PROCEEDINGS

for

Water and Energy

Montana Section American Water Resources Association
2013 Conference

October 3 – 4, 2013
GranTree Inn, Bozeman, 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**
  Russell Levens, President – Montana Department of Natural Resources and Conservation
  Katherine Chase, Vice President – USGS Montana Water Science Center
  Julie Ahern Butler, Treasurer – Montana Bureau of Mines and Geology

- **Montana Water Center** – **Meeting Coordination**
  Duncan Patten, Nancy Hystad

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

Russell Levens

Katherine Chase

Julie Ahern Butler

Duncan Patten

Nancy Hystad

A special thanks to our generous conference sponsors!

WEDNESDAY, OCTOBER 2, 2013

REGISTRATION ***Entrance***

10:00 am – 7:00 pm REGISTRATION - Speakers load presentations between 5:00 PM and 7:00 PM
Pre-conference registration available at http://water.montana.edu/awra/registration/

FIELD TRIP

1:00 pm – 5:00 pm **Montana AWRA 2013 Bozeman Water Supply Field Trip**
Key features of Bozeman's water supply and their changes through the years
Bus leaves GranTree Inn promptly at 1 pm, returns at 5 pm

HYDROPHILE 3-MILE RUN

6:00 pm – 7:00 pm **Hydrophile 3-mile Run/Walk**
Leave from GranTree Inn after the field trip

Dinner – on your own

THURSDAY, OCTOBER 3, 2013

REGISTRATION ***Entrance***

7:30 am REGISTRATION - Speakers load presentations 7:30 am - 8:00 am. Coffee and snacks provided
Preconference registration available at http://water.montana.edu/awra/registration/

OPENING SINGLE SESSION ***Madison-Lewis Room***

8:00 am WELCOME, INTRODUCTIONS & ANNOUNCEMENTS
Welcome & Introductions - Russell Levens (MT AWRA President)

8:15 Duncan Patten – *Montana Water Center Director*

8:20 Joe Kolman – *Legislative Services Division*
Legislative Update

9:00 KEYNOTE SPEAKER
Carol Collier – *AWRA President*
Two Water Organizations: National AWRA – Directions for the Future and DRBC – Planning for the Basin Changing Needs

10:00 *BREAK*

10:15 KEYNOTE SPEAKER
Mike Hightower – *Sandia National Laboratories*
Energy Water Nexus in the Western U.S.: Emerging Trends and Impacts

LOGISTICS, ANNOUNCEMENTS, & LUNCH ***Atrium***

12:00 pm *Break for Lunch in the Atrium - provided to all registered conference attendees*

ORAL PRESENTATIONS

SESSION 1 (Concurrent) *Madison-Lewis Room*
GROUNDWATER

Moderator: Melissa Schaar

1:00 pm

1:20 Tom Michalek. *Hydrogeologic Investigation of the Four Corners Study Area Gallatin County, Montana.*

1:40 Scott Fleener. *Development of a MODFLOW Tool to Automate Delineation of Stream Depletion Zones.*

2:00 Mark Cunnane. *Madison Aquifer Test Well Near Judith Gap, Montana.*

2:20 Andrew Bobst. *Investigation of the Source of Water for Cold Spring - Boulder River Valley, Montana.*

2:40 Luke Carlson. *Modeling Managed Recharge and Base-flow Enhancement in an Unconsolidated Aquifer in the Boulder River Valley, Montana.*

3:00 *BREAK*

SESSION 2 (Concurrent) *Hyalite-Clark Room*
SURFACE WATER

Moderator: Chuck Dalby

1:00 pm Jacob Feistner. *High Mountain Lakes as Indicators of Atmospheric Pollution and Climate Change.*

1:20 Stephanie McGinnis. *Biotic and Abiotic Correlates to Whirling Disease Risk.*

1:40 Karin Mainzhausen. *Flood Hydrology of the Clark Fork River and its Tributaries from Warm Springs to Garrison: A Basis for Remedial Design.*

2:00 Lauren Helland. *Adding Time-Lapse Photography to Monitoring Parameters for a Remote Stream Station.*

2:20

2:40 Paul Kusnierz. *An Instability Index to Describe Sediment Dynamics in Western Montana and Northern Idaho Mountain Streams.*

3:00 *BREAK*

SESSION 3 (Concurrent) *Madison-Lewis Room*
WATER QUALITY - PART 1

Moderator: Tom Michalek

3:15 pm Stephanie Ewing. *Judith Basin Nitrogen Project: Role of Soils in Nitrate Leaching to Groundwater.*

3:35

3:55

SESSION 4 (Concurrent) Hyalite-Clark *Room*
EVAPOTRANSPIRATION

Moderator: Marco Maneta

3:15 pm Chuck Dalby. *Estimating Evapotranspiration Using Remote Sensing and Surface-Energy Balance Methods: Montana Experience.*

3:35 Aiden Johnson. *Remote Sensing of Evapotranspiration in Montana Agricultural Ecosystems: Exploring Landsat 8 Data Products and Testing Approaches to Estimate Plant Groundwater Access From Space.*

3:55

4:15 Adam Sigler. *Use of a Vertical Hydrologic Model to Assess Leaching Nitrate to Groundwater Under Agricultural Soils of the Judith River Watershed.*

4:35 John Mallard. *The Combined Influence of Stream Network Scale Physical and Biogeochemical Processes on In-Stream Nutrient Concentrations.*

4:15 Kevin Chandler. *Methods for Estimating Wetland Evapotranspiration through Groundwater Flow Modeling of Diurnal Groundwater Fluctuations at Gartside Reservoir Fen, Crane Montana.*

4:35 Paul Stoy. *The Climate Record of Montana Over the Past Half-century. Consequences for Water Resources and Opportunities for Teaching Practitioners How to Study the Whole Bowl of Cherries.*

POSTER SESSION & SOCIAL HOUR — *Atrium*

5:00 – 7:00 pm AWRA 2013 POSTER PRESENTATIONS

1. John Anderson. *Using Major Ions, 222Rn, ΔD And Δ18O To Characterize The Role Of Subsurface Flow To The Upper Boulder River, MT.*
2. Anna Bergstrom. *An Assessment of Factors Controlling Spatial and Temporal Patterns of Stream Yield in Forested Mountain Watersheds.*
3. Troy Blandford. *The Montana State Library's Water Information System.*
4. Daniel Blythe. *Using ArcGIS and Modelbuilder for Groundwater Susceptibility Analysis of the Shields River Drainage Basin, Montana.*
5. Patrick A. Byorth. *Restoring Aquatic Resources by Synergizing Regulatory and Non-Regulatory Funding.*
6. Heidi Clark. *Historical Resource Use In The Greater Yellowstone Region, Response and Resilience of Rivers: A Rephotographic Analysis.*
7. Michella Craddock. *Inventory and Assessment of a Portion of Rock Creek in the Upper Big Hole River Drainage Near Wisdom, Montana.*
8. Jeremy Crowley. *Hydrogeologic Framework Database for Madison and Gallatin Counties, Montana.*
9. Larry Dolan. *Estimating the Evapotranspiration Component of Irrigation Water Use in Southwestern Montana.*
10. Jacob Feistner. *High Mountain Lakes as Indicators of Atmospheric Pollution and Climate Change.*
11. Capri Gillam. *Carbon and Nutrient Cycling in a Headwater Stream and Riparian Zone: Tenderfoot Creek Experimental Forest, Montana.*
12. Elizabeth Harris. *Flux Tower Data Analysis in the Judith Basin, Montana: A Measure of Evapotranspiration Over a Winter Wheat Field.*
13. Zach Hoylman. *Landscape Heterogeneity Modulates Forest Sensitivity to Climate.*
14. Gary Icopini. *Arsenic Source Investigation Near Anaconda.*
15. Darrin Kron. *Montana Oil and Natural Gas Activities Ambient Water Monitoring Program.*
16. John LaFave. *Long-Term Stream-Flow Trends In The Bitterroot River Watershed, Montana.*
17. Martin Lorenzo. *Effect of Sedimentation and Sediment Pore Water Chemistry on Water Quality in a Small Beaver Pond.*
18. James Madison. *Hydrogeologic Framework of Cascade and Teton Counties, Montana.*
19. Amber McGivern. *Geologic Constraints on the Geochemistry of Acidic and pH-neutral Pit Lakes in Butte, Montana.*
20. Katie Mitchell. *Groundwater and Lake Interactions at Georgetown Lake, MT.*
21. Mark Peters. *Stream Losses to Carbonate Bedrock Along Dry Fork Belt Creek, Little Belt Mountains, Montana.*

22. Jon Reiten. *Hydrogeology of the East and West Benches of Rock Creek Near Red Lodge, MT.*
23. Michael Shirley. *Estimating Gaining and Losing Reaches of the Boulder River Using Geochemical Modeling*.
24. Nick Silverman. *A Bayesian Approach to Quantifying the Winter Precipitation in the Mountainous Terrain of Western Montana.*
25. Mary Sutherland. *Groundwater Modeling of the Four Corners Study Area, Gallatin County, Montana.*
26. James Swierc. *Helena Area Ground Water Project.*
27. Joanna Thamke. *A Comparison of Groundwater Recharge Estimation Methods in the Williston and Powder River Structural Basins*.
28. Joanna Thamke. *Interaction of Groundwater and Surface Water in the Williston and Powder River Structural Basins*.
29. Andrew Wilcox. *Linkages Between Geomorphology, Geochemistry, and Aquatic Ecology in Mining-Impacted Headwater Streams: Mike Horse Mine Complex, Upper Blackfoot River Basin, Montana.*

BANQUET — *Grand Ballroom*

7:00 pm **Banquet**

8:00 **Special Speakers**
Yasmin Chaudhry and Bronwyn Rolph - MSU Chapter of Engineers Without Borders

8:30 **Water Legend**

8:45 **Photo Contest and Awards**

8:45 **Closing Announcements**

FRIDAY, OCTOBER 4, 2013

7:00 am Speakers load presentations 7:00 am - 8:00 am. Coffee and snacks in Atrium

SESSION 5 (Concurrent) — *Madison-Lewis Room*
MINING

Moderator: Susan Firor

8:15 am Mark Peters. *The Use of Fluorescent Tracers at an Abandoned Mine for Determining Connectivity of Subsurface Workings at the Moulton Group of Mines, Judith Basin, Montana.*

8:35 David Donohue. *Dye Tracer Study, Associated Investigations, and Surprising Results, Landusky Mine Site.*

8:55 Melissa Schaar. *Environmental Isotopes Applications in a Fractured Bedrock Aquifer System, Landusky Mine Site.*

SESSION 6 (Concurrent) — *Hyalite-Clark Room*
WATER RESOURCE PLANNING

Moderator: Chuck Dalby

8:15 am Susan Gilbertz. *Water Resources and Conditions of Stress: Building Local Capacities Via Citizen Councils and Scoping Meetings.*

8:35 Shanna Lewis. *Water Resources and Conditions of Stress: Building Local Capacities Via Discourse Coding.*

8:55 Lucas Ward. *Water Resources and Conditions of Stress: Building Local Capacities Via Q Sort Exercises.*

9:15 George Williams. *An Examination of Sources of Acidic Drainage in the Judith Mountains, Central Montana, USA.*

9:35 Elliot Barnhart. *In-Situ and Enriched Microbial Community Composition and Function Associated With Coal-bed Methane from Powder River Basin Coals.*

9:55 BREAK

9:15 Amy Chadwick. *An Innovative Approach to Watershed Data Management and Restoration Planning in the Yaak Watershed of Northwest Montana.*

9:35 Marco Maneta. *A Comprehensive Hydroeconomic Analysis Framework for Optimal Management of Agricultural Water and Land.*

9:55 *BREAK*

SESSION 7 (Concurrent) ***Madison-Lewis Room***
RESTORATION / REMEDIATION

Moderator: Dave Donohue

10:10 am Peter Skidmore. *Restoration Assessment and Management Plan for Deep Creek, MT.*

10:30 Doug Martin. *Floodplain Restoration Integrated With Dam and Sediment Removal.*

10:50 David Patrick. *Aquatic Resource Conservation Tool: Wetland & Stream Mitigation Banks.*

11:10 Susan Firor. *Trestle Area Assessment, Design & Remedial Action on the Clark Fork River Operable Unit of the Milltown Reservoir / Clark Fork River Superfund Site.*

11:30 Karin Boyd. *Geomorphology of the Clark Fork River From Warm Springs to Garrison: Implications for Remedial Design.*

SESSION 8 (Concurrent) ***Hyalite-Clark Room***
WATER QUALITY - PART 2

Moderator: Adam Sigler

10:10 am Jill Frankforter. *Water-Quality Assessment of the Upper Fort Union Aquifer - Williston Basin.*

10:30 Joanna Thamke. *Brine Contamination from Energy Development in the Williston Structural Basin, Montana.*

10:50 Steve Sando. *Flow-Adjusted Trends in Copper and Arsenic in the Upper Clark Fork Basin, Water Years 1996-2010.*

11:10 David Naftz. *Applications of High Frequency Limnological Data: Real-time Visualization, Water-quality Mapping, and Calibration/verification of Hydrodynamic Models.*

11:30 Adel Haj. *Combining the Precipitation-Runoff Modeling System with the RegCM3 Regional Climate Model to Estimate Potential Effects of Climate Change on Northern Great Plains Streams.*

11:50 Rod Caldwell. *Radionuclides in Groundwater of Jefferson County and Surrounding Areas, Southwestern Montana, 2007 through 2010.*

CLOSING PLENARY ***Madison-Lewis Room***

12:15 pm CLOSING PLENARY - Announcements - Elected Officer, Student Awards

12:30 pm ADJOURN

1:00 pm Ground Water Assessment Program Steering Committee Meeting - Aspen Room

Carol Collier

Delaware River Basin Commission
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Ms. Collier was appointed Executive Director of the Delaware River Basin Commission (DRBC) on August 31, 1998. The DRBC is an interstate/federal commission that provides a unified approach to water resource management without regard to political boundaries. Before joining DRBC Ms. Collier was Executive Director of Pennsylvania's 21st Century Environment Commission and Regional Director of the Pennsylvania Department of Environmental Protection (PADEP) Southeast Region. Prior to PADEP, Ms. Collier served 19 years with BCM Environmental Engineers, Inc., Plymouth Meeting, Pa., beginning as a student intern and ultimately becoming Vice President of Environmental Planning, Science and Risk.

Ms. Collier has a B.A. in Biology from Smith College and a Masters in Regional Planning from the University of Pennsylvania. She is a Professional Planner licensed in the State of New Jersey, a member of the American Institute of Certified Planners (AICP) and a Certified Senior Ecologist. In 1997 she was presented the Touchstone Award from the Society of Women Environmental Professionals and in 1998 the Woman of Distinction Award from the Philadelphia Business Journal. In 2007 the American Water Resources Association (AWRA) presented her with the Mary H. Marsh Medal for exemplary contributions to the protection and wise use of the nation's water resources.

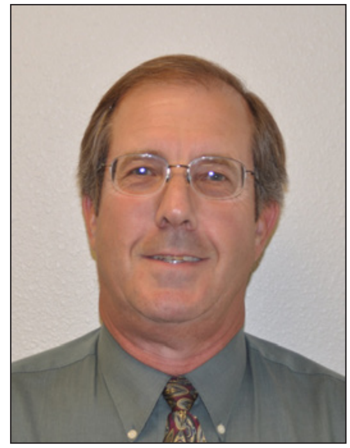
She is a member of her township's environmental protection advisory board, on the Boards of the American Water Resources Association (AWRA) (President - 2013), the U.S. Water Alliance, and recent past chair of the Board for the Pinchot Institute for Conservation. She is also an appointee to the ACWI Water Resources Adaptation to Climate Change Workgroup. She teaches environmental management courses at the University of Pennsylvania and has published on environmental and water-related topics. She has testified before the House of Representatives and the Pennsylvania Legislature. In 2004 she was a member of a nine person U.S./China/Japan team to assist the Peoples Republic of China with river basin management. She has also participated in water management and sustainable forest practice events along the Yangtze River in China and in the rain forests of Ecuador which involved building sustainable communities. She believes proper management of water resources is the key to our economic and environmental future.

Abstract

Two Water Organizations: National AWRA – Directions for the Future and DRBC – Planning for the Basin Changing Needs

This presentation will be in two parts with time for questions and dialogue. The first part will cover current activities of AWRA National and some changes in the works to improve member benefits. The second part will address challenges in the Delaware River Basin, including the potential for natural gas drilling and efforts by the Delaware River Basin Commission (DRBC) to prepare for the likely changes. After a brief description of the interstate/federal compact commission, there will be a discussion of the multiple drivers of change, potential impacts and work in progress. Special emphasis will be placed on natural gas development.

KEYNOTE SPEAKER



Mike Hightower

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Mr. Hightower is a Distinguished Member of the Technical Staff in the Military and Energy Systems Analysis Department at Sandia National Laboratories in Albuquerque, New Mexico. He is a civil and environmental engineer and has over 35 years of experience in research and development projects. His current efforts include research and evaluation of innovative environmental and energy technologies and the security and protection of critical water and energy infrastructures. He also conducts research on the use of distributed and renewable energy technologies and distributed water and waste water systems to enhance sustainable economic development, global public health, and infrastructure resiliency and security. Since 2006 he has supported the US in developing a science and technology program plan for addressing energy and water interdependencies, most recently working with the National Science Foundation to conduct a US national workshop on energy and water research priorities.

Mike holds Bachelor's and Master's degrees in civil engineering from New Mexico State University. Mike has published over 100 technical papers and reports including articles in NATURE, three Reports to Congress, and authored chapters in two books, one on advanced desalination and one on energy and water challenges.

Abstract

Energy Water Nexus in the Western U.S. : Emerging Trends and Impacts

Water and energy are interdependent – water is used extensively in energy development as cooling water in thermoelectric power generation; in oil and alternative transportation fuels refining, and in biofuels production. At the same time, water and waste water pumping, treatment, and distribution is one of the largest energy use sectors in many developed countries. At a time when fresh water availability is becoming limited in many regions due to changing precipitation patterns, increased ecological and environmental demands for water, and issues over sustainable surface and groundwater withdrawal and use, water consumption demands by the energy sector could expand significantly in the next two decades. The emerging water needs for the energy sector and the emerging energy needs for the water sector could significantly change how these two critical natural resources are developed and utilized.

This presentation will provide an overview of potential water resource issues in the western United States and the need and opportunities for using non-traditional water resources, such as domestic and industrial waste water, brackish water, and oil and gas produced water, to meet the increasing shortfall between the growth in water demands and the reduction in fresh surface water and ground water supply availability. The presentation will also highlight emerging water use and water demand trends for energy development in the western U.S. and how they could impact water and energy development globally.

SPECIAL SPEAKERS

Joe Kolman

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Joe Kolman is director of the nonpartisan Environmental Policy Office of Legislative Services, where he has worked for 9 years. Over the past five legislative sessions, he has staffed committees on natural resources, fish and game, agriculture, and local government. During the interim, he is staff for the Environmental Quality Council and the Water Policy Interim Committee. Prior to working for the Legislature, he wrote for newspapers in Montana, Nebraska, Iowa, and Idaho. A native of Harlowton, he grew up wading across the Musselshell River hoping not to drown in Deadman's Basin.

BANQUET SPEAKER

Yasmin Chaudhry and Bronwyn Rolph

Engineers Without Borders – MSU
Chapter website: http://www.ewb-msu.org/
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EWB-MSU collaborates with the Khwisero Community in Western Province, Kenya. They work with community boards to implement clean water and sanitation facilities for the primary schools of the district.

Hydrogeologic Investigation Of The Four Corners Study Area Gallatin County, Montana

Tom Michalek, Hydrogeologist, Montana Bureau of Mines and Geology, 1300 West Park St., Butte, MT, 59701, USA, (406)496-4405, tmichalek@mtech.edu. Additional authors: Mary Sutherland, Montana Bureau of Mines and Geology.

The purpose of the Four Corners Groundwater Investigation was to assess the possible hydrologic effects of land use conversion from irrigated agriculture to high-density residential. Subdivisions, rural residential and commercial development are transforming agricultural land in the area of this busy community four miles west of Bozeman. Commercial water distribution and wastewater treatment systems are replacing irrigated land and traditional well and septic systems. Water for domestic and commercial use in the Four Corners area is typically obtained from the local alluvial aquifer. This aquifer is composed of Quaternary unconsolidated sand and gravel floodplain deposits and underlying finer-grained Tertiary sediments. High yields are common for wells completed in the alluvial aquifer. Irrigation water is almost exclusively diverted from the Gallatin River and local tributaries. Both applied irrigation water and canal leakage are known to recharge groundwater and affect subsequent late-season surface-water return flows. If irrigation is significantly curtailed groundwater quantities and water levels could be affected. To further support management of water resources in this area it is important to identify groundwater flow directions (including both horizontal and vertical gradients) and the hydrologic relationship between the aquifer and the river. Specifically, the main objectives of the Four Corners investigation were to: • Determine the extent of alteration to the groundwater system in the Four Corners Area over the last 60 years. • Correlate groundwater flow changes to land use conversion. • Document the effects of irrigation and canal leakage on groundwater recharge. • Develop a numeric model to evaluate likely effects of future changes and development. Monitoring wells and stream gauging sites were installed, aquifer tests conducted and water samples analyzed to support the objectives. This study concludes that, although groundwater elevations have not significantly changed, the groundwater flow system is highly dynamic and small changes in hydraulic gradients caused by individual stresses likely have a greater impact to groundwater flow than can be discerned from static water levels. If future changes reduce groundwater flow entering the study area, or if development continues to increase demand on groundwater while decreasing agricultural recharge, flow through the aquifer will continue to decrease.

Development Of A MODFLOW Tool To Automate Delineation Of Stream Depletion Zones

Scott Fleener, Student, Montana Bureau of Mines and Geology, GWIP, 1300 W. Park, Butte, MT, 59701, USA, (509) 592-8842, SCFleener@mtech.edu. Additional authors: Andrew Bobst, Montana Bureau of Mines and Geology.

Stream depletion occurs when a well is pumped near a stream due to the well capturing water from the stream, or intercepting groundwater flow to the stream (Jenkins, 1968). A stream depletion zone (SDZ) is a mappable three dimensional zone that can be delineated based on aquifer properties, pumping duration, pumping rate, and a depletion threshold. For example, in Montana a SDZ is defined by law as an area where hydrogeologic modeling concludes that as a result of a ground water withdrawal, the surface water would be depleted by a rate equal to at least 30% of the ground water withdrawn within 30 days after the first day a well or developed spring is pumped at a rate of 35 gallons a minute. Similar laws have been adopted in several western states to recognize the interconnection between surface water and groundwater, and to facilitate their integrated management. Assuming that a properly developed and calibrated numerical model is available for an area, the stream depletion that would result from a hypothetical well at any particular location within the model can be estimated. However, manually testing the effects of wells at all possible locations would be extremely inefficient and time consuming. To address this problem, a tool has been developed for MODFLOW which automates the procedure of testing stream depletion throughout a model grid and provides the needed results in a format which can be used to easily map SDZs.

Madison Aquifer Test Well Near Judith Gap, Montana

Mark Cunnane, Principal, Western Groundwater Services, LLC, 6595 Bear Claw Lane, Bozeman, MT, 59715-9109, USA, (406) 585-5947, markc@westerngroundwaterservices.com.

The Central Montana Regional Water Authority includes several communities between Hobson and Melstone that have joined together to construct a regional water system. The water system is planned to develop a groundwater source from the Madison aquifer, near to Judith Gap. Starting in 2008, planning work was completed to review the hydrogeology conditions at five prospective wellfields. Information was compiled to compare drilling depth, static water level, and costs. A preferred wellfield was selected near Judith Gap. The first test well was drilled to 2250 feet in 2012, finding a productive aquifer of good quality. There were no other existing successful Madison wells in Judith Basin prior to the test well. The drilling approach included provisions to maintain well control in the event of large artesian flows of water, oil and/or gas. The borehole penetrated several formations ranging from Cretaceous to Mississippian age, ultimately terminating in the Charles or Mission Canyon Formation of the Madison Group. The producing zone spans only three feet, consisting of fractured limestone. Hydraulic testing of the well included step rate and constant rate pumping tests. Hydraulic modeling was completed to estimate potential well yield at the site. A revised wellfield layout and cost estimate was also completed.

Investigation Of The Source Of Water For Cold Spring – Boulder River Valley, Montana

Andrew Bobst, Hydrogeologist, Montana Bureau of Mines and Geology, GWIP, 1300 West Park St., Butte, MT, 59701, USA, 406-496-4409, abobst@mtech.edu.

Cold Spring is a major spring which occurs within the floodplain of the Boulder River Valley. The average flow from this spring is approximately 31 cubic feet per second (cfs), and during low flow periods it supplies more water to the lower Boulder River than is supplied by the main stem. The reach below the spring is important fish habitat. The Boulder River is perennial below Cold Spring, while above it the Boulder River often runs dry in the late summer. The source of the spring was unclear but understanding the source and flow path is critical to management of the resource. Water quality samples were obtained from the river, alluvium, and upland Tertiary sediments to assist in delineation of Cold Spring's source. Samples were analyzed for field parameters, major ions, trace elements, tritium (3H), radon (222Rn), hydrogen isotopes (dD), oxygen isotopes (d18O), stable carbon isotopes in dissolved inorganic carbon (d13C of DIC), and strontium isotopes (87Sr/86Sr). Results of these analyses indicated that the spring water is chemically similar to the Boulder River for major ions, trace elements, and field parameters. Tritium values are similar to surface waters, consistent with relatively young (post bomb blast) water. Radon values are also similar to surface waters, indicating that the spring water either was in the aquifer for a very short period of time (days), or that it was flowing through a low radon aquifer. Stream flow measurements indicate that it is unlikely that this volume of water left the river and arrived at the spring in a few days, thus flow through a low radon aquifer is indicated. In order to obtain the observed spring water chemistry, the flow path from the low radon aquifer to the surface must have minimal interaction with the alluvial groundwater and sediments. From these analyses it is clear that the spring is not getting its water from the river, from the alluvium, or from the Tertiary sediments. Given the current data set, it seems likely that the source is the faulted and deformed bedrock of Doherty Mountain (limestone and volcanics). Conduits of flow may have developed within the brecciated zones adjacent to faults, which would explain the localized nature of the discharge.

Modeling Managed Recharge And Base-flow Enhancement In An Unconsolidated Aquifer In The Boulder River Valley, Montana

Luke Carlson, Engineering Intern, Morrison Maierle Inc., Natural Resources, 1 Engineering Place, Helena, MT, 59602, USA, 4064953438, lcarlson@m-m.net. Additional authors: Andrew Bobst, Montana Bureau of Mines and Geology; Julie Butler, Montana Bureau of Mines and Geology.

Increasing water consumption has become an issue across much of the western United States. As the demands on water resources increase, legislative and regulatory bodies must work hard to balance available water with varied and sometimes conflicting demands. Managed recharge is one approach that may be able to help balance supply with demand by adding water to aquifers when there are abundant surface supplies, so that it can later be extracted or allowed to flow back to streams during dry periods. Managed recharge as a tool to enhance surface water supplies in the late summer was evaluated in the Boulder River Valley at a 17 square mile study area approximately 9.5 miles south of Boulder, Montana. The Boulder River loses water to the aquifer throughout most of the study area; thus the objective for managed recharge is to reduce the stream loss. This loss reduction would be achieved by reducing the gradient between the river and groundwater, and by reducing the length of the losing reaches. Irrigation canals provide a pre-existing proxy for infiltration basins. Predictive groundwater modeling simulations indicate that if recharge from irrigation canals ceased (termination of use or lining) the groundwater table would decline by 3-12 feet and increase leakage from the Boulder River. Effects of an infiltration basin located downgradient of an existing irrigation canal using excess water from mid-March through early May would reduce leakage from the Boulder River by increasing groundwater head, with the greatest reductions in July, August, and September. As such, an infiltration basin at this location would meet the objective of enhancing flow. As modeled, the amount of additional surface water flow would be insufficient for enhancing irrigation water availability; however this approach may be economic for offsetting depletion caused by other groundwater developments. While the study area has the physical properties which indicate that a managed recharge project would be feasible, legal and regulatory issues would need to be addressed. A managed recharge project would be dependent on securing appropriate water rights. An additional concern at the study area is that arsenic levels in the Boulder River are 1-10 times higher than the background level in groundwater.

SESSION 2 SURFACE WATER

High Mountain Lakes As Indicators Of Atmospheric Pollution And Climate Change

Jacob Feistner, Student, Salish Kootenai College, Hydrology, P.O.Box 311, 205 6th Ave. East, Polson, MT, 59860, USA, 406-883-3869, jacobfeistner@student.skc.edu. Additional authors: Shandin Pete, Salish Kootenai College.

Lakes in mountainous areas are of special interest in environmental studies because of their sensitivity to inputs of atmospheric pollution and climate change. Globally, high mountain lakes tend to be detached from the local sources of pollution such as logging, mining, agriculture, and land development (Rabe 2006). Mountain lakes can therefore be early indicators of more widespread environmental changes (Skjelkvale 2012). There is growing concern that these high mountain lakes are understudied (Campbell 1995 in Mast 2010) and therefore the wealth of knowledge that can be gleaned from studying them is lost. The need to study and gather information on conditions in our Nation's lakes has never been greater (E.P.A. 2002). Studying these lakes is important since documenting current trends in high mountain lake water quality can assist in assessing the overall health of the environment. Future generations will be able to accurately compare and contrast environmental changes, and present generations can begin to better understand trends in their constantly changing world if high mountain lakes are studied and monitored. The objectives of this study were to determine baseline water quality parameters for high mountain lakes in the Mission Mountain Tribal Wilderness (MMTW) of northwestern Montana, specifically the chain of Mud Lakes, Courville Lake, and Lucifer Lake. Chemical analyses were conducted in the field and a full anion-cation balance was conducted on field samples by the University of Montana Biogeochemistry Laboratory. Lake mercury levels were obtained from fish samples analyzed by the Salish Kootenai College Environmental Chemistry Laboratory. Data were evaluated to determine if geographic location affected the lakes chemical composition or health. Another objective was to determine if warming air temperatures and changing snowpack is having an affect on high mountain lake chemistry within the MMTW. Historical Snotel data were used to find trends in annual weather patterns, and compared with chemical analyses from high mountain lakes. These data were used to model trends and implications of the effects that climate change and atmospheric pollution are having on high mountain lakes of the MMTW.

Biotic And Abiotic Correlates To Whirling Disease Risk

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Myxobolus cerebralis, the causative agent of whirling disease (WD), appears to be a major contributor to the reduction in rainbow trout populations in numerous watersheds in the Intermountain West. Much progress has been made examining the characteristics of the fish host, the worm host, and the environment that correlate with spatial and temporal variation in infection risk. However, much variation in disease risk remains unexplained. For example, in Montana, certain tributaries have consistently tested negative for the parasite even though they are proximate to streams where populations have declined, or WD severity has remained low for several years after introduction of the parasite. For whirling disease, anthropogenic alteration of stream parameters may increase disease risk by creating favorable habitat for the worm host, Tubifex tubifex, and therefore, favorable habitat for M. cerebralis. Within eight Montana watersheds, sixteen subbasins (8 with high WD risk and 8 with low WD risk) were selected to assess the relationship between WD risk and lineage composition of T. tubifex, physicochemical features, and landscape structure in high and low risk subbasins. Subbasins (i.e., the entire area draining into one sentinel cage location) within watersheds were selected such that the collections were independent of each other and paired subbasins were of similar size. Whirling disease risk was measured as the infection prevalence and disease severity in sentinel caged trout. Cages associated with high risk subbasins typically were severely infected for several years, whereas sentinel cages in low risk subbasins were either never infected or only lightly infected in a small percentage of the times the sentinel cages were in place. Biotic features that we examined included oligochaete assemblage structure, abundance, and genetic structure and infection prevalence of T. tubifex populations. Lineage III (the susceptible lineage) was more prevalent than lineage I (the less susceptible lineage) in high WD risk subbasins than in low WD risk subbasins. Physicochemical features assessed included width, velocity, depth, conductivity, pH, dissolved oxygen, flow, and substrate composition. High WD risk subbasins had deeper channels and a higher proportion of fine sediments than low WD risk subbasins. Land use and land cover data identified as forest, agriculture, disturbance, mines, and residential area were quantified at two spatial scales, the subbasin and riparian zone. Low WD risk subbasins had a higher percentage of forest cover than high WD risk subbasins. For all statistical analyses, paired t-tests were used to determine whether factors differed between high and low risk subbasins. Managing the parasite by eliminating one part of the life cycle is not realistic in natural systems but efforts to limit the effects of land use practices that create favorable habitat for T. tubifex, and therefore the parasite, could prove useful. Reducing erosion, the input of organic material, and mitigation of other contributors to stream degradation may reduce habitat conditions that promote high densities of T. tubifex and lower the incidence and severity of whirling disease.

Flood Hydrology Of The Clark Fork River And Its Tributaries From Warm Springs To Garrison: A Basis For Remedial Design

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Flood Hydrology Of The Clark Fork River And Its Tributaries From Warm Springs To Garrison: A Basis For Remedial Design. W. H. Bucher, P.E., K. Mainzhausen, P.E, and K. F. Boyd, P.G. Reach A of the Clark Fork River Operable Unit (CFROU) of the Milltown Reservoir/Clark Fork River Superfund site extends 45.5 river miles from Warm Springs to Garrison, MT. This reach is the focus of remedial activities for the restoration of the river and its floodplain where historic upstream mining has resulted in the deposition of metals-laden tailings. To develop remedial designs for this reach, a quantitative, defensible understanding of flood hydrology of the main stem and its tributaries is essential. Using the USGS gages located along the mainstem, a peak flow analysis for floods up to the 25-year recurrence level is feasible. However, less frequent events (e.g., the 50- year and 100-year floods) are not predicted adequately by these relatively short-record gages, and existing regression equations in this area also are problematic. Therefore, less frequent floods are predicted by developing correlations with downstream gages and other gages in the upper Clark Fork River basin that have longer periods of record.

Effects of peak flow attenuation due to the presence of Warm Springs upstream of the reach are noted. Flood hydrology of tributaries to Reach A is constrained by the lack of gages with long periods of record. A further challenge for peak flow analysis is that the only operating tributary gages in Reach A exhibit peak flow behavior atypical for streams in western Montana. Existing regression equations are also problematic, but a method was developed that used applicable gage records to develop scaling factors to adjust flows predicted by regression equations. The 2-, 5-, and 10-year recurrence floods for 12 tributaries to Reach A were predicted using this technique. Less frequent events were not estimated due to the lack of any long period of record data on small streams in the area. An interesting anomaly in this reach is that the tributary with the largest basin area, Lost Creek, consistently has the lowest peak flows of any of the tributaries. Flow-duration curves were developed for the USGS gage at Deer Lodge to quantify the expected frequency distribution of periods of high flow. Two large floods of record (1981 and 2011) were also analyzed for flow duration to provide an understanding of the potential destructiveness of large floods in this system. The flood of 2011, with a peak flow at approximately the 10-year recurrence level, had 60 days of almost continuous flow above the 2-year recurrence event. Where gage records for mainstem and contributing tributary streams are both spatially and temporally limited, a fully integrated approach of gage correlation, record extension, and defensible regional regression output adjustments is necessary to provide adequate hydrologic parameters for remedial design. Such an analysis also provides insight into hydrologic characteristics of individual subwatersheds.

Adding Time-Lapse Photography To Monitoring Parameters For A Remote Stream Station

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This presentation will describe a case study of using time-lapse photography for monitoring in a remote mountain stream. The evolution of monitoring equipment has provided an ever-increasing arsenal of instruments for monitoring surface water. Time-lapse photography, in conjunction with stage, water quality, and weather data, can be used to better document and visualize stream dynamics. A small stream was instrumented prior to spring snowmelt and monitored through spring and summer seasons. Presentation of monitoring data normally involves tables and charts that illustrate the data collected by a remote monitoring program. The addition of time-lapse photography adds another dimension to monitoring that, due to its graphical nature, is more memorable and impactful in presentations than are tables and graphs. A field season of monitoring data, supplemented by time-lapse photographs, demonstrates how the visual record aids in interpretation of both natural changes, such as stream stage, and equipment changes, such as movement of instruments.

An Instability Index To Describe Sediment Dynamics In Western Montana And Northern Idaho Mountain Streams

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Water quality professionals seeking to determine the health of aquatic ecosystems benefit from physical metrics that are easy to measure, can be used to differentiate between streams in reference and managed watersheds, and can be linked to aquatic life effects. A search of the peer-reviewed literature yielded an instability index (ISI) that has been used in Canada and Finland to link sediment dynamics to the status of aquatic life. This index describes the instability of a stream by relating the tractive force of a stream at bankfull discharge to the median substrate size. Streams with small substrate relative to the tractive force have a larger ISI value and are thus more unstable. Although ISI has potential for use as an indicator of excessive bedload movement, it has been used relatively infrequently. I used physical and macroinvertebrate data collected by the PACFISH/INFISH Biological Opinion program from western Montana and northern Idaho streams to determine if ISI can be used to differentiate between managed and reference sites and if ISI correlates with macroinvertebrate indices. Preliminary analysis indicates that there are significant differences in ISI between managed and reference sites and that ISI correlates with some macroinvertebrate indices. These results vary by ecoregion and Rosgen stream type. In this presentation I will describe how analysis was performed, present final results, and discuss how ISI can be used as an indicator of stream health.

Judith Basin Nitrogen Project: Role Of Soils In Nitrate Leaching To Groundwater

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Increasing levels of nitrate have been observed in both groundwater and surface water in the Judith River Watershed (JRW) of central Montana over the past two decades. A potential driver of elevated nitrate levels is leaching of fertilizer and mineralized organic nitrogen (N) through soils with generally less than 60 cm of fines over gravel contacts on fluvial and alluvial landforms. Here we present textural sequences coupled with nitrate and water inventories to 120 cm depth in 65 cultivated soil profiles on three key landforms in the JRW during late summer 2012 and evaluate variation in nitrate and water inventories as a function of physical soil properties and land management practices. Nitrate distribution with depth and overall pool size following chemical fallow were closely tied to depth to gravel, suggesting greater nitrate leaching potential in soils with shallower gravel contacts. Near surface nitrate was dramatically reduced in soil profiles where peas (a legume requiring negligible fertilization) had been planted in place of fallow, suggesting that this management practice can reduce nitrate leaching. In spring and summer 2013, we sampled to 30 cm in paired cultivated and uncultivated sites co-located with the 2012 locations. Our results provide insight about seasonal patterns in soil nitrate inventories as a function of fertilization, plant growth in cultivated and uncultivated settings, and mineralization of soil organic matter.

Use Of A Vertical Hydrologic Model To Assess Leaching Of Nitrate To Groundwater Under Agricultural Soils Of The Judith River Watershed

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The movement of water through soils and unsaturated zones is a fundamental driver of groundwater biogeochemistry. In agricultural systems, precipitation regimes, cropping systems and soil physiochemical processes interact to determine the influence of nitrate leaching on underlying groundwater quality. In the Judith River Watershed of central Montana, rising groundwater nitrate concentrations in shallow unconfined gravel aquifers may be associated with dryland wheat production and fallowing practices on thin and fine-textured soil horizons overlying the gravel. To better understand the transport of nitrate from soils to groundwater, we used a simple one-dimensional modeling approach to simulate the downward movement of water and nitrate through these soils and unsaturated sediments. We use multiple approaches to quantify evapotranspiration and address highly variable precipitation and thickness of fine textured soil horizons across the watershed. The model accounts for inputs of nitrate from mineralization of soil organic matter and application of fertilizer, as well as losses of nitrate to volatilization and plant growth. We start with a box model approach based on known soil textures and associated water holding capacities to characterize soil water balance on a daily time step, and find that simulated deep percolation is within the range of reasonable estimates of recharge. The model will be calibrated with moisture sensor data, validated with lysimeter sample results and ultimately coupled with landform-scale water and nitrogen mass balance models to inform cropping system and groundwater management strategies.

The Combined Influence Of Stream Network Scale Physical And Biogeochemical Processes On In-stream Nutrient Concentrations

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Stream networks lie in a crucial landscape position between terrestrial ecosystems and downstream water bodies. As such, whether inferring terrestrial watershed processes from watershed outlet signals or predicting the effect of observed terrestrial processes on stream nutrient signals, it is requisite to understand how stream networks can modulate terrestrial nutrient inputs. Broadly, stream networks can modify terrestrial signals through biogeochemical processes or through hydrologic processes. To date integrated understanding and modeling of hydrologic and biogeochemical influences on nutrient concentrations at the stream network scale have been limited. However, watershed scale groundwater – surface water exchange (hydrologic turnover), concentration-variable biological uptake, and the interaction between the two can all strongly influence stream water nutrient concentrations. Stream water and associated nutrients are lost to and replaced from groundwater with distinct nutrient concentrations while in-stream nutrients can also be retained by biological processes at rates that vary with concentration. We developed an empirically based network scale model to simulate these three influences on nutrient concentration across stream networks: hydrologic turnover, concentration-dependent nutrient uptake and their interaction. Exchange and uptake parameters were measured using conservative and nutrient tracer addition experiments in the Bull Trout Watershed of the Sawtooth mountains in central Idaho. We found that the interaction of hydrologic turnover and concentration-dependent uptake combined to modify and subsequently stabilize in-stream concentrations, but at specific concentrations dependent on the magnitude of hydrologic turnover, groundwater nutrient concentration, and the shape of nutrient uptake kinetic curves. We additionally found that by varying these physical and biological parameters within measured ranges we were able to generate a range of stream network concentration distributions representing the continuum of shifting magnitudes of physical and biological influences on in-stream concentrations. These findings elucidate the important and variable influence of physical and biological processes in both modifying and stabilizing nutrient concentrations and emphasize the crucial role stream networks play as intermediaries and modifying filters between terrestrial input signals and measured signals in downstream receiving water bodies. We contend that in the absence of an integrated understanding of stream network processes, inferences about the effects of terrestrial processes on downstream water bodies or vice versa may be intractable.

SESSION 4 EVAPOTRANSPIRATION

Estimating Evapotranspiration Using Remote Sensing And Surface-Energy Balance Methods:Montana Experience Montana Experience

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Evapotranspiration (ET), a key component of the water balance, is very difficult to accurately measure at a watershed scale. Over the past 10 years, significant progress has been made in the application of surface-energy balance methods that allow improved estimation of ET, at various spatial (typically 30 m to 1 km) and temporal (daily, weekly, monthly) resolution. The METRIC (Measured Evapotranspiration at High Resolution with Internalized Calibration) method, developed by the University of Idaho, has been recently applied in the Flathead and Smith River Basins of Montana, in support of hydrologic modeling and water management. This

report gives an overview of three remote sensing-based, surface-energy balance methods currently available (METRIC, SEBAL, SSEB) for estimating ET; Montana applications; and current efforts underway.

Remote Sensing Of Evapotranspiration In Montana Agricultural Ecosystems: Exploring Landsat 8 Data Products And Testing Approaches To Estimate Plant Groundwater Access From Space

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Water quality and availability are of increasing concern as global demand for water resources and uncertainty in precipitation increase. The Judith Basin in central MT provides a unique opportunity to remotely sense water resources, as thin soils and a near-surface groundwater table have resulted in high levels of nitrate pollution but also the opportunity to study when and where vegetation taps groundwater. We generated a water table height map from well data collected in-situ and a digital elevation model (DEM) using kriging. We combined land surface temperature (LST) data from the newly launched Landsat 8 with a Normalized Difference Vegetation Index (NDVI) layer developed using published algorithms to locate areas of higher than expected evapotranspiration (ET), indicating the potential for water table access by plants. ET estimates derived from Landsat 8 products and surface meteorology were compared to eddy covariance observations of evapotranspiration in a winter wheat field near Moore, MT. Initial comparisons demonstrate an improvement over ET products derived from Landsat 7 on account of the new thermal band available on Landsat 8. Results demonstrate that new remote sensing data streams can provide important insights into Montana water resources and water management.

Methods For Estimating Wetland Evapotranspiration Through Groundwater Flow Modeling Of Diurnal Groundwater Fluctuations At Gartside Reservoir Fen, Crane Montana

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This project's goal was to construct a numerical groundwater flow model capable of simulating diurnal water-level fluctuations resulting from evapotranspiration (ET) at Gartside Reservoir fen near Crane Montana. The fen is a flourishing wetland ecosystem of approximately 30 acres with diverse vegetation and surface conditions that are very different from the dry grasslands of the surrounding hills. Development of a fen requires a nearly continuous supply of mineral rich ground-water upwelling to the surface and such creates an ideal site for prolonged ET. Field work at Gartside during the summers of 2011-2012 provided the background data necessary for model development. Sixteen shallow wells were installed throughout the wetland in 2011, and fitted with data loggers for hourly water-level measurements. The stratigraphy of the shallow subsurface was carefully recorded during well installation and sediment samples were collected for sieve analyses. Several short-term aquifer tests were conducted to constrain the aquifer property parameters used in the models. In 2012 two additional wells were installed near the center of the study area, and were shown to have nearly identical diurnal water-level fluctuations. In early September of 2012 these two wells were the site of the tarp test. Reflective poly tarps covering an area of 341 ft2 were installed around one of the wells to restrict ET for a 24 hour period, and the diurnal water-level fluctuations in the tarp covered well were compared to the control well. The tarps were shown to significantly reduce the diurnal water-level fluctuations in the test well. Two MODFLOW based numerical flow models were developed to simulate the diurnal water-level fluctuations observed in many of the Gartside wells. A six layer model was initially developed in attempt to simulate flow through the complex stratigraphy of the fen which consists of silty sands and gravels, clay layers interbedded with peat, and highly conductive sandy gravels. The steady state version of this model calibrated closely to heads observed at the shallow wells, but failed to replicate the diurnal water-level fluctuations as a transient model. A more simplistic two layer model was developed with the goal of matching the diurnal fluctuations measured at two wells in the center of the study area. The second model generated diurnal head fluctuations that closely matched the observed diurnal water-level fluctuations from Gartside wells in late September. Four day transient simulations were used to model the water-level fluctuations of the tarp test. Annual ET rates were calculated from the model simulations and compared to other estimates of wetland ET in Eastern Montana.

The Climate Record Of Montana Over The Past Half-century. Consequences For Water Resources And Opportunities For Teaching Practitioners How To Study The Whole Bowl Of Cherries

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Water science students and professionals now live in the era of 'Big Data' in which open access databases coupled with modern data analysis techniques simplify the study of water resources in a changing climate. Here, I discuss multiple meteorological forcing datasets that have been created by combining observational records with reanalysis products, with a focus on the updated Sheffield et al. (2006) daily 0.5° data product that extends from 1948 until 2008. The Sheffield et al. climate database is highlighted because it corrects known biases in previous precipitation and meteorological reanalysis products. Pixels corresponding to Montana have been extracted from the database and variables of interest to water science are presented. When averaging all data for the state, air temperature significantly increased ($P<0.0001$) and is characterized by the well-known jump during the 1980s. Incident shortwave radiation decreased through the first half of the study period and then increased, consistent with the well-known global dimming and global brightening phenomena observed worldwide. Wind speed has increased across the state ($P<0.0001$), making Montana one of the unique areas of the globe that has, on the whole, not experienced the near-ubiquitous 'global stilling' phenomenon of a decrease in wind speeds across most global stations. No significant change in precipitation over time was found; rather, the precipitation record highlights the well-known multi-year drought periods that characterize the climate of Montana. Combined, an increase in the drivers of evapotranspiration, and thereby potential evapotranspiration, coupled with no significant trend in precipitation results in a situation where the aridity index has increased over the past six decades across the state as a whole. Data stations and datasets with open-access climate data are briefly discussed.

SESSION 5 MINING

The Use Of Fluorescent Tracers At An Abandoned Mine For Determining Connectivity Of Subsurface Workings At The Moulton Group Of Mines, Judith Basin County, Montana

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This presentation will describe investigations of a series of adjacent abandoned mines in Judith Basin County that identified numerous discharging adits. The adit discharge water quality is very poor and represents nearly all of the flow in Galena Creek. As part of an evaluation to improve water quality, an investigation was conducted to locate the sources of water discharging from the adits. Three different fluorescent tracers were deployed, with one tracer deployed in Galena Creek and the other two tracers deployed separately in two mine shafts. Several adit discharges and downstream locations in Galena Creek were monitored using activated charcoal samplers and surface water samples. Analytical results for the tracers identified a direct hydraulic connection between sources and discharges. These results were combined with surface mapping and limited historic mine workings maps and cross-sections to construct a three-dimensional representation of underground workings and flow paths.

Dye Tracer Study, Associated Investigations, and Surprising Results Landusky Mine Site 2013

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The State of Montana and Bureau of Land Management sponsored intensive hydrogeological, geophysical, and engineering investigations of the Landusky mine site and Swift Gulch in the Little Rockies Mountains of

north-central Montana. The investigations were targeted at understanding the sources and pathways associated with the worsening quality of groundwater, beneath the former pit and potential discharge to Swift Gulch. During the 2012-2013 field seasons, two dye tracer investigations were initiated at the Landusky Mine site at the north end of the Surprise Pit. A forced gradient tracer test was completed during the seven-day aquifer test in May 2012. The seven day aquifer test was completed to estimate the hydraulic properties of the fractured bedrock and to provide information to help assess the potential for in-situ source control technology for ARD movement to Swift Gulch. During the aquifer test, several monitoring wells and one spring discharge location were monitored in an attempt to establish the degree of direct connection from monitoring well ZL-405 to Swift Gulch via the Niseka Shear. Rhodamine WT dye was injected into down gradient well ZL-404 prior to the start of the aquifer test. Dye recovery was monitored in the discharge of pumping well ZL-405 and spring discharge BKSP-2E using charcoal packets and water grab samples. Rhodamine WT dye was found in samples collected within 24 hours after pumping began, but were not reported in samples collected after that period through completion of the aquifer test. Following the pumping test, a long-term natural gradient tracer test was initiated by injecting eosine dye into monitoring well ZL-405 and collecting water samples from down-gradient monitoring wells ZL-404 and ZL-403, spring locations BKSP-2E and BKSP-2, and Swift Gulch using charcoal packets and water grab samples. As of June 2013, approximately 12 months after initial injection of eosine dye, dye breakthrough has not been reported at any sample location; sampling continues to occur on a regular basis. A better recognition of the complexities and speed of groundwater movement through the Niseka shear and adjacent Surprise shear, and implications for identifying and predicting hydraulic connections between the ARD groundwater, shear zone, and spring discharge points has resulted from these dye tracer studies.

Environmental Isotopes Applications In A Fractured Bedrock Aquifer System, Landusky Mine Site

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Groundwater flow in and around the Landusky Pit is dominated by a complex shear zone system. Understanding fracture flow at the north end of the Landusky Pit is important in order to evaluate pathways for discharge of groundwater and acid rock drainage (ARD) constituents to Swift Gulch. During the summer of 2013, water samples were collected from monitoring wells and Swift Gulch surface water and analyzed for basic chemistry and environmental isotope concentrations. The combined use of basic chemistry with environmental isotopes allows for a more comprehensive view on the nature of water moving through the aquifer system to Swift Gulch. The isotopic compositions of various environmental isotopes in ground water were used to identify sources of water, trace directions of groundwater flow, measure the time that has elapsed since recharge (ground-water age), and interpret environmental conditions that occurred during recharge. Oxygen and hydrogen isotopes are stable isotopes used to effectively fingerprint sources of water, as each source may have a distinct isotopic value. Strontium isotopes used in this study are radiogenic in origin, produced by radioactive decay but stable in nature, and a major component of groundwater. Strontium isotopes are mainly controlled by the geology and can provide a direct indication of flow-path history and groundwater origin. Uranium isotopes are naturally occurring radioisotopes used to differentiate groundwater bodies and identify locations of interconnectivity, place constraints on groundwater flow paths and rates, assess groundwater mixing and volumes, identify instances of pore-water mixing, and assess water-rock chemical interactions. Environmental isotopes allow for a more comprehensive view of the nature of water moving through the aquifer system. A greater understanding of the fracture flow system and ARD pathway at the north end of Landusky Mine has been gained from this application of stable isotope analysis.

An Examination Of Sources Of Acidic Drainage In The Judith Mountains, Central Montana, USA

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Pre-mining water quality and the magnitude of mining impacts on water quality are questions of interest for catchments disturbed by hard rock mining. The purpose of this research is to investigate natural and mining influenced acidic water in three drainage basins located in the Judith Mountains, central Montana. The Judith Mountains consist of a large number of alkaline plutons that have intruded into Paleozoic and Mesozoic sedimentary rock. Three streams of interest form a radial drainage pattern around a central stock of pyrite-rich porphyry termed Red Mountain. Each of these streams is highly acidic in its headwaters (pH 2 to 3.5), and transitions to neutral pH with distance downstream over several km. Although the Judith Mountains have a history of precious metal mining, no present day mining is taking place, and the watersheds of interest have not been heavily impacted by mining. This ongoing study over past two year period has collected data in order to determine seasonal, spatial and temporal water quality conditions and solute loads. Funded by the U.S. Bureau of Land Management, this study seeks to: 1. access whether the water quality of these streams is natural or anthropogenic ally influenced and 2. provide present-day baseline data for making future decisions regarding the management of mineral resources on public lands. To augment routine water quality monitoring, three types of field experiments are being conducted: 1)Continuous tracer (KBr) injection studies, following established USGS methods to quantify longitudinal changes in the concentrations and loads of contaminants of concern, including Al, Cu, F, Fe, Mn, Pb, Tl, Zn and sulfate. This work will allow us to identify in greater detail the major zones of metal or acid loading in each watershed. 2)Examine diel (24-h) changes in the concentration and redox speciation of trace metals, following diel sampling methods. This will quantify the extent of short-term, temporal variations in water quality, and will help determine the optimal times of the day that long-term monitoring samples should be collected. 3)Collect a longitudinal transect of natural ferricrete samples for trace metal analysis, to compare with modern Fe- and Al-hydroxide precipitates. This method has recently been proposed by the USGS as a valuable assessment technique to compare pre-mining vs. post-mining water quality in headwater streams where no pre-mining baseline data exist. Analytical results will be summarized and discussed as well as the sampling techniques and procedures used to evaluate the water quality of these streams. The study area is a potential reference site to help constrain pre-mining water quality in nearby mining districts with similar geology but more severe acid rock drainage, such as Zortman-Landusky, Montana.

In-situ And Enriched Microbial Community Composition And Function Associated With Coal-bed Methane From Powder River Basin Coals

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The majority of the coal in the Powder River Basin (PRB) occurs in formations too deep to be economically mined but microorganisms within some of these deep coal seams generate coal-bed methane (CBM) which can be harvested and utilized as an energy source. However, little is known about the in-situ microbial community, the environmental conditions conducive to CBM production, or the microbial community interactions that promote CBM production. Several sampling locations within the PRB were identified as methane-producing sites based on geochemical analysis of groundwater. Coal from core samples and diffusive microbial samplers (DMS) were analyzed with DNA sequencing and microscopy to determine the in-situ microbial community structure and composition. Microscope images of microbes within the DMS revealed that the coal was actively colonized through biofilm formation. DNA analysis of the cores and DMS coal identified the predominant bacteria and archaea communities, providing insight into microbes generating CBM within the PRB. Changes in the composition and structure of microbial communities that occur under stimulated conditions were investigated by applying molecular methods in combination with cultivation techniques (with and without nutrient supplementation) to identify conditions which maximize methane production in batch, bench-scale incubations. An increased understanding of this microbial system has resulted in novel approaches for microbially-enhanced CBM production utilizing sustainable processes that occur naturally in the PRB.

Water Resources And Conditions Of Stress: Building Local Capacities Via Citizen Councils And Scoping Meetings

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In March of 2013 the Yellowstone Basin Advisory Council (BAC) convened under the direction of the Montana Department of Natural Resources and Conservation (DNRC) to begin to the process of planning for future water conditions in the basin, especially as they will impact water availability and water uses. The BAC consists of a mix of public officials, agricultural representatives, and representatives from private industries. During the scoping phase, completed during March and May, 2013, a series of regional initial meetings were held involving BAC members and the general public. The first and last meetings were held in Billings, with other regional meetings held in Glendive, Forsyth, and Big Timber. These meetings were designed to scope and assess the public's perceptions of the major water-related issues in the basin. In the process, the meetings provided an opportunity to explore new and different modes of public participation. Rather than the typical town-hall style where individuals are given three minutes to deliver comments, the meetings were structured around other ways of accessing public perception. This paper explains the advantages and disadvantages of charging a citizen council with the task of making recommendations about how water in their basin should be managed. The paper outlines the principles that guided the formation of the Yellowstone BAC, the coordination of the public scoping meetings, and the difficulties inherent to interests-based meetings and rights-based appropriations. Using the Yellowstone BAC as a case study, the paper identifies the technical and process support needed to meld local concerns with capacity-building activities that will ultimately help the council move forward in terms of being able to make sound recommendations.

Water Resources And Conditions Of Stress: Building Local Capacities Via Discourse Coding

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In March of 2013 the Yellowstone Basin Advisory Council (BAC) convened under the direction of the Montana Department of Natural Resources and Conservation (DNRC) to begin to the process of planning for future water conditions in the basin, especially as they will impact water availability and water uses. The BAC consists of a mix of public officials, agricultural representatives, and representatives from private industries. During the scoping phase, completed during March and May, 2013, a series of regional initial meetings were held involving BAC members and the general public. The first and last meetings were held in Billings, with other regional meetings held in Glendive, Forsyth, and Big Timber. These meetings were designed to scope and assess the public's perceptions of the major water-related issues in the basin. In the process, the meetings provided an opportunity to explore new and different modes of public participation. Rather than the typical town-hall style where individuals are given three minutes to deliver comments, the meetings were structured around other ways of accessing public perception. This paper explains the mechanics, advantages and disadvantages of employing a discourse coding records as a method for gathering and documenting key concerns and regional distinctions. The paper explains the findings derived from the Yellowstone BAC discourse data. Finally, the paper discusses how the data help illustrate the key issues on which capacities-building activities should focus.

Water Resources And Conditions Of Stress: Building Local Capacities Via Q Sort Exercises

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In March of 2013 the Yellowstone Basin Advisory Council (BAC) convened under the direction of the Montana Department of Natural Resources and Conservation (DNRC) to begin to the process of planning for

future water conditions in the basin, especially as they will impact water availability and water uses. The BAC consists of a mix of public officials, agricultural representatives, and representatives from private industries. During the scoping phase, completed during March and May, 2013, a series of regional initial meetings were held involving BAC members and the general public. The first and last meetings were held in Billings, with other regional meetings held in Glendive, Forsyth, and Big Timber. These meetings were designed to scope and assess the public's perceptions of the major water-related issues in the basin. In the process, the meetings provided an opportunity to explore new and different modes of public participation. Rather than the typical town-hall style where individuals are given three minutes to deliver comments, the meetings were structured around other ways of accessing public perception. This paper explains the mechanics, advantages and disadvantages of employing a Q Sort as a key method of gathering and documenting public inputs. The paper explains the key findings derived from the Yellowstone BAC data. Comparisons across the regional meetings are discussed. Finally, the paper discusses how the Q Sort analyses can help build local capacities for managing water resources under conditions of stress.

An Innovative Approach To Watershed Data Management And Restoration Planning In The Yaak Watershed Of Northwest Montana

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The Yaak Headwaters Restoration Project Partnership (YHRPP) was initiated by Yaak Valley Forest Council (YVFC) in 1999 and includes partners from US Forest Service and Montana Fish, Wildlife and Parks, with additional involvement from user groups, technical consultants, and environmental organizations. To date the YHRPP has coordinated and implemented over 40 miles of road decommissioning projects; created or improved over 20 miles of non-motorized trails where degraded roads once existed; upgraded or maintained over 4 dozen at-risk culverts; and surveyed between 500-600 miles of streams in the Yaak watershed. Inventories documented sediment sources in and adjacent to the stream and characteristics and condition of road-stream crossings. The road-stream crossing inventory, which encompasses 1, 067 crossings over much of the watershed, has provided data used in analysis of current and potential sediment delivery, aquatic organism passage, and culvert risk of failure. Results of the inventory and analysis have been made widely available in a data clearinghouse website that uses open-source GIS and database software. The data management components of the site include a database containing all available environmental datasets relevant to the roads network, fisheries distribution, and stream condition, with analysis queries developed to meet analysis objectives defined by YHRPP. The information website allows users to select from queries and datasets to create outputs as tables viewable on-line or in spreadsheet programs. Additionally, the website features an interactive mapping tool that allows users to map roads, fisheries, water quality, stream condition, and/or stream crossing data, with a number of base layer options such as current or historic aerial photos or topographic maps of various scales. Recently YHRPP began working with NGOs and agency representatives in southern British Columbia to address and replicate watershed restoration efforts in the Canada portions of the Upper Yaak River, known as the Yahk River, which will make the Headwaters Project an international, transboundary habitat restoration effort covering the entire basin. In addition to incorporating GIS data from the Yahk into the information website and mapping tool, recent and upcoming efforts in the Yahk include conducting stream condition assessments and crossing inventories, prioritizing restoration sites, and developing restoration concepts for priority sites. The innovative approach of the YHRPP for data management, information sharing, and collaborative restoration planning has fostered a successful and expanding watershed restoration effort and is serving as the foundation of watershed data management in another western Montana watershed.

A Comprehensive Hydroeconomic Analysis Framework For Optimal Management Of Agricultural Water And Land

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At the end of the last decade, crops in the state of Montana were worth more than $1.1 billion and employed more than 35, 000 people. Only 18% of all cropland was irrigated even though irrigated crops accounted for a disproportionate share of the total economic value. The absence of adequate policy and poor coordination between stakeholders rather than lack of water or land seem a major limit to the expansion of irrigation. Optimal and sustainable policy that maximizes the opportunity for irrigated agriculture while minimizing the negative impacts needs to take into account the decisions farmers make regarding water and land in response to external factors. Examples of external factors that affect water and land use include climate variability (e.g. droughts), changes in water policy and rules, changes in the market price of agricultural products (e.g. fluctuation in the demand of certain products) or availability of labor. The ability to simulate and predict how farmers react to policy, to environmental, and to socioeconomic change is a key step to design optimal policy capable of mitigating the negative environmental impact of agricultural activity while maximizing its social and economic benefits. We present and demonstrate an integrated modeling and observation framework to enable robust regional assessment and prediction of environmental and socioeconomic change on agricultural production, management decisions and socioeconomic policy. We use a novel combination of satellite remote sensing inputs and coupled socioeconomic and hydrometeorological models in a data assimilation framework. These models use remotely sensed information to quantify the amount of land, water, fertilizer, and labor that farmers will allocate for each crop they choose to grow in response to their perception of the environmental, policy and market conditions. The backbone of the method is an economic model of agricultural production based on a class of resource economic models referred to as positive mathematical programming (PMP), which have been extensively used to predict agricultural supply behavior under constrained conditions and in policy analysis. Biophysical constraints to production (e. g. water available for irrigation, precipitation) are provided by an integrated hydrologic model and meteorological or climatic datasets. The hydrologic model also permits the calculation of the impact of the economic activity (e. g. water diversions for irrigation) on the hydrologic system. The models are informed by remote sensing data and automatically adjusted to represent the observed reality using an ensemble Kalman Filter. This rigorous interdisciplinary methodology provides a means to monitor and forecast what crops will be grown and how farmers will allocate land, water and other agricultural resources under unexpected and adverse environmental conditions. It will also permit to simulate the impact of water policy on rural community livelihoods and on their water resources.

SESSION 7 RESTORATION / REMEDIATION

Restoration Assessment And Management Plan For Deep Creek, MT

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The goal of the Deep Creek Watershed Restoration Project is to achieve water quality improvement and long-term watershed protection and enhancement through improved coordination with land owners, agencies, and interested groups. In 1996, one of the state's first TMDLs completed for Deep Creek identified sediment as the primary water quality impairment. Early efforts to control sediment, including 18, 000 feet of soft bank stabilization and promoting passive revegetation with riparian fencing, did not achieve TMDL water quality goals, and the 2011 floods left land owners feeling at risk of further erosion. In response, Broadwater County Conservation District applied for and received a DNRC Reclamation and Development Planning Grant to develop a watershed management and restoration plan. The restoration plan is founded on an assessment of the inherent geologic character and human-influenced watershed processes that define restoration potential and opportunity through the stream system. Over a century of river corridor land uses has resulted in an entrenched channel system that aggravates erosion risks for landowners and water quality concerns and has imposed constraints on ecological restoration potential. Assessment was conducted through field investigations and analyzed in a GIS to compare existing conditions to historic and to evaluate the outcomes of management and stabilization efforts in the past 15 years. Deep Creek originates in the Big Belt mountains and flows through 22 miles of primarily agricultural lands to its confluence with the Missouri River near Townsend, MT. Deep Creek expresses varying stages of incised channel evolution resulting from riparian degradation, channelization, and beaver management initiated as early as pre-1900. Incised channel systems reduce alluvial aquifer storage and associated late-season flows, increase erosion and land loss potential, and result in substantial loss of habitat and ecosystem services, including maintenance of water quality and temperature. Incised stream channels typically follow a predictable evolution of downcutting, widening, and the eventual establishment of an entrenched and inset floodplain. The range of restoration alternatives for entrenched systems is largely determined by the stage of channel evolution. A watershed restoration plan for Deep Creek includes general stream corridor management recommendations and reach-specific concepts for reducing risk to landowners and restoring stream habitat and other values. General recommendations are founded on a stream corridor management concept. Within the delineated corridor, voluntary land use practices minimize constraints and impacts to natural process to increase long-term benefits and over the long term, reduce costs to land owners. Other general recommendations include concentrating infrastructure to reduce constraints to channel process, using a geologic context to guide management actions, and establishing BMPs for the contributing watershed area. Reach-specific recommendations included instituting beaver management plans for specific properties, reconfiguration of road crossings, bank stabilization at corridor margins, and levee setback or removal.

Floodplain Restoration Integrated With Dam And Sediment Removal

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Two dam and sediment removal projects in Montana, the completed Milltown Dam project and the Smelter Dam project, currently in design phase, have similar floodplain restoration components and both are components of large cleanup projects. Milltown Dam was built in 1906 at the confluence of the Clark Fork River and Blackfoot River as a component of the mining that was occurring within the Upper Clark Fork River Basin. The East Helena Smelter Dam was built in 1888 on Prickly Pear Creek as a component of the East Helena custom lead smelter operations. The Milltown Dam had more than 6.6 million cubic yards of contaminated sediments located behind it, while the Smelter Dam has approximately 250, 000 cubic yards of contaminated soils in the floodplain which were associated with the site's former operations. The fact that both of these dam removal examples have contaminated material associated with them makes them similar, but the other site characteristics as well as site cleanup goals make for different project designs and approaches. Designing a floodplain restoration project associated with dam and sediment removal cannot be done without a complete understanding of the issues that each site presents. Intense negotiations led to the dam and sediment removal associated with the Milltown project. The floodplain restoration was a component of a larger project, not the main project goal. The removal of 2.3 million cubic yards of contaminated sediment to cleanup the groundwater and improve surface water quality near the Milltown site drove the Milltown dam removal project. Floodplain restoration, which includes channel reconstruction, at the Milltown site had to consider the site constraints associated with larger project - contaminated sediment removal - as well as the contaminated sediments that were not removed, 4.3 million cubic yards. In addition, numerous other site constraints (bridges, roads, pipelines, landownership, cultural sites, cost) affected the floodplain restoration that occurred. The Smelter Dam removal on Prickly Pear Creek is in the planning stages and is a component of the cleanup activities at the East Helena Smelter RCRA site. The primary environmental concern at East Helena site is contaminated groundwater leaving the site. Smelter Dam impounds water up-gradient of the site which artificially recharges the groundwater system increasing the volume and rate of contaminated groundwater leaving the site. Elimination of Smelter Dam is a critical component of reducing off-site transport of contaminated groundwater. The floodplain and channel restoration that is being proposed following the removal of the Smelter Dam has to consider the adjacent contaminated material as well as infrastructure and other cleanup actions, limiting options for restoration. This presentation compares these two projects illustrating how floodplain restoration is only a small part of these larger dam removal projects and how site constraints and trustee goals can limit restoration efforts from reaching the historic geomorphic condition and determine what is actually constructed on the ground. In addition, monitoring results of the Milltown floodplain restoration project will be presented to quantify the effectiveness in meeting the restoration project goals.

Aquatic Resource Conservation Tool: Wetland & Stream Mitigation Banks

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Aquatic Resource Conservation Tool: Wetland & Stream Mitigation Banks Wetland and stream mitigation banks represent a powerful, and relatively new, tool to help preserve and enhance Montana's aquatic resources. As the economy rebounds and populations grow so must the Montana's infrastructure. Wetland and stream mitigation banks provide a mechanism for enabling this necessary growth to occur while preserving the functioning values of the states aquatic resources. Development and infrastructure projects frequently face significant environmental permitting hurdles associated with Montana's rich aquatic resources. Permit applicants, in many cases, are required to mitigate the wetland or stream impacts of their project. Historically, identifying a mitigation solution regulatory agencies find acceptable can add several months to several years to a permit applicant's approval process. These delays can significantly impact a project's economic viability and result in small postage stamp mitigation solutions. This presentation provides an overview of the wetland and stream permitting process and mitigation options currently available to Montana permit applicants. It will also examine how commercial mitigation banks fit into a permit applicant's mitigation solution. Case studies of mitigation bank customers from around the state will be used to highlight the biological, economic and logistical benefits of using mitigation banks. Target Audiences, Aquatic Restoration Professionals, Environmental Attorneys, Land Planers o Engineers.

Trestle Area Assessment, Design & Remedial Action On The Clark Fork River Operable Unit Of The Milltown Reservoir/Clark Fork River Superfund Site

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The Clark Fork River Operable Unit (CFROU) of the Milltown Reservoir/Clark Fork River Superfund Site is on the National Priority List. Historical mining and smelting operations are responsible for arsenic, lead, copper, and other metals contamination along the Clark Fork River. Located in Deer Lodge, a residential community of about 3, 500 people, the Trestle Area lies within Reach A of the CFROU on the banks of the Clark Fork River. The Project faced many human health risks and environmental challenges including: removal of contamination in the river banks, management of the river water during construction, and reclamation of the river banks to meet multiple objectives including integrating ecological habitat restoration features within an urban setting which required maintaining structural stability of local infrastructure. TerraGraphics' incorporated the human health cleanup activates within the streambank stabilization engineering design. The design included mitigation of contaminants within the banks through removals and stabilization of banks by installing a log crib wall, reclamation of the point bar, and strategic plantings. TerraGraphics developed a database and GIS system to manage, store and link data associated with the Trestle Area assessment in conjunction with the larger CFROU mitigation effort. This creative approach resulted in the reduction of human and environmental exposure to contaminated soils and sediments through mitigation of this impacted stream system.

Geomorphology Of The Clark Fork River From Warm Springs To Garrison: Implications For Remedial Design

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Reach A of the Clark Fork River Operable Unit (CFROU) of the Milltown Reservoir/Clark Fork River Superfund site flows through the core of the Deer Lodge Valley, extending 45.5 river miles from Warm Springs to Garrison, MT. In this section of river, historic upstream mining impacts have resulted in the delivery of vast quantities of metals-laden tailings to the river and its adjacent floodplain. During the fall of 2012, a stream assessment was performed on the entirety of Reach A to provide some geomorphic and hydrologic context for ongoing and future remediation efforts in Reach A. The geomorphic investigation included an evaluation of geologic controls on river behavior, estimation of lateral migration rates and associated tailings entrainment potential, an inventory of bank stability, an assessment of floodplain turnover rates, and a determination of existing floodplain connectivity through the reach to help identify current issues of hydrologic disconnection between the modern Clark Fork River and its floodplain. Reach A was subdivided into seven subreaches based on geomorphic form and behavior. Geomorphic trends in Reach A are strongly affected by the influences of Holocene terraces that are comprised of reworked glacial outwash on the west side of the stream corridor, and fine sand and silt colluvial wedges that bound the east side of the valley. Valley slope and sinuosity are inversely related, indicating planform adjustments to accommodate valley profile variability. The most extensive active bank erosion is located upstream of Deer Lodge, where over 20% of the bankline was mapped as severely eroding. Since 1950, over 131 acres of river floodplain has been eroded by the river recruitment. Over the same time period, 171 acres of channel area has become floodplain, highlighting potential areas and extents of reworked tailings deposition. Since 2006, approximately 33 acres of impacted soils and 0.7 acres of slickens were entrained by the river. Channel migration rates increase in the downstream direction; based on over 1800 measurements of 1955-2011 bankline migration, approximately 1130 acres of floodplain alluvium can be demonstrated as at risk of erosion over the next century. Numerous avulsion hazards are present in the reach where tailings pulses could result from cutoff channel formation. These data will collectively help identify tailings entrainment risk throughout Reach A, and will also help determine appropriate requirements for bank protection that are geomorphically appropriate in the context of remedial actions.

SESSION 8 WATER QUALITY - PART 2

Water-Quality Assessment Of The Upper Fort Union Aquifer– Williston Basin

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Domestic oil and gas production and clean water are critical for economic growth, public health, and the national security of the United States. While the Williston structural basin (WSB) has been a major domestic oil and natural gas producing region since the 1950s, oil and gas development from deep formations such as the Bakken and Three Forks Formations has been increasing due to the improved accessibility of these resources using hydraulic fracturing and horizontal drilling methods. There is increasing public concern about the effects of energy production on surface-water and groundwater quality. Activities associated with oil and gas development (such as road and well-pad construction, storage of chemicals, disposal of produced wastewater, and transmission of oil and gas products) can potentially affect surface-water and groundwater quality. Contaminants (including fracturing chemicals, produced wastewater, and oil and gas products) might be conveyed to surface-water and (or) groundwater by: storage-tank leaks; chemical spills; wastewater-storage pond infiltration; failed casing seals; pipeline breaks; and deep-well disposal of produced wastewater with induced subsurface migration pathways. Quaternary (Glacial), lower Tertiary (upper and lower Fort Union) and Upper Cretaceous (Hell Creek/Fox Hills) aquifers in the WSB provide the majority of groundwater used for domestic, livestock, industrial, and public-supply uses. A study was initiated to characterize water-quality conditions in the shallowest bedrock aquifer (upper Fort Union) in Montana and North Dakota, while

developing a protocol for similar assessments in other areas of the United States also undergoing increased oil and gas development. Thirty domestic wells completed in the upper Fort Union aquifer were selected using a spatially-distributed randomized grid-based method, and were sampled for field parameters, selected major ions, nutrients, and organic compounds. While it is generally assumed that the water-bearing aquifers in the WSB are separated by units with low hydraulic conductivity, little water-quality data has been collected to verify the level of connection between the aquifers. A second set of 6 domestic wells completed in the underlying formation (lower Fort Union or Hell Creek/Fox Hills) were selected to improve spatial coverage of wells for the study. At 10 of the 36 sites, water-quality samples were analyzed for additional parameters which will improve understanding of the hydraulic interactions between the aquifers. In addition to the field components of the study, a retrospective analysis of groundwater and surface-water quality was conducted. The retrospective analysis included: a compilation of bibliographies, compilation and summary of all existing water-quality and produced water data within the WSB, and identification of key water-quality issues, data gaps, and (or) limitations. Water-quality samples and the retrospective datasets were collected and compiled during August and September 2013. Interpretation and reporting of analytical results and retrospective datasets is planned for early 2014.

Brine Contamination From Energy Development In The Williston Structural Basin, Montana

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Since the 1950s, billions of barrels of brine have been produced with oil from deep formations (>5, 500 feet) in the Williston structural basin. This brine—also called 'produced water'—from the Williston basin is some of the most saline water in the Nation, with chloride concentrations that are near saturation and dissolved solids concentrations as high as 300, 000 mg/L from the Bakken Formation. Brine disposal and handling methods include storage pits, evaporation pits, and injection into subsurface units that use storage tanks and wells connected by a network of pipelines. These disposal and handling methods have resulted in contamination of surface water and shallow groundwater at multiple locations throughout the Williston basin. Brine contamination can persist in shallow aquifers for decades and has been shown to migrate in plumes that extend at least a mile from the source(s). Using a combination of geophysical and geochemical methods, the U.S. Geological Survey (USGS) has delineated brine contamination of the shallow aquifers over as much as 17.9 square miles in and near the East Poplar oil field along the western flank of the Williston basin. The contamination is present throughout the shallow saturated zone in contaminated areas. The brine contamination has been documented for several decades and has not only affected the water quality of privately owned wells, but also the City of Poplar's public-water supply wells. The USGS, Montana Bureau of Mines and Geology, and the U.S. Fish and Wildlife Service have identified brine contamination at multiple locations throughout the Medicine Lake National Wildlife Refuge, located in the northwestern portion of the Williston basin. The source of the contamination may be buried storage pits that were installed in the mid- to late-1960s. Lateral migration of the contamination appears to be controlled, in part, by near-surface sediments, with travel distances up to 0.5 mile from the source. Concerns about current energy development of the Bakken Formation in the Williston basin focus on the hydraulic fracturing component and the associated chemical additives. Lessons from previous energy development in the Williston basin indicate that concerns should also focus on the large volumes of hyper-saline water that can inadvertently cause serious impacts to water resources from oilfield infrastructure. More information about these projects can be obtained at: http://mt.water.usgs.gov/projects/east_poplar/index.html http://steppe.cr.usgs.gov/.

Flow-Adjusted Temporal Trends In Water Quality For The Upper Clark Fork Basin, Montana, 1985–2010

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A large-scale study of flow-adjusted temporal trends in specific conductance, selected trace elements (arsenic, cadmium, copper, iron, lead, manganese and zinc), and suspended sediment was recently conducted for 22 sites in the upper Clark Fork basin (upstream from Missoula), based on data collected during 1985–2010.

To facilitate presentation of selected results among sites with variable periods of data collection, emphasis is placed on the period 1996–2010. Trend analyses were conducted using two parametric methods: a time-series model and least squares regression on time, streamflow, and season. Trend results for 1996–2010 indicate large decreases in median concentrations and estimated flow-normalized loads of copper (and other metallic elements) and suspended sediment in Silver Bow Creek upstream from Warm Springs. Deposition of metallic elements and suspended sediment within Warm Springs Ponds substantially reduces the downstream transport of those constituents. However, mobilization of copper and suspended sediment from floodplain tailings and stream banks in the Clark Fork reach from Galen to Deer Lodge is a relatively large source of metallic elements and suspended sediment, which also influences downstream transport of those constituents. Copper and suspended-sediment loads mobilized from within this reach accounted for about 40 and 25 percent, respectively, of the loads for Clark Fork at Turah Bridge; whereas, streamflow contributed from within this reach only accounted for about 8 percent of the streamflow at Turah Bridge. Little change in concentrations and loads of copper and suspended sediment are indicated for this reach during 1996–2010. Clark Fork reaches downstream from Deer Lodge are relatively smaller sources of metallic elements than the reach from Galen to Deer Lodge. In general, small decreases in loads and concentrations of copper and suspended sediment are indicated for Clark Fork sites downstream from Deer Lodge during 1996–2010. Thus, although large decreases in concentrations and loads of copper and suspended sediment are indicated for Silver Bow Creek upstream from Warm Springs, those large decreases are not translated to the more downstream reaches largely because of temporal stationarity in constituent transport relations in the Clark Fork reach from Galen to Deer Lodge. Unlike metallic elements, arsenic (a metalloid element) in streams in the upper Clark Fork basin typically occurs mostly in dissolved phase, has less variability in concentrations, and has weaker direct relation with suspended-sediment concentrations and streamflow. Arsenic trend results for 1996–2010 indicate large decreases in concentrations and loads in Silver Bow Creek upstream from Opportunity. In general, small temporal changes in loads and concentrations of arsenic are indicated for Silver Bow Creek and Clark Fork reaches downstream from Opportunity during 1996–2010. Contribution of arsenic (from Warm Springs Ponds, the Mill-Willow bypass, and groundwater sources) in the Silver Bow Creek reach from Opportunity to Warm Springs is a relatively large source of arsenic. Arsenic loads originating from within this reach accounted for about 11 percent of the load for Clark Fork at Turah Bridge; whereas, streamflow contributed from within this reach only accounted for about 2 percent of the streamflow at Turah Bridge.

Applications Of High Frequency Limnological Data: Real-time Visualization, Water-quality Mapping, And Calibration/verification Of Hydrodynamic Models

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Recent technological advances in instrumented buoys and autonomous underwater vehicles (AUV) have resulted in the collection of high-frequency data from lakes and reservoirs worldwide. Instrumented research buoys, such as the Lake Environmental Sensing Platform (LakeESP®), can record/transmit data from multiple sensors at 1-minute intervals. AUVs, such as the Yellow Springs Instruments (YSI) Ecomapper®, can collect spatially referenced data at 1-second intervals from multiple water-quality, pressure, and water-velocity sensors to produce detailed two- and three-dimensional maps of a water body. Three applications of high-frequency data sets to address various limnological issues are presented. A LakeESP has been operating seasonally on Great Salt Lake (GSL), Utah, since May 2010, to monitor short term (< 1 hour) changes in the density stratification of a mercury- (Hg) and nutrient-enriched layer below the thermocline. The LakeESP has 30 sensors that provide near real-time data for 90 water-quality, water-current, and meteorological parameters, mostly at 1-minute time intervals. Visualization of the real-time data is enhanced by the commercially developed software ESP_Plot (rev. 2.29) which provides user generated contours of water temperature for selected time intervals, lake mixing and stratification indices, and bivariate plots of layer velocity/direction, wind speed/direction, photosynthetically active radiation, as well as other parameters. A second application on GSL involved the use of an AUV to map the movement of a rhodamine WT dye tracer that was injected near the mouth of a freshwater inflow to GSL. The AUV was programmed to carry out a near-surface mission immediately offshore of the inflow source to about 1 kilometer off shore. Dye concentration was measured with an onboard YSI 6130 rhodamine sensor at a sample rate of 1 hertz. Results from the plume mapping are being used to calibrate a 3-D hydrodynamic model to simulate the movement of selenium-enriched freshwater inflows and their interaction with the hypersaline lake water of GSL. A third application involved the deployment of a buoy with a 10-thermistor string in a small reservoir in southwestern Utah to monitor the artificial manipulation of thermocline elevation by a solar-powered pump designed to remediate Hg contamination. The thermistor string was located about 60 meters from the pump station and water temperature was measured at 15-minute intervals at 10 different depths before and after the initiation of pumping. The LakeAnalyzer software was used with this high-frequency data set to calculate the average daily elevation of the reservoir thermocline and the effectiveness of the remediation strategy. Results of this analysis indicated a sustained decrease in thermocline elevation (4 meters) about 60 meters from the pump 10 days after the initiation of pumping. Additional modeling and analyses are ongoing to verify the process(es) contributing to the observed decrease in thermocline elevation.

Combining The Precipitation-Runoff Modeling System With The RegCM3 Regional Climate Model To Estimate Potential Effects Of Climate Change On Northern Great Plains Streams

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Streams in the Northern Great Plains provide critical green lines of habitat for aquatic and terrestrial wildlife. The fish in these streams have evolved to survive heat, cold, floods, and drought. However, changes in water quantity associated with global climate change may transform some prairie streams from essential refuges to habitats no longer capable of supporting fishes. U.S. Geological Survey researchers and their partners are studying these potential changes in stream ecosystems in the Montana portion of the northern Great Plains. The study design and preliminary results will be discussed during this presentation. The Precipitation-Runoff Modeling System (PRMS) loosely coupled with the RegCM3 regional climate model is being used to estimate possible changes in streamflow under future climate scenarios in eastern Montana. PRMS is a deterministic, distributed-parameter, process-based model that simulates the effects of precipitation, temperature, and land use on streamflow. RegCM3 is used to dynamically downscale global climate simulations. Local PRMS models will be constructed for the Redwater River and O'Fallon Creek watersheds in eastern Montana. Parameters for these local models will be extracted from a regional PRMS model for the entire Missouri River watershed. The local models will then be calibrated to historical streamflow data. Both the local and regional PRMS watershed models will be used to simulate streamflows for more than 1, 000 sites in eastern Montana where fisheries data have been collected. General circulation models (GCMs) simulate a wide range of possible future climate scenarios on a global scale. RegCM3 uses lateral boundary conditions from selected GCMs, and then simulates atmospheric circulation and surface interactions internally at a 15-kilometer resolution. Precipitation and temperature time series simulated by RegCM3 will be used to force the PRMS models to generate streamflows under possible future climate scenarios. Fisheries managers will be able to combine possible future streamflows with fisheries data to help focus conservation and restoration efforts in the northern Great Plains. Information related to changes in timing and quantities of streamflow also will be useful to watershed conservation groups, ranchers, and others that rely on northern Great Plains streams.

Radionuclides In Groundwater Of Jefferson County And Surrounding Areas, Southwestern Montana, 2007 Through 2010

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The U.S. Geological Survey, in cooperation with Jefferson County and the Jefferson Valley Conservation District, sampled groundwater from primarily domestic wells in southwestern Montana to evaluate the occurrence of naturally-occurring radioactive constituents and to identify geologic settings and environmental conditions in which elevated concentrations of those constituents occur. Water-quality samples were collected from

128 wells completed in 6 geologic units within Broadwater, Deer Lodge, Jefferson, Lewis and Clark, Madison, Powell, and Silver Bow Counties from 2007 through 2010. Typically, samples were analyzed within a few days after collection; therefore, data closely represent the quality of water consumed by area residents. Initial water-quality analyses included uranium, radon, gross alpha-particle activity, and gross beta-particle activity. Thirty-eight wells with elevated concentrations were sampled a second time to examine temporal variability. Those 38 samples were analyzed for additional radioactive constituents including polonium-210 and isotopes of radium and uranium. Radioactive constituents were detected in water from all 128 sampled wells and nearly 41 percent of those wells had at least one constituent that exceeded U.S. Environmental Protection Agency drinking-water standards or screening levels. Radioactive constituents exceeded at least one drinking-water standard or screening level in five of six geologic units assessed. Water from the Late Cretaceous Boulder batholith and other similar intrusive rocks exceeded these standards or levels most frequently (38 of the 62 wells). Uranium and radon concentrations exceeded established or proposed standards in 14 and 27 percent of the wells, respectively. Adjusted gross alpha-particle activity and combined radium (radium-226 and radium-228) both exceeded standards in about 24 percent of the samples. Gross beta-particle activity exceeded a 50 picocurie per liter (pCi/L) screening level in about 5 percent of the samples analyzed. Gross alpha-particle activities may be a potential indicator for elevated radioactive constituents in the area as all radioactive constituents whose concentrations exceeded drinking-water standards or screening levels had gross alpha-particle activities of 7 pCi/L or more. Radiochemical concentrations or activities varied temporally in most wells that were sampled a second time. The concentrations or activities of at least one radiochemical constituent (gross alpha-particle activity, gross beta-particle activity, radon, or uranium) varied by more than 30 percent in 30 of the 38 of those wells. Nonparametric Spearman correlation coefficients (rho) were computed to measure the strength of the relation among various constituents and field parameters and many relations were not statistically significant (p-value > 0.05). Total-dissolved solids were moderately correlated (rho = 0.62 to 0.71) with gross alpha-particle activity and gross beta-particle activity, indicating that higher activities can be associated with higher total-dissolved solids. Gross beta-particle activity was moderately correlated (rho = 0.72 to 0.82) with potassium, most likely because one potassium isotope (potassium-40) is a beta-particle emitter. Three radium isotopes were moderately to strongly correlated (rho = 0.78 to 0.92) to one another. Gross alpha-particle activities were moderate to strongly correlated (rho = 0.77 to 0.91) with gross beta-particle activities.

POSTER SESSION

Using Major Ions, 222Rn, ∆D And ∆18O To Characterize The Role Of Subsurface Flow To The Upper Boulder River, MT

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The role of groundwater and other subsurface flow paths in stream flow generation within the mountain block is poorly understood. In this study, we established sites in the Boulder River from the headwaters in mountainous terrain, to the USGS gauging station in the alluvium-filled valley near Boulder, MT. The purpose of this project was to: i) characterize how groundwater interacts with the Boulder River, ii) identify and separate source waters in the river, and iii) investigate how mixing between these source waters varies spatially and temporally. Radon samples were collected at ten locations on March 2013 to locate regions of possible groundwater influx. Monthly major ion and stable isotope (∆D and ∆18O) samples were collected at three locations from May 2011 until present. Using major ions and stable isotopes, three endmembers were identified, and used in an endmember mixing analysis (EMMA). They appear to be overland flow (or fresh snowmelt), either lateral subsurface flow or irrigation return flow, and groundwater. During spring runoff the majority of the streamflow is comprised of overland or near-surface flow. As snowmelt decreases during summer both lateral subsurface flow and groundwater become increasingly important to streamflow. By late summer and early autumn, groundwater becomes the dominant source of water to the Boulder River (approximately 65-85% of total flow). Radon-222 results suggest a continuously gaining river. However, there are discrete locations with greater quantity of groundwater influx illustrating the complexity of groundwater/surface water interactions occurring within the mountain block.

An Assessment Of Factors Controlling Spatial And Temporal Patterns Of Stream Yield In Forested Mountain Watersheds

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The timing and spatial patterns of stream and groundwater exchange in forested mountain catchments are important for water use planning, stream chemistry, and in-stream biota. However, quantifying the catchment characteristics that contribute to spatio-temporal patterns of stream and groundwater exchange remains a challenge. We examined the differences in stream discharge at approximately 200m increments along the stream networks of five nested mountain catchments ranging in size from 3.18 to 23 km2 in the Tenderfoot Creek Experimental Forest, MT. We performed dilution gauging throughout peak stream flow to base flow in order to quantify the difference in discharge between each reach and develop stage-discharge relationships at each monitoring location (hourly discharge measurements at 52 sites). For each reach, we quantified topographic, vegetative, and geologic indices from Airborne Laser Swath Mapping derived digital elevation models and Moderate Resolution Imaging Spectroradiometer data (MODIS). These indices represent the propensity for the stream to gain or lose water from the groundwater system. Preliminary analyses suggest that each watershed has unique topographic, geologic, and vegetative properties, which lead to strong differences in the spatial patterns of water delivery across stream networks of differing structure. Additionally, the dominant controls shifted from peak snowmelt through the recession to low flow. These findings provide a better understanding of factors leading to the timing and nature of delivery of water from uplands to streams in forested mountain watersheds and provide a context for apriori water management decisions.

The Montana State Library's Water Information System

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The Montana State Library's Water Information System (WIS) makes high quality water information, including GIS data, interactive applications, maps, and other water-related resources, discoverable from one common starting place. This poster will provide an overview of the WIS and its core, the Montana Spatial Data Infrastructure Hydrography Dataset. Information about the National Hydrography Dataset stewardship program and how to become involved with the Montana Hydrography Workgroup will be presented.

Using ArcGIS And ModelBuilder For Groundwater Susceptibility Analysis Of The Shields River Drainage Basin, Montana

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The Cody Shale has been identified as a potential shale-gas play in the Shields River Basin of southwest Montana. Between 2007 and 2009, six exploration wells were drilled in the Basin. Although the wells were abandoned or shut-in and the drill sites reclaimed, there is local concern about impacts from the recent and future drilling. The Montana Bureau of Mines and Geology's Groundwater Assessment Program is designed to improve the understanding of Montana's groundwater resources by collecting and disseminating essential groundwater information. As part of the MBMG Park-Sweet Grass Ground Water Characterization study about 20 wells will be sampled for major ions and trace metals, in addition to a suite of organics. The Shields Valley Watershed Group and the Park County Conservation District secured funding for the additional organic analysis. Basin residents rely heavily on groundwater; most domestic and stock wells are completed in bedrock aquifers within 300 feet of the land surface. Conceptually, groundwater is susceptible to contamination where groundwater is shallow, soils are thin or permeable, and permeable bedrock units exist at the surface. ArcGIS ModelBuilder is an application designed to develop and run models in a visual programing environment. The visual programing environment allows the user to drag-and-drop geoprocessing tools directly from ArcGIS and connect the tools in any order. To assist with developing a target list of wells to sample, an ArcGIS groundwater susceptibility model was developed. The model was constructed to rank physical characteristics from 1-10: slope, geology, soils, and depth to groundwater, and sum the results to provide a groundwater susceptibility ranking from 4 to 40. Higher rankings indicate areas where groundwater is likely more susceptible to surface contamination than areas with lower rankings. The model results were used along with geologic cross-sections, land use information, oil and gas well data, and structural setting to select sample sites. The Basin groundwater susceptibility model can be easily updated to incorporate new field data and changes in hydrogeologic understanding from the ongoing Bureau study in Park and Sweet Grass counties.

Restoring Aquatic Resources By Synergizing Regulatory And Non-regulatory Funding

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Restoring the health and function of aquatic resources has become a political, economic, and ecological force in Montana for several decades. However, the supply of funding and capacity in the public and private sectors to accomplish restoration projects rarely meets abundant demand for aquatic restoration around Montana. Montana Aquatic Resources Services, Inc. (MARS) incorporated as a 501(c)3 corporation in 2011 to build funding and technical capacity for the capable network of resource professionals across the state by synergizing funding opportunities from the private and public sector. MARS is the statewide sponsor for an In-Lieu Fee compensatory mitigation program designed to mitigate for Clean Water Act and Rivers and Harbors Act unavoidable impacts. In addition to mitigation fees, MARS is partnering with industry through regulatory and non-regulatory processes to focus aquatic restoration funding to projects of ecological significance statewide. An example of MARS' work presented includes a floodplain conservation program along the Lower Yellowstone River analyzing channel migration data and land use between Laurel and Sidney, Montana.

Inventory And Assessment Of A Portion Of Rock Creek In The Upper Big Hole River Drainage Near Wisdom, Montana

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The Environmental Field Studies class at the University of Montana Western conducted an inventory and assessment of Rock Creek, a tributary of the Big Hole River near Wisdom, Montana from September 24th to October 17th, 2012. The project included analysis of stream morphology, in-stream macroinvertebrates, riparian vegetation and stream habitat. The purpose of the project was to assess riparian restoration efforts started in 2006 to improve habitat for fluvial Arctic grayling in the upper Big Hole River watershed. The study area included a total of eight stream cross sections located upstream from the confluence of Rock Creek and the McDowell Reach of the Big Hole River. The cross sections were located on existing cross section pins established during the initial restoration phase of the project in 2006. The University of Montana Western team surveyed a total of four sites, each of which consisted of riffle and pool cross-section pairs. Restoration efforts on this segment of Rock Creek included the diversion of the stream into its historic channel, installation of riparian fencing to preclude cattle grazing, in-stream water level agreements, willow planting and the installation of fish ladders. An assessment of the restoration work had not previously been done on this segment of Rock Creek, yet it was the first stream to be restored as a part of the extensive U.S. Fish and Wildlife Service and Montana Fish, Wildlife and Parks upper Big Hole River grayling project. The data show that Rock Creek is functioning as a Rosgen C4b stream, and is evolving into an E4b stream. In-stream macroinvertebrate diversity and richness have improved and riparian vegetation diversity and density have increased. The stream habitat survey shows that pools are short and deep, while riffles are long and shallow, optimal conditions for grayling reproduction and survival. Stream bank vegetation is dense, with abundant willows and sedges and very little exposed ground along the length of Rock Creek within the study area. Cattle were allowed to graze the upstream reach of Rock Creek within the study area during the summer of 2012, which reduced vegetative stability of stream banks and liberated significant sediment into the channel, at least in comparison with the lower reach of Rock Creek. It is recommended that grazing not be allowed on Rock Creek, especially since it is such an important tributary for reproduction of fluvial Arctic grayling living in the main stem of the Big Hole River.

Hydrogeologic Framework Database For Madison And Gallatin Counties, Montana

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As part of the Montana Bureau of Mines and Geology (MBMG) Ground Water Assessment Program Madison and Gallatin county groundwater characterization study, a hydrogeologic framework map was developed for the area. Geologic data were compiled from multiple sources, including: MBMG geologic maps at the 1:100, 000 scale, United States Geologic Survey (USGS) geologic maps at the 1:100, 000 and 1:250, 000 scale, Montana Board of Oil and Gas well logs (MBOG), and well logs and site inventories from the Ground Water Information Center (GWIC). To create a GIS-based hydrogeologic framework, a database was developed based on MBMG and USGS geologic codes to relate geologic and hydrogeologic descriptions. Traditionally, these data were widely scattered among multiple sources and difficult to access. This database will be the evolving repository that links the USGS and MBMG coding system and will allow standardization of geologic and hydrogeologic coding within MBMG. Standardized coding will facilitate expedited map production and eventually downloadable GIS datasets to the public. In the past, without such a database, this process has been tedious, repetitive, and subjective. GIS-based cross-sections that illustrate groundwater flow paths were compiled from the hydrogeologic framework map. Representative sections showing the sub-surface distribution of major aquifers were developed for the Ruby Valley, Madison Valley, Gallatin Valley and Big Sky. A semi-automated process using the geologic and well log data listed above, an ArcGIS based cross section tool (Xacto, developed by Jennifer Carrell of the Illinois State Geological Survey), and ArcScene was developed to generate the cross sections.

Estimating The Evapotranspiration Component Of Irrigation Water Use In Southwestern Montana

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The amount of water that is diverted from a stream for irrigation can be directly measured, as can the amount of water that is applied to an irrigated field. It is much more difficult though to measure or even accurately estimate how much of that diverted water actually is consumed by the crop through the process of evapotranspiration (ET). For water management purposes, it is important to know what the ET component is because this is the portion of the diverted water that is consumed by the irrigated crop and unavailable to users downstream. As part of the State water planning process, the Montana Department of Natural Resources and Conservation (DNRC) is developing a remote-sensing method for estimating irrigation ET statewide. This poster will describe how that method might be applied by using the Ruby River watershed in southwestern Montana as an example. The ET estimating procedure, including the delineation of irrigated lands and the processing of satellite imagery, will be explained. The poster also will compare irrigation ET estimates using the method being developed by DNRC to estimates based on a water-balance approach, theoretical equations and other remote-sensing techniques.

High Mountain Lakes As Indicators Of Atmospheric Pollution And Climate Change

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Lakes in mountainous areas are of special interest in environmental studies because of their sensitivity to inputs of atmospheric pollution and climate change. Globally, high mountain lakes tend to be detached from the local sources of pollution such as logging, mining, agriculture, and land development (Rabe 2006). Mountain lakes can therefore be early indicators of more widespread environmental changes (Skjelkvale 2012). There is growing concern that these high mountain lakes are understudied (Campbell 1995 in Mast 2010) and therefore the wealth of knowledge that can be gleaned from studying them is lost. The need to study and gather information on conditions in our Nation's lakes has never been greater (E.P.A. 2002). Studying these lakes is important since documenting current trends in high mountain lake water quality can assist in assessing the overall health of the environment. Future generations will be able to accurately compare and contrast environmental changes, and present generations can begin to better understand trends in their constantly changing world if high mountain lakes are studied and monitored. The objectives of this study were to determine baseline water quality parameters for high mountain lakes in the Mission Mountain Tribal Wilderness (MMTW) of northwestern Montana, specifically the chain of Mud Lakes, Courville Lake, and Lucifer Lake. Chemical analyses were conducted in the field and a full anion-cation balance was conducted on field samples by the University of Montana Biogeochemistry Laboratory. Lake mercury levels were obtained from fish samples analyzed by the Salish Kootenai College Environmental Chemistry Laboratory. Data were evaluated to determine if geographic location affected the lakes chemical composition or health. Another objective was to determine if warming air temperatures and changing snowpack is having an affect on high mountain lake chemistry within the MMTW. Historical Snotel data were used to find trends in annual weather patterns, and compared with chemical analyses from high mountain lakes. These data were used to model trends and implications of the effects that climate change and atmospheric pollution are having on high mountain lakes of the MMTW.

Carbon And Nutrient Cycling In A Headwater Stream And Riparian Zone: Tenderfoot Creek Experimental Forest, Montana

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Researchers at Montana State Univ., Duke Univ., the Univ. of Nebraska, the Univ. of N. Carolina, and North Carolina State Univ. are currently investigating annual fluxes of carbon dioxide and other greenhouses gases (nitrous oxide, methane) into and out of different landscape types at the Tenderfoot Creek Experimental Forest (TCEF), Little Belt Mountains, Montana. This interdisciplinary effort includes hydrologists, microbiologists, geochemists, and air monitoring specialists. Montana Tech is teaming with the larger TCEF group to characterize the geochemistry and stable isotope composition of shallow groundwater, soil water, and stream water near sites that are being investigated for gas chemistry and microbiology studies. The field site of interest is the riparian zone of upper Stringer Creek, a second-order tributary near the headwaters of Tenderfoot Creek. Field work began in the summer of 2012, and is continuing through the summer of 2013. Flow in Stringer Creek is maintained by groundwater entering the stream from the surrounding forested hills. Based on seasonal trends in water isotopes, the residence time of groundwater in the watershed is short, probably less than 1 year. Shallow groundwater in a subalpine meadow near the head of Stringer Creek shows large lateral variations in chemistry, which are attributed to heterogeneous rates of microbial metabolism in the fertile but patchy wetland soil. Several monitoring wells contain anoxic water with elevated concentrations of dissolved iron and ammonium. The anoxic groundwaters have higher alkalinity and concentrations of total dissolved inorganic carbon (DIC). In general, the DIC becomes isotopically lighter as DIC concentration increases, consistent with an input of biogenic CO2 from microbial respiration of buried organic matter. A single well with anomalously high DIC concentration falls off this trend. Here, methanogenesis may be producing isotopically heavy DIC and isotopically light methane. Being insoluble, the methane escapes to the soil zone and diffuses into the atmosphere, while the DIC remains dissolved in the shallow groundwater. The concentrations of methane in soil gas are being measured by other groups working in Stringer Creek. Our data show that methanogenesis and microbial respiration influence the chemistry and isotopic composition DIC and other compounds in soil water and shallow groundwater in the upland soils at TCEF. Further work will attempt to quantify concentrations and isotopic compositions of dissolved organic carbon (DOC) and dissolved methane in the groundwater wells. This material is based on work supported by the National Science Foundation under Grant EPS-1101342.

Any opinions, findings and conclusions are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Flux Tower Data Analysis In The Judith Basin, Montana: A Measure Of Evapotranspiration Over A Winter Wheat Field

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Evapotranspiration (ET) is often considered the most difficult component of the ecosystem water balance to measure, but is critical for accurate assessment. We used the eddy covariance technique to measure ET on a half-hourly time step over the course of the 2013 growing season. Water tables in the Judith Basin are near the surface (~1-10m depth), presenting a unique opportunity to study hydrological and meteorological variability in a location where plant roots may be able to tap the water table. Based on preliminary eddy covariance observations of ET in a wheat field near Moore, Montana, we estimate that evaporation dominates before crop growth but quickly shifts to transpiration dominance as the canopy grows, resulting in rapid summer drydown of soil moisture. The flux tower measurements can additionally be used in determining CO2 exchange, such that the coupled carbon and water dynamics can be studied to understand ecosystem water use efficiency. Key Words: Evapotranspiration, Flux Data Analysis, Eddy Covariance, Judith Basin, Wheat, Hydrological and Meteorological Variability.

Landscape Heterogeneity Modulates Forest Sensitivity To Climate

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At higher elevations in the Rocky Mountains, snowmelt strongly influences the magnitude and timing of net ecosystem productivity. Throughout the western U.S., increased spring temperatures, declining snowpack, and earlier snowmelt have been observed over multiple decades. These trends have been correlated with decreased water availability and coniferous forest productivity and concurrent increases in forest wildfire activity and tree mortality. However, previous work has provided little insight into how topographic complexity may modulate plant available water and therefore forest productivity. We hypothesize that landscape scale lateral water redistribution patterns influence the persistence of soil water during the growing season and subsequently tree biomass accumulation. To evaluate this hypothesis we collected an extensive survey of tree cores (~500) from four coniferous tree species across a range of elevations, aspects, and topographic positions in the Lubrecht Experimental Forest, MT. We compared the rate of annual tree growth to annual precipitation (rain and snow) across a 60-year data record and a suite of topographic indices derived from a 1m LIDAR digital elevation model. Preliminary results indicate positive linear relationships (with differing slopes) between the amount of annual basal growth across all four-tree species and the amount of annual precipitation. Further, initial comparisons of measured tree growth rates to the topographic wetness index suggest differential tree growth response as a function of landscape position. Generally, trees located in wetter landscape positions exhibited greater annual growth per unit of precipitation relative to trees located in drier landscape positions. This indicates that landscape scale water redistribution patterns may lead to differences in plant available water, providing climate refugia for vegetation productivity.

Arsenic Source Investigation Near Anaconda, MT

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Groundwater quality has been impacted by arsenic (As) in some areas around Anaconda, Montana. The primary goal of this work is to differentiate between the potential sources of this arsenic contamination. Previous work has shown that elevated arsenic concentrations exist in soil and shallow groundwater as a result of historic smelting and mining activities. However, elevated arsenic concentrations in groundwater (~30 µg/L) have

also been observed at depths of ~525 feet; presumably far beneath the zone expected to be contaminated by smelter emissions. This indicates that there may be naturally occurring As-bearing minerals in some areas that contribute to the observed concentrations. Sediment samples and rock cores were collected in four areas with elevated arsenic in the groundwater near Anaconda (Powell Vista, English Gulch, Crackerville, and Fairmont areas). The surface soil samples (< 1 foot) typically had arsenic concentrations ranging from 30 to 150 mg/kg. The core from English Gulch had the highest arsenic concentrations at depth (up to 26, 000 mg/kg). The high arsenic concentrations in the English Gulch core were associated with sulfide mineralization from 125 to 300 feet below ground surface. The Crackerville core consisted of valley-fill material, possibly volcanic tuffs and intrusive igneous rock, with evidence of hydrothermal alteration. The Crackerville core also had high arsenic concentrations at depth (up to 955 mg/kg), but the arsenic concentrations in shallow samples generally ranged from below detection to 150 mg/kg. The Powell Vista core was entirely composed of valley-fill sediments. The Fairmont core consisted primarily of valley-fill sediments and volcanic rock but the original sediment and rock was highly altered in most of the core. The majority of the arsenic concentrations in the Powell Vista and Fairmont cores were less than 5 mg/kg, with few arsenic concentrations exceeding 100 mg/kg in either core. Aqueous samples were collected from 80 wells and 6 springs. Correlation of the dissolved sulfate isotopic data ($\delta 34S$ and $\delta 18O$) suggests there are at least two separate geologic signatures for sulfur, which may indicate at least two geologic sources of arsenic. The geologic source areas include the English Gulch and Crackerville areas, which are supported by the core data. Most of the sulfate isotope data for the shallow domestic and monitoring wells plot within a general cluster that is likely indicative of surface or smelter derived sulfate and presumably arsenic. The three samples collected from wells in the Opportunity Ponds Repository area were isotopically ($\delta 34S$ and $\delta 18O$) distinct from the other samples and likely represent the sulfate isotopic signature of the water leaching from the repository. Evaluation of other water-quality parameters is ongoing.

Montana Oil And Natural Gas Activities Ambient Water Monitoring Program

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Due to heightened public concern over health effects associated with oil and natural gas development, and the potential for this development to adversely affect water quality in Montana, the Department of Environmental Quality (DEQ) began a surface water quality monitoring project in 2012. This monitoring project supports an ambient water quality monitoring program, which investigates baseline water quality and potential water quality contamination that may occur with new oil and natural gas extraction techniques, in the Lower Missouri and Yellowstone Basins. Contamination routes could potentially come from compromised well casings, mishandled hydraulic fracturing fluids, inadequate sewage systems (in terms of population served), or associated transportation and industrial processes associated with an increase in oil and natural gas development. This project will investigate baseline conditions in small watersheds where oil and natural gas development are occurring, using a targeted station approach. Pollutants associated with oil and natural gas development will likely disperse to low levels in surface waters if they are present; therefore the project targets areas of heavy development. Limited resources lead to an approach where a broad array of pollutants is analyzed at relatively few targeted monitoring sites where pollutants associated with oil and natural gas development have the highest probability of detection. This poster identifies sample site locations and water quality parameters analyzed for the project. No results are presented at this time. During 2014, DEQ will begin an additional ground water sampling project in areas of ongoing oil and natural gas development in eastern Montana. The ground water monitoring effort focuses on an alternate set of water quality analyses than the surface water monitoring program. Due to limited resources and the need to assess public health risks, DEQ is using a risk-based design similar to the surface water quality monitoring project for ground water monitoring site selection. Along with the surface water monitoring plan, this poster reviews some of the risk-based selection criteria that DEQ will use for selection of ground water monitoring sites.

Long-Term Stream-Flow Trends In In The Bitterroot River Watershed, Montana

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Development of groundwater disrupts the natural flow of water into and out of an aquifer. Groundwater removed from the system must be balanced by a decrease in groundwater storage and some combination of increased recharge and/or decreased groundwater discharge. The combination of increased recharge and decreased discharge in response to pumping is termed capture. Usually ground-water discharge (rather than increased recharge) is captured during development (Bredehoeft, 2005). Groundwater supplies most of the municipalities and private residences in the Bitterroot watershed. Records from the Groundwater Information Center (GWIC, http://mbmggwic.mtech.edu/) show a more than eightfold increase in the number of wells (mostly private domestic, or exempt wells) installed in the watershed between 1970 and 2012. The well density for the entire watershed is approximately 7 wells per square mile and the density on private land is approximately 30 wells per square mile. These are some of the highest well densities in the state, and make this watershed ideal for evaluating the long-term impact of exempt wells on surface water supplies. To assess the impact of groundwater development on river discharge, long-term stream flow from the Bitterroot River Watershed (USGS gauge 12352500) was analyzed using the Exploration and Graphics for River Trends (EGRET) model developed by R.M. Hirsch and L.A. De Cicco at the USGS. This program uses seasonal trend analysis and Loess smoothing to compute flow statistics (daily maximum, daily median, daily mean, and 7-day minimum) for a stream-flow time series, and assesses long-term trends in the datasets (Hirsch and De Cisso, 2012). Baseflow in the watershed was determined as stream discharge during the period of time (Dec-Feb) when the vast majority of discharge is due to groundwater discharge. Although there are more than 20, 000 wells in the Bitterroot Valley, groundwater use has not produced measurable impacts, on a basin-wide scale, to Bitterroot River baseflows or stream flow. Long term trends in stream flow show an increase in baseflow during the winter months and on an annual basis for the high, median, and low flow statics over the past decade. The timing of increased development of groundwater resources (1970-2012) also does not coincide with an overall decrease in stream flow in the Bitterroot River. The trends in stream flow appear to be highly correlated to precipitation records and relatively uncorrelated with increased groundwater development in the watershed.

Effect Of Sedimentation And Sediment Pore Water Chemistry On Water Quality In A Small Beaver Pond

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Historic smelting activities by the Anaconda Copper Mining Company's smelter in Anaconda emitted large quantities of metals and metalloids into the air, much of which fell to the ground downwind of the smelter. The Mill Creek drainage, located southeast of Anaconda, MT, was often downwind of the smelter and in close proximity to the smelter, and therefore was drastically impacted by the fallout of metals and metalloids. Chemical concentrations in Mill Creek and its tributaries often exceed of Montana surface water-quality standards for the metals and metalloids. Storm water runoff carries these contaminants into the streams; some of the contaminants are in a particulate form that settles to the bottom in depositional areas and contaminates the stream sediments. A small (0.1 Ac) beaver pond on Cabbage Gulch, a tributary to Mill Creek, was investigated to assess its impact on metal and metalloid (arsenic, cadmium, copper, lead and zinc) concentrations in the stream. The hypothesis was that the beaver ponds would act as sedimentation basins and reduce the particulate metal load in the creek. Automatic samplers collected water samples from Cabbage Gulch above and below the pond during storm water runoff events in the late spring and summer of 2013. The samplers were triggered by rising stream levels and samples were collected hourly for five hour after activation. These samples were analyzed for total recoverable and dissolved metals. Flow rates were measured and recorded at both monitoring stations as well. The flow rates and metal concentrations were used to calculate metal loads into and out of the pond, and the fraction of the influent load removed by the pond was calculated. In addition, sediment pore water chemistry samplers (peepers) were installed in the pond. The peepers collected samples that could be analyzed for the five contaminants of concern, as well as pH, Eh, hydrogen sulfide, ammonia, alkalinity and phosphorus. The pore water concentrations and their distribution over depth were used to calculate fluxes of the contaminants into the pond water. This work is being funded by the Montana Natural Resources Damages Program. The information obtained in this project can be used to determine if beaver ponds are a solution or partial solution to improving water quality so that there are fewer surface water quality exceedences in Mill Creek and its tributaries.

Hydrogeologic Framework Of Cascade And Teton Counties, Montana

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Hydrogeologic Framework of Cascade and Teton Counties, Montana James P. Madison Montana Bureau of Mines and Geology Montana Tech of The University of Montana 1300 W. Park Street Butte, MT 59701 The Cascade-Teton Ground-Water Characterization Area includes all of Cascade and Teton counties encompassing about 5, 000 square miles in north-central Montana. Cascade and Teton counties lie within the transition between the Great Plains and Rocky Mountains, and contain topographic elements of both. Most of the area is characterized by gently sloping plateaus and terraces that are bordered by the Little Belt and Adel mountains to the south and Disturbed Belt of the Rocky Mountains to the west. Sedimentary rocks from Mississippian through upper Cretaceous are exposed in the area, as well as Eocene intrusive, and upper Cretaceous volcanics rocks. These bedrock units are overlain in places by unconsolidated Quaternary or Tertiary age deposits. The structural setting is controlled by the Sweet Grass Arch, a broad northwest-plunging anticline whose axis extends through the middle of the study area, and the Disturbed Belt along the northwest border. More than 100 geologic units have been mapped in the area; for this investigation, they have been combined into 12 hydrologic units based on water-bearing characteristics. Regional bedrock aquifers include the Madison Group (Mmu), the Kootenai Formation (Kk) and the Telegraph Creek-Virgelle formations (Kvt). The Madison and Kootenai supply water to wells mostly in the Great Falls area; the Telegraph Creek–Virgelle supplies water to wells mostly in its outcrop area along the Rocky Mountain Front. These three hydrologic units supply water to about 30% of the 7, 300 wells in the two counties. Older, pre-Madison Groups rocks, and the Cretaceous shale units are generally not aquifers. However, the Colorado Group (Kcg) shale, which underlies 43 percent of the study area, does supply water to about 740 (10%) of the wells. Unconsolidated sediments including alluvium along modern channels and flood plains, alluvial terraces, glacial outwash, glacial till, and Glacial Lake Great Falls silt and clay have been combined into three hydrologic units based on grain size and water-bearing characteristics: Quaternary course-grained sediment (Qsc), Quaternary—Tertiary course-grained sediment (QTsc), and Quaternary fine-grained sediment (Qsf). About 3, 560 (50%) of the wells are completed in these three units.

Geologic Constraints On The Geochemistry Of Acidic And PH-neutral Pit Lakes In Butte, Montana

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The Berkeley Pit lake in Butte, Montana is well-known as a worst-case scenario in terms of the spectrum of water quality in flooded, open-pit metal mines. However, little has been written about surface water with near-neutral pH and relatively low metal concentrations in an adjacent Cu-Mo open pit, referred to as the Continental Pit, which is currently active. During the period 2001-2003, dewatering pumps in the Continental Pit were temporarily shut off and two small lakes formed. Also during this time, water quality samples from the lake were collected monthly by the Montana Bureau of Mines and Geology. The purpose of this study is to describe the geochemistry of these water samples, to compare to the adjacent Berkeley Pit lake, and to place this information within the context of the bedrock geology and mining history of the Butte district. Some of the more important characteristics of the water quality data for the Continental Pit lake in 2002-2003 include the following (values in parentheses are 2-year averages): 1) the lake had near-neutral pH (7.3±0.5) with significant alkalinity (120±40 mg/L $CaCO_3$); 2) the specific conductivity averaged near 2000 μS/cm, with major ions dominated by Ca^{2+}, SO_4^{2-} and HCO_3^-; 3) average trace metal concentrations were as follows: Cu (0.62 mg/L), Fe (0.05 mg/L), Mn (3.4 mg/L), Mo (0.69 mg/L), and Zn (3.6 mg/L). Based on geochemical modeling, the Continental Pit waters are near equilibrium with a number of carbonate, sulfate, and molybdate minerals. The above data show a stark contrast between the acidic and metal-rich Berkeley Pit lake and the near-neutral, metal-poor Continental Pit lake. The main reason for these differences is geological. Whereas the Berkeley Pit mined highly-altered granite rich in pyrite with no neutralizing potential, the Continental Pit is mining weakly-altered granite with lower pyrite concentrations and significant concentrations of hydrothermal carbonate minerals. New samples have been collected and are being analyzed for stable isotopes of water, S and C to further understand the processes controlling the chemistry of the Continental Pit lake.

Groundwater And Lake Interactions At Georgetown Lake, MT

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Georgetown Lake is a highly recreated shallow lake located in southwestern Montana. The Georgetown Lake area has experienced population and recreation increases over the past few decades and therefore interest in quantity and quality of the Lake have arisen. This study presents a geochemical investigation that builds on our previous conceptual understanding of how groundwater interacts with the lake. The Georgetown thrust fault splits the lake with west dipping Paleozoic carbonates to the east and west dipping Precambrian metasedimentary rocks to the west. Previous studies show that groundwater enters the lake through the carbonates near the perimeter of the lake. However, these studies 1) do not investigate groundwater inflows to the lake interior, 2) show no indication of groundwater outflows from the lake, and 3) could not quantify groundwater inflow or outflow rates to and from the lake. To address these three concerns we sampled lake, surface water, and groundwater for major ions, radon, and water isotopes (δD and $\delta^{18}O$). We used radon to map groundwater inflows to the interior of the lake. Results show inflows occur from the eastern boundary to about halfway to the thrust fault. Stable isotopes of lake water and groundwater were used to investigate groundwater recharge from lake seepage through bedrock. Groundwater wells around the lake perimeter show that the water has undergone little to no evaporation, while Georgetown Lake water shows significant evaporation. However, springs discharging down gradient to the west of the lake show a similar evaporation signal to the lake samples, suggesting that the lake recharges groundwater through the westward dipping bedding planes and fractures. Monthly surface water inflows and outflows, lake stage, evaporation, and precipitation were used in a physical mass balance to determine the net gain or loss of groundwater from the lake. Stable isotopes and major ions were collected monthly from all major inflows and outflows to use a chemical mass balance to separate and quantify groundwater inflows and outflows.

Stream Losses To Carbonate Bedrock Along Dry Fork Belt Creek, Little Belt Mountains, Montana

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This poster will describe measurements of discharges to bedrock from Dry Fork Belt Creek, a large, ephemeral stream in central Montana. The stream flows as much as 140 cubic feet per second (cfs) during spring runoff, but by late summer the downstream portion dries up completely. A seepage run was conducted on the Dry Fork of Belt Creek during base flow in September 2012 to locate gaining and losing reaches. Discharge measurements were taken at 15 main stem stations and 10 tributaries. One minor and one major losing reach were identified and one minor gaining reach was found. The major losing reach occurred where the stream bed was bedrock of Jefferson dolomite with minimal to no alluvium. At base flow, the entire flow of 5 cfs was lost to bedrock. Supplemental gaging along the main stem of Belt Creek north of Monarch found a loss of 12 cfs to Madison limestone bedrock in Sluice Boxes canyon. The Little Belt Mountains uplift includes numerous streams where major losses to carbonate bedrock occur, representing a major recharge area for Madison and Devonian aquifers in central Montana.

Hydrogeology Of The East And West Benches Of Rock Creek Near Red Lodge, MT

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Hydrogeology of the East and West Benches of Rock Creek near Red Lodge, MT The East Bench and West Bench of Red Lodge Creek are relatively flat north-sloping land surfaces that parallel Rock Creek from above Red Lodge to about Boyd, Montana. The benches are underlain by very coarse gravel deposits, that when saturated form the most easily accessible and typically reliable source of ground water in the area. Residents of this part of Carbon County are dependent on the alluvial aquifer system underlying the benches as the primary or only source of ground water. This project was driven by concerns of residents and the agriculture community that land –use changes will negatively impact water resources of the area. Bedrock units underlying and surrounding the valley primarily consist of interbedded layers of sandstone and mudstone of the Fort Union Formation. The Linley Conglomerate and Tongue River Member underlie the benches near Red Lodge. Downstream of Roberts the Lebo Shale Member underlies the benches. In many locations the bedrock (in particular the Lebo Shale) is an unreliable aquifer because of low yield potential and/or poor water quality. In general, the availability and quality of bedrock ground water decreases significantly downstream. The East and West benches of Rock Creek are underlain by alluvial deposits overlying the Fort Union Formation. The sand and gravel alluvium underlies multiple terrace levels. The alluvial aquifer system is shown to be primarily recharged by flood irrigation and canal leakage. Isotope data shows that irrigation water from Rock Creek is primarily derived from high-altitude snow melt and contains low total dissolved solids. Changes in the source, quantity and quality of the recharge may degrade the availability and quality of ground water. Ground-water from the alluvial aquifers underlying the benches discharge into small streams and drains and then eventually into Rock Creek. Recent development of water resources and land–use change from agricultural to residential has dramatically increased the total number of water wells since the 1980's. Changes in land use are shown to significantly alter the hydrologic system and should be addressed by natural resource managers prior to significant development. This poster documents the hydrogeology and historic water-level trends and speculate on causes of these trends.

Estimating Gaining And Losing Reaches Of The Boulder River Using Geochemical Modeling

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Reaches of the Boulder River between Boulder and Cardwell, Montana, often run dry during the late summer, causing problems for farmers and ranchers who depend on the river for irrigation and stock water. Some of these reaches of the Boulder River are gaining groundwater, while other reaches are losing to groundwater. It is also apparent that the most significant reaches of groundwater gains occur where alluvial materials thin and narrow just above bedrock pinch points. If modifications to water management practices are introduced, their effectiveness will depend on the distribution of these gaining and losing reaches. Geochemical modeling can simulate mixing, dilution, concentration, precipitation and dissolution. The results of this modeling can be used in conjunction with physical flow measurements to aid in understanding how the system functions, and particularly the geographic distribution and magnitude of gains and losses. Inverse geochemical modeling using the computer code PHREEQC and a geochemical mass balance approach were used. The PHREEQC model was constrained to use only minerals occurring in the geologic materials of the watershed. Geochemical modeling shows that the observed surface water compositions cannot be reconstructed by simply mixing surface water inputs, thus surface-water/groundwater interactions, as well as rock/water interaction play a significant role in determining the eventual chemical composition of the stream water.

A Bayesian Approach To Quantifying The Winter Precipitation In The Mountainous Terrain Of Western Montana

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Understanding winter precipitation in remote, mountainous terrain is critical to evaluating water resources within Western Montana. Hydrologic models used to analyze snowpack, soil moisture, stream discharge, and evapotranspiration are driven by precipitation estimates that oftentimes exhibit disagreements among various development approaches. Empirical approaches, based on observations collected at the point scale, can be biased due to gage inaccuracies and under-representation; while mechanistic approaches, such as physically-based climate models, can be biased due to parameter uncertainty and errors in the boundary conditions. If these biases are not controlled, estimation of the regional water balance can be compromised. In this study, we present an approach to quantify the contribution of observational bias and model bias to the total bias existing in our regional estimates of precipitation. We use a bias aware optimal interpolation method based on Bayesian inference to investigate winter precipitation over the complex terrain of Western Montana. Using this method, we assimilate SNOTEL precipitation data with regional climate model output (The Weather Research and Forecasting [WRF] model) for years 2000-2010. WRF is forced using the NCEP FNL reanalysis product and data is downscaled to 4km resolution. Initial results indicate we may be experiencing higher amounts of precipitation in the mountains than our observations suggest. We discuss whether this enhanced snowpack could be going undetected by our observational network through the analysis of uncertainty in the assimilated dataset. Finally, we suggest a method that could potentially be used to fully delineate the biases associated with observations from the biases associated with the regional climate model; thus providing a more accurate climate dataset to be used as forcings for future hydrologic studies.

Groundwater Modeling Of The Four Corners Study Area Gallatin County, Montana

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A numerical groundwater flow model was developed as part of the Four Corners Groundwater Investigation project (Michalek and others, in preparation). The primary purpose of the research project was to evaluate the effects of the conversion of irrigated agricultural land to residential and commercial uses on the groundwater flow system and subsequently to local stream flows. Urbanization and evolving water uses precipitated a Gallatin River Basin-wide water-level evaluation in the 1990's by the U.S. Geological Survey (Slagle, 1995). Slagle concluded that little-to-no decline in water levels had occurred over the preceding 40 years. However, the increasing rate of growth and land-use change through the first decade of the 21st century compelled a new study. The accompanying numeric model will aid in understanding the hydrologic system in addition to predicting future changes. The three-dimensional finite-difference model domain encompassed the Four Corners area west of Bozeman. The model design was based on a conceptual model of the study area that was developed from this study and previous research, analysis of water budget components, drilling data and aquifer testing wells logs, and surface water flow and stage measurements. Streams and canals interact with groundwater in the model interior, and precipitation and irrigation contribute aquifer recharge in the model. Four scenarios were simulated following calibration of the transient model. Three of these were predictive scenarios that modeled possible future changes in stress on the system 1) a decrease in source-water recharge to the overall system; 2) expansion of urban development (with decreasing agricultural use); and 3) a hypothetical aquifer storage and recovery system. A fourth scenario attempted to replicate the historic system as described in 1960 by the USGS (Hackett and others, 1960). The model results showed little change in water table elevations, though the overall groundwater flow volume changed significantly as future stresses were increased. The model results agree with the other study findings that, although groundwater elevations have not significantly changed, the groundwater flow system is highly dynamic and individual stresses likely have a greater impact than can be discerned from static water levels. If climatic conditions cause reduced flow entering the Four Corners area, and development continues to intensify demand on groundwater and decrease agricultural recharge, flow through the aquifer will continue to decrease.

Helena Area Ground Water Project

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The Helena Area Ground Water Project was implemented from July 2009 through September 2012 with general objectives to characterize baseline nutrient concentrations in ground water, evaluate potential sources of nutrients in local waters, and evaluate the interaction of surface and ground water. The project incorporated 6 ground water sampling events from the 25 monitoring wells in the Lewis and Clark Water Quality Protection District (LCWQPD) network; and 3 sampling events from 11 shallow piezometers installed adjacent to surface water monitoring locations. Additional data was obtained from the Montana Bureau of Mines and Geology (MBMG) studies in the area, and the Ground Water Information Center (GWIC) database at MBMG. The final project report compiled water quality, water temperature, water levels and isotope datasets and is available online at the LCWQPD website (http://www.lccountymt.gov/health/water-quality.html). Major ion data were used to classify ground water types in the area, identifying two major water types, and several minor types. Locally recharged waters, present from direct infiltration of precipitation and from water loss from streams and irrigation canals, are predominantly a Calcium-Magnesium/Bicarbonate water type. In the northeastern and southeastern parts of the Helena Valley, ground water is predominantly a Sodium-Potassium/Sulfate-Bicarbonate water type. Ground water temperatures generally increase with depth based on the geothermal gradient. The local gradient was determined using temperatures measured in background wells in the hills north and west of the valley. Ground water temperatures along the eastern side of the Helena Valley are elevated above normal. Ground water temperatures combined with water quality data in the valley wells indicate areas where locally recharged ground waters mixes with deeper ground waters, characterized by a mixed major ion chemistry and temperatures above those expected by the geothermal gradient. The project ground water isotope assessment utilized two isotope pairs. Oxygen and hydrogen isotopes of water were utilized as a conservative tracer to help delineate flowpaths from surface recharge; however, the limited dataset was not sufficient to evaluate seasonal trends. The results are consistent with conclusions derived from other datasets. The second isotope pair, nitrogen and oxygen isotopes of dissolved nitrate in ground water, were utilized to characterize potential sources of nitrate. The nitrate isotopes indicate that the majority of detected nitrate is from an animal source – either agricultural animal waste or from septic systems discharging to ground water. Agricultural fertilizer is the additional source identified with this method. The combined datasets show results consistent with the conceptual model of the Helena Valley Aquifer hydrogeology, as streams gain flow in bedrock areas with little alluvium upgradient from the valley, lose water to ground water where they enter the valley, and again gain flow from ground water as they approach the center of the valley. Nutrient loading to local ground water is most evident in the areas around the valley margins where Silver Creek, Tenmile Creek and Prickly Pear Creek enter the valley.

Interaction Of Groundwater And Surface Water In The Williston And Powder River Structural Basins

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Groundwater availability in the Lower Tertiary and Upper Cretaceous aquifer systems in the Williston and Powder River structural basins is currently being assessed by the U.S. Geological Survey (USGS). The Williston basin is located in parts of North Dakota, South Dakota, and Montana in the United States and Manitoba and Saskatchewan in Canada. The Powder River basin is located in parts of Montana and Wyoming. Both structural basins are in the forefront of energy development, with an increased demand for both surface water and groundwater uses. As part of this study, the interaction between groundwater and surface water is being quantified. Estimates of base flow, gaining streams, sinking streams, and reservoir interactions have all been computed. Streamflow records from more than 300 streamgages available in the USGS National Water Information System database were used in conjunction with the hydrograph separation software, PART, developed by the USGS. To eliminate interference from natural and anthropogenic processes associated with measuring streamflow, only fall estimates of base flow were used in the study. A net balance approach was used along stream reaches where streamgages were located. Base-flow estimates from PART were compared to actual streamflow measurements. The streamflow estimates were used in the final quantification of the interactions. A water budget for each mainstem reservoir along the Missouri River was completed using data from the U.S. Army Corps of Engineers. Most of the streams in the study area are gaining flow from the aquifers, whereas the main-stem reservoirs are recharging or contributing water to the underlying aquifers. This information has been published as a M.S. Thesis at the South Dakota School of Mines and Technology and can be obtained at the project web site: http://mt.water.usgs.gov/projects/WaPR/

A Comparison Of Groundwater Recharge Estimation Methods In The Williston And Powder River Structural Basins

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The water-table fluctuation (WTF) and chloride mass-balance (CMB) methods were used as a comparison to a numerical soil-water-balance (SWB) model to estimate groundwater recharge in the Williston and Powder River structural basins in the Northern Great Plains. Recharge was estimated for glacial deposits and exposed areas of the Lower Tertiary and Upper Cretaceous aquifer systems in Montana, the Dakotas, Wyoming, Saskatchewan, and Manitoba. The WTF and CMB methods were applied to local areas with available groundwater-level and chloride data. The SWB model consisted of 1 km2 grid cells across the entire study area. The WTF method uses easily accessible groundwater-level data to estimate groundwater recharge under the assumption that rises in unconfined groundwater levels are a result of recharge from precipitation. For this assumption to be valid, only recharge to unconfined aquifers can be estimated by this method. Recharge is then calculated by multiplying the specific yield of the aquifer by the change in water level. The CMB method determines the rate of recharge to an aquifer based on the chloride concentration in the groundwater and the rate of atmospheric chloride deposition. An assumption with this method is that all chloride in the aquifer is derived from atmospheric deposition, although other sources of chloride can be accounted for if known. Both the WTF and CMB methods inherently take into account mechanisms of flow through the unsaturated zone and are simple to apply. The SWB model is based on a modified Thornthwaite-Mather approach and is used to estimate recharge as infiltration below the root zone to each model cell on a daily time step. Inputs for the SWB model include daily precipitation and air temperature data, land-use classification, soil type, and surface-water flow direction for each model cell. The sources and sinks of water within each grid cell are determined by the SWB model on the basis of input data. Recharge is then calculated as the difference between the change in soil moisture and the flow rates of sources and sinks. This information has been published as a M.S. Thesis at the South Dakota School of Mines and Technology and can be obtained at the project web site: http://mt.water.usgs.gov/projects/WaPR/

Linkages Between Geomorphology, Geochemistry, And Aquatic Ecology In Mining-impacted Headwater Streams: Mike Horse Mine Complex, Upper Blackfoot River Basin, Montana

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Restoration of the form and function of mining-impaired streams requires understanding of linkages between geochemistry, geomorphology, and the accumulation of contaminants in ecosystems. Our goals were to provide a complete pre-restoration baseline as well as develop insights into linkages between the physical and chemical processes across the landscape and contaminant accumulation to inform restoration efforts. To develop such insights, we measured metals concentrations in water, fine sediment, invertebrates, and fish livers, as well as channel topography, bed material, and discharge, in 12 streams in the upper Blackfoot River basin, Montana, USA. We distributed study sites longitudinally along the mainstem Blackfoot River downstream from the primary source of metals, Mike Horse Dam, a tailings dam that failed in 1975 and is slated for removal; these sites were interspersed among natural wetland complexes. In addition, 4 study sites were located in nearby tributaries that were impaired by mining and 4 sites were in tributaries considered controls to determine background levels. In fine sediments, As, Cd, Cu, Pb and Zn concentrations near mining sources were very high, averaging 260, 14, 1200, 5000, and 3600 mg/kg, respectively. Most of these contaminants are effectively trapped by the wetlands, resulting in sediment concentrations below the wetlands at background levels of 15, 5, 100 and 62 mg/kg for As, Cd, Cu and Pb. Contaminant concentrations in water also decreased several-fold in a downstream direction as a result of dilution from tributaries and likely due to solid phase interactions in wetlands. As and Pb were near or below detection in many of the biotic samples, but Cu, Cd, and Zn concentrations were highest in interspecific invertebrate and fish at the upper mainstem site and decreased by a factor of >2.5 after the wetland complexes where they were approaching background levels. Thus, the general trend of decreasing contamination downstream, with large reductions at sites interspersed among wetlands, was also seen in food web components and had implications for the biotic community. Aquatic invertebrate density and richness increased with greater distance from the impoundment. In addition, there were stark contrasts in the relative abundance of metals tolerant taxa were evident between the samples collected above and below the wetland complex. Fish community composition changed downstream from the sources as well with native cutthroat trout only found in sites with lower metal concentrations. The physical and chemical processes determined by the landscape context are key variables determining the accumulation of metals and subsequent community composition and potential for restoration of the food web.

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