PROCEEDINGS

for

Surface Water/Ground Water: ONE RESOURCE

22nd Annual Meeting
of the
MONTANA SECTION
of the
American Water Resources Association
Bozeman, Montana
October 27th and 28th, 2005
Holiday Inn

Table of 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**

Chuck Dalby, President, Montana Department of Natural Resources and Conservation
Kate McDonald, Vice President, Montana Bureau of Mines and Geology
Tammy Crone, Treasurer, Gallatin Local Water Quality District
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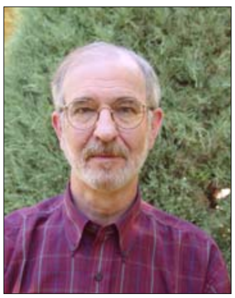

Chuck Dalby

Katie McDonald

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- **Montana Water Center, Meeting Coordination**

Gretchen Rupp, Susan Higgins, Sue Faber, Molly Boucher, MJ Nehasil and Alicia Paz-Solis

- **Our Generous Sponsors (please see agenda, next page)**

- **And especially, the many dedicated presenters, field trip leaders, moderators, student paper judges, and student volunteers**

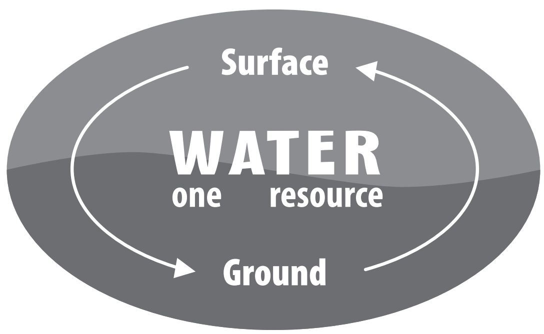
American Water Resources Association Montana Section
22nd Annual Meeting

SURFACE WATER/GROUND WATER: ONE RESOURCE

Holiday Inn, Bozeman, Montana

FINAL AGENDA

(“S” indicates a student presentation)



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Contributing Sponsors (Tributary)

- Confluence Consulting, Inc., Bozeman
- Ecosystem Research Group, Butte and Missoula
- Kendy Hydrologic Consulting, LLC, Helena

THURSDAY, OCTOBER 27, 2005

7:00 am – 5:00 pm REGISTRATION, Holiday Inn Lobby, Bozeman

8:00 am Meet in Holiday Inn Lobby for optional **Field Trip** examining surface water/ground water problems of the Gallatin Valley with guides Alan English and Dr. Steve Custer. Please bring appropriate outdoor gear.

Noon Return from Field Trip; Lunch on Your Own

PLENARY SESSION. SURFACE WATER/GROUND WATER: ONE RESOURCE *Gallatin/Jefferson Room*

1:00 pm Welcome and Introductions, Chuck Dalby, AWRA Montana Section President
Water Center Welcome, Gretchen Rupp, Director, Montana Water Center
Logistics and Announcements, Katie McDonald, AWRA Montana Section Vice President

1:15 pm *Water Follies*. Dr. Robert Glennon, University of Arizona.

2:15 pm *Examining the Exchange of Groundwater with the Stream/Floodplain System: Physical, Thermal, and Geochemical Approaches with Ties to Stream Renaturalization.* Dr. Bill Woessner, University of Montana.

3:15 pm Break

3:30 pm Panel Discussion: *Conjunctive Surface Water/Ground Water Management in Montana*
Moderated by Gretchen Rupp, Director, Montana Water Center
Panelists: Robert Glennon, John Wilson, Eloise Kendy, Gerald Mueller, and Scott Compton

5:00 pm Business Meeting

5:15 pm Adjourn for the Day

5:15 pm **Poster Session/Happy Hour** (see poster list on last page) ~ *Montana State University Room*
Beer, wine, and appetizers on the house, plus a cash bar
Featuring fiddlers Maggie Tweedy and Dana Leibelson
Book signing by Robert Glennon
Other displays

7:00 pm **Pig Roast Banquet** (ticket required; options for vegetarians)
Featured speaker: Dr. Jack Ward Thomas, Former U.S. Forest Service Chief presents
From Managing a Deer Herd to Moving a Mountain—One Pilgrim's Progress.
Afterwards: Water Legend Presentation
Then: The famous photo contest (to include amazing prizes)

FRIDAY, OCTOBER 28, 2005

SESSION 1 (Concurrent). *Jefferson Room*
CHANNEL AND FLOODPLAIN PROCESSES

Moderator: Mike McLane, Montana Department of Natural Resources and Conservation

8:00 am *Generalized descriptions of natural stream channel geometry.* Matt Klara, Joel Cahoon, and Otto Stein. Confluence Consulting and Montana State University, Bozeman.

8:20 am *Atypical floodplains and uncertainty in floodplain delineation.* George Austiguy, EMC², Bozeman.

8:40 am *Two-dimensional flood-plain modeling of Tenmile Creek north of Helena, Montana.* Katherine J. Chase, USGS, Helena.

9:00 am *Delineation of a composite hydrologic/geomorphic hazards corridor, Big Hole River.* Karin F. Boyd and Tony Thatcher, Applied Geomorphology and DTM Consulting, Bozeman.

9:20 am **S** *Direct assessment of trout passage through culverts.* Jesse Patton, Andy Solez, Joel Cahoon, Tom McMahon, and Matt Blank, Montana State University.

9:40 am **S** *Investigation of hydrologic properties at a microbial scale, Nyack Floodplain, Montana.* Dale Engstrom, William Woessner, and James E. Gannon, University of Montana.

10:00 am **S** *Effects of mountain resort development on streamwater nitrogen export: Importance of spatial location of land use / land cover change.* Kristin Gardner, Brian McGlynn, and Duncan Patten, Montana State University.

10:20 am Break

SESSION 2 (Concurrent). *Gallatin Room*
GROUND AND SURFACE WATER INTERACTION

Moderator: John LaFave, Montana Bureau of Mines and Geology

8:00 am *Stable isotopes of precipitation, evaporated mine water, and river water in SW Montana.* Chris Gammons, Simon Poulson, and Pam Reed, Montana Tech.

8:20 am **S** *Groundwater-stream interactions in a mountain-valley transition: impacts on catchment hydrologic response and stream water chemistry.* Tim Covino, Montana State University.

8:40 am **S** *Effect of drought in the Beaverhead Valley north of Dillon, Montana.* Dean Snyder and Willis Weight, Montana Tech.

9:00 am *Salt loads in an intermittent prairie stream: Sage Creek hydrogeologic basin, northern Montana, USA.* Kate Miller, Montana Bureau of Mines and Geology.

9:20 am *Impacts of irrigation conversion on ground water, streamflow, and wetlands.* Eloise Kendy, Kendy Hydrologic Consulting.

9:40 am *Water management and the implementation of a Candidate Conservation Agreement with Assurances (CCAA) in the upper Big Hole River basin.* Mike Roberts, Montana DNRC.

10:00 am *Patterns of ground-water fluctuations in aquifers: irrigation and short- and long-term climate influences on ground-water levels, Clark Fork River basin, Montana.* Larry Smith, John LaFave, and Thomas Patton, Montana Bureau of Mines and Geology.

10:20 am Break

SESSION 3 (Concurrent). *Jefferson Room*
PONDS, SEDIMENT and DAM REMOVAL

Moderator: Christine Brick, Clark Fork Coalition

10:40 am *Guidebook to Montana ponds: communicating water science to the public*. Karen Filipovich, Montana Watercourse.

11:00 am *GIS methods for modeling sediment yield to streams in the Shields River Watershed, Montana.* Jim Johnson, Confluence Consulting, Bozeman.

11:20 am *A screening level model for identifying sediment yields in the Ruby River watershed, Montana.* Donna DeFrancesco, Golder Associates, Coeur d'Alene.

11:40 am *The role of beaver in managing sediment and water in southwest Montana.* Amy Chadwick, Watershed Consulting, LLC, Whitefish.

12:00 noon *Long-term hydrogeomorphic effects of dam failure/removal - a pilot study.* Denine Schmitz, Selita Ammondt, Matt Blank, and Duncan Patten, Montana State University.

12:20 pm *Surface water quality impacts of Milltown dam removal.* Don Booth, Matt Fein, and Jerry Sweeney; EMC^2, Envirocon, and Atlantic Richfield.

SESSION 4 (Concurrent). *Gallatin Room*
WATER QUALITY/COALBED METHANE

Moderator: Clain Jones, Montana State University

10:40 am **S** *Field investigation of contaminated groundwater near the Comet Mine Reclamation Site, Basin, Montana.* Andrew Sudbrink, James Madison, Willis Weight, and Chris Gammons, Montana Tech.

11:00 am **S** *Hydrogeochemisry of arsenic in lower Silverbow Creek below Warm Springs Ponds, Montana.* Tracy Grant and Chris Gammons, Montana Tech.

11:20 am *Electromagnetic methods to delineate areas of high conductivity in shallow aquifers, east poplar oil field area, northeastern Montana, 2004.* Joanna N. Thamke, Bruce D. Smith, and Christa Tyrrell, USGS, Helena.

11:40 am *Monitoring the biological, physical, and chemical integrity of the Powder River: implications for sustainable development of coalbed methane*. Carol Endicott, Confluence Consulting, Bozeman.

12:00 noon *Update on coalbed methane ground-water monitoring activities in Southeastern Montana.* Shawn Reddish and John Wheaton, Montana Bureau of Mines and Geology.

12:20 pm *Tongue River surface-water-quality monitoring network.* David A. Nimick, John H. Lambing, Thomas P. Chapin, and Thomas E. Cleasby, USGS, Helena.

CLOSING PLENARY *Gallatin Room*

12:40 pm NEW OFFICERS, STUDENT AWARDS, and RAFFLE

1:00 pm Adjourn – Happy Trails!

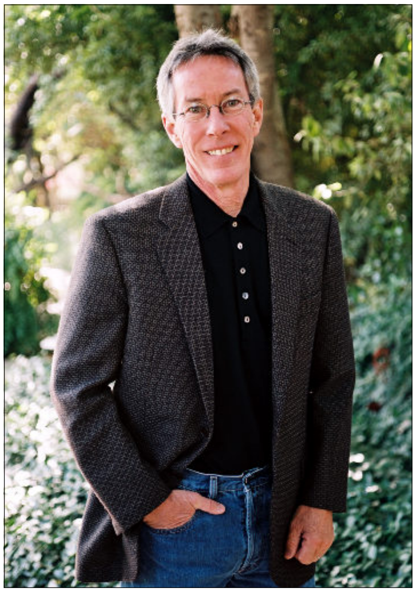
POSTER SESSION ***Montana State University Room***

AWRA 2005 POSTER PRESENTATIONS
5:15 - 7:00 pm
"**S**" indicates student poster

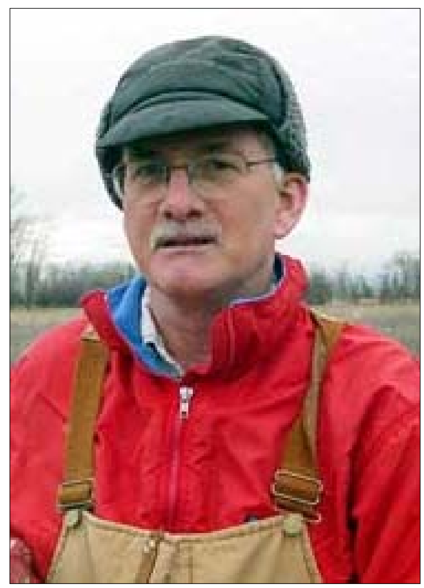
1. **S** Selita Ammondt, Denine Schmitz, and Duncan Patten, Montana State University. *The effects of small dam removal on woody riparian species in Montana.*
2. **S** Justin Brown, Montana Tech. *Identifying buried channels in the lower Yellowstone River Valley.*
3. **S** Steve Cook, Montana State University. *Characterization of metal contamination in the riparian wetlands at the headwaters of the Stillwater River, Montana.*
4. **S** Patricia Jenkins and Steve G. Custer, Montana State University. *Map-based tests of anabranch controls on the lower Yellowstone River, Montana.*
5. **S** Vince Pacific, Montana State University. *Variability in CO_2 production and efflux across riparian/hillslope transitions in the Tenderfoot Creek Experimental Forest, Montana.*
6. **S** Sheetal Patel, William W. Woessner, and Jon Harvala, University of Montana. *The impact of multiple contaminant sources to the water quality of the unconfined Missoula-aquifer, Missoula, Montana.*
7. **S** Diego Riveros, Montana State University. *CO_2 Production and efflux variability across a subalpine catchment.*
8. **S** Kate Colenso Hasenbank, Motoshi Honda, Cheryl Vann, University of Montana. *Missoula's riparian resources: condition, risks, potential.*
9. **S** Daniel F. Hoffman and Manny Gabet, University of Montana. *Effects of sediment pulses on channel morphology, sediment transport and flow resistance in gravel bed rivers.*
10. **S** Aaron Fiaschetti, University of Montana. *Assessment of pre re-naturalized ground water exchange in two stream channels and riparian zones, Jocko Valley, western Montana.*
11. Vicki Watson and Mike Suplee, University of Montana and Montana DEQ. *Trophic state of lakes in the Blackfoot and Swan River basins.*
12. Jim Bailey, Golder Associates, Coeur d'Alene. *Maintaining optimum well performance.*
13. Camela Carstarphen, Montana Bureau of Mines and Geology. *MBMG's ground-water characterization program: a progress report.*
14. John Huddleston, Natural Resource Conservation Service, Fort Collins. *Groundwater modeling of the Upper Skunk: connecting surface and subsurface GIS data with ArgusONE.*
15. Kristin Keith, Montana Water Center. *Wild Fish Habitat Initiative.*
16. John LaFave and Don Mason, Montana Bureau of Mines and Geology. *Occurrence and chemistry of springs in the Pryor Mountains, Montana.*
17. Richard Mulder, Montana Department of Agriculture, Helena. *Ground-water monitoring for agricultural chemicals in the Yellowstone River Valley, Montana, spring/summer 2005.*
18. Thomas Patton, Montana Bureau of Mines and Geology. Giant Springs: *climate impact on a first-magnitude spring in Montana.*
19. Liz Galli-Noble, Montana Water Center. *The Whirling Disease Initiative.*
20. Rye Svingen, Montana Bureau of Mines and Geology. *Northern Park County water resource assessment.*
21. Mark Teply, Latrix Systems/Helena, and Keith Gopher, Chippewa Cree Tribe, Box Elder. *National Wetlands Inventory (NWI) classification accuracy assessment for Rocky Boy's Reservation, Montana.*
22. Shanna Adams, Greg Robertson, and Dan Harmon, HDR Engineering, Missoula. *Grant Creek environmental restoration and flood control project.*
23. Jay Hanson, Montana Bureau of Mines and Geology-Billings. *Salinity risk model for the bullhead valley-integrating sustainable agriculture with water-quality protection.*

KEYNOTE SPEAKERS

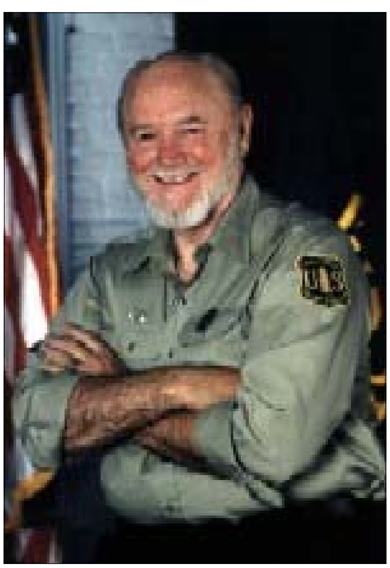
- Plenary Session -



***Dr. Robert Glennon** is an author, historian, and legal scholar specializing in constitutional law, American legal history, and water law. He is currently the Morris K. Udall Professor of Law and Public Policy at the University of Arizona. Dr. Glennon is author of the recent book, "Water Follies: Groundwater Pumping and the Fate of America's Fresh Waters."*



***Dr. William "Bill" Woessner** is a hydrogeologist, Regents Professor on the faculty of the University of Montana Geology Department, and director of the University of Montana's Center for Riverine Science and Stream Renaturalization. He is a co-author of "Applied Groundwater Modeling," and was selected by the Geological Society of America as the 2005 Birdsall-Dreiss Distinguished Lecturer.*



***Dr. Jack Ward Thomas** is the Boone and Crocket Professor of Wildlife Conservation in the College of Forestry and Conservation at the University of Montana. He was Chief of the U.S. Forest Service from 1993 to 1996 and has 50 years experience applying objective science to controversial issues. In early 2005, at the celebration of the Forest Service's centennial in Washington D.C., Dr. Thomas was recognized as the outstanding scientist in that 100 year period.*

SESSION 1 CHANNEL AND FLOODPLAIN PROCESSES

Generalized Descriptions of Natural Stream Channel Geometry

Matt Klara, E.I., Confluence, Inc,, P.O. Box 1133, Bozeman, MT 59771-1133, 406-585-9500, mklara@confluenceinc.com; Joel Cahoon, M. ASCE and Otto Stein, M. ASCE, Associate Professors, Civil Engineering Department, Montana State University, Bozeman, MT 59717

Channel cross-sections from streams in Montana and Wyoming were analyzed to develop generalized ratios of the flow area centroid depth, the hydraulic depth, and the hydraulic radius relative to the flow depth. The relationships were developed for the pooled data, then tested for significant differences when grouped using the Rosgen Level 1 classification system. Analyses of variance indicated that the ratio of centroid depth to flow depth was not significantly different across Rosgen classes. The same held for the ratio of hydraulic depth to flow depth. Significant differences across Rosgen classes were found for the ratio of hydraulic radius to flow depth. Rosgen class E channels had a significantly lower ratio of hydraulic radius to flow depth than class B channels. Based on these results, the centroid depth and hydraulic depth are linearly related to flow depth with ratios of 0.63 and 0.62, respectively, across the stream classifications tested for varied depths from the thalweg to bankfull. The ratio of hydraulic radius to flow depth varied by Rosgen classification between 0.49 and 0.60.

Atypical Floodplains and Uncertainty in Floodplain Delineation

George Austiguy P.E., Project Manager/ Hydraulic Engineer, EMC2, 205 Haggerty Lane, Suite120, Bozeman MT 59718, (406) 522-0251; gaustiguy@emc-squared.net

Increasing development pressure along riparian corridors has created an environment where greater accuracy of floodplain delineation is being assumed in decision making than the typical tools and techniques used to delineate floodplains can deliver. A typical approach used in delineating floodplains is compared with field conditions on the atypical floodplain of the West Gallatin River. Areas of significant uncertainty are identified and the consequences examined. Historical aerial photos and results from recent floodplain studies are used to illustrate the significant uncertainty that can exist in floodplain delineations and the potential consequences of aggressive riparian development.

Two-Dimensional Flood-Plain Modeling of Tenmile Creek North of Helena, Montana

Katherine J. Chase, U.S. Geological Survey, 3162 Bozeman Ave, Helena, MT 59601, kchase@usgs.gov

A two-dimensional flow model is being used by the U.S. Geological Survey, in cooperation with the Federal Emergency Management Agency (FEMA), to refine previous estimates of the Tenmile Creek flood-plain boundaries north of Helena, Montana. Tenmile Creek, which has a perched channel and a relatively small channel capacity, has overflowed its banks and flooded parts of the Helena Valley on many occasions. When flood discharges exceed about a 10-year event, flows overtop the channel banks and move northeast from Tenmile Creek across the Helena Valley. Historically, floods have inundated agricultural and suburban areas as much as 2.5 miles north of the channel.

The Surface-Water Modeling System (SMS)* and the Two-Dimensional Depth-Averaged Flow and Sediment Transport Model (FST2DH)* are being used to simulate the two-dimensional flow patterns for the overflow area north of the main channel. The graphics-based SMS computer program manages input and output data for the surface-water model. FST2DH is a computer program that simulates two-dimensional flow in rivers, estuaries, and coastal waters.

**Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.*

Delineation of a Composite Hydrologic/Geomorphic Hazards Corridor, Big Hole River

Tony Thatcher, DTM Consulting, Inc., 211 N. Grand Suite J, Bozeman, MT, 59715, 585-5322, tony@dtmgis.com;
Karin Boyd, Applied Geomorphology, Inc. 211 N. Grand Suite C, Bozeman, MT, 587-6352 kboyd@imt.net

Numerous large river corridors of Montana are experiencing increased development pressure and conversion from agricultural to residential land use. This shift creates substantial challenges to rural counties concerned with public safety and provision of other critical services. Securing sufficient funding to define regulatory flood boundaries is difficult in rural areas due to the high unit cost of floodplain delineation modeling. The determination of setbacks is commonly arbitrary due to a lack of documentation of anticipated rates of channel change. As a result, rural floodplain managers and resident stakeholders commonly have few tools available to proactively guide river corridor development and provide for associated public safety. The Big Hole River Valley exemplifies a rural river corridor that is facing increased development pressure. Floodplain mapping in the region is limited. However, in an effort to address the anticipated risks associated with development, the counties that contain and border the Big Hole are collaboratively addressing the hydrologic and geomorphic hazards inherent to the river system.

The results of the locally led, four-county effort to coordinate land use planning in the Big Hole Basin include the identification of hydrologic hazard corridor boundaries for the main stem of the Big Hole River. The corridors were developed using a GIS modeling application and geomorphic assessment techniques. The composite corridor includes an inundation corridor that approximates the 100-year floodplain, a Channel Migration Zone (CMZ) that identifies areas in terms of risk of channel occupation, and an Avulsion Potential Zone (APZ) that identifies areas at risk of large-scale relocation of primary river channels. The composite corridor provides a cost-effective means of developing process-based criteria for managing floodplain development over approximately 100 miles of the Big Hole River.

Direct Assessment of Trout Passage through Culverts

Jesse Patton,, Andy Solcz, Joel Cahoon, Tom McMahon, Matt Blank, Civil Engineering, 205 Cobleigh Hall, Bozeman, MT 59717-3900, (406) 994-2293

The extent to which culverts affect fish mobility in streams is an increasing concern in Montana. Some studies have been performed on fish passage, but there is still much to be learned about the ability of trout to successfully swim through culverts. We are currently studying the ability of Yellowstone Cutthroat trout to swim through five culverts located on Mulherin Creek near Gardiner, Montana.

This study puts a technology called passive integrated transponder (PIT) tagging to a relatively new use. PIT tags are small capsule-shaped electronic devices that are implanted under the skin of the fish. Then, when a tagged fish passes through a looped antenna , the date, time, and pit tag code are recorded. In this study, ten antennas were installed to monitor all the major culverts in a drainage basin that provides spawning habitat for trout that are resident in the Yellowstone River. At each of five culverts, antennas are placed at both the upstream and downstream end (photo, right) of the culvert. With this arrangement, the number of attempts and successful passes made by each tagged fish is recorded electronically. Ultimately, we will correlate the passage data with hydraulic and habitat conditions. This presentation will focus on the deployment and success of the PIT technology.

Investigation of Hydrologic Properties at a Microbial Scale, Nyack Floodplain, Montana

Dale Engstrom, William W. Woessner, and James E. Gannon, University of Montana, Missoula, MT, 59812; (406) 243-2471; Fax: (406) 243-4184; Jim.Gannon@umontana.edu.

An NSF-funded Microbial Observatory project was begun in 2004 to examine the microbial diversity in the floodplain of the Middle Fork of the Flathead River in Western Montana. The need to trace flowpaths and determine flux rates at the cm- to m-scale in this highly heterogeneous sand, gravel and cobble dominated-site presents a number of hydrologic challenges. A number of traditional and innovative techniques are being applied to characterize field conditions. A network of small diameter piezometers were used to develop a potentiometric surface and determine general flow directions. Slug and aquifer testing were used to establish general aquifer properties. Local, small-scale horizontal water velocities through the bar sediments were determined by using pit dilution experiments and tracer breakthrough trials. The local vertical distribution of hydraulic conductivity was investigated by using borehole pneumatic slug tests and borehole dilution tests. Attempts to characterize geologic bar structure included surface geological mapping, pit excavation and the installation of several "glass wells" (clear PVC), which were logged using a down-hole camera and digital recorder. Preliminary results suggest rapid flow occurs in discrete flow paths in coarse sediments and not diffusively. The pathways seem to be unrelated to sediment composition or grain size, and may be determined by "connectedness" (the chaos of the sedimentation process). As of yet, these discrete paths are not predictable, making the location or prediction of "well-to-well" flowpaths difficult. Flow rates near the water table are seen to vary as much as from 3.9 to 231.1 m/d. Future work is to include detailed well-to-well tracer studies, application of borehole and surface GPR and other surface geophysical techniques, and attempts at modeling the sedimentary processes forming the floodplain microbial environments.

Effects of Mountain Resort Development on Streamwater Nitrogen Export: Importance of Spatial Location of Land Use / Land Cover Change

Kristin K. Gardner, Brian L. McGlynn, and Duncan T. Patten, Montana State University, Bozeman

Human alteration of the patterns of land use/land cover (LULC) on the earth's surface is one of the most profound impacts on the functioning of natural ecosystems. At the watershed scale, we expect that not only the amount and type of landscape alteration, but also the corresponding watershed characteristics and spatial distribution, will dictate the resulting impact on streamwater quality. We are in the early stages of developing an innovative method to examine the impact of watershed location and spatial distribution of LULC change on the spatial, seasonal, and temporal patterns of streamwater nitrogen (N) export and its consequent speciation. LULC and topography will be mapped with high resolution imagery (QuickBird) and elevation data (Airborne Laser Swath Mapping - ALSM) and combined with streamwater chemistry data analyzed from four synoptic streamwater sampling events, and fine-resolution streamwater sampling. In the future, an N export coefficient model combined with isotopic analysis of ^{15}N and ^{18}O of nitrate will be used to define relationships between streamwater chemistry, LULC, watershed geomorphology and geology.

SESSION 2 GROUND AND SURFACE WATER INTERACTION

Stable Isotopes of Precipitation, Evaporated Mine Water, and River Water in SW Montana

Chris Gammons, Simon Poulson, and Pam Reed; Montana Tech (cgammons@mtech.edu), University of Nevada-Reno and Montana Bureau of Mines and Geology

Stable isotopes have the potential to add new insights into any hydrological field study. Despite popular misconception, stable isotope analyses are neither expensive nor difficult to obtain. This presentation will summarize some stable isotope work that our group has recently conducted in southwest Montana.

To begin with, the isotopic composition of a full year of rain and snow samples collected at the Montana Pole site was used to construct a local meteoric water line (LMWL) for Butte, Montana. The derived equation ($\delta D = 7.312\delta^{18}O - 7.48$, $r^2 = 0.987$), represents the first published LMWL based on direct precipitation for any location in the northern Rocky Mountains. Samples of underground and surface mine waters in Butte, including the Berkeley pit-lake and the Yankee Doodle tailings pond, fell on a different linear trend ($\delta D = 5.00\delta^{18}O - 49.54$, $r^2 = 0.991$) with a much lower slope and intercept than the LMWL. The mine water trend is explained by *evaporation* at an average relative humidity of roughly 65%. Detailed calculations indicate that the shallow Berkeley pit-lake was approximately 25% evaporated in October, 2003, whereas the surface of the tailings pond was at least 50% evaporated at that time. The intersection of the LMWL and mine water evaporation trend was used to calculate the average isotopic composition of recharge water to the flooded mine complex. The result is consistent with the main period of groundwater recharge occurring in the early spring, i.e., from snowmelt and spring rains.

The results of our work in Butte were also compared with stable isotope data that have been collected by the U. S. Geological Survey for a number of rivers in Montana. The majority of the larger rivers (e.g., the Bighorn, Clark Fork, Yellowstone, Missouri, and Flathead) have isotopic compositions that show very little seasonal variation, and that fall near the Butte LMWL but with slightly different slopes and intercepts that are specific to each watershed. In contrast, several of the smaller rivers (e.g., the Musselshell, Milk, and Tongue) as well as the Missouri River below Fort Peck, clearly show the effects of evaporation, especially for water samples collected during mid-summer, low-flow conditions. Following the example we have shown for the Berkeley pit lake, it should be possible to use stable isotopes to place constraints on the degree of evaporation of these waters, or any other lake, stream, or irrigation ditch. Information of this type could have important implications to future water conservation and management decisions.

Groundwater-Stream Interactions in a Mountain – Valley Transition: Impacts on Catchment Hydrologic Response and Stream Water Chemistry

Tim Covino, Montana State University

As mountain headwater catchments increase in size to the meso-scale, they incorporate new landscape elements including mountain-valley transition zones. Mountain-valley transition zones form part of the mountain front, and influence groundwater (GW)-stream interactions and impact hydrologic response and stream water composition. Mountain front recharge (MFR) in mountain-valley transition zones and subsequent GW discharge to streams in the valley bottom are important hydrological processes. These GW-stream interactions are dynamic in both space and time, playing a key role in regulating the amount, timing, and chemistry of stream water exiting the mountains and reaching the valley floor. We hypothesize that mountain-valley transitions function as hydrologic and biogeochemical buffers via GW recharge and subsequent GW discharge. More specifically, we propose that streams often recharge GW near the mountain front and receive stored GW further downstream. To investigate these processes we applied physical hydrology techniques (four stream gauging stations, 19 wells, and 18 piezometers), and geochemical hydrograph separations in the Humphrey Creek watershed in southwestern Montana. Our intensive instrumentation network allowed us to assess the spatial and temporal variability of mountain front GW recharge and GW-stream interactions across a mountain-valley transition. Geochemical signatures were used to partition stream flow into alpine runoff and GW sources. We found multiple lines of evidence necessary to investigate complex GW-stream interactions – single lines of evidence would have been misleading. Our results indicate that much of the alpine stream water recharged GW at the mountain front and that stored GW of a different chemical composition sustained down-valley stream discharge. Down-valley stream discharge was dominated by GW inputs and responded to GW stage more closely than upstream reaches. A critical GW stage height was necessary for down-valley channel flow, as this was the only major input to channel flow during early and late season base flow. Conversely, GW contributed little to stream flow in the upper reaches of the study area. GW-stream water exchange served as a flow and geochemical buffer, resulting in significant changes in stream chemistry from the alpine, to the MFR zone, to the valley bottom and muting fluctuations in channel flow, both at high and low flow. Implications are that mountain front GW recharge magnitudes can control valley aquifer storage state which combined with alpine runoff magnitude and valley bottom GW discharge controls stream water quantity and geochemical composition downstream.

Effect of Drought in the Beaverhead Valley North Of Dillon, Montana

Dean M. Snyder and Willis D. Weight, Montana Tech of the University of Montana, 1300 West Park Street, Butte, MT 59701

The study area encompasses the region from Dillon to Beaverhead Rock, about 30 miles northeast and tributaries in between. The area is experiencing a decrease in average annual precipitation from a 30-year-average of 11.6"/year to 8.7"/year since 1999. In 2004 the East Bench Irrigation District received none of its allotment from the Clark Canyon Reservoir. In response to the ongoing drought high capacity wells are being installed to compensate for the water shortage. The cumulative effects on the aquifer and ultimately the baseflow of the Beaverhead River from drought, well drawdown, and lack of normal recharge from the East Bench Canal are largely unknown. A comparison of static water levels in several wells between June 2005 and June 2004 reveal a decrease in the water table of approximately 4 feet indicating the aquifer requires more than 1 year to fully recover.

The objectives of the study are to obtain baseline data without influence of East Bench Canal, determine the impacts of groundwater development on groundwater levels and surface water availability for recreation, fisheries, and irrigation diversion, obtain data while drought exists, and obtain baseline data of Central Beaverhead Basin.

Preliminary results will be presented using existing and new observation wells, documenting the occurrence and flow of groundwater, determine aquifer properties by analyzing drawdown impacts through aquifer testing, measuring streamflow, evaluating SW-GW interactions, and the development of a groundwater flow model. Comparative data from remeasurement of wells used in 1991-1996 in the DNRC groundwater study by Uthman and Beck will also be presented.

Salt Loads in an Intermittent Prairie Stream: Sage Creek Hydrogeologic Basin, Northern Montana, U.S.A.

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The Sage Creek watershed, in Liberty and Hill Counties in north-central Montana, is geologically and hydrologically typical of many basins drained by intermittent streams in the semi-arid Northern Great Plains of the United States. Sage Creek supports a variety of uses such as stock watering, irrigation and habitat for aquatic biota. The prevalent land use in the watershed is the production of dryland small grain crops. Most of the drinking water used on farmsteads is derived from ground water.

Ground-water discharge to Sage Creek controls water quality over the long term and causes the presence of perennial pools in the stream channel. Mean total dissolved solids (TDS) concentrations of the three most commonly used aquifers in the watershed, Quaternary deposits (inclusive of alluvium, glacial outwash, inwash and till), the Judith River Formation and the Eagle/Virgelle Formation, were 1,500 milligrams per liter (mg/L), 2,780 mg/L, and 1,350 mg/L respectively. In areas where farming-induced dryland salinity processes have caused elevated salt concentrations in shallow ground water, TDS concentrations greater than 8,000 mg/L have been noted in Quaternary deposits. Potentiometric contours, the presence of perennial pools in the stream channel, saline seeps in the stream channel, color infrared photography, and water-quality information indicate that ground water from Quaternary deposits and the Judith River Formation is discharging along the stream channel.

The discharge rate of ground water from Quaternary deposits in a 50-km stream reach was estimated at 164 liters per second (L/s), or about 3.3 L/s per stream kilometer. But the net loss of moisture along Sage Creek (25-33 cm precipitation/year vs. 102 to 104 cm evaporation/year) causes non-flowing conditions and drives the evapoconcentration of salts and elevated TDS concentrations in perennial pools and stream sediments. Total salt loads in ground water in Quaternary deposits along a 50-km reach of Sage Creek averaged 156,000 kg per stream kilometer per year for 1994-2001. Salts that accumulate in the stream channel after ground water evaporates are flushed downstream by infrequent, high-discharge, low-duration runoff events. Streamflow occurring in 1999 and 2002 ranged from 28 L/s to about 1,020 L/s. In June 2002 a 25-year flood occurred in Sage Creek, with estimated peak flows in excess of 173,000 L/s.

Reducing salt loads to Sage Creek and other streams requires the implementation of land uses (Best Management Practices) that reduce or eliminate ground-water discharge to the watercourse. One of the most effective methods for reducing the quantity of ground-water discharge is by growing deep-rooted alfalfa in selected recharge areas. If this or another effective alternative cropping system were to be implemented on a watershed-wide basis for a sufficient length of time, a mechanism for salt transport from salinized ground water to surface water would be destroyed. Suggested achievable targets to improve water quality to pre-farming levels could be measured by 1) percent reduction in overall acreage of summer fallow in the entire watershed – perhaps starting with 10% in 10 years, or 2) percent lowering of water levels in shallow ground water that results from implementing Best Management Practices – perhaps 10% watershed wide in 10 to 15 years.

Impacts of Irrigation Conversion on Ground Water, Streamflow, and Wetlands
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Across the West, land that has been flood irrigated for generations is undergoing major change. Near cities, irrigated cropland is converting to residential and commercial development, while the remaining agricultural areas are converting from flood to sprinkler irrigation. These land-use changes, if unmitigated, reduce ground-water recharge, late-season streamflow, and, in many cases, wetland extent and hydroperiod.

Traditionally, irrigation systems in the West use diverted surface water. Irrigation water that crops do not use seeps into the soil and eventually reaches the water table, where it recharges ground water in the underlying aquifer. So-called irrigation return flow is a major source of ground-water recharge in irrigated western valleys. The irrigation-charged ground water slowly makes its way underground to streams and wetlands, where it eventually discharges. Because potential evaporation exceeds precipitation in most of the West, many of the region's wetlands depend on ground-water discharge from irrigation return flow to maintain their extent, hydroperiod, and quality.

Converting from flood irrigation to more efficient sprinkler systems reduces surface-water diversion, but also reduces irrigation return flow by roughly the same amount. Thus, while streamflow may increase during the diversion period, flows that depend on late-season ground-water discharge predictably decrease. Conversion to residential and commercial developments has the same impact, often exacerbated by new ground-water withdrawals to supply the developments and by impermeable rooftops, pavement, and other impermeable surfaces, which inhibit ground-water recharge.

Case studies illustrate methods of identifying, predicting, and mitigating adverse hydrologic impacts of irrigation conversion on wetlands.

Water Management and the Implementation of a Candidate Conservation Agreement with Assurances (CCAA) in the Upper Big Hole River Basin.

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The use of wild flood irrigation techniques in the upper Big Hole River basin has resulted in high demands for diversionary water in an area susceptible to extremely low flow conditions. Surface and ground water monitoring before, during, and after irrigation season have provided critical data pertinent to the course of management of limited water resources in the area. Further, the implementation of strategies to mitigate the dewatering of critical reaches of the upper Big Hole River are being facilitated through voluntary landowner efforts as well as the development of a Candidate Conservation Agreement with Assurances (CCAA). The CCAA is a U.S. Fish and Wildlife Service program that provides regulatory assurances to landowners who agree to participate in conservation measures, including irrigation water management, that assist in the protection of the fluvial Arctic grayling, a candidate for endangered species listing that is exclusive to the upper Big Hole River.

Patterns of Ground-Water Fluctuations in Aquifers: Irrigation, Runoff, and Short- and Long-Term Climate Influences on Ground-Water Levels, Clark Fork River Basin, Montana

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Ground-water level fluctuations in the Clark Fork River basin were analyzed by evaluating monthly and daily water-level data for more than 100 wells having multi-year data. The data reveal distinct patterns of seasonal fluctuations. Large areas show a seasonal response to irrigation and canal leakage. In other areas, a runoff response–where short-term spring meltwater is mimicked in ground water–is common. Some wells show both signals. Other wells, especially in fractured bedrock aquifers, show dry/wet cycles over multi-year periods that must be separated from short-term cycles to interpret trends.

The irrigation response is marked by a springtime water-level rise maintained through the irrigation season and declines through winter. The ground-water level data show that the use of irrigation canals in many major valleys has profound impact on ground-water levels, hence recharge. The irrigation recharge signal is observed mostly in shallow water-table aquifers but has also been observed where the water table is more than 100 feet below land surface. Some ground water, in turn, discharges to surface water, affecting surface-water flows, probably on seasonal time-scales. The data suggest that changes or disruptions in irrigation practices should also change seasonal ground-water levels and recharge.

The runoff water-level response is common near major and minor streams and in the canyon reaches of streams. In these areas, ground water rises during flood stages and falls quickly as flood seasons pass. The Missoula valley shows a different runoff pattern, in that after springtime water level-rises, levels slowly decline throughout the summer and fall, reflecting the spreading pulse of springtime recharge water from the Clark Fork River.

Long-term climatic dry/wet cycles can profoundly affect ground-water levels. Climatic cycles of ground-water levels can be recognized by separating the hydrograph into its component signals. Runoff and irrigation signals (high frequency) are often overprinted on low-frequency climatic patterns. This separation process allows the comparison of primary trends with climate and seasonal water-level patterns. Many wells showed a water-level rise during 1996-1998, followed by a decline during the comparably drier years of 1999 through the present.

Water-level data and hydrographs for all wells are continually updated and can be obtained from the Ground Water Information Center website: http:\\mbmggwic.mtech.edu.

SESSION 3 PONDS, SEDIMENT AND DAM REMOVAL

Guidebook to Montana Ponds: Communicating Water Science to the Public

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Artificial ponds are a fast-growing amenity in Montana, often installed with little thought or knowledge about the long-term consequences of the decision. Reaching landowners before they build is a critical step in minimizing negative impacts. Montana Watercourse developed a 20-page guidebook to help landowners understand the basic science and legal issues of ponds so that landowners can make more informed decisions. *A Guidebook for Montana Ponds* highlights important topics such as: alternatives to pond development, where will the water come from, how will the pond affect local water resources, wildlife, soils, and vegetation, what permits are needed, and how will the pond be maintained. This talk focuses both on the specific resource concerns raised by pond development and on the educational strategy used to get good information in the right hands.

GIS Methods for Modeling Sediment Yield to Streams in the Shields River Watershed, Montana

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Comprehensive estimates of sediment loading to streams from various sources are necessary to the TMDL assessments and target setting. Geographic Information System (GIS) based models, estimating tools, and extrapolation methods can facilitate this process.

A Screening Level Model for Identifying Sediment Yields in the Ruby River Watershed, Montana

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The Ruby River Watershed is a 620,000 acre watershed located in Madison County, southwestern Montana. There are currently 27 303 (d)-listed impaired water bodies in the Ruby River Watershed. All of these water bodies are listed for impairment caused by sediment or sediment sources. This assessment was designed as a screening level model to determine relative sub-basin sediment yields and provide individual focus areas for more detailed data collection and analysis.

Fourteen sub-basins within the Ruby River Watershed were delineated using a GIS-based watershed analysis framework. The GIS-based framework was used to intersect topography, soil, land cover, and precipitation data layers within the selected watershed area to quickly derive the essential hydrological model input parameters. The KINEROS2 hydrological model was used to complete detailed, event-based sediment yield modeling. In this manner, sub-basins with inherent high sediment potential could be quickly identified. Each individual sub-basin was then modeled to determine small, localized areas of high sediment detachment within each sub-basin. Through the screening level assessment, sub-basins in the southeastern portion of the watershed, including the Warm Springs Creek sub-basin and the East Fork Ruby River sub-basin were identified as high sediment risk areas. Modeling effects of various land management scenarios (road removal, riparian buffer enhancement, and placement of ponds) versus the baseline condition was also completed to determine the potential for reducing sediment detachment in individual sub-basins through various land management activities.

The Role of Beaver in Managing Sediment and Water in Southwest Montana

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This is a case study of the Ruby watershed that incorporates information from other watersheds in southwest Montana. The presentation covers a brief historic perspective of beaver in the area, habitat requirements for beaver, and management considerations. Management considerations include the profound effect beaver and habitat removal have had on water and sediment yield, and benefits, detriments, and challenges to reestablishing beaver populations in their historic habitat. Photos are used to illustrate stream succession after beaver activity in beneficial and detrimental situations, the effects of a beaver pond complex on suspended sediment, and examples of beaver habitat and benefits to stream recovery after mining. This presentation also describes results of a cursory examination of the effect of beaver ponds as investigated in sediment yield modeling and includes recommendations for further research.

Long-term Hydrogeomorphic Effects of Dam Failure/Removal – a Pilot Study

Denine Schmitz, Selita Ammondt, Matt Blank, and Duncan Patten, Montana State University

The restorative potential of dam removal on ecosystem function depends on the reversibility of the hydrogeomorphic effects of a dam and its operations. While dam removal is an established engineering practice, the long-term ecological response remains speculative. We used paleoflood hydrology, topographic surveys, hydrologic modeling (HEC-RAS), and aerial photograph interpretation to investigate the long-term hydrogeomorphic and ecologic responses to dam failure and removal. We compared downstream hydroecological responses of a controlled dam removal, which used natural sediment removal (Mystic Lake Dam in 1985), with that of a dam failure (Pattengail Dam in 1927). Our data showed greater geomorphic response at Pattengail compared to Mystic. Very few flood stage indicators were observed at Mystic and indicated muted hydrogeomorphic and ecologic responses. In contrast, the size of the flood following the Pattengail dam breach initiated a series of channel adjustments and reworked over 0.2 km2 of floodplain immediately downstream of the dam. Floodplain vegetation responded similarly. Nearly 100 vegetation points below Mystic Lake Dam showed no statistically significant changes in canopy type in the 20 years since dam removal. However, 165 vegetation points downstream of Pattengail dam indicated active floodplain succession during the first 70 years. Our results suggest that 1) hydrogeomorphic and ecologic responses to dam removal depends on the sizes and timing of high flow events during and following removal. 2) Dam removal effects on channel evolution and floodplain development depend on reach types and their responsiveness to flow regime change. We intend to develop these ideas into testable hypotheses as the basis of a multiyear, interdisciplinary research project. Further investigation into the long-term hydrogeomorphic and ecologic response to dam removal/failure will advance the knowledge of dam removal methods and their effects, leading to healthier ecosystems and associated human communities.

Surface Water Quality Impacts of Milltown Dam Removal

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Milltown dam, located on the Clark Fork River just upstream of Missoula, Montana, is proposed for removal in the next few years. As part of the Milltown dam removal project, evaluation and management of sediment scour has been carefully considered in a predictive sense to provide time-based release and to, where possible, minimize the impacts on downstream surface water quality and beneficial uses. As part of such minimization efforts, consideration has been given to a host of potentially applicable Best Management Practices (BMPs). These BMPs include simple methods, such as staging reservoir drawdown to take advantage of dilution provided by high flows and placement of silt curtains around work areas, to more enhanced methods of flow diversion and sediment isolation using cofferdams and bypass channels. Each of these approaches has been considered as a function of project economics and the associated benefits. A comprehensive monitoring plan is proposed to evaluate dam removal and other construction impacts on downstream water quality. The monitoring plan identifies warning levels for constituents of concern which, if exceeded, may trigger changes in monitoring frequency, operational controls or implementation of BMPs. This presentation provides a summary of the sediment scour evaluations, the BMPs considered to mitigate sediment release, their applicability to the Milltown reservoir, implementation considerations, and the proposed monitoring that will be used to assess BMP effectiveness.

SESSION 4 WATER QUALITY/COADBED METHANE

Field Investigation of Contaminated Groundwater near the Comet Mine Reclamation Site, Basin, Montana

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High Ore Creek is a tributary of the Boulder River and is located near the abandoned mining town of Comet three miles northeast of Basin Montana. The Comet mine site operated from 1880 to 1940 mining lead, zinc, copper, gold, and silver. Throughout its history mine tailings were conveniently placed in the flood plain of High Ore Creek. This resulted in high heavy metals concentrations in groundwater and surface water due to acid mine drainage. In 1997, Phase I of reclamation began and 300,000 cubic yards of waste rock and tailings were removed from the flood plain and placed in a repository constructed at the Comet Mine Site. In 2001 Phase II removed 39,000 cubic tons of rock waste and tailings from beneath the High Ore Creek diversion, which were placed at a repository 1 mile south east of the Comet Mine site.

After the completion of the reclamation, levels of zinc in High Ore Creek are still elevated above aquatic life standards. In addition several seeps and bare spots have developed in the reclaimed floodplain, which are characterized by poor water quality and precipitation of salts. This study examines the principle sources of Zn and other metals providing insight into; the loading of metals into High Ore Creek, hydrogeology of seeps, and causes of locally poor vegetation. In order to characterize groundwater flow in the aquifer and delineate the principle point sources of zinc over 100 mini-piezometers were installed. In addition, stream gauging stations and bucket dams were installed and a tracer study was conducted on High Ore Creek to examine the surface/ ground water interaction. Heavy metal concentrations are being determined using the ICP at Montana Tech. From the field and lab data a groundwater flow model and contaminant transport model are being constructed using GMS 5.1 to quantify and predict the loading of zinc into High Ore Creek.

Hydrogeochemistry of Arsenic in Lower Silver Bow Creek below Warm Springs Ponds, Montana

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In recent years, diurnal (24-hour) fluctuations in the concentrations of many metal species have been observed in streams and rivers. The primary purpose of this research was to document the extent of diurnal cycling of arsenic and trace metals in lower Silver Bow Creek, below the Warm Springs Ponds treatment facility.

This field work was conducted on July 22-23, 2004. Three sites were chosen for study, including the outlet to the Warm Springs Ponds (WS1), the mouth of the Mill-Willow Bypass (WS2), and the mouth of lower Silver Bow Creek (WS3) just upstream of its confluence with Warm Springs Creek, which marks the head of the Clark Fork River. The flows from WS1 and WS2 merged at the upper end of the study reach, and it was 1500m from this point downstream to WS3. Field parameters including pH, temperature, SC, alkalinity, and streamflow were monitored continuously at each site, and water samples were collected every other hour for analysis of major and minor cations (both filtered and non-filtered), anions, As(III)/As(V) speciation, and stable isotope analysis.

Dissolved As concentrations exiting the treatment ponds at WS1 were high (38-40 μg/L) but showed no variation with time of day. Mixing in the lake may even out any temporal variations on a short (hourly) time scale. In contrast, results from the two stream sites showed a significant increase in dissolved As concentration during the afternoon (41% change at WS2 and 33% change at WS3, where % change is $[C_{max}-C_{min}]/C_{avg}$). Although the 24-h average concentration of As at WS2 (24 μg/L) was lower than at

WS1 (39 µg/L), the contribution to the total As load in lower Silver Bow Creek from the Mill-Willow Bypass was ~ 3 times higher than from the treatment pond outflow, due to the much larger streamflow of WS2 on the dates of our sampling. The concentrations of As at WS2 and WS3 correlated positively with water temperature, pH, and dissolved O_2 concentration. Other diel changes at WS2 and WS3 included a decrease in SC, alkalinity, and dissolved concentrations of Ca, Mn, and Zn during the afternoon.

Based on the data in hand, we believe the most likely mechanism to explain the diel cycle in dissolved As concentration is adsorption (during the day) and desorption (during the night) onto the streambed. The same process may explain the opposite pattern for Mn and Zn (which are cations, and therefore show the opposite sorption behavior to As, which mainly is present as the anion $HAsO_4^{2-}$). It is also possible that Mn and Zn are co-precipitating with calcite in the afternoon, when stream temperature and pH are at a maximum. The results of this study agree with previous investigations of diel cycling of arsenic and trace metals in other contaminated streams in the northern Rockies, and show once again that sampling of rivers must take into account the time of day.

Electromagnetic Methods to Delineate Areas of High Conductivity in Shallow Aquifers, East Poplar Oil Field Area, Northeastern Montana, 2004

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Areas of high electromagnetic (EM) conductivity in shallow aquifers in the East Poplar oil field area are being delineated by the U.S. Geological Survey (USGS), in cooperation with the Fort Peck Assiniboine and Sioux Tribes, in order to determine areas of saline-water contamination. An airborne EM survey was conducted during August 2004 in a 106-square-mile area that includes the East Poplar oil field on the Fort Peck Indian Reservation. The EM equipment consisted of six different coil-pair orientations that measured resistivity at separate frequencies from about 400 Hertz (Hz) to more than 100,000 Hz. The EM resistivity data were converted to six conductivity grids, each representing different approximate depths. The conductivity grids (at depths similar to the shallow aquifers) were used to delineate areas of high EM conductivity. Boreholes in the area were logged with electrical conductivity probes to aid in calibration and electrical characterization of lithology and ground water. Water-quality samples were collected from selected wells during September 2004 to correlate geophysical measurements with the chemical composition of water from shallow aquifers.

Ground EM methods were previously used by the USGS during the early 1990s to delineate more than 12 square miles of saline-water contamination in a portion of the East Poplar oil field area. Those efforts determined that saline water had affected 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 the East Poplar oil field area changed markedly. The current (2004) extent of saline-water plumes likely differs from that delineated in the early 1990s. The City of Poplar, which relies solely on the shallow aquifers for water, is less than 3 miles downgradient from these saline-water plumes that were delineated in the early 1990s. A current delineation of high EM conductivity in the shallow aquifers will aid in understanding possible plume migration.

Monitoring the Biological, Physical, and Chemical Integrity of the Powder River: Implications for Sustainable Development of Coalbed Methane

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Coalbed natural gas (CBNG) is a non-traditional energy source with significant development slated for the Powder River basin in Montana and Wyoming. Water is the principal by-product of CBNG extraction and wastewater disposal strategies have an unknown effect on fish and aquatic life. The objective of this investigation was to document the existing biological, chemical, and physical integrity of the Powder River in Wyoming, upstream and downstream of areas with CBNG development. The investigation included assessments of fish, periphyton, macroinvertebrates, water chemistry, riparian vegetation, fluvial geomorphology, and instream habitat. Fish populations reflected habitat availability and habitat results emphasized the importance of large woody debris in forming pools. The scarcity of sturgeon chub (*Macrhybopsis gelida*), especially compared to its distribution in the early 1990s, emerged as major concern, although the cause of the decline is unknown. Water samples collected downstream of CBNG wastewater discharges had anomalously high concentrations of salts. Invasion of salt cedar (*Tamarisk* sp.) and the potential for increased salt loading from CBNG to give this nonnative species a competitive advantage over Plains cottonwood (*Populus deltoides*) may have long-term implications for fish habitat. Recommendations for sustainable development of CBNG included incorporation of the river's ability to assimilate wastewater given its unique hydrology and integration of an understanding of the life history strategies and movements of native fishes.

Update on Coalbed Methane Ground-Water Monitoring Activities in Southeastern Montana

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Southeastern Montana supports a rural economy based mainly on agriculture along with several major coal mines and an emerging coalbed methane (CBM) industry. The primary aquifers for wells and springs in this semi-arid area are the subbituminous coalbeds of the Fort Union Formation. The Powder River Basin (PRB), extending from northeastern Wyoming into southeastern Montana, is the dominate geologic control in the area. Coalbed methane production requires that ground water be pumped from the coalbed aquifers to reduce hydrostatic pressure for the life of the project. This reduced pressure allows methane to be released from the coal. The reduced pressures may reduce or eliminate flow to wells, springs, streams, or coal mine reclamation projects within and adjacent to CBM fields.

In order to evaluate possible ground-water impacts, a ground-water monitoring network is being operated by the Montana Bureau of Mines and Geology. This network will be used for long-term monitoring to evaluate hydrologic impacts of CBM production in the Tongue River and Powder River watersheds. The monitoring wells target coalbed, sandstone, and alluvial aquifers. Coalbed methane production began in Montana in 1999; in 2004, there were 439 producing CBM wells, each having an average groundwater production of 3.2 gallons per minute. Monitoring wells documented 20 feet of drawdown about one mile from the production fields at the end of 2004.

The existing well network was enhanced during 2005 with installation of new sites along the Montana /Wyoming state line. Samples from these new monitoring wells indicate that in the coalbed waters, total dissolved solids concentrations range from 1,000 to 1,600 mg/l and sodium absorption ratios range from 38 to 59. CBM resource assessments indicate presence of methane in each coal seam monitored in these new wells. At two sites, free gas appears to be migrating to the outcrops along the Powder River valley. Site 6 is approximately 8 miles west of the Canyon coal outcrop near the Powder River. The shut-in gas pressure in the Canyon coal at this site was measured at 42 pounds per square inch (psi). At site 7, about 3 miles west of the Canyon coal outcrop, shut-in gas pressure was measured at 17 psi. The difference in gas pressure at these wells, relative to their respective distances from the outcrop, suggests gas depletion by migration of methane to the outcrop.

Tongue River Surface-Water-Quality Monitoring Network

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Coal-bed methane (CBM) production is increasing in the Tongue River watershed in Montana and Wyoming. The U.S. Geological Survey has been operating a monitoring network in the watershed since 2004 to provide information for evaluating potential changes in surface-water quality. Water samples are collected periodically for laboratory analysis, and real-time monitors are operated to measure or estimate specific conductance (SC) and sodium adsorption ratio (SAR), the water-quality parameters of main concern. Data are collected at seven Tongue River and five tributary sites and disseminated primarily via the Internet.

Real-time SAR information is important to irrigators and is provided by two methods. First, SAR is estimated from continuous SC data for sites with statistically significant SC-SAR relations. However, SC-SAR relations are affected by temporal variability in the relative amounts of dissolved solids in the water. Therefore, a second approach using an analytical instrument designed for long-term instream deployment is being developed. This field SAR analyzer, which is being tested at two sites, analyzes samples and calibration standards using an ion-selective micro-electrode for sodium and spectrophotometric methods for magnesium and calcium.

Monitoring results for 2004 provide an initial overview of water quality in the watershed. SC and SAR values in the Tongue River increase gradually downstream, with a distinct increase at Tongue River at Miles City. All SC values were less than the Montana irrigation-season standard of 1,500 microsiemens per centimeter for individual samples. SAR values in the mainstem generally were near or less than 1, except Tongue River at Miles City, where values ranged from about 2 to 4. The Montana irrigation-season SAR standard of 4.5 was not exceeded in any mainstem sample. SC and SAR values varied widely in the tributaries and typically were slightly higher to much higher than values in the mainstem. Total nitrogen and phosphorous concentrations generally were less than U.S. Environmental Protection Agency guidelines to prevent eutrophication in the Northwestern Great Plains (1.5 and 0.075 milligrams per liter, respectively). Concentrations of almost all trace elements were less than Montana and Wyoming chronic aquatic-life standards at all sites except Pumpkin Creek near Miles City.
Sampling intensity was reduced slightly in 2005 without sacrificing data essential for characterizing current and future conditions. However, data collected thus far probably do not adequately represent a sufficiently broad range of hydrologic and water-quality conditions to support assessments of compliance with water-quality standards, or changes over time associated with climate variations or with CBM development or other land-use activities.

POSTER SESSION, THURSDAY EVENING, OCTOBER 27

The Effects of Small Dam Removal on Woody Riparian Species in Montana

Selita Ammondt, Denine Schmitz, and Duncan T. Patten, Montana State University

Riparian systems have been negatively impacted by dams for decades. Many dams are being removed because they have become unsafe or obsolete due to changing community needs or dam age. Unfortunately, they are being removed without much study into the long-term ecological effects of dam removal. We explored the potential of dam removal to reverse a dam's effects on woody riparian vegetation through historic aerial photograph interpretation and field surveys. We studied two sites. Built in 1901, the Pattengail Creek dam failed in 1927 during high water, sending a catastrophic flood downstream and initiating ecological responses throughout the floodplain. 165 survey points 2 km downstream of Pattengail dam exhibited statistically significant changes in the landcover types. Major changes include increased areas of coniferous vegetation, transitions from bare ground to deciduous and coniferous vegetation, and transition from deciduous to coniferous vegetation. The Mystic Lake dam was built in 1903 on the headwaters of Bozeman Creek, and removed by engineers in the early spring of 1985. The ecological response to the 20-year-old Mystic Lake Dam removal was limited. Bozeman Creek is a smaller, more constrained river system than Pattengail. 99 survey points downstream of the dam exhibited almost no change. In the Pattengail Creek site, most observed change occurred between 1942 and 1979, while the Bozeman Creek site did not exhibit much change between any years. Our results indicate that ecological response to dam removal/failure is largely affected by the type of impacted fluvial system, the length of time the system has had to rejuvenate, and the timing and magnitude of high water flows following the dam breach. Further analysis is planned to quantify vegetation response to a natural flow regime, and will help in implementing a multi-year interdisciplinary research study on this subject.

Identifying Buried Channels in the Lower Yellowstone River Valley

Justin Brown, Montana Tech

The purpose of this project is to identify ground-water resources in a buried channel aquifer underlying parts of the Yellowstone River Valley in Richland County. This channel was incised into the underlying bedrock allowing thick deposits of coarse-grained sand and gravel to be deposited. Identifying this resource will be accomplished by delineating the aquifer from its known extent near the town of Sidney to unmapped areas both north and south of town. Obtaining information on this aquifer system will protect the city of Sidney's water resource while promoting economic development through additional irrigation development.

Characterization of Metal Contamination in the Riparian Wetlands at the Headwaters of the Stillwater River, Montana

Steve Cook, Montana State University. Other authors: Brian McGlynn, Joe Gurrieri, George Furness, and Mary Beth Marks.

Heavy metal contamination in riparian wetlands downstream of abandoned mines is a recognized problem in the western United States. However, the differentiation of pre- and post-mining contamination and the spatial locations of contaminated sediment deposition are often poorly documented.

We investigated the impact of mining activity on metal concentrations in a riparian wetland at the headwaters of the Stillwater River, Montana, situated just upstream of the Beartooth Wilderness Area. The wetland is located in the New World Mining District, which became active ~100 years ago. During the first field season, we sampled soils across a 100 hectare area on a 100 meter grid to develop an understanding of the areal extent of metal contamination. We also installed monitoring wells and piezometers to determine primary groundwater gradients in the wetland complex. During the second field season, we sampled soils at selected transects to further understand areas of higher metal concentration and for ^{210}Pb dating. This field season, we selected samples for ^{14}C dating and described the dominant vegetation habitat types of the wetland. Our primary objective is to establish the geochronology of metal deposition, both aerially and vertically, in the Stillwater Wetland.

We analyzed the soil samples with XRF (X-Ray Fluorescence) and ICP (Inductively Coupled Plasma Electron Spectroscopy. XRF is a tool designed for rapid soil metal characterization. We assessed the uncertainty of the XRF measured concentrations through comparison to ICP data. ICP analysis is considered an accurate and accepted method for determining the metal content of a soil sample, and allows determining the accuracy and precision of the XRF unit. The EPA 3050B protocol was followed for the ICP analysis. This protocol is similar to a total metals extraction, which allows comparison to that of the XRF.

Spatial mapping of metal concentrations in the wetland revealed that the highest concentrations are located along the stream channel and in the depressional areas of the wetland. This supports the hypothesis that the main mechanism of metal deposition is flooding events. These maps highlighted the areas that were examined in more detail and guided selection of samples for ^{210}Pb- and ^{14}C age dating. We will present results of the XRF and ICP analysis, along with spatial maps of metal concentrations and vegetation habitat types within the wetland.

Map-Based Tests of Anabranch Controls on the Lower Yellowstone River, Montana

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Processes responsible for the formation of anabranching river systems are poorly understood. The Yellowstone River, Montana, is a major undammed and extensively anabranched river. There are over 800 km of anabranched channel, ranging from one to 11 channels per reach. Current literature, identifies at least seven variables that may influence anabranch river character: tributary junction, bedrock, channel slope, vegetation, sediment pulse, debris/ice jam, and tectonism. Several of these variables have been analyzed for the lower Yellowstone River using aerial infrared photographs, topographic maps and field surveys. Specifically, the relationships between anabranch character and tributary junction, bedrock geology, valley width and channel slope were analyzed at 0.5-1km intervals along the lower 770km reach. The literature suggests a relationship between tributary junctions and number of anabranches. No such relationship is found on the lower Yellowstone River. The literature suggests that a change from resistant to erosive substrate leads to an increase in the number of anabranches. Valley width is highly correlated with bedrock geology at a coarse scale and neither appear to have a perceptible control on number of anabranches; however, more detailed stratigraphic analysis is planned. Similarly, initial analysis of channel slope on 1:24,000 topographic maps with 20ft contours shows no correlation with anabranch character, however more detailed analyses are underway.

Variability in CO_2 Production And Efflux Across Riparian/Hillslope Transitions in the Tenderfoot Creek Experimental Forest, Montana

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The spatial and temporal controls on soil CO_2 production and efflux have been identified as an outstanding gap in our understanding of carbon cycling. We investigated the primary driving factors and their variability over space and time of soil CO_2 concentration and efflux across environmental gradients in the 550 ha Stringer Creek watershed, Little Belt Mountains, Montana. We collected measurements of soil temperature, soil moisture, C:N ratios, CO_2 efflux, and soil air CO_2 concentrations at two depths

(20 cm and 50 cm) at 32 locations across riparian/hillslope transitions in a high elevation mountain watershed in the northern Rocky Mountains. We found that aspect exerted a large control on soil CO_2 concentrations and efflux as western aspects had larger CO_2 concentrations and efflux than eastern aspects. We also found that riparian landscape positions showed greater variability in soil CO_2 concentrations and efflux than hillslope landscape positions. In addition, we installed and collected hourly data from groundwater monitoring wells at over half of the sampling locations in order to determine the effect of groundwater fluctuations on soil CO_2 concentrations and efflux. We found a large increase in soil CO_2 concentrations and efflux as riparian landscape positions changed from saturated to unsaturated conditions. We also examined the diurnal variation in soil CO_2 concentrations and efflux and found that both CO_2 concentrations and efflux reached their maximum during the late afternoon. We conclude that environmental gradients related to catchment topography in soil moisture and soil temperature led to CO_2 concentration and efflux heterogeneity through space and time. We suggest that controlling variables such as riparian versus hillslope landscape position, aspect, differences in C:N ratios, and groundwater fluctuations are the primary controls on heterogeneity in CO_2 concentration and efflux across riparian/hillslope transitions.

The Impact of Multiple Contaminant Sources to the Water Quality of the Unconfined Missoula Aquifer, Missoula, Montana

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One hundred percent of the water supplied to the 57,000 residents of Missoula, Montana comes from the unconfined Missoula Valley Aquifer, a Sole Source Aquifer. Water, in this region, is predominantly used for irrigation and municipal/domestic purposes. Missoula's long history of varying land uses have transformed its riverine landscape and altered the way the aquifer is utilized making it vulnerable to contamination. The objectives of the study are to characterize the occurrence, flow character, water quality and transport dynamics of a portion of the aquifer located north of the Clark Fork River. This work will identify factors controlling the transport and fate of groundwater contamination and how such impact may affect future groundwater uses. In addition to standard hydrologic investigation techniques, numerous consulting reports will be reviewed and incorporated into the study. A monitoring network has been established for water level observation and water quality characterization. The conceptual model will be assessed by developing a three dimensional numerical model. Study results will be utilized by the Missoula Water Quality District to suggest modifications of aquifer management to protect ground water supplies.

CO2 Production and Efflux Variability Across a Subalpine Catchment

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The uncertainties embedded in current estimates of net ecosystem CO_2 exchange (NEE) are well acknowledged. More than two-thirds of total terrestrial C is stored below ground and exchanged to the atmosphere through plant and microbial activity, but the mechanisms of such exchange are not well understood. We investigated the variability of the environmental factors that control CO_2 production to understand the heterogeneity of soil CO_2 concentration and efflux at the watershed scale. We present measurements of CO_2 concentrations and flux over one year in mountainous, complex terrain of the 550-ha Stringer Creek watershed located in the Little Belt Mountains of Central Montana. Our results showed that the interaction of soil moisture and soil temperature plays a major role in controlling CO_2 production and efflux across topographic positions. High temporal resolution measurements showed two main trends in the variability of soil CO_2: short-term (daily) variability controlled mainly by soil temperature, and long-term variability controlled by soil moisture. Long-term soil CO_2 concentration showed similar trends at other sites across the watershed. At upland sites, soil CO_2 concentrations reached their maximum after snowmelt and decreased thereafter. At lowland sites,

soil CO_2 concentrations did not peak until the late summer. Similarly, dry upland areas showed a greater relative increase in soil CO_2 concentrations after rewetting events than wet lowland areas. We seek to assess the role of topography in controlling soil temperature, soil moisture and soil nutrient status to measure and model CO_2 production and efflux at the watershed scale. Our results are the first to show watershed-scale concentrations and fluxes of CO_2 over time.

More specific results: Lower hillslope showed the highest flux rates, while higher hillslopes have the fastest potential for increasing concentration during rewetting events. During the cold months, snowpack causes building of CO_2 in the soil since flux is decreased.

Wrap up: We are going to tell a story mainly based on we have found at T1E2. The main idea is to take continuous data and show that at other sites CO2 concentrations behave similarly. Then, we can add more of the other sites to show cases, just as an example, of T2E4 peaking at different times (much earlier in the season) than T2W3, because the soil moisture status is different. Here we introduce topographic index (so a map of topographic index should be included) and this will support our hypothesis about topography as a major control of CO2 production. That as a second part. A third part of the poster would be to show how long-term monitoring behaves at other places in the watershed and show that even though we don't have continuous data, we still have data from monitoring over two months, and there are similarities with the more-controlled spots in the watershed. Finally, we can show simulations of concentration that we can obtain by running the model under, say, two different hydrologic conditions, wet and dry.

Missoula's Riparian Resources: Condition, Risks, Potential

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In fall 2003, an inventory and assessment of the condition of riparian resources within the Missoula city limits was conducted by the University of Montana Watershed Health Clinic for Save Open Space (a Missoula nonprofit organization dedicated to preserving open space in the greater Missoula urban area). Nineteen sites were surveyed within five areas: Grant Creek Area, Rattlesnake Creek Area, Clark Fork River/Downtown Area, Pattee Creek/South Hills, and Bitterroot River Area. Sites were categorized by quality (high, medium, or low) and by degradation risk (high or low) and restoration potential. Eight sites were identified as high priority for restoration, and four sites were identified as high priority for preservation. An education program focused on communicating to private landowners the value of maintaining/ restoring natural riparian vegetation was recommended for long-term protection of riparian resources.

Effects of Sediment Pulses on Channel Morphology, Sediment Transport and Flow Resistance in Gravel Bed Rivers

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Sediment delivery to stream channels in mountainous basins is strongly episodic with large inputs of sediment typically delivered by infrequent mass wasting events. Identifying the role of mass wasting in the evolution of channel morphologies and fluvial sediment transport is crucial to an understanding of the erosional development of mountain basins. In July of 2001, an intense precipitation event triggered numerous debris flows in the severely burnt Sleeping Child watershed, Sapphire Mountains, Montana. Nine large debris flow fans were deposited on the valley floor, completely filling the stream channel with 2-3 meters of sediment. Investigations focused on the channel response to the large influx of sediment. The channel has aggraded immediately upstream of the pulses, incised through the pulses, resulting in the formation of coarse-grained terraces, and braided in reaches immediately downstream. The deposition upstream of the pulses consists almost exclusively of fine material resulting in a bed material D50 one to two orders of magnitude lower than the ambient channel material. The volume of sand being transported is so great that these aggrading reaches extend hundreds of meters upstream of the

pulses with one to two meters of sand deposited across the entire valley floor. Spatial distribution of critical shear stress values from analysis of bed material size and channel geometry were calculated along with the distribution of potential bedload transport rates and provide insight on the processes of sediment wave dispersal.

Assessment of Pre Re-naturalized Ground Water Exchange in Two Stream Channels and Riparian Zones, Jocko Valley, Western Montana

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The Confederated Salish and Kootenai Tribes have acquired a large track of riparian land in which the river, streams and wetlands have been degradated. The wetlands have been altered by drainage ditches, which have lowered the water table reducing the amount of functioning emergent wetlands. The main river channel has been straightened by levies to protect adjacent hay fields. Channel confinement on this site has caused incision of the river. The goal of this research is to provide reference conditions of ground water / surface water exchange prior to re-naturalization efforts and to predict how possible restoration efforts will likely effect existing exchange rates. The Confederated Salish and Kootenai Tribes would like to reestablish pre-alteration riparian wetlands and more naturally functioning stream channels. Assessment of ground water/ surface water exchange requires the knowledge of the following parameters:

Trophic State of Lakes in the Blackfoot & Swan River Basins

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Mike Suplee, Montana Department of Environmental Quality; Presented by Kate Hasenbank

In 2003 & 2004, the Montana Department of Environmental Quality & the University of Montana collaborated on a survey of Montana's lakes to develop a lake classification system based on key physical, chemical & biological characteristics. Lakes in the Clark Fork basin that were surveyed were concentrated in the Blackfoot & Swan River drainages and included a group of lakes intensively studied in the 1970's & early 1980's by Dick Juday & Ed Keller. Key indicators of lake trophic state were computed from the recent & historic data and compared. The 2003 & 2004 data placed most of the lakes in the oligotrophic (low algal levels) class; only one reservoir appeared to be mesotrophic (moderate algal levels). In contrast, the historic data placed many more of the lakes in the mesotrophic class. It is likely that the lakes were responding to heavy logging during the 1970's. Despite the increase in residential development around the lakes in recent years, the lakes seem to have improved since the 1970's & 80's. However, continued growth in residential development may cause the lakes to degrade in the future. These data provide a baseline against which development impacts can be judged in future.

Maintaining Optimum Well Performance

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Operation of any ground water supply well requires constant monitoring and occasional rehabilitation in order to optimize long term performance and yield. Naturally occurring bioactivity and natural water chemistry in the well and surrounding aquifer is impacted by the operation of the well and the frequency of regular maintenance activities. Failure to carefully monitor well performance often results in declining yield and reduced well capacity.

The well rehabilitation technologies available for water supply wells include chemical, mechanical and impulse generation. Since ground water chemistry is a critical factor in the operation of most water supply systems, it is often the choice of well owners to avoid the use chemical rehabilitation technologies if possible. If chemical treatment is required, limit it to only those chemicals that minimize changes in water chemistry and are tailored to the specific bio-fouling problem. Recent university research on well rehabilitation technologies has provided additional understanding to which technologies are most effective.

In Germany, strict environmental laws related to ground water quality have resulted in the development and enhancement of non-chemical well rehabilitation technologies. The City of Berlin's water supply comes exclusively from 900 wells. The City has developed and maintained a very aggressive research and development program on well performance monitoring, operation, and maintenance over the past 50 years. Pigadi GmbH is a subsidiary company within Berliner Water Group, the former City of Berlin Water Bureau. They have developed a unique and successful approach to optimizing long term well performance.

Some of the most effective non-chemical rehabilitation technologies used to maintain the Berlin well system include impulse generation devices in conjunction with other traditional mechanical methods. These technologies are similar to some used in the United States but with some significant differences and improvements based on the experience with the large Berlin well field. The key differences involve the careful documentation of long term performance to allow early identification of declining well yield and detailed rehabilitation processes designed specifically for each well. The application of the Berlin well field experience to municipal water supply wells throughout the Northwest offers an excellent approach to optimizing long term performance of these systems.

Montana Bureau of Mines and Geology's Ground-Water Characterization Program: A Progress Report

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The Montana Ground-water Assessment Act of 1991 established the characterization program and a complementary program to conduct long-term statewide monitoring of ground-water quality and water levels. A statewide steering committee establishes policy and coordinates the program. The Montana Ground-Water Assessment Program is housed within the Montana Bureau of Mines and Geology.

The primary purpose of the ground-water characterization study is to provide information to landowners and officials who make decisions on how to manage, protect, and develop the ground-water resources. The program works closely with local governments and agricultural, business, and conservation groups to identify important ground-water issues to be addressed within the area encompassed by each characterization study. The program has recently completed field work in its sixth study area, the Clark's Fork River Study Area (all of Carbon and Stillwater counties), and has begun work in the seventh study area, the Giant Springs Study Area (all of Teton and Cascade counties).

In a given study area approximately 1,000 wells are visited. Roughly 20% are sampled for major cations/anions, trace metals and nitrate (some samples also undergo isotopic analyses), and 10% of the wells visited are measured monthly for water-levels over the course of 3 years. This information, including analysis and compilation of available geological information, is used to produce maps that illustrate locations and distribution of visited sites throughout the study area (data map), water-quality, direction of ground-water flow (potentiometic surface and water-table maps), and thickness and depths of aquifers. These maps, as well as all data collected, including sample results for the water-analyses (major ions and trace metals) and nitrate analyses, are available through the Ground-Water Information Center (GWIC) at http://mbmggwic.mteh.edu SESSION PREFERENCE: Poster

Groundwater Modeling of the Upper Skunk: Connecting Surface and Subsurface GIS Data with ArgusONE.

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An inverse groundwater model of a 5,000 hectare watershed was created using the USGS MODFLOW model. The forward parameters of the smaller watershed were applied to a larger encompassing 156,000 hectare aquifer system. Groundwater modeling of the 156,000 hectare aquifer was made possible by intersection of hypsography (surface contours) and hydrography (river) polyline layers. The elevations of the river were used as input prescribed heads for the groundwater model. The results enabled groundwater model levels to match observed data within one meter.

Wild Fish Habitat Initiative

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Habitat degradation is one of the principal reasons for the listing of wild fish as "threatened" or "endangered" under the Federal Endangered Species Act. Habitat degradation can exacerbate the detrimental effects of fish predators, exotic competitors, and diseases such as whirling disease. In addition, land values are diminished by habitat degradation and the subsequent loss of wild fish populations.

A critical national effort towards the restoration of important fish and wildlife habitat is the Partners for Fish and Wildlife Program, administered by the US Fish & Wildlife Service. This voluntary program provides financial and technical assistance to private landowners interested in restoring habitat on their lands. The *Wild Fish Habitat Initiative* seeks to augment the success of the Partners Program and other habitat restoration programs by conducting targeted research related to habitat restoration techniques, by implementing a technology transfer program to provide technical information to land owners and project managers, and by collating information on habitat restoration projects completed within the intermountain west.

The Wild Fish Habitat Initiative began in summer 2002 with a grant from the US Fish & Wildlife Service to the Montana Water Center. It is being carried out by Montana State University biologists in collaboration with several private- and public-agency biologists. Our poster will be an update on accomplishments since our 2004 poster at the last MT AWRA conference.

Occurrence and Chemistry of Springs in the Pryor Mountains, Montana

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More than 140 springs in and around the Pryor Mountains of south-central Montana, are the primary source of fresh water in this arid to semiarid environment. They are used for stock watering, irrigation, domestic supply, and support two fish hatcheries.

The Pryor Mountains are a series of four tilted and dissected fault-rotated blocks that are cored by Mississippian/Pennsylvanian limestones (Madison and Amsden Formations). The mountains were formed by eastward thrusting and each block is highest at the northeast corner with peaks as high as 8,776 feet; block margins are faults or faulted folds. Younger beds (Pennsylvanian to Jurassic sedimentary rocks) are exposed at lower elevations along the flanks of the mountains.

The springs range from water-table seeps to high-flow artesian springs and occur across an elevation range of 3,720 to 8,280 feet. Most of the springs occur in the limestones, however the large fish hatchery springs and several springs that are used as a water supply occur in the overlying Pennsylvanian to Jurassic sedimentary sequence.

As part of the Montana Ground-Water Characterization Program, 40 springs were inventoried; 21 of the springs were sampled for major ions and trace metals, of those 15 were sampled for oxygen-18 ($\delta^{18}O$), deuterium (δD), and tritium (^{3}H).

The chemistry of the spring water is related to the geology and altitude. Water discharging from the higher elevation (5,020-8,280 feet) Madison and Amsden limestone springs (6 samples) is a uniform Ca-Mg-HCO_3 type water, having total dissolved solids (TDS) less than 210 mg/L. Springs discharging from the Triassic Chugwater Formation and the Jurassic Ellis Group (9 samples) occur at lower elevations (3,900-4,610 feet), are much more mineralized (TDS: 766-2,212 mg/L) and are a Ca-Mg-SO_4 type water.

These units contain shale, limestone and gypsum sequences. Water discharging from the Tensleep Formation (6 samples) is variable; springs on the east side of the mountains are a Ca-Mg-SO_4 type water with tds ranging from 252-1,652 mg/L, while springs on the west side are Ca-Mg-HCO_3 type with TDS between 257-280 mg/L.

All of the spring samples contained tritium, except for one from the west side of the mountains; concentrations ranged from 2.2 to 20.4 TU. Tritium values from three Madison/Amsden limestone springs were between 12.6-15 TU, consistent with recent recharge. The δD and δ18O values plot along the meteoric water line, with no clear difference based on geologic source.

Ground-Water Monitoring for Agricultural Chemicals in the Yellowstone River Valley, Montana, Spring/Summer 2005

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The Montana Department of Agriculture's (MDA) Ground Water Program is in its first year of performing groundwater/pesticide characterization projects within the state. The goal of these projects is to collect ground-water samples within specific geographic regions throughout the state over the next several years to assess ground-water quality in relation to agricultural chemicals. During this year, 2005, the MDA will collect 44 ground-water samples from 22 wells in the Yellowstone River Valley as part of the Yellowstone Characterization Project (YCP). The samples will be analyzed for numerous types of pesticides and nitrate. Sampling locations stretch from Columbus, west of Billings, to Sidney near the North Dakota border. Seven of the 22 wells to be sampled are permanent monitoring wells maintained by the MDA as part of its statewide ambient ground water monitoring program. Fifteen of the 22 sampling sites are private domestic and irrigation wells sampled as part of the YCP. All the wells used in this monitoring program are shallow (<60 feet), located down gradient of areas with intensive agriculture (mostly irrigated agriculture), and are screened in unconfined alluvial aquifers containing shallow ground water (<30 feet). The wells were sampled once in spring/early summer (May and June) before the onset of irrigation and will be sampled again in the middle to late summer (July and August) after the onset of irrigation. Results of this monitoring effort will be available in the fall of 2005.

Giant Springs: Climate Impact on a First Magnitude Spring in Montana.

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Giant Springs, in Great Falls, Montana, is a first magnitude spring that discharges about 300 cubic feet per second (cfs) from Kootenai Formation sandstone at Great Falls Montana. Although the springs issue from joints in sandstone of the Kootenai Formation, the source of the water is the underlying Madison Limestone, which is about 300 ft below land surface at the springs.

Long-term water-level data from a well about 700 ft distant from the springs and completed in the Kootenai Formation show that hydrostatic pressure in the Giant Springs discharge zone varies. Comparison of 1-5 day duration water-level fluctuations to reservoir elevations controlled by Rainbow Dam shows that the spring's base level fluctuates slightly with reservoir stage. Comparison of 1-5 year duration water-level fluctuations to water-level changes in the Madison Limestone at and near Great Falls shows that Giant Springs' water-levels correspond closely with changes in the regional Madison Limestone potentiometric surface.

Since 1995, water levels in the Madison Formation near Great Falls have fallen about 30 ft, most likely in response to dry climate. Because declines in water levels in the Giant Springs discharge zone occur at the same time as declines in the regional potentiometric surface, climate is an important factor in spring discharge. As the regional potentiometric surface declines relative to the base level of the springs, discharge at the springs must also decline because less hydrostatic head is available to drive flow upward from the Madison Formation to the land surface. Because the springs appear to be climate sensitive, it is also reasonable that the water from the springs is relatively young. Multiple samples from Giant Springs contain elevated tritium indicating a post-1950 recharge date. Analytical results from recent chlorofluorocarbon samples are consistent with the tritium results and suggest that water discharging from the springs is on the order of 20 to 30 years old.

The Whirling Disease Initiative

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Whirling disease is caused by the *Myxobolus cerebralis* parasite—which has a two-host life cycle involving a salmonid fish and a tubificid worm. When an infected fish dies, millions of tiny indestructible *M. cerebralis* myxospores (each about the size of a red blood cell) are released into the environment. These myxospores can survive in a somewhat "dormant" form for up to 30 years. Waterborne myxospores are ingested by *Tubifex tubifex* worms, undergo a transformation in the gut of the worms, and are ultimately released in a highly-infective form, the *Triactinomyxon* (TAM). TAMs free-float in the water until they infect a salmonid through the skin; penetration of the fish takes only a few seconds. Within a few hours, the parasite spreads through the fish and infiltrates the head and spinal cartilage where it multiplies rapidly. Cartilage destruction often causes the fish to swim erratically (hence the name, *whirling disease*) and in severe cases leads to death. Whirling disease is most infective to rainbow and cutthroat trout, but can infect all salmonid species. Its range has spread in the past 100 years from Germany to most of Europe (including Russia), the United States, South American and South Africa. Where *M. cerebralis* has become well-established, it has caused decline or even elimination of whole cohorts of fish. It is considered to be one of the major fisheries management problems in the Intermountain West and is continuing to spread.

The National Partnership for the Management of Wild and Native Coldwater Fisheries is a consortium of public agencies and non-governmental organizations with an interest in sustaining the health of coldwater fisheries in the United States. The Partnership exercises oversight over the Whirling Disease Initiative and detailed scientific direction is provided by the Whirling Disease Steering Committee. The Montana Water Center manages the Initiative, and funding comes from the U.S. Fish and Wildlife Service.

In 2004, the Initiative launched a concerted effort to increase accessibility and availability of whirling disease information through its new outreach program. The primary audience to be served through the outreach program is technical professionals—fishery managers and administrators, hatchery operators and fish health professionals, researchers and agency land managers. The secondary audience comprises fishery industry and education professionals, both within the agencies and in private organizations such as the Whirling Disease Foundation, Trout Unlimited, and the Federation of Fly Fishers.

Northern Park County Water Resource Assessment

Rye Svingen, Montana Bureau of Mines and Geology-Billings

The availability of water resources in northern Park County is under increasing pressure from rapid subdivision developments in the area surrounding Livingston. The number of wells in northern Park County has increased by 50 to 70 percent between 1990 and 2000. Much of the new development in this area is occurring in rural areas outside municipal services, the new growth is dependant on wells for potable water and septic drains for sanitary disposal. The study collected hydrologic data on the aquifers and there interaction with surface water and also will determine aquifer sensitivity to land-use change and increasing number of septic systems.

In 2004 and 2005 ground-water wells were inventoried, samples were taken for common ions, trace metals, nutrients, and isotopes. Ground-water flow was calculated, stream flows were measured, and aquifer tests were conducted. The study aims to help Park County and its residents make better decisions concerning land-use change in the future.

National Wetlands Inventory (NWI) Classification Accuracy Assessment for Rocky Boy's Reservation, Montana

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The Chippewa Cree Tribe of Rocky Boy's Reservation, in north central Montana, is establishing a Wetland Protection Program within their Environmental Protection Program. In order to develop a permitting program similar to the Federal program, the Tribe must develop specific environmental criteria. Fundamental to this program is a reliable wetland database for the reservation.

The purpose of this study was to statistically evaluate the classification accuracy of National Wetlands Inventory (NWI) mapping completed within the reservation. Using reference data collected by the Tribe, evaluations were performed at various classification levels, testing the hypothesis that classification accuracies meet the Tribe's specifications for allowable accuracy levels.

Error matrices were used to evaluate classification accuracy. Error matrices express the number of reference sites assigned to a particular NWI classification relative to the actual classification observed on the ground. This is a common technique used to represent accuracy of remotely sensed data (Congalton 1991). Reference classifications (Cowardin classification as specified in FWS/OBS – 79/31) were made at 290 randomly located sites within the reservation.

In general, spatial accuracy of wetland mapping conformed to USFWS standards and error attributable to unmapped wetland extent was considered to be very low. There were however, omissions of wetland classifications along the margins of riverine wetlands. Overall, user's accuracy at the System level was greater than 90 percent; within the Tribe's requirements for allowable accuracy. User's accuracy at the Class level was generally between 60 and 80 percent; only in selected instances did this meet CCT's specifications. User's accuracy at the Water Regime level was generally less than 50 percent and thus never met the CCT's requirements for classification accuracy. As part of the project, the NWI mapping was compiled into GIS using data qualifiers that serve as a "heads up" as to the types of discrepancies that Tribe could encounter when using NWI maps in the field.

Grant Creek Environmental Restoration and Flood Control Project

Shanna Adams, HDR Engineering, Inc.
Greg Robertson, P.E., CFM, Missoula County
Dan Harmon, P.E., HDR Engineering, Inc.

Grant Creek flows south into the Missoula Valley from the foothills of the Rattlesnake Mountains northwest of the City of Missoula. The creek's headwaters are in national forest and private ranchlands; however, residential and commercial development has grown rapidly from I-90 to Grant Creeks' confluence with the Clark Fork River.

A 10 year recurrence flood in 1997 resulted in extensive damage to homes in the Mullan Trail subdivision adjacent to lower Grant Creek. Multiple lawsuits resulting from the $6.2 million damage incurred by this flood necessitated a re-evaluation of this segment of Grant Creek. Flooding was observed to come from creek overflow as well as groundwater seepage into daylight basements. Flooding occurs coincident with flow in unlined irrigation ditches. Further upstream, the stream channel is severely incised and erosion is contributing significant amounts of sediment to downstream reaches of the creek. This is reducing the hydraulic conveyance of downstream reaches, and is contributing to environmental degradation of the creek ecosystem. Native cutthroat trout utilize lower Grant Creek as a migration corridor from the Clark Fork River to spawning habitat in upper reaches. Several undersized and failing culverts at road crossings are known fish passage barriers.

Missoula County developed a project that will reduce flood hazards and solve environmental degradation problems in lower Grant Creek within the western Missoula valley. The proposed project will balance hydraulic capacity, flood control, sediment management, maintenance, new development, airport expansion, aesthetics, and aquatic habitat. The project goals for lower Grant Creek were to:

- Reduce surface and groundwater flood problems,
- Improve fish passage,
- Improve fish habitat,
- Improve recreational and aesthetic opportunities.

The proposed solutions includes the following; installing a peak flow bypass structure, channel realignments, channel terracing, riparian habitat restoration, re-routing of irrigation flows, culvert replacements, channel lining, and others.

Salinity Risk Model for the Bullhead Valley: Integrating Sustainable Agriculture with Water-Quality Protection

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Objective: Produce a shallow ground-water assessment mapping/planning tool, integrating sustainable agriculture with water-quality protection that is transferable to the rest of the Golden Triangle regions and the glaciated Northern Plains region of Montana. Located in Montana's Golden Triangle, the Bullhead area of the Marias River watershed is the testing ground for the salinity risk model. The Bullhead area was chosen as the demonstration site because of the occurrence of dryland and irrigated salinity in the area and because of the large amount of available ground-water information produced by the Montana Salinity Control Association.

The model identifies the primary environmental variables that influence saline seep formation, by assigning a ranking system to the variables, resulting in a model of the sections that are at high risk for saline seep formation. Using, in part, methods developed by Eilers et al (1997) 5 GIS layers have been integrated to produce a salinity risk model. Although limited field checking has shown model accuracy in predicting dryland salinity, the final evaluation of the accuracy and utility of the model will be accomplished during the site assessment for implementing Best Management Practices (BMPs).

Available assessments and research have shown that virtually all salinity problems occur in shallow ground-water systems in surficial geological units. Most of the perennial streams in this portion of the watershed are gaining; that is, receiving a portion of their flow from ground water. Hence, the interruption of the hydraulic connection between ground water and surface water is critical to the reduction of salinity and nutrient concentrations in surface water. The soils and surficial geologic deposits are derived mostly from mineral-rich glacial ground-moraine deposits (till) and lesser amounts of stream-deposited sediments (outwash, inwash, and terrace deposits). Land use in this area is primarily dryland small-grain production using the crop/fallow farming system. The methodology for mitigating dryland salinity and saline seeps is well-proven, and involves planting vegetation in ground-water recharge areas to prevent excess water from migrating downward into the saturated zone.

The shallow ground-water assessment map will serve as a layman-friendly system of ranking major physical characteristics with respect to areas at high risk salinization and/or saline seep development and prioritizing the location of drilling projects for salinity control.