2009 Annual Conference

Waters that Cross Divides

A Joint Meeting of the American Water Resources Association & the University of Montana Center for Riverine Science

September 30 - October 2, 2009
Holiday Inn Downtown at the Park - Missoula, Montana

PROCEEDINGS

Contents

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

THANKS TO ALL WHO MAKE THIS EVENT POSSIBLE!

- **The AWRA Officers**
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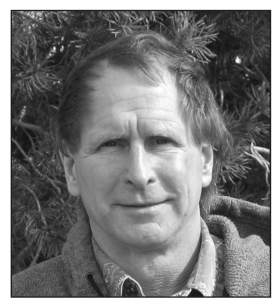
- **The University of Montana Center for Riverine Science**
  Andrew Wilcox and Dr. Johnnie Moore

- **Montana Water Center, Meeting Coordination**
  Steve Guettermann, Nancy Hystad, Gretchen Rupp, and MJ Nehasil

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

Cam Carstarphen

Margie Patton



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WEDNESDAY, SEPTEMBER 30, 2009

REGISTRATION

10:00 am – 7:00 pm REGISTRATION

FIELD TRIP

1:00 pm – 5:00 pm **Milltown Dam Removal Site**

THURSDAY, OCTOBER 1, 2009

REGISTRATION

7:30 am REGISTRATION

OPENING SINGLE SESSION

Garden City Ballroom A & B

8:30 am WELCOME & INTRODUCTIONS
Cam Carstarphen -- AWRA Montana Section President
Andrew Wilcox -- River Center Director.
Gretchen Rupp -- Montana Water Center Director
Gerald Sehlke -- National AWRA President

LOGISTICS & ANNOUNCEMENTS
Kirk Waren -- Montana Section AWRA Vice President

9:00 KEYNOTE SPEAKER
Jon Major, Ph.D. -- USGS, Cascades Volcano Observatory
Short-term sediment erosion, transport, and deposition on the Sandy River following removal of Marmot Dam

10:15 KEYNOTE SPEAKER
Steve Running, Ph.D. -- University of Montana
Climate Change and Declining Surface Water Balance in the Northern Rockies

11:15 BREAK for lunch

ORAL PRESENTATIONS

SESSION 1 (Concurrent). *Garden City Ballroom A*
RIVER RESTORATION

Moderator: Andrew Wilcox -- River Center

12:45 pm Kyle Blasch, *Environmental Controls On Drainage Behavior Of An Ephemeral Stream: Implications For Stream Restoration.*

1:05 Matthew Daniels, *Restoration Of The Clark Fork River After Removal Of Milltown Dam.*

1:25 pm Tom Parker, *Vegetation Response On Historical Floodplain Surface At Milltown Dam.*

1:45 Russ Anderson, *Mattie V Creek: A Collaborative Restoration Approach Between A Conservation Organization, Local And Federal Agencies, Academia, And Professional Consultants*

2:05 Peter Skidmore, *Principles Of Successful River Restoration.*

2:25 Mark Vander Meer, *Lessons Learned From Revegetation Projects: The Story Of The Lower Clark Fork Revegetation Manual Analyzing The Steps To Successful Riparian Restoration.*

2:45 BREAK

SESSION 2 (Concurrent). *Garden City Ballroom B*
CLIMATE

Moderator: Don Potts -- University of Montana

12:45 pm Joel Harper, *Timing Of Present And Future Snowmelt From High Elevations In Northwest Montana.*

1:05 Blase Reardon, *Summer And Winter Surface Water Balances At Sperry Glacier, Glacier National Park, Montana.*

1:25 pm Bruce Anderson, *Global Warming, Restoration, And The Rocky Mountain Front.*

1:45 Katherine Chase, *Watershed Scale Response To Climate Change: South Fork Flathead River, Montana.*

2:05 Phil Farnes, *Montana Precipitation Map*

2:25 Tom Patton, *Wells And Climate: Can We Find El Niño?*

2:45 BREAK

SESSION 3 (Concurrent). *Garden City Ballroom A*
RIVER & WATERSHED PROCESSES

Moderator: Traci Sylte -- US Forest Service

3:05 pm Chuck Dalby, *Comparison Of Reconnaissance-Level And Detailed Methods Of Channel Migration Zone Delineation For The Upper Yellowstone River, Park County, Montana.*

3:25 Peter McCarthy, *Determination Of Travel Times And Dispersion Rates In The Yellowstone River In Montana.*

SESSION 4 (Concurrent). *Garden City Ballroom B*
GROUNDWATER

Moderator: Bill Woessner -- University of Montana

3:05 pm Kevin Chandler, *A Comparison Of Shallow Aquifer Diurnal Water-level Fluctuations At Different Vegetation Sites In Hay Creek, Whitetail Basin, Montana.*

3:25 David Donohue, *Historic Perspective, Assessment and Proposed Rehabilitation of a Flowing Artesian Well in North Central Montana.*

3:45 Stephen Holnbeck, *Monitoring Hydraulic Conditions And Scour At I-90 Bridges On Blackfoot River Following Removal Of Milltown Dam Near Bonner, Montana, Spring 2009.*

4:05 Kelsey Jencso, *Hillslope Water Table Connectivity Controls Groundwater Turnover Rates In The Near Stream Riparian Zone: Implications Of Catchment Structure For Source Water Contributions In The Tenderfoot Creek Experimental Forest, MT.*

4:25 Lucy Marshall, *Predictive Modeling Of Snowmelt And Runoff Dynamics: Thresholds And The Hydrologic Regime Of The Tenderfoot Creek Experimental Forest, Montana*

3:45 Tom Osborne, *Probing The Plumbing Of The Landusky Mine Site.*

4:05 Willis Weight, *Evaluating The Hydraulic Properties of Shallow First -order Alluvial Systems: An Analysis in Hay Creek, Whitehall Basin, Montana.*

4:25 Garrett Smith, *Tracing Dissolved Oxygen Dynamics In The Nyack Aquifer*

POSTER SESSION & SOCIAL HOUR ***Holiday Inn Atrium***

5:00 - 7:00 pm AWRA 2009 POSTER PRESENTATIONS

1. John Babcock. *Diel Variability Of Stable Isotopes Of Ammonia, Nitrate, And Dissolved Oxygen In Silver Bow Creek.*
2. Zara Berg. *Monitoring Brine Water Seepage In The Poplar River.*
3. Douglas Brinkerhoff. *Downstream Response To Shifts In Point Bar Morphology Associated With Dam Removal.*
4. Joel Brown. *Irrigators' Vulnerability to Drought in the Flathead River Basin, Montana.*
5. Victoria Bunn. *The Influence Of Riparian Grazing Exclosures On Adjacent Riverine Ecosystems.*
6. Rod Caldwell. *Heat As A Tool To Trace Groundwater/ Surface-Water Interactions In The Smith River Watershed, Meagher County, Montana.*
7. Matthew Corsi. *Management Of Anthropogenically Derived Hybrid Trout Populations: Explicit Recognition Of Assumptions.*
8. Kelly Crispen. *Ecology Of Salmonid Fishes In The Umpqua River, Oregon: History Of Anadromous Runs, Current Condition And Restoration Potential.*
9. Tammy Crone. *Assessment And Distribution Of Pharmaceuticals, Personal Care Products, And Endocrine Disrupting Compounds In Surface Waters In The Gallatin Valley, Gallatin County, Montana.*
10. Ellie Davis. *Nutrient Concentrations and Bacterial Biomass in Streams Located in the West Fork Watershed in Big Sky, MT.*
11. Lorri Eberle. *A Conceptual Foundation For The Klamath River.*
12. Alan English. *Waste-water pharmeceuticals.*
13. Abror Gadaev. *The Water Well Screen And Its Clogging Issue.*
14. Alaina Garcia. *Mechanical Analysis Of A Tesla Turbine To Produce A More Efficient Microhydro Turbine System.*
15. Rya Hawks. *Behavior of Residual heat in Groundwater at an MTBE Site Treated with Electrical Resistance Heating.*
16. Gary Icopini. *Assessment Of Pharmaceuticals And Endocrine Disrupting Chemicals In The Groundwater Of Gallatin County, Montana.*

17. James Johnsen. *Sediment Transport Of The Clark Fork River's Milltown Dam Removal.*
18. Nadia Klif. *Impact Of Anthropogenic Pollution And Agriculture Practices On Soil And Water Quality In Phosphate Mining Basin Of An Arid Region (Moulares-Redayef Aquifer, Southwestern Tunisia).*
19. *Seth Kurt-Mason. Assessing Stream Function And Groundwater-surface Water Connectivity In A Restored Streambed: Science To Inform The Restoration Process.*
20. *John LaFave. Arsenic In Groundwater Near Dayton, Montana.*
21. *Jonathan Leiman. Total Dissolved Solids Toxicity: Challenges and Future Directions.*
22. Rick Mulder. *Stream Sampling For Hydrophilic Pesticides In Montana Using Polar Organic Chemical Integrative Samplers (POCIS).*
23. Ivan Orsic. *Downstream Deposition Of Contaminated Sediment Following The Removal Of Milltown Dam, Montana.*
24. Todd Preston. *20 Years Later: Reexamining Oilfield Brine Contamination In The Prairie Pothole Region Of Sheridan County, Montana.*
25. Donna Smith. *Arsenic Speciation In Groundwater Related To The Clark Fork River, The Floodplain And Organic Rich Substrates..*
26. Molly Staats. *Mercury In Sediments Of The Upper Clark Fork River And Tributaries.*
27. David Stagliano. *Stream Ecological Classification, Ecosystem Diversity And Crucial Watershed Areas In Montana's Columbia River Basin.*
28. Sean Sullivan. *Using Bioassessment Methodologies To Assess Recovery Of Silver Bow Creek, MT.*
29. Joanna Thamke. *Geophysical Studies Of Brine Contamination in And Near The East Poplar Oil Field, Northeastern Montana, 2009.*
30. Kirk Waren. *Potentiometric Surface Map Of Basin Fill And Selected Bedrock Aquifers, Deer Lodge, Granite, Powell, And Silver Bow Counties.*

BANQUET — *Sapphire Room C & D*

7:00 pm BANQUET

8:00 SPECIAL SPEAKER
Jack Schmidt, Ph.D., Utah State University
The science and politics of restoring bi-national rivers: the Rio Grande/Rio Bravo and the Colorado River/Rio Colorado

PHOTO CONTEST
Kirk Waren

FRIDAY, OCTOBER 2, 2009

7:30 am Morning Coffee

SESSION 5 (Concurrent). ***Garden City Ballroom A***
AQUATIC ECOSYSTEMS

Moderator: Lisa Eby -- University of Montana

8:20 am Linda Vance. *Wetland Landscape Profiling.*

8:40 Virgil Dupuis. *Flowering Rush: An invasive Aquatic Macrophyte infesting the Headwaters of the Columbia River System.*

9:00 David Feldman. *Describing Sampling Variability Bias to the Macroinvertebrate Biometrics of Stream Condition in Montana.*

9:20 Catherine McIntyre *Predicting Amphibian Occurrence Based On Local And Landscape Level Factors In Montana.*

9:40 Adam Sepulveda. *The Role Of Movement To Stream Salamander X Fish Coexistence: On A Road To Nowhere?*

10:00 David Stagliano. *Western Pearlshell (Margaritifera Falcata) Mussel Distribution In Montana Watersheds: A Legacy Of Lost Native Species, Connectivity & Dewatering.*

10:20 BREAK

SESSION 6 (Concurrent). ***Garden City Ballroom B***
WATERSHED HYDROLOGY

Moderator: Chuck Dalby -- DNRC

8:20 am Julie Ahern. *Modeling Stream Depletion In The Lower Beaverhead River Sub-basin: Results And Lessons Learned.*

8:40 Randy Overton. *Determining When Streams Become Hydraulically Disconnected From Groundwater.*

9:00 Able Mashamba. *A Discussion Of Results, Insights And Challenges In Assessing Watershed Management Practices Using A Semi-distributed Environment Model.*

9:20 Curt Coover. *Arsenic Mobility In Wetlands Near Anaconda, Montana.*

9:40 Karen Newlon. *A Rotating Basin Wetland Assessment Strategy For Montana.*

10:00 Greg Bryce. *Surface Water Mitigation Using Induced Groundwater Storage.*

10:20 BREAK

SESSION 7 (Concurrent). *Garden City Ballroom A*
WATER QUALITY & QUANTITY

Moderator: Tom Osborne -- HydroSolutions, Inc

10:50 am Gerald Mueller. *The Milltown Dam Water Rights And Water Use In The Upper Clark Fork River Basin.*

11:10 Jacob Petersen-Perlman. *An Assessment Of Municipal Water Systems And Water Rights In The Clark Fork River Basin.*

11:30 Christian Schmidt. *Groundwater And Surface Water Monitoring For Pesticides And Nitrate In The Bitterroot Valley, Montana.*

11:50 Alicia Stickney. *Exciting Opportunities For Natural Resource Projects In Montana! Two Examples From The Blackfoot River.*

12:10 Vicki Watson. *10 Years Of Nutrient Reductions On The Clark Fork River.*

12:30 Boris Krizek. *Municipal Impacts From The General Permit For Stormwater Discharges Associated With Small Municipal Separate Storm Sewer Systems (MS4s).*

SESSION 8 (Concurrent). *Garden City Ballroom B*
INTERNATIONAL & TRANS-BASIN WATER SCIENCE

Moderator: Clint Muhlfeld -- USGS

10:50 am Tom Bansak. *The Salmonid Rivers Observatory Network: A Habitat-Based Assessment Of Production Across The Pacific Rim.*

11:10 Samantha Chilcote. *The Riverscape Analysis Project: A Model for the Integration of Spatial Data and Management Planning of Aquatic Resources.*

11:30 Tony Prato. *Adaptive Fuzzy Decision-making For Collaborative Water Management.*

11:50 Clint Muhlfeld. *Proposed Coal Mining and Coal-bed Methane Development Threaten Aquatic Resources in the Transboundary Flathead Ecosystem.*

CLOSING PLENARY *Garden City Ballroom A & B*

1:00 pm CLOSING PLENARY

1:45 ANNOUNCEMENTS
Officers, Photo Contest Awards, Student Awards

2:00 ADJOURN

2:00 MT Ground Water Characterization Committee Meeting

KEYNOTE SPEAKER

Jon Major, Ph.D.

Research Hydrologist
U.S. Geological Survey Cascades Volcano Observatory
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Jon Major is a research hydrologist with the U.S. Geological Survey Cascades Volcano Observatory in Vancouver, Washington. He received his Ph.D. in 1996 from the Department of Geological Sciences at the University of Washington. His research focuses on hydrogeomorphic responses to landscape disturbance, particularly in volcanic river systems. During his 26 years with the USGS, he has worked on groundwater flow in landslides, mechanics of deposition by debris flows, post-eruptive sediment transport and streamflow hydrology, hydrogeomorphic response to dam removal, and analyses of debris flow and flood hazards at volcanoes in Washington, Oregon, Alaska, El Salvador, and the Philippines. He is a fellow of the Geological Society of America (GSA), and has received the GSA E.B. Burwell Award (Engineering Geology Division research publication award), the GSA Kirk Bryan Award (Quaternary Geology and Geomorphology Division research publication award) and a Department of Interior Award for Excellence of Service.

Abstract: *Short-term sediment erosion, transport, and deposition on the Sandy River following removal of Marmot Dam*

The 2007 removal of Marmot Dam on the Sandy River, Oregon, triggered a rapid sequence of fluvial responses as ~730,000 m^3 of sand and gravel that filled the former reservoir was suddenly exposed to an energetic river. From direct measurements of sediment transport, photogrammetry, and repeat surveys between transport events, we report on the rapid erosion, transport, and redeposition of this sediment in the hours, days, and months following breaching. Measurements of suspended load and bedload documented an initial spike in the flux of suspended silt and clay in the minutes after breaching followed by high rates of bed- and suspended-load transport of sand. Significant gravel transport did not begin at a measurement site 0.5 km downstream of the dam until 18-20 hours after breaching, when bedload transport achieved rates in excess of 70 kg per second -- rates that greatly exceeded concurrent measurements of less than 10 kg/s at sites upstream and farther downstream of the dam. Bedload transport rates just below the dam site remained 10-100 times above upstream and downstream rates through subsequent high flow events during the winter and spring of 2007 and 2008.

Much of the elevated sediment load was derived from eroded reservoir sediment, which initially eroded when a multi-meter tall knickpoint migrated upstream 200 meters in the first hour. Rapid knickpoint migration triggered bank collapse in the unconsolidated fill which swiftly widened the channel. Over the following months, the knickpoint migrated slowly upchannel, simultaneously lowering and becoming less distinct. By May 2008, a riffle-like feature approximately 1 m high and 2 km upstream from the breached dam persisted. Knickpoint and lateral erosion evacuated ~100,000 cubic meters of sediment from the reservoir in the first 48 hours, and by the end of high flows in May 2008 about 350,000 cubic meters (45% of the initial reservoir volume) had been evacuated. Large stormflows in November 2008 and January 2009 eroded another 25,000 cubic meters of sediment. Thus, within 15 months of breaching, about 51% of the impounded sediment (375,000 cubic meters) had been eroded. About 40% of the eroded sediment has been redeposited in a tapered wedge of sediment that extends 2 km from former dam site to the entrance of a confined bedrock gorge. Much of the balance of the eroded sediment is distributed along and partly fills pools within the Sandy River gorge, a narrow bedrock canyon extending 2-8 km downstream of the former dam site. An estimated sediment budget reveals that gravel was rapidly redeposited along the channel immediately below the dam site and within the gorge, and that additional dispersed sediment storage occurred in the 8-km-long channel reach below the river gorge.

KEYNOTE SPEAKER

Steve Running, Ph.D.

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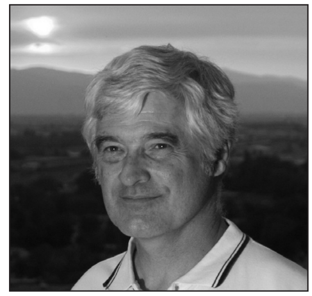

Steven W. Running received a Ph.D. (1979) in Forest Ecology from Colorado State University. He has been with the University of Montana, Missoula since 1979, where he is a University Regents Professor of Ecology. His primary research interest is the development of global and regional ecosystem biogeochemical models integrating remote sensing with bioclimatology and terrestrial ecology. He is a Team Member for the NASA Earth Observing System, Moderate Resolution Imaging Spectroradiometer, and he is responsible for the EOS global terrestrial net primary production and evapotranspiration datasets. He has published over 240 scientific articles and two books. Dr. Running has recently served on the standing Committee for Earth Studies of the National Research Council and on the federal Interagency Carbon Cycle Science Committee. He recently has served as a Co-Chair of the National Center for Atmospheric Research Community Climate System Model Land Working Group, a Member of the International Geosphere-Biosphere Program Executive Committee, and the World Climate Research Program, Global Terrestrial Observing System. He currently serves on the advisory NASA Earth Science Subcommittee, and the NOAA Science Advsiory Board Climate Working Group. Dr. Running shared the Nobel Peace Prize in 2007 as a chapter Lead Author for the 4th Assessment of the Intergovernmental Panel on Climate Change. Dr. Running is an elected Fellow of the American Geophysical Union and is designated a Highly Cited Researcher by the Institute for Scientific Information. In the popular press, his essay in 2007, "The 5 Stages of Climate Grief" has been widely quoted.

Abstract: ***Climate Change and Declining Surface Water Balance in the Northern Rockies***
While the most pressing discussion of climate change focuses on temperature increases, projections show the biggest issue of climate change for the Northern Rockies will be a declining surface water balance, defined as precipitation minus potential evaporation. Global Climate Model (GCM) projections done for the Intergovernmental Panel on Climate Change Fourth Assessment report - known as the IPCC AR4 - http://www.ipcc.ch/ will be addressed. In this presentation, the climate model projections are downscaled to focus on the Northern Rockies. They show increasing summer evaporative demand with no increase in precipitation. Additionally, the region's key water storage, snowpack, is now melting two weeks earlier, a trend that will continue. The net result for the future appears to be a shorter winter hydration season, and a longer summer desiccation season for Northern Rockies landscapes.

SPECIAL SPEAKER

Gerald Sehlke

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Jerry is an Advisory Scientist at the Idaho National Laboratory, in Idaho Falls, Idaho. He has worked in the water and energy fields for 23 years and has experience as a program manager and research scientist/Principle Investigator for regulatory compliance, environmental restoration, water resources policy and planning, groundwater monitoring, and groundwater protection programs. His research interests include integrating water policy/law and science, the nexus between energy and water, and the development of adaptive management programs. He is the INL's PI for developing NASA Solutions Networks; Co-PI for the Department of Energy's Energy-Water Nexus and Water Supply Technology Act Programs; PI for the INL's Climate Change Adaptation Initiative; and a member of the National Science and Technology Council's Water, Energy and Food Task Committee.

Jerry is the President of the American Water Resources Association. He helped develop/chaired numerous professional conferences and workshops including helping develop and participating in the four National Water Policy Dialogs. He has written numerous scientific and policy papers, and has formally/informally assisted numerous state and federal agencies address water and energy related policy, planning and management issues. He has a B.S. in Biology, M.S. in Entomology, M.S. in Hydrology, and is currently working on a PhD in Water Resources Management, focused on: Evaluating and Adaptively Managing Potential Impacts of Climate Change and Natural Variation on Energy and Water Systems.

Jack Schmidt, Ph.D.

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Jack Schmidt is Professor of Watershed Sciences and Director of the Intermountain Center for River Rehabilitation and Restoration at Utah State University. He leads a research group focused on environmental management of many of the large rivers of the western United States, and on improving the practice of stream restoration. He has worked on issues related to rehabilitating the Colorado River in Grand Canyon, downstream from Glen Canyon Dam, for more than 20 years. He and his students also work on the Green River in Colorado and Utah, on the Snake River in Wyoming, on the Rio Grande in the Big Bend region, on the Walker River in Nevada, and on smaller streams throughout the region. He co-authored the award winning USGS book Dams and Rivers: Primer on the Downstream Effects of Dams and The Controlled Flood in Grand Canyon, published by the American Geophysical Union.

Abstract: ***The science and politics of restoring bi-national rivers: the Rio Grande/Rio Bravo and the Colorado River/Rio Colorado***
The United States and Mexico share two of the great rivers of the North American Cordillera. The Rio Grande and the Colorado River have their headwaters in the middle and southern Rocky Mountains, drain southward across the Basin and Range, and cross into or form the common boundary with Mexico. Today, only 10% of the pre-development stream flow of the Colorado crosses the international border, because most of the stream flow serves more than 30 million people in 7 western states. Similarly, the entire flow of the Rio Grande, called the Rio Bravo in Mexico, is diverted in Colorado, New Mexico, Texas, and Chihuahua and only irrigation return flow reaches the border cities of Presidio and Ojinaga.

More than $40 million/year is now spent in the United States in efforts to rehabilitate parts of the Colorado River system and an emerging effort is underway to provide mitigation stream flows to the Colorado River delta in Mexico. Similarly, substantial effort is underway to mitigate habitat of the Rio Grande silvery minnow in New Mexico and an effort is now emerging to rehabilitate the Rio Bravo in the Big Bend region.

Despite application of state-of-the-science to many of the ongoing river restoration program in the U.S., and the attention of many large U.S. based non-government organizations, it is unclear whether any of the efforts presently underway will be successful. Each of these great rivers is prisoner to its distinctive geography of water and sediment sources in relation to the locations of major urban and agricultural centers, and to the uncertainty of how water- and energy-short societies will respond to population growth in a changing climate.

Environmental Controls On Drainage Behavior Of An Ephemeral Stream: Implications For Stream Restoration

Kyle Blasch, Assistant Director, U.S. Geological Survey, Montana Water Science Center, 3162 Bozeman Ave, Helena, MT, 59601, (406) 457-5901, kblasch@usgs.gov. Additional authors: Ty Ferr, Department of Hydrology and Water Resources, University of Arizona; Jasper Vrugt, Earth and Environmental Science Division, Los Alamos National Laboratory; Willis Weight, Carroll College; Willis Weight, Carroll College, Department of Mathematics, Engineering, and Computer Science; Clayton Marlow, Montana State University, Department Animal and Range Sciences.

Characterizing groundwater availability for vegetation establishment is an important component in stream-restoration planning. Quantifying groundwater availability within ephemeral streambed sediments requires knowledge of the sediment profile's infiltration and drainage rates. Streambed drainage rates were measured at after 26 ephemeral streamflow events in Rillito River, Arizona, from August 2000 to June 2002 using time-domain reflectometry. Streambed sediments at the Dodge Boulevard study site consist of an upper layer of Holocene alluvial stream-channel deposits and a second deeper layer of Pleistocene or older basin-fill deposits. Cores collected near the site indicate that the alluvial deposits are about 7 meters thick and consist predominantly of loose to moderately compacted sands and gravels, with less than 10 percent clay and silt combined. The underlying basin-fill deposits, which extend to depths of several hundred meters, consist of unconsolidated to poorly consolidated interbedded gravel, sand, and silt. An unusual drainage response was identified in the upper layer, which was characterized by rapid drainage from saturation to near field capacity (the water content of the soil after excess water has drained) with an increasing delay of drainage onset at deeper depths. More specifically, the drainage front decelerated as it moved deeper below the streambed surface. The drainage response was simulated using a variably saturated one-dimensional numerical flow model representing a two-layer system with a high permeability layer overlying a lower permeability layer. Both the observed data and the numerical simulation show a strong correlation between the drainage velocity and the temperature of the stream water. Higher drainage rates are proportional to warmer temperatures. A linear combination of temperature and the length of interflow period (time between ephemeral streamflow events) preceding streamflow explained about 90 percent of the measured variations in drainage velocity. However, evaluation of correlation between temperature, length of interflow period, and drainage velocity using the one-dimensional numerical flow model showed that the observed temperature fluctuations could not reproduce the magnitude of variation in the observed drainage velocity. Instead, the model results indicated that flow duration exerts the most control on drainage velocity, with the drainage velocity decreasing nonlinearly with increasing flow duration. These findings suggest flow duration is a primary control of water availability for plant uptake in near-surface sediments of an ephemeral stream, which is an important finding for estimating the ecological risk of natural or engineered changes to streamflow patterns. Correlative analyses of soil-moisture data, although simple and widely used, can result in erroneous conclusions of hydrologic cause and effect relationships. These results demonstrate the need for joint physically-based numerical modeling and data synthesis for hypothesis testing to describe groundwater behavior.

Restoration Of The Clark Fork River After Removal Of Milltown Dam

Matthew Daniels, Principal Engineer, River Design Group, 5098 Highway 93 South, Whitefish, MT, 59937, (406) 862-4927, mdaniels@riverdesigngroup.net.

Throughout the United States, dam removal is quickly becoming a viable river restoration alternative as many dams have exceeded their useful life or become safety concerns. Likewise, innovative construction techniques and heightened desires to restore natural stream processes have created opportunities to make dam removal feasible. Milltown Dam was built in 1906 at the confluence of the Clark Fork River and Blackfoot River, eight miles east of Missoula, Montana. During the Clark Fork River flood of record in 1908, the reservoir filled with approximately 6.6 million cubic yards of sediment including tailings from mining operations 150 miles upstream near Butte, Montana. In the 1980s, contaminated reservoir sediments were linked to elevated levels of arsenic in drinking water wells in nearby communities. As part of a settlement agreement between the State of Montana, the Environmental Protection Agency and Atlantic Richfield Company, 2.2 million cubic yards of contaminated sediments were removed and Milltown Dam was demolished, setting the stage for restoration of the Clark Fork River. Removal of Milltown Dam in 2008 restored fish passage and free flowing river conditions for the first time in over 100 years. This presentation provides an overview of the restoration work that is occurring following removal of Milltown Dam. Topics addressed will include restoration planning, feasibility, hydraulic and sediment analysis, geomorphic investigations, restoration design and implementation. Implementation of the restoration plan is scheduled to occur between 2009 and 2012. Monitoring of the restoration work is planned for up to 15 years following construction. An extensive data collection effort was undertaken to support the restoration design. Data collection included aerial, bathymetric and ground surveys, field calibration of bankfull discharge at gage stations, subsurface borings, geomorphic data from reference reaches, bedload and suspended sediment, soil geochemistry and vegetation community mapping. Data were used to evaluate restoration feasibility and estimate the pre-dam configuration of the Clark Fork River floodplain. Restoration design focused on restoring pre-dam river and floodplain morphology as well as native riparian plant communities. Because the entire pre-dam floodplain was impacted by the reservoir and subsequent sediment removal, restoration of the entire floodplain was addressed. Floodplain design included development of layouts for several features including terraces, side channels, wetlands, springs, and tributaries. On-going remedial work at the site has revealed intact portions of the historical floodplain resulting in an adaptive approach to implementation. In addition, restoration implementation in 2009 has led to improved construction techniques and best management practices for controlling construction-related impacts.

Vegetation Response On Historical Floodplain Surface At Milltown Dam

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In winter 2006, portions of the Milltown Dam Remedial Area were excavated as test pits to help finalize methods for removing contaminated sediments. The elevation of these excavated surfaces corresponds closely with the pre-Milltown Dam floodplain surface elevation as evidenced by the presence of tree and shrub stumps, and developed soils that contrast with sediments deposited behind Milltown Dam. As of late spring 2009, these historical floodplain areas have been exposed for two full growing seasons and the soil surface is being colonized by vegetation. Because colonizing vegetation is composed mostly of native vegetation rather than weedy or invasive species typically seen on disturbed construction sites, it appears at least some of the plants may be establishing from a pre-dam residual seed bank. To evaluate the vegetation establishing on the exposed historical floodplain surface, several transects were established in May 2009. Plant species were identified along these transects and aerial canopy cover recorded as a measure of abundance. Emerging plants will be evaluated at various times during the 2009 growing season. Plant species observed as of early May 2009 include: sandbar willow (Salix exigua), Pacific willow (Salix lasiandra), Bebb willow (Salix bebbiana), red-osier dogwood (Cornus sericea), cattail (Typha latifolia), bluejoint reedgrass (Calamagrostis canadensis), aspen (Populus tremuloides), sedges (Carex spp.), rushes (Juncus spp.), small-fruited bulrush (Scirpus microcarpus), largeleaf avens (Geum macrophyllum), lupine (Lupinus species), and a variety of other forbs. If native species are establishing from a long-buried seed bank at the site, this would have positive implications for restoring portions of the floodplain where the pre-dam floodplain surface is still present. In addition, this provides an opportunity for ecological researchers to essentially open a "time capsule" and view a glimpse of western Montana riparian plant species composition from more than one hundred years ago. Related to these observations and the ongoing river and floodplain restoration work along the Clark Fork River, several research questions could be further explored, including: will site conditions continue to support desired species such as willow and aspen; will there be residual metal toxicity effects on plant growth and survival; to what degree is vegetation establishing from an exposed soil seed bank as opposed to other sources such as wind borne, animal or vehicle transported seed; and do soil characteristics favor native plant establishment over non-native plants? As the Milltown Dam restoration project develops, there will be opportunities for collaborative research to help answer these and other questions related to the historical ecology of the Milltown Dam site.

Mattie V Creek: A Collaborative Restoration Approach Between A Conservation Organization, Local And Federal Agencies, Academia, And Professional Consultants

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Restoring stream channel functions to mining impacted watersheds in Western Montana presents unique challenges and opportunities to restoration practitioners. Mattie V Creek, a tributary to Ninemile Creek in the Middle Clark Fork River drainage, has been historically and severely impacted by mining activities. This resulted in a channelized section of the creek that has no connectivity with a floodplain, provides a significant barrier for fish passage, and imposes artificial constraints on channel alignment and morphology. Furthermore, the disturbed landscapes coupled with beaver activity results in complex and altered surface and ground water flow patterns that create extensive pond networks through which Mattie V Creek flows. These disturbances created preferential habitat for non-native trout species and reduced the ability of migratory bull trout to access upper reaches of the Mattie V Creek watershed. Additional impacts within the Mattie V Creek watershed include past logging activities, associated road networks, and road crossings that are barriers to aquatic organism passage. However, road decommissioning and culvert removal have occurred in the upper reaches of the watershed. In this presentation, we discuss the issues associated with the degraded Mattie V Creek, define the restoration objectives, and present decision based tools and field activities utilized to achieve desired restoration goals. Collaboration with project partners resulted in utilizing existing information (watershed studies, photogammetry, and fisheries data) to provide more efficient, targeted field surveys and data collection. Proposed alignments were screened based on results of testing disturbed soils for mercury contamination, and through collecting sediment bedload and streamflow measurements. Initial soil sample results indicated mercury levels consistent with expected background levels. We are analyzing spring 2009 runoff data, and preliminary results indicated moderate peak flows associated with snowmelt resulting in little sediment transport. These factors were used to reduce the uncertainties related to meeting project objectives and resulted in a finalized conceptual stream channel design.

Principles Of Successful River Restoration

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Stream management projects conducted under the banner of "restoration" often include habitat enhancements, bank stabilization, relocations, and remediation of impacts from agricultural, mining, development, and forestry practices. The river restoration industry is a multi-billion dollar industry in the western states, and multi-million dollar industry in Montana. Yet there is an emerging consensus that we do not know if these mostly public monies are well spent. Monitoring to date has not been sufficient in design or practice to answer questions regarding project success. Increasing press and public scrutiny of "failed" projects may jeopardize public will to continue funding such work. To facilitate project planning and implementation that leads to real and defensible benefits to fishery and aquatic resources, eight principles of successful restoration planning are described: 1. First things first -- address constraints and ultimate causes rather than symptoms; 2. Look both ways -- consider watershed context from headwaters to mouth; 3. If it ain't broke don't fix it -- recognize that dynamic systems do not necessarily need to be repaired; 4. Question constraints -- rock and rootwad structures constrain natural process; 5. Accommodate uncertainty -- it is equally important to consider what we don't or cannot know; 6. Do no harm -- implementation should have no lasting impact; 7. Keep the door open -- ensure alternative does not limit future options; and 8. Invest wisely and protect your investment -- protect project from potential future impacts. These principles will help project proponents and reviewers guide restoration practices toward more sustainable and effective end results. New project planning tools and resources have been developed and are now available to assist in developing and reviewing proposed projects.

Lessons Learned From Revegetation Projects: The Story Of The Lower Clark Fork Revegetation Manual Analyzing The Steps To Successful Riparian Restoration.

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Watershed Consulting offered comprehensive analysis services to the Lower Clark Fork (LCF) Watershed Group to improve future revegetation planning processes and watershed restoration decisions. The manual is holistic in approach and covers riparian issues and conditions, reviews disturbance ecology in the LCF, offers lessons learned from past projects, describes a set of characteristics and conditions that lead to successful projects, and presents recommendations and direction for future riparian revegetation projects in the area. The LCF watersheds have experienced a variety of disturbances that have long-term influences on plant community dynamics and associated river and watershed ecologic and physical integrity. The influence of disturbance on this landscape is also complex and varied. Some activities that had and continue to have a significant influence on the ecosystem include: logging, roading, clearing for agriculture, river and stream dredging and straightening, grazing, clearing for aesthetics, and utility corridor clearing. In many places in the LCF region the cycle continues as human made disturbance intensifies the influence of natural disturbance, directing ecologic trends towards an unfortunate end. Note that each of these activities supports an essential element that allows us to live and work in the area. Often, it is not what we do that causes long-term shifts in ecologic trends, but how we do it. The study area for the revegetation manual encompasses all the tributaries to the Clark Fork River and associated watersheds from the Thompson River, west to the Idaho border. A simple reconnaissance of the country yields forest types and riparian ecosystems that vary in association with elevation, aspect, and topography, geology and soils. From the dry Ponderosa Pine forest of the Thompson River Valley to the lush, cedar forests in the Bull River watersheds, diversity is the only steady factor. Each of these activities influences the ecosystems biological and physical resiliency to further disturbance. The goal of the manual is to provide direction for future revegetation efforts in the LCF Watersheds in order to increase the economic and ecologic efficacy of riparian restoration projects within the area. In this manual we have raised several key considerations for future revegetation efforts. Our assessment of the revegetation projects in the LCF Watersheds yielded four primary recommendations that will lead to project success. (In a basic sense, success can be defined as plants surviving with enough vigor to significantly enhance soil stability or provide habitat for fish and wildlife.) 1) Perform a detailed pre-projects site assessment; 2) Design and implement features that increase site revegetation potential; 3) Revegetate in phases; and 4) Provide project monitoring and maintenance into the future. Four primary issues mean the difference between success and failure for most revegetation projects: soil moisture & aeration, animal browse, plant to plant competition, and long-term ecologic trends. Finally, the manual provides detailed explanations of various restoration techniques and discusses the possibility of establishing a native plant nursery in the LCF. While the manual was written for a specific area, we believe it has great relevance for restoration projects across Montana.

SESSION 2 CLIMATE

Timing Of Present And Future Snowmelt From High Elevations In Northwest Montana

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The sensitivity of snowmelt-driven water supply to climate variability and change is difficult to assess in the mountain west, where strong climatic gradients coupled with complex topography are sampled by sparse ground measurements. We developed a snowmelt model, which ingests daily satellite imagery and meteorological data and is suitable for areas >1000 km^2, yet captures spatial variability in steep mountain terrain. We

applied the model for the years 2000-2008 to a 2900 km^2 snowmelt-dominated watershed in NW Montana. We found that >25% of the basin's snow water equivalent (SWE) accumulates above the highest measurement station and >70% accumulates above the mean elevation of surrounding SNOTEL stations. Consequently, scaling point measurements of snow water equivalent to describe basin conditions leads to significant misrepresentation. Simulations found that present day temperature variability causes measures of snow melt timing to vary by over 4 weeks from year-to-year. Temperature variability causes a larger spread in snow melt timing measures in a warmer climate. On average, snowmelt timing occurs 3 weeks earlier in late 21st century projections, with about 25% of future conditions observed today.

Summer And Winter Surface Water Balances At Sperry Glacier, Glacier National Park, Montana

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In the U.S., the dramatic retreat of glaciers in Glacier National Park (GNP) has become an icon for a worldwide trend that is both an effect of, and evidence for, global climate change. While the loss of glacier area in GNP is higher than in other mountain areas in the contiguous U.S., there have been no quantitative studies of changes in glacier mass or volume in GNP. We present the results to date of an ongoing study of the mass balance of Sperry Glacier, one of the largest remaining glaciers in GNP. We relied on a glaciological approach for direct measurements of mass balance in 2005 through 2008. Results show that the net annual balance was negative for three years but positive for the fourth. The glacier lost a total of 2.29 x 106 m3 of water in the four-year period, with mean annual net balance was -5.72 x 105 m3 a-1; over half of that loss occurred in one year (2007). To calculate multi-decadal mass balances, we use a geodetic method that compared digitized 1950 and 1960 maps of the glacier surface with a DEM of the 2007 glacier surface created from a differential GPS survey. For the older and longer periods, mean annual net balances were substantially less negative (-2.7 x 105 m3 a-1 for 1950-60; -3.7 x 105 m3 a-1 for 1950-2007). To examine longer-term climate patterns, we compare a 40-year record of snow water equivalent and a 26-year temperature record from a nearby SNOTEL with the glacier's winter balance and with data from an automated weather station at the glacier. Examination of the climate data shows no significant precipitation or temperature trends, but the ablation seasons in 2006 and 2007 were the warmest years in the period, while springtime melt during 2008 (the positive mass balance year) was among the slowest in 40 years. Sperry Glacier's cumulative negative balance since 1950 suggests that a complex set of meteorological factors typically combine to maintain an unfavorable climate for the glacier, but that even small variations in these factors can dramatically affect the volume of water gained or lost at the glacier surface each year.

Global Warming, Restoration, And The Rocky Mountain Front

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Time (and temperature) will settle any on-going debate about the magnitude or meaning of global warming. In the meantime, restoration specialists are faced with prioritizing actions to maximize potential benefits to fisheries, stream systems, and water quality. The biological consequences of potentially elevated water temperatures, changing water yield/timing, and reduced snowpack have significant implications both for resource management and allocation of limited funding. Data from the Rocky Mountain Front shows trends in reduced water yield and snowpack. In-stream temperature monitoring shows average and maximum temperatures well above thresholds considered sustainable for salmonids. Competition for irrigation water increases pressure on limited supplies and reduces in-stream flow. What happens if the environment becomes yet warmer, or if we respond with assertive restoration strategies? The temperature model SNTEMP provides a means to evaluate an array of potential restoration actions including alteration of stream W/D ratio, baseflow discharge, riparian shading, and groundwater recharge. Application of this model along the Rocky Mountain Front provides a potentially enlightening perspective on our collective restoration focus. Add a couple degrees Fahrenheit to the mean air temperature, or increase riparian coverage 20%. We'll review the modeled in-stream results, and you may reconsider your priorities as fisheries manager or stream restoration specialist.

Watershed Scale Response To Climate Change: South Fork Flathead River, Montana

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In 2008, the U.S. Geological Survey Global Change Program funded a study to examine integrated watershed scale response to global change in selected watersheds across the United States. Fourteen watersheds for which hydrologic models had been created using the Precipitation Runoff Modeling System (PRMS) were selected as study sites. PRMS is a deterministic, distributed-parameter, watershed model developed to evaluate the effects of various combinations of precipitation, temperature, and land use on streamflow and basin hydrology. The portion of the South Fork Flathead River watershed located upstream from Hungry Horse Dam in northwestern Montana is 1 of the 14 study sites. Results from six General Circulation Models (GCMs), each using three GCM scenarios, were used to develop climate change scenarios for 2001-2099 for input to the existing PRMS model for the South Fork Flathead River. These PRMS simulations using the GCM scenarios were compared to PRMS simulations for current (1988-2000) conditions. All GCM simulations project an overall increase in temperature, although the magnitude is variable. Projected changes in precipitation for the South Fork Flathead River watershed were variable, with a slight tendency towards an increase in precipitation in the latter half of the 21st century. Uncertainties associated with precipitation projections for the South Fork Flathead River watershed are smaller than for most of the other watersheds in the study. PRMS simulations using the GCM scenarios project slightly increased mean annual streamflow in the South Fork Flathead River from about 2020-2099. However, these simulations project that less precipitation falls as snow, so projected mean monthly streamflow increases January through April and decreases June through September. These simulations did not consider land-cover dynamics, such as changes in the watershed due to forest fires. Information from these climate-change simulations will be useful for long-term management of Hungry Horse Reservoir and for downstream water users.

Montana Precipitation Map

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An accurate average annual precipitation can be a useful tool when developing hydrology and other parameters. A new average annual precipitation (AAP) map has been developed that incorporates as many stations as possible and 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. 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 would be compared to hand-drawn products to assure appropriate results. Stations adjacent to Montana in Idaho, Wyoming, North Dakota, South Dakota, Alberta, and British Columbia were also 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 second. Isohyetal lines were 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 two or three neighbors and graduated inverse square of the distance (GISD). 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. It is planned to include monthly and seasonal precipitation in the future. Data will be available through Montana DEQ or NRIS web sites electronically.

Wells And Climate: Can We Find El Nino?

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Distance-to water measurements (or pressures) in wells are the only direct gauge of groundwater storage (pressure) in aquifers. As water levels fall (distances increase) groundwater storage (pressure) in the aquifer near a well decreases. Conversely, as water levels rise (distances decrease) groundwater storage (pressure) increases. Montana has a statewide network of more than 900 wells from which the Montana Bureau of Mines and Geology collects distance-to-water measurements. The resulting long-term water-level records show where and when groundwater storage (pressure) changes in many of Montana's aquifers. Factors that can influence groundwater storage include pumping at or near the monitoring point, general development in the aquifer, irrigation practices, and climate. Almost 40 percent of Montana's statewide network wells produce water-level records that exhibit large amplitude slowly changing signals likely related to climate. Time series water-level records often include variable frequency components. For example, a hydrograph may show a daily pumping cycle overprinted on an annual cycle caused by seasonal precipitation, snow melt, or irrigation practices. The combined daily and annual signals may themselves be superimposed on low-frequency patterns that have multi-year periods. Hanson and others (2006) have examined long-term groundwater-level records in the southwestern United States and related similar low-frequency components to precipitation variability caused by the El Nino-Southern Oscillation (ENSO) phenomenon with a cyclic pattern of 2-6 years, the North American Monsoon (NAM) with a periodicity of 6-10 yrs, or the Pacific Decadal Oscillation (PDO) with durations of 10-25 yrs. Water levels in eight wells completed in the Madison Limestone in Cascade County, Montana, have risen between 4 and 15 ft since 2005, and continue to climb despite the regional presence of at least 800 Madison Formation production wells. Rising water levels in the face of continued development and the areal extent across which the recovery is occurring indicates that a regional factor, likely climate variability, is causing the increased groundwater storage. One of the eight wells is directly up-gradient from Giant Springs and currently has an almost continuous record covering about ~25-yrs; the record shows a ~10-yr cyclic pattern that changes about 5 ft. The 25-yr record is likely too short to evaluate potential relationships with the NAM and PDO indices but may contain components related to the ENSO.

SESSION 3 RIVER & WATERSHED PROCESSES

Comparison Of Reconnaissance-Level And Detailed Methods Of Channel Migration Zone Delineation For The Upper Yellowstone River, Park County, Montana

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The Channel Migration Zone (CMZ) of an alluvial river is the area adjacent to the main channel that the river has occupied in the recent past (~50-100 years) and is likely to occupy over a similar time span into the future. As part of river and flood plain management efforts on the Upper Yellowstone River, the CMZ was mapped for Park County using both reconnaissance-level and detailed methods of analysis. Both efforts used protocols similar to those developed by the state of Washington, and mapped a composite 100-Year CMZ consisting of the following zones: historic migration, avulsion hazard, and an erosion hazard area (projected future lateral erosion and mass wasting over 100-year period)--all adjusted for the disconnected migration area where manmade structures (e.g. riprap, levees, barbs, roads) physically moderate or eliminate channel migration. Both applications relied on estimating rates of lateral channel movement through spatial overlay of successive traces of the bankfull channel and projecting these rates into the future to establish a 100-year future condition. Principal differences in application of the two methods are as follows: Reconnaissance-Level: developed "reach-average" erosion rates and applied these to segments of channel extending for one to several miles; used two-dimensional viewing, supported by LiDAR for delineation of avulsion hazards and mapping disconnected migration area. Detailed-Level: estimated and projected future erosion rates for each eroding bank using method that accounts for error in spatial overlay; used three-dimensional (i.e. stereoscopic) viewing of large-scale, aerial photos for delineation of avulsion hazard areas and mapping disconnected migration areas. Comparison of CMZ polygons for the reconnaissance-level and detailed mapping of shows: 1. Historic migration rates estimated by reach averages tend to overestimate erosion rates at sites where little or no erosion occurred in the past, and underestimate erosion rates at sites where erosion did occur; 2. Areas of disconnected migration were significantly underestimated by the reconnaissance method--likely due to the inability of two-dimensional viewing to capture floodplain attributes distal from the main channel. Reconnaissance-level methods are suitable for large-scale, rapid estimation of general CMZ characteristics. However when used to support flood hazard and erosion-risk mapping, detailed methods, based on site-specific analysis should be used.

Determination Of Travel Times And Dispersion Rates In The Yellowstone River In Montana

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In 2008, the U.S. Geological Survey (USGS), in cooperation with Montana Department of Environmental Quality, measured instream travel times and dispersion rates using a water-soluble dye-tracer in the Yellowstone River from Billings to Glendive, Montana. These data will be used for nutrient cycle modeling and planning emergency response for accidental contaminant spills into the Yellowstone River. Between September 23 and October 10, 2008, Rhodamine WT dye was injected near Lockwood, Myers, Forsyth, and Miles City. Rhodamine WT is a conservative, water-soluble, non-toxic dye that can be detected at low concentrations. Fluorescence readings, when compared to known dye concentrations, can be used to determine dye concentrations in water. At numerous sites downstream of the dye injections a Self-Contained Underwater Fluorescence Apparatus (SCUFA) was used to measure the fluorescence of the dye cloud as it traveled past each site. Grab samples also were collected at 15-, 30-, 45-, 60-, and 90-minute intervals depending on the expected time-of-passage of the dye cloud. Dye concentrations for the grab samples were analyzed with a bench fluorometer and used to verify the data collected with the SCUFA. Three-parameter log-normal curves were constructed using the collected data. These curves were used to determine the travel times of the leading edge, peak, centroid, and trailing edge of the dye cloud. Dye was injected during steady streamflow conditions that approximated uniform flow, which is desirable for obtaining reliable results. Streamflows ranged from 3,500-3,770 cubic feet per second upstream from the confluence of the Bighorn River and ranged from 6,520-7,570 cubic feet per second downstream from the confluence of the Bighorn River. Mean streamflow velocities measured from the dye movement ranged from 1.83 feet per second to 3.18 feet per second between Lockwood and Glendive. Data collected during the study indicate the transport model YTOT (a computer program for estimating instream travel times and concentrations of a potential contaminant in the Yellowstone River) developed by USGS (2006) predicted the travel times and peak concentrations of the Yellowstone River between Billings and Glendive with reasonable accuracy. Measured velocities for the peak concentration from this study averaged 13 percent faster than the predicted most probable stream velocity and averaged 6 percent slower than the predicted maximum probable stream velocity. Additional dye-tracer studies are needed to develop relations between travel times and streamflows in the Yellowstone River over a broader range of streamflows.

Monitoring Hydraulic Conditions And Scour At I-90 Bridges On Blackfoot River Following Removal Of Milltown Dam Near Bonner, Montana, Spring 2009

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Substantial river and flood-plain reconstruction related to the 2008 removal of Milltown Dam on the Clark Fork of the Columbia River, near Bonner was predicted to affect pier and abutment foundations of nearby bridges due to the altered geomorphic environment. Bridge piers and abutments of the I-90 eastbound and westbound bridges that cross the Blackfoot River near the confluence with the Clark Fork underwent substantial modification (2008-09) as part of the mitigation activities related to removal of the dam. With dam removal and bridge mitigation completed, the U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (USEPA), began monitoring related hydraulic and scour conditions at the I-90 bridges beginning with the spring 2009 runoff season. The purposes of monitoring are to measure effects of high-flow conditions on the I-90 bridge pier and abutment structures and nearby stream channel morphology, to compare hydraulic and scour data to that of previously modeled conditions, to characterize the extent to which effects are due to local hydraulic factors versus more broad-based geomorphic factors, and to provide stream velocity data for this reach to aid in the evaluation of bull trout passage. Hydraulic monitoring began prior to spring 2009 runoff, and provided a timely characterization of initial conditions following dam removal. Activities focused on the pier and abutment structures, but also included measurements collected several hundred feet upstream and downstream of the bridges to document long-term stream degradation or aggradation, general scour, and local-scour effects. Real-time hydroacoustic instrumentation at bridge piers was installed, bathymetry of the streambed during pre- and post-runoff conditions at the bridge contraction or opening was surveyed, and topography of the riprap blanket at bridge abutments and cross sections near the bridge were surveyed. Finally, hydraulic data including water stage and slope near the bridge and flow velocity were collected using conventional and hydroacoustic technology. Monitoring is continuing so that ongoing changes can be evaluated.

Hillslope Water Table Connectivity Controls Groundwater Turnover Rates In The Near Stream Riparian Zone: Implications Of Catchment Structure For Source Water Contributions In The Tenderfoot Creek Experimental Forest, MT

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Hydrologic connectivity between catchment upland and near stream areas is considered a requisite for the transmission of water, solutes, and nutrients to streams. Our current understanding of how landscape hydrologic connectivity relates to the turnover and export of water and solutes to the stream is poorly understood. We define a hydrologic connection as the presence of saturation across the interface of dominant catchment landscape elements. In mountain catchments, hillslope and riparian zones are the dominant landscape elements and they can often be distinguished by distinct topography, hydro-chemical function, and water table connectivity dynamics. We tested the relationship between the time of Hillslope-Riparian-Stream (HRS) hydrologic connectivity and the amount of riparian groundwater turnover along four transects of HRS groundwater recording wells within the Tenderfoot Creek Experimental Forest (TCEF), MT. Each transect exhibited a different time of HRS water table connectivity, ranging from 123 to 9 days during snowmelt. Hillslope water tables were always characterized by low specific conductance (~27 uS cm-1). In transects with transient hillslope water tables, riparian groundwater was concentrated during baseflow conditions (~128 uS cm-1), but shifted towards hillslope signatures when a HRS groundwater connection was established. The rate of turnover in riparian zone wells was proportional to the duration of HRS connectivity and inversely related to the riparian:hillslope area ratios (buffer ratio; r2 = 0.95). We applied this relationship to the stream network in 7 catchments within the TCEF and compared their turnover distributions to source water contributions measured at each catchments outlet. The amount of riparian groundwater exiting each of the 7 catchments was linearly related (r2 = 0.92) to their median turnover time distribution. These observations suggest that the size and arrangement of hillslope and riparian zones along a stream network and the timing and duration of groundwater connectivity between them has significant influence on whole catchment hydro-chemical response.

Predictive Modeling Of Snowmelt And Runoff Dynamics: Thresholds And The Hydrologic Regime Of The Tenderfoot Creek Experimental Forest, Montana

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Our project aimed to improve the physical and predictive understanding of snow accumulation and melt, watershed streamflow generation, and the effect of watershed topographic structure on watershed processes. The need for this improved insight is particularly relevant given our reliance in the inland northwest region on mountain water resources, and our relatively poor understanding of thresholds and controls on runoff generation in mountain environments. We addressed these themes via a synthesis of field observations, data analyses and conceptual model development at the Tenderfoot Creek Experimental Forest, located in the Little

Belt Mountains in central Montana. We combined digital elevation model (DEM) based terrain analyses with high frequency water table measurements. A strong correlation was observed between the longevity of upland water table connectivity to the stream network and upslope accumulated area. We applied this relationship to an entire stream network to quantify landscape scale connectivity through time and determine its relationship to catchment scale runoff dynamics. Our analysis strongly indicates that topography (as represented by upslope accumulated area) controls upland-stream connectivity and the spatial integration of this connectivity across the stream network drives stream flow magnitude through time. We additionally implemented a modular suite of 30 simple watershed model structures to assess the relative importance of different elements of watershed runoff. Our results emphasize the importance of characterizing the spatial distribution of snowmelt (strongly correlated to aspect and elevation) and its temporal variability according to climatic indicators such as temperature and radiation, and the importance of utilizing a flexible modeling framework when incorporating topographic data. Our current work is aimed at using empirical analyses and our perceptual model of watershed behavior to develop new mathematical models of catchment behavior. We aim to compare these new models with well-established modeling approaches while recognizing the tradeoffs between model uncertainty, complexity, and predictive capacity. Coupled field observations and modeling approaches provide insight into the variables controlling runoff source areas and the utility of different watershed data for quantifying these variables. This project identifies watershed drivers that may be transferable to other catchments and seeks to develop general principles that can guide future conceptualizations of watershed models.

SESSION 4 GROUNDWATER

A Comparison Of Shallow Aquifer Diurnal Water-level Fluctuations At Different Vegetation Sites In Hay Creek, Whitetail Basin, Montana.

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Abstract The following study was done as part of the Whitetail Basin Watershed Restoration Project in Hay Creek Canyon approximately 16 miles north of Whitehall Montana. An in-depth study of the riparian area hydrogeology started in the fall of 2007 with the installation of more than 40 additional deeper (> 1 m) wells to complement the metal pipe piezometers previously installed in four first-order drainages. The shallow groundwater system was found to consist of two components separated by silty clay layers. The upper zone usually dried or drained in the summer months, but the deeper zone remained saturated. This component of the study was focused on determining if diurnal water-level fluctuations in the shallow aquifer could be used to evaluate differences in water use by various types of riparian vegetation. Data from pressure transducers deployed in wells completed in the deeper zone showed diurnal water-level fluctuations at different riparian vegetation "type" sites in Hay Creek. Comparisons were made among the four different vegetative types (Doulas Fir, Aspen, Willow-Alder, and Grass-Sagebrush) using water-level data collected from May of 2008 through July of 2009. The diurnal water-level fluctuations became more pronounced with warmer temperatures, and dryer surface conditions of late summer, 2008. All sites showing diurnal water-level fluctuations had diminished diurnal cycles with the seasonal changes in fall and winter of 2008-09. Water-level diurnal fluctuations at the Douglas fir sites compared to the aspen and willow/alder sites were not significantly different but did show some differences in magnitude. Further analysis of the shallow aquifer water-level data will include meteorological data to assess the impacts of temperature changes and precipitation on diurnal cycles. The seasonal changes and the driving forces in shallow aquifer diurnal water-level fluctuations will be discussed.

Historic Perspective, Assessment and Proposed Rehabilitation of a Flowing Artesian Well in North Central Montana

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Flowing Artesian aquifers are often encountered when wells are drilled at depth north of the Little Belt Mountains in North-Central Montana. A hydrogeologic evaluation related to potential refurbishing the flowing artesian well on the grounds of the Central Agricultural Research Station located at Moccasin, Montana was completed. This well was initially drilled in 1947, and was deepened in 1953 to freely flow about 33 gallons per minute (gpm) with a closed-in well head pressure of 55 pounds per square inch (psi). The flow from this well has diminished over time, and the State of Montana requested that the potential to restore flow to near original condition be evaluated. Records indicate that this well was initially drilled to a depth of 1,387 feet in 1947, but that it only produced 588 gallons per day and contained significant amounts of iron. The well was re-entered and drilled down to a total depth of 1,620 feet in 1953. Deepening of this well apparently resulted in completion in sandstone of the Kootenai Formation. The Kootenai Formation is known in this region as a productive aquifer that has groundwater under sufficient pressure to cause cased wells to flow at the land surface. This well has been monitored periodically by the Montana Bureau of Mines and Geology (MBMG) since 1971 for both water quality and flow. Water quality records indicate a slightly alkaline groundwater (pH 7.5) with total dissolved solids concentrations less than 260 milligrams per liter. Discharge records indicate that the well head pressure has fluctuated but generally declined over the 38 year monitoring period. The flow of the well has also declined to unacceptable levels and irrigation use by the Central Agricultural Research Station is limited. Several possible factors can cause the flow of an artesian well to diminish, including casing corrosion, casing breakage, well intake encrustation, borehole collapse, or regional decline in artesian pressure. Most of these causes cannot be assessed until downhole inspection and testing is completed. Downhole video camera and casing collar log were used in the summer of 2009 to provide initial assessment of borehole and casing conditions. Following the down hole assessment, a proposal was developed that would provide the next step in determining whether the flowing artesian well can be restored to near-original production levels. Costs associated with this restoration plan were also developed.

Probing The Plumbing Of The Landusky Mine Site

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The State of Montana and Bureau of Land Management sponsored intensive hydrogeological, geophysical, and engineering investigations of the Landusky mine site and Swift Gulch in the Little Rockies Mountains of north-central Montana during 2008. The investigations were targeted at understanding the sources and pathways associated with the worsening quality of groundwater and seeps in the area between Swift Gulch and the northern edge of the former Landusky pit complex. Six deep monitoring wells were completed to characterize the geology and mineralogy of northeast-trending shear zones, enable detailed chemical characterization of groundwater, and to obtain aquifer parameters via a 48-hour pumping test. Relatively high concentrations of pyrite were encountered at variable depths in most boreholes, and shear zones were identified by the interception of oxidized fractured rock. Intervals found to produce high flow rates (20 to 40 gpm) and which had low pH and high specific conductance were good indicators of transmissive fractures or shear zones in otherwise unfractured syenite and gneiss. Groundwater in more unaltered matrix rock had better water quality with pH near neutral and lower specific conductance when compared to altered rock. An abrupt contrast was found in water quality from fracture zones to the aquifer matrix. A large-scale electrical resistivity survey was completed at the Landusky mine to more precisely locate potential acid rock drainage pathways and map their continuity from the former mine to Swift Gulch. The survey consisted of 15 surface lines, along with energizing electrodes placed directly in wells and seeps to increase the sensitivity of the survey at depth. Strong correlation (R2 = 0.85) was found between groundwater total dissolved solids obtained from well samples and collocated bulk resistivity measurements. These studies suggest that a pool of highly conductive ARD groundwater occurs within the upper 100-feet of the syenite aquifer beneath the former mine pits, that low resistivity linear features correlating with mapped fracture zones extend to Swift Gulch, and that good hydraulic connection occurs between wells located on the same or interconnected shear and fracture zones.

Evaluating The Hydraulic Properties Of Shallow First-order Alluvial Systems: An Analysis In Hay Creek, Whitetail Basin, Montana

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The hydrogeology of first-order streams have been evaluated for approximately three years, as part of the Whitetail Basin Watershed Restoration Project in Hay Creek Canyon located 16 miles north of Whitehall Montana. The shallow alluvial groundwater system was found to consist of two zones separated by silty clay layers. The upper zone usually dries or drains during the summer months, becoming resaturated during the fall, but the deeper zone remains saturated. The deeper water-level responses go from seasonal patterns to strongly diurnal during summer months. Diurnal patterns continue until leaves drop from riparian vegetation; however Douglas fir trees show the same pattern. Resaturation of the upper zone occurs in the fall with sources of recharge coming from up-drainage. A detailed evaluation of water-level responses from up-drainage to down-drainage piezometers indicate a "wave-like" resaturation phenomenon that allows one to estimate the hydraulic conductivity of the "alluvial system" aquifer using principles of Darcy's Law. It was found that "system" hydraulic properties compare well with hydraulic conductivity values estimated from pumping tests and laboratory and grain-size analysis using the Hazen method (1911). The seasonal water-level patterns and methods used to evaluate the "system" hydraulic properties will be presented.

Tracing Dissolved Oxygen Dynamics In The Nyack Aquifer

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Floodplain aquifers are shallow ground water systems that can have agricultural, industrial and domestic uses, but they are also critical components of natural river ecosystems. The water quality and microbiology of shallow aquifer systems are greatly influenced by the concentration and sources of dissolved oxygen gas (DO). Biogeochemical processes involving DO and CO2 in subsurface waters are of particular interest, since these parameters exert a primary control on the redox state and pH of ground water. By studying the stable isotope ratios of dissolved molecular oxygen (Delta 18O-DO) and inorganic carbon (Delta 13C-DIC) in ground water, it is possible to determine how rates of both metabolic and inorganic processes effect the concentrations of DO and DIC throughout the aquifer. These isotope ratios can also be used to trace interactions with surface water. The field site for this study was the Nyack aquifer along the floodplain of the Middle Fork of the Flathead River, near Glacier National Park. The hydrogeology, geochemistry, and microbiology of the Nyack aquifer system have been well characterized by a diverse group of scientists. Additionally, a well-maintained set of ground water monitoring wells exists and the oxygen dynamics of the system have been well described. Consequently, Nyack provides a pristine, reasonably well constrained groundwater system for studying changing oxygen consumption rates over both short and long flow paths. Our study shows that over short flow paths (< 1 km), changes in the O2-isotope ratios (Delta 18O-DO) are consistent with microbial respiration as the primary process consuming O2 (alpha < 1). However, over the total length of the aquifer (~ 9 km), the Delta 18O-DO changed in a pattern inverse to that produced by community respiration (alpha > 1). This suggests that processes such as diffusion or root oxygen loss may become more important in influencing O2 concentrations as the ground water travels further from the river recharge area. This trend in inverse Delta 18O-DO changes has been observed elsewhere, but is not well understood. However, the results presented here will take the form of a model designed to help interpret the O2 dynamics across the floodplain. One outcome of this project will be the development of a new set of tools that can be used to assess the various chemical and biological processes acting on ground water resources. Additionally, interpretation of ground water data that includes following Delta 18O-DO and Delta 13C-DIC as progress variables will produce a better understanding of processes that affect these reservoirs.

Wetland Landscape Profiling

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Wetland landscape profiling is a GIS-based classification and analysis of wetland types, scaleable to any geographic (e.g. state, county, reservation) or hydrologic (e.g. basin, subbasin, watershed) extent. Basic profiles can be derived from the lifeform and water regime information in National Wetlands Inventory maps. When NWI map polygons are further attributed with hydrogeomorphic (HGM) modifiers such as landscape position, landform, water flow path and waterbody type, wetland landscape profiles allow rapid visualization of the distribution of particular habitats, functions, and/or impacts across the landscape, allowing decision makers to assess the broader implications of actions affecting wetlands. In this presentation, we will review the kinds of geospatial data available for profiling wetlands in Montana (NWI, ReGAP, NHD), discuss the relationship between different wetland classification schemes (NWI, HGM, National Vegetation Classification Standard), provide an overview of the process for assigning HGM modifiers to NWI polygons, and demonstrate examples of wetland landscape profiles that have recently been completed by the Montana Natural Heritage Program. We will also discuss how we have combined landscape profiles with other GIS-derived data to produce watershed-scale assessments of wetland condition.

Flowering Rush: An Invasive Aquatic Macrophyte Infesting the Headwaters of the Columbia River System

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Flowering rush (Butomus umbellatus) is an invasive Eurasian aquatic macrophyte with emerged and fully submerged forms that can dominate irrigation systems, wetlands, littoral zone of lakes, river edges and sloughs. Mapping in Flathead Lake has delineated ~ 2,000 acres. It has passed through Kerr Dam and infested the Flathead and Clarks Fork Rivers 165 miles downriver into Lake Pend Oreille in north Idaho. There is also a large infestation near the headwaters of the southern reach of the Columbia Rivers System in an irrigation system that spills into American Falls Reservoir on the Snake River. These large infestations at the headwaters of the Columbia River will continue to spread downstream and infest much of the main stem of the system. The Flathead Lake hydroelectric facility is operated to reach low pool in early spring, whereas an unregulated natural lake would reach low pool in late summer. This unnatural late summer through winter high pool with spring drawdown creates conditions that are favorable for establishment of flowering rush infestations and disadvantages to native macrophytes evolved to a hydrologic cycle with a late summer low pool. It colonizes previously unvegetated portions of variable drawdown zones. These monotypic colonies in previously open water littoral zones are likely to induce cascading ecosystem and trophic effects on the Columbia River System. However higher order impact have not yet been studied. They are likely to include alteration of sediment transport and deposition, and formation of new habitat favorable to introduced fish and disadvantages to native trout and salmon.

Describing Sampling Variability Bias to the Macroinvertebrate Biometrics of Stream Condition in Montana

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The Montana Department of Environmental Quality currently uses macroinvertebrate populations as indicators of water quality (i.e., biometrics). However, these biometrics were built using data collected via different macroinvertebrate sampling protocols. The majority of samples in the DEQ database were either collected using (a) the USEPA Environmental Monitoring and Assessment Protocol (EMAP) reach wide (i.e., multi-habitat) approach (Lazorchak et al. 1998), or (b) the traveling kick, riffle-focused (i.e., single-habitat) approach (DEQ 2006). Any major differences in the biometric results caused by sampling method will impact biological determinations of stream water quality. Therefore, our goal for this study was to determine if there were systematic biases on the DEQ biometric results caused by the two sampling methods. We sampled 60 sites using both protocols to achieve our goal. The majority of the sites were located in the mountain and low valley bioregions, with a few sites sampled in the plains. We analyzed the data using statistical tests, including Chi-square and paired t-tests, to compare the differences between several biometrics and their indications of water quality. We also used ordination analyses to determine if the different protocols actually collected different taxa from the same site on the same day. Several biometrics were sensitive to how the samples were collected. The biometrics that scored significantly higher values from EMAP samples included: The Montana Observed/Expected (O/E) model, Taxa Richness, Hilsenhoff Biotic Index, the Metals Biotic Index, and the Shannon-Wiener Diversity Index ($p < 0.001$). The percent Ephemeroptera, Plecoptera, and Trichoptera (% EPT), and % EPT Taxa metrics both scored significantly higher in the traveling kick samples ($p < 0.001$). The Mountains, Low Valleys, and Plains Multimetric Indices (MMIs) showed no significant difference between the protocols. In addition, we found that out of the 269 taxa sampled by both protocols at least 5 times in the dataset, observations of 30 taxa were significantly associated specifically with the EMAP protocol. Overall, samples collected following the EMAP protocol averaged 10% more taxa (3 taxa) than the traveling kick samples at 72% of the sites. However, the samples collected following the traveling kick protocol had a slightly lower coefficient of variation compared to those collected using the EMAP protocol (7.2% vs. 10%, respectively). This might be expected since the traveling kick is a single-habitat method and will only capture taxa associated with riffles. The results of this study underscore how important it is to understand the effect caused by a particular sampling method on biological indicators of water quality when conducting stream assessments. We used the information obtained from this study to determine which macroinvertebrate sampling protocol will be employed by DEQ to collect macroinvertebrate data in the future.

Predicting Amphibian Occurrence Based On Local And Landscape Level Factors In Montana.
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Amphibians have a complex life history that requires a mosaic of habitats including breeding, rearing, foraging and over-wintering areas. Historically, researchers and regulators have focused on wetland breeding habitat quality to explain amphibian presence or absence. Recently other habitat requirements including landscape level factors have been examined. Because amphibians require a mosaic of high quality habitats that occur at a variety of spatial scales to complete various stages of their life cycle, they are significantly affected by landscape level impacts. Data collected from amphibian surveys conducted by the Montana Natural Heritage Program were used to determine if local wetland quality factors or landscape level factors were better determinants of amphibian occurrence. Twenty-six habitat models were constructed a priori for six species of amphibians in Montana. These models included five local level models that contained parameters associated with wetland quality, ten landscape level models and ten models that combined both local and landscape covariates. Landscape level models were assessed at three broad spatial scales: 500, 1,000 and 2,000 meters. An information-theoretic approach was used to select the best approximating model that explained the presence or absence of amphibians. Results suggest landscape level factors or a combination of local wetland and landscape factors affect the presence or absence of amphibians in Montana at all three scales. Models that included only wetland variables were not good predictors of amphibian occurrence. The results emphasize the importance of maintaining intact watersheds to meet the habitat requirements of amphibians during all stages of their life cycle.

The Role Of Movement To Stream Salamander X Fish Coexistence: On A Road To Nowhere?
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Understanding how dispersal affects community dynamics and emergent patterns of species diversity is a

major goal in stream ecology because dispersal is a phenomenon occurring in most species and because habitat fragmentation, riparian land use, and climate change have altered dispersal rates for many freshwater organisms. We examined the relative contributions of dispersal between stream reaches and local ecological and evolutionary processes within stream reaches to stream salamander persistence and coexistence with fish. Empirical data and lab experiments suggest that salamander and fish interactions in headwater streams are unstable because fish are predators and superior competitors of salamanders. These data are consistent with observations across North America that salamanders are largely limited to fishless stream reaches. However, my data show not only that salamanders persist with fish, but also that salamanders in reaches with fish have downstream-biased dispersal. These results call into question the mechanisms allowing for species coexistence and lead to the hypothesis: dispersal from upper reaches offsets negative effects of fish predation and competition in lower reaches. In this study, we used mark-recapture methods in multiple headwater streams to test whether dispersal could foster coexistence between the stream salamander, Dicamptodon aterrimus (the Idaho giant salamander), and salmonid fish. We estimated net dispersal rates, apparent survival, recruitment, and realized rate of population growth of D. aterrimus in upstream reaches without fish and downstream reaches with fish from multiple streams. Our results suggest that dispersal did not influence population growth rates or coexistence with fish, and that salamander dispersal between stream reaches is not the primary mechanism for D. aterrimus x fish coexistence. Apparent survival, recruitment, and population growth rate did not differ between reaches within a stream. Population growth was a function of local survival and recruitment, but not of dispersal because there was no evident difference in net emigration between upstream and downstream reaches. We did find that D. aterrimus movement within and between stream reaches was common. These results suggest that local processes within stream reaches, and not spatial processes between stream reaches, promote D. aterrimus x fish coexistence.

Western Pearlshell (Margaritifera falcata) Mussel Distribution In Montana Watersheds: A Legacy Of Lost Native Species, Connectivity & Dewatering

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Montana's only trout stream mussel, the western pearlshell (Margaritifera falcata), has disappeared from many of our watersheds in relatively recent times. During 2006 & 2007, we reviewed western pearlshell occurrence records and systematically resurveyed sites of current and historic occupation in watersheds throughout the state. Twenty-five of the original 40 site records proved to be either extirpated or contained non-viable mussel populations; only 7 of the 15 populations documented in 2007 had excellent (A ranked) viability. Extensive field surveys and biologist training workshops continued in 2008, but only 4 additional viable populations were reported. Of the ~820 stream reaches (avg. length ~150m) surveyed over the course of 3 years, western pearlshell populations were absent from 660 (76 %) of the reaches and non-viable to severely declining from another 139 sites (16%). Sites with excellent population viability (11) were rare and represented disjunct sink populations with little ability to colonize other stream reaches in the watershed. Separation distances between viable populations in the same watershed were on the order of 100's of river kilometers. Because of this fact, the evaluation of current vs. previously occupied river miles and the severity of the decline, we officially placed this species on the Species of Concern list in November 2008 ranked an S2 (vulnerable to extirpation in the state). Introduction of non-native fishes, reduction of westslope cutthroat populations, disrupted connectivity by diversions and dewatering, reduced in-stream flows and warmer water temperatures have all been implicated in the decline of the western pearlshell. Reintroduction of western pearlshells into westslope cutthroat trout restored stream reaches in the Blackfoot River drainage is currently being investigated.

Modeling Stream Depletion In The Lower Beaverhead River Sub-basin: Results And Lessons Learned

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Concern and conflict over Montana's water resources have recently increased due to a combination of natural and human-induced changes. In 2007 House Bill 831 was passed with goals of examining groundwater withdrawals and their impacts on surface-water and groundwater resources. The MBMG was directed to perform case studies that would provide a background for finding site-specific solutions within the watersheds of concern in Montana. This presentation deals with one such study, located in the lower Beaverhead River Basin. The case study involved an extensive field effort, a hydrogeologic characterization, and an evaluation of stream depletion. The stream depletion evaluation was performed primarily through groundwater-flow modeling. Various pumping conditions were simulated to study their impacts to river flow. Mitigation strategies were also simulated to determine their effectiveness in offsetting depletion. Results indicated that the timing, rate, and location of depletion depended heavily on the timing, rate, and location of pumping. For instance, pumping distant wells appeared to deplete the river at relatively low rates, though pre-stream capture was substantial at times. Stream depletion generally showed a significant increase in the early years of seasonal pumping, followed by relatively minor change. Furthermore, depletion and offset results were very sensitive to small changes in input property values, which stress the importance of being highly confident in the property estimates. The lower Beaverhead study provided valuable information on stream depletion and mitigation analyses. Lessons learned throughout the investigation can be applied to upcoming stream depletion studies.

Determining When Streams Become Hydraulically Disconnected From Groundwater

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Determining the rate and timing of stream depletions caused by pumping groundwater generally leads to a requirement for mitigation or replacement of water to streams to offset the depletion. However, many streams are, or may become, hydraulically disconnected from the underlying watertable, and consequently, groundwater extraction under disconnected streams do not result in depletion of stream flows. The limitations of common methods used to estimate stream depletions are examined with respect to disconnected streams. Methods to identify when streams become disconnected are presented, and the conditions necessary for disconnection to occur are outlined. Examples from an investigation identifying a disconnected state are provided including the use of the USGS code VS2DT to examine changes in state during a theoretical seasonal high water event.

A Discussion Of Results, Insights And Challenges In Assessing Watershed Management Practices Using A Semi-distributed Environment Model

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We present results and challenges in modeling watershed management practices using a well-researched semi-distributed hydrological model (the Soil and Water Assessment Tool, SWAT) for a large agricultural basin with limited water quality data. The main objective of the study is to identify beneficial conservation practices and quantify their effects in improving water quality and quantity in a large agricultural case study watershed. The Buffalo Rapids case study watershed is a 4.6m acres agricultural tributary to the Yellowstone River in eastern Montana. The watershed contains 155 full-time agricultural crop and or livestock producers with an average of 164 acres per full time farm. Issues of assessment of pollution and prevention, managed irrigation water use and watershed conservation are integral to the future agricultural sustainability and economics of

the watershed. Potential causes of water-resource degradation in the watershed include agriculturally-relate nitrogen, phosphorus and sediment to shallow alluvial groundwater and to channels, and inefficient use of irrigation water pumped from the Yellowstone River, which critically reduce discharge during low-flow periods of the year. Multiple watershed management scenarios were simulated and studied for the resulting variability in main channel discharge, loadings and concentrations of sediment, total nitrogen and total phosphorus, and crop yields. Scenarios were developed considering different irrigation delivery systems, conservation tillage, crop rotation, field borders, nutrient management, channel stabilization, stream-bank protection among others. These scenarios were applied to smaller sub-basins of the much larger watershed, which gave insights into how the sizes of the areas of conservation practice application affect watershed response in the model and thus perhaps in the case study as well. Studying such a watershed provided further insights into possible agricultural and irrigation related and in-stream processes of sediment creation and loadings. Challenges in implementing the analysis include the scarcity of water quality time-series data (which significantly reduce the confidence in the reliability of the model's predictions for total nitrogen and total phosphorus concentrations and yields), the differing scales of the study area and the variables of interest, and the computational difficulties in assessing the natural uncertainty associated with scenario simulations for a highly parameterized complex model. We present the methodology used in the study, detailed findings, insights and challenges.

Arsenic Mobility In Wetlands Near Anaconda, Montana

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This presentation will summarize investigations of the mobility of arsenic in wetlands in the Upper Clark Fork River basin at the Anaconda Smelter Superfund Site. Although wetland treatment has been used to attenuate metals and arsenic at other sites, the wetland conditions near the Anaconda site have been shown to have an undesirable effect. Specifically, investigations have demonstrated that naturally occurring wetlands actually mobilize arsenic from the contaminated soil to ground water. Similarly, application of irrigation water has created artificial wetland hydrology that also mobilizes arsenic from the soil into the underlying ground water. Studies involving irrigation with Madison River water containing elevated concentration of arsenic have concluded that arsenic attenuates in soil, but the opposite was found near Anaconda. Data indicate that little iron is available in ground water and irrigation water for use in coprecipitation with arsenic. No significant correlation was observed between arsenic concentrations and alkalinity, chloride, sulfate, and magnesium while a slight correlation with arsenic was observed for nitrogen and phosphate. Although the mobility of arsenic in wetland conditions involves numerous factors, the available data from Anaconda suggest that redox conditions resulting from wetland hydrology the lack of iron and are primary causes of the release of arsenic from contaminated soil.

A Rotating Basin Wetland Assessment Strategy For Montana

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Statewide watershed-scale wetland condition assessments are critical to inform conservation, restoration, and mitigation efforts at the state, local, and tribal levels. To meet this need, the Montana Natural Heritage Program has initiated a rotating basin assessment strategy in the Milk, Marias, and St. Mary's River basins. We are conducting a basin-wide wetland condition assessment to characterize wetlands across the assessment area. The basin-wide condition assessment follows a spatially balanced sampling design and involves three levels. Level I assessments provide a GIS-based characterization of wetland condition for 1,000 wetlands using a landscape integrity model developed by the Montana Natural Heritage Program, incorporating several digital data layers including land cover and land use, roads, cadastral data, hydrology, and energy development. Level II assessments incorporate field-based observations and measurements using rapid assessment methods, allowing for the assignment of a condition rank for 100 wetlands across the assessment area. Finally, Level III assessments provide intensive onsite vegetation measurements for 30 wetlands to provide quantitative field indicators of wetland condition. We will discuss the methodology used to conduct the condition assessments and present preliminary results from data collected during the summer of 2009.

Surface Water Mitigation Using Induced Groundwater Storage

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Groundwater withdrawals in unconfined and semi-confined aquifers are capable of producing significant surface-water depletions that extend beyond the irrigation season (off-season). Using induced groundwater storage is one alternative to mitigate for off-season depletions. Squaw Creek, located in the Bitterroot Valley, MT, has the potential to have off-season depletions from groundwater withdrawals. A field study and numerical modeling effort was conducted to evaluate induced groundwater storage as a means to facilitate off-season mitigation on Squaw Creek. Field work was conducted to evaluate the groundwater and surface-water interactions, with a focus on the streambed conductance of Squaw Creek. Three methods were used to evaluate streambed conductance: 1) Sieve Analyses, 2) Permeameter tests, and 3) temperature gradient modeling. An infiltration pilot test was conducted over a two-week period to assess the amount of water the aquifer was capable of storing and the ability for Squaw Creek to receive the water. Groundwater levels were monitored in piezometers and surface-water stage and flows were monitored regularly in Squaw Creek. Results from the pilot test indicate that the shallow aquifer in the vicinity of the infiltration pond was able to receive a significant amount of water; however water storage was found to be limited due to the highly transmissive characteristics of the aquifer. This characteristic allowed for the injected water to be transported to Squaw Creek within hours of it being infiltrated. A numerical model was developed to evaluate induced groundwater storage over a long period and its capability to facilitate off-season mitigation on Squaw Creek. A system of ponds and streams were introduced into the model to simulate a possible infiltration design scenario. Preliminary results of the modeling indicate that the aquifer is capable of receiving a significant amount of water; however the transport of the water to the stream is rapid. Induced groundwater storage has the ability to facilitate off-season mitigation in areas where there is a significant distance to the surface-water body or the off-season depletions only occur for a short period. However in highly transmissive aquifers (typical of those found in intermontane basins), the rapid transport of the groundwater to surface water may limit the ability for induced groundwater storage as a mitigation alternative, when infiltrated water is in close proximity to the depleted surface water body.

SESSION 7 WATER QUALITY & QUANTITY

The Milltown Dam Water Rights And Water Use In The Upper Clark Fork River Basin

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As a part of the Clark Fork River Superfund remediation, the Milltown Dam power house and spillway have been removed from the Clark Fork River. Pursuant to the settlement of litigation filed by the EPA under the Comprehensive Environmental Response, Compensation, and Liability Act, the State of Montana is poised to accept ownership of water rights formerly used to store water and generate electricity at Milltown Dam. The removal of the dam means that the purpose of the existing rights will cease to exist and the water rights must be changed or they will be void. Should the State accept the water rights, the settlement agreement provides that the existing rights may not be changed to a consumptive use. Because the hydropower right is large with a relatively old priority date, its fate is important to many upper Clark Fork River basin water users. The Upper Clark Fork River Basin Steering Committee, a statutory water management body, has examined the existing Milltown Dam hydropower rights and their relationship to water rights that support water uses upstream in the upper Clark Fork Fork River basin. It also identified alternatives for the state's management of water rights changed to support a new instream use. This presentation reports on the Steering Committee's findings.

An Assessment Of Municipal Water Systems And Water Rights In The Clark Fork River Basin

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In the arid Inland Northwest, water is undoubtedly the most important natural resource. Western Montana's Clark Fork River basin is no exception. As the population of western Montana continues to grow and the Clark Fork River basin remains in de facto closure to the establishment of new water rights, it is essential for communities to know how well their legal entitlements to water can meet growing demands of the future. This assessment of municipal water rights and systems in the Clark Fork River basin was conducted by ascertaining the volume(s) and maximum flow(s) of each community's municipal water right(s), analyzing the volume of water used annually, and projecting future water consumption amounts for the next 20 years based on their county's projected population growth rates. Other information gathered for each community's assessment include water conservation measures, water-related infrastructure, rate structures, demand forecasting, and metering. Interviews of water system managers/operators were conducted to gage their level of understanding of water resource policies. The preliminary results coming from this assessment will be reported.

Groundwater And Surface Water Monitoring For Pesticides And Nitrate In The Bitterroot Valley, Montana

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During the summer of 2008, the Montana Department of Agriculture (MDA) conducted a monitoring project in the Bitterroot Valley of southwestern Montana between the towns of Darby and Lolo. The Bitterroot Valley is an intermontane basin filled with Tertiary (65 to 1.5 million years before present) and Quaternary (1.5 million years to present) sediments. All groundwater samples collected during this project were from wells obtaining water from Quaternary alluvium (n=19), undifferentiated Tertiary sedimentary rocks in the northern half of the valley (n=3), or Tertiary volcanic rocks in the southern part of the valley (n=1). Study objectives were to determine potential impacts to groundwater and surface water from the use of pesticides and contributions from nitrogen sources (i.e. fertilizer, manure, septic). The MDA collected 46 groundwater samples from 23 wells and 10 surface water samples from 5 sites and analyzed them for 95 pesticide compounds as well as nitrate/nitrite. Pesticides were detected in 25 of the 46 groundwater samples. There were a total of 53 detections of 14 different pesticide compounds and 3 pesticide degradates in the 25 samples with detections. Nitrate was detected in 24 of the 46 groundwater samples, but was not detected in any of the surface water samples. The source(s) of nitrate in groundwater were not determined during this project. Two samples collected from a single well had NO3--N detections which exceeded the human health drinking water standard of 10 mg L-1. Nitrate was not detected in any of the surface water samples. The most commonly detected pesticide in groundwater was prometon. Atrazine and one of its degradates, deethyl atrazine was also a common detection. Prometon is a non-crop herbicide used in areas where long term control of weeds is desired. Atrazine detections are likely due to historical uses before 1993 when it was a common general use herbicide. Beginning in 1993 the use of atrazine was restricted mostly to corn crops. The most common pesticide detections in surface water samples was 2,4-D, a widely used herbicide, and diuron which is an herbicide used extensively in non-cropland applications. A myriad range of pesticides were detected in groundwater and surface water samples collected during the summer of 2008, but all of the pesticide concentrations were low and none exceeded or approached human health drinking water standards, where such standards exist in surface and groundwater samples. Groundwater and surface water contamination by agricultural chemicals is occurring in the Bitterroot Valley but at levels which do not threaten human health..

Exciting Opportunities For Natural Resource Projects In Montana! Two Examples From The Blackfoot River

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Montana Department of Natural Resources and Conservation Renewable Resource Grant and Loan Program funds projects that conserve, develop, manage and preserve natural resources. Applicants present many different types of projects to DNRC for funding. Here are two very different natural resource projects, funded in 2007, that are taking place in the Blackfoot River drainage. These projects highlight just two of the many potential projects that would help support wise use of Montana's natural resources. Stream Channel Study Project: The Mike Horse Dam is 24 kilometers east of Lincoln, Montana in the Upper Blackfoot Mining Complex. Mike Horse Dam impounds Bear Trap Creek, a head water tributary to the Upper Blackfoot River. The river is a water source to residents in the Lincoln area, and the watershed is a resource to anglers, hunters, and other recreational visitors. The past 150 years of mining contaminated the floodplain with heavy metal laden sediments. The US Forest Service (USFS) is leading a clean up effort of the Mike Horse Dam. With support from the DNRC, Montana State University researchers classified stream reaches, surveyed topography, assessed hydrology, characterized current and historical geomorphic conditions, and mapped existing and prior riparian vegetation distribution in the Mike Horse Dam area. The project objective is to estimate the sensitivity of the channel and floodplain to changes that may result in streamflow patterns due to removal of the Mike Horse Dam. Researchers developed hazard probability maps for high risk areas with high concentrations of metals and high probability of metal mobilization under high flows. Irrigation Efficiency Project: North Powell Conservation District sponsored a grant in which the CD and the Blackfoot Challenge teamed on a project to evaluate pivot irrigation system operations in the Blackfoot River valley. With support from the DNRC, the Blackfoot Challenge has been able to continue the activities of its Drought Response Committee, develop much needed drought educational materials, monitor stream flows to aid in the development of water conservation projects, compile GIS data on water uses, and expand its restoration action plan. Using this information, Blackfoot Challenge has developed an exciting irrigation efficiency program. Efficiency evaluations have been conducted on 14 irrigation systems so far (with many more planned in 2009) and have begun to develop a program for irrigation scheduling in the Blackfoot. If you have a project in mind that will help to conserve, develop, manage, and preserve Montana's natural resources, contact the Montana DNRC.

10 Years Of Nutrient Reductions On The Clark Fork River

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In the 1980s much of the Clark Fork River was identified as impaired by nuisance algae as a result of excess nutrients. Basin stakeholders developed a voluntary nutrient reduction plan (VNRP) which the EPA allowed to substitute for a mandatory TMDL. Nutrient and algae studies, mass transport models and best professional judgment were used to set targets for acceptable algae levels and to estimate nutrient levels and loads expected to meet those targets. The 10 year plan was formally adopted in August, 1998 and ended in August 2008. In 2001, the Montana Board of Environmental Review, in response to DEQ review of nutrient standards, approved new nutrient and algae standards for the Clark Fork which were essentially identical to the targets being used by the VNRP. Over the course of the VNRP, the major point source dischargers to the river reduced Total Nitrogen loads by 18% and Total Phosphorus loads by 66%. While new homes were being built with septic systems, the city of Missoula worked to connect many more old homes to the sewer, resulting in a net reduction of over 3,000 septic systems in Missoula. The Tristate Water Quality Council also helped fund nonpoint nutrient reduction programs on the river's tributaries. In-river levels of Total Nitrogen, Total Phosphorus and Soluble Reactive Phosphorus decreased significantly over the 10 years of the VNRP, but Dissolved Inorganic Nitrogen did not decline. Achievement of nutrient targets in the last three full years of the program reached over 90% for total nitrogen targets in the middle river (Missoula and Huson), and over 70% of phosphorus targets in the middle river. Compliance with targets in the upper river was lower, partly because total phosphorus targets are stricter there. Algae targets were met in only 30% of the sampling times in the upper river and below Missoula. However, the two downstream sites (Huson & above the Flathead confluence) met algae targets 70% of the sampling times. Trend analysis of algae levels showed improving or static condition in the middle river. However, algae levels in the upper river were static or increasing. Reducing algae in the upper river is difficult potentially because the dominant species of algae there -- Cladophora glomerata is notoriously difficult to control. Flows play an important role in attached algae levels in streams. Stream disharge was substantially higher the first few years of the VNRP. The lower flows later in the program likely provided less scour of algae, and could have resulted in nitrogen-rich groundwater being a higher percentage of the stream flow.

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

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

SESSION 8 INTERNATIONAL & TRANS-BASIN WATER SCIENCE

The Salmonid Rivers Observatory Network: A Habitat-Based Assessment Of Production Across The Pacific Rim

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The Salmonid Rivers Observatory Network (SaRON; www.umt.edu/flbs/Research/SaRON.htm) is a long-term, multi-disciplinary research project that investigates freshwater habitat and its relationship to aquatic production, particularly of salmonids, in a suite of large, pristine rivers (observatories) around the Pacific Rim. The three main themes of the research are 1) that aquatic production and diversity of salmonids are linked directly to the types, amounts and quality of habitat available; 2) that production and diversity are highest in unconstrained floodplain reaches of rivers where there is an abundance and variety of off-channel habitats such as springs, backwaters, beaver ponds, and wetlands; and 3) that these habitats are a constantly shifting mosaic controlled by natural biophysical processes. To investigate these themes, SaRON research has been conducted over the course of 10 years on more than 20 rivers (including the Middle Fork Flathead as a no-salmon control site) with nearly 20 different partners in the US, Russia and Canada. To allow for direct, cross-site comparisons among rivers and habitat types, we utilized a consistent scientific protocol, which entailed both remote sensing and field measures in time series. We developed techniques to classify multi-spectral satellite imagery according to habitat type for study reaches of observatory rivers, and production proxies were measured (water chemistry, thermal regimes, algal biomass, benthic invertebrate biomass and density, juvenile salmonid density and species composition, marine derived nutrients via stable isotopes) to assess overall production potential for each river. Our research has shown that there are significant differences between rivers and habitat types, that production is higher in off-channel habitats, and that greater habitat complexity is associated with greater biological complexity and production. Additionally, marine derived nutrients brought upriver by adult salmon foster production throughout the entire aquatic foodweb as well as in riparian vegetation. We plan to use this uniform data set to create and calibrate models that describe salmon production in the context of river basin morphometry, the shifting habitat mosaic, geochemistry, and ecosystem processes (climate oscillations, cut and fill alluviation, nutrient cycling, plant succession, predator-prey interactions). The ultimate goal of this wide-ranging research is to better understand how pristine, natural salmon river ecosystems function, to use this information to devise and promote new conservation strategies to protect healthy salmon rivers, and to restore salmon rivers which have been impacted by human activities, such as harvest, impoundments, hatcheries, and climate change.

The Riverscape Analysis Project: A Model for the Integration of Spatial Data and Management Planning of Aquatic Resources

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Montana has a wide range of aquatic resources with different levels of available information and which require management by multiple groups across a large spatial scale. Often, inventorying resources, prioritizing actions, and coordinating activities with limited money and personnel is challenging to effective conservation and management efforts. The Riverscape Analysis Project (RAP) is a spatial database which uses Landsat satellite images and digital elevation models (DEMs) to remotely quantify the physical habitat of rivers. The approach assumes that the greater the physical complexity of a river system, the greater the potential fish production. Currently, the RAP database contains over 35 different measures of watershed and riverine habitat characteristics, ranging from watershed size to the extent of human impacts, for over 1500 rivers around the Pacific Rim. Although, RAP presently focuses on salmon rivers around the Pacific Rim, it can be easily expanded to a larger geographic scope and provides a model for other areas and species of interest. The RAP spatial data engine allows for the integration of multiple data sets and the geospatial analysis of data within a single platform. Watersheds can be ranked using different combinations of physical characteristics, depending on the research or conservation objective. For instance, different combinations of watershed characteristics can be used to rank the potential production of different fish species. For example, watersheds can be ranked for either potential sockeye salmon production (by more heavily weighting lake habitats) or for potential coho salmon production (by more heavily weighting floodplain habitats) in any large river around the Pacific Rim. RAP provides this data in a publicly available, web-accessible decision support system for resource managers, scientists and conservationists. The ranking of rivers allows them to be prioritized for management and conservation activities. RAP ranks rivers for current planning efforts by defining those with the highest fish production potential or the least amount of human impact, providing the most "bang for the buck" on a set of planned activities. RAP provides these estimates for all large rivers, even those with little or no available data. This reduces the need for expensive field expeditions which are normally required to estimate habitat conditions or potential fish production in remote locations. RAP can also be used to quantify the loss of potential habitat complexity and fish production from proposed development projects, such as dams or mines, at a particular location. This enhances the cost benefit analysis associated with a particular project, allowing the benefits of a specific project to be more realistically compared to the ecological losses associated with habitat alteration. Although currently, this database has been developed for salmon in the North Pacific region, it provides a model for similar efforts in other regions and with other target species.

Adaptive Fuzzy Decision-making For Collaborative Water Management

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In collaborative environmental management, diverse stakeholders work together to find local solutions to environmental problems. This form of management can be implemented for water resources using a variety of analytical approaches. An analytical approach is proposed that combines adaptive management and fuzzy decision-making. The approach is illustrated for a decision problem in which a group of diverse stakeholders want to determine the best allocation of river water to alternative uses over a multi-year planning period. Adaptive management is used to account for uncertainty about how future climate change is likely to influence the quantity and quality of water in the river during the planning period. For this purpose, the planning period is divided into equal subperiods (e.g., a 20-year planning period is divided into five subperiods of four years each). Fuzzy decision-making is used to account for imprecision in how stakeholders rate the acceptability of water allocation schemes based on their attributes and the relative importance of attributes to stakeholders. The solutions to the decision problem are the best water allocation schemes for the subperiods. These schemes are determined using an approach that integrates the fuzzy Technique for Order Preference by Similarity of Ideal Solution, or fuzzy TOPSIS, and the minimax regret criterion. Fuzzy TOPSIS is a multiple-attribute decision-making method that generates a cardinal ranking of schemes based on their closeness to a fuzzy ideal solution. The minimax regret criterion minimizes the maximum loss the stakeholder group incurs in each subperiod due to uncertainty about future climate change. Steps in the integrated approach are: (1) using a collaborative approach to select water allocation schemes and their attributes; (2) determining the values of the attributes for different schemes using expert-based methods, such as the Delphi method or the Nominal Group Technique, and/or simulation; (3) identifying a set of future climate change scenarios for the planning period; (4) having subgroups rate the acceptability of schemes and the relative importance of attributes using linguistic variables; (5) averaging the subgroups' acceptability and relative importance ratings for attributes to obtain overall group ratings; (6) identifying feasible water allocation schemes (i.e., schemes that satisfy certain sustainability constraints on the attributes); (7) calculating the distances of all feasible schemes from the fuzzy positive--ideal solution and fuzzy negative-ideal solution for each climate change scenario and subperiod; (8) using the distances to calculate the closeness coefficients for all feasible schemes, future climate scenarios, and subperiods; and (9) combining the closeness coefficients and minimax regret criterion to determine the overall best water allocation scheme for each subperiod. The latter scheme is the one for which the maximum loss across the feasible management schemes is a minimum. The adaptive management element of the approach occurs in real time as climate change occurs. The integrated fuzzy TOPSIS-minimax approach is demonstrated for the case where there are three subgroups, three water allocation schemes, and three attributes of the water allocation schemes. Calculations for the proposed method can be done using a spreadsheet.

Proposed Coal Mining and Coal-bed Methane Development Threaten Aquatic Resources in the Transboundary Flathead Ecosystem

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The Transboundary Flathead River basin in Montana (USA) and British Columbia (Canada) hosts one of the most diverse and unique aquatic ecosystems throughout North America. Migratory bull trout (Salvelinus confluentus) and non-hybridized westslope cutthroat trout (Oncorhynchus clarkii lewisi) migrate from Flathead Lake upstream to the Canadian headwaters to spawn and rear, representing some of the last remaining strongholds in the basin. However, proposed open-pit coal mining and coalbed methane (CBM) drilling in the Canadian headwaters threaten water quality, invertebrate communities, and migratory fish populations downstream to Glacier National Park (GNP) and Flathead Lake. In response to these threats, a multi-agency, long-term research and monitoring program was initiated in 2005 to examine water and sediment chemistry, contaminant levels, aquatic habitat, and the distribution and genetic diversity of native fishes. Comparative data collected in the neighboring Elk River drainage, a system impacted by coal mining and CBM development, show increased nutrients and heavy metal concentrations in the water and lower invertebrate species richness than the Flathead. In 2008, basin-wide fisheries surveys were initiated and data were collected at 119 sites in

Canada and GNP. Native fishes were found throughout much of the system, including proposed mining locations. Additionally, the highest quantity of bull trout redds in the system was detected immediately downstream of proposed mine sites. Continuation of these collaborative investigations will provide necessary baseline data to inform conservation and management decisions impacting this diverse and sensitive transboundary system.

POSTER SESSION

Diel Variability Of Stable Isotopes Of Ammonia, Nitrate, And Dissolved Oxygen In Silver Bow Creek

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Diel (24-hr) fluctuations in field-measured water quality constituents have long been documented in biologically productive streams. Measurements of dissolved oxygen (DO) and pH typically increase during daytime hours due to photosynthetic production of oxygen and consumption of carbon dioxide, and decrease at night due to plant and microbial respiration. Numerous studies also describe diel changes in concentrations of heavy metals and nutrients, which are commonly influenced by the previously described changes in DO and pH. Further research also describes diel fluctuations in stable isotopes of carbon and oxygen, which like DO and pH, are strongly influenced by photosynthetic processes and show significant variability in eutrophic streams. Despite the growing body of research on diel processes in streams, little research exists describing the 24-hr variability of stable isotopes of nutrients, particularly those of ammonia and nitrate. Silver Bow Creek, in the vicinity of Butte, Montana, has historically been contaminated with heavy metals from nearby mining and smelting operations. However, after years of extensive reclamation, concentrations of heavy metals have subsided, and more recently the stream has exhibited eutrophic conditions as a result of nutrient loading from Butte's waste water treatment plant (WWTP). During mid-summer months, night-time DO concentrations downstream of the WWTP drop to near zero due to plant and microbial respiration, creating a "dead-zone" that cannot support fish and beneficial aquatic organisms. High concentrations of ammonia (~5 mg/L) also exist immediately downstream of the WWTP, creating additional oxygen demand. During daytime hours when DO is present, the ammonia is converted to nitrite then nitrate through microbial oxidation. However, during anaerobic conditions at night, ammonia persists in the stream and little additional nitrate is produced. This study investigates mid-summer diel changes in the isotopic composition of nitrate (delta 15N and delta 18O), ammonia (delta 15N), and dissolved oxygen (delta 18O) at two locations in Silver Bow Creek. A synoptic sampling event was also conducted during mid-day to evaluate nutrient concentrations and their associated isotopic composition as they change spatially downstream of the WWTP. Results of this study show that delta 15N of ammonia increases downstream of the WWTP, since nitrogen oxidizing bacteria preferentially select the lighter nitrogen isotopes for conversion to nitrate. Conversely, delta 15N of nitrate decreases immediately downstream, but eventually increases once the isotopically light ammonia has been depleted and only isotopically heavier ammonia remains for oxidation. Diurnally, delta 15N of ammonia is lowest during night hours when DO concentrations are low and little ammonia is being oxidized to nitrate, and highest in early morning when DO first increases due to photosynthetic production, and during late afternoon when stream temperatures are highest. delta 15N of nitrate is also lowest during night when little nitrate is being produced from ammonia oxidation, and is highest during mid-day when DO concentrations are highest and ammonia oxidation is rapidly occurring. Measurements of delta 18O in nitrate and DO show similar relationships, with the lowest readings observed during mid-day when photosynthetic oxygen production is highest, and the highest readings observed during night when DO is low. These diel trends were observed at a monitoring site ~3.5 km downstream of the WWTP. Diel results collected closer to the WWTP were much more subdued, showing little 24-hr variability in the isotopic composition of ammonia and nitrate.

Monitoring Brine Water Seepage In The Poplar River

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The East Poplar Oil Field has been in production for over 50 years. Saline water injection wells were put into place around the East Poplar Oil Fields many years ago. After time, a leak developed in one or more of the injection wells and/or storage tanks which caused a brine plumes to develop. Saline has contaminated the area around the Poplar River, a vital water source for Poplar residence. In 2008, our team developed a sampling plan, located old USGS sample sites by using GPS coordinates and were trained on proper sampling techniques by the Fort peck Tribes Office of Environmental Protection. The research team gathered water samples and measured the flow of the Poplar River at thirteen different sites, once a month for seven months. Our team has found that the chloride loads from the brine plumes are extremely high at our last site PR-9, which is closest to the city of Poplar. Our team had a concern about high chloride loads entering into our water system and the possible ill health effects it may have on the natural surroundings. We also found that chloride loads peaked at sites PR-5, PR-6 and PR-7. Therefore we have decided to do further investigations by adding more sites this spring to find out where these peaks are coming from and what effects, if any, the high chloride loads will have on the natural surroundings of the Poplar River.

Downstream Response To Shifts In Point Bar Morphology Associated With Dam Removal

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The breaching of the Milltown dam in March of 2008 exposed some 6 million cubic meters of sediment deposits to erosion, mostly of sand size or smaller (less than 2mm). GIS analysis has shown that approximately 180,000m3 of Copper and Arsenic laden sediment has been eroded from the Clark Fork arm of the former reservoir since the removal of the dam. An undetermined volume of uncontaminated material has been eroded from the Blackfoot arm. In March 2008, before the breaching of the dam, surveys were undertaken to characterize the size and composition of existing depositional features (i.e. point and mid-channel sand and gravel bars). These surveys were then repeated in July and August of 2008, following the breach, in order to characterize shifts in the volumetric and compositional properties of the bars. This study has shown that downstream features have experienced a net volumetric increase of sand sized material. Composition in these features has tended towards a net decrease in grain size. Additionally, geochemical data have shown increased levels of As and Cu within texturally equivalent deposits at various locations within the Clark Fork River corridor. Analysis of spectral and textural changes within the Kelly Island region of the Clark Fork River have been used to locate these newly formed sedimentary deposits, and other remote sensing based techniques have been employed to quantify the river's response to the resultant change in sediment supply and channel geometry.

Irrigators Vulnerability To Drought In The Flathead River Basin, Montana

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Irrigation is designed to reduce vulnerability to drought for farmers. However, long-term drought can strain irrigation water availability by lowering stream flows, diminishing stored surface water supplies, and depleting aquifers. The Flathead River Basin is home to a large agricultural community with a major portion of it relying on irrigation water. The lower portion of the basin contains the Flathead Irrigation Project (FIP) which is the largest irrigation project in Montana and the largest of the Bureau of Indian Affairs' (BIA) 16 federally managed irrigation projects. Drought vulnerability is conceptualized within this study as a construction of both the physical components of drought and socioeconomic and political factors that affect how drought impacts are felt at the individual farm level. Qualitative methods were used to gather data on individual irrigators -- perceptions of drought, future climate variability and water availability, and irrigation water management. Initial findings suggest that through time, farmer attitudes, institutional arrangements affecting water availability, and socioeconomic change have all affected the agricultural community's vulnerability to drought in the Flathead River basin. Key words: drought, irrigation, climate, vulnerability.

The Influence Of Riparian Grazing Exclosures On Adjacent Riverine Ecosystems

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Livestock grazing has had widespread influences on native ecosystems of western North America, with a high percentage of the land area of most western states used for grazing. In the arid landscapes of these states, riparian and stream ecosystems make up no more than 1% of the surface area while supporting about 70-80% of all indigenous plants and animals at some point in their life cycle. Erecting physical barriers, or "exclosures", that prevent livestock and/or wildlife from accessing riparian zones is one method used to assess the impacts of grazing and browsing, and the potential for recovery in these fragile areas. Exclosures are also recommended as a tool for inducing riparian recovery, especially in vulnerable and sensitive reaches. Research has addressed the effects of livestock and wildlife exclusion on riparian and instream vegetation, water quality, channel morphology, hydrology, riparian soils, and a variety of aquatic and riparian wildlife. However, the body of this research has focused on comparisons inside and outside exclosures and lacks investigation of the effects of the exclosures themselves on nearby ecosystems. An understanding of these effects is critical to use of exclosures as an effective management tool, and could inform decisions about exclosure duration, dimensions, and placement, as well as interpretation of inside and outside data. Our hypotheses are: (1) exclosures create intensified grazing impacts at their boundaries, but primarily within the areas immediately adjacent to where the barrier crosses the riparian zone, and (2) exclosures create intensified grazing impacts at their boundaries, with a gradient of impact that decreases with distance from where the barrier crosses the riparian zone, while the null hypothesis is: exclosure boundaries have no effect on the intensity of grazing impacts, with areas immediately adjacent to where the barrier crosses the riparian zone being no different than areas distant from the barrier. Exclosures will be selected from existing exclosure sites in National Forests of the Greater Yellowstone Area. Cross-stream transects will be placed at random intervals along a baseline extending from the exclosure boundaries up and down stream away from the exclosure and into the exclosure. Data collected across the transects will include channel geomorphology, and riparian vegetation (e.g., woody and herbaceous vegetation cover). Additional data to characterize the exclosure sites will include upland vegetation types, exclosure age and dimensions, and grazing history. Methods to address the hypotheses and preliminary findings of an ongoing study will be presented.

Heat As A Tool To Trace Groundwater/Surface-Water Interactions In The Smith River Watershed, Meagher County, Montana

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The U.S. Geological Survey, in cooperation with the Meagher County Conservation District, is currently (2006-2010) conducting a study of the hydrogeology of the Smith River Watershed. The study focuses on groundwater/surface-water interactions in the watershed and will expand knowledge of the groundwater system. The use of heat as a tracer in conjunction with stage and groundwater-level measurements has proven to be an effective tool for quantifying the movement of water between groundwater and streams for this as well as many other studies. Heat is transported by advection with the flowing water and, to a lesser extent, by thermal conduction through the streambed and aquifer materials. In a stream system, heat flows continuously between surface water, underlying sediments, and adjacent groundwater. Quantifying this heat flow is a useful method to examine the interaction of groundwater and surface water. The method requires continuous monitoring of temperature in the stream and at multiple depths below the streambed surface as well as stream stage and groundwater levels at a streambed cross section. A network of 8 staff gages and 30 monitoring wells were used to evaluate the flow of heat and water at 10 sites along the Smith River, North Fork Smith River, and South Fork Smith River. Sites with one or two wells were designed to determine the general groundwater-flow direction, whereas sites with four to five wells positioned along cross sections were designed to determine streambed hydraulic conductivity and water flux across the streambed interface. A typical cross section consisted of a staff gage with wells installed on both stream banks and within the stream near each stream bank. Groundwater levels, stream stage, and temperature data were collected at each site at frequencies ranging from semi-monthly to hourly from April through November during 2007 and 2008. Pressure transducers were installed in one monitoring well and on the staff gage at each site. Temperature loggers were installed in the stream and in each of the monitoring wells at approximately 1.5 and 3.0 feet below the streambed. Qualitative determinations of the direction of water flow (to or from the stream) were made by comparing the temperatures and water levels of the stream and the adjacent groundwater. The hydraulic conductivity of the streambed material at five of the cross-sections was estimated by using a numerical heat and transport model (VS2DH). Models for each site were calibrated by matching simulated temperatures with observed streambed temperatures. Fluxes across the streambed interface were estimated using the results of the calibrated models and evaluated by comparison with data on streamflow gains and losses determined from multiple seepage runs and continuous streamflow records.

Management Of Anthropogenically Derived Hybrid Trout Populations: Explicit Recognition Of Assumptions

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Abstract: Hybridization and introgression between native and introduced species is one of the most challenging issues currently facing fisheries managers. While recognizing we are simplifying arguments, we suggest two hybrid management paradigms have emerged. The first posits that as long as introgression is at moderate to low level, and the resulting hybrids are morphologically and ecologically similar to the native taxon, they should be considered a member of the parental species. The alternative view suggests that conservation efforts should be focused on native genomes that have evolved in response to localized selective pressures and hybridized populations are a conservation threat. We suggest that both management approaches are based on a few key assumptions about the nature and ultimate outcome of hybrid fitness and ecology. Although these assumptions are implicit in the arguments presented by both sides of the argument, neither camp has explicitly recognized the assumptions nor discussed the management implications of violations of those assumptions. In our poster, we present a framework that explicitly addresses various assumptions surrounding hybridization and the ecological outcomes each assumption would predict. We further suggest hybridization management actions should have clearly defined goals and be explicit about their assumptions. Finally, we present an example of our decision framework where we way the pros and cons of using artificial stream barriers to limit the spread of hybrid individuals.

Ecology Of Salmonid Fishes In The Umpqua River, Oregon: History Of Anadromous Runs, Current Condition And Restoration Potential

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Decline of salmonid fishes in the Pacific Northwest is a national concern. Since the turn of the 20th century the productivity of salmon in Oregon, Washington, California, and Idaho has declined by approximately 80 percent as riverine habitat has been destroyed (Lichatowich, 1999). Negative impacts to available habitat due to anthropogenic alterations are the primary drivers of decreased fish survival. Degraded ecosystems commonly reflect influences of land uses such as mining, logging, road construction, fire suppression, livestock grazing, dams, irrigation, flood control and other human actions. Important consequences of anthropogenic alterations include: degradation and fragmentation of habitats, changes in riparian plant associations, isolated fish populations and altered flow and sediment regimes (Wissmar 2004). Other major factors affecting fish population survival are overharvest and decreased water quality due to development and pollution. The Umpqua River in southwestern Oregon is a famous steelhead river, with designated Wild and Scenic status along the Rogue/ Umpqua divide. It is home to Native American tribes whose survival once depended upon the river, however today the Umpqua River is a system in need of attention. The salmon and steelhead runs have been declining over time, and degradation to the watershed due to human activity has caused freshwater limitations to

salmonid sustainability which needs to be identified. Narrowing down the possible causes of degradation and addressing those issues can shed light on the current trends and help restore traditional values. A retrospective analysis of information, including traditional ecological knowledge, is being used to evaluate the history of the watershed and fishery, as well as major impacts to the system over time. Specifically, information related to historic water temperature and flow, land use, fish species composition and abundance, dam construction and fish harvest in the Umpqua River are being examined. From this analysis it has been determined that salmon runs in the Umpqua are a fraction of what they used to be, which leads to the question, what correlates with the decline of salmon in the Umpqua historically and what are the current freshwater factors that could be limiting salmonid production? To explore the question of current freshwater conditions, I am conducting an analysis of current river conditions using the Salmonid Rivers Observatory Network (SaRON) protocol, which focuses on sampling juvenile fish for species composition and abundance; water quality (DIC, DOC, TOC, DN, TN, pH, conductivity, dissolved oxygen and temperature); benthic invertebrate species composition and density, and periphyton (aufwuchs) at 11 main channel sites on the Umpqua. Examining these freshwater conditions will help determine which areas of the river should be focused on for restoration of salmonid habitat. Restoration issues pertaining to The Umpqua River will also be evaluated by a comparison of historic and current ecology to determine changes in habitat over time. Ultimately the restoration recommendation will incorporate traditional and local resource values as well as specific recommendations for salmonid sustainability in the Umpqua.

Assessment And Distribution Of Pharmaceuticals, Personal Care Products, And Endocrine Disrupting Compounds In Surface Waters In The Gallatin Valley, Gallatin County, Montana

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Pharmaceuticals, personal care products (PPCPs) and endocrine disrupting compounds (EDCs) have been reported in water resources throughout the United States and recently in Montana. These biologically active compounds are detected at very low levels (nanograms/liter) and have been reported to have adverse health effects on wildlife, particularly aquatic species. The potential public health effects are still unknown. The source of these compounds can be attributed to point and nonpoint source pollution, entering the environment through wastewater discharge from municipal and onsite wastewater disposal systems as well as agricultural wastewater. Our project, conducted in partnership with the Montana Bureau of Mines and Geology, examined the distribution of PPCPs and EDCs in wastewater, ground water and surface water in the Gallatin Valley. Influent and effluent samples were collected from different types of wastewater treatment systems to look for these compounds. Ground-water samples were collected from public water supplies, monitoring wells, and domestic wells down-gradient of wastewater treatment facilities and in unsewered areas. This presentation is focused on the surface water component of the project. One municipality which utilizes surface water as a drinking water supply and ten surface water sites were sampled. Surface waters were sampled above and below wastewater treatment outfalls on the East Gallatin River, at several sites on the West Gallatin River, and along two streams in sewered and unsewered areas. These sites were sampled in August, February and April to examine seasonal variability. Samples were collected from the municipal water supply post-treatment. Preliminary results reveal PPCPs and EDCs are present in surface waters in the Gallatin Valley as a result of the inputs from wastewater point sources and nonpoint sources. Some compounds were found to be persistent in the environment. Further studies are recommended to look for effects these compounds may be having on local aquatic species.

Nutrient Concentrations and Bacterial Biomass in Streams Located in the West Fork Watershed in Big Sky, MT

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Streams located in the West Fork of the Gallatin River watershed, near Big Sky, MT, were compared in terms of dissolved chemical constituents and microbial biomass during the 2009 summer. Biomasses were hypothesized to be different between two streams in undeveloped areas (Beehive and Yellow Mule Streams) and one stream affected by sewage effluent (Lower Middle Fork Stream). Concentrations of NO3-N varied from 9 ug L-1 at Beehive Basin to 108 ug L-1 at Middle Fork in July 2009. Phosphate concentrations were highest in June at all sites except the Middle Fork. Alkalinity and electrical conductivity were highest at the undisturbed Yellow Mule site, which drains a limestone and sandstone basin. Greater than 70,000 cells were observed per ml of the Middle Fork and Yellow Mule Stream waters during June 2009, and 10^3 cells were measured at both sites in July 2009. There were weak correlations (R2 < 0.5) between cell counts and nitrate, carbonate, or phosphate concentrations. The cell morphologies were mostly filamentous at Middle Fork and mostly cocci at Yellow Mule. We also assessed cultivable forms of bacteria using a series of selective media and identified coliform bacteria from Middle Fork stream waters and a variety of heterotrophic bacteria at all sites. Overall, undisturbed headwaters of the South Fork (Yellow Mule Stream) contained similar cell numbers as a human-impacted site on the Middle Fork, but the cellular morphologies were very different between the two sites.

A Conceptual Foundation For The Klamath River

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The Klamath River Basin in southern Oregon and Northern California has been an epicenter of debate over how to restore and sustain water quality, salmon runs and other natural goods and services of a damaged river ecosystem without unduly compromising current uses of water for agriculture and hydropower, among other cultural issues. Historically the Klamath River was the third largest producer of salmon on the west coast of the USA (not considering Alaska) and the watershed included some 350,000 acres of wetlands, marshes and shallow lakes supporting huge numbers of migratory birds and waterfowl. Today development and irrigation have drained 75% of the wetlands and water diversions from the Klamath, Trinity, Shasta and Scott Rivers have significantly reduced the total annual flow of the river. Ten major impoundments facilitate flow alteration to promote agriculture and hydropower. Construction of four main-stem dams in the middle reach of the river increased flow regulation in the lower river and extirpated anadromous fishes in Upper Klamath Lake and upstream. Altered water flux by the plethora of human activities in the basin is interactive with other problems, notably nutrient and other water pollution, high summer water temperatures, toxic algae blooms and fish diseases, that have reduced ecosystem integrity to the point that sustaining natural attributes, like clean water and wild salmon runs, is doubtful. The issue is finding common ground to restore and sustain natural and cultural goods and services in a functional ecosystem context. The goal of this paper is to provide a conceptual foundation or model to underpin plans for restoration of salmon runs and other key attributes of the Klamath River Ecosystem. We include boundaries, principles, and assumptions for the Klamath River Ecosystem, with a scientific retrospective analysis serving as the basis for our conceptual foundation. Our conceptual foundation for the Klamath summarizes the connections between ecosystem elements and environmental stressors and provides the basis for adaptive management to help shape the scope of restoration efforts. We believe restoration efforts should aim for a "normative state", rather than a "pristine or normal state." Normative in context of salmon restoration means providing enough ecological connectivity and quality habitat to achieve specific biotic objectives (Stanford et al., 1996). In our view, a conceptual foundation provides unified understanding of the ecosystem structure and function, including natural and cultural characteristics, to guide management and restoration to the normative state. The explicit goal of the conceptual foundation is enhancing productivity of the full suite of wild Klamath salmon and steelhead stocks. To accomplish this goal, the full gamut of stressors will have to be substantially moderated or eliminated. Substantial improvement of water quality and other ecosystem goods and services (e.g., healthy timber, fertile soils, and diverse wildlife) should be coherent with increased salmon productivity in this view. We believe that an adaptive, whole-system approach to management and restoration that is science-based is the key to restoring this river.

Assessment Of Pharmaceuticals, Personal Care Products, And Endocrine Disrupting Compounds In Raw And Treated Wastewaters In Gallatin County.

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As part of a larger project to assess the occurance and distribution of pharmaceuticals, personal care products, and edocrine disrubting compounds in surface waters, ground waters, and wastewaters in Gallatin County, influent and effluent samples were collected from eight different types of wastewater treatment systems in the County. The samples were collected to assess the occurance and concentrations of these compounds present the raw influent, and in the final treated efflunet. A total of 44 samples were collected from the treatment systems as either grab samples, or as time integrated composit samples when possible. The sampling results are currently being evaluated. Preliminary results indicate that most wastewater treatment systems are removing a significant percentage of these compounds from raw wastewater but several compounds appear to persist through most common wastewater treatment processes.

The Water Well Screen And Its Clogging Issue

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This presentation will address the need for water resource management in Central Asia with a focus on Uzbekistan. The normal vital activity of population is directly related to their stable drinking water supply. As it is known the process of society development is impossible without influence upon nature and such influence leads to changes in natural balance. Solution of the problem of society development is becoming more urgent influence of improvement of social condition of population and preservation the environment. It requests modernization of water supply technologies and devices. The first and very important part of the water supply system is water intake and lifting equipments such as water wells and it's screen. This presentation is about water wells issues in Central Asia and particularly in Uzbekistan where ground waters are the primary source of quality drinking water. It represents 85-90% of the general water budget. There are territories where underground water is the only source Uzbekistan is a region with a very hot and dry climate. During the long summer (from May until October) water consumption increases sharply and wells with declining productivity cannot meet the demand. Existence of a water supply source, constructions for getting and lifting water to the consumers is not always sufficient. This brings about necessity of the better founded approach to operation structure to rational use of water resources. However, some of these wells are not in a good and operable condition. There are lots of deficiencies in the well pumping system ranging from the wells themselves to the equipment and switchgear installed. All wells are in different state in their performance and use. The further utilisation of some of the wells might be critical for various reasons, such as physical condition of the well, existing pollution or potential pollution of the water catchments area, risk for contamination, etc. The main reason for ineffective operation of wells is clogging of filters and filter area by salt deposits and corrosion products of metallic elements. The clogging deposits consists mainly salts calcium and iron oxides. When wells lost more than 40 % productivity they need to be rehabilitated (restoring as a cleaning up filters and gravel zone). This situation requests groundwater use management by improving efficiency existing water wells. From the economical and ecological points of view the regular water supply of the population should be based on the active structures of a system of water supply as there is a considerable potential of increasing the efficiency of use of investments which they can provide. With the use of the new developed technology, the degree of rehabilitation of productivity of water well is 90 %. The economic benefit of processing one well is $13500 US. The developed method is combined (blended) for water well rehabilitation by using complexions as chemicals and solid dioxide carbonic as an agent for pressing of the selective solvent into filter area and helps make a process as cyclic. The combined rehabili-

tation method can fully restore the water well capacity and economic value is equal 15-20% from overall value of construction of new wells.

Mechanical Analysis Of A Tesla Turbine To Produce A More Efficient Microhydro Turbine System.

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A Tesla turbine is a different type of turbine that extracts power from the working fluid by using the frictional shear forces in the fluid flow as it passes through the turbine. By building a microhydro Tesla Turbine, the prototype model will then be used to investigate how the turbine parameters, such as rotor radius, efficiency of the ball bearings and the difference in the change in pressure compare to the overall performance of the turbine. A micro hydro is defined as a hydro water system that has the capacity to produce 100 kW or less. The basic operation and governing principles of a Tesla Turbine, also known as a shear-torque turbine, consists of a series of thin disks stacked close together and fastened to a central shaft. A regular blade turbine operates by transferring kinetic energy from the moving fluid to the turbine fan blades. In the Tesla Turbine, the kinetic energy transfer to the edges of the thin platters is very small. Instead, it uses the boundary layer effect, i.e. adhesion between the moving fluid and the rigid disk. This is the same effect that causes drag on airplanes. A fluid is forced into the disks tangentially at the outer edge of the rotor via a pressure gradient and the fluid exhausts at the center of the rotor. The viscous forces between the fluid and the disks cause the rotor to spin. This design accounts for the term "bladeless turbine" which illustrates the difference between the Tesla Turbine and conventional turbines. Conventional turbines rely on the impact energy exchange between the fluid and the rotor blades; whereas, a Tesla Turbine operates on a viscous energy exchange between the fluid and the rotor disks. This difference in energy transfer mechanisms between the two types of turbines gives each type separate areas of applications and results in a unique theoretical model for the Tesla Turbine. The goal of this proposal is to expound upon Nikola Tesla's theory of a bladeless turbine. There were a number of advantages to Tesla's radical invention. For one, bladed turbines are very high-precision machines built to specific tolerances. As a result, the creation of such a device is both long and expensive. As well, bladed turbines are not reversible in direction, whereas, Tesla's device was. Finally, Tesla himself claimed that while running on steam, his device could achieve up to 95 percent efficiency. Even today, bladed turbines operate at approximately 60 to 70 percent efficiency. Tesla's design, however, had one fatal flaw to it. In designs that used both higher speed and higher power, the disks would greatly warp and distort at extended periods of usage. Even today, the alloys of disks are not powerful enough to withstand the tremendous temperatures (over 3000 Celsius) and pressures they are subjected to. The following points summarize the project goals: Goal 1: Identify the following stream characteristics of the head, flow, the necessary pipeline, and the electrical transmission length (from turbine to home). Goal 2: Build a Tesla turbine to run on water. Goal 3: Analyze results and compare to electrical output from a 300 W bladed micro hydro.

Examining The Avulsion History And The Causes Of Anastomosis Of The Kelly Island Reach Of The Clark Fork River Downstream Of The Milltown Dam

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Anastomosis is a multi-threaded channel belt pattern, with individual channel belts separated be floodplain mantled, semi-permanent islands. This pattern is a result of the timing of avulsions for a river system. When the period between avulsion events is shorter than the duration for those avulsions to heal or complete, the river is kept in a perpetual split-channel state. Both the frequency and duration of avulsion events are controlled by sediment supply to the river. Avulsions most commonly occur when a river aggrades faster than it migrates laterally, making the river super-elevated relative to the flood basin. The healing or completing of avulsions is controlled by the ability of a river to fill one of the anabranches, returning flow to a single thread, which is controlled by the stability of the bifurcation created by an avulsion. On the western edge of Missoula, MT exists an anastomosing segment of the Clark Fork River (CFR), known as Kelly Island (KI). The Milltown Dam, ~15 km upstream of KI, has restricted sediment flux to the CFR through Missoula, MT for 100 years. The removal of this dam in 2008 resulted in a large release of stored sediment into the downstream reaches of the CFR. KI is the first major depositional reach downstream of the dam and experienced large degrees of deposition and landform change following the dam removal. KI is unique in the region in that it anastomoses. Rivers in the same valley and further downstream on the CFR all experience avulsions, but those avulsions do not result in the persistent and complex anastomosis present in KI. Three questions are posed: (1) What were the rates and patterns of avulsion development and abandonment in KI in recent decades? (2) How has an increase in the supply of fine sediment resulting from the removal of Milltown Dam affected bifurcation dynamics in KI, including sediment distribution within bifurcated reaches and bifurcation stability? (3) What is the main cause for anastomosis in KI? This study incorporates historical aerial photographic analysis, field surveys and two-dimensional flow modeling of Kelly Island bifurcations in order to investigate the causes of avulsion in KI, the mechanisms that stabilize bifurcations in KI, and how those bifurcations' evolution were affected by the release and subsequent deposition of Milltown Reservoir sediment. The hypothesis tested is that anastomosis in KI is a result of sediment restriction from the Milltown Dam, leaving avulsions unable to complete or heal. Also, avulsions in KI are not caused by channel super-elevation from in-channel deposition but rather meander bend cut-offs and large woody debris jams diverting flow over the floodplain.

Behavior Of Residual Heat In Groundwater At An MTBE Site Treated With Electrical Resistance Heating

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Electrical resistance heating (ERH) techniques are being used to remediate BTEX and MTBE contaminated source areas and groundwater plumes. This method injects large, known amounts of thermal energy into impacted soil and groundwater systems heating groundwater to temperatures near 100 C for a number of months. Both during and post treatment groundwater advection and dispersion and heat dissipation mechanisms result in the down gradient transport of heat. Observed temperature breakthrough at monitoring points and changes in temperature within the heated source zone reveal information about the local groundwater velocity and hydraulic conductivity. This work placed thermistors in down gradient monitoring wells and the heated source area located within the glacial fluvial and lacustrine aquifer at the Ronan MTBE research site in western Montana. Three-dimensional temperature distribution data are being collected since the heating event terminated. Soil characteristics have been described and point hydraulic conductivity testing will be completed. Observed field conditions will be used to calibrate a heat transport model and simulations will be used to suggest how temperature dissipation relates to aquifer conditions at the site. Preliminary results suggest down gradient heat transport by groundwater system is limited, and the residual temperature of the groundwater has remained elevated over the past 16 months and is slowly decreasing.

Assessment Of Pharmaceuticals And Endocrine Disrupting Chemicals In The Groundwater Of Gallatin County, Montana

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Recent media attention has highlighted the fact that pharmaceuticals and other endocrine-disrupting chemicals (EDCs) have been reported in a number of aquifers and streams throughout the U.S.A. When present these biologically-active chemicals generally occur at very low concentrations (typically ng/L to micro g/L). Even at these low concentrations, they have been shown to have adverse impacts on aquatic life (e.g. feminization of fish). These adverse impacts on aquatic life have raised concerns for the affects that these chemicals may have on human health. The source for these chemicals to the environment is usually human or animal sewage waste. While wastewater treatment plants (WWTPs) operated by urban municipalities can be effective at removing many of these chemicals, they are not capable of completely removing all potential EDCs. In the Gallatin Valley many of the WWTPs discharge directly to groundwater or apply treated effluent to the surface where it

can infiltrate to groundwater. In addition to WWTPs, EDCs can also enter groundwater from minimally treated or untreated waste sources, such as septic tanks and confined-animal feeding operations, which are less likely than WWTPs to remove EDCs from the waste stream prior to being released to the environment. All of these possible of EDC contamination sources currently exist in the Gallatin Valley, which makes the near-surface aquifers susceptible to EDC contamination. We will report data from an assessment of pharmaceuticals and endocrine disrupting chemicals in the groundwaters of Gallatin County, Montana. Groundwater samples were collected from 14 monitoring wells, 14 domestic wells, 13 public water-supply wells, and one public water-supply spring at locations throughout the valley. In general the wells that were sampled for this study were not selected because they were deemed to be at high risk for EDC contamination, with the exception of four domestic and four monitoring wells that were downgradient of two separate WWTP discharges. Initial data from the first 28 wells sampled indicates that 68% (19 wells) contained at least one EDC. Data from the first 19 water-supply wells (both domestic and public) sampled indicates that approximately 53% (10 wells) contained at least one EDC. The most common EDCs detected were sulfamethoxazole (antibiotic; 36% of wells sampled), bisphenol A (chemical in plastics; 14%), and carbamazepine (anticonvulsant/mood-altering drug; 11%). Three domestic wells in this initial dataset were considered to be at high risk for EDC contamination prior to sampling and water from all three of these wells did contain EDCs. However, the initial data also shows that EDCs were present in water from wells that were not considered to be at high risk for EDC contamination

Sediment Transport Of The Clark Fork River's Milltown Dam Removal

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The Milltown Dam removal is, to date, the largest dam removal in United States history in terms of sediment exposed to river transport. The HEC-6 model was used to predict the transport of the reservoir sediments. 2008 and 2009 preliminary bedload results, scour pool filling analysis and USGS suspended sediment data illustrates inaccuracies in the model predictions and raises questions about the relationship between sediment transport and discharge in dam removal scenarios with fine and coarse grained sediment. The HEC-6 model predicted that after the breach of the dam in March of 2008 to December 2008, approximately 250,000 tons of sediment would be transported out of the reservoir by river processes. Using USGS suspended sediment data to develop a budget for the reservoir sediments shows that well over 400,000 tons of suspended sediment was transported out of the reservoir by the Blackfoot and Clark Fork Rivers in 2008. Bedload transport calculations along with scour pool filling estimates downstream of the dam could be as high as 300,000 tons. Bedload sampling results provide some of the first insight to the flux and processes of reservoir sediment transport after dam removal.

Impact Of Anthropogenic Pollution And Agriculture Practices On Soil And Water Quality In Phosphate Mining Basin Of An Arid Region (Moulares-Redayef Aquifer, Southwestern Tunisia)

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In the phosphate mining basin, the degradation of soil and water ressources of the aquifer of Moulares-Redayef (Southwestern Tunisia) is a serious peril for the human happiness and the natural environment as a result of the unique climate, topography, soil characteristics and peculiarities of agriculture. The hurtful effects of nitrate pollution and agriculture practices on soil quality involve salinization, compaction and pollution. The resultant impact on water ressources includes pollution due to nutrient and pesticide discharge. In order to select the appropriate sustainable strategies for preventing those impacts, research should focus on developpment of an accurate soil quality monitoring system at multiples scales based on a functional evaluation of soils. The problematic of this study is to underline the most important impacts of agricultural practices and anthropogenic sources on soil and water quality. The integration of these elements provided the mechanism to assess groundwater pollution risks and identify areas that must be prioritized in terms of groudwater and restriction on use. The proposed assessment methodology would provide information about the status of the soil and water resources, correlate water quality with management and aid with the development of sustainable management practices. Keywords: Water quality, Soil quality, Nitrate pollution, Phosphate mining basin.

Assessing Stream Function And Groundwater-surface Water Connectivity In A Restored Streambed: Science To Inform The Restoration Process.

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The naturally occurring continuous and often bidirectional exchange of water between a stream channel and its underlying aquifer is responsible for transporting water and solutes among the groundwater system, hyporheic zone and stream channel. Such water exchange creates vertical and lateral linkages among surface and subsurface biotic communities distributed along stream corridors. Although stream restoration activities continue to multiply in number and scope across Montana and the U.S, few studies have investigated how restoration design and subsequent evolution of restored streams and floodplains may influence groundwater-surface water (GW/SW) exchange processes. This lack of knowledge impedes the development of stream restoration techniques to target and enhance hydrologic exchanges in rivers that would yield self-sustaining improvements in water chemistry and habitat quality. We seek to investigate GW/SW exchange processes on impacted and restored reaches of Silver Bow Creek, Butte, Montana. We hypothesize that: 1) increasing complexity in channel morphology promotes groundwater-surface exchange; and 2) rates and patterns of near-stream exchange provide a means for assessing associated hydrologic and ecological function. We will test these hypotheses by analyzing and comparing data describing channel morphology, solute transport, spatial variation in channel discharge, temperature regimes, and stream metabolism from undisturbed, impacted and restored reaches. Results from this research will: 1) elucidate the relationships between restoration actions, channel morphology, hydrologic exchange, abiotic and biotic stream processes, and 2) provide a protocol for assessing restoration-derived changes in GW/SW interaction, a critical component of stream function in future restoration planning, monitoring, and evaluation.

Arsenic In Groundwater Near Dayton, Montana

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In 2007, arsenic was detected at a concentration of 375 micrograms per liter (ug/L) in the Dayton elementary school well. Samples from four other wells near Dayton also contained arsenic at concentrations greater than the 10 ug/L maximum contaminant level (MCL). In response, the Lake County Board of Health approved funding for additional groundwater sampling in the Dayton area to assess the extent of elevated arsenic. With assistance from the Montana Bureau of Mines and Geology Ground-Water Assessment Program, and the Montana Department of Environmental Quality Source Water Protection Program, 42 wells, and Dayton Creek were sampled between May and August 2008. Results from an additional 32 samples were obtained from other sources. The groundwater arsenic concentrations ranged from non-detect to 490 ug/L. Dayton creek was sampled in the upper and lower valley with respective arsenic concentrations of non-detect and 1 ug/L. High concentrations (greater than 50 mg/L) were associated with a confined alluvial aquifer directly beneath the town of Dayton. Samples from nine wells, completed from 165-185 feet below land surface, contained arsenic at concentrations between 70 to 490 ug/L, with a median of 280 ug/L. Ten samples from the shallow alluvial aquifer had concentrations from non-detect to 8 ug/L. Measured specific conductance values were generally less than 800 uS/cm and pH values ranged from 6.2 to 8.0 with a median of 7.0, indicating all the sampled groundwater is generally low in total dissolved solids and neutral. The source of the arsenic is not clear. Water samples from confined alluvial aquifers in the nearby Flathead and Mission Valleys are not known to contain elevated arsenic. The variation in arsenic concentrations between the shallow and deep aquifers in the Dayton area suggests a geologic source and differing (more reducing) geochemical conditions. Two samples from adjacent wells, one completed in the shallow and one completed in the deep aquifer, were analyzed for major ions and trace metals. The results show similar concentrations of major ions, and total dissolved solids. However the deep aquifer had elevated concentrations of arsenic (336 vs. 5.7 ug/L), iron, and manganese; all of these metal tend to be soluble and mobile in reducing environments.

Total Dissolved Solids Toxicity: Challenges and Future Directions

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Waste water treatment and industrial water use has become increasingly efficient over time, increasing salt loading in waste streams. This has increased the prevalence of Total Dissolved Solids (TDS) related Whole Effluent Toxicity (WET) issues in areas of the country where water conservation has not been a critical issue in the past. With increasing frequency of drought from global warming effects, receiving streams are under greater challenges to adapt to increases in TDS loadings. In areas of reduced rainfall TDS concentrations of shallow groundwater basins increase and stream base flows are reduced. The purpose of this presentation is to demonstrate an array of solutions to TDS-related WET by reviews of available technologies and case histories. Solutions to TDS-related WET are multidisciplinary. Tools for dealing with TDS came from engineering, the biological/toxicological arena, and regulatory disciplines. The functionality of these tools fall under basic headings of: • Dilution -- which are primarily regulatory in nature. • Transformation -- primarily from biological/toxicological disciplines. • Sequestration -- primarily by engineering based controls. Cost effective solutions generally required modeling of multidisciplinary options to properly inform decision makers, and within each discipline advantages and disadvantages are apparent. The present array of cost effective tools for solving TDS-related WET problems is limited, particularly in the area of engineering controls.

Stream Sampling For Hydrophilic Pesticides In Montana Using Polar Organic Chemical Integrative Samplers (POCIS).

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During the summers of 2008 and 2009, the Montana Department of Agriculture (MDA) used Polar Organic Chemical Integrative Samplers (POCIS) to collect samples from streams across Montana. POCIS consist of a sequestering medium placed between two semi-permeable membranes. POCIS are passive samplers which are deployed in streams for several weeks to several months. Analytical results can be used to determine time-weighted average water concentrations which gives a more accurate picture of aquatic-life exposures for chronic effects. Traditional grab sampling only provides a "snap shot" of chemical concentrations at the time of sampling and may miss events such as changes in stream flow, precipitation events, and chemical loading. POCIS were deployed during June and September of 2008 in the Teton River near Dutton, Big Sandy Creek near Havre, the Marias River near Shelby, and the Marias River near Loma. In June of 2009, POCIS were deployed in the Judith River near Denton, the Clarks Fork of the Yellowstone River near Edgar, and at two sites in the Billings Bench Water Association main irrigation canal above and below Billings. Grab samples were collected when POCIS were deployed and again when retrieved. Analytical results show that the POCIS contained more pesticides than were detected in the grab samples, indicating that pesticide presence was transient or that the POCIS were able to sequester trace levels of pesticides which could not be detected in grab samples. Commonly detected pesticides included 2,4-D, MCPA, prometon, atrazine, and tebuthiuron, among others. In order to calculate a time-weighted average water concentration based on POCIS results a sampling rate must be determined for each pesticide. The MDA Analytical Laboratory Bureau completed sampling rate experiments by exposing POCIS for 7, 14, 21, and 28 days to known concentrations of 95 pesticides. Sampling rate experiments had mixed results.

Downstream Deposition Of Contaminated Sediment Following The Removal Of Milltown Dam, Montana

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Since its construction in 1907, Milltown Dam and Reservoir (in western Montana) has accumulated approximately 5 million m3 of sediment. Much of this sediment was contaminated with arsenic, copper, lead, zinc, and cadmium, produced by upstream mining and smelting. As part of the remediation activities, Milltown Dam was removed in March 2008. In preparation for removal, a permanent reservoir drawdown was completed in June 2006. The drawdown resulted in a significant flux of suspended sediment out of the reservoir and mobilized bed load within the reservoir. After the dam removal, 3 million m3 of sediment was made available for river erosion. Since the dam was breached, at least 340,000 metric tons of suspended sediment was eroded out of the reservoir (USGS Water Watch). Geochemical analyses of fine-grained sediment collected below the dam showed metals concentrations elevated more than 5 times the pre-removal levels for arsenic and about 3.5 times the pre-removal levels for copper. These elevated concentrations, approximately 275 ppm arsenic and 1800 ppm copper, extended more than 70-river km downstream of the dam. Deposition of reservoir sediment has not been limited to those reaches immediately downstream, as it has been measured and observed approximately 254-river km downstream of the dam. We focus on the spatial distribution of deposition, the processes and mechanisms associated with the deposition, and the distribution of metals within the sediment deposited. The reservoir sediment has accumulated in mid-channel bars, sloughs, side channels, channel margins, downstream of flow constrictions, vegetated banks, interstitial spaces in gravel bars, eddy bars, and the toe of bars. In the fall of 2008, maps of surficial deposits in two representative field areas were completed. In both areas, more than 20% of the total area was impacted by the deposition of reservoir sediment. Sand comprises approximately 70% of the surficial material. The stratigraphy of these deposits reflects a distinct set of transport/depositional events. The first wave of sediment transported downstream following the removal of the dam covered the previous surface. This unit is comprised of extremely organic-rich, muddy sands with cross-bedding and climbing ripples. The organic-rich unit is overlain by sand with cross-bedding. This unit likely reflects the change in coarser material eroded by the reservoir headcut. The highest flows blanketed banks, channel margins and bars with mud and muddy sand. This deposition has significantly altered the bed characteristics of Clark Fork River for at least 20 km downstream from the dam.

20 Years Later: Reexamining Oilfield Brine Contamination In The Prairie Pothole Region Of Sheridan County, Montana

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The Prairie Pothole Region of Montana contains thousands of wetlands that provide critical habitat to numerous grassland and wetland bird species and also recharge shallow groundwater resources used for irrigation, drinking, and stock water purposes. Co-produced waters from oilfield activities in Sheridan County have contaminated many of these wetlands and water resources. Hydrological investigations beginning in the 1970s documented brine contamination to surface and groundwater resources in T36N, R58N Sec 27 (referred to hereafter as the Rabenberg site because the southern half section is the Rabenberg Waterfowl Production Area) within the Goose Lake Oilfield. This investigation will reevaluate the Rabenberg site to determine temporal changes of impacted water resources and rates of brine migration. The Rabenberg site is underlain by coarse-grained partially-saturated glacial outwash deposits that are up to 30 feet thick, which overlay poorly-sorted clay-rich glacial tills. Groundwater in the outwash is unconfined, with groundwater flow direction and decreasing topographic relief to the southeast towards West Goose Lake. Potential sources of contamination at the Rabenberg site are from a storage tank battery to the west and oil well and injection well sites to the north and within the square mile section. Improper disposal methods, pipeline breaks, and leachates generated from reserve pits excavated at these sites are likely the primary sources of brine contamination. The higher hydraulic conductivities of the outwash deposits control the lateral transport of brine contamination. A detailed hydrological investigation of the area was conducted in 1989 on wells and wetlands within the Rabenberg site and included major-ion chemistry, specific conductance and pH. Co-produced waters from this oilfield are characterized by high specific conductance (~291,000 us/cm in 2009), elevated chloride levels, and slightly acidic pH values. Uncontaminated shallow groundwater may have high specific conductance but lacks elevated chloride levels and is slightly basic. To determine the presence of brine contamination in the field, Jon Reiten of the Montana Bureau of Mines and Geology developed a contamination index (CI) defined as the ratio of chloride concentration to specific conductance. Reiten determined that waters with a CI greater than 0.035 have likely been impacted by oilfield brines. Results from the 1989 study delineated groundwater contamination nearly one mile downgradient from their potential sources based on CI values. In May of 2009 water from wells and wetlands in the Rabenberg site were resampled and compared to the 1989 values. Initial 2009 field data shows a decrease in specific conductance and an increase in pH in several wells and wetlands near potential contamination sources and specific conductance increases and pH decreases in sites downgradient. This is interpreted as illustrating the movement of the contaminated groundwater towards West Goose Lake. Electromagnetic data was collected in 1989 to determine the lateral extent of shallow groundwater contamination using an EM-31. Areas of high apparent conductivity were found at several locations associated with oilfield activities within the Rabenberg site. Repeat electromagnetic surveys are planned for September 2009 using an EM-34 which, unlike the EM-31, can determine contamination at various depths up to 60 meters

Arsenic Speciation In Groundwater Related To The Clark Fork River, The Floodplain And Organic Rich Substrates.

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Arsenic transport in groundwater is evaluated at Eko Compost, a site with measurable levels of arsenic, organic carbon and nutrients in the ground water. The compost facility is located adjacent to the Missoula wastewater treatment plant on a contaminated floodplain of the Clark Fork River in the Missoula Valley, Montana, USA. This site was evaluated over two years for hydrological and chemical characteristics. A series of potentiometric surface maps was created over time and hydraulic conductivity and ground water movement were characterized. Water samples were also collected monthly and results from chemical analyses of the waters were contoured over the site map to evaluate chemical and hydrologic transport. Arsenic, organic carbon, iron and sulfate increased across the site in summer after water table elevations rose in spring. "Redox pump" mechanisms were characterized in two locations, where reducing conditions with high levels of iron and organic carbon liberated anomalously high concentrations (60 to150 ug/L) of dissolved arsenic in spring. The source of arsenic appeared to be buried contaminated flood sediments at the site. A conceptual model is presented where the chemical character of the water was influenced vertically by the layer of the sediment that contained the top of the water table, and laterally by the chemical character induced by the path of the groundwater. Hydraulic conductivities (K) of around 1100 ft/day were estimated for sections of the uppermost layer of the aquifer, K values were higher near the river, and lower in wells finished in the organically enriched zones. During spring and early summer a local flow pattern was described that is seasonally different from the established regional pattern. Two distinct hydrogeologic occurrences were observed during runoff season while the aquifer was recharging 1) A direct connection developed between the aquifer and the river at the Eko Compost backwater, and 2) potentiometric maps showed flow direction in the aquifer through backfilled channels of organically enriched areas that had been used as sludge ponds for the nearby water treatment plant. Our findings indicate that both hydrogeology and chemical transport at this site were heavily influenced by the human altered landscape.

Mercury In Sediments Of The Upper Clark Fork River And Tributaries

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Mercury is gaining increasing attention as a priority contaminant in aquatic ecosystems that is causing the deterioration of habitat quality for certain species and for human uses. In Montana, elevated mercury levels are the leading cause for human fish consumption advisories. One source of environmental mercury is the aerial deposition from regional and global sources; however, historic mine wastes seem to contribute the majority of the mercury found in the Upper Clark Fork River Basin in Western Montana. Despite its significant and long-term environmental impact, mercury-related issues have gained little attention in the planning of remediation and restoration in the Upper Clark Fork River Basin. However, activities targeting other priority contaminants may not be effective for mercury or may potentially increase its detrimental impacts. A detailed inventory of mercury levels in sediments is necessary for future decisions on the remediation of this contaminant. The objective of this study is to determine levels of total mercury in sediments along the main stem of the Upper Clark River and in tributaries that drain areas of intensive historic gold mining. Besides identifying mercury source areas, we attempt to elucidate the temporal variability and trends in sediment mercury concentrations. We analyze archived sediment samples that were collected over almost two decades from the upper (Deer Lodge), middle (Gold Creek) and lower (Turah) reaches of the Upper Clark Fork River. Preliminary data indicate that sediment mercury concentrations in the Upper Clark Fork River are generally elevated compared to those from the other large, less contaminated rivers in the Basin, i.e. the Blackfoot River (0.04 mg/kg) or the Bitterroot River (0.02 mg/kg). Concentrations in Warm Springs Ponds were measured at about 0.1 mg/kg and increased to over 1 mg/kg in Deer Lodge. Levels decrease downstream to around 0.5 mg/kg near Garrison, but reach their highest levels in the main stem downstream of Gold Creek and Flint Creek near Drummond (1.4 mg/kg). Concentrations downstream of the confluence with the Bitterroot River to Tarkio are consistently between 0.35 and 0.45 mg/kg. More detailed sampling is currently ongoing to identify mercury contributions from individual tributaries. Initial samples from Flint Creek reveal very high sediment mercury levels between 10 and 24 mg/kg. This suggests that a large fraction of the total mercury input into the Clark Fork River may be contributed by a small number of tributaries. Thus, remediation of a few tributaries or locations may provide a cost effective way of reducing mercury exposure of the whole watershed.

Stream Ecological Classification, Ecosystem Diversity And Crucial Watershed Areas In Montana's Columbia River Basin

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Effective conservation of aquatic biodiversity requires a system for identifying high quality aquatic species/communities and understanding the landscape habitat conditions that support them. Until now, Montana lacked a system for defining and classifying these lotic aquatic communities. In 2009, we developed a hierarchical framework of variables and analyzed associated biological data, enabling us to classify all lotic ecological systems within the Columbia River Basin of western Montana. This involved coding and delineating 26,052 total stream reaches (NHD 1:100,000 stream reach layer) based on 7 abiotic variables within a GIS producing 1044 stream reach class permutations. These abiotic classifications were truncated to produce 35 significantly distinct aquatic ecological systems (AES) for the Columbia River drainages. Six of these AES types comprise 67% (17,688 / 26,052) of the stream reaches or 20,756 of 29,060 river miles evaluated. Concurrently, we analyzed over 5,000 aquatic biological samples for group associations and indicator species correlations within the abiotic classes to define 6 broader ecological systems encompassing the lotic aquatic community diversity of western MT. We produced tables of expected "reference condition" native aquatic vertebrates and selected invertebrates within all classified AES. For example, the Forested Headwater Source Stream AES in the Bitterroot Mountains is significantly defined by Idaho Giant Salamanders, Tailed Frogs and the Northern Rocky Mountain Refugium macroinvertebrate indicator species (7 of these are MT Species of Concern). Mapping delineated stream classifications and their expected associated native species will enable aquatic scientists or land managers to develop an understanding of the aquatic resources at various spatial scales depending on the level of depth or breadth of information needed (i.e., at the landscape level: number of river miles of the Forested Mountain Stream AES in their watershed or management region, or at the local reach scale: finding similarly classified stream reaches for a targeted survey).

Using Bioassessment Methodologies To Assess Recovery Of Silver Bow Creek, MT

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The Upper Clark Fork River is the site of one of the most well known and complex remediation /restoration efforts in the world. Over 100 years of mining & smelting in the upper watershed resulted in over 100 miles of river designated as a USEPA superfund site, mandating remediation of hazard and reclamation of lost resources. Silver Bow Creek and Warm Springs Creek, headwaters to the Clark Fork, have been the subject of massive in-stream remediation and restoration efforts. Silver Bow Creek, the focus of this paper, suffered from sediment loading that contained elevated levels of heavy metals toxic to aquatic life and humans. Toxic sediments settled in the streambed and deposited in the floodplain during overbank events. The contamination was so extensive that removing much of it required complete reconstruction of the stream channel and revegetation of the floodplain. Restoration efforts have created what will hopefully be "the last best disturbance", so that Silver Bow Creek can recover to an ecologically viable system. To learn from the Silver Bow Creek experience, a rigorous monitoring scheme is in place to evaluate the progress of the restoration. Predetermined end point goals for restoration have set the bar high for Silver Bow Creek -- restoration will be "successful" biologically when biotic sampling yields two consecutive years of Non-Impairment status using Montana's Multi-Metric Index. This paper uses pre and post restoration benthic macroinvertebrate data to evaluate which combination of statistical methods and biological parameters provide the most useful assessment of restoration success. Four methods were used to evaluate community composition and trend analysis post reclamation in Silver Bow Creek: Bray Curtis Dissimilarity, Multiple Regression of key biological indicators, Repeated Measures Analysis, and Before After Control Impact. Recommendations for assessment method(s) were made by assessing which method(s) demonstrate: 1) the smallest amount of unexplained variation, 2) accurate representation of community composition, 3) robustness to sample/replicate size, 4) ease of repeatability in a wide range of monitoring scenarios.

Geophysical Studies Of Brine Contamination in And Near The East Poplar Oil Field, Northeastern Montana, 2009

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Areas of brine contamination within the shallow aquifers in and near the East Poplar oil field, northeastern Montana, were delineated by the U.S. Geological Survey (USGS) in cooperation with the Fort Peck Assiniboine and Sioux Tribes. The success of this study is attributed to the use of a combination of geophysical methods integrated with hydrologic and geologic studies. Ground electromagnetic methods were first used during the early 1990s to delineate about 12 square miles of saline-water contamination in a portion of the East Poplar oil field area. A helicopter electromagnetic survey of nearly 106 square miles was conducted in 2004. Borehole electromagnetic induction and natural gamma logs collected at wells throughout the study area in 1993, 2004, and 2005 provided information on vertical electromagnetic conductivity and lithologic controls on brine movement. Direct-current resistivity surveys completed in 2006 defined the location of gravel channels within the shallow aquifers. Ground electromagnetic methods were used again in 2008 to delineate movement of a discrete brine contamination plume near the City of Poplar. Hydrogeologic data corroborated findings from the geophysical data. About 700 wells and geologic controls were used to map the bottom of the shallow aquifers. Water-quality samples were collected from wells throughout the study area during 2003-08 to compare geophysical measurements with the chemical composition of water from shallow aquifers. Helicopter, ground, and borehole conductivity data were used to delineate subsurface areas of high electromagnetic conductivity and compared to hydrogeologic data to identify areas of contamination. The USGS concluded that handling and disposal of brine in and near the East Poplar oil field resulted in contamination of not only the shallow aquifers, but also the Poplar River. In the 10 years since the first delineation, the quality of water from wells completed in the shallow aquifers in and near the East Poplar oil field has changed markedly and continues to change. Ground electromagnetic surveys and borehole geophysical logging are planned in 2009 to document the

progress of plume remediation that began in 2008. Use of these methods to monitor remediation progress is unprecedented, and these techniques might be used to supplement future industry standards for monitoring remediation.

Potentiometric Surface Map Of Basin Fill And Selected Bedrock Aquifers, Deer Lodge, Granite, Powell, And Silver Bow Counties

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This map shows the potentiometric surface for basin-fill and bedrock aquifers at a few locations within the Upper Clark Fork River groundwater characterization area. This work is part of the Montana Bureau of Mines and Geology (MBMG) Groundwater Assessment Atlas for the Upper Clark Fork River. The map is based on measured water levels for 779 wells and 19 spring elevations, largely inventoried during site visits conducted between February, 2000 and November, 2001; water well records from drillers' well logs and water rights records available in the MBMG Groundwater Information Center database; topographic maps; and, in many areas, previous groundwater investigations and reports. The geologic setting of the Upper Clark Fork River groundwater characterization area consists of bedrock-cored mountains separating large valleys and a few canyons along major streams. Three categories of geologic materials are defined and mapped: bedrock, Tertiary sedimentary rocks, and unconsolidated surficial sediments. The hydrogeologic setting is similar to many mountainous areas in western North America, where precipitation is higher in the mountains than in the large valleys or intermontane basins, and the seasonal storage of water in mountains as winter snowpack is an important element of the area hydrology. Bedrock in this area is generally highly indurated and fractured to varying degrees. The intermontane basins are sediment-filled and surrounded by less permeable bedrock, therefore forming somewhat isolated groundwater flow systems. Each basin likely has a range of shallow, intermediate, and deep groundwater flow components. Unconsolidated surficial sediments are generally associated with either modern streams or glacial features. Due to their surficial nature, they receive recharge from direct precipitation and surface water sources. Surficial sand and gravel deposits, where sufficiently thick and saturated, make excellent aquifers. Many of the larger valleys include substantial acreage of irrigated crop lands. Irrigation has a dramatic impact on the hydrology of major streams due to the amounts of water diverted, consumed by evapotranspiration, and infiltrating into underlying aquifers. The irrigation season extends from roughly mid-April through the end of September in most valleys. In and near irrigated areas, water level changes in wells are clearly associated with seasonal irrigation. In such wells, water levels tend to rise dramatically at the start of the irrigation season, and stay generally high with some irregularities during summer months. They then decline at a diminishing rate after the irrigation season, at some sites even until the next spring cycle begins. Generally, most of the excess irrigation water stored in aquifers eventually discharges to streams as irrigation return flow. Discussions of most of the major valleys in the mapped area provide additional details of the results of previous large-area groundwater investigations. The map shows potentiometric contours with contour intervals of 100 feet in most areas mapped, but with supplemental 20-foot contours in selected areas. The map includes inset hydrographs for selected wells.

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