that can keep a ranch sustainable. As folks grow older they often run into issues trying to transition their lands to their families and land ends up being bought up by absentee owners who might not follow local conservation practices which in turn can affect the surrounding communities. Due to the large landscape and history much of the land in the region is held by the federal government, either through the Bureau of Land Management or the US Fish and Wildlife Service, as well as several hundred acres owned by Non-Governmental Organizations. Landowners rely on grazing leases on these federal lands to provide affordable ways to graze their cattle. The unique nature of the region means that there are a number of interesting partners participating in any venture. The focus of one of my projects has been the coordination of the Charles M. Russel Community Working Group; a loose organization ran by the Missouri River Conservation Districts Council that endeavors to boost communication and partnerships in order to support the economic development and social continuation of the region. To that end the CMR CWG has been working on telling the story of the region, a necessary tool to boost the message that people are here, they do good work for the economy and land, and they want to stay and thrive. My specific outcome has been an interactive map that can be utilized in this process to quickly get a snapshot of the region and understand the trends and issues present there. These include economic profiles, population trends, land ownership, and the most important thing to producers: precipitation.

**Quantifying a Parafluvial Soil Response to Beaver Mimicry Restoration**

Briana K Whitehead[1]

[1]Montana State University - Land Resources & Environmental Science Dept

Beaver Mimicry Restoration is a relatively new aquatic ecological restoration practice that has shown to be beneficial to an array of degraded stream functions and sequential services. The practice is designed to rejoin hydrologically disconnected streams back to their respective floodplains via the installation of small-scale, natural material derived, human-made structures that span the stream width. These structures capture sediment, elevate stream stage, create thermal refugia, and help in the reestablishment of riparian and hydrophytic vegetation. The majority of published work on this stream restoration technique as focused on the hydrological or botanical results, while little is known about the response in riparian soils or rather parafluvial soils post Beaver Mimicry Restoration. This work is a first attempt at measuring the effects of Beaver Dam Mimicry on parafluvial soils post Beaver Mimicry Restoration. Three novel approaches were used in conjunction to quantify the effects of Beaver Mimicry within adjacent soils, 1. An array of Indicators of Reduction in Soils (IRIS), 2. An array of soil sensor probes, and 3. On-site plant cameras. These methods were deployed at a treatment and control location during the growing season June - September in 2018 and 2019. Preliminary results show that soils adjacent to Mimicry Structures experience an extended moisture regime, elevated anoxic conditions, a dampened soil temperature range, and support vegetation greenness during the dry months compared to the control location. Although this work is limited in scope, these observations will further our understand of how this restoration practice influences floodplain connectivity, plant reestablishment and subsurface conditions.