25th Anniversary

Montana Section of the American Water Resources Association
25th Annual Meeting

Water Sustainability: Challenges for Montana

October 2-3, 2008
Yellowstone Conference Center – Big Sky, Montana

PROCEEDINGS

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!

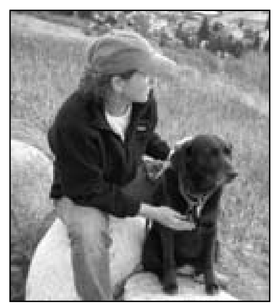
- **The AWRA Officers**
  Mike Roberts, President, Montana Department of Natural Resources and Conservation
  Camela Carstarphen, Vice President, Montana Bureau of Mines and Geology
  Kirk Waren, Secretary / Treasurer, Montana Bureau of Mines and Geology

- **Montana Water Center, Meeting Coordination**
  Gretchen Rupp, Director
  Steve Guettermann, Director of Outreach
  Nancy Hystad, Office Manager

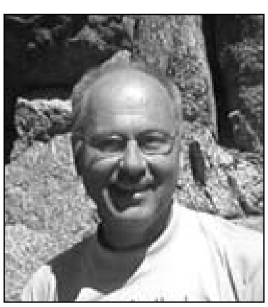
- **Our Generous Sponsors (please see next page)**
  KirK Environmental LLC, Montana Department of Natural Resources and Conservation, Montana Bureau of Mines and Geology, Montana Department of Environmental Quality, Oxbow, Inc., Hydro Solutions Inc. and the Montana Water Center.

And especially, the many dedicated presenters, field trip leaders, moderators, student presentation judges, and volunteers

Mike Roberts



Camela Carstarphen



Kirk Waren

Steve Guettermann

25th Anniversary

Montana Section of the American Water Resources Association 2008 Conference

Water Sustainability: Challenges for Montana

A special thanks to our generous conference sponsors!

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Montana AWRA

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Water Sustainability: Challenges for Montana

October 2-3, 2008
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AGENDA

WEDNESDAY, OCTOBER 1, 2008

7:00 pm – 9:00 pm ON-SITE REGISTRATION - Yellowstone Conference Center, Big Sky (Upper Atrium, near the Dunraven/Obsidian rooms)

8:00 pm MOVIE - *Dimming the Sun*, Amphitheatre

THURSDAY, OCTOBER 2, 2008

7:00 am – 5:00 pm ON-SITE REGISTRATION - Yellowstone Conference Center, Big Sky
Preconference registration available at water.montana.edu/awra/registration/default.asp

FIELD TRIP

7:50 am Board buses. Buses leave promptly at 8:00 a.m.!

8:00 *Geology of the Big Sky Area* - Larry N. Smith, Geologist, Montana Bureau of Mines and Geology (MBMG)

12:00 pm Buses arrive back at Huntley Lodge - Lunch on your own

OPENING PLENARY — *Jefferson Room*

1:00 **Welcome and Introductions** - Mike Roberts, Montana Section of the American Water Resources Association (MT AWRA) President
Water Center Welcome - Gretchen Rupp, Director, Montana Water Center
Logistics and Announcements, Introduction of Richard Opper - Cam Carstarphen, Montana Section of the American Water Resources Association (MT AWRA) Vice President

1:15 **Keynote Speaker** - Richard Opper, Department of Environmental Quality (DEQ) - *25-year Perspective on Montana Water Issues: What is Sustainability?*

Technical Presentations:

2:00 Eloise Kendy, The Nature Conservancy (TNC) - *Instream Flows: Montana vs. the World*

2:30 Tom Osborne, HydroSolutions - *A 25-year Perspective on Sustainability Issues: The Challenges We Face With Answering Water Quality and Water Quantity Concerns in Our Developing Landscape*

3:00 BREAK

3:30 Tom Patton, Hydrogeologist, MBMG, Butte - *Towards A National Ground-Water Monitoring Network*

4:00 Larry McKay, GSA Birdsall-Dreiss Distinguished Lecturer - *Germs and Geology*

5:00 ADJOURN

5:30 **Poster Session** (see poster list on following page) — ***Upper Atrium and Lamar/Gibbon Rooms***

BANQUET — *Jefferson and Madison Rooms*

7:00 **Banquet**

7:45 25 Year Celebration of Montana AWRA: An Oral and Pictoral History - Cam Carstarphen

Special Presentations:
Montana Water Legend Award
Montana AWRA Photo History Show

9:00 Announcements

POSTER SESSION - 5:30 pm ***Upper Atrium and Lamar/Gibbon Rooms***

1. Galena Ackerman, Research Technician, MSU-Bozeman. *Mineral Weathering as a Source of Nutrients to the West Fork of the Gallatin River, MT.*
2. Julie Ahern, Assistant Research Hydrogeologist, MBMG, Butte. *Stream-Depletion analysis in the Lower Beaverhead River Sub-basin: Expanding the Study Area.*
3. **S** Jessica Ahlstrom, (MSU). *Effects of Municipal Storm Water Runoff on Water Quality in Mandeville Creek.*
4. **S** Sabrina Behnke, (MSU). *Chlorine Susceptibility of Salmonella Typhimurium and Biofilm Detachment Characteristics.*
5. Bob Boyno, Electronic Data Solutions, Boise, ID. *Meeting Southern California's Water Demands with Innovative Recharge Practices.*
6. Rod Caldwell, Hydrologist, USGS, Helena. *Uranium and Other Radioactive Elements in Ground Water of Jefferson County, Montana.*
7. **S** Kevin Chandler (MTech): *Horse Creek Temprorary Controlled Groundwater Area: Defining the Recharge Area.*
8. Leif Cox, Assistant Professor, Geophysical Engineering, Montana Tech, Butte. *Use of Geophysical Methods for Remediation Investigation of Little McCormick Creek, Alberton, MT.*
9. Steve Custer, Associate Professor, Earth Science, MSU-Bozeman. *Spatial Distribution of Shallow Ground-water Response to Snow-melt, Precipitation, River Stage, and Irrigation in the Four Corners Area, Gallatin County, Montana.*
10. Gary Icopini, Research Hydrogeologist, MBMG, Butte. *Screening for Pharmaceuticals and Endocrine Disrupting Chemicals in Montana Ground Water.*
11. **S** Kelsey Jensco, (MSU). *Hydrologic Connectivity between Landscapes and Streams: Transferring Reach and Network Scale Understanding to the Catchment Scale.*
12. Amber Kirkpatrick, Research Associate, MSU-Bozeman. *Jack Creek Water Monitoring Project: An Uncommon Partnership with Remarkable Results.*
13. John LaFave, Associate Research Hydrogeologist, MBMG, Butte. *Elevated Sulfate and Nitrate Associated with the Boulder Batholith at the Headwaters of the Clark Fork Basin.*
14. **S** Able Mashamba, (MSU). *Challenges in Assessing Watershed Management Practices with a Semi-Distributed Environmental Model under Uncertainty.*
15. **S** Jessica Mason, (MSU). *Modeling the Potential for Transport of Contaminated Sediment from a Mine-Impacted Wetland.*
16. **S** Rebecca McNamara, (MSU). *In-Stream Nitrate Immobilization across Development Gradients, Ambient Nitrate Concentrations, and Stream Network Position in a Rapidly Developing Mountain Watershed.*
17. Rick Mulder, Hydrologist, MDA, Helena. *Ground Water and Surface Water Monitoring for Pesticides and Nitrate in the Beaverhead and Ruby Valley.*
18. Steve Parker, Associate Professor, Chemistry and Geochemistry, Montana Tech, Butte. *Diel Biogeochemical Processes; Stable Isotopes Variations of Dissolved Oxygen and Inorganic Carbon.*
19. Steve Parker, Associate Professor, Chemistry and Geochemistry, Montana Tech, Butte. *Temporal Variability of Dissolved Organic Carbon in the Big Hole River.*
20. Larry Smith, Research Geologist, MBMG, Butte *Altitude of the Top of the Madison Group, Cascade County.*

("S" indicates a student poster)

FRIDAY, OCTOBER 3, 2008

NOTE - Concurrent sessions 1A, 1B and 1C begin at 8 am and run through 10:20 am. Sessions 2A, 2B and 2C begin at 10:40 am and run through 12:30 pm.

SESSION 1A (8:00 - 10:20 am) *Jefferson Room*
SURFACE WATER

Moderator: Chuck Dalby, Department of Natural Resources and Conservation (DNRC)

8:00 am Eric Chase, Hydrologist, DNRC, Helena. *A Hydrologic and Temperature Assessment of the Dearborn River.*

8:20 Kimberly Chase, Hydrologist, CDM, Helena. *Manning's Equation Vs. HEC-RAS: A Comparison Of Methods On Cottonwood Creek, Deer Lodge, MT.*

8:40 **S** Victoria Balfour, (U of M). *The Effects of Fuel Type, Combustion Temperature, and Wetting on the Infiltration Characteristics of Wildfire Ash.*

9:00 David Nimick, Hydrologist, USGS, Helena. *An Empirical Method For Estimating Instream Premining PH And Dissolved Cu Concentration In Catchments With Acidic Drainage And Ferricrete.*

9:20 Katherine Chase, Hydrologist, USGS, Helena. *Determination Of Lateral Migration, Channel Incision, And Potential Channel Erosion On The Madison River At Quake Lake Outlet, Montana.*

9:40 **S** Lisa Bithell Kirk, (MSU). *In-Situ Subsurface Microbial Transformation Of Selenium As Source Control In Backfilled Phosphate Overburden, SE Idaho.*

10:00 **S** James Swierc, (U of M). *Missoula Valley Vadose Zone Stratigraphy And Geologic Conceptual Model.*

10:20 Break ***Upper Atrium***

SESSION 1B (8:00 - 10:20 am) *Madison Room*
WATER QUALITY

Moderator: Steve Parker, Montana Tech

8:00 am Steven Sando, Hydrologist, USGS, Helena. *Reconnaissance Of Organic Wastewater Compounds In The Treated Effluent Of The Helena Wastewater Treatment Plant And Prickly Pear Creek, Montana.*

8:20 **S** John Babcock, (MTech). *Diurnal Cycling Of Nutrients In A Hyper-Eutrophic Stream, Silver Bow Creek, MT.*

8:40 Christian Schmidt, Hydrologist, Montana Dept. of Ag, Helena. *Influence of irrigation recharge on groundwater nitrate-N on the Greenfields Bench, MT.*

9:00 Alan English, District manager, Gallatin Local Water Quality District, Bozeman. *River Rock Subdivision Area Ground Water Resource Assessment, Gallatin County, Montana.*

9:20 **S** Carrie Taylor, (MSU). *Selecting Plant Species To Improve Wastewater Treatment In Constructed Wetlands.*

9:40 Laura Fay, Research Scientist, Western Transportation Institute, Bozeman. *Ways In Which Winter Maintenance Practices Influence Water Quality.*

10:00 W. Adam Sigler, Water Quality Associate, Montana State University, Bozeman. *Armored Stanchion Cattle Water Access Effects on E. coli, Suspended Sediment, and Nutrient Loading to Spring Creeks.*

10:20 Break ***Upper Atrium***

("S" indicates a student presentation)

NOTE - Concurrent sessions 1A, 1B and 1C begin at 8 am and run through 10:20 am. Sessions 2A, 2B and 2C begin at 10:40 am and run through 12:30 pm.

SESSION 1C (8:00 - 10:20 am) ***Gallatin Room***
SUSTAINABILITY

Moderator: Martha Kaufman, Oxbow, Inc.

8:00 am Gerald Mueller, Clark Fork River Basin Task Force, Missoula. *Managing Montana's Water: Challenges To The Prior Appropriation Doctrine In The 21st Century By The Clark Fork River Basin Task Force.*

8:20 Rankin Holmes, Montana Water Trust, Missoula. *ReWatering Prickly Pear Creek In The Lake Helena Watershed.*

8:40 Chris Brick, Clark Fork Coalition, Missoula. *Low Flows, Hot Trout: Climate Change In The Clark Fork Watershed.*

9:00 David Shively, Professor, Geography, University of Montana, Missoula. *Montana's Clark Fork River Basin Task Force: A Vehicle For Integrated Water Resources Management?*

9:20 Alice Stanley, Resource Development Bureau, Helena. *Montana Water Sustainability Project Funding Options.*

9:40 Gary Wiens, Environmental Engineer, DEQ, Helena. *Sustainability Strategies For Water Utilities.*

10:00 Break ***Upper Atrium***

SESSION 2A (10:40 - 12:30 am) ***Jefferson Room***
FLUVIAL GEOMORPHOLOGY

Moderator: Katherine Chase, United States Geological Survey (USGS)

10:40 Sean Lawlor, USGS, Helena. *Techniques And Equipment For Sampling Large Rivers At Near-Bankfull Conditions: A Case Study Of The Kootenai River Tributaries, Montana, Spring 2008.*

11:00 Stephen Holnbeck, USGS, Helena. *Observations On The Sediment Dynamics Of Selected Tributaries To The Kootenai River, Montana, Spring 2008.*

11:20 **S** Tyler Smith, (MSU). *A Flexible Modeling Framework For Rainfall And Snowmelt.*

11:40 Willis Weight, Professor, Hydrogeology, Montana Tech, Butte. *The Hydrogeology Of First Order Riparian Drainages.*

12:00 pm Karin Boyd, Applied Geomorphology, Inc., Bozeman. *The Geomorphic History Of Grayling Creek Near West Yellowstone, Montana: Influences Of The 1959 Hegben Lake Earthquake On Channel Form And Process.*

12:20 Martha Kauffman, Oxbow, Inc., World Wildlife Fund, Bozeman. *In Search Of High Functioning Small Prairie Streams.*

NOTE - Concurrent sessions 1A, 1B and 1C begin at 8 am and run through 10:20 am. Sessions 2A, 2B and 2C begin at 10:40 am and run through 12:30 pm.

SESSION 2B (10:40 - 12:30 am) *Madison Room*
GROUND WATER

Moderator: Steve Custer, Montana State University (MSU)

10:40 John LaFave, Associate Research Hydrogeologist, MBMG, Butte. *Incidental Recharge In Montana.*

11:00 Ian Magruder, Kirk Engineering & Natural Resources, Missoula. *The Ruby Groundwater/Surface Water Interaction Modeling Project: Evaluating Connections Between Water Management And River Flows.*

11:20 Ginette Abdo, Assistant Research Hydrogeolgist, MBMG, Butte. *Ground Water And Surface Water In A Study Area Within The Upper Big Hole River Basin.*

11:40 **S** Antony Berthelote, (U of M). *Field Observations And Groundwater Modeling As Tools To Mitigate Groundwater Supply Impacts During The Removal Of Milltown Dam, Western Montana.*

12:00 pm **S** Kevin Chandler, (MTech). *Shallow Aquifer Response To Phreatophye Water Use: A Comparison Of Different Vegetation Types.*

12:20 Curtis Link, Professor, Geophysical Engineering, Montana Tech, Butte. *Time Lapse Seismic Refraction For Monitoring Zones Of Water Table Fluctuation.*

SESSION 2C (10:40 - 12:30 am) *Gallatin Room*
MANAGEMENT AND ASSESSMENT

Moderator: Tammy Crone, Gallatin Local Water Quality District (GLWQD)

10:40 Mike Van Liew, Hydrologist, DEQ, Helena. *Streamflow, Sediment, And Nutrient Simulation Of The Bitterroot Watershed Using SWAT.*

11:00 **S** Sunni Heikes-Knapton, (MSU). *Subalpine Wetlands: Characteristics, Environmental Drivers, And Response To Human Perturbation And Restoration.*

11:20 Tim Mulholland, Lanyard Engineering, Billings. *Floating Treatment Wetlands - Multiplying Wetland Efficacy By 1000%.*

11:40 Jim Robinson, Water Resource Specialist, DNRC, Helena. *Yellowstone River LIDAR Mapping Applications.*

12:00 pm Boris Krizek, Environmental Engineer, Public Works Dept., Billings. *Municipal Impacts From The General Permit For Stormwater Discharges Associated With Small Municipal Separate Storm Sewer Systems (MS4s).*

12:20 Peter Skidmore, Skidmore Restoration Consulting, LLC., Bozeman. *Tools For Restoration Project Planning, Review, And Screening.*

CLOSING PLENARY *Jefferson Room*

12:40 ANNOUNCEMENTS - OFFICERS, PHOTO CONTEST AWARDS, STUDENT AWARDS

ADJOURN - HAPPY TRAILS!

1:30 MT Ground Water Assessment Steering Committee Meeting ***Dunraven/Obsidian Rooms***

KEYNOTE SPEAKER

Richard Opper

Director
Montana Department of Environmental Quality
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Richard Opper was appointed as Director of the Montana Department of Environmental Quality in 2005 by Governor Brian Schwietzer. Opper received a master's degree in Environmental Science in 1979 from Montana State University, where his research focused on mined land reclamation. As Director of the Montana DEQ, Opper oversees his department's work on superfund cleanups and ensuring that the state's air and water quality standards are met. He also has worked with citizens to develop a statewide climate change action plan, and has participated in national discussions of how to work with other states and Congress to reduce the country's greenhouse gas emissions.

Abstract of his presentation:
Over the past quarter century we have enjoyed some successes in the battles to protect Montana's water resources. Despite the many victories, our remaining state and federal Superfund Sites and acid mine drainage issues indicate we could have done better. As wonderful as it is to look back on 25 years of accomplishments for the organization, it's more important to look ahead to the next 25. It's essential to ask ourselves what legacies our inaction today may create for future generations. One of those legacies might be climate change. But another one closer to home may be the degradation of our surface and ground water resources by the proliferation of residential developments in Montana's western valleys and elsewhere around the state. So today's presentation will discuss some possible ways to address these development impacts on our precious water resources.

Eloise Kendy

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Eloise Kendy joined The Nature Conservancy in 2006. She works closely with governments, water resource managers, and NGOs to advance tools and policies for protecting and restoring environmental flows. Previously, Eloise conducted water-resource assessments and hydrologic modeling and provided public education and policy support for sustainable surface and groundwater management, primarily in Montana. She has worked independently and in the U.S. Geological Survey, the International Water Management Institute, and the U.S. Senate. Eloise holds a Ph.D. in Environmental Engineering from Cornell University, an M.S. in Hydrogeology from The University of Wisconsin, and a B.A. in Geological Sciences from the University of California.

Abstract of her presentation:

Instream Flows: Montana vs. the World

Increasingly, people and governments worldwide are recognizing the value of healthy lakes, rivers, and wetlands, and enacting policies to encourage economic development without compromising those inherent values. In many ways, Montana is a world leader in managing limited water resources for potentially conflicting uses. As the rest of the world struggles to catch up and, in some cases, surpass Montana's model, diverse solutions to water allocation and management problems are emerging. This presentation will highlight innovative approaches to managing water for people and nature in other states and countries, and compare and contrast them with recent advances in Montana.

Tom Osborne, P.H.

Principal Hydrologist
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Tom Osborne has 31 years of professional experience. He began practicing hydrology in Montana in 1976. Tom earned his Bachelor of Science Degree, Cum Laude, University of Wisconsin at Stevens Point, Forestry, Natural Resource Management in 1970. He went on to earn his Master of Science Degree at University of Wisconsin at Madison, Water Resources Management in 1974. Tom has successfully completed hundreds of hydrologic and environmental projects for private and governmental entities. He has worked throughout the Pacific Northwest and Upper-Midwestern United States. Tom conducts both surface water and groundwater investigations, and specializes in the application of physical and chemical methods and models to identify and solve water related issues. He is routinely engaged as a hydrology expert in civil actions and regulatory compliance cases. Tom's experience includes quantifying soil water balance, groundwater recharge, runoff, stream flows, soil loss, water chemistry, and point and non-point sources of contamination. He is experienced in conducting research and applications of best management practices to improve water quality. Recently, Tom has spearheaded large hydrology and water quality investigations into groundwater characterization and reclamation of hardrock mining operations, soil and groundwater evaluations around coalbed methane production in Montana and Wyoming, the fate and migration of contaminants in alluvial and fractured rock aquifer tests, and groundwater modeling. Tom is the author and co-author of numerous publications.

Abstract of his presentation:

A 25-year Perspective on Sustainability Issues: The Challenges We Face With Answering Water Quality and Water Quantity Concerns in Our Developing Landscape

Nearly 120 years after Montana's statehood, the concept of sustainable water use has begun to supplant that of limitless supplies. The author's retrospective view of some historic water issues suggests we have understood and remedied some, others continue to threaten, and new challenges loom. Questions over the sustainability of crop-fallow farming grew in the 1970s along with the increase in dryland saline-seep to over 200,000 acres across Montana's grain producing region. Erosion from irrigation wastewater discharge to Muddy Creek resulted in 200,000 tons/year of sediment delivery to the Sun River and Missouri River. These unsustainable practices have been successfully addressed with landowner-agency partnerships. New concerns over ag-land conversion and loss of aquifer recharge now emerge in the path of ex-urban development. Coal strip mining in southeastern Montana did not produce the degree of negative cumulative impacts to water quality which were feared in the 1970s. Coal bed natural gas development raised new issues of sustainability currently in the vortex of energy-agriculture-environmental policy making. In response, new state monitoring guidelines and ag-water quality studies have been implemented. Free-draining historic coal and hardrock mines discharging elevated acidity and metals (ARD) were recognized early as unsustainable, and extremely difficult to control with passive measures. New mine reclamation sustainability concerns have arisen over pit backfilling, post-reclamation ARD development and perpetual water treatment. Sustainable water issues in Montana's future include water storage in a drying climate, satisfying consumptive and recreation uses in the face of habitat loss, pharmaceuticals in groundwater and streams, and demands on our water rights system.

Tom Patton

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Thomas Patton is a senior research hydrogeologist with the Montana Bureau of Mines and Geology (MBMG) located in Butte, Montana. His research interests include relationships between long-term ground-water level records and climate, and systems to improve public access to ground-water data. Tom manages Montana's Ground-Water Assessment Program that includes ground-water characterization, long-term water-level and quality monitoring, and data distribution through Montana's Ground-Water Information Center.

Abstract of his presentation:

Towards A National Ground-Water Monitoring Network

The Advisory Committee on Water Information (ACWI), formed under a mandate by the U. S. Office of Management and Budget, is charged with improving the quality of and accessibility to water information necessary for natural-resource management and environmental protection decisions. In 2007 ACWI formed the Subcommittee on Ground Water (SOGW) to develop and encourage the implementation of a nationwide, long-term, ground-water quantity and quality monitoring framework. The framework is a data-collection/management plan, that when implemented, will provide data to assess the quantity and quality of the nation's ground-water reserves. The framework addresses: (1) data collection, (2) data quality and comparability, (3) data management, (4) network design, and (5) network implementation and operation. SOGW work groups have completed their draft chapters and SOGW has forwarded the framework document to ACWI.

The design of the National Ground-Water Monitoring Network (NGWMN) addresses important ground-water issues hierarchically. At the highest level are core questions about supply and quality that must be addressed at statewide, regional, and national scales. Questions in descendent levels address issues that require comparison of NGWMN data to increasing amounts of ancillary data.

The NGWMN will be a "network of networks" that utilizes existing monitoring to gather data from significant regional, state, and local aquifers. In conjunction with its own monitoring, each state or regional cooperator will submit qualified data to a central clearinghouse, or allow access to the data through portals. In that way data from all areas of the nation will become more easily accessible and useful to answer questions at regional (multi-state) and national scales. State or regional cooperators may also use the data to address questions at statewide or local levels. Sub-networks within the NGWMN will focus on three main areas. The primary

component will address the quantitative status of the nation's ground water. Surveillance monitoring will assess long-term trends in natural conditions and the effects of human activities. Targeted monitoring will evaluate the status of ground water determined to be at risk from depletion or contamination.

Larry McKay - 2008 Geological Society of America Birdsall-Dreiss Distinguished Lecturer

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Larry McKay, Jones Professor of Hydrogeology in the Department of Earth and Planetary Sciences at the University of Tennessee (UT), was selected as the 2008 Birdsall-Dreiss Distinguished Lecturer. The lecture tour is sponsored by the GSA Hydrogeology Division with travel funding provided by the GSA Foundation and The University of Tennessee.

Dr. McKay received a Bachelor's degree (1981) in Geological Engineering from the University of British Columbia. After working for five years as a consulting engineer in western Canada, he returned to graduate school at the University of Waterloo, where he received a PhD in Hydrogeology in the Department of Earth Sciences in 1991. His dissertation research investigated solute and colloid transport in fractured clay tills in Ontario, and he continued with this type of research during his post-doctoral studies with the Geological Survey of Denmark in 1992.

In 1993, Dr. McKay became an Assistant Professor (and later, Associate and Full Professor) at University of Tennessee. On arrival in Knoxville, he was faced with the problem of how to apply his research experience in glacial deposits to scientific problems in the non-glaciated terrain of the American southeast. Fortunately, he quickly noted the hydrogeological similarities between glacial tills and clay-rich saprolite, and began a series of field, lab and modeling studies of contaminant transport in fractured shallow saprolite at nearby Oak Ridge National Laboratory. This research later expanded to include investigations of occurrence and transport of pathogens and industrial chemicals in floodplain soils and streams. Dr. McKay developed strong collaborative ties with researchers at the UT Center for Environmental Biotechnology and the Department of Civil and Environmental Engineering, so that nowadays many of his graduate students spend as much time working with molecular microbiological methods (qPCR and gene sequencing) and stream gauging as they do with conventional hydrogeological methods. Dr. McKay has worked closely with the UT College of Social Work to help establish an Environmental Health and Justice Collaborative, which carries out research and provides community education for residents affected by industrial contamination in the Chattanooga Creek area of southeast Tennessee. Dr. McKay is also Leader of the Water Resources Group in the UT Institute for a Secure and Sustainable Environment and has served on a variety of national or international panels, including the Canadian Water Network's Pathogens-In-Groundwater Consortium. He was an Associate Editor for the Journal of Ground Water for six years and is a regular reviewer for several other journals.

Abstract of his presentation:

Germs and Geology: Emerging Issues in Waterborne Pathogen Research

This lecture will address how recent hydrological research and development of new analytical methods in molecular microbiology can combine to change how we detect, monitor and predict the exposure of human populations to waterborne pathogens. Much of our understanding of waterborne pathogen

occurrence and transport is based on conceptual models and investigative methods that have changed little in the past 30-50 years. Traditional paradigms for waterborne pathogens can be described with terms as simple as coliforms=pathogen-risk, surface-water=bad, groundwater=good, karst=bad, sand=good, true-groundwater=good, and groundwater-under-the-direct-influence-(GWUDI)-of-surface-water=bad. Recent investigations at UT and many other institutions challenge the existing paradigms. For example, a study of community water supply wells in karst aquifers in east Tennessee indicated that enteric viruses are common and can occur even in wells that don't exhibit other indicators of fecal contamination. Other studies at UT show that very rapid transport of bacteria and viruses can occur in fractured clay-rich sediments and in partially-saturated soils, both of which are settings where slow transport of pathogens is usually expected. There is a great need for additional field-based studies of pathogen occurrence and transport, as well as better collaboration between hydrologists, microbiologists and the public health community. Development of faster or easier to use microbial assays, as well as better sample collection and concentration methods, are providing hydrological researchers with improved tools to help carry out this research. Chief amongst these tools is the development of molecular assays, such as qPCR, which detect pathogens or other fecal microorganisms based on their DNA or RNA signature. Investigators at UT have developed a series of qPCR assays for Bacteroides (a major constituent of feces), which can be used to rapidly and inexpensively determine both the fecal concentration in a water sample and the likely source (human, cattle, horse, etc.). These assays have been used to delineate contaminant sources in watershed studies and have the potential for use in field experiments, allowing bacteria from different fecal sources to be traced throughout a flow system.

A Hydrologic And Temperature Assessment Of The Dearborn River

Eric Chase, Hydrologist, DNRC Water Resources, 1424 9th Ave., Helena, MT, 59620, (406) 444-0578, echase@mt.gov.

The Dearborn River Watershed is a 550 square mile basin located in Lewis and Clark and Cascade Counties in west-central Montana. During recent drought years, summer baseflows have not been sufficient to meet all demands on the Dearborn River. As a result, Montana Fish, Wildlife and Parks (FWP) identified the Dearborn River and its major tributaries as chronically dewatered. In addition, the Dearborn River appears on Montana's 2006 303(d) list for thermal modification. This project aims to characterize the surface water hydrology and temperature regime of the watershed using seven continuous flow and temperature monitoring sites, along with additional temperature monitoring sites throughout the watershed. Results from the first year of monitoring (2007) indicate surface water temperatures in the main stem of the Dearborn River are elevated enough to inhibit growth and propagation of salmonids. The 2007 data also identified periods of summer low flows, and provided estimates of irrigation withdrawals. The study will continue through 2009 with the goals of 1) creating a water balance for the entire system; 2) identifying gaining, losing, and dewatered reaches; and 3) defining how human-caused flow alterations affect thermal modification in the basin. Moderate flooding of the Dearborn River during May of 2008 resulted in the loss of monitoring equipment and has led to some minor project changes. An overview of the flooding event, 2008 data collection, and next steps for the project will also be presented.

Mannings Equation Vs. HEC-RAS: A Comparison Of Methods On Cottonwood Creek, Deer Lodge, MT

Kimberly Chase, Hydrologist, CDM, 50 W 14th St., Helena, MT, 59601, (406) 441-1429, chasekj@cdm.com.

Two common computational methods for analyzing flood hazards and estimating channel flow capacity are Mannings equation and the computer model HEC-RAS. Mannings equation is an empirical equation used to predict uniform flow in open channels. HEC-RAS is a hydraulic model based on the one-dimensional energy equation, which also utilizes Mannings equation. These approaches are sometimes seen as interchangeable, but in fact can produce very different results, especially when designing a new or modified channel. This presentation will explain why a change in modeling approach can yield such different results. Using the urbanized reach of Cottonwood Creek flowing through Deer Lodge, MT as an example, both methods are used to calculate the channel capacity and design an improved channel in a dense residential area. The resulting capacities and channel designs are presented to illustrate the differences between methodologies.

The Effects of Fuel Type, Combustion Temperature, and Wetting on the Infiltration Characteristics of Wildfire Ash.

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Severely burned landscapes are often covered by a layer of ash. The ash layer is generally considered to reduce post-fire infiltration either by clogging soil pores or by forming a low permeability crust on the soil surface, but only a handful of studies have actually documented such effects with field or lab measurements. In fact, an increasing number of studies have found that, at least in the short term, ash increases infiltration by storing rainfall and protecting the soil surface from rainsplash-induced surface sealing. Variability in the effect of ash on infiltration may reflect the influence of fire severity, fuel type and post-fire rainfall on the mineralogy and internal structure of ash, and resultant effects on ash porosity, water retention characteristics and hydraulic conductivity. However, these relationships have not been quantified. In an effort to address this research gap, we conducted a detailed analysis of ash samples generated in a muffle furnace using fuel from the three dominant tree species of western Montana ((Lodgepole Pine (Pinus contorta), Ponderosa Pine (Pinus Ponderosa) and Douglas Fir (Pseudotoga menziesii)) and at 100 deg C temperature increments from 300 to 900 deg C. A subsample of each ash specimen was saturated, left undisturbed for 24 hours and then oven dried at 105 deg C. Dry and wetted ash samples were characterized in terms of: particle size and shape (using a scanning electron microscope), carbon content, mineralogy (using X-ray diffraction), aggregate stability, porosity, water retention properties and hydraulic conductivity. Initial results indicate that the physical and chemical characteristics of ash vary considerably with combustion temperature but less so with fuel type. Wetting of ash results in the formation of large rosette-like crystals and precipitates of calcium-based compounds, and this leads to swelling of the ash and an associated reduction in porosity and hydraulic conductivity. These changes may explain why newly deposited ash absorbs water and increases infiltration, whereas older ash develops a surface crust that reduces infiltration.

An Empirical Method For Estimating Instream Premining PH And Dissolved Cu Concentration In Catchments With Acidic Drainage And Ferricrete

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Methods for assessing natural background water quality of streams affected by historical mining are vigorously debated. An empirical method is proposed in which stream-specific estimation equations are generated from relations between either pH or dissolved Cu concentration in stream water and the Fe/Cu concentration ratio in Fe-precipitates presently forming in the stream. The equations and Fe/Cu ratios for pre-mining deposits of alluvial ferricrete then were used to reconstruct estimated pre-mining longitudinal profiles for pH and dissolved Cu in three acidic streams in Montana (Fisher Creek and Daisy Creek near Cooke City and Swift Gulch near Landusky). Assumptions underlying the proposed method are that alluvial ferricretes and modern Fe-precipitates share a common origin and that the Cu content of Fe-precipitates remains constant during and after conversion to ferricrete. The method was evaluated by applying it in a fourth, naturally acidic stream unaffected by mining (Paymaster Creek near Lincoln), where estimated pre-mining pH and Cu concentrations were similar to present-day values, and by demonstrating that inflows, particularly from unmined areas, had consistent effects on both the pre-mining and measured profiles of pH and Cu concentration. Using this method, it was estimated that mining has affected about 480 m of Daisy Creek, 1.8 km of Fisher Creek, and at least 1 km of Swift Gulch. Mean values of pH decreased by about 0.6 pH units to about 3.2 in Daisy Creek and by 1 to 1.5 pH units to about 3.5 in Fisher Creek. In Swift Gulch, mining appears to have decreased pH from about 5.5 to as low as 3.6. Dissolved Cu concentrations increased due to mining almost 40 percent in Daisy Creek to a mean of 11.7 mg/L and as much as 230 percent in Fisher Creek to 0.690 mg/L. Uncertainty in the fate of Cu during the conversion of Fe-precipitates to ferricrete translates to potential errors in pre-mining estimates of as much as 0.25 units for pH and 22 percent for dissolved Cu concentration. The method has potential for use in monitoring remedial efforts at mine sites with ferricrete deposits. A reasonable remediation objective might be realized when the downstream pattern of Fe/Cu ratios in modern streambed Fe-precipitates corresponds to the pattern in pre-mining alluvial ferricrete deposits along a stream valley.

Determination Of Lateral Migration, Channel Incision, And Potential Channel Erosion On The Madison River At Quake Lake Outlet, Montana

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The 1959 Hebgen Lake earthquake caused a massive landslide which dammed the Madison River and formed Quake Lake. The U.S. Army Corps of Engineers excavated a relief spillway through the slide to permit outflow from Quake Lake. In June 1970, high flows on the Madison River severely eroded the channel through the landslide and washed out the roadway embankment along U.S. Highway 287 downstream from the landslide. Flooding and additional erosion also occurred in 1971. Based on several studies undertaken following these flood events, a streamflow of 3,500 cubic feet per second was determined to be a threshold beyond which substantial erosion could be expected. Since then, the owners of Hebgen Dam just upstream from Quake Lake have tried to manage releases from Hebgen Reservoir to prevent streamflows from exceeding 3,500 cubic feet per second at Quake Lake outlet. The Madison River is a blue-ribbon trout fishing stream, and the operation of Hegben Reservoir to minimize high streamflows has led to concerns about the potential for decreased removal of fine sediments on spawning beds downstream from Quake Lake. Further, the lack of recent erosion problems at the Quake Lake outlet and along the roadway embankment, even during the relatively high runoff years of 1996 and 1997, suggests that the channel is now armored and fairly stable and perhaps not as susceptible to erosion as it was in the early 1970s. Objectives of this ongoing project are to determine the amount of lateral erosion and incision of the river channel downstream from Quake Lake since 1972 and to provide hydraulic data so that reservoir and fisheries managers can determine whether the 3,500 cubic feet per second threshold streamflow is currently applicable. To accomplish these objectives, channel cross sections originally surveyed by the USGS in 1971 were re-surveyed in 2006 at approximately the same locations and compared to the original cross sections. Particle sizes of the bed and bank materials were also measured. A one-dimensional hydraulic model (HEC-RAS) will be used to analyze boundary shear stresses for various streamflows; these calculated boundary shear stresses will be compared to critical shear stresses to determine sediment-entrainment potential. In addition to the topographic surveys and the HEC-RAS simulations, meander migration rates will be calculated by comparing the stream centerlines from several aerial photographs between 1976 and 2006. Site-to-site comparison of entrainment potential, combined with meander migration rates from the aerial photographs, will provide a method to evaluate the relative effects of different streamflows on sediment entrainment and bank stability. These analyses can be used by reservoir and fisheries managers to evaluate whether the previously determined threshold streamflow is still appropriate for the Madison River downstream from Quake Lake.

In-Situ Subsurface Microbial Transformation Of Selenium As Source Control In Backfilled Phosphate Overburden, SE Idaho

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Selenium oxidation and dissolution associated with weathering mine waste has been recognized as a threat to water resources in Montana and other western states. In situ selenate reduction by indigenous microorganisms using native carbon in phosphate waste mined from the Meade Peak member of the Phosphoria Formation of Southeast Idaho offers a potential microbial ecology-based strategy for limiting selenium release through management of water and waste rock placement. Integration of microbial ecology into operational hydrogeochemical mine waste management practices presents new options for protecting water resources through improved source control of biogeochemically-mediated contaminants. Samples of groundwater and mine waste collected from three backfilled phosphate mines with distinct lithologic and hydrologic characteristics in SE Idaho were studied to identify organisms responsible for in situ subsurface selenate transformation and to evaluate the rate and extent of selenate removal. Samples were collected from sonic drill holes that were subsequently instrumented to allow ongoing monitoring of in situ oxygen, moisture, and temperature by mine operators. Primary variables influencing selenate reduction to insoluble elemental selenium include waste lithology, carbon speciation, water content, oxygen concentration, and temperature. Dechloromonas, a betaproteobacterium capable of coupling hydrocarbon oxidation to selenate reduction, is the dominant organism that been isolated from samples of backfill groundwater and mined rock using both cultivation and non-cultivation dependent methods. Microbes were cultivated and isolated using groundwater-based media containing varied carbon sources, including lactate, acetate, pyruvate, and soluble carbon extracted from waste samples using a bottle roll extraction, and incubated under microaerophilic conditions at a field relevant temperature of 10oC and 25oC. Colony PCR methods were used to amplify DNA that was then sequenced to identify Dechloromonas. Denaturing gradient gel electrophoresis was used to compare community-level diversity characteristics between mine sites and individual experiments. Most probable number (MPN) experiments indicate significant lithological influence on the number of selenate reducing organisms present in backfilled mine waste, and demonstrate low rates of selenate reduction under fully aerobic conditions. The number of selenate-reducing organisms present range from less than 102 microbes per gram of mine waste to greater than 105 microbes per gram in anaerobic MPN tests. In saturated waste microcosms under microaerophilic conditions, selenate reducing organisms removed more than 95% of soluble selenium at rates which varied significantly depending upon lithology, temperature and availability of oxygen. These variables can be influenced significantly through selective placement of mine waste and water management during operations, thus incorporating selenate reduction into mine waste facility design. Ongoing experiments that quantify levels of oxygen and moisture tolerance, as well as transformation rates, are planned to support conceptual facility designs.

Missoula Valley Vadose Zone Stratigraphy And Geologic Conceptual Model

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The geologic properties of the upper part of the unconsolidated valley fill material in the Missoula Valley of western Montana were evaluated as part of a study of the unsaturated hydrology of the system. Continuous soil samples of the unconsolidated coarse grained vadose zone materials were collected using rotary sonic drilling methods at five locations within the Missoula urban area. The stratigraphy from these logs, environmental site geologic data, and water well logs were used to develop a conceptual geologic model of the Missoula area depositional environment. The preliminary models were refined using grain size distribution data, grain lithology counts, and mineral identification results. In general, the uppermost deposits appear to represent a thin layer of alluvium overlying a relatively thick sequence of medium to coarse grained sand, gravel and cobbles with limited amounts of silt and clay. The fluvial deposits are thickest proximal to the area now occupied by the west flowing Clark Fork River in the central part of the valley. The northeastern part of the valley is characterized by relatively homogenous beds, up to 15 feet thick, of well sorted coarse sand and gravel. These beds are capped by thin layers of laminated, cohesive clays. The deposits in the east-central part of the valley comprise thicker beds, with rudimentary pedogenic development at the top of the beds. The beds of coarse materials are interpreted to have been deposited during the last draining cycles of Glacial Lake Missoula, with each bedform representing a distinct drainage event. The laminated clay layers are interpreted to have been deposited in each developing glacial lake.

Reconnaissance Of Organic Wastewater Compounds In The Treated Effluent Of The Helena Wastewater Treatment Plant And Prickly Pear Creek, Montana

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In March 2007, the U.S. Geological Survey in cooperation with the Lewis and Clark Water Quality Protection District, the City of Helena, and the Montana Department of Environmental Quality sampled two sites on the Helena wastewater treatment plant (HWWTP) effluent canal, one site on Prickly Pear Creek upstream from the HWWTP effluent canal, and two sites downstream from the HWWTP effluent canal. One objective of the reconnaissance sampling was investigation of the occurrence and fate of organic-wastewater compounds (OWCs) in the HWWTP effluent and Prickly Pear Creek. Prior to sampling, pressure transducers were installed at selected sites on the HWWTP effluent canal and Prickly Pear Creek to help define flow variations. Also, dye was injected and tracked to define travel times between the sampling sites. Water samples were analyzed for 123 OWCs and streambed-sediment samples were analyzed for 57 OWCs. Analytes included selected human-use pharmaceuticals, human and veterinary antibiotics, plant and animal sterols (including hormones), commonly used household and industrial compounds, pesticides, and polyaromatic hydrocarbons. Nine OWCs were detected in the water sample collected from Prickly Pear Creek upstream from the HWWTP effluent canal, 41 OWCs were detected in the sample collected from the HWWTP effluent, and 28 and 25 OWCs, respectively, were detected in the samples collected from the two sampling sites on Prickly Pear Creek downstream from the HWWTP effluent canal. The total concentration of all detectable OWCs combined was about 0.4 micrograms per liter (mg/L) for the water sample collected from Prickly Pear Creek upstream from the HWWTP effluent canal, about 15 mg/L for the sample collected from the HWWTP effluent, and about 1.7 mg/L for both of the samples collected from the two sampling sites on Prickly Pear Creek downstream from the HWWTP effluent canal. Mass-balance comparisons of loads calculated using concentration and streamflow data provide useful information on the source and fate of OWCs in the HWWTP effluent canal and Prickly Pear Creek. The total load for all detectable OWCs combined was equivalent to about 45 grams per day (g/d) for Prickly Pear Creek upstream from the HWWTP effluent canal, about 180 g/d for the HWWTP effluent, and about 215 and 235 g/d, respectively, for the two sampling sites on Prickly Pear Creek downstream from the HWWTP effluent canal. Ten OWCs were detected in the streambed-sediment sample collected from Prickly Pear Creek upstream from the HWWTP effluent canal, nine OWCs were detected in the sample collected from the HWWTP effluent canal, and nine and 11 OWCs were detected, respectively, in the two samples collected from Prickly Pear Creek downstream from the HWWTP effluent canal. The total concentration of all detectable OWCs combined was about 11 milligrams per kilogram (mg/kg) for the sediment sample collected from Prickly Pear Creek upstream from the HWWTP effluent canal, about 60 mg/kg for the sediment sample collected from the HWWTP effluent canal, and about 50 and 37 mg/kg, respectively, for the sediment samples collected from the two sites on Prickly Pear Creek downstream from the HWWTP effluent canal.

Diurnal Cycling Of Nutrients In A Hyper-Eutrophic Stream, Silver Bow Creek, MT

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The area surrounding Butte, Montana, is historically significant for its extensive mining and smelting operations, which has led to widespread groundwater and surface water contamination from heavy metals. A secondary, although environmentally significant, source of contamination in this area comes from various point and non-point sources of nutrients, which produce elevated concentrations of ammonium ($NH4+$) and nitrate ($NO3-$) in local surface waters. These elevated concentrations of nutrients have produced hyper-eutrophic conditions in Silver Bow Creek, in which prolific growth of aquatic vegetation is occurring. The hyper-eutrophic conditions in Silver Bow Creek induce significant diurnal (24-hour) fluctuations in several water quality constituents, especially pH and dissolved oxygen. During summer months, dissolved oxygen concentrations

drop to near zero during nighttime hours due to biological respiration and microbial oxidation of ammonia. This creates a "dead zone" downstream of the Butte wastewater treatment plant (WWTP) in which trout and many aquatic organisms cannot survive. The flux of nutrients through this area also displays significant diurnal variability in response to hyper-eutrophic conditions. These processes are biologically driven, and are generally controlled by the amount of photosynthetically available light and stream temperature. This study investigates the biogeochemical processes controlling the diurnal fluctuations of nutrients and stable isotopes in the dead zone of Silver Bow Creek. Three diurnal sampling events have been conducted on Silver Bow Creek, including two summer sampling events (July 2007 and 2008) and one winter sampling event (February 2008). A synoptic sampling event is also planned for July 2008 in which two samplers will move in opposite directions (upstream and downstream) to evaluate the effect of sample time and location on monitoring of nutrient loads. Preliminary results of this study indicate that – during the warm summer months – ammonia concentrations downstream of the WWTP decrease with distance downstream during the day, while nitrate concentrations increase. These changes are caused by two-step microbial oxidation of ammonia to nitrite, and then nitrite to nitrate. During nighttime hours, however, ammonia persists in the system due to low concentrations of oxygen. Furthermore, stable isotopes of nitrogen and oxygen become isotopically heavier during daytime hours due to biological fractionation, and become isotopically lighter during nighttime hours when biological activity is limited. Diurnal cycling of nutrient concentrations and redox speciation is much more subdued in the winter months because of lower water temperatures and much slower microbial oxidation rates. One of the most important conclusions of this study is that very different concentrations of nutrients (in particular, nitrate and ammonia) are obtained at any given location in upper Silver Bow Creek depending on what time of day a sample is collected. This has important implications to how future nutrient monitoring sampling programs are designed and implemented.

Influence of irrigation recharge on groundwater nitrate-N on the Greenfields Bench, MT

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The Greenfields Bench aquifer is located in north-central Montana roughly 30 miles northwest of the city of Great Falls and encompasses ~ 83,000 acres located in southern Teton County and northern Cascade County. The Bench includes the town of Fairfield. The aquifer is comprised of three benches, or terraces, which fall in elevation from south to north and from west to east. The benches consist primarily of gravels overlying bedrock. Well-drained to excessively drained soils dominate on the Bench. A system of extensive canals and ditches originating at Gibson Reservoir provide irrigation water to large acreages on the Bench artificially raising the water table. Domestic water supplies are dependent on groundwater recharge via irrigation and are susceptible to drought and to contamination from nutrients and chemicals applied at the surface and leached downward through the soil profile. On the Greenfields Bench, the Montana Department of Agriculture has been testing wells for nitrate-N continuously since 1998. In examining MDA data for wells that have been tested a minimum of 5 of the last 10 years, a decrease in the median value of nitrate-N was observed. The dataset consisted of a total of 10 wells, including three used for public water supplies, sampled during the growing season (April-September) from 1998–2007. The median nitrate-N concentration was 5 mg/L during the study period with large variances between the wells. All wells used for public water supplies had median values of 4.8 mg/L nitrate-N or less. In examining the nitrate-N findings on the Greenfield Bench, seasonal and annual concentrations were examined in respect to cropping and irrigation practices in the aquifer. In addition, climatic data such as precipitation and temperature was also analyzed. Weather data was taken from the Greenfields weather station operated by the National Oceanic and Atmospheric Administration (NOAA) located 2.5 miles northwest of the town of Greenfield. Over the course of the study, median nitrate-N concentrations initially fell and have subsequently leveled off at 5 mg/L with small annual fluctuations. Precipitation was found to have high seasonal fluctuation with mean annual precipitation totals 0.5 inches less than the 40 year average during the study period. Most importantly, of the 171 samples collected during the growing season from 1998-2007 only 6.43% (n = 11) were equal to or greater then the US EPA standard of 10 mg/L nitrate-N and all were collected from the same well. The study found that while elevated nitrates as a result of agronomic practices certainly exist in the Greenfield Bench aquifer, they do not pose a significant risk to human health.

River Rock Subdivision Area Ground Water Resource Assessment, Gallatin County, Montana

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Unconsolidated and semiconsolidated sand and gravel aquifers are one of the largest principle water yielding aquifers in the U.S. There are over 2.5 million small dams (< 6 ft high), approximately 80,000 large dams (> 6 ft high) and 8036 major dams (> 50 ft high) in the U.S. At least one fourth of these major dams are located in settings associated with these high hydraulic conductivity aquifers. Dam removals are being advocated because of adverse ecological and social impacts, deteriorating conditions of aging dams, and appreciation for the many societal values of undammed rivers and fisheries. As regulators evaluate the environmental benefits or costs of removing dams, little thought is given to the associated response of the adjacent shallow ground water system to the resulting changes in hydrologic conditions. At the Milltown Dam site in western Montana (a large, ~30 foot high dam), regulators asked for estimates of the number of over 500 water supply wells that would become inoperable as a result of dam removal activities. Extensive river monitoring, groundwater monitoring and well inventory data were combined with numerical groundwater modeling techniques to forecast areas that would experience groundwater declines. Field observations and data analyses showed that groundwater level changes were directly influenced by non-linear leakage from the reservoir and river channels. It was predicted that between 48 and 95 wells would need replacement after lowering 24 ft of reservoir stage. Management decisions need to incorporate prediction uncertainty data to limit risk and cost.

Selecting Plant Species To Improve Wastewater Treatment In Constructed Wetlands

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Constructed wetlands are used around the world for treating domestic, agricultural, and industrial wastewater, stormwater runoff, and acid mine drainage. Determining whether plants species affect wastewater treatment, if those effects are species-specific, and understanding the mechanisms underlying plant influences could increase the efficacy of wastewater treatment in constructed wetlands. If relationships exist between plant traits and species' effects on wastewater, plants could be selected to optimize treatment. My research investigated seasonal plant effects on wastewater treatment by monitoring water chemistry in model subsurface wetlands planted with monocultures of 19 plant species and unplanted controls. COD removal in the unplanted control declined during colder temperatures, likely due to decreased microbial activity. In contrast, wetlands with select plant species had constant COD removal across seasons. Redox potential and sulfate concentrations were measured as indirect indicators of oxygen availability in the wastewater. Wetlands that had a decline in COD removal in winter or intermediate removal during the study had constant low redox potentials and sulfate concentrations throughout the seasons. Wetlands with high COD removal across seasons had elevated redox potentials and sulfate concentrations during the winter, indicating elevated oxygen availability. Enhanced oxygen supply mediated by plant root oxygen loss could offset the negative temperature effect on microbial processes and may explain elevated sulfate concentrations and redox potentials and constant COD removal. I measured root oxygen loss in the summer and the winter to determine whether oxygen release was sufficient to influence wastewater treatment and cause seasonal and species-specific effects on water chemistry. COD removal and ROL were positively correlated at 4°C but not at 24°C; however, the amount of root oxygen release only accounted for a portion of the oxygen to facilitate COD removal. Root oxygen loss is one possible mechanism for species-specific influences on treatment but further research is needed to investigate other mechanisms. Other plant traits including the plant's botanical grouping, Wetland Indicator Status, and flooding tolerance were compared to plants' influences on wastewater treatment. All the sedges and rushes, obligate wetlands species, and 8 of 9 flood-tolerant plants had greater COD removal than the control at 4°C, the coldest temperature. Results suggest that plant selection can improve wastewater treatment, especially in cold climates.

Ways In Which Winter Maintenance Practices Influence Water Quality

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Each year the United States and Canada use approximately 20 million tons of deicing salts to maintain safe and passable roadways for the traveling public. What then happens to these materials once theyve been applied? Do they remain on the road or does some amount get splashed off, plowed away, or stuck to vehicles? And once theyve done their job of helping clear snow and ice from the roadway, what sort of risk to these salts pose to environmental quality? This talk will provide a general overview of winter maintenance practices and how they can influence water quality, including a discussion of point and non-point sources and their specific impacts. Applied winter maintenance materials fall into two categories: deicers and anti-icers. Deicing is the reactive application of material after a storm has started, aimed at reducing accumulated snow and ice. Anti-icing is the proactive application of material prior to the storm, or when the first flakes start falling, to prevent snow and ice from adhering to the roadway. Winter maintenance materials that are applied to roadways can be solids or liquids, and can be applied alone or blended with sand. These materials are usually a form of salt, sodium chloride, magnesium chloride or calcium chloride, and may also contain agriculturally derived products such as sugar beet or corn by-products. After these materials are applied to the roadway, a number of things can happen to them: they can be carried off the pavement by melting snow; they can be splashed off the road by the tires of passing vehicles; or they can get plowed off the road through routine maintenance. After leaving the roadway these materials often end up in adjacent bodies of water. Runoff from roadways has been shown to elevate chloride levels in adjacent waterways up to the EPA limit of 250 mg/L. Elevated concentrations of salts in stagnant water bodies have been shown to cause stratification and density differences in the water and can taint drinking water wells. Winter maintenance materials have been shown to spread up to 55 ft off the roadway, and can cause browning, singing, and death to plants, leading to increased erosion. In order to reduce and prevent potential impacts to water quality caused by winter maintenance materials, the method of application can be as important as the application rate. State departments of transportation have shown that by utilizing anti-icing practices and new technology—by applying the right material at the right place and at the right time—they can reduce the amount of deicing and anti-icing materials they use while still successfully maintaining winter roadways.

Armored Stanchion Cattle Water Access Effects on E. coli, Suspended Sediment, and Nutrient Loading to Spring Creeks

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Livestock grazing activities contribute to impairment of 5,200 miles of Montana streams. Implementation of most water quality improvement efforts addressing this issue is voluntary. Thus, it is important to present land owners with simple, cost effective approaches to mitigate water quality impairment. An armored stanchion (AS) water access was designed, implemented, and tested on Thompson and Story Creeks near Belgrade, MT. Riparian fencing was constructed to allow access at a water gap where the AS was constructed. The AS allows animals to access spring creek water to drink but does not allow them to enter the stream. An AS was constructed adjacent to a traditional (TRAD) water access on each stream for comparison. Water quality impairment was quantified downstream of each access with and without animals actively using the accesses. Instantaneous loads of E. coli, suspended sediment concentration (SSC), total Kjeldahl nitrogen (TKN), nitrate (NO_3), total phosphorus (TP), and orthophosphate (PO_4) were evaluated using Kruskal Wallis procedures. Contaminant loading from the AS access was not significantly greater than loading from the control with or without animals present. The Story Site did not consistently produce significant differences for the TRAD access with animals present versus absent under the different analysis approaches employed. Results at the Thompson Site produced significant differences for E. coli, TKN, and TP for the TRAD access when animals were present versus absent from the access. Estimates were made of percentage of time cattle occupied the Thompson TRAD access. These estimates facilitated calculation of daily loads attributed to animals actively using the access. For E. coli the load was 6.0 E9 CFU per day, 425.9 g per day for TKN, and 53.1 g per day for TP. These results indicate the AS access can reduce water quality impacts from cattle, compared to traditional access methods.

Managing Montana's Water: Challenges To The Prior Appropriation Doctrine In The 21st Century By The Clark Fork River Basin Task Force

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The basis of Montana's system for regulating and managing water is the prior appropriation doctrine which is commonly summarized by first-in-time, first-in-right. First-in-time, first-in-right means that water use is based on water rights with a priority determined by when water was first put to a beneficial use. Increased competition for water resources and increased management complexity are creating challenges for implementation of this doctrine. The challenges result from reliance on individual water users for administration and enforcement that threatens the viability of water rights, groundwater development that impacts surface water, choices related to domestic water sources, and federal statutes and regulations that constrain the operation of federal water projects and river flow. The Clark Fork River Basin Task Force was created in 2001 pursuant to a state statute, 85-2-350 MCA. This statute charged the Task Force with developing a water management plan for the Clark Fork River basin that identified options to protect the security of water rights and provided for the orderly development and conservation of water in the future. As a part of its duties, the Task Force has recently reviewed the status of Montana's water allocation and management system and examined the challenges to it. This presentation will discuss the Task Forces findings.

ReWatering Prickly Pear Creek In The Lake Helena Watershed

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Prickly Pear Creek faces numerous beneficial use impairments due to metals, nutrients, siltation, and thermal modification, as summarized in the Water Quality Restoration Plan and Total Maximum Daily Loads (TMDLs) for the Lake Helena Watershed. Addionally, the Restoration Plan states that the lack of in-stream flow exacerbates poor temperature conditions, sedimentation loads, and nutrient (phosphorus/nitrogen) concentrations, and contributes to the degradation of riparian vegetation. In the summer of 2008, the Montana Water implemented a flow restoration project for Prickly Pear Creek funded by Montana DEQ and FWP. This project brought in numerous partners such as the Bureau of Reclamation, Helena Valley Irrigation District, Prickly Pear Water Users, MT DEQ, MT FWP, as well as private landowners and irrigators, all of whom contributed to make this possible. This presentation will discuss our efforts, challenges, and succusses in attempting to restore flows on this Montana stream.

Low Flows, Hot Trout: Climate Change In The Clark Fork Watershed

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Released in July 2008, the Clark Fork Coalition's report "Low Flows, Hot Trout" is an educational effort designed to encourage basin-wide discussion on how communities can best adapt to a changing world climate. Our goal is to bring the large, daunting discussion of climate change down to the local level, and to initiate a discussion of what it means for our way of life now and in the future in western Montana. We start by compiling existing information and showing trends in temperature, precipitation, snowpack, fire, fish, and wildlife that are already observable in the Clark Fork basin. During the last half-century, western Montana has seen drought, extreme wildfire seasons, shrinkage of glaciers, a temperature increase of almost 2 degrees Fahrenheit, a longer growing season, less late-spring snowpack to recharge our rivers, and longer periods of low streamflow in the summer. In addition, we discuss what these trends mean for the landscape, economy, and natural resources of our watershed, and what we might expect in the future if the trends continue. All of this leads to a discussion of what we as citizens of the basin might do about it in terms of local and state-wide initiatives. One of the goals of the report is to provide a starting point for developing policy tools to use water more efficiently in the basin. In most parts of western Montana, it's clear that a warming climate coupled with rapidly shifting land-use patterns as a result of double-digit growth rates will create considerable challenges for maintaining flows and water quality in our streams and rivers.

Montana's Clark Fork River Basin Task Force: A Vehicle For Integrated Water Resources Management?

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We assess the prospects for moving towards greater integration and sustainability in water resources management in western Montana by analyzing the activities and contributions of the Clark Fork River Basin Task Force using Mitchell's conceptual framework for integrated water resources management (IWRM). First we review the multi-faceted concept of IWRM. We then review and reformulate Mitchell's analytical framework. Next we characterize the Montana system of water resources management and review the context under which it is evolving. We then describe the Task Force with attention to its creation, mandate and operations. Finally, we apply Mitchell's framework to the activities of the Task Force identifying specific accomplishments that promote and detract from IWRM. Specifically, we seek to answer the question: are the activities and contributions of the Task Force working to promote a more strongly integrated and sustainable approach to water resources management in Montana? Our findings show that the Task Force is an effective vehicle for promotion of IWRM in Montana. Spatial planning and hydrologic connectivity are principal concerns. It is highly proactive in promoting a progressive agenda focused on integrating water management, water supply, land use, & economic change. However, water quality, environmental quality, and ecological concerns are not given much attention owing to institutional constraints. The Task Force is a unique institution in the West which, because of its very nature, is able to push the envelope of prior appropriation to move Montana's system forward in inventive and significant ways.

Montana Water Sustainability Project Funding Options

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Montana's businesses, communities, agricultural users and ecosystems are increasingly in competition with one another for clean water throughout the state. Montana's aging infrastructure systems and some water management methods often result in water waste and contamination rather than conservation and protection. At the same time, The Federal government has drastically reduced funding for many programs that supported water sustainability projects in the past. The State of Montana recognizes that a government holds natural resources in trust for its people and is responsible for managing water resources. The State invests millions of dollars a year into projects and research that result in water conservation and its sustainable use and development. Some water sustainability projects funded by the State address nonpoint source pollution, irrigation management, water storage projects, aquifer recharge and water reuse studies, fish screen construction, wastewater management and reuse, pharmaceuticals in drinking water, watershed studies, instream flow maintenance projects, surface water/ground water investigations, wetlands creation and restoration, and development of sustainable water strategies This paper is for Montana researchers and water managers seeking project funding. It will summarize State programs that fund research and on-the-ground projects addressing water conservation and the sustainable use and development of Montana's water. Each program summary will include program priorities, applicant eligibility requirements, funding levels, application deadlines, agency contact information, and examples of projects typically-funded projects.

Sustainability Strategies For Water Utilities

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Water utility managers have many reasons to provide incentives for reducing water consumption by residential, commercial and industrial customers. Population growth, stricter water quality regulations, drought, flooding (which can impact source water quality) and the increasing cost of energy, capital improvements and treatment chemicals can tax the capability of a water system to provide reliable quantities of potable water to all its customers. Furthermore, global warming and a trend toward more erratic weather patterns make reliance on traditional stochastic hydrological models for water supply less reliable. By reducing customer demand utilities can recover some of their operational safety margin. Plumbing code improvements, sustainable housing developments, alternate onsite water sources and innovative rate structures are among the strategies available to water utilities to encourage efficient water use. Although many improvements have been made to plumbing codes in recent years, there are still areas where greater water efficiency could be achieved. Sustainable housing developments can be constructed when utilities work with land developers to minimize the water footprint of new developments. Using alternate onsite water sources for non-potable water needs can reduce demands on the public water supply. Revised rate structures can offer incentives to consumers to reduce water use, especially when offered in conjunction with popular programs that support environmental restoration.

Techniques And Equipment For Sampling Large Rivers At Near-Bankfull Conditions—A Case Study Of The Kootenai River Tributaries, Montana, Spring 2008

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Suspended-sediment, bedload-sediment and streamflow data were obtained on five tributaries to the Kootenai River in northwest Montana by the U.S. Geological Survey during the Spring 2008 runoff season. The sampling was part of research efforts coordinated through the U.S. Fish and Wildlife Service White Sturgeon Recovery Team with the goals of restoring natural recruitment of Kootenai River white sturgeon and to assess the feasibility of enhancing white sturgeon spawning habitat in the Kootenai River. The Kootenai River population of white sturgeon inhabits a portion of the Kootenai River from Kootenai Falls in Montana downstream to Kootenai Lake, British Columbia. This population of fish is one of 18 land-locked populations in the Pacific Northwest. Analysis of data indicates a decline in successful recruitment of white sturgeon that began in the 1950s. No substantial natural recruitment has occurred during the past 25 years. Scientists and resource managers charged with assisting Kootenai River white sturgeon recovery are evaluating strategies or methods to enhance spawning substrate and improve spawning, early life survival, and recruitment. Several proposed recovery actions include the alteration of streamflow or channel geometry to enhance spawning substrate. To bolster these efforts an improved understanding of the sediment-transport characteristics of the Kootenai River and its tributaries was needed. The U.S. Geological Survey sampled suspended and bedload sediment and collected streamflow and velocity data on tributaries to the Kootenai River in an effort to help characterize the sediment-transport characteristics over a range of sites and hydrologic conditions. Several north-northwest-trending tributaries and one south-southwest-trending tributary to the Kootenai River were sampled multiple times. The bedrock geology surrounding most of these tributary channels is composed of Middle Proterozoic rocks of the Belt Supergroup. Quaternary deposits in these tributary valleys include Pleistocene glacial drift and Holocene alluvial deposits. These Quaternary deposits, consisting of fine-grained lakebed deposits to the cobbles and boulders, are likely the source of most of the sediment load to the Kootenai River. The largest materials, such as course gravels and cobbles, typically are mobilized and transported primarily during high streamflow conditions, such as bankfull discharge. Preliminary results appear to indicate that the higher-gradient, north-northwest-trending streams from the Cabinet Mountains delivered substantial sediment loads to the Kootenai River system. Many of these tributaries flow from steep, mountainous bedrock and boulder-dominated channels into glaciofluvial channels prone to erosion by high-velocity flows during runoff conditions. Sampling bedload on large streams at near-bankfull conditions presents multiple logistical and safety challenges. During lower streamflow sampling events, the sampler was deployed as a hand held device while wading. Sampling during high flow was conducted from bridges or cableways and required the use of a tether line to control the downstream drift of the sampler caused by the high velocities. A variety of suspended- and bedload-sampling equipment was used to obtain representative samples during the wide range of flow conditions.

Observations On The Sediment Dynamics Of Selected Tributaries To The Kootenai River, Montana, Spring 2008

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Suspended-sediment and bedload-discharge measurements were made by the U.S. Geological Survey on five tributaries of the Kootenai River in northwest Montana during the spring 2008 runoff season. The measurements were made to provide spawning-habitat data for white sturgeon recovery studies being conducted on the Kootenai River in Idaho. The five tributaries investigated were Ruby Creek, Libby Creek, Parmenter Creek, Yaak River, and Fisher River, which are high-gradient coarse-bed streams with drainage areas ranging from about 12 to 838 square miles. Collectively, these tributaries compose about two-thirds of the Kootenai River drainage basin between Libby Dam in Montana downstream to the Montana-Idaho border. Large variations in sediment transport observed between sites and between flow conditions provide preliminary indications of the sediment dynamics in that portion of the basin. Above-average snowpack in water year 2008 produced peak streamflow of at least a 2-year recurrence-interval at the measurement sites, enabling collection of sediment data over a range of streamflow that included bankfull discharge. Detailed bedload-discharge data indicate substantial lateral variation in particle size and mass transport. Bedload ranged from sand- to cobble-size material. Sediment-transport curves relating water discharge to suspended-sediment and bedload discharge indicate substantial variability in transport capacity among the sites investigated. Comparison of channel cross sections where repeated streamflow measurements were made during the 2008 runoff season show that channel-geometry changes ranged from minimal to substantial. Sediment-transport characteristics were compared among the five Montana sites and with other selected coarse-bed streams in the Northern Rocky Mountains and western United States to gain some perspective on the sediment-transport characteristics of these streams relative to those for other high-gradient, coarse-bed streams. Sediment transport was normalized for comparison by dividing the suspended and bedload discharge components at bankfull stream discharge by the drainage area of each stream.

A Flexible Modeling Framework For Rainfall And Snowmelt

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In Montana and much of the Rocky Mountain West, the single most important parameter in forecasting the controls on regional water resources is snowpack. In the mountainous areas of Montana, in particular, the runoff of snowmelt is the key driving force in downstream supplies of water. The ability to understand and predict the behavior of snowmelt and its result on streamflow is of significant importance. In an effort to bridge the gap between theoretical understanding and functional modeling of snow-driven watersheds, a flexible hydrologic modeling framework has been developed; this framework will operate as a tool to investigate the link between hydrologic model predictive performance, uncertainty in predictions, model complexity, and observable hydrologic processes. A fundamental part of this toolkit is its usability across a variety of watersheds, making use of readily available data (NRCS & USGS) which offers water managers the ability to enact near real-time, small-scale forecasts. Tenderfoot Creek Experimental Forest (TCEF) was used as the study site for the model development, where existing field observations were an essential component for developing and testing model hypotheses and simulations under uncertainty. In developing the modeling framework, a suite of conceptual model structures have been analyzed and assessed. By varying the complexity of model structure from simple to more complex, comparisons can be made to suggest the appropriate tradeoff between model uncertainty and the degree of model parameterization. Fundamental to this research is developing an understanding of which variables of a watershed are important for the prediction of snowmelt and associated runoff processes in light of uncertain data and imperfect existing knowledge of hydrological processes. Due to the conceptual nature of the models, parameter estimation and uncertainty analysis were performed using Markov chain Monte Carlo principles. Serving as an integration of all the individual components of the modeling framework, a software package (graphical user interface, GUI) has been developed.

The Hydrogeology Of First Order Riparian Drainages

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A detailed study of the hydrogeology of first order riparian drainages is presented. The study resulted from seeking to understand the response of stream flow and riparian vegetation communities to prescribed fire in the upper portions of the Whitetail Creek watershed. Four drainages, two burned and two unburned by prescribed fire were evaluated for vegetation response and hydrologic response. The thrust of this presentation is to inform others on the significant dynamics and timing of groundwater and surface water behavior during a given water year. Before any drainage was burned (Fall 2005 and Spring 2006) each was evaluated for water-level data from five transects of driven piezometers. Since the 2006 approximately an additional 50 piezometers were added, while collecting surface and groundwater quality field parameters, plus some IC analyses and nutrient data. Water-level data through 2007 was mostly collected monthly but was increased to weekly during 2008. The weekly data have helped immensely in understanding the hydraulic gradient changes from side slope and down-drainage directions. The driven piezometers frequently "went dry" after spring runoff so little was understood about continuing groundwater flow through the summer, fall, and winter to be able to connect with the understanding of how riparian vegetation likely derive there water supplies. Deeper hand-driven wells up to 13 feet were drilled to better understand the changing dynamics of shallow riparian alluvial systems. It was discovered that there is a highly connected surface and groundwater interaction in the upper 5 feet or so of the alluvial sediments. There are also deeper zones separated by clay and volcanic ash layers that contain groundwater year around. It is in these deeper zones where roots from larger trees extend to sustain themselves during late summer through winter conditions.

The Geomorphic History Of Grayling Creek Near West Yellowstone, Montana: Influences Of The 1959 Hegben Lake Earthquake On Channel Form And Process

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Lower Grayling Creek, located near West Yellowstone, Montana, experienced a wholesale conversion in channel type since 1950. Prior to that time, the lower segments of Grayling Creek supported a densely vegetated willow bottom with multiple, highly sinuous channels (anastomosing channel type). Since that time, the creek has downcut and perched the anastomosing channel system on a low terrace. The creek now flows through a single thread, entrenched channel with a coarse grained bed and a sparsely vegetated riparian corridor. Low redd counts and on Grayling Creek have prompted investigations regarding the feasibility of restoring the stream to its multi-channeled state. Preliminary feasibility evaluations identified local land use practices and highway encroachment into the floodplain as drivers of geomorphic change. Further investigations have identified the profound effect of the 1959 Hegben Lake earthquake on channel form. The effects of the earthquake dramatically altered sediment loading rates and local topography, resulting in a series of events that collectively define the channel today. The implications of this catastrophic natural event with respect to the formulation of sustainable restoration design approaches is complex and worthy of discussion, as it forces restoration designers to carefully consider project unknowns, anticipated natural recovery trajectories, and long term equilibrium state.

In Search Of High Functioning Small Prairie Streams

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Restoring prairie streams to their highest ecological potential is a difficult task due to the high degree of alteration and our limited understanding of these systems. Almost without exception prairie streams in Montana's glaciated plains have experienced significant hydrologic alteration. Farmers and ranchers began developing secure water sources in the early 1900s in an effort to sustain a productive livelihood in this semi-arid landscape. The primary forms of alteration include damming and diverting creeks and development of an extensive network of stock reservoirs. DEQ in their efforts to identify reference streams by ecoregion found no Tier 1 (or "pristine") streams in the northern glaciated plains. Until very recently, little attention or study had been focused on these creeks. From a biologic standpoint, recent efforts to inventory fish populations and develop an Index of Biotic Integrity as well as an Aquatic Community Classification system have made large strides in our understanding. Hydrologically these streams are not well understood. There are very few stream gaging stations in the region, and isolated and sporadic rain events often are not captured by the existing network of rain gages. The World Wildlife Fund has been studying three streams in the ecoregion for the last three years -- monitoring stream flow and rainfall events, inventorying fish, modeling events, and monitoring stream response to changes in water management practices. This presentation summarizes those efforts and the lessons learned.

Incidental Recharge in Montana

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Incidental recharge occurs when normal irrigation operations result in infiltration of water to an underlying aquifer, examples include leakage from unlined canals or flood irrigation (Johnson and others, 1999). The effect (ground-water recharge) is generally unintended but the impacts are profound. In Montana there are more than 7,000 miles of canals that divert about 11.6 million acre feet of water per year to irrigate 2 million acres. Most crops annually require less than 2 feet of water. That means, evaporation, conveyance losses, and irrigation returns (to surface and ground water) may be as much as 7.6 million acre feet per year. Much of this water ends up as incidental recharge. To put this volume in perspective, total ground-water withdrawals in Montana (for irrigation, municipal, private domestic, industrial, and stock uses) are estimated to be about 305,000 acre feet per year (Cannon and Johnson, 2004); therefore, incidental ground-water recharge may be more than 20 times total ground-water withdrawals. The effects of incidental recharge are the result of more than 100 years of irrigation practices, and have created, in many places, "unnatural" hydrologic conditions that many consider to be "normal" (Kendy, 2006). These conditions are observable—and have been recognized by many—throughout the irrigated areas of the state. In the Yellowstone River Valley from Laurel to Sidney, and in the north central part of the state near Fairfield and Choteau, high quality irrigation water recharges the shallow alluvial aquifers that overly Cretaceous shales and are in places the sole source of potable water. In the Beaverhead Valley incidental recharge from the East Bench Canal project resulted in water levels increases of more than 40 feet in the underlying aquifer; long term water-level fluctuations (aquifer storage) are strongly controlled by irrigation diversions. In the Bitterroot Valley incidental recharge supports wetlands and shallow aquifers on the upland benches along the dry, east-side of the valley. In many of the intermontane basins incidental recharge and its subsequent discharge to streams contributes substantially to late season stream flows. As land-use change (e.g. from agricultural to residential) and irrigation efficiencies (lining canals, converting from flood to sprinkler) drive changes in water use, it is important to recognize the hidden significance of incidental recharge. Changes that inadvertently reduce recharge may also cause unforeseen changes in ground-water storage, environmental flows, and stream flow resulting in adverse impacts to other water users and the environment. However, recognition of and accounting for incidental recharge may provide beneficial management opportunities.

The Ruby Groundwater/Surface Water Interaction Modeling Project – Evaluating Connections Between Water Management And River Flows

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Wise long term management of water resources in Montana requires an understanding of how changes in land and water use will affect water supplies. The Ruby Groundwater/Surface Water Interaction Modeling Project, undertaken by the Ruby Watershed Council and KirK Engineering & Natural Resources, Inc. is an effort to develop a modeling tool which links groundwater and surface water management to river flows. Modeling was accomplished using MODFLOW and the USGS streamflow routing package STR1 and makes use of focused field data which describes connections between groundwater and surface water. Irrigation water loss currently supplies the majority of recharge to groundwater in the Lower Ruby Valley and one focus of this study is the connection between irrigation and late summer return flows to the Ruby River. Predictive scenarios modeled include ditch lining and conversion of flood irrigation to center pivot sprinklers, construction of ponds which tap the water table, and large subdivision developments. The model provides a planning tool useful for evaluating potential changes in water management as well as an educational venue that demonstrates connections between water management, groundwater, and surface water flows.

Ground Water And Surface Water In A Study Area Within The Upper Big Hole River Basin

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A hydrologic investigation was performed in a study area in the Upper Big Hole River basin. Data was collected during 2005-2006 to assess the dynamics between the surface water, ground water, evapotranspiration and precipitation. The study area encompassed about 10 mi2 and included a three mile segment of the Big Hole River just north of Jackson, Montana. Within the study area, ground water was monitored monthly and every two weeks during the growing season. Big Hole River stream flows were monitored continuously from April – October as it entered and exited the study area. Monthly synoptic measurements of ground water and surface water provided information used to estimate a water budget within the study area. In spite of the fact that the study area was relatively small (about 10 mi2), there was significant variability in how the ground-water system responded to natural and man-made influences. Ground-water levels ranged from artesian conditions to depths of about 90 feet below the surface. Ground-water levels fluctuated from about 2 to 29 feet, with the greatest amount of fluctuation in wells located in Tertiary sediments on the east side of the river. After accounting for all surface water entering and exiting the system within the study area, more water was leaving the system than entering during May and June - indicating a gain in flow. However, these gains were within 10% of the amount of water entering the system. From July, ground water was rapidly released from aquifer storage once irrigation ended. From July through October the surface water system showed a slight loss or the system essentially balanced with no significant gains or losses after irrigation ended. These results were consistent for both 2005 and 2006. A water budget was approximated during the synoptic run dates within the study area to examine the components that contribute water to the system (sources) and losses (sinks). Although the budget was only estimated during the synoptic run dates, the analyses provided information on how the system responds during periods of pre-irrigation, at the height of irrigation and later on in the summer/fall. The water budget revealed that an equivalent amount or more of ground water released from storage was lost to evapotranspiration. This does not mean that ground water discharged from storage was not returning to the river during this time –evapotranspiration was taking an equivalent amount or more of water out of the system. Although no surface water flows were monitored throughout the winter months when evapotransipration losses were minimal, it was estimated that about 3 to 5 cfs was released from ground-water storage within the study area and most likely helped sustain river flows during this time. These results were consistent with a previous investigation performed during 1997 and 1998 on the east side of the Big Hole River. Therefore, it can be assumed that in spite of variability within the upper basin – the system responds similarly. This information can help stakeholders assess the affects off altering land use practices as they make water management decisions.

Field Observations And Groundwater Modeling As Tools To Mitigate Groundwater Supply Impacts During The Removal Of Milltown Dam, Western Montana

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Unconsolidated and semiconsolidated sand and gravel aquifers are one of the largest principle water yielding aquifers in the U.S. There are over 2.5 million small dams (< 6 ft high), approximately 80,000 large dams (> 6 ft high) and 8036 major dams (> 50 ft high) in the U.S. At least one fourth of these major dams are located in settings associated with these high hydraulic conductivity aquifers. Dam removals are being advocated because of adverse ecological and social impacts, deteriorating conditions of aging dams, and appreciation for the many societal values of undammed rivers and fisheries. As regulators evaluate the environmental benefits or costs of removing dams, little thought is given to the associated response of the adjacent shallow ground water system to the resulting changes in hydrologic conditions. At the Milltown Dam site in western Montana (a large, ~30 foot high dam), regulators asked for estimates of the number of over 500 water supply wells that would become inoperable as a result of dam removal activities. Extensive river monitoring, groundwater monitoring and well inventory data were combined with numerical groundwater modeling techniques to forecast areas that would experience groundwater declines. Field observations and data analyses showed that groundwater level changes were directly influenced by non-linear leakage from the reservoir and river channels. It was predicted that between 48 and 95 wells would need replacement after lowering 24 ft of reservoir stage. Management decisions need to incorporate prediction uncertainty data to limit risk and cost.

Shallow Aquifer Response To Phreatophye Water Use: A Comparison Of Different Vegetation Types

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Fire suppression over the last 100 years has led to higher levels of plant community succession in small mountain valleys. Without fire to reset the clock of succession, there has been extensive conifer encroachment in riparian areas and a decline in aspen stands. The hydrologic response to this succession is not fully understood. Some studies suggest this change has reduced water flows from first order basins. To investigate the water use by different riparian vegetation types, piezometers were installed in the shallow aquifers of Hay Creek Canyon north of Whitehall, Montana. Initial pressure transducer water level data was collected in the fall of 2007. Different vegetation type sites were selected for piezometer installation in the early spring of 2008. The dominant vegetation at the four study sites are Aspen, Douglas fir, Grass /Sage, and Willow/ Alder. The PVC piezometers were installed with a hand auger at depths 6 to 12 feet below the surface. The different vegetation sites were selected within one small area of Hay Creek Canyon to minimize elevation and exposure differences. Water levels at the four vegetation sites were recorded simultaneously every 20 minutes using Level Logger pressure transducers during the spring and summer of 2008. Water levels will continue to be recorded into the fall to record the seasonal changes in water use by the different vegetation types. Meteorological conditions were recorded at a study area weather station. Water quality parameters were all also recorded monthly. Analysis if the water level and water quality trends of each site will be presented. This study is part of the Whitetail Watershed Restoration Project, a cooperative study to assess the use of prescribed fire as a tool for watershed management.

Time Lapse Seismic Refraction For Monitoring Zones Of Water Table Fluctuation

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Seismic refraction has long been used as a method for determining water table depths. However, many refraction studies have calculated water table depths much deeper than corresponding well measurements. To investigate this phenomenon, we recorded a series of refraction profiles over a four month time period at six different locations in a tropical aquifer near Cairns, Australia. Our survey locations were adjacent to monitoring wells used to monitor water level on a regular basis. Approximately six profiles were recorded at each well location over the period February 2007 through May 2007 spanning the wet season to dry season transition. A layered refraction analysis approach was able to determine water table depth to sub-meter precision based on proper understanding of the water table annual zone of fluctuation and the trapped residual air that exists within this zone. This trapped residual air reduces saturation to approximately 99.5% which significantly reduces the measured compressional wave velocity from refractions. Additionally, refractions are also observed from the lower limit of water table fluctuation that are largely independent of water table current depths. Beneath the lower limit of water table fluctuation, saturation is 100% resulting in refractions exhibiting compressional wave velocities of 1,500m/s or greater, the commonly used value. The depth to the lower limit of the water table fluctuation has been found to create a seismic boundary that is largely independent of current water table depths. Refraction velocities for this depth can be used to accurately predict the greatest depth for water table zone of annual fluctuation.

Streamflow, Sediment, And Nutrient Simulation Of The Bitterroot Watershed Using SWAT

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The Department of Environmental Quality has employed the Soil and Water Assessment Tool (SWAT) to aid in the development of sediment and nutrient total maximum daily loads (TMDLs) for impaired stream systems within the 7300 km2 Bitterroot Watershed in Western Montana, USA. A revised 2005 version of SWAT that consisted of a modification to consider losses of organic nitrogen and phosphorus due to bank erosion was used to perform simulations on the watershed. Parameters that govern streamflow, sediment, nitrogen (N), and phosphorus (P) in SWAT were calibrated in a distributed fashion for seven regions within the Bitterroot. A dryer than normal four year period of record from 2000 to 2003 was used for model calibration while a wetter than normal four year period from 1995 to 1998 was used for model calibration. Based on computed values of percent bias and the coefficient of efficiency as well as measured versus simulated graphical comparisons of daily, monthly, and average monthly streamflow, SWAT exhibited an element of robustness in that it performed at least as well under wetter than average conditions (validation period) as compared to dryer than average conditions (calibration period). From the comparison of measured versus simulated average monthly and duration of daily sediment, total N, and total P concentrations for the calibration and validation periods, SWAT also did a reasonable job in predicting sediment and nutrient constituents for the Bitterroot Watershed. Results of model simulations suggest that bank erosion accounts for about 72%, 46%, and 70% of the total sediment, nitrogen, and phosphorus yields from the watershed, respectively. These simulated nutrient yields due to bank erosion are appreciably different from previous SWAT simulations in Montana that have not considered the impact of bank erosion on nutrient transport. To substantiate nutrient loadings simulated in this study, field investigations should be implemented to measure losses of nitrogen and phosphorus associated with bank erosion.

Subalpine Wetlands: Characteristics, Environmental Drivers, And Response To Human Perturbation And Restoration

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Development in mountainous landscapes has dramatically increased in recent years. Associated land disturbances often influence unique natural subalpine wetlands. These wetlands are largely understudied, creating significant challenges when disturbance and required restoration occur. Affected wetlands often lose some ecological and physical functions during perturbation and restoration, despite techniques that attempt to restore these functions. The goal of this study is to define the characteristics of undisturbed subalpine wetlands, examine their specific environmental drivers, and to compare the parameters of restored/created wetlands to those of undisturbed wetlands in a mountain landscape in southwestern Montana. These data can be used to better understand processes for restoration of disturbed wetlands. Wetland characteristics and functional parameters compared include biological, physical, and chemical conditions. This study examines a number of undisturbed wetlands in the subalpine region of Big Sky, Montana. Studies of restored/created wetland sites in the same watersheds are included to examine the range of variability of characteristics and functional parameters of these altered sites. Wetlands in the study were categorized into depressional and linear types. The study tested two primary hypotheses: 1. Distinct differences in wetland characteristics and environmental drivers exist between the two types of wetlands found in this region. 2. Restored/created wetlands exhibit biological, physical, and chemical characteristics that vary from those of undisturbed wetlands. Preliminary analyses indicate that although linear and depressional wetlands share some similar characteristics, over half of metrics are significantly different between these types in the study area. Also, although a perched water table appears to be evident in both wetland types, it is more pronounced in depressional wetlands. However, the depth to the perched water table and to the non-perched water table seems to play differing roles as environmental drivers for vegetation characteristics. Finally, restored sites appear to have a more pronounced

variability in vegetation characteristics compared to undisturbed sites. Researchers and agencies alike stand to gain by exploring the condition and environmental drivers of these subalpine wetland types. Restoration practioners stand to gain by examining the success levels of affected wetlands in response to restoration techniques. Findings and conclusions from this project may better define appropriate goals for restoration/creation projects, and may allow better prediction of anticipated recovery of functional integrity of affected wetlands in the subalpine.

Floating Treatment Wetlands - Multiplying Wetland Efficacy By 1000%

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Floating Treatment Wetlands (FTWs) are a recent innovation developed by Floating Island International, an invention company based in Shepherd, Montana. FTWs are a low-cost technology made of recycled plastics, and represent a new stewardship tool to address non point source pollution. The FTWs, trade named BioHavens, provide a concentration of wetland surface area. Wetlands are already characterized by a high ratio of surface area to water, and BioHavens multiply this by (conservatively) a factor of ten, setting the stage for microbial biosequestration of nutrients, heavy metals, pharmaceuticals and other suspended solids occuring within Montana's waterways. Based on this concentrated surface area BioHavens provide a modular wetland effect that can be readily installed in sensitive riparian areas. Our presentation will describe practical applications for this technology throughout the waterways of Montana, and will include a description of how BioHavens are being used as an educational tool/project. We will present efficacy measurements, generated via a $400,000 study co-funded by the state of Montana and Floating Island International, and by other independent research institutes. Associated benefits, including expansion of critical riparian edge habitat, fisheries enhancement, and strategic carbon sequestration will also be covered.

Yellowstone River LIDAR Mapping Applications

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Back to back 100-year floods along the Yellowstone River in 1996 and 1997 heightened public awareness and renewed emphasis on understanding riverine ecologic processes. In response, the Yellowstone River Conservation District Council and the U.S. Army Corps of Engineers initiated a cumulative effects assessment of the Yellowstone River Corridor. LiDAR terrain mapping and high resolution orthophotography form key baseline elements of an interdisciplinary scope of work that includes geomorphology, hydrology, hydraulic modeling, and GIS analyses. The project area extends from the Yellowstone National Park (YNP) boundary to the Missouri River confluence and includes the adjacent floodplain and active channel migration zone.
As of this writing, LiDAR mapping of the 750 square-mile project area is complete. The dataset provides a high accuracy (0.5 m vertical; 2 m horizontal) digital terrain model of the Yellowstone River corridor from headwaters to mouth - a distance of 560 river miles. High resolution true color orthophotos and planimetric feature datasets such as roads, railroads, buildings, and bridges have also been developed as part of the mapping project. The overall purpose of the cumulative effects assessment is more informed decision-making at all levels of government, but is primarily aimed at supporting local growth and development decisions. In the more urbanizing the segments of the river, hydraulic modeling (HEC-RMS) and DFIRM production are major objectives; in more rural segments channel migration zone mapping and GIS-based inundation mapping are shown to be cost-effective ways to identify flooding and erosion hazard areas. The Yellowstone River corridor is experiencing residential growth and bank stabilization pressure, particularly in its upper portions known for a blue-ribbon trout fishery. For the middle and lower reaches, key questions include the effects of altered hydrology on channel morphology, ice jam occurrence, and aquatic habitat availability. High accuracy terrain models facilitate the determination of water surface extent under a variety of flow conditions. When combined with high resolution orthophotography, the terrain data facilitate mapping of flood and erosion control structures, and allow ready discernment of relic channels and ancestral floodplain features at risk of re-activation.

Municipal Impacts From The General Permit For Stormwater Discharges Associated With Small Municipal Separate Storm Sewer Systems (MS4s)

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MPDES permit MTR040000 is a new General Permit for Storm Water Discharges Associated with Small Municipal Separate Storm Sewer Systems (MS4s). MPDES permitting of these discharges is required to be implemented nationally through the EPA, or delegated states and tribes, as Part of EPA's Storm Water Phase II requirements. EPA Phase I and II requirements have been incorporated into the Administrative Rules of Montana (ARM), Title 17, Chapter 30, Subchapters 11, 12, and 13. These rules became effective on February 14, 2003. An MS4 is typically a conveyance or system of conveyances owned by a state, city, town, or other public entity that discharges to state waters, and is designed or used for collecting or conveying storm water and is not part of a publicly owned sanitary sewer system. The City of Billings along with six other Montana communities are currently regulated by the Phase II program. MS4s must develop a Stormwater Management Program (SWPMP) that incorporates the following six minimum control measures; 1. Public Education and Outreach on Stormwater Impacts. 2. Public Involvement/Participation. 3. Illicit Discharge Detection and Elimination. 4. Construction Site Stormwater Runoff Control. 5. Post-Construction Stormwater Management in New Development and Redevelopment. 6. Pollution Prevention/Good Housekeeping for Municipal Operations. Also, MS4s must evaluate whether a storm water discharge results in or has the potential to result in exceedances of water quality standards, including impairment of designated uses, or other significant water quality impacts, including habitat and biological impacts. Address current and future financial, legal, and manpower challenges and impacts on the City of Billings to meet the requirements of the Phase II program.

Tools For Restoration Project Planning, Review, And Screening

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Millions of dollars are spent in Montana and billions nationally every year on restoring damaged rivers. Ideally, these dollars are buying us restored stream systems that provide better aquatic habitat today, tomorrow, and into the future with minimal maintenance or management. But are we making progress to that end? Are these projects fostering resilient habitat, self-sustaining systems, and future fisheries? The unfortunate answer is that we do not know. The unfortunate reality is that if we are achieving these goals, we are not differentiating these project successes from projects that fail to meet these goals. A current collaborative effort among federal and state resource agencies, restoration practitioners, and leading governmental and academic researchers is actively developing a resources and tools to guide planning and regulatory review of proposed restoration and stabilization projects in the western U.S. The project was initially conceived to address a need among regulatory agencies to provide guidance and training for staff biologists in the evaluation of probable outcomes of proposed restoration and stabilization projects. However, the resources have also proven to be of great utility as project planning and screening tools. A suite of three public domain resources are currently under development and will be soon available to resource agency managers, biologists, and funding entities to guide planning or evaluation and screening of proposed projects: 1. Science synthesis document: A peer-reviewed document resource that includes a synthesis of the science of physical processes that influence and sustain aquatic habitat, a review of channel design methods and resources, and an annotated bibliography of existing restoration planning and design resources. 2. Project information checklist: A comprehensive checklist of information that is necessary to evaluate a project proposal and design and which can serve as a template for organizing project information and data. 3. Project evaluation and planning tool: An electronic and interactive project planning and evaluation tool that assists users in considering all elements of project development from definition of project goals and objectives through design review and analysis of probable outcomes.

1. Mineral Weathering As A Source Of Nutrients To The West Fork Of The Gallatin River, MT

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Mineral weathering is a key process that may deliver biologically important nutrients (e.g., carbon, nitrogen, phosphorus) to downstream ecosystems. The origin(s) of nutrients in watershed and landscape scale studies are often poorly understood. A laboratory experiment was conducted to test whether solutes such as NO3-, NH4+, PO43-, and organic C are generated from parent materials located in headwater catchments near Big Sky, MT. Eight distinct rock types were selected from the 112 km2 West Fork catchment in July 2007. Rock samples were cut to remove all weathered faces, ground to a < 0.25 mm flour, mixed with ultra pure water (40 g flour: 75 g water), and incubated in glass serum bottles at room temperature for up to 790 hours. Aqueous samples were collected at pre-determined time points over the course of the experiment and analyzed for all major dissolved chemical species. X-ray diffraction, surface area analysis, and elemental analysis were used to characterize the mineral composition of the original whole rock samples. Carbonate mineral slurries yielded the highest solute per unit surface area (TDSm-2 = 9.06 ppm for YM-1), the greatest NO3- concentrations (434 ± 7.5 μM NO3- for the YM-1 mixture), and the greatest DOC values (> 1000 μM). Six of the eight sample mixtures produced NO3- in significantly higher concentrations than silica bead controls, and the ratio of C:N for sedimentary samples BSS-1, BSS-2, BSS-3, and YM-2 closely followed the Redfield ratio. NH4+ increased significantly in carbonate, evaporite, and some silicate sample mixtures, with the highest concentrations observed in the mudstone sample BSS-1 and the evaporite BH-11 (57.7± 0.7 and 53.3± 2.0 μM NH4+, respectively). These results indicate that rock: water interactions can generate C, N, P species and we hypothesize that these interactions occur in parts of West Fork hydrologic system. Headwater stream NO3- concentrations in carbonate-dominated catchments of the West Fork may be attributed to geologic sources. The spatial extent of geologic features, and hydrologic variables such as sediment loading and residence times throughout the West Fork watershed may further explain the role of rock weathering on stream water signatures and lead to a more complete understanding of biogeochemical nutrient cycling in the Big Sky area and other headwater environments.

2. Stream-Depletion analysis in the Lower Beaverhead River Sub-basin: Expanding the Study Area

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Ground-water development in Montana has significantly increased in recent years due to a combination of factors, including increased demand and drought as well as basin closures for surface water. Consequently, surface-water depletion and water-rights conflicts have become serious concerns. These concerns led to a 2006 DNRC decision to discontinue issuing new ground-water appropriations in closed basins. In 2007, the Montana Legislature passed House Bill 831 to allow DNRC to continue processing ground-water permit applications in closed basins. HB831 also directed MBMG to conduct case studies that would provide a background for finding site-specific solutions within the closed basins of Montana. The lower Beaverhead River sub-basin was one of the selected case study areas. The study is examining 1) interactions between the Beaverhead River and shallow alluvial aquifer, 2) interactions between shallow and deep aquifers, 3) influences of irrigation canals on the ground-water flow system, and 4) impacts of production wells to the ground-water flow system. Researchers installed several wells to perform aquifer tests; monitored river stage and ground-water levels; and sampled surface and groundwater for isotopes, trace metals, and major cations/anions. The MBMG used the new data as well as existing data to prepare a draft report that presents hydrogeologic cross sections and a potentiometric surface map across the sub-basin. Results included an estimation of aquifer properties such as hydraulic conductivity and ground-water flow gradient, and the discovery of a thin clay layer

in the floodplain that appears to confine a deeper aquifer and separate it from the shallow alluvial aquifer that is directly connected to the river. The report also presents a stream-depletion analysis based on a numerical ground-water flow model that encompassed the lower Beaverhead River floodplain and extended eastward to the East Bench Canal. Various pumping conditions were simulated to study their impacts to river flow and to evaluate the effectiveness of certain strategies for offsetting stream depletion. In transient simulations, stream discharge did not fully recover between pumping cycles; thus, stream depletion increased with time. The simulations also revealed that the timing, rate, and location of depletion depend heavily on the timing, rate, and location of pumping; the same was true for offsetting depletion. In comparing offset methods, ground-water replenishment was found to be far more effective than stream replenishment. Conveyance loss from irrigation canals is a potentially viable mitigation measure; taking advantage of seasonally high flows could be especially useful. Preliminary work, started in July of 2007, focused primarily on the eastern part of the sub-basin. While continuing to study the east side, further attention is now being given to the western half. Field efforts in the 2008 field season included river and canal gaging, ground-water-level monitoring, water sampling, and the compilation of data gathered by canal operators. In addition, a ground-water flow model was developed for the west side of the sub-basin and is intended to meet the same objectives as the east-side model.

3. Effects Of Municipal Storm Water Runoff On Water Quality In Mandeville Creek

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The effects of municipal storm water runoff on water quality have received increasing attention since the 1987 amendments to the Clean Water Act (CWA). Municipal separate storm sewer systems (MS4s), are addressed in two phases under the National Pollutant Discharge Elimination System (NPDES). Phase one requires municipalities with populations greater than 100,000 to attain NPDES permits for storm water. Phase two requires municipalities with populations greater than 50,000 to apply NPDES permits before 2003. It also extends permitting requirements to include, industrial sites disturbing greater than five acres of land, and construction sites disturbing greater than one acre of land. The city of Bozeman, Montana State University (MSU), and Montana Department of Transportation (MTDOT), hold a phase two permit for storm water discharge. Mandeville Creek is a spring-fed system that originates south of Bozeman before flowing through the city of Bozeman and MSU campus where it collects urban runoff. The creek is sensitive to water quality impairment from storm water runoff, making event triggered sampling important in understanding contaminant loading. The current study is evaluating the suspended sediment concentration (SSC), E-coli concentration, and nutrient concentration at several sampling sites along Mandeville Creek. It is the objective of this study to evaluate the impacts of land use, storm runoff, and channel characteristics on the water quality of Mandeville Creek. Preliminary observations indicate that SSC increases greatly with contribution of storm water runoff from MSU parking lots. Water quality results from the outlet of a storm water culvert on the MSU campus show that the SSC is about five times greater than that of the creek just above the culvert. Preliminary observations indicate that E-coli concentrations increase downstream through the city of Bozeman. Preliminary observations also indicate changes in nutrient species concentrations in the creek. Understanding sources of water quality impairment is important for focusing management on priority areas of Mandeville Creek. This study will provide understanding and guidance as to what the sources of contamination are, and where to focus management.

4. Chlorine Susceptibility Of Salmonella Typhimurium And Biofilm Detachment Characteristics

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Although the detachment of aggregated cells from biofilms is of fundamental importance to the dissemination of contamination and infection in both public health and clinical settings, the disinfection efficacies of commonly used biocides on detached particles have not been investigated yet. Therefore, the question arises: Can cells in detached aggregates be killed with disinfectant concentrations sufficient to kill planktonic cells? We hypothesize that detached particles are less susceptible to biocides than planktonic cells. For the purpose of testing and comparing biocide susceptibilities of planktonic cells, cells in biofilms and detached cell aggregates, we designed experiments as follows: Salmonella typhimurium, as a model pathogen, is grown in standardized laboratory reactors for enhanced repeatability. Planktonic cultures are grown in a continuously stirred chemostat, while biofilm is obtained from a tube reactor. Detached aggregates can be sampled from the outflow of the tube reactor. Log reductions have been assessed for planktonic cultures for the range of 1 - 4 ppm of sodium hypochlorite. Cell concentrations in the chemostat were on average 7.00E+07 CFU/ml. However, fluorescent microscopy revealed that only ~ 35% of the biomass was present as single cells. The majority of biomass appeared in small clusters of up to 10 cells. Detachment in the tube reactor at standard conditions has been observed and compared to detachment characteristics after induced nutrient starvation (removal of nutrients from the feed) and also after stopped-flow conditions to allow for accumulation of molecules that may trigger detachment. The size distribution of clusters and cells during regular detachment is similar to that occurring in the chemostat. After removing nutrients from the feed to mimic starvation conditions, more single cells and fewer cell clusters leave the outflow of the biofilm tube reactor. Detachment of more clusters and less single cells is induced by stagnation of the feed in the tube reactor for 20 minutes, likely due to the accumulation of molecules that trigger detachment in S. typhimurium biofilms.

5. Meeting Southern California's Water Demands With Innovative Recharge Practices

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Due to increasing water demands, decreasing supplies of imported water, and recurring drought conditions, state and local governments are expanding or developing ground water replenishment or recharge systems. These systems divert highly treated wastewater, currently discharged into the ocean or local surface waters, into natural storage areas. Reclaimed waters, once purified, are injected into seawater intrusion barriers, piped to recharge areas, or discharged to surface waters and eventually diverted to ground water basins. Water management agencies aim to meet future water demands, protect against droughts, and preserve high-quality ground water through innovative, cost-effective, and environmentally sensitive basin management practices. The existing and future limitations of water resources in Southern California have prompted more efficient management of water supplies. The Water Replenishment District (WRD) is the regional ground water management agency for overall water resource management in southern Los Angeles County. As the population continues to increase, it becomes even more important to maximize the use of both imported and recycled or local water sources available to the WRD. The WRD manages ground water for nearly four million residents in 43 cities of southern Los Angeles County. To meet requirements of the California Water Code Section 60300, WRD hydrogeologists and engineers track ground water levels from a network of specialized monitoring wells and from ground water producer's production wells. Currently, the network consists of about 220 WRD and USGS-installed monitoring wells at 48 locations throughout the District and is supplemented by existing ground water production wells. Currently, 100 wells are outfit with In-Situ® Level TROLL® 500 instruments that accurately measure and log water level and temperature data every six hours. The primary purpose of water level monitoring is to meet statutory responsibility to maintain ground water availability. The Level TROLL 500s reduce trips to the field and enhance the WRD's monitoring program by allowing for more measurements, which increases data resolution.

6. Uranium And Other Radioactive Elements In Ground Water Of Jefferson County, Montana

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In September 2007, the U.S. Geological Survey (USGS) in cooperation with the Jefferson Valley Conservation District and Jefferson County, sampled ground water in Jefferson County, Montana, for uranium and other radioactive elements. Most of the wells included in the study provide water for human and/or domestic-animal consumption. The objectives of the study were to evaluate the geologic setting in which elevated uranium concentrations occur in Jefferson County and to provide information about the occurrence and concentration of other radioactive elements which had not been studied previously. The presence of uranium in area ground water had previously been documented from required monitoring of public-supply systems, information from private citizens, and a Montana Department of Health and Human Services biomonitoring study. Some of the previously reported uranium concentrations were greater than the drinking-water standard, or Maximum Contaminant Level (MCL) of 30 micrograms per liter (μg/L), set by the U.S. Environmental Protection Agency (USEPA) for public drinking-water supplies. Forty wells throughout Jefferson County were sampled. Thirty of these wells were randomly selected to represent different geologic settings. Ten of these wells were selected in areas where elevated uranium concentrations had been previously reported. Water samples collected for the study had uranium concentrations higher than the USEPA MCL of 30 μg/L in about 12 percent of the wells. Radon concentrations exceeded the proposed MCL of 4,000 picocuries per liter (pCi/L) in about 41 percent of the sampled wells. Samples from 12 of the 40 wells also were analyzed for radium, radon, gross alpha particle activity, and gross beta activity. Of these wells, 67 percent of the samples exceeded the MCL of 15 pCi/L for gross alpha particle activity, 33 percent exceeded the MCL of 5 pCi/L for total radium, and 17 percent exceeded 50 pCi/L (approximately equivalent to the MCL of 4 millirem per year) for gross beta particle activity. Nearly all of the wells that had radionuclide concentrations exceeding one or more USEPA drinking-water standards obtained water from fractures within the igneous rocks of the Boulder batholith. The Boulder batholith is one of the most extensive geologic units found in Jefferson County. The Boulder batholith is known to contain uranium-bearing minerals in some areas, was intensively prospected for uranium in the 1950s, and some uranium ore was mined locally. However, it is important to note that 27 percent of the wells completed in the Boulder batholith had radionuclide concentrations below USEPA drinking-water standards. Results from this study identified two major topics for possible future evaluation. First, concentrations of radioactive elements in individual wells may vary over time and follow-up sampling would be needed to determine if concentrations are less than or greater than drinking-water standards part or all of the time. Second, some radioactive elements (including radium isotopes, gross alpha, and gross beta) were analyzed in samples from only a few wells; therefore, the occurrence of these elements throughout the county is not well documented. Additional sampling and analysis would better describe the extent and magnitude of radionuclide concentrations in ground water.

7. Horse Creek Temporary Controlled Groundwater Area: Defining The Recharge Area

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The Horse Creek Temporary Controlled Groundwater Area (TCGA) was initiated in 2001 by local ranchers and residents who petitioned the Montana Department of Natural Resources and Conservation (DNRC) to more closely examine the water resources of the Horse Creek basin, three miles southwest of Absarokee, MT. The area's water resources had been in a relatively steady state for decades under primarily agricultural use. That changed when a 67 lot rural subdivision received final county and state approval. Residents fear that over-appropriation of the basin's water resources will lead to the decline and eventual demise of springs and Horse Creek itself. The Horse Creek Controlled Groundwater Study Area is approximately 7,500 acres of dryland, underlain by the Tongue River, Lebo, and Tullock members of the Fort Union Formation dipping northward. Several major faults cross the area and allow for upward flow from deeper groundwater. Initial water reports from the subdivision developer claim the Beartooth Mountains, 14 miles away, as the recharge area. More than four years of hydrographs and chemical water analyses from the monitoring points lend support for a local recharge area. Once a month, volunteers go out "in the field" to measure and sample Horse Creek, two monitoring wells, eight private wells and 14 springs currently in the study area. Springs and Horse Creek are measured for flow rate and basic water quality parameters, including temperature, pH and conductivity. Wells are measured for water column height and water quality. This is a time consuming process, taking an entire day to visit all sites in all kinds of weather. In addition, water samples are gathered for periodic chemical analysis at Energy Labs in Billings. This information is used by hydrologists to help characterize and identify the aquifer(s) in the groundwater system. The Horse Creek TCGA just received its second two year extension of study time in preparation for a final DNRC hearing in late 2009. It is believed that six years of data acquisition and analysis will lead to a scientifically sound decision on how the water resources of the Horse Creek basin should be managed going forward.

8. Use Of Geophysical Methods For Remediation Investigation Of Little McCormick Creek, Alberton, MT

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Little McCormick Creek is part of the Nine-Mile drainage just west of Missoula, Montana. The creek has been heavily placer mined for gold during the early to mid-1900s. The extensive placer mining reworked the original creek deposits resulting in the loss of fine sediments. The remaining coarse sediments are not able to support surface water flow for a significant fraction of the year thus causing a section of the creek to run dry. Trout Unlimited is interested in restoring the native fishery in the creek through remediation efforts such as emplacing groundwater dams or rerouting the creek. Determining the best approach requires knowledge of the current subsurface conditions of the Little McCormick drainage. To this end we performed a series of geophysical investigations to determine 1) the nature of the existing sediments within the drainage and 2) bedrock depths. The methods we used included seismic refraction, electrical resistivity, and time and frequency domain electromagnetic methods. Our results show bedrock at a depth of one to four meters in the upper part of the drainage increasing to five to ten meters downstream. We interpret two distinct zones of lithology. The first zone consists of a top layer of poorly sorted alluvium sitting on extensively weathered bedrock exhibiting high permeability. The second zone has the same top alluvial layer but lying on top of an underlying layer of competent bedrock with little to no alteration. The geophysical investigations were performed by the 2008 Field Camp class of Montana Tech. The geophysical methods proved to be effective and efficient in characterizing the subsurface lithology of about a 1.0km section of the drainage for purposes of stream restoration.

9. Spatial Distribution Of Shallow Ground-water Response To Snow-Melt, Precipitation, River Stage, And Irrigation In The Four Corners Area, Gallatin County, Montana

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The Gallatin River near Bozeman,Montana is part of the Upper Missouri River Basin. The Upper Missouri River Basin is closed to further appropriation until water rights are adjudicated. As a result, there has been increased pressure on the ground-water resource, but there is considerable concern regarding the relationship between ground-water withdrawal and the river. The area is has been heavily irrigated since approximately 1865, and this irrigation influences the ground water levels. Data on both the surface water and the ground water is sparse. To help shed light on the interaction between irrigation, ground water and surface water, data was collected on ground-water levels and the surface-water system in the Four Corners area, Gallatin County, Montana. Continuous water level recorders were installed in over twenty wells. Levels were recorded every hour. Data from the wells with recorders allow one to distinguish water level rise caused by snow melt, rain fall, river stage changes, and irrigation. Wells near the river (100 m), the effect of changing river stage on the ground water is limited or not evident, but irrigation recharge is clear. Irrigation raises the water table in the gravel alluvial aquifer by as much as 10 feet, but more commonly one to four feet. River stage generally influences ground-water levels one to four feet. Irrigation typically ends in mid October. Water levels return to pre-irrigation levels as early as November, but irrigation effects often continue into February and beyond.

10. Screening For Pharmaceuticals And Endocrine Disrupting Chemicals In Montana Ground Water

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Pharmaceuticals and other endocrine disrupting chemicals (EDCs) have been reported in a number of streams throughout the U.S.A. The source for these chemicals to the environment is usually human or animal sewage waste. These biologically-active chemicals are generally present at very low concentrations (generally ppt to ppb). Even at these low concentrations, they have been shown to have adverse impacts on aquatic life (e.g. feminization of fish). Wastewater treatment plants operated by urban municipalities can be effective at removing many of these chemicals. However, biologically-active chemicals coming from minimally treated or untreated waste sources, such as septic tanks and confined-animal feeding operations, are less likely to be degraded or removed from the waste stream prior to being released into the environment. Since these contaminants are derived from human and/or animal waste, near-surface aquifers, as well as streams, may be at risk. A recent assessment of ground water in the Helena Valley, Montana revealed that human and/or animal waste pharmaceuticals were present in approximately 80% of the wells sampled. The majority of the chemicals in the analyte list were human pharmaceuticals and most of the occurrences were attributable to human waste emanating from septic systems. However, there were also a number of occurrences that appear to be attributable to agricultural activities. These results demonstrate that pharmaceutical and endocrine disrupting contaminants are likely present in Montana's near-surface aquifers. I will report data from an initial survey for the presence of the pharmaceutical and endocrine disrupting chemicals in near-surface aquifers in Montana, which was completed this year. The primary goal of this survey was to assess aquifer contamination from agricultural practices and in particular livestock operations. A secondary goal of this survey was to assess aquifer contamination from human sources in predominately agricultural areas. The selection of wells for this survey reflected these goals. Approximately 50 to 60% of the selected wells are from agricultural areas that have a potential to be impacted by livestock waste. Approximately 30 to 40% of the selected wells are from areas in or near unsewered subdivisions in former agricultural areas. Approximately 10% to 20 % of the selected wells are from agricultural areas that are unlikely to be impacted by livestock waste. A total of 73 wells were sampled for this project. Concentrations of ten different EDCs were quantified in these samples, which very small analyte list compared to other studies. Even with this limited analyte list approximately 23% of the wells sampled contained at least one EDC compound. Although there were a significant number of occurrences of EDCs in ground water, the occurrences could not be correlated to geology, well depth, or general water-quality indicators. More work is needed in this area to fully evaluate the vulnerability of ground-water resources in Montana to EDC contamination.

11. Hydrologic Connectivity Between Landscapes And Streams: Transferring Reach And Network Scale Understanding To The Catchment Scale

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The relationship between catchment structure and runoff characteristics is poorly understood. In steep headwater catchments with shallow soils, topographic convergence and divergence (upslope accumulated area-UAA) is a hypothesized first-order control on the distribution of soil water and groundwater. Hillslope-riparian water table connectivity represents the linkage between the dominant catchment landscape elements (hillslopes and riparian zones) and the channel network. Hydrologic connectivity between hillslope-riparian-stream (HRS) landscape elements is heterogeneous in space and often temporally transient. We sought to test the relationship between UAA and the existence and longevity of HRS shallow groundwater connectivity. We quantified water table connectivity based on 146 recording wells and piezometers distributed across 24 HRS transects within the Tenderfoot Creek Experimental Forest (U.S. Forest Service), northern Rocky Mountains, Montana, USA. Correlations were observed between the longevity of HRS water table connectivity and the size of each transect's UAA ($r2=0.91$). We applied this relationship to the entire stream network to quantify landscape scale connectivity through time and ascertain its relationship to catchment scale runoff dynamics. We found that the shape of the estimated annual landscape connectivity duration curve was highly related to the catchment flow duration curve. This research suggests internal catchment landscape structure (topography and topology) as a 1st order control on runoff source area and whole catchment response characteristics.

12. Jack Creek Water Monitoring Project: An Uncommon Partnership With Remarkable Results

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The Jack Creek watershed is a mountain stream system located within the Madison Range east of Ennis, Montana. Jack Creek originates in high elevation environments and flows through developed and undeveloped areas, rangeland, pasture and cropland as it makes its way to the Madison River. The study area is exceptional because of main channel accessibility and its location with respect to proposed development and wilderness control points. The stream feeds directly into the Madison River, a tributary to the Missouri River and a blue ribbon trout fishery. An uncommon collaborative partnership between Moonlight Basin, Jack Creek Preserve Foundation, Madison River Foundation, Ennis High School district, private landowners, and Montana State University Extension Water Quality program was formed based on the shared belief of "giving back to the community". Partners have developed a water monitoring project along the main stem of Jack Creek for the following reasons: 1) to monitor Jack Creek to preserve and/or maintain water quality; 2) to introduce students to the practical/applicable side of math and science through experiential learning while gathering useful water quality and quantity data; and 3) to educate people of all ages about habitat and ecology, responsible development and environmental stewardship by providing opportunities that give people a deeper appreciation and foster a deeper understanding and involvement with our environment.

13. Elevated Sulfate And Nitrate Associated With The Boulder Batholith At The Headwaters Of The Clark Fork Basin

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Chemical analyses of ground water from 1,201 sites in the Clark Fork Basin show that the TDS of ground water is generally low, indicating good quality water for drinking and other uses; the median concentration is less than 250 mg/L. However, there are differences in the water composition between the headwaters, in the Summit Valley near Butte, and the rest of the basin. Most notably, nitrate and sulfate are detected more frequently and at higher concentrations in the Summit Valley. The average ground-water composition in Summit Valley samples is a Ca-SO4 type (median SO4 concentration = 66 mg/L), whereas the remainder of the Clark Fork Basin samples are a Ca-HCO3 type (median SO4 concentration = 8 mg/L). The difference in water chemistry between the Summit Valley and the rest of the Clark Fork Basin most likely reflects differences in geology. The Boulder Batholith, which forms the headwaters of the Clark Fork Basin, hosts the rich sulfide-ore deposits that made Butte a famous mining district. Similar sulfide deposits do not occur, or occur to a much lesser extent, in other granitic intrusions within the Clark Fork Basin. Therefore, oxidation of the sulfide minerals, predominately pyrite, in the bedrock and basin-fill materials most likely accounts for the elevated sulfate concentrations in the Summit Valley ground-water samples. The Boulder Batholith hosts a fractured-bedrock/ basin-fill ground-water system in the Summit Valley that is susceptible to surface sources of contamination. The basin-fill, derived from the Butte Quartz Monzonite, is very permeable and underlies thin, well-drained soils that have low organic carbon content. The valley margin is underlain by fractured granite, with thin or no soil cover, that can readily transmit water to depth. The high susceptibility is a major factor in the elevated concentrations of nitrate in the Summit Valley's ground and surface water as compared with other parts of the Clark Fork Basin. Of 239 sampled wells from the Summit Valley, 13 percent had nitrate concentrations exceeding the 10 mg/L health standard, and an additional 51 percent had concentrations greater than 2 mg/L, suggesting some land-use impact. Detailed sampling in the southeast part of the valley clearly showed a land-use impact where median nitrate concentrations in ground water below unsewered subdivisions were 5 to 9 times higher than adjacent undeveloped land. Baseflow samples from Blacktail and Silver Bow Creeks upstream from the wastewater treatment plant show elevated nitrate concentrations indicating ground-water impacts. The results illustrate that the Boulder Batholith is an important control on ground-water chemistry and the intrinsic susceptibility of the ground-water system at the headwaters of the Clark Fork River Basin.

14. Challenges In Assessing Watershed Management Practices With A Semi-distributed Environment Model Under Uncertainty

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The Buffalo Rapids watershed is an agricultural tributary to the Yellowstone River in eastern Montana. The watershed includes 155 full-time agricultural crop and or livestock producers with an average of 164 acres per full time farm. Issues of assessment of drinking water, pollution and prevention, and watershed management and conservation are integral to the future agricultural sustainability and economics of the watershed. Potential causes of water-resource degradation in the watershed include irrigation-related nutrient, sediment, and salinity loading, agriculturally-related nitrate-nitrogen and pesticide loading to shallow alluvial groundwater, and potentially inefficient use of water pumped from the Yellowstone River thereby critically reducing in-stream flows during low-flow periods of the year. Using a well researched hydrologic model (the Soil and Water Assessment Tool, SWAT) we aim to model, simulate and assess the effects of implementing watershed management scenarios on water quality and quantity. Current efforts are focused on studying the utility of automated calibration, sensitivity and uncertainty analysis algorithms for large-scale distributed models and on assessing the model performance using readily available flow, topographic, and soils data. Significant parameter and input data uncertainty associated with large-scale watershed scenario modeling, and the unavailability of adequate water quality data needed for satisfactory model calibration makes estimation of error in simulated output particularly challenging for distributed hydrologic modeling. The main objectives of the research are: i. To develop an uncertainty framework for the proposed model thus enabling the quantification of the prediction error of the model. ii. To assess and quantify the sensitivity of model to input data and parameters so as to guide future prioritization of data collection. iii. To develop and assess beneficial scenarios for future watershed management practices implementation. We will present the methodology used in the study, initial findings and ongoing challenges, and current plans for future work.

15. Modeling The Potential For Transport Of Contaminated Sediment From A Mine-Impacted Wetland

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Wetlands located downstream from Montana hard rock mines play a paradoxical role. The benefits they offer in attenuating flood waters and suspended sediments has led to wetlands serving as sinks for metal precipitates and contaminated sediment. However, during high spring runoff or storm events these wetlands may become significant sources of resuspended contaminants. The potential impacts to downstream groundwater, surface water, and sediment quality affect people, aquatic and riparian resources. As more money is devoted toward remediating mine sites and their downstream impacts, agencies, consulting firms, and watershed groups need a method to assess the potential for mine-impacted wetlands to resuspend contaminated sediments during large spring runoff events. The gains of removing contamination must warrant the amount of effort, funding, and site disturbance necessary to carry out the remediation. Remediation requires more than knowledge of the metals distribution. It also requires an understanding of the potential for redistribution. In our study, we combine surface water hydrology and hydraulics with groundwater hydrology to assess the potential for resuspension of metals from a mine-impacted wetland in west-central Montana. By coupling a one-dimensional surface water model (HEC-RAS) with spatial data gathered on soil types and contaminant loads in the area of interest, we explore the influence of spring run-off events on fluvial processes. This task entails estimating the catchment hydrologic response to precipitation events with 10, 25, 50, 100, 200 300 and 500 year recurrence intervals. Probability distributions for flood events in the ungauged basin are determined and analyzed for output uncertainties. Peak discharges for flood events are incorporated into HEC-RAS for event simulation. The modeled output is then used to determine distributions of shear stresses across the floodplain for each flood stage. Overlaid with spatial data from a GIS depicting metals distributions, the risk for sediment resuspension of contaminated areas is mapped. The central questions to our project are: 1. How will the magnitude and power of future spring runoff events impact the role of the wetlands in buffering the stream against sediment-born contamination? 2. How will the physical hydrologic processes during spring runoff events affect the transport of contaminated sediment out of the wetland complex? Our approach aims to develop a cost effective risk analysis approach that relies on easily procured data. This methodology will allow water resource managers, consulting firms, restorationists and decision makers to efficiently conduct risk-analyses regarding the potential for resuspension and redistribution of mine-impacted sediments in similarly affected fluvial environments throughout the region.

16. In-Stream Nitrate Immobilization Across Development Gradients, Ambient Nitrate Concentrations, And Stream Network Position In A Rapidly Developing Mountain Watershed

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Nitrogen immobilization in streams is an important process and partially determines the balance between N loading and export from headwater catchments. In-stream immobilization of streamwater N is well-studied, yet poorly understood, especially as one moves from reach to stream network scales, and across morphologic or ground water- surface water exchange gradients, seasons, and ranges of ambient N concentrations. We sought to quantify in-stream nitrate-N immobilization rates across the watershed to assess the role of the stream network in modifying observed watershed N loading patterns and controlling spatial distributions of stream network nitrate. We focused on the 212 km2 watershed of the West Fork of the Gallatin River, Big Sky, Montana for analysis of landuse change impacts on water quality because of its accelerated land development and interspersed wilderness. We conducted 45 stream tracer tests (22 steady-state and 23 slug additions) in nine stream reaches across a range of discharges, development intensities, ambient nitrate-N concentrations, and seasons. Six of the nine streams were paired for comparison based on similar watershed area and total discharge; each pair included a stream of high and low ambient nitrate-N, reflecting varying degrees of exurban development and upland wastewater disposal. For each stream addition, we tracked a concurrent conservative (NaCl) and non-conservative (KNO3) tracer with synoptic and breakthrough curve sampling. We further characterized gross and net streamflow gains/losses over each reach with mass recovery methods. This work represents a first step toward integrating watershed and stream network biogeochemistry in a rapidly developing mountain watershed.

17. Ground Water And Surface Water Monitoring For Pesticides And Nitrate In The Beaverhead And Ruby Valleys

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During the summer of 2007, the Montana Department of Agriculture conducted a sampling project to determine pesticide and nitrate impacts to the water resources of the Beaverhead and Ruby Valleys. Forty-six groundwater samples from 23 wells and six surface water samples from three sites were collected in June and September and analyzed for 95 pesticide compounds as well as nitrate and nitrite. Although pesticides were detected in less then half of the samples (46%), the concentrations were very low and the overall impact appears to be minimal. Nitrate was also detected in a little less then half the samples (44%), but concentrations were low in all samples. There were 40 detections of 10 different pesticides and one pesticide degradate in 20 of the 46 groundwater samples from 13 of the 26 sampling sites. The most commonly detected pesticide in groundwater was atrazine and one of its degradates, deethyl atrazine, and prometon. Atrazine detections are likely the result of historical uses before 1993 when it was a common general use herbicide. Prometon is a non-crop herbicide used in areas where long term control of weeds is desired. All of the pesticide concentrations in groundwater were low and none exceeded or approached human health drinking water standards, where such standards exist. Nitrate was detected in 23 of the 46 groundwater samples from 12 of the 23 sites. None of the nitrate concentrations exceeded 50 percent of the human health drinking water standard of 10 mg/L. The source(s) of nitrate in groundwater were not determined during this project. There were four detections of a single pesticide in four of the six surface water samples from two of the three sampling sites. The only pesticide detected in surface water samples was 2,4-D. 2,4-D is a very common herbicide used in both agricultural and non-agricultural situations. All of the concentrations in surface water samples were low and none exceeded or approached the human health drinking water standards or EPA aquatic life benchmarks. Nitrate was not detected in any of the surface water samples.

18. Diel Biogeochemical Processes; Stable Isotopes Variations Of Dissolved Oxygen And Inorganic Carbon

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Stable isotopes of hydrogen, carbon, oxygen and other elements have been widely used as probes to investigate the mechanisms operating in a variety of geochemical and biological processes for many years. More recently a number of studies have monitored the 18O composition of dissolved molecular oxygen (d18O-DO) and the 13C composition of dissolved inorganic carbon (d13C-DIC) as a means of assessing the metabolic balance (photosynthesis/respiration) in aquatic systems. Daily changes in the rates of photosynthesis, respiration and gas-exchange have been shown to have profound influences on critical geochemical variables such as pH, dissolved oxygen, alkalinity, dissolved carbon dioxide, redox state as well as the concentration of dissolved and particulate chemical species. Here we present a comprehensive picture of the persistence and reproducibility of diel cycles of d18O-DO and d13C-DIC across five Montana rivers investigated over a 4-year period. Additionally, a laboratory mesocosm experiment showed the same behavior in d18O-DO and d13C-DIC as seen in riverine settings across light and dark periods. A photosynthesis inhibitor was added to the mesocosm and stopped the effect attributed to photosynthesis while respiration and gas-exchange continued to produce the expected changes in d18O-DO and d13C-DIC. A comparison of the diel changes in d18O-DO and d13C-DIC to each other from four streams exhibits an elliptical pattern which is attributed to the daily changes in the balance of metabolic rates as well as air-water gas-exchange. The amplitude of the change in the isotope composition is shown to be directly related to the degree of change in the net productivity of the aquatic system. One of the streams investigated had high nutrient levels from anthropogenic sources and exhibited significantly larger changes in d18O-DO and d13C-DIC than any of the other systems studied. This work emphasizes that normal instream processes (respiration, photosynthesis, gas exchange, groundwater contributions, etc.) are significantly influencing not only the concentrations of both DO and DIC but are also producing substantial changes in the stable isotope composition of these compounds that are far from atmospheric equilibrium. There is a critical need to better understand the interrelationships between the various phases and components present in aquatic systems, and knowledge of the underlying mechanisms controlling diel concentration changes will allow us to make better predictions of how rivers and streams will react to changing conditions of eutrophication, climate change, drought, industrialization, and other variables.

19. Temporal Variability Of Dissolved Organic Carbon In The Big Hole River

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Diel (24 hour) concentration fluctuations of metals and metalloids in streams have been well documented in the literature. Daily cycles of temperature and solar radiation force chemical and physical changes in pH, alkalinity, dissolved oxygen, redox speciation, dissolved carbon dioxide, and dissolved and particulate concentrations of various chemical species. This project investigated the diel changes in the concentration of dissolved organic (DOC) and inorganic (DIC) carbon in the Big Hole River (BHR) during the summers of 2006 and 2007. DOC represents the single largest pool of reduced organic carbon in most aquatic systems. The presence of short-term temporal changes in the concentration of DOC has only been recently demonstrated. Sources of DOC to aquatic systems can include decomposition of organic matter and secretion by aquatic plants and microbes. Previous investigations have demonstrated that there are significant and reproducible diel cycles in the concentration DIC as well as the carbon stable isotope composition of DIC (d13C-DIC) in several Montana rivers. These changes are caused by the combined effects of gas-exchange, photosynthesis and respiration of aquatic plants and microbes; as well as carbonate mineral dissoulution. During a diel sampling in August 2006 in the BHR near the Mudd Creek USGS gage the DIC displayed little diel concentration change which is unusual for highly productive aquatic systems that have large diel changes in pH. However, the d13C-DIC did show a more typical diel pattern characteristic of the influences of photosynthesis and respiration. This is significant since is indicates that the composition of DIC can change while the concentration stays relatively constant. DOC during the 2006 BHR sampling increased dramatically during the night which is opposite to the results observed in other streams. A diel sampling in 2007, in the same reach and time of year as 2006, found no change in DOC concentration at three separate sampling sites over the 24-h period. This is in significant contrast to the results from 2006. The average flow in 2007 was about 1.7-times higher than 2006. Additionally, the unusual diel pattern in pH, specific conductivity and flow observed during 2006 was not repeated in 2007. It is possible that the diel change in DOC concentration measured in 2006 was connected to the hydrologic flow cycle that is present in the BHR especially during low flow periods. Significant streamside sources of DOC were identified during this field work in 2007. Diel changes in the physical and chemical composition of rivers can have a critical impact on the concentrations of a broad spectrum of chemical species being carried in dissolved and suspended forms. This work emphasizes that yearly differences in stream biogeochemistry and hydrology can have a significant influence on the diel behavior of important dissolved species such as DOC.

20. Altitude Of The Top Of The Madison Group, Cascade County, Montana

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The Mississippian Madison Group is an important and productive aquifer in much of Cascade County. As part of the Ground-Water Characterization Program study, the altitude of the top of the Madison was mapped across much of Cascade County and parts of Judith Basin and Chouteau Counties from 750 water-well and 340 hydrocarbon-well logs. The depth to the Madison is irregular because of structural deformation (folding and faulting) and erosion of the bedrock before younger deposits buried the unit. The Madison Group is 1,200 to 1,700 feet of thick-bedded limestone with thin chert and mudstone beds. Solution breccias of limestone, reddish shale, and residual soils formed on the Madison beneath the Jurassic unconformity. Most water wells penetrate a few tens of feet into the Madison; however, some wells in the map area penetrate hundreds of feet into the unit because the Madison aquifer is not saturated with ground water everywhere. The Madison is folded into a northwest-plunging anticline, the Sweetgrass Arch, that trends from the Little Belt Mountains, through Great Falls. Between the gently dipping flanks of the anticline, the crest is irregular in the Great Falls area. Kootenai and Blackleaf Formations are gently folded across the Sweetgrass Arch, showing the structure had a long history of activity during the Cretaceous. The top of the Madison beneath Jurassic and Cretaceous rocks is very irregular between the airport and the Big Bend in the Missouri River, southwest of Great Falls. This relief likely reflects paleotopography on the erosional unconformity that affected the top of the Madison. Near to and west of the city of Belt, the Madison is at a lower altitude than most adjacent areas. A map on the coal and black shale interval in the Morrison Formation shows that the Jurassic rocks filled in this depression, and may be related to both structural deformation and collapse of karst features. Stream and glacial Lake Great Falls sediments overlie the Madison in the subsurface along the long-recognized, pre-glacial Missouri River canyon. The greatest local relief developed on the Madison Group was from stream erosion during pre-glacial, likely Pleistocene, incision by the Missouri River along a now buried paleochannel. The Missouri eroded through the overlying Cretaceous and Jurassic strata, forming a narrow canyon in the Madison Group along what is now the lower reach of Sand Coulee Creek. About 80 well logs represent locations where Quaternary deposits directly overlie Madison limestone. This sediment-filled canyon is about one-quarter to one-half mile wide, and has local relief of about 300 feet. The maximum thickness of fill recognized in well logs was 495 feet near the downstream end of the channel. As the late Pleistocene continental glacier advanced into the area, the Missouri was dammed forming Glacial Lake Great Falls. Sedimentation in the lake back-filled the Missouri River valley and its tributaries. Deglaciation and lake drainage caused rearrangement of the lower stream courses to their present locations.

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