



PROCEEDINGS

for

Rivers of Change: Science, Policy & the Environment

American Water Resources Association Montana Section 2010 Conference

October 14 - October 15, 2010

Red Lion Colonial Hotel -- Helena, Montana

Contents

Thanks to Planners and Sponsors

Full Meeting Agenda

About the Keynote Speakers

Concurrent Session and Poster Abstracts*

Session 1. Stream Restoration & Assessment

Session 2. Groundwater

Session 3. Aquatic Ecosystems

Session 4. Water Policy & Use

Session 5. Water Resources Information Sources

Session 6. Geochemistry & Water Quality

Session 7. Hydrology & Streamflow Evaluation

Session 8. Riparian Zones

Poster Session

Meeting Attendees

***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!

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Steve Guettermann, Nancy Hystad, Gretchen Rupp, and MJ Nehasil

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



Margie Patton



Kirk Waren



Steve Guettermann



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WEDNESDAY, OCTOBER 13, 2010

REGISTRATION

10:00 am – 7:00 pm REGISTRATION
Preconference registration available at water.montana.edu/awra/registration/

FIELD TRIP

1:00 pm – 5:00 pm **Upper Tenmile Creek Mining Area Superfund Site**
Bus leaves Red Lion Colonial Inn promptly at 1 pm, returns at 5 pm
Dinner on your own.

THURSDAY, OCTOBER 15, 2010

REGISTRATION

7:30 am REGISTRATION
Preconference registration available at water.montana.edu/awra/registration/

OPENING SINGLE SESSION

Executive Room

8:25 am WELCOME & INTRODUCTIONS
Kirk Waren -- *AWRA Montana Section President*
Gretchen Rupp -- *Montana Water Center Director*

LOGISTICS & ANNOUNCEMENTS
Eric Chase -- *Montana Section AWRA Vice President*

8:50 WATER POLICY INTERIM COMMITTEE (WPIC) UPDATE
Joe Kolman -- *WPIC Staff*

9:05 KEYNOTE SPEAKER
Michael Campana -- *Professor of Geosciences, Oregon State University*
Title: *Hydrophilanthropy: Quo Vadis?*

10:05 BREAK

10:20 KEYNOTE SPEAKER
Robert Glennon -- *Morris K. Udall Professor of Law & Policy, University of Arizona*
Title: *Unquenchable: America's Water Crisis and What to Do About It*

11:20 BREAK for lunch

ORAL PRESENTATIONS

**SESSION 1 (Concurrent) *Legislative/Judicial*
Room
STREAM RESTORATION & ASSESSMENT**

- Moderator: Katherine Chase -- *USGS, Helena*
- 12:45 pm Tony Thatcher. *State of the Science: Channel Migration Zones in Different Landscapes and Scales.*
- 1:05 Nicholas Hehemann. *Metal Contamination in Mine Influenced Rocky Mountain Alluvial Streams Is Inversely Related to the Geomorphic Complexity of the Stream.*
- 1:25 pm Stephen Holnbeck. *Field Measurements of Flow Velocity Near the Mouth of the Blackfoot River to Evaluate Bull Trout Passage.*
- 1:45 Corey Engen. *Use of Biometric Data for Evaluating Fishery Improvement Project Success.*
- 2:05 Angela Frandsen. *Results of the Epa Third Five-year Review for the Silver Bow Creek/ Butte Area Superfund Site.*
- 2:25 BREAK

**SESSION 3 (Concurrent) *Legislative/Judicial*
Room
AQUATIC ECOSYSTEMS**

- Moderator: David Nimick -- *USGS, Helena*
- 3:00 pm Sean Sullivan. *Community Composition Analysis and Trace Metal (As, Cu, Cd, Zn, Thg) Concentrations in Benthic Biota: a Pre-restoration Description of the Upper Blackfoot River Mining Complex, Montana.*
- 3:20 Robert Thomas. *Inventory and Assessment of Fluvial Arctic Grayling Habitat Restoration on the Upper Big Hole River and Its Tributaries, Southwest Montana.*

**SESSION 2 (Concurrent) *Executive Room*
GROUNDWATER**

- Moderator: Tom Osborne -- *HydroSolutions, Inc.*
- 12:45 pm Scott Brown. *Saline Seep: from Farm to River.*
- 1:05 Christian Schmidt. *Sediment Bound Pyrethroid Insecticides in the Canal/Ditch Network Around Missoula, Montana.*
- 1:25 pm Randy Overton. *Estimating Annual Groundwater Production and Recharge from Confined Aquifers in the Intermontane Valleys of Montana.*
- 1:45 Curt Coover. *Sources and Flow Paths of Ground Water in the Southern Deer Lodge Valley Near Opportunity, Montana.*
- 2:05 Tom Patton. *Montana's Statewide Monitoring Network: a Potential NGWMN Cooperator.*
- 2:25 BREAK

**SESSION 4 (Concurrent) *Executive Room*
WATER POLICY & USE**

- Moderator: James Workman -- *SmartMarkets, Inc.*
- 3:00 pm James Workman. *Timeless H2Ownership: an Ancient and Equitable Tradition of Efficient Water Resource Trading in Desert Cultures.*
- 3:20 Monique Dutkowsky. *Institutions, Third-parties and Water Markets: an Analysis of the Role of Water Rights, the No-injury Rule, and Third-party Protection Laws on Water Markets in California Counties.*

THURSDAY, OCTOBER 14, 2010 (continued)

3:40	David Feldman. <i>Evaluating Macroinvertebrate Responses to Nutrients in a Prairie Stream Using Biometrics.</i>	3:40	Mike Roberts. <i>Instream Flow Management In The Upper Big Hole River: A Progress Report.</i>
4:00	Molly Staats. <i>Mercury Bioaccumulation in the Upper Clark Fork River Basin.</i>	4:00	Jim Robinson. <i>The Montana State Water Plan - an Implementation Strategy.</i>
4:20	Seth Kurt-Mason. <i>Hydrologic Behavior In Restored Streambeds: Does Function Follow Form?</i>	4:20	Tom Osborne. <i>Drinking Water Resource Development In Uganda- A Case Study.</i>

POSTER SESSION & SOCIAL HOUR

Natatorium

5:00 – 7:00 pm AWRA 2010 POSTER PRESENTATIONS

- | | |
|--|--|
| 1. Ginette Abdo. <i>Dillon Area Groundwater Investigation Program Study: Lower Beaverhead.</i> | 11. Amber McGivern. <i>Groundwater Quality in the Recently Reclaimed Silver Bow Creek Floodplain.</i> |
| 2. Victoria Balfour. <i>The Physical, Chemical and Hydrological Characteristics of Wildfire Ash.</i> | 12. Tom Michalek. <i>Gallatin Valley Groundwater Investigation Program Studies: Belgrade and Four Corners.</i> |
| 3. Adam Clark. <i>Quantifying Glacier-derived Summer Runoff in Northwest Montana.</i> | 13. Rick Mulder. <i>Nitrate and Pesticide Impacts in Shallow Gravel Aquifers of the Judith River Basin, Central Montana.</i> |
| 4. Allison Brown. <i>Using Stable Isotopes to Track Contamination of the Madison Aquifer by Acidic Coal Mine Drainage in the Stockett-centerville Area, Central Montana.</i> | 14. Joe Naughton. <i>Effects of Ammonia and Dissolved Oxygen Concentration on the Distribution and Abundance of Fishes in Silver Bow Creek, Montana.</i> |
| 5. Leah Burrell. <i>A Spatially Distributed Ecohydrological Model for Forested Catchments.</i> | 15. Tom Prescott. <i>Distribution of Nutrients and Metals Along Silver Bow Creek from Butte to Warm Springs Ponds.</i> |
| 6. Lauren Gordon. <i>Undergraduate Research: Groundwater Monitoring in the Upper Clark Fork River Floodplain.</i> | 16. Ann Marie Reinhold. <i>Seasonal Use of Side Channels and Shallow Slow-velocity Habitats by the Fish Assemblages of the Middle and Lower Yellowstone River.</i> |
| 7. Daniel Hatley. <i>Investigating Water Quality and Nutrient Loading in Salmon and Seeley Lakes, Montana.</i> | 17. Kien Seng Lim. <i>Rapid Detection of Pathogens in Water Using a Combination of Molecular Techniques.</i> |
| 8. Erwin Jeremiah. <i>A Comparison of the Robustness of Monte Carlo Samplers Used in Bayesian Calibration and Uncertainty Analysis of Hydrological Models.</i> | 18. Mikel Siemens. <i>Spatial Distribution of Transmissivity and Storativity for the Deep Alluvial Aquifer in the Flathead Valley.</i> |
| 9. John LaFave. <i>Groundwater Use in the Clark Fork Basin, Montana.</i> | 19. Adam Sigler. <i>Expanding the Network of Citizen Water Quality Monitoring in Montana.</i> |
| 10. Mariah Mayfield. <i>Fisheries Restoration Potential of the Clark Fork River Superfund Site: Habitat Use and Movement in Relation to Environmental Factors.</i> | |

THURSDAY, OCTOBER 14, 2010 (continued)

20. Tyler Smith. *Reducing Hydrological Uncertainties in Ephemeral Watershed Modeling Through Improved Statistical Inference.*
21. David Stagliano. *Wetland Habitat Associations of Dragonflies, Damselflies and Other Invertebrates in Montana's Reference Condition Wetlands: Uses in Statewide Assessment and Monitoring.*
22. Andrea Stanley. *A Watershed Study in an Evolving Agricultural Watershed, Upper Smith River, Meagher County, Montana.*
23. James Swierc. *Helena Area Ground Water Project.*
24. Jackie Timmer. *Screening for Organic Wastewater Chemicals in the Groundwater of Summit Valley, Montana.*
25. Kirk Waren. *Helena Area Groundwater Investigation Program Studies: North Hills and Scratchgravel Hills*
26. John Wheaton, et al. *MBMG Various Groundwater Posters.*

BANQUET

Capital Room

7:00 pm BANQUET

8:00 SPECIAL SPEAKER

Rich Moy -- *Chair of the Flathead Basin Commission*

Title: *History of Negotiations to Protect the Trans-boundary Flathead River Basin*

PHOTO CONTEST

Eric Chase

7:30 am Coffee in the Atrium

SESSION 5 (Concurrent) *Legislative/Judicial Room*

WATER RESOURCES INFORMATION SOURCES

- Moderator: David Feldman -- MT DEQ
- 8:20 am Karen Newlon. *Development of a Statewide Wetland Reference Network for Montana.*
- 8:40 Kyle Blasch. *Streamstats: a Water-resources Web Application for Montana.*
- 9:00 Katherine Chase. *Streamflow and Climate Variability Modeling Activities of the U.S. Geological Survey in Montana and the Western United States.*
- 9:20 Phil Farnes. *Montana Electronic Precipitation Map.*
- 9:40 Meghan Burns. *New Web-based Landcover Applications Available from the Montana Natural Heritage Program.*
- 10:00 BREAK

SESSION 7 (Concurrent) *Legislative/Judicial Room*

HYDROLOGY & STREAMFLOW EVALUATION

- Moderator: Chris Gammons -- Montana Tech
- 10:30 am Stan Jones. *Estimation of Canal Seepage Using Measurements of Inflow and Outflow: Flathead Indian Irrigation Project.*
- 10:50 Chuck Dalby. *Error Propagation in a Canal Seepage Study: Flathead Indian Irrigation Project.*
- 11:10 Bob Alexander. *A Search for an Alternative Water Supply for the Community of Rimini Located Within the Upper Tenmile Creek Mining Area Superfund Site.*

SESSION 6 (Concurrent) *Executive Room*
GEOCHEMISTRY & WATER QUALITY

- Moderator: Angela Frandsen -- CDM, Helena
- 8:20 am Chris Gammons. *Geochemistry and Limnology of a Small Pit Lake at the Abandoned Calvert Tungsten Mine, West Pioneer Mountains, Montana.*
- 8:40 Leslie Piper. *Stream Isotopic and Stoichiometric Response to Spatially-variable Nitrogen Loading in a Rapidly Developing Mountain Watershed.*
- 9:00 Tim Mulholland. *The Use of Biohaven® Floating Treatment Wetlands for Reducing Nutrient Concentrations in Raw Waste Water.*
- 9:20 Jim Wilbur. *Nutrient Reduction by Use of a Floating Treatment Wetland Placed in a Flowing Agricultural Irrigation Drain.*
- 9:40 David Nimick. *A Biological Cause for Large Summer Diel Streamflow Cycles, Upper Big Hole River, Southwestern Montana.*
- 10:00 BREAK

SESSION 8 (Concurrent) *Executive Room*
RIPARIAN ZONES

- Moderator: Tim Mulholland -- Headwaters Floating Island
- 10:30 am Tammy Crone. *Riparian Buffer Public Education Campaign.*
- 10:50 Christopher Kellogg. *Monitoring of Vegetation in the Riparian Corridor with Dams Using Remote Sensing Integrated with Geographic Information System.*
- 11:10 Linda Vance. *Assessment of Riparian Forests, Shrublands and Wetlands Along Montana's Large Rivers.*
- 11:30 Watson & Sigler. *Volunteer Water Monitoring.*

CLOSING PLENARY

Executive Room

11:55 am CLOSING PLENARY

Announcements, Officers, Photo Contest Awards, Student Awards

12:35 pm ADJOURN

MT GROUNDWATER CHARACTERIZATION COMMITTEE MEETING

Board Room

1:00 pm MT GROUNDWATER CHARACTERIZATION COMMITTEE MEETING

KEYNOTE SPEAKER

Michael E. Campana, Ph.D.

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Michael E. Campana is Professor of Geosciences (hydrogeology and water resources management) and former Director of the Institute for Water and Watersheds at Oregon State University. He previously (1989-2006) worked at the University of New Mexico, where he was the Albert and Mary Jane Black Professor of Hydrogeology and Director of the Water Resources Program. From 1976 to 1989 he was a research hydrologist at the Desert Research Institute in Reno and taught at the University of Nevada-Reno, where he was active in the hydrologic sciences program as a teacher and mentor. He also taught at Georgia State University and the University of California-Santa Cruz. He has supervised the work of 70 graduate students at three universities and has published widely in the areas of hydrology; hydrogeology; water resources planning, policy, and management; transboundary water resources; water quality; developing countries; and education.

Campana's primary international work is in Central America, the South Caucasus, and Central Asia. He has been a Fulbright Scholar (Belize), the Gallagher Visiting Scientist at the University of Calgary, and a Visiting Scientist at the Research Institute for Groundwater (Egypt) and the International Atomic Energy Agency (Vienna). At the 2009 Fifth World Water Forum in Istanbul he played a major role in getting groundwater into the Forum's discourse.

He is a former board member and Vice President of the National Ground Water Association and chaired its largest division, the Scientists and Engineers Division. In 2005 he received the division's Keith Anderson Award for excellence in service. He will be President of AWRA in 2011 and serves as President of the Oregon section of AWRA. He has also served on the boards of American Institute of Hydrology and the Universities Council on Water Resources. Since 1988 he has served on numerous committees and boards of the National Research Council, Heinz Center and other organizations. He currently serves on two NRC committee: 1) Evaluation of Cycle 3 of the USGS's National Water Quality Assessment (NAWQA) program; and 2) Sustainable Water and Environmental Management in the California Bay-Delta.

Campana has become increasingly involved with: 1) hydrophilanthropy; and 2) communication, especially among water professionals and between them and the public and decision makers and policy makers. He established the nonprofit Ann Campana Judge Foundation (<http://www.acjfoundation.org>) that supports and undertakes water and sanitation projects in Central America. He founded NGWA's Developing Countries Interest Group. With respect to communication, he has made effective use of traditional methods and electronic/social media. In the mid-1990s he was one of a small group that initiated regional water planning in the Albuquerque, NM, area and in 2009 was one of the main organizers of Oregon's Statewide Water Roundtables, the first such series of facilitated meetings designed to ascertain Oregonians' concerns about present and future water issues and communicate the results. He has created and maintained several email lists devoted to water and related issues, initiated the popular WaterWired blog (<http://aquadoc.typepad.com/waterwired>) in early 2007 and more recently, the WaterWired Twitter (<http://twitter.com/waterwired>). He posts regularly to the AWRA and other blogs. In recognition of his communication efforts AWRA awarded him the 2009 Icko Iben award.

He is a native New Yorker who has lived in the western USA almost continuously (save for one year in Atlanta) since 1970. He received his BS (geology) from the College of William and Mary, and MS (hydrology) and PhD (major: hydrology; minor: mathematics) from the University of Arizona.

Abstract

Hydrophilanthropy: Quo Vadis?

Many believe that we in the developed world have a responsibility to assist our sisters and brothers in the world's emerging regions (ER) address their own water, sanitation, and hygiene (WaSH) needs. There recently has been unprecedented interest, especially among students, in ER water work. This interest takes a variety of forms: 1) performing research in-country, in collaboration with locals, to help build in-country research capacity and educate/enlighten students; 2) conducting philanthropic work, including disaster relief; 3) developing formal programs with ER institutions to facilitate research, and student and faculty exchanges; 4) doing professional work; and 5) developing appropriate technologies.

The term hydrophilanthropy was coined by Dr. David Kreamer of UNLV to describe the type of work described above. In attempting to define the term I often channel former Supreme Court Justice Potter Stewart: "I can't define hydrophilanthropy, but I know it when I see it." One definition of hydrophilanthropy I use is: the altruistic concern for the water, sanitation, and related needs of humankind, as manifested by donations of labor, money, or resources. Not everyone likes the term or the aforementioned definition; for an excellent perspective, read Dr. Kreamer's article in the September 2010 issue of *Water Resources IMPACT*, which is devoted to hydrophilanthropy.

In addition to the aforementioned issue of *Water Resources IMPACT*, the current issue of the *Journal of Contemporary Water Research and Education* is also devoted to hydrophilanthropy.

Many North American technical groups are invested in ER hydrophilanthropy. The best-known are Engineers Without Borders, Water For People, Hydrogeologists Without Borders, and more recently, professional/trade societies such as the National Ground Water Association (NGWA). Religious and church groups are often practitioners of hydrophilanthropy. The SAIWI (Student Association for International Water Issues) group at the University of Nevada-Reno has been active since 2000; the University of Oklahoma has its WaTER (Water Technologies for Emerging Regions) Center. Large and small NGOs, such as my own, are also involved. Some private firms encourage their employees to participate in hydrophilanthropic endeavors. Indeed, the US Congress is involved; witness the Water for the Poor Act.

Michael's presentation will cover: 1) his own and his students' hydrophilanthropic experiences; 2) pitfalls; and 3) speculate upon where hydrophilanthropy is headed.

KEYNOTE SPEAKER

Robert Glennon, Ph.D.

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Robert Glennon is the Morris K. Udall Professor of Law and Public Policy in the Rogers College of Law at the University of Arizona. A recipient of two National Science Foundation grants, he serves as Water Policy Advisor to Pima County, Arizona; as a member of American Rivers' Science and Technical Advisory Committee; and as a commentator and analyst for various television and radio programs. He is also a Huffington Post blogger.

Glennon is the author of the highly-acclaimed *Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters* (Island Press, 2002). His new book, *Unquenchable: America's Water Crisis and What To Do About It*, was published in April 2009. Since then, he has been a guest on *The Daily Show* with Jon Stewart, *The Diane Rehm Show*, C-SPAN2's *Book TV*, and National Public Radio shows in New York City, Chicago, Phoenix, and Cleveland. He's also published pieces in the *Washington Post*, the *Arizona Republic*, and the *Arizona Daily Star*. In 2009, his speaking schedule took him to Switzerland, Canada, and 17 U.S. states.

Glennon received a J.D. from Boston College Law School and an M.A. and Ph.D. in American History from Brandeis University. He is a member of the bars of Arizona and Massachusetts.

Abstract

Unquenchable: America's Water Crisis and What To Do About It

Professor Robert Glennon's presentation will revolve around some of the issues presented in his recent book, "Unquenchable: America's Water Crisis and What to Do about It." Many reviewers claim Glennon has captured the tragedy and irony of water in America. According to Glennon, America's water woes will get worse before they will get better because water is the overlooked resource. He asserts that the burgeoning love affair with biofuels will turn to heartbreak once America realizes that thousands of gallons of water are required to produce one gallon of fuel. A new ethanol plant in Minnesota, for example, quickly began depleting an important local aquifer.

Can we engineer our way out of the problem with projects such as the one designed to divert Mississippi River water to Nevada? Glennon doesn't think so. America must make hard choices to address its water crisis and take action on multiple fronts to solve it. His answer is a market-based system that values water as a commodity and a fundamental human right. Glennon will also sign copies of his book "Unquenchable" during the Thursday evening social. Books will be available for purchase at the conference.

SPECIAL SPEAKER

Rich Moy

Chair of the Flathead Basin Commission
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Email: rmoy@netzero.com



Rich works as a land and water consultant and recently finished coordinating the development of a comprehensive trans-boundary Crown of the Continent eco-region strategy and agenda for the National Park Conservation Association. He is also a Senior Fellow at the Center of Natural Resources and Environmental Policy at the University of Montana where he is working on Crown of the Continent and water policy initiatives. Presently, he is building a home on Swan Lake.

For 27 years, Rich focused on collaborative, strategic and science-based approaches to water policy, planning and trans-boundary and regional water and land issues. He helped oversee Montana's water policies; planning and management for the Montana Department of Natural Resources and Conservation.

Rich worked extensively with other states and federal governmental agencies on regional water management issues in the Missouri and Columbia River basins including; water allocation, fisheries, water quality, reservoir operations, and drought management. Recently, Rich served as chair of the 23-member Flathead Basin Commission which has a statutory duty to protect water quality and the environment of the largest fresh water lake west of the Mississippi River.

Rich worked at length with the Canadian provinces of British Columbia, Alberta and Saskatchewan, the Canadian federal government and the International Joint Commission (IJC) on water quality, fishery, wildlife, apportionment, and landscape issues for over 25 years. Rich served as the U.S. Secretariat on IJC's trans-boundary Flathead Study that evaluated the potential impacts of a proposed B.C. coalmine in the headwaters of the Flathead River. He represented the State of Montana on the IJC's Milk/St. Mary Rivers Task Force that evaluated the apportionment of flows between Montana and Alberta and on the Crown Manager's Partnership whose members are responsible for managing the Crown of the Continent eco-region. Rich oversaw the implementation of the apportionment between Montana and Saskatchewan on the Poplar River. He has negotiated two trans-boundary environmental accords with the provincial governments of British Columbia and Alberta on behalf of the State of Montana.

Prior to this work, he directed Montana's involvement in the High Plains Research Experiment for 4 years and before that, worked as a park ranger and ecologist in Glacier National Park where he was primarily responsible for developing the park's backcountry management plan.

Rich received an MA from the University of Montana and almost completed a Ph.D. in animal ecology from the University of Missouri-Columbia. Rich enjoys carpentry, traveling, skiing, hiking and fly fishing. He and his wife, Gigi have three grown children.

Abstract

History of Negotiations to Protect the Trans-boundary Flathead River Basin

Rich Moy has years of experience working to maintain the wildness of the North Fork of the Flathead River. He will elaborate on some of that work in his talk “History of Negotiations to Protect the Trans-boundary Flathead River Basin.” U.S. efforts to protect the trans-boundary Flathead from mining impacts in British Columbia have been a roller coaster ride for over 30 years. Rich will identify the highs and lows of negotiations with British Columbia, and then elaborate on the reasons that led to Premier Campbell of B.C. and Montana’s Governor Schweitzer to draft and sign the February 2010 Memorandum of Understanding and Cooperation (MOU & C).

Rich will also describe the diverse ecological values within the Crown of the Continent eco-region and the trans-boundary Flathead, why these areas need protection and the role science, education and local outreach played in getting to the current state. He will go behind the scenes to describe the International Joint Commission process and its conclusions about the Cabin Creek Mine proposal that sought to open the area to mining. Rich will close with an overview of challenges that still exist to permanently protecting the trans-boundary Flathead.

State of the Science: Channel Migration Zones in Different Landscapes and Scales

Tony Thatcher, DTM Consulting, Inc., 211 North Grand, Suite J, Bozeman, MT, 59715, tony@dtmgis.com. Additional authors: Karin Boyd, Applied Geomorphology, Inc.; Bryan Swindell, DTM Consulting, Inc.

Mapping Channel Migration Zones (CMZs) at a range of scales provides a variety of challenges and opportunities. CMZ boundaries can be used to define erosion hazards and identify appropriate boundaries for river corridor management in an ecological context. CMZ maps typically define a corridor of channel occupation over a given time frame and are becoming increasingly popular as a floodplain management tool. Since the original work by the Washington Department of Ecology (Rappe and Abbe, 2004) a suite of CMZ mapping techniques have been developed and applied to rivers ranging in scale from large rivers to small streams. The techniques form a matrix of available methodologies that can be applied to a variety of stream scales and landscapes. DTM Consulting and Applied Geomorphology have mapped over 700 miles of Montana rivers and streams using a variety of CMZ techniques. Our current projects include the Flathead River, Ruby River, and Prickly Pear Creek and provide an opportunity to apply and assess the CMZ concept on a range of stream sizes. This talk will discuss the challenges we have encountered associated with scale and quality of available data, the geomorphic context of the corridor, and the desired management outcomes.

Metal Contamination in Mine Influenced Rocky Mountain Alluvial Streams Is Inversely Related to the Geomorphic Complexity of the Stream.

Nicholas Hehemann, University of Montana, Geosciences, 125 W. Sussex, Missoula, MT, 59801, nh142968@grizmail.umt.edu.

Many site assessment programs test the geochemistry of the water and sediment while ignoring the role geomorphology plays in dictating the environmental health of a stream. By considering the geomorphology in conjunction with the geochemistry, an accurate assessment of how physical processes control the health of a stream is possible. The Upper Blackfoot River (UBFR) basin is a mine-impacted metal laden stream system which has provided an interesting opportunity to study the relationship between channel form and water/sediment quality. The basin contains both clean reference streams and mine-impacted streams. The UBFR and its many tributaries have allowed for an examination of how geomorphology and geochemistry vary within a channel network, and planned restoration provides a unique opportunity to study how the contaminated streams may be restored to the natural state observed in the reference streams. It is hypothesized that metal contamination in mine influenced Rocky Mountain alluvial streams is inversely related to the geomorphic complexity of the stream. Geomorphic complexity is being measured by surveying the channel geometry and analyzing channel bed sediment size distribution at various study reaches. To test this hypothesis, channel geometry, and bed material composition are coupled with geochemical analysis of water and sediment samples to determine geomorphic form controls on metals transport through the stream system. Study reaches include locations upstream and downstream of two wetland complexes, and on tributaries which have and have not been impacted by mining. Determining how physical processes control the health of the streams in the basin will increase understanding of how to remove contaminants and restore natural channel form in these and other mine influenced Rocky Mountain alluvial streams. The calculation of geomorphic complexity is the summation of three separate spatial scales: sediment size complexity, cross-section complexity, and thalweg complexity. The three spatial scale complexity calculations are then assigned a scaling factor and their products are summed. Greater geomorphic complexity values correspond to larger summation values. Statistical relationships are established between the explanatory variable, geomorphic complexity, and response variables of interest (i.e. various metal concentrations and contaminant levels). Relationships established between the variables allow for an assessment of when and where contamination levels rise and fall. The preliminary geochemical analysis of metal concentrations from 2009 has shown that the reach of the Blackfoot River between the two marsh complexes exhibit similar concentrations to the upstream contaminated reaches, whereas, the reach downstream from the second marsh has greatly

reduced concentrations of all metals. This is interesting because field observations of the reach between the two marshes, suggest healthy biodiversity and geomorphic complexity. It is hypothesized here that the first marsh acted as a contaminant sink until it became contaminated enough to be a source, and the second marsh is simply not yet completely contaminated. This would provide credence to the belief that a marsh complex may function as a contaminant filter on a short term spatial scale, but if the marsh becomes fully inundated with contaminants it may then become a source of downstream contaminant transfer.

Field Measurements of Flow Velocity Near the Mouth of the Blackfoot River to Evaluate Bull Trout Passage

Stephen R. Holnbeck, Hydrologist, USGS, 3162 Bozeman Ave., Helena, MT, 59602, (406) 457-5929, holnbeck@usgs.gov. Additional authors: Sean M. Lawlor, USGS; Peter M. McCarthy, USGS.

The Blackfoot River watershed in western Montana is important habitat for the threatened bull trout (*Salvelinus confluentus*). The removal in 2008 of Milltown Dam on the Clark Fork, 0.27 miles downstream from the mouth of the Blackfoot River, eliminated a major obstacle that hindered migration of bull trout into the Blackfoot River for over 100 years. With the dam removed, scientists anticipate that bull trout can enter the Blackfoot River to reside until fall spawning. However, two interstate bridges near the mouth of the Blackfoot River cause substantial contraction of streamflow, and high flow velocities result during spring runoff when bull trout migrate upstream into the Blackfoot River. Field measurement of flow velocity was needed to supplement hydraulic design studies. Consequently, the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, began measuring flow velocities near the mouth of the Blackfoot River in 2009 to quantify hydraulic conditions created by the contracted bridge opening and to characterize flow velocity over the spring runoff hydrograph. During spring 2009, velocities measured at bankfull discharge exceeded the threshold velocity of 6.0 feet per second generally considered favorable for bull trout passage. Data collection was expanded in 2010 to include velocity measurements closer to the channel edges and over a wider range of streamflows. Velocity was measured using an acoustic Doppler current profiler and a vertical-axis current meter. The profiler was deployed using a tethered boat attached to cableways at four transects. Measurements were made to identify where the favorable flow threshold was exceeded.

Use of Biometric Data for Evaluating Fishery Improvement Project Success

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FlyWater, inc. is a professional corporation specializing in fishery development, improvement and management. Over the course of the last six years, we completed a number of stream improvement projects. As part of the baseline assessment for some these projects, we collected biometric data in conjunction with physical and hydrological data. A portion of the biometric data collected utilized electrofishing means to sample fish populations. After the improvements were implemented, post project conditions were sampled via electrofishing with the same methodology as baseline assessments. Electrofish catch rates and fish population characteristics from both pre and post improvement conditions were compared. This comparison enabled us to determine whether or not the project was successful in recruiting and holding more of the targeted fish species. During the oral presentation, we would like to discuss these projects and process and suggest how incorporation of biometric data into pre and post project assessment can be valuable in evaluating success of fishery improvement projects.

Results of the Epa Third Five-year Review for the Silver Bow Creek/Butte Area Superfund Site

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The Silver Bow Creek/Butte Area Superfund Site, part of the Clark Fork River Basin, is made up of 8 unique remedial operable units (OU), each in various stages of the Superfund process. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) provides that remedial actions which result in any hazardous substances, pollutants, or contaminants remaining at a site above levels that allow for unlimited use and unrestricted exposure be reviewed every five years to ensure protection of human health and

the environment. Thus, as required, EPA conducted the third, five year review for the Silver Bow Creek/ Butte Area Site in 2010. This review included 6 of the 8 OUs: Warm Springs Ponds Active Area, Warm Springs Ponds Inactive Area, Streamside Tailings, Rocker, Butte Priority Soils, and Butte Mine Flooding. Previous five year reviews have focused on the performance of the Warm Springs Ponds. The 2010 review provided an opportunity to perform a comprehensive evaluation of the remedial progress and health of Silver Bow Creek from its headwaters in Butte to the Warm Springs Ponds. This is because of the progress made on the Streamside Tailings OU (construction is estimated to be completed in 2012) and because the record of decision for Butte Priority Soils was completed in 2006. This presentation will present the major findings of the Silver Bow Creek/Butte Area Site 2010 Five Year Review, with the goal of showing the remedial progress made on Silver Bow Creek without being constrained by operable unit boundaries. Successes and potential issues will be presented to provide perspective on remaining work at the Site.

SESSION 2 GROUNDWATER

Saline Seep: from Farm to River?

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The PowerPoint presentation will be an overview of how MT Salinity Control Association works with individual landowners, government agencies, conservation districts, and watershed groups to reduce saline seeps that are adversely affecting surface water drainages. In some areas of the glaciated plains, ground water seeps to the surface, carrying with it salts from the bedrock and soil, resulting in a traditional saline seep. When multiple saline seeps occur, they can collectively impact surface water drainages. Land-use changes on the surface can minimize that impact. In other words, when anthropological activity (such as crop/fallow farming, or leaking irrigation canals) on the surface exacerbates saline seep formation, the activity can be changed to slow the process of saline seep formation, and subsequently reduce surface water degradation. This involves identifying treatable ground water recharge areas, and establishing perennial forage in those areas to minimize salt transport throughout the watershed. Cooperation among various organizations and individuals makes this possible. Examples of ongoing projects in the Teton River, Sun River and Sage Creek Watersheds will be discussed.

Sediment Bound Pyrethroid Insecticides in the Canal/Ditch Network Around Missoula, Montana.

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In 2009, the Groundwater Protection Program of the Montana Department of Agriculture (MDA) conducted a sediment investigation within the canal/ditch network in and around Missoula, MT to investigate the existence and potential aquatic invertebrate toxicity of sediment-bound synthetic pyrethroids. Pyrethroids are structural analogues of natural pyrethrins of botanical origin. They are largely insoluble, non-persistent chemicals, and are relatively immobile in the environment. Pyrethroids have high adsorption coefficients and bind tightly to the organic fractions in soils and sediment. Bound to soil particles, these chemicals are prone to off-site transportation and deposition in surface water bodies via overland flow. Average 10-day LC50 for the amphipod *Hyalella azteca* for several commonly used pyrethroids have been reported in the range of 0.45 -- 10.83 µg/g OC (organic carbon-normalized) in several California streams. These insecticides have been observed to alter invertebrate physiology at concentrations much lower than established sediment toxicities. Known aquatic LC50s for detected pyrethroids were examined to assess risk of exposure to multiple pyrethroids in the form of a toxic unit (TU) assessment. Five different pyrethroids were detected in the project area: bifenthrin, cypermethrin, lambda-cyhalothrin, permethrin (cis- and trans- isomers), and allethrin. Toxic units (TUs) per sediment sample were calculated to evaluate toxicity due to exposure to multiple sediment-bound pyrethroids. Per site, TUs had a range of 0.01 -- 0.32 TUs with a mean of 0.07 TUs (n=9) for the July 9th

sampling event and a range of 0.00 -- 0.14 TUs and a mean of 0.04 TUs (n=11) for September 10th samples. Aquatic invertebrate growth is typically inhibited at concentrations approximately 1/3 to 1/2 of the LC50. One author found that the average, animal biomass was 38% below the level of the controls when exposed to pyrethroid sediment concentrations at these levels, and a majority of samples displayed >40% mortality of *H. azteca* when total pyrethroids reached ~0.4 TUs. The mortality increase at 0.4 TUs is not linear and mortality curves have not been formulated due to a paucity of data and the site-specific nature of pyrethroid toxicity on aquatic invertebrates. The TU analysis for MDA samples did not yield a sample in excess of 0.4 TUs. The highest observation was a July 2009 sample collected in Orchard Homes which contained 0.32 TUs. Bifenthrin was responsible for 80% of sediment toxicity on average including 98% of total toxicity in the Orchard Homes sample discussed above. No sediment toxicity testing was done as part of this investigation. Therefore, peer-reviewed literature from pyrethroid studies performed most often in California were used to gather LC50 data for selected pyrethroids. In referencing the literature, it was determined that sediment-bound pyrethroids in the canal/ditch system in and around the City of Missoula are not at concentrations that would be considered toxic to *H. azteca*. It is likely that retail sales and structural pest control and residential maintenance and control by professional applicators are the source of detected pyrethroids. However, in-state sediment toxicity experiments are needed to critically quantify risk to aquatic invertebrates in Montana.

Estimating Annual Groundwater Production and Recharge from Confined Aquifers in the Intermontane Valleys of Montana

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A method for estimating the annual groundwater production and recharge from confined aquifers is explained and demonstrated. The deep alluvial aquifer of the Flathead Valley north of Flathead Lake is used as an example. The method utilizes information derived from hydrographs generated from the Montana Bureau of Mines and Geology groundwater monitoring network and characteristics of the confining unit, but does not rely on pumping records. The estimated annual production volumes and the recharge differential between years are compared to the sum of existing groundwater appropriations for the deep alluvial aquifer. The result illustrates the year to year trend of the net annual decline or gain from the aquifer, and how the aquifer responds to and recovers from cycles of drought. Implications of the method use for long term aquifer management are outlined.

Sources and Flow Paths of Ground Water in the Southern Deer Lodge Valley Near Opportunity, Montana

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This presentation will describe investigations performed by or under the direction of CDM to determine whether a known ground water contamination source is a threat to nearby residential wells. The Southern Deer Lodge Valley in Montana is impacted by widespread contamination of surface water, irrigation water and ground water by arsenic as a result of nearly 100 years of copper smelting. Some areas contain uncontaminated ground water that supplies domestic wells within and near the community of Opportunity, MT. To determine whether the wells are threatened or if a long-term clean water source is present, several surface water and ground water investigations traced the flow of water from two watersheds to the points of use. Investigations included detailed mass loading evaluations, installation and monitoring of four USGS gaging stations, mapping of irrigation ditches and irrigated lands, mapping and sampling of tile drains, installation of permanent and temporary monitoring wells, ground water monitoring, and sampling of domestic wells. Through comparison of common ion concentration ratios, water table mapping, and surface water loading analyses, it was determined that the ground water within deeper portions of the aquifer have a source upgradient of the contaminated areas of the site, ensuring a long-term source of clean ground water.

Montana's statewide monitoring network: A potential NGWMN cooperator

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Montana's statewide groundwater monitoring network provides long-term time-series data useful to address groundwater resource issues. The network is part of the Ground Water Assessment Program at the Montana Bureau of Mines and Geology (MBMG). Water-level and water-quality data from the network are stored in Montana's Ground Water Information Center (GWIC) database and are available through the GWIC website at <http://mbmgtgwic.mtech.edu>. The network design is based primarily on aquifer extents, conceptual groundwater flow models, and density of groundwater development. Water-resource managers, consultants, government scientists and others use statewide network data to help address issues including: how might the sealing of irrigation distribution canals or adoption of more efficient irrigation practices change the amount of groundwater in storage and the timing of discharge to streams? How do aquifers react to interannual or longer precipitation variability? State-level monitoring programs generate data that not only address state issues but are also useful to address national questions. A challenge for the nation is to successfully integrate information generated by non-federal monitoring networks into a National Ground Water Monitoring Network (NGWMN). Successful integration will require reconciling differing field practices, data management systems, and location and well construction data sets. Overall alignment of mission between non-federal networks and a NGWMN is also important to insure that long-term data will be collected. Integrated state and NGWMN sites will produce data important at the state and national levels. Therefore, the federal and non-federal partners must ultimately share the costs of measuring, processing, and making the data available nationally. The ACWI/SOGW framework document, A National Framework for Ground-Water Monitoring in the United States addresses the many issues surrounding integration of non-federal and federal networks and includes a portfolio of funding/data gathering models that tailor potential funding options to the interests, capabilities, and long-term monitoring missions of potential NGWMN cooperators.

SESSION 3 AQUATIC ECOSYSTEMS

Community Composition Analysis and Trace Metal (As, Cu, Cd, Zn, THg) Concentrations in Benthic Biota: a Pre-restoration Description of the Upper Blackfoot River Mining Complex, Montana

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The Upper Blackfoot Mining Complex (UBMC) is located in the headwaters of the Blackfoot River Montana and is scheduled for remedial activities following decades of surface and groundwater contamination. In the summer of 2009 concentrations of select metals (As, Cu, Cd, Zn, and THg) were determined from whole body samples of select macroinvertebrates taxa. Sampling was also conducted to determine community composition of sites affected by the surface and groundwater contamination. The goal of these analyses is to 1) describe pre-restoration bioavailability of metals in an area scheduled for restoration 2) determine concentrations of select metals in reference reaches and contaminated sites, and 3) establish baseline benthic insect community composition data for reference and contaminated reaches within the UBMC. Five sites were sampled along the contamination gradient below a surface water impoundment on Mike Horse Creek; additionally four sites were sampled in the same area not directly affected by the Mike Horse Dam to serve as reference sites. Results suggest that the surface water impoundment and upstream mining has enriched the concentrations of metals in benthic invertebrates as compared to local reference reaches. Analysis demonstrates Zinc and Copper are of highest concentrations in invertebrate tissues, while Cadmium, Arsenic and Total Mercury show signs of being minimally bioavailable to the benthic biota at both the impacted and un-impacted sites. Trophic analysis

shows that a significant difference exists for THg between scrapers and predators in the Upper Blackfoot Mining Complex. Invertebrate communities as a whole have suffered from the presence of elevated metals, and significant differences exist between reference and study sites in: mean density, mean taxa richness, mean Metals Tolerance Index and general community structure. Mine reclamation and stream restoration will ideally result in a decrease in the concentration of metals found in invertebrate tissues in the main stem of the Upper Blackfoot River and allow for the recovery of the invertebrate communities post restoration. Reclamation and restoration are prolific in the Rocky Mountain west and these data serve as a baseline assessment of pre-restoration conditions in the UBMC. Historical data to base invertebrate “recovery” on is often lacking in historically mined areas. The inclusion of baseline information into restoration plans may play a pivotal role in determining the success of the “Last Best Disturbance” in the Upper Blackfoot Mining Complex.

Inventory and Assessment of Fluvial Arctic Grayling Habitat Restoration on the Upper Big Hole River and Its Tributaries, Southwest Montana

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The Environmental Field Studies classes at the University of Montana Western (UMW) in Dillon, Montana have been conducting assessments of stream morphology, in-stream macroinvertebrates, riparian vegetation and stream habitat on the upper Big Hole River and its tributaries in southwest Montana for the last three years. The goal of the project is to assess riparian restoration efforts conducted by the U.S. Fish and Wildlife Service and Montana Department of Fish, Wildlife and Parks in order to improve habitat for fluvial Arctic grayling. The UMW assessment data are being used by the agencies to adjust their restoration efforts in order to maximize limited resources. The upper Big Hole River and its tributaries are primarily degraded by ranch activities, including bank degradation and siltation caused by cattle grazing, dewatering for irrigation, mechanical straightening of sinuous channels and removal of bank vegetation through grazing and human activities. In addition, persistent and increasing drought and the introduction of invasive species have taken their toll on fluvial Arctic grayling numbers, which are estimated to be down to less than 1000 individuals in the entire Big Hole River drainage. The assessment data show that the upper Big Hole River and many of its tributaries are significantly impaired. They should be functioning as E4b streams based on Rosgen’s classification system, but are currently functioning as C4 channels with increased width-depth ratios, in-stream braiding and decreased sinuosity. The in-stream macroinvertebrate data show relatively poor diversity and richness, and the total number of individuals is low for a functioning stream of this type. The riparian vegetation is relatively robust and diverse, but the percentage of willow is low for a stream of this type. The stream habitat data show a high percentage of non-vegetated stream banks and an overall morphology dominated by shallow pools and long riffles. Following restoration work in 2007, the McDowell Reach of the upper Big Hole River evolved into a stream with improved sinuosity, smaller width/depth ratios and increased grain sizes, showing that the restoration work is having the intended impact. Arguably, the most important change was in the morphology of pools, which evolved from 41 to 19 meters in length and doubled in depth one year after the restoration work. Continued monitoring by UMW students is planned for the foreseeable future in order to document long-term changes associated with the restoration.

Evaluating Macroinvertebrate Responses to Nutrients in a Prairie Stream Using Biometrics

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The Montana Department of Environmental Quality currently uses macroinvertebrate populations as indicators of water quality (i.e. biometrics). In order to accurately depict biometric responses to different stressors, data must be collected along a gradient from high quality (i.e. reference sites) to low quality (i.e. stressed sites). This study focused on nutrients as the stressor, and instead of sampling different stream sites along the gradient from reference to stressed, we decided to dose a prairie stream (Box Elder

Creek, Carter County, MT) with varying levels of nitrogen and phosphorus using a control and two different treatments. We will then measure the impact and recovery over time. The nutrient dosing will occur summer 2010, and the recovery will be measured periodically through 2014. The purpose of this presentation will be to provide an overview of the study design and how macroinvertebrate populations will be evaluated prior to the dosing event and the recovery afterward.

Mercury Bioaccumulation in the Upper Clark Fork River Basin

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Mercury is a heavy metal that exists naturally in small quantities in the environment, but today, the major global source is from atmospheric-anthropogenic processes. At a local scale, such as the Upper Clark Fork River Basin, historic gold/silver mining contributes the majority of the mercury found in the environment. Mercury enters aquatic systems in inorganic forms, such as Hg⁰ and Hg²⁺ and is transformed to methylmercury by sulfur reducing bacteria and filamentous algae. Methylmercury (MeHg) is of the greatest concern due to its ability to bioaccumulate within higher trophic levels, causing severe neurotoxic diseases and mortality. In Montana, elevated mercury levels are the leading cause for human-fish consumption advisories. At the local watershed scale, the theory of mercury bioaccumulation is dependent on two factors, a source of inorganic mercury and the rate of methylation. Fine-grained sediment can be designated as the sole source term, as it facilitates the sorption of inorganic Hg due to the high surface area, presence of clay minerals, organic matter, solid oxides and hydroxides. While the methylation term is dependent on the presence and activity of sulfate reducing bacteria, which are effected by environmental characteristics such as water velocity, depth, soil matrix, presence of organic matter and temperature. Thus, in areas with a high mercury source term and high methylation potential term, bioaccumulation of methylmercury should approach a maximum, potentially leading to toxic effects in upper trophic level biota. The objective of this study is to test this theory by determining the source term (total mercury concentration of fine-grained sediment) in 10 reaches within the Upper Clark Fork River Basin, evaluate environmental factors that determine the methylation potential of mercury, and the amount of total mercury that bioaccumulates in multiple trophic levels through the sampling of aquatic invertebrates, riverine fish, and osprey. In addition the aim of this study is to determine which environmental factors and which term (source or methylation potential) facilitates greater amounts of mercury to bioaccumulate through the food web. Preliminary data indicates that in the Lee Metcalf Wildlife Refuge Bitterroot River reach the mercury concentration of the fine-grained sediment is relatively low (0.02 mg/kg) and the mercury methylation potential is high (due to the wetlands) resulting in levels in the blood of young osprey being higher than expected (average of 243.5 µg/L). The Bearmouth reach on the Clark Fork River is associated with a high source term (3.20 mg/kg) and a medium methylation potential term, resulting in a mercury level of 690 µg/L in the osprey blood. Once additional reaches have been sampled and the invertebrate and fish trophic levels included this study will be able to identify areas of high Hg accumulation, with minimal cost associated with sampling an entire system.

Hydrologic Behavior in Restored Streambeds: Does Function Follow Form?

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Interactions between the physical structure of streambeds and the hydraulic characteristics of overlying surface-waters govern storage and exchange processes responsible for transporting water and solutes among the stream, riparian zone, and alluvial aquifer. Despite well-documented linkages between individual channel features, hydrologic retention, water quality, and in-stream habitat quality, the influence of reach-scale channel reconfiguration on the complex interactions between streambed structure, channel hydraulics, and hydrologic behavior are not well characterized. Prior to and immediately following large-scale channel realignment of several reaches of Silver Bow Creek in southwestern Montana, we seek to 1) elucidate changes in hydrologic behavior resulting from channel realignment, 2) identify relationships between measures of

hydraulic and topographic complexity, solute transport characteristics and larger spatio-temporal exchanges with groundwater, and 3) identify useful metrics for evaluating the condition of hydrologic behavior and its trajectory toward or away from baseline conditions. We suggest that incorporating assessment of hydrologic storage and exchange dynamics into adaptive management frameworks will lead to more cost effective restoration approaches, while providing new avenues for improving long-term water quality, ecological and economic value of restored streams.

SESSION 4 WATER POLICY & USE

Timeless H2ownership: an Ancient and Equitable Tradition of Efficient Water Resource Trading in Desert Cultures

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Who, if anyone, should own water and what is it worth? That question, far from abstract, has stumped thinkers as eminent as Adam Smith. Yet the answer remains emphatically important for the scarcity valuation and equitable management of increasingly contentious water resources. Across the U.S., 52,000 absolute monopolies control fixed rates of what is essentially rent-controlled water, leading to conflict and waste. Some believe there is no alternative. But three case studies of desert cultures show that where individuals own and exchange equitable shares of water, civilization can thrive in the harshest of landscapes. Taken together, their lessons provide the basis for how the rest of our increasingly urbanized world can develop institutional resilience and adapt to the extreme flux of climate change, demographic stress and political conflict.

Institutions, Third-parties and Water Markets: an Analysis of the Role of Water Rights, the No-injury Rule, and Third-party Protection Laws on Water Markets in California Counties

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Given the apparently large potential gains from the trade of water, why do we observe so few water market transactions? This paper argues that policy-driven transaction costs stemming from two common water laws are an important trade-hindering factor. It examines the allocation of property rights under the No-Injury Rule, which gives rights to riparian users, and California's third-party protection law, Water Code 386, which gives quasi-blocking rights to third-parties, making water rights less clear. The results indicate that the No-Injury Rule decreases the likelihood that the county will have an active export market by 30 percent and decreases the ratio of exports to appropriations in counties with active markets by 7.4 percent. This suggests that if California's goal is, as stated in the 1970's, to reallocate water to its highest valued use via water markets, the current allocation of property rights may be creating policy-driven costs that hinder reaching that goal.

Instream Flow Management in the Upper Big Hole River: a Progress Report

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Continued efforts towards mitigating low flows in the upper Big Hole River watershed has resulted in marked improvement of streamflows on a daily and annual basis since the inception of a program designed to address habitat and flow concerns for a potentially Federally-listed species, the fluvial Arctic grayling. This program, Candidate Conservation Agreement with Assurances (CCAA), was implemented in 2006 by the U.S. Fish and Wildlife Service and three other partner agencies including the Montana Department Fish, Wildlife and Parks, the U.S. Natural Resource and Conservation Service, and the Montana Department of Natural Resources and Conservation (DNRC). The DNRC's responsibilities have focused on improving instream flows through the quantification and control of water use, and the negotiation of flow reduction agreements with 34 participating landowners who use the water for irrigation and stock. In order for landowners to agree to reduce diversionary amounts that in most cases have not changed for several generations, the DNRC

has had to acquire an intensive knowledge base of basin hydrology, site-specific water use, instream biological needs, and irrigation and cultural practices. With several site-specific flow plans signed in the past year, the approach to instream flow enhancement has transitioned from the voluntary approach employed from 2005 to 2009 to CCAA-required diversion reductions. While many site-specific plans have yet to be completed, the contributions of all the landowners participating in the project have improved not only instream flows but water management practices in general.

The Montana State Water Plan: An Implementation Strategy

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Recent amendments made by the 2009 State Legislature to Montana's water planning legislation (MCA 85-1-203) reflect the water resource challenges faced by the state. In summary, the legislation directs DNRC to characterize the state's water resources, inventory the myriad demands placed on those resources, and make recommendations regarding the means by which water resources may be applied for the benefit of the people. Credible estimates of supply/demand relationships are fundamental to understanding water availability in any given watershed, and DNRC's approach to implementing Montana's water planning legislation is multi-faceted, reflecting the basic relationship between water supply, use, and availability. There are two primary initiatives under the water supply component of the Montana State Water Plan (SWP): 1) the USGS/DNRC Cooperative Stream-flow Gaging Program (Coop Program) and 2) StreamStats. The Coop Program is a long-standing partnership between USGS, DNRC, and other local partners that funds operation of approximately 250 stream-flow gaging stations statewide. Newly initiated in 2010 is a partnership between USGS and DNRC to produce StreamStats - an interactive Internet map application designed by USGS and Earth Systems Research Institute, Inc. (ESRI) to provide stream-flow statistics (e.g., 100-year high flow, 7-day, 10-year low flow) for both gaged and un-gaged locations statewide (see <http://water.usgs.gov/osw/streamstats>). Together, the stream gage network and StreamStats form the basis of DNRC's approach to quantifying water supply under the SWP. Chief among the initiatives intended to characterize water use in Montana are development of a geospatially enabled version of the DNRC Water Rights Database (WRDB), and updating of the DNRC Water Resource Surveys (WRS) (see http://www.dnrc.mt.gov/wrd/water_rts/survey_books). The two geospatial components of a water right are the point of diversion (POD) and place of use (POU). Geospatial enabling of the WRDB involves mapping PODs to the National Hydrography Dataset (NHD) and linking those PODs to mapped representations of associated POUs. Approximately 96.5% of the water diverted in Montana is used for irrigation (USGS SIR 2004-5223); therefore, initial emphasis of the Water Resource Survey update involves development of an irrigated lands GIS layer attributed with water use information such as water right number, method of irrigation, and crop type. This will allow estimation of consumptive water use associated with a given irrigated parcel. Once water supply and water use are adequately characterized, both the physical and legal availability of water can be assessed. DNRC's goal is to provide water use information with sufficient accuracy to allow meaningful geographic queries of PODs and POUs within a given basin. To accomplish this, DNRC has partnered with USGS and the Montana State Library, Natural Resource Information System (NRIS) to update and publish the high resolution (1:24,000) version of the NHD with mapped PODs as an associated dataset. When combined with hydrologic data returned from a StreamStats query, the two sources of information (StreamStats and the updated Water Resource Surveys) will allow preliminary assessment of the often large disparity between water claimed via the DNRC water right administrative process, and water physically available in a given basin.

Drinking Water Resource Development in Uganda: A Case Study

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Over the past three years we have been involved with the Hope 2 One Life Foundation of Billings (<http://www.hope2onelife.org>) in developing water supplies and drip irrigation projects to address the water needs of Ugandan school children sponsored by Montana families, and for 50 war refugee families who live on

a resettlement farm near Masindi in west central Uganda. Uganda is a country roughly the size of eastern Montana with a population of 30 million people. It occupies the great east African rift valley with basement rock dominated by Precambrian gneiss and granite. A thick mantle of laterite residuum blankets the uneven bedrock surface. Tectonic activity through late Pleistocene resulted in major river changes such as the Nile's reach to Lake Victoria, and has produced "drowned valleys" such as Lake Kyoga and 2-way flow of the Kafu river. Millions of Ugandans are without sanitary and reliable sources of drinking water, leading to rampant water-borne diseases, and shortened life-spans for those suffering from sickle cell anemia and malaria. In the 2008 dry season we found that for 10,000 people of Bugogge village, the only available water was from three perched mud-holes. Development of village water supplies is challenging due to limited groundwater availability from residuum and fractured bedrock aquifers, lack of capital, and difficult operating logistics. We've observed numerous "failed wells" with people waiting hours or days for wells to recover sufficiently to allow hand pumping. For the better drilling companies, it is standard practice to conduct pre-drilling geophysical surveys using electrical conductivity and resistance profiling methods to target deeper bedrock "pockets" and fracture zones. "Successful" wells are those which produce 1,000 liters per hour (l/h, 4.4 gpm) or more. Our January 2010 trip to Uganda was focused on rehabilitating one of the two water wells on the refugee farm which produced water tainted with iron and sediment. We found that the pump cylinder was buried in 7 meters (m) of fine sediment, likely due to inadequate well screen and filter pack construction. Filter pack was added to the inside of the well, reducing the total depth from 45 m to 34 m. Static water level was at 18 m. The water cleared after a day of well development, with a yield of about 600 l/hr (2.6 gpm). The well was fitted with a submersible diaphragm pump and operated by a battery charged with two 75-watt solar panels. Buried plumbing connects the well to 3,500 liters of elevated storage, which is about the maximum sustainable daily yield of the well. Although manual transport is still required, many of the families on the farm are relieved of having to hand-pump their daily water supply. It also minimizes their need to dip into ponds and mud-holes for drinking water. Time and experimentation is required to determine if such installations are effective through the wet seasons and maintainable with available resources.

SESSION 5 WATER RESOURCES INFORMATION SOURCES

Development of a Statewide Wetland Reference Network for Montana

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The creation of a statewide wetland reference network is a critical part of a comprehensive wetland assessment and monitoring program in Montana. The Montana Natural Heritage Program has established a statewide wetland reference network representing least disturbed examples of Montana's herbaceous wetland systems. Defining least disturbed condition for wetland systems across the state helps identify appropriate expectations or targets for management actions that affect wetland condition, such as restoration and mitigation projects. Examples of wetlands in least disturbed condition also promote a broader understanding of our wetland resources by providing managers and watershed groups with accessible guidelines for evaluating and characterizing wetland systems. Additionally, the reference network allows for the establishment of baseline wetland condition to track changes over time. We will discuss the development of Montana's reference network as well as how information from this network can be used to inform other wetland assessment and monitoring projects across the state. We will also discuss the development of our wetland assessment database that will allow wetland professionals to access statewide wetland assessment data.

StreamStats: a Water-resources Web Application for Montana

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Streamflow statistics for gaged and ungaged locations on Montana rivers and streams are used by many organizations involved with flood control, infrastructure design, resource development, or regulatory issues. Currently, not all streamflow statistics for gaged stations are available through the Web, and no current equations exist for computing streamflow statistics for ungaged locations. The Montana Water Science Center of the U.S. Geological Survey (USGS) in cooperation with the Montana Department of Natural Resources and Conservation (DNRC) is pursuing plans to implement a Web-based interactive tool called StreamStats to provide this type of streamflow data. StreamStats was developed nationally by the USGS and its implementation locally will provide a convenient method for determining streamflow statistics at any stream location within Montana. StreamStats for Montana will provide users with access to analytical and geospatial tools to compute streamflow statistics, drainage-basin characteristics, and other pertinent information for any stream site selected. StreamStats users choose locations of interest from an interactive map to obtain the hydrologic information. If a user selects the location of a USGS streamflow-gaging station, streamflow characteristics will be determined from recorded data. If a user selects an ungaged location, StreamStats will delineate the drainage-basin boundary, calculate basin characteristics, and estimate natural streamflow characteristics for the site using published regression equations. By automating these tasks, StreamStats saves users substantial time. Further, StreamStats will serve as a useful clearinghouse for important basin-characteristics and hydrologic information normally inaccessible to most scientists and water resource managers within Montana. Currently, the USGS and DNRC are surveying water resource agencies to compile a list of useful statistics to incorporate into StreamStats and also have initiated a low-flow statistics study. Results from this study will be incorporated into StreamStats. In cooperation with the Montana Department of Transportation, the USGS is currently updating flood-frequency estimates for gages around the state to be used in StreamStats. Pending the availability of resources, full implementation of StreamStats for Montana is projected for 2013.

Streamflow and Climate Variability Modeling Activities of the U.S. Geological Survey in Montana and the Western United States

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The U.S. Geological Survey (USGS) uses a variety of tools to assist Federal, State, Tribal, and local agencies in water-resources planning in the face of climate variability and change and shifting land-use practices. These tools include techniques for obtaining and using precipitation and temperature output from General Circulation Models (GCMs), regional climate models, precipitation-runoff models, water-management models, fully coupled surface-water/groundwater models, and a Web-based portal to help compile and share model input and output data. GCMs simulate physical processes around the globe in the atmosphere, ocean, cryosphere, and on the land surface. They are used to project future climate change caused by increasing greenhouse-gas concentrations and other factors. Temperature and precipitation output from GCMs can be used in precipitation-runoff models to simulate streamflow response to projected climate change, but first the data must be transferred from the global-scale GCM to a smaller-scale local watershed (downscaled). GCM outputs have been downscaled for watershed modeling in the South Fork Flathead River watershed in Montana and in several other states. In addition, regional climate models using boundary conditions from GCMs have been created for parts of Montana. The Precipitation-Runoff Modeling System (PRMS) numerical model is being used to simulate daily streamflow and snowpack under changing climate and land use conditions for watersheds in Montana and other western states. These watershed models use precipitation and temperature data from GCMs or from historical records. PRMS is being coupled with RiverWare, a river basin modeling and management tool, to help water users plan for and adapt to variable water availability and changing water demands in Washington and Colorado. PRMS also is being coupled with the MODFLOW groundwater model in California, Colorado, and several other states to investigate surface-water/groundwater interactions; the resulting GSFLOW hydrologic model can be used to study the effects of changes in irrigation practices and climate on streamflows. As PRMS is becoming more widely used, the USGS is striving to streamline data collection for precipitation-runoff modeling and to coordinate model development among model users.

To that end, the USGS, in cooperation with the U.S. Fish and Wildlife Service, is developing a Web-based portal where digital elevation models and soils, land-cover, and vegetation data can be downloaded for watersheds throughout the United States in a format compatible with PRMS. Model input and output datasets can be shared through the same portal.

Montana Electronic Precipitation Map

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An accurate average annual precipitation is a useful tool when developing hydrologic and hydraulic parameters. A new average annual precipitation (AAP) map has been developed that incorporates Montana and surrounding states stations that meets criteria for accuracy and scale. It was done using GIS techniques and is capable of being updated with new base periods. Currently, the standard is to use 30-year base periods updated every 10 years. The current average period used by most agencies is 1971-2000. The next period will be 1981-2010. Previous studies indicate that the scale of elevation base map must be less than 500 meters in order to be useful in hydrologic studies. Electronic results are compared to hand-drawn products to assure appropriate results. Stations adjacent to Montana in Idaho, Wyoming, North Dakota, South Dakota, Alberta, and British Columbia are used to assure compatibility along the border. The location of all stations was converted to NAD 83 with latitude and longitude recorded to the nearest degree-minute-second. Isohyetal lines are set at 2-inch increments under 20 inches AAP and 10 inch increments above 20 inches. Isohyetal lines pass through known points of precipitation i.e., the 20 inch line goes through stations with 20 inches AAP. AAP was determined using nearest neighbors and multivariate inverse distance squared (MIDW). Approximately 500 National Weather Service (NWS) stations were used. In addition to those with 30 years of record in the base period, estimates of average were determined for stations with less than 30 years record in the base period and for discontinued stations by correlation with nearby active stations. AAP was estimated at approximately 200 active and discontinued snow course locations using correlation between April 1 snow water equivalent (SWE) and AAP from SNOTEL stations in their area. SNOTEL stations provided another 80 locations having AAP. Data from an old NWS storage precipitation gage network were also incorporated as well as a few stations from individuals, USGS, USFS, and others. To assure that precipitation for elevations above the data sites is being applied correctly, 170 synthetic points were developed using linear elevation-precipitation relationships from nearby measured sites. It is planned to include monthly and seasonal precipitation in the future. Data will be available through Montana DEQ or NRIS web sites electronically.

New Web-based Landcover Applications Available from the Montana Natural Heritage Program

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Several new web-based applications have been recently developed by The Montana Natural Heritage Program (MTNHP) that could assist water resource professionals. In addition to Montana Field Guides that provide information on plants, animals, and lichens, we have recently added an Ecological Systems field guide. This new field guide provides information on the range, distribution, associated species, photographs, and more for over 50 naturally occurring systems in Montana. Another new addition includes downloadable digital maps of wetland and riparian mapping created by The Wetland and Riparian Mapping Center at MTNHP. These maps provide wetland and riparian attribute information for U.S. Geological Survey 1:24,000 topographic quadrangle maps. Finally, our most recent addition is the new Montana Land Cover Map Viewer, which provides statewide land cover information within a web-mapping application format. Land cover data information can be viewed from the county or 4th code hydrologic unit levels down to the section level while allowing the user to view land cover information simultaneously with various imagery sources, including the 2005 and 2009 true-color and color infrared aerial imagery.

Geochemistry and Limnology of a Small Pit Lake at the Abandoned Calvert Tungsten Mine, West Pioneer Mountains, Montana

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The Calvert Mine is an abandoned open pit tungsten mine located in the Pioneer Mountains of southwest Montana. Approximately 110,000 tons of ore were mined between 1956 and 1961, and the principal ore mineral was scheelite (CaWO_4). The main pit flooded after mining ceased creating a lake that is currently up to 90 feet deep and 350 by 410 feet in diameter at the surface. Prior to this study there was minimal published data on the water quality of the pit lake. Steep side slopes surround the lake and the geology of the walls of the pit is dominated by a weakly-altered granitic intrusion with pockets of whitish-gray marble and epidote-garnet skarn. The lake is clear, cold, has very good visibility (secchi depth > 50 ft.), and no signs of associated acid mine drainage (AMD). The absence of AMD is attributed to an abundance of marble and low concentrations of metal sulfides at the site. The Calvert pit lake therefore is an interesting contrast to most metal-mining pit lakes which typically have AMD and associated problems related to elevated concentrations of metals and/or metalloids. Water-quality depth profiles were collected at the site four times between August and December, 2009. A prominent thermocline existed at a depth of 25 to 35 ft. in late summer, but disappeared by December as wind and cold weather brought a complete top-to-bottom lake turnover. pH values ranged between 7.0 and 8.5 for all sampling dates, and tended to be lower at depth in the lake. In late summer, dissolved oxygen concentrations were near atmospheric saturation in the epilimnion of the lake, increased near the thermocline, and then decreased with depth, with an anoxic hypolimnion. Concentrations of all trace metals and metalloids were extremely low, with the exception of Mn, which increased towards the bottom of the lake indicating a probable zone of bacterial Mn-oxide reduction. Stable isotope analysis of water shows that the pit lake has been significantly evaporated, which is consistent with the absence of any surface inlet or outlet. Small groundwater seeps entering a nearby creek were shown by stable isotopes to be a mixture of lake water and background groundwater. However, we have no data to suggest that this seepage is degrading water quality in the creek. Overall, the Calvert pit lake is a clean lake, with no obvious water quality problems.

The Role of Nutrient Uptake by Epilithon in Controlling Concentrations and Ratios of Dissolved Nutrients in a Developing Mountain Watershed

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Traditionally, the impacts of anthropogenic nutrient loading on streams have been estimated based on measurements of dissolved nutrient concentrations at their outlets during summer baseflow. In large and heavily-impacted systems, these measurements are often correlated to the extent of development and/or agriculture within the contributing watershed. In the West Fork of the Gallatin River, a developing mountain watershed in southwestern Montana, we see this pattern clearly in the winter, but there is a complete disconnect between development influence and nutrient concentrations during the summer months. One theory on the cause of this disconnect is that biota in the watershed is “resetting” the development signal through nutrient uptake during the active summer growing season. In this talk, we will present data in support of this theory, focusing largely on the role of epilithon and how uptake by this assemblage can alter water column nutrient concentrations and ratios. We will also discuss how easily-measured nutrient uptake values can be used as a more reliable estimate of the magnitude of human impact on systems.

The Use of Biohaven® Floating Treatment Wetlands for Reducing Nutrient Concentrations in Raw Waste Water.

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Floating Treatment Wetlands (FTWs) are an innovative technology that can be used to retrofit traditional sewage lagoons for treatment of nitrogen and phosphorus constituents in raw waste water prior to discharge. The need for this technology is driven by the ever more stringent Total Maximum Daily Loading (TMDL) standards. The FTW technology is based on the concept of Biomimicry where nature is looked to as a resource for engineered solutions. The BioHaven® FTW technology is modeled after naturally occurring peat-based floating islands common to the upper Midwest but also found in Montana. These specific FTWs are constructed of eight inch thick porous mats of 100% recycled polyester fibers with marine grade foam for flotation. The BioHavens are then planted with specific vegetation and the roots grow through the mats and suspend into the water column. The mats offer approximately 300 square feet of internal surface area for each cubic foot of volume and the plant stems and roots offer even more surface area for the growth of microbes and other biofilm to transform waste water contaminants to meet applicable standards. The result is a combination of phyto- and microbial remediation of waste water that is cost effective and easy to operate. Several years of bench and field scale testing has been conducted on BioHaven FTWs since 2005 and in November 2009, the first full scale demonstration project was launched in an aerated lagoon waste water setting. The aerated lagoon services Rehberg Ranch Residential Subdivision which was built in 2005 on the outskirts of Billings, Montana USA, a city of 120,000 people. Rehberg Subdivision is located in an area beyond the reach of the City of Billings' municipal sewer system. The stand-alone wastewater treatment system for the subdivision is an aerated lagoon designed to meet USEPA secondary standards for BOD and TSS. Treated water, rather than being discharged to surface water or groundwater, is land-applied to native prairie grasses that require relatively low nutrient loads. The BioHaven FTWs are being used to remove contaminants so treated water can be applied to less acreage at a higher rate, which will reduce costs. The particular BioHaven FTW embodiment includes both a submerged portion of approximately 1300 ft² and a 1000 ft² elevated plant growth perimeter. It was partially planted during the November 2009 launch and will have additional vegetation added in spring 2010. While the BioHaven continues to mature, initial cold weather treatment results are very encouraging and approach those measured in the earlier studies. A summary of initial results are summarized below. Results (May 2010 data): Improvement Compared to Control Lagoon -- Ammonia 29%, Total phosphorus 40%, TSS 62%, BOD 3%

Nutrient Reduction by Use of a Floating Treatment Wetland Placed in a Flowing Agricultural Irrigation Drain

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The recently developed Water Quality Restoration Plan and Total Maximum Daily Loads for the Lake Helena Watershed identified nutrient enrichment from both nitrogen and phosphorus as a source of impairment to several stream segments and the lake. The source of excessive nutrient loading is from both point and non-point sources. At the watershed scale, the most significant sources of total nitrogen and total phosphorus loading are wastewater management (septic systems and municipal wastewater treatment facilities); return flows from the Helena Valley Irrigation District (HVID), and agriculture. The plan states that the solution to the nutrient problem is to immediately begin reducing nutrient loads from all sources, both point and non-point in the watershed. Given the difficulties in controlling non-point pollution sources, a pilot project to study the effects of innovative floating treatment wetland (FTW) technology on reducing nutrients concentrations within an agricultural irrigation and groundwater drain was conducted. FTW's have been shown to treat nutrients, suspended solids, and other contaminants by means of microbial biosequestration similar to a natural wetland but more concentrated. This concentration of treatment is believed to be due the growth of biofilm on the expanded surface area matrix provided by the materials used to construct the FTW. Most uses of the FTWs have been in pond settings. This project was one of the first uses of the FTW technology in a flowing water

setting. Monthly water quality sampling and laboratory analysis was conducted for ten months within the HVID drain prior to installation of the floating wetland. After installation was complete, monthly water sampling and analysis continued both upgradient and downgradient of the wetland. The sampling was conducted to evaluate the impact of the FTW on water quality within the drain. The project continued throughout two growing seasons after installation to compare the seasonal affect of the FTW. The project identified several issues related to the use of the FTWs for this purpose. These include the question of water contact timing in a flowing water setting and whether a measurable result could be achieved. The performance of the technology during cold weather season and winter plant dormancy combined with the seasonal variation of nitrate and nitrites which show a winter high concentration in the drain. Other problems included trash and debris buildup, development of preferential flow patterns, wildlife predation of the wetland vegetation, and flooding impacts.

A Biological Cause for Large Summer Diel Streamflow Cycles, Upper Big Hole River, Southwestern Montana

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During summer, amplitudes of diel streamflow cycles in the upper Big Hole River can vary substantially from year to year at a site 15 miles downstream from Wisdom, Montana. For example, flows during mid-August 2005 ranged from 55-101 ft³/s in the late afternoon to 141-210 ft³/s before dawn, with daily increases of as much as 156 percent from the minimum. In contrast, daily increases for the same period during 2007 were only 12-24 percent. Possible causes of the interannual variation in diel flow cycles were studied by review of historical data as well as synoptic sampling of tributaries upstream from the site and repeated measurement of streamflow and water quality during diel sampling of the mainstem on September 7-8, 2005. These studies suggested that evapotranspiration (ET) by riparian vegetation is not the main cause of the diel flow cycles in this reach of the Big Hole River because (1) estimates of potential water uptake by riparian vegetation are much smaller than the diel flow fluctuations, (2) diel cycles in concentrations of conservative ions that often accompany ET-induced diel flow cycles and that would be expected based on calculated composition of groundwater inflow are absent, and (3) the magnitude of the diel flow cycles varies substantially from year to year. Alternatively, the diel flow cycles are thought to be driven by diel changes in biological activity of periphyton and macrophytes that “puff up”, perhaps related to O₂ production, while actively photosynthesizing during the day to “dam” the river, and then relax during the night to release the pooled water. This hypothesis is reasonable because (1) diel flow cycles are reduced in years when unusually high spring runoff presumably scoured the streambed and removed much of the aquatic vegetation, (2) river stage increased while measured flow decreased during mid-afternoon of the diel sampling episode, and (3) the magnitude of the diel flow cycles during August 2005 correlated more closely with daily mean water temperature ($R^2 = 0.73$) than with daily mean air temperature ($R^2 = 0.33$), indicating that the effect of temperature on biological activity of aquatic vegetation may have been more pronounced than the effect on water consumption by riparian ET. This proposed biological damming phenomenon may affect other streams, which, like the Big Hole River, are wide, shallow, and biologically productive.

SESSION 7 HYDROLOGY & STREAMFLOW EVALUATION

Estimation of Canal Seepage Using Measurements of Inflow and Outflow: Flathead Indian Irrigation Project

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Heavy water demand on the Flathead Indian Irrigation Project leaves many streams with little water for

instream flow and other water uses. Seepage from earthen irrigation canals represents substantial water loss to local groundwater. As part of ongoing water right negotiations between the CSKT, the State of Montana, and the federal government, negotiators are looking for practical ways to conserve water that can be freed up for Tribal uses. Accordingly, the Montana RWRCC authorized the Flathead Indian Irrigation Project Canal Seepage Study to develop estimates of canal seepage losses. Several methods have been used to estimate canal seepage including, ponding studies, surface-groundwater models calibrated with dense piezometer net works, and mass-balance or inflow-outflow studies. We chose the latter for pragmatic (e.g. ponding studies require taking canals out of production) and scientific reasons (e.g. we anticipated canal losses large enough to measure). Two approaches were considered for measuring canal mass balance: instantaneous synoptic measurements, and seasonal hydrographs. Given the potential for rapid changes in flow during normal operation of the canals, we thought synoptic measurements could give misleading results, so the hydrograph approach was chosen. Twelve study reaches were selected, and all inflow and outflow of surface water within each reach was measured for most of the 2009 irrigation season. On canals and larger laterals, standard USGS area-velocity methodology was used to measure discharge. On one small lateral, ramp flumes were installed instead. At locations where pipelines had previously been tapped directly into the canal, in-line propeller meters were installed. At each open-channel measurement site, recorders were installed to record water height on 15 minute increments of time. Approximately five flow measurements were taken over a range of flows and rating curves were established from the five flow measurements. Flow rates and volumes were then calculated, and incremental results were averaged for each 24 hour period to determine mean daily flow. Seepage loss for each study reach was determined by subtracting daily outflow from daily inflow. Results were summarized for the seasonal periods and on unit canal length basis.

Error Propagation in a Canal Seepage Study: Flathead Indian Irrigation Project

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The accuracy of canal seepage estimates, derived from inflow-outflow studies, is limited by two principal sources of error: (1) uncertainty in discharge measurements, and (2) uncertainty in measurement of water-surface elevation. Errors in discharge and stage at upstream and downstream canal sections contribute to statistical uncertainty in final regression-based discharge estimates used to calculate the inflowing and outflowing volume of water in a canal over a period of time. If errors upstream and downstream flow values are large, and the canal loss is small, then actual seepage is within the measurement error and cannot be accurately measured by this method. Errors discharge measurements (2%) were estimated based on replicates at each station. Errors in water-surface elevation were estimated to be about ± 0.04 ft and were ignored. Nonlinear regression curves, with exponents constrained to vary within the range of typical canal sections, were fit to stage-discharge data. Fifteen-minute stage observations were converted to daily averages and the regressions were used to compute daily flow rate and volume. The 95% prediction limits were used as estimates of uncertainty and propagated through the calculation of flow differences between upstream and downstream canal sections, and the final conversion of daily canal losses into the irrigation season sum. At most of the 12 study reaches, canal seepage was statistically significant during times of peak water delivery in late June, July, and August; however at the beginning and end of the season, losses were small compared with canal discharge and could not be resolved.

A Search for an Alternative Water Supply for the Community of Rimini Located Within the Upper Tenmile Creek Mining Area Superfund Site

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The Upper Tenmile Creek Mining Area Superfund Site near Helena, Montana, contains over 150 abandoned mine and mill sites. Degradation of surface and groundwater quality in the watershed is primarily related to the residual waste rock/tailings piles and discharging adits at the abandoned sites. Residential well sampling in the Community of Rimini demonstrated that arsenic and metals concentrations exceeded water

quality standards. The EPA is currently providing bottled drinking water for most of Rimini's residents. To find an alternative source of drinking water, an investigation was conducted to locate an alluvial or bedrock groundwater drinking water source for Rimini. The goals of this investigation were to find a groundwater source that has sufficient quantity, requires no treatment, have limited operation and maintenance costs, and is located in close proximity to the community. A lineation analysis using aerial photography and topographic data was implemented to identify subsurface features, such as faults, folds, or fractures. Three drilling locations were initially identified. Alluvial and bedrock test borings were drilled at each location and those borings with the highest preliminary discharge were completed as wells and sampled for water quality. The drilling program yielded mixed results: the alluvial wells had moderate to high discharge but contained arsenic concentrations in excess of water quality standards, while the bedrock wells met water quality standards but had insufficient discharge. As a result, it became necessary to explore other options, including drilling additional wells, evaluating spring sources, providing arsenic treatment for known sources with adequate flow, developing a surface water source, and piping water from the City of Helena water treatment plant. The preferred option at this time is treatment of a surface water source to reduce arsenic concentrations. The ability/willingness of the community to operate and maintain a long-term treatment system for surface water remains in question.

SESSION 8

RIPARIAN ZONES

Riparian Buffer Public Education Campaign

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Riparian areas offer important water quality protection for rivers, streams, lakes, wetlands and ground water. Increasing development pressure is disproportionately stressing riparian areas as people choose to live near water. This development pressure and its associated outcomes -- growth in the numbers of residences, septic systems, stormwater runoff, transportation infrastructure, and other activities -- are impacting the extent and health of riparian areas and water quality across Montana. The Montana Governor's Task Force for Riparian Protection, as well as statewide efforts from Montana Watercourse and other groups, have targeted developers and realtors with information about the importance of healthy riparian areas and wetlands. While efforts to reach these groups are important, and should continue, these services are driven by consumer demand. Therefore, the general public must also be informed so that valuing and maintaining healthy riparian areas becomes the social norm in Montana. Local government agencies such as conservation districts, water quality districts and health departments are uniquely positioned to reach out to their communities with this message, and to provide supporting strategies such as workshops and demonstration projects. Partners in this campaign include: Flathead Conservation District, Missoula Valley Water Quality District, Lewis & Clark County Water Quality Protection District, Gallatin Local Water Quality District, Ravalli County Environmental Health, and Lake County Environmental Health. Building upon a riparian vegetation public education campaign launched by the Missoula Valley Water Quality District in 2007, the goal of this project was to increase public awareness of the important functions of native riparian vegetation, and foster development of a social norm that encourages establishing, improving, and maintaining healthy riparian areas in Montana. Professional television and radio public service announcements, web page banner ads and billboards were created, and media time was purchased to air these materials in the partners' geographic areas in western Montana in spring 2010. Campaign effectiveness was evaluated using pre- and post-campaign surveys designed to measure the public's awareness of the importance of riparian vegetation. The surveys were conducted in Gallatin County. The results of these evaluations will be presented.

Monitoring of Vegetation in the Riparian Corridor with Dams Using Remote Sensing Integrated with Geographic Information System

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A satellite-based monitoring system using remote sensing integrated with geographic information system (GIS) is currently being built in an effort to study changes in vegetation in the riparian corridor as a result of recent dam removals/constructions. Two sites are being studied: the Milltown Dam site on the Clark Fork River in western Montana that was removed in March 2008 and the Three Gorges Dam site on the Yangtze River, in central China, that was constructed in October 2008. Time series of Landsat Thematic Mapper (TM) and MODIS images, bracketing pre/post dam removal/construction, are being used to monitor vegetative cover variation along riparian sections of the dam sites. Since few dam removals have occurred in the past and it is unknown how the local eco-hydrologic regime will react to such events. Likewise; the effects on the hydrologic regime due to the construction of a hydroelectric project at a magnitude of the Three Gorges Dam is also unknown. Changes in vegetative cover at the dam sites are used as an indicator of how groundwater systems and soil moisture are being affected. An ArcGIS-based geoprocessing system and a deseasonalization filter have been developed. Variations in spectral vegetation reflectance and spectral vegetation indices (NDVI, LAI, EVI) will be studied using time series plots constructed from Landsat TM (biweekly temporal resolution; 30mx30m spatial resolution) and MODIS (8 and 16 day temporal resolution; 250mx250m spatial resolution) imagery. The seasonal impact is removed through the deseasonalization filter so the impact of the dam construction/removal can be isolated. The approach developed from this study can be applied for predicting the response of the local hydrologic regime at future dam removal/construction sites.

Assessment of Riparian Forests, Shrublands and Wetlands Along Montana's Large Rivers

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In Montana, as in the rest of the west, the broad, flat valleys created by large rivers have been a magnet for the development of agricultural, residential, and transportation corridors. Many of the floodplains that once supported a complex matrix of riparian forests, seasonally flooded willow thickets, wet meadows, beaver-created ponds, and oxbows are now largely cleared, filled with homes and farms, and crisscrossed by railroad tracks and roads. Even undeveloped upper reaches of these large rivers have seen hydrologic alteration by dams and withdrawals. The Montana Natural Heritage Program (MTNHP) has begun a comprehensive reach-by-reach characterization of riparian forests, shrublands, and wetlands along Montana's large river systems, using remote sensing, GIS, and field sampling. The goal of the project is to provide local planners, watershed groups, and resource managers with geographically-specific data to use in watershed plans, conservation efforts, and TMDL development. This presentation reports on the study design, the GIS and remote sensing tools used to classify vegetation condition, and development of GIS- and field-based assessment metrics. We will also present results from 2010 fieldwork on several of the state's large rivers

Volunteer Monitoring in Montana

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Montana Watercourse (MTWC) has been instrumental in providing state-wide water education programs, trainings, resources and support to water users since 1989. MTWC, in partnership with Montana State University Extension Water Quality Program (MSUEWQ), provides leadership, training, and resources to volunteer monitors across the state. This session will cover the history of volunteer monitoring in Montana, current success stories, how the partnership holistically meets the VM needs of the community, future direction, and opportunities for involvement.

Dillon Area Groundwater Investigation Program Study: Lower Beaverhead

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The Lower Beaverhead River - West project area is north of Dillon and extends downstream to Beaverhead Rock. The mainstay of the economy in this area is agriculture which is supported by groundwater and surface water irrigation. The Beaverhead River basin has been closed to new surface water appropriations since 1993. Groundwater permit applications must include a hydrogeologic assessment that evaluates whether the proposed appropriation will result in a net depletion of surface water. If so, the application must be accompanied by aquifer recharge or mitigation plans. Irrigation needs are primarily met by the Clark Canyon Reservoir and Beaverhead River, which supply the East Bench Canal, West Side Canal, and ditches throughout the valley. As a result of drought and increasing irrigation demands, there has been an increase of high-volume production wells since the mid-1990s. Applications for well permits have resulted in conflicts between senior and junior groundwater and surface-water rights holders. A primary concern is that groundwater withdrawals will result in stream depletion by inducing flow away from the stream or by capturing stream recharge. Several hydrogeologic studies were previously conducted in the Beaverhead River valley but none provided adequate information for the west side of the Beaverhead River valley north of Dillon. This investigation will provide more detailed hydrogeologic information in order to better understand the effects of pumping high capacity wells on groundwater and surface water. Data collection will include well and test-hole drilling, aquifer testing, water-chemistry sampling and monitoring groundwater and surface-water. A numerical groundwater model will be used to predict impacts of groundwater development on the Beaverhead River and its tributaries and stream depletion mitigation scenarios. The final products will be a publically available report and several web-based project maps, and the groundwater model. GWIP results will provide land owners and regulatory personnel with scientific information to help make informed water management decisions that provide a balance between further development and protection of water.

The Physical, Chemical and Hydrological Characteristics of Wildfire Ash

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Following wildfires, a layer of vegetative ash of varying thickness and composition often blankets the landscape. The amount of ash as well as its physical, chemical and hydrological characteristics vary depending on fuel density, fuel moisture content, fire severity, and the type and quantity of fuel. Ash can have a range of ecological effects on post-fire environments from alterations in soil chemistry to changes in runoff, erosion and water quality. While ash effects on soil chemistry are fairly well defined, there are still important questions regarding the effects on runoff, erosion and water quality. Currently ash has been shown to both increase and decrease post-fire runoff and erosion, and have varying effects on water quality ranging from no change relative to pre-fire conditions to the introduction of major contaminants such as heavy metals and cyanide. Causes of this variability are not well understood and we hypothesize that they are linked to variability in the physical, chemical and hydrological characteristics of the ash itself. The objective of this study was to characterize the variability in ash properties as a function of fire severity and fuel type to aid in understanding the variability of ash on post-fire runoff and erosion responses. Ash was created in the laboratory from the three dominant tree species of western Montana (Lodgepole Pine (*Pinus contorta*), Ponderosa Pine (*Pinus Ponderosa*) and Douglas Fir (*Pseudotsuga menziesii*)). Each fuel type was oven dried and heated in a muffle furnace for two hours at four combustion temperatures (300°C, 500°C, 700°C, 900°C). A sub-sample of each was saturated with de-ionized water and left undisturbed for 24 hours to air-dry. Dry and wetted ash samples were characterized in terms of: particle size and shape, porosity, particle density and bulk density, organic and inorganic carbon content, elemental composition, mineralogy, hydraulic conductivity and water retention characteristics.

Initial results indicate that the physical, chemical and hydrological characteristics of ash vary considerably with combustion temperature but less so with fuel type. Ash is primarily made up of silt and sand size particles, with particle size showing a non-linear relationship to combustion temperature. Hydraulic conductivity values are generally similar to those of mineral soils of the same texture. However the porosity of ash, which can be as high as 90%, is 2 to 3 times higher than that of a mineral soil with a similar particle size. The organic carbon content of the ash decreases with increasing combustion temperature, while inorganic carbon has a non-linear relationship initially increasing then decreasing. Also in the 900°C samples the inorganic carbon content increases following hydration due to a transformation of oxides into carbonates. This chemical shift is observed to be associated with an irreversible alteration in the ash structure. We expect these results will provide new and improved understanding towards the role ash plays in the post-fire environment.

Using Stable Isotopes to Track Contamination of the Madison Aquifer by Acidic Coal Mine Drainage in the Stockett-centerville Area, Central Montana

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This study shows the potential of using stable isotopes to track sources of pollution near abandoned-mine sites. The Stockett-Centerville area, south of Great Falls, Montana, was extensively mined for coal in the late 1800's through the early 1950's. The coal seams are located at the top of the Jurassic Morrison Fm. These mines were mainly underground and covered very large areas. After closure, the mine portals were sealed and the workings became flooded. Many of the mines have drains that are point sources of acid rock drainage (ARD) which flows into dry streambeds and soaks into the ground. People living in the area rely on the Madison limestone, which is located several hundred feet below surface and stratigraphically below the coal, for their drinking water. The purpose of this study was to determine if ARD from the coal mines is contaminating the Madison aquifer. The stable isotopic composition of dissolved sulfate is a sensitive indicator of ARD contamination because the isotopic composition of ARD sulfate is very different from that of sulfate in background Madison groundwater. Also, because the sulfate concentrations in the ARD waters are extremely high, even a relatively small amount of mixing of Madison water with coal-mine water will shift the isotopic composition of dissolved sulfate in the well water. To date, twelve domestic water wells completed in the Madison near Stockett and Centerville have been sampled for water chemistry and stable isotope analysis of water and dissolved sulfate. The data show sulfate-S and sulfate-O isotopic compositions that plot on a mixing line between background sulfate in the Madison Aquifer (e.g., as measured at Giant Spring and Big Spring) and sulfate from ARD waters associated with the coal mines. The only domestic well in our study that shows no evidence of mixing with ARD sulfate is located south (upgradient) of the coal mines. For the majority of the other wells, the percentage of sulfate derived from ARD is probably less than 10 to 25%. However, two wells show a much greater extent of mine water influence, with > 80% of their dissolved sulfate apparently coming from ARD sources. Despite this contamination, all of the wells have neutral-pH water with low dissolved metal concentrations. This shows how the Madison limestone can naturally buffer groundwater chemistry. Further sampling is in progress and will be reported at a later date.

A Spatially Distributed Ecohydrological Model for Forested Catchments

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Accurate modeling of how the hydrology in a system affects vegetation is necessary for forest and water resource management as well as for guiding climate change policy. Ecohydrological models afford us the capacity to predict the ecological water needs and production of a forest stand over time. Due to the strong coupling between hydrology and ecosystems, any change in the water balance of the watershed will affect the ecosystem. Likewise, any impact in the composition or structure of the forest will affect the hydrology of the watershed. Capturing the interactions between the systems is important to understand how policy or climate may impact our hydrological and forest resources. As of now there are few tools that accurately

evaluate feedback between ecosystems and hydrologic systems. Water availability is a limiting factor to forest growth. Existing forest growth models often ignore mortality or growth caused by the heterogeneous spatial distribution of the soil water resources because they lack a sufficient description of the connection to the hydrologic system within a watershed. A new model that couples a simplified forest growth model to a spatially distributed hydrologic model is presented. The backbone of the new model is a production function that takes into account weather data, initial biomass, soil type, stand age, and maximum available soil water. It contains a hydrologic module that consists of an infiltration and a water routing function based on soil characteristics and local topography. It generates estimates of net primary production across the watershed, as well as estimates of water consumed by the ecosystem among other outputs. As the research continues, additional improvements are hoped to be made on carrying capacities of species, seed dispersal, and competition. Currently the model is being compiled and parameterized for a demonstration run in Lost Horse Canyon outside Hamilton, Montana.

Quantifying Glacier-derived Summer Runoff in Northwest Montana

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Glacier National Park in northwest Montana contains the second largest concentration of mountain glaciers in the Rocky Mountains of the United States. Observations over the past 100 years have shown a marked recession in glacier extent in this region. An important consequence of glacier retreat is the decline and/or complete loss of glacier-melt runoff during the typically hot and dry summer months. There are currently no detailed estimates for this meltwater volume despite Glacier Park's relatively high amount of glacier-covered area. In this study we calculate the glacier-derived component of summer runoff in Glacier National Park using a spatially distributed snow and ice melt model. The model is run using daily time steps and requires the input of temperature and potential direct short-wave radiation in order to calculate meltwater production. The model is calibrated to direct measurements of temperature, solar radiation, and melt made on five different glaciers in Glacier National Park, Montana. The anticipated result of this research will be a robust estimate of the total glacier meltwater production that originates in Glacier National Park during the months of June, July, August, and September. This study will provide a better understanding of the role of glacier meltwater in this region's hydrograph, and will develop new methodology for quantifying glacier-derived runoff in mountain regions.

Undergraduate Research: Groundwater Monitoring in the Upper Clark Fork River Floodplain

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An undergraduate research project was undertaken in 2009 to investigate groundwater levels and water quality in shallow monitoring wells in the upper Clark Fork River (CFR) floodplain. Two different focus areas were examined. The first site is located downstream of Warm Springs Ponds within the Governor's Demonstration Project where streamside tailings were treated in place in 1990-1991 via lime amendments and then revegetated. Seven new monitoring wells were installed with a hollow-stem auger in two well fields, one on the west and one on the east side of the CFR. A second focus area was further downstream, near the Clark Fork Coalition's working ranch at Galen. In the lower reach, streamside tailings have not been reclaimed, and bare areas of tailings are still present. Two shallow, one-inch monitoring wells were installed by hand into the saturated gravel layer at the base of the tailings. Two pre-existing two-inch wells in a nearby tailings area on the Coalition ranch were also sampled. Water levels have been collected manually each month since November 2009, and at least one continuous levellogger has been deployed at each focus area. Water quality samples were collected in Nov-2009 and Feb-2010. We plan to continue sampling quarterly for another year. Results to date show that static water levels in the alluvial floodplain at both focus areas are highly correlated to streamflow of the CFR at Galen, which is to be expected for a coarse, gravel-bottom river floodplain. Groundwater levels tend to decrease during periods of ice cover on the CFR. Groundwater quality at the upstream Governor's Project area is generally good, with near-neutral pH and low concentrations of dissolved metals or metalloids (e.g., As < 0.01 mg/L, Cu and Zn < 0.05 mg/L). However, specific conductivity values and dissolved

sulfate concentrations for wells on the west side of the CFR are considerably higher than on the east side. Interestingly, several wells contain water that is anoxic, with low but readily detectable concentrations of H₂S. Although groundwater at the downstream focus area also has near-neutral pH, concentrations of several contaminants of concern are elevated, including As (up to 0.11 mg/L), Cu (up to 0.38 mg/L) and Zn (up to 1.2 mg/L). Interaction of deionized water with surficial tailings from the lower site created an acidic solution (pH 4.4 to 5.1) with extremely high metal concentrations (e.g., 220 mg/L Cu, 350 mg/L Zn). Based on these results, it is somewhat surprising that the groundwater directly beneath the tailings isn't worse. This situation may reflect the presence of carbonate cobbles and boulders in the native alluvium (e.g., eroded from Paleozoic carbonate rocks in the surrounding mountains), and/or a high through-put of groundwater with moderate alkalinity passing through the floodplain corridor. We thank Tom Mostad, Brian Bartkowiak, the Montana NRDP, and the Montana DEQ for their support of this project.

Investigating Water Quality and Nutrient Loading in Salmon and Seeley Lakes, Montana

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Salmon and Seeley Lakes, lower lakes in the Clearwater Lakes chain, have experienced increased development in their watersheds. The Town of Seeley Lake and other communities in the area rely heavily upon tourism and depend on clean water in order to attract visitors. While growth in Seeley Lake and around the Clearwater Lakes is unavoidable and even potentially beneficial for economic reasons, residents within the communities strive for responsible growth that does not come at the cost of the critical natural resources in the watershed (Seeley Lake Regional Plan 2009). The Clearwater Lakes have experienced water quality problems in the past and there is concern that adverse conditions will arise again. In the 1970's there was some evidence of eutrophication-related water quality problems associated with heavy logging and Mt St Helens ash (Juday and Keller 1978). These circumstances may have been improving as forests grew back, but could be offset by additional development and climate changes. Construction of more homes (& septic systems) and failing older septic systems could contribute to water quality problems. Increased nutrient loading from new development and the long term accumulation of nutrients from older development may speed eutrophication of the Clearwater Lakes. Warmer weather could lead to decreased flow and reduced lake flushing, longer stratification periods, changes in the cycling of carbon in wetlands and other synergistic effects within the Clearwater system. Current lake conditions and their relationship to existing and changing conditions in the watershed are unclear and require further investigation. There is uncertainty about current conditions in part because the scattered available data has never been pulled together and examined systematically. Sampling has been sporadic and potentially inconsistent across studies. Available data may not be sufficient to draw statistically meaningful conclusions. The potential synergistic effects of future development, changes in forest practices, and climate change on the water quality and trophic conditions of the lakes are unknown and should be considered. Salmon and Seeley Lakes will be analyzed for current and past water quality and trophic conditions. Because the lakes are low in the basin, they are affected by cumulative effects experienced all over the basin. Salmon and Seeley Lakes will be the focus of the study due to their ability to represent conditions from throughout the chain of lakes as well as their location in relation to current and potential development.

A Comparison of the Robustness of Monte Carlo Samplers Used in Bayesian Calibration and Uncertainty Analysis of Hydrological Models

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Hydrologic model parameter optimization has been deemed challenging due to the intricate nature of the catchments dynamics which creates strong parameter interactions and complex posterior distribution. Uncertainties contributed from the data, parameters and model structure itself only hinder the task in obtaining the variables that best fit the model. Implementing Bayesian statistical inferences helps to

encounter some of these uncertainties but the implementation of the Bayesian framework requires the aid of a Monte Carlo sampler in search of the posterior distribution. The effectiveness of a Monte Carlo sampler highly depends on the methods of generating proposal distributions especially when sampling the maximum a posteriori at the tails of the distribution. In this paper, a Sequential Monte Carlo (SMC) approach is used to obtain the optimized parameters of a hydrologic model and the results are compared against the Adaptive Metropolis. The SMC method, owing to data assimilation and having multiple parallel sampling mechanisms, offer improved efficiency in computation time and sampling robustness especially in identifying Maximum a Posteriori (MAP) in the tails of the distribution.

Groundwater Use in the Clark Fork Basin, Montana

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The Groundwater Information Center database (GWIC) has records of 85,400 wells in the Clark Fork Basin, most (73,200) have a reported use of “domestic”, that is, they are wells that serve individual households. Other wells provide water for irrigation, municipal, industrial/commercial, and stockwater use. Although the number of wells seems large, groundwater accounts for only 7 percent of the water withdrawals in the basin. Surface water dominates the water withdrawals; an estimated 1,510 million gallons per day (MGD) of surface water is withdrawn (93 percent), primarily for irrigation use, as compared to 112 MGD of groundwater. Of the groundwater withdrawn, most is used for irrigation, municipal water, and industrial uses. Domestic use accounts for only 8 percent of groundwater withdrawals. In the Clark Fork Basin, there are generally two types of basin-fill aquifers: (1) shallow water table and (2) deeper confined to semi-confined. The extent of basin-fill aquifers generally coincides with the extent of basin-fill deposits. Near-surface sand and gravel deposits (mostly Quaternary alluvium) coincident with the floodplains of main-stem streams contain very permeable alluvial water-table aquifers that store and yield large volumes of water. These aquifers are generally in hydraulic connection with adjacent streams. The deeper confined-semi-confined aquifers occur in layers of sand and gravel separated by silt and clay. Pumping groundwater will remove water from aquifer storage. Long-term water-level data, collected as part of the Montana Groundwater Assessment Program, show changes in groundwater storage in the basin-fill aquifers across the Clark Fork Basin. The data show that groundwater fluctuations in basin-fill aquifers vary with regard to the timing and magnitude of recharge and discharge. Most long-term trends are stable, indicating little or no depletion of basin-fill aquifer storage. Water levels in parts of the highly utilized deep aquifer in the Flathead Valley show long-term declines. In groundwater systems, water removed by pumping is derived from aquifer storage, and some combination of increased recharge and/or decreased groundwater discharge (as base flow to streams). During the months of December, January, and February the steady low flows shown in stream hydrographs represent the “base flow” period, when groundwater contributes most, if not all stream flow. Annual December-February flows were averaged to provide a measure of the base-flow rate at stations on the Clark Fork, Bitterroot, Swan, and Blackfoot Rivers. The base-flow graphs show variability from year to year but flat long-term trends.

Rapid Detection Of Pathogens In Water Using A Combination Of Molecular Techniques

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Many types of pathogens can be found in contaminated water, including *Escherichia coli*, *Cryptosporidium*, *Giardia lamblia*, some protozoa and viruses such as hepatitis A virus, rotaviruses, and Norwalk and other Caliciviruses. Infection by these pathogens can range from self-limiting diarrhea to life threatening illnesses. Therefore, it is important to find ways to detect pathogens in water rapidly, so that prevention of an outbreak can be implemented swiftly after the first few cases. In this research, the objective is to identify and quantify water pathogens present in a water sample without the need for standard overnight incubation in order to be able to detect pathogens in the water. A novel approach to detection and quantification methods for pathogens in water samples is the use of fluorescent in situ hybridization (FISH) coupled with tyramide signal amplification (TSA) followed by solid phase laser cytometry (SPLC), i.e., the ScanRDI (AES-Chemunex), also

known as the ChemScanRDI. This research has progressed to optimization of the ChemScanRDI parameters to specifically detect stained cells that were filtered from water sample. Once this step is completed, it will be possible to start collecting water samples from field sites to demonstrate performance of the method for environmental samples and make further adjustments to optimize detection and quantification of water pathogens.

Groundwater Quality in the Recently Reclaimed Silver Bow Creek Floodplain

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An undergraduate research project was undertaken in 2009 to investigate the chemistry of shallow groundwater in the reclaimed floodplain of Silver Bow Creek (SBC) at Miles Crossing, roughly 2 miles downstream of the town of Ramsay. Streamside tailings in this reach of SBC were completely removed in 2008, the stream was rebuilt, and the floodplain was revegetated. Thus, this study was initiated about one year after reclamation. Five 2" monitoring wells were installed with a hollow-stem auger in August, 2009, as part of Montana Tech's Field Hydrogeology course. These wells encountered a shallow, 5-foot thick saturated gravel layer underlain by Tertiary (?) clay. A pumping test performed by the students yielded an average hydraulic conductivity of 105 ft/day, and a storativity value of 0.015 (i.e., partially confined). The same wells were sampled for a full set of water quality parameters in August and November of 2010. Although a February sampling event was planned, 4 of the 5 wells were frozen and therefore could not be sampled. The results show that shallow groundwater at the Miles Crossing site has surprisingly poor water quality, based on low pH values (4.1 to 5.9), high dissolved metals concentrations (e.g., Cu up to 15 mg/L, Fe up to 35 mg/L, Zn up to 14 mg/L), and the absence of dissolved oxygen. The groundwater also has high concentrations of ammonium (up to 3.7 mg/L as N) and phosphate (up to 0.4 mg/L as PO₄) but undetectable nitrate (< 0.01 ft³/sec), due to the low hydraulic gradient and limited saturated thickness of the gravel layer. Nonetheless, discharge of even a small amount of metal-rich groundwater could have a measureable impact on metal concentrations in Silver Bow Creek. Monitoring will continue through 2010 to see if conditions improve as polluted groundwater is "flushed through the system". We thank Greg Mullen and the Montana Natural Resources Damages Program for their support for this project.

Gallatin Valley Groundwater Investigation Program Studies: Belgrade and Four Corners

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New neighborhoods, utilizing both on-site septic systems and community wastewater systems, are replacing agricultural land along the West Gallatin River between Belgrade and Gallatin Gateway. The possible hydrologic effects of land-use conversion from irrigated agriculture to high-density residential have raised questions concerning both water quality and water availability. To assist in the appropriate management of water resources in this area it is important to identify details concerning groundwater flow directions (including both horizontal and vertical gradients) and the hydrologic relationship between the aquifer and the river. Subdivision of agricultural land has partially evolved from individual septic to commercial public water supply coupled with public wastewater treatment utilizing both surface and groundwater. Planned or proposed expansion of the coupled system along with planned aquifer storage recovery offers alternatives to conventional water supply and treatment options. The impact of these systems has been the subject of question, particularly by non-participants and senior water rights holders. As with other small sub-basins in the Gallatin Valley, the density of development with respect to groundwater and surface water warrants a detailed groundwater flow model. Project Elements: Water-level and water-quality data private operators as well as researchers, along with new, comprehensive surface water measurement, will be compiled and used to construct detailed potentiometric maps and a water balance for the area. Drilling new monitoring wells and conducting long-term aquifer testing at multiple locations will yield more realistic values for aquifer parameters. A detailed groundwater flow model will use these data to test potential changes in water use resulting from changes in land use and irrigation practices and to examine the effectiveness of proposed mitigation projects.

Nitrate and Pesticide Impacts in Shallow Gravel Aquifers of the Judith River Basin, Central Montana

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In 2009, the Ground-Water Protection Program (GWPP) of the Montana Department of Agriculture (MDA) conducted a monitoring project in the Judith River Basin in central Montana. The objective of the study was to determine potential impacts to groundwater and surface water from the use of pesticides and contributions from nitrogen sources. Sampling efforts were focused on wells and springs in shallow, unconfined Quaternary/Tertiary gravel aquifers. These aquifers are vulnerable to contamination by agricultural chemicals given the dominant cropping systems and the hydrogeologic characteristics of the basin. The GWPP detected 33 different pesticides and degradates in the basin in 2009. Detections reflected the cropping systems and agricultural practices of the region with sulfonylurea herbicides comprising 41.7% of the 199 total detections in groundwater and 8 of the 33 different analytes detected. The weighted mean of detections in samples collected from wells in terrace deposits (n=14) and alluvium (n=3) were 5.46 and 0.33 pesticide detections per sample respectively. All springs (n=6) had pesticide detections and samples averaged 3.75 detections per sample. In surface waters (n=7), the weighted mean was 4.07 detections per sample. There were 62 pesticide detections in surface waters. Most importantly, none of the pesticide detections exceeded established interim numerical standards and federal standards where applicable for drinking water. Wells in agricultural areas completed in the terrace gravel deposits had a weighted mean of 19.60 mg L⁻¹ nitrate-N (NO₃⁻-N) in the MDA study. Including springs, terrace gravel aquifer concentrations of NO₃⁻-N exceeded the HHS (≥10 mg L⁻¹) at 75% of sites. Analyses of δ¹⁵NNO₃ and δ¹⁸ONNO₃ isotopes suggest that soil NH₄⁺ is the dominant source of NO₃⁻-N in groundwater. In dryland systems, where excess fertilizer is applied, a significant proportion of N is converted into soil or plant organic N before being re-released and leached through the profile as NO₃⁻-N. Changes in cropping practices and strategies will have the greatest long-term impact to water quality in the basin. The geology, thin soil mantle, rapid infiltration and low relative saturated thickness of the terrace gravels render groundwater susceptible to contamination from surface application of pesticides and fertilizers.

Effects of Ammonia and Dissolved Oxygen Concentration on the Distribution and Abundance of Fishes in Silver Bow Creek, Montana

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The fish populations of Silver Bow Creek near Butte, Montana were extirpated by more than a century of contamination from local mining operations and municipal wastes. Portions of the watershed were designated as Superfund sites and remediation of the stream has been ongoing for more than a decade. Six species of fish are now present in the stream, including three in the family Salmonidae. Despite signs of improvement, water quality problems apparently continue to influence the distribution of individual fish taxa in the stream. To assess the success of remediation in reestablishing stream fish populations, we conducted spatially continuous electrofishing and mobile antenna surveys of P.I.T.-tagged fish in 27 km of Silver Bow Creek and two tributary streams. Stream temperatures and concentrations of heavy metals, ammonia, and dissolved oxygen (DO) were monitored in corresponding stream sections. Toxic metal concentrations and loads in the stream have been reduced; however, within six kilometers of the Butte wastewater treatment plant outfall ammonia concentrations reached toxic levels (NH₃-N=2.8 mg/l) and hypoxia (DO<2 mg/l) was evident. Preliminary analysis suggests that salmonid abundance is substantially reduced in the hypoxic zones, but catostomid abundance does not appear to be affected.

Distribution of Nutrients and Metals Along Silver Bow Creek from Butte to Warm Springs Ponds

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This study documents the longitudinal distribution of ammonia, nitrate, phosphate, arsenic and metals

along Silver Bow Creek (SBC) from Butte to Warm Springs Ponds (WSP) near the headwater of the Clark Fork River. Sampling was conducted bi-monthly starting in early June (2010) through early October at nine sites along SBC. The upstream most site was directly above the Waste Water Treatment Plant (WWTP) for the city of Butte and the downstream most site was about 0.5 mi below the outlet from WSP. Samples were collected at approximately the same time of day at each site on each sampling visit to minimize the influence of diel changes in solute concentration. Soils, sediments, and underlying groundwater in the Butte area have been severely contaminated from 130 years of mining, milling, and smelting of polymetallic ores. The stream course and surrounding riparian zones of SBC have been largely restored from Butte to Opportunity with the exception of some segments in Durant Canyon. This restoration work is being completed to limit further contamination of SBC and the Clark Fork watershed from the residual materials left by the mining operations. In addition to the historical problem of metals contamination along SBC the WWTP is a major point source of nutrients to SBC. Significant zones of low oxygen concentration have been measured downstream of the WWTP due to the effects of this nutrient addition. This study verifies findings of earlier work that examined the distribution of nutrients in the Butte area and extends the area examined downstream of the WSP area. Inputs and outputs of nutrients through the WSP system are also examined for the study period. An increase in the concentration of ammonia in the WSP outlet was measured during the early summer. Additionally, this investigation looks at the distribution of trace metals along the study reach.

Seasonal Use of Side Channels and Shallow Slow-velocity Habitats by the Fish Assemblages of the Middle and Lower Yellowstone River

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Although the Yellowstone River remains the longest undammed river in the continental United States, it is nonetheless exposed to anthropogenic stressors including bank stabilization, diversion dams, water withdrawals, and altered hydrographs and sediment regimes from dammed tributaries. These perturbations may result in changes in channel morphology, local main-channel bathymetry, and fish habitat features such as secondary channels and other shallow slow-velocity habitats. Bank stabilization results in decreased seasonal secondary-channel formation and a reduction in the abundance of shallow slow-velocity habitats during high flows. We sampled seasonal secondary channels and shallow slow-velocity habitats in the mainstem Yellowstone River from Park City to Sidney, Montana, in 2009 and 2010 during runoff (July 2009 and June 2010) using bag seines and mini-fyke nets. Seasonal channels and other shallow slow-velocity habitats provided critical habitat for many families of fish representing diverse feeding guilds. Many individuals were reproductively active, suggesting that secondary channels and other shallow slow-velocity habitats are important for spawning.

Spatial Distribution of Transmissivity and Storativity for the Deep Alluvial Aquifer in the Flathead Valley

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Results of aquifer tests conducted on the confined deep alluvial aquifer of the Flathead Valley over the last ten years are summarized and the aquifer parameters are displayed on a series of maps. Most transmissivities and storativities were determined from the analysis of 24 to 72 hour aquifer tests and vary by about 4 orders of magnitude, although the some reported storativities appear anomalously high. These distributions provide insight into the hydraulic structure of the deep alluvial aquifer.

Expanding the Network of Citizen Water Quality Monitoring in Montana

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Volunteer or citizen based monitoring is about getting land owners and community members outside together and in the water. It's about having fun, learning about local water resources and potentially, collecting data that will help water managers to make decisions about water resources. Montana State University Extension Water Quality (MSUEWQ) and the Montana Watercourse are working with a number of watershed groups in Montana to increase citizen based stream monitoring. Volunteer monitoring is a great way to educate kids about science and the fact that water resources are critical and need protecting and the Montana Watercourse has been successfully supporting these activities across Montana for many years. More recently there is increased interest in getting adults out to learn about water resources, to affect change in their watersheds, and to collect quality data that can be used to inform water management decisions. In 2007 MSUEWQ and the MT Watercourse began working with the MT Department of Environmental Quality (MT DEQ) on a volunteer monitoring certification program with support from a 319 grant. The training program has three levels. Levels one and two are primarily education based with level two tending toward long term data collection and higher quality data. At the third level, volunteers must have some previous monitoring experience, will undergo more rigorous training, and have to pass a test, but can then receive status as a certified citizen monitor. The initial pilot program is underway in the Careless Creek Watershed in collaboration with the Lower Musselshell Conservation District. Lake Helena, Madison, Shields and Gallatin watershed groups were all involved in trainings at various levels in 2009 and 2010 and are now poised for training at the certification level. In July of 2010, MSUEWQ and the MT Watercourse will start work under a second 319 grant to continue volunteer monitoring efforts including work to certify volunteers from three watershed groups. The groups are all at different phases of the TMDL planning process and each hope make valuable contributions to data collection efforts through their efforts.

Reducing Hydrological Uncertainties in Ephemeral Watershed Modeling Through Improved Statistical Inference

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Ephemeral watersheds pose particular difficulties to efficient calibration of hydrologic model parameters for streamflow forecasting. These difficulties are brought about by violations of the underlying assumptions commonly made by the statistical approaches (i.e., the statistical form of the model residuals) regularly used to calibrate such model parameters. This study investigates the application of Bayesian statistical methods in estimating the parameters of a simple hydrologic model applied to an ephemeral watershed through the consideration of two modeling case studies: (1) a synthetically generated data set and (2) a real data set of an arid Australian watershed. The case studies investigate some typical forms of the likelihood function (the formal function describing the assumptions of the model residuals in Bayesian statistics) which have been applied widely by previous researchers, as well as introducing new implementations aimed at better addressing the complications caused by ephemeral watersheds. Specifically, hydrologic models applied to ephemeral watersheds tend to result in zero-inflated model residuals due to the model's ability to correctly predict the "no flow" state. The results of the case studies indicate the importance of explicitly accounting for zero-inflation of the modeled errors in the parameter estimation method (via the likelihood function). In particular, the form of the likelihood function was found to significantly impact the calibrated parameter posterior distributions (statistical distributions of the calibrated parameter values), which in turn have the potential to greatly affect the uncertainty estimates. In each application, the likelihood function that explicitly accounted for the zero-inflation of the errors and the non-constant variance of the errors (another common characteristic in hydrologic model errors) resulted in (1) equivalent or better fits to the observed discharge in both timing

and volume, (2) superior estimation of the model uncertainty, and (3) better representation of the model residuals. The results are expected to inform current and future efforts in hydrologic forecasting in ungauged basins.

Wetland Habitat Associations of Dragonflies, Damselflies and Other Invertebrates in Montana's Reference Condition Wetlands: Uses in Statewide Assessment and Monitoring

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The Montana Natural Heritage Program (MTNHP) has conducted intensive wetland site assessments in watersheds across the state, as well as compiled a network of high-quality, minimally-disturbed wetlands from data collected by or for numerous state and federal agencies and non-governmental organizations into a Wetland Monitoring and Assessment Database. We have developed macroinvertebrate species lists expected to occur at particular wetland types by investigating the habitat requirements and ecological attributes of the dragonfly, damselfly, and butterfly species inhabiting the state's wetlands and associating them with particular wetland ecological characteristics. Based on literature accounts, published or unpublished data and field site visits involving subsets of the reference wetlands in the database, we will determine an "expected" (E) site assemblage of invertebrates that should occur at particular wetland classes (types). Evaluation of species tolerance values, occurrences of Species of Concern and the sensitivity of particular wetland invertebrate species to anthropogenic factors will enable us to further refine this indicator species list. Observations (O) of characteristics in the invertebrate species assemblages, such as the number of dragonfly species at a particular wetland site, that deviate from the expected condition (O/E) can be used in determining an impairment status of the invertebrate community which may be correlated to wetland condition. Despite the sampling difficulties and high costs related to using macroinvertebrates in wetland assessments, we intend to use significant associations to develop cost effective Level II and III assessment protocols for inclusion into the Montana's Wetland Monitoring and Assessment Plan. Furthermore, this project contributes significantly to the overall knowledge of wetland macroinvertebrates, an understudied aspect of wetland ecology in the state.

A Watershed Study in an Evolving Agricultural Watershed, Upper Smith River, Meagher County, Montana

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The U.S. Geological Survey (USGS), in cooperation with the Meagher County Conservation District, began a study of the hydrologic framework and water budget of the upper Smith River watershed in 2006 to provide local water users and managers more detailed information on the hydrology of the watershed. The agricultural and recreational communities in this semi-arid watershed depend on the perennial flows of the Smith River and its tributaries; however, the hydrologic system and water budget of the watershed are not well understood. This USGS study focuses on the upper portion of the watershed (upstream from the confluence of the Smith River with Rock Creek), which includes approximately 36,000 irrigated acres (about 20 percent of the upper watershed). Similar to agricultural watersheds in other parts of the West, the upper Smith River watershed has experienced changes in the past decades, including amount of irrigated lands, irrigation techniques, crop types, and climate conditions. Since 2006, some of the methods of investigation to define the water budget of the watershed have included continuous streamflow gaging at fixed sites; synoptic-flow measurements of the Smith River, its tributaries, and irrigation canals; and groundwater level monitoring. This data will be used with the USGS Precipitation-Runoff Modeling System (PRMS) to construct a watershed model. The PRMS model will be used to investigate how changes in the watershed may have influenced the hydrology and water-budget of the Smith River. Similarly, the PRMS model will be used to test how sensitive the water-budget will be to potential future changes.

Helena Area Ground Water Project

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The Lewis & Clark Water Quality Protection District (LCWQPD) began implementation of a long-term ground water monitoring program in the Fall of 2009. The program included semi-annual sampling from 25 wells in the LCWQPD Monitoring Well network, which includes 9 single wells and 8 nested well sets (16 total wells), and from 5 residential wells where historical data is present. The nested wells provide information on changes in ground water chemistry with depth. The goal of the project is to characterize the current ground water quality across the Helena Valley, with an emphasis on identifying nutrient levels in ground water. The nutrient data represents the initial effort to characterize the impacts of non-point pollutant sources, primarily agriculture and septic systems, to ground water quality. In the Helena Valley, all surface and ground water discharges through Lake Helena, and the ground water data will be used to estimate water quality impacts from nutrients to Lake Helena from ground water recharge. Additionally, the current data can be compared to historical data to evaluate changes in water quality, as well as provide baseline data for comparison with the results from future sampling events. The second component of the sampling and analysis program incorporated monthly sampling at the five residential wells to assess seasonal trends. The nutrient data from the two semi-annual sampling events show nitrate concentrations ranging from less than 0.01 mg/L up to 13.7 mg/L, with a median value of 1.71 mg/L. Ammonia was detected at 0.07 mg/L at the location where nitrate was not detected during both sampling events. Total phosphorus concentrations ranged from 0.01 mg/L to 1.57 mg/L, with a median of 0.03 mg/L. Arsenic was detected in approximately half of the samples, with detected concentrations ranging from 0.003 mg/L up to 0.020 mg/L, with samples from 5 wells exceeding the drinking water standard of 0.010 mg/L. The poster will present the major ion chemistry data using stiff diagrams, as well as the results of the monthly sampling program.

Screening for Organic Wastewater Chemicals in the Groundwater of Summit Valley, Montana

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Organic Wastewater Chemicals (OWCs), including pharmaceuticals and other endocrine disrupting chemicals, have been reported in a number of streams and aquifers in Montana. 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, some of these chemicals 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, 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. Recent assessments of OWC groundwater contamination in the Helena and Gallatin Valleys of Montana revealed that OWCs were present in 70 to 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. A previous groundwater study in the Summit Valley near Butte documented elevated nitrate concentrations relative to other areas of western Montana that was attributed to septic system discharges to the groundwater. Since the factors that control nitrate sources, mobility and persistence in the subsurface are similar to those that influence OWCs, it is likely that the groundwaters of the Summit Valley may also contain elevated OWC concentrations. The same wells that were sampled in the nitrate study will be sampled again and analyzed for OWCs using enzyme-linked immunosorbent assays. We will report on the occurrence of a select group of indicator OWCs in the groundwater and surface waters of the Summit Valley.

Helena Area Groundwater Investigation Program Studies: North Hills and Scratchgravel Hills

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The North Hills and Scratchgravel Hills study areas are located north and north west of the Helena Valley. Both are unincorporated areas where both subdivisions and individuals rely on groundwater. Septic systems are a common wastewater treatment approach. Increasing development and declining groundwater levels resulted in the establishment by the Montana DNRC of a temporary Controlled Groundwater Area (CGWA) in 2002 in the North Hills. After a study was completed through a cooperative effort by the MBMG, the Lewis and Clark County Water Quality Protection District, and the DNRC, the temporary CGWA was terminated in 2006. The matter was reevaluated in 2008, resulting in the establishment of a second, smaller CGWA. The primary concerns are the likelihood of impacts from continued groundwater development and the practice of using individual septic systems in dense housing developments. The Scratchgravel Hills project area is northwest of Helena. Within this area the Green Meadow temporary controlled ground water area was designated by the DNRC in April of 2008. After two years this temporary designation will be allowed to expire, made permanent, or extended. The investigations will provide more accurate descriptions of the geologic setting, hydrologic properties of the aquifers available, water supplies, and stresses on the hydrologic systems. Work will include assembling existing data and reports, establishing new meteorological and hydrologic monitoring, drilling exploratory and test wells, conducting aquifer tests, water-quality sampling, and evaluating transpiration consumption by both crops and natural vegetation. Numerical groundwater models will be constructed to simulate observed hydrogeologic conditions and evaluate the response of the groundwater system to specific stresses such as new wells or well fields.

Montana Bureau of Mines and Geology Groundwater Investigation Program - Overview

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The 2007/2008 Water Policy Interim Committee (WPIC) recognized that competition for water resources and the lack of detailed information on groundwater/surface water interaction has challenged informed water-resource management and development in Montana. The WPIC found that “continued and expanded study of groundwater resources is vital to shaping statewide policy as well as providing the data necessary for local decisions regarding water.” HB 52 was drafted by the WPIC in response to this finding. The 61st Montana Legislature passed HB 52 with a first biennium appropriation of \$4.2 million; based on the program design, this will provide funding for 6 to 8 projects lasting 1 to 3 years. The Ground Water Investigations Program (GWIP) established by HB 52 will add to Montana’s capability to deal with important water-resource issues including: stream depletion from groundwater development by subdivisions or changes in irrigation projects; cumulative effects of existing and proposed water development on stream flow; impacts to groundwater and surface water from changes in irrigation practices or land use; implementation of aquifer storage and recovery (ASR) in Montana; and evaluating the success of mitigation/ offset plans in closed basins. The first seven projects are underway, and include the North Hills and Scratchgravel Hills projects north and northwest of Helena, the Four Corners and Belgrade projects in the Gallatin Valley west of Bozeman, the Lower Beaverhead project north of Dillon, the Florence project in the Bitterroot Valley, and the Flathead Valley Deep Aquifer project in the vicinity of Kalispell.

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