68th Annual Meeting
Rocky Mountain Hydrologic Research Center

Friday, 18 October, 2013: 8 a.m. to 5 p.m.

University of Colorado RL3 (ARC) Bldg., Room 620,

3100 Marine Street

Boulder, Colorado

Purpose: This meeting provides an opportunity for scientists and students working in the Rocky Mountain region to discuss their research in a relaxed, yet scientifically stimulating atmosphere. The meeting encourages interdisciplinary communication among professionals and students in the fields of ecology, engineering, environmental science, geology, hydrology, meteorology, and water resources.

Registration fee: $5 for students, $20 for professionals, payable at the meeting

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Friday, 18 October 2013
8 AM to 3:30 PM

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8:00 – 8:30 AM	**REGISTRATION**
8:30 – 9:00 AM	**Glenn Patterson**, Steven Fassnacht and Amanda Weber **Trends in snow accumulation and melt in Rocky Mountain National Park, Colorado, USA**
9:00 – 9:30 AM	**Zach Schwalbe** and Nolan Doesken **Review of the 2013 Water Year, including a closer look at the September 2013 storm rainfall totals**
9:30 – 10:00 AM	**Kaelin Cawley**, Amanda Hohner and Fernando Rosario---Ortiz **Wildfire impacts on dissolved and particulate organic matter quality in a sub---alpine stream**
10:00--- 10:20 AM	**BREAK**
10:20 – 10:50 AM	**Robert Ettema** and Edward Kempema **Ice effects on stream channels in the Rocky Mountains**
10:50 – 11:20 AM	**Kristin Bunte**, Kurt Swingle, Dan Cenderelli and Steven Abt **Effective Discharge (Magnitude --- Frequency Analysis) typically not at bankfull for coarse---bedded Rocky Mountain streams**
11:20 --- noon	**Alexandra Rose, Virginia Scott** and M. Deane Bowers INVITED **The Bees' Needs: a Citizen Science Project of the University of Colorado Museum of Natural History**
Noon – 1:00 PM	**LUNCH**

1:00 – 1:40 PM	**Ken Wright** **Andean hydrologic research at prehistoric Water Temple in Peru**
1:40 – 2:20 PM	**Dave Gochis** INVITED **Integrated hydrometeorological modeling in the Colorado Front Range using a multi---scale, multi---physics platform for hydrologic research and prediction**
2:20 – 3:00 PM	**Jonathan Friedman** INVITED **Flow reconstruction from riparian cottonwood trees**
3:00 – 3:30 PM	**Rory Cowie**, Garrett Rue, Mark W. Williams, Mike Wireman **Isotopic and geochemical approaches to characterizing water movement through abandoned mine workings, Nelson---Wooster---Humphrey Tunnel, Creede, Colorado**
3:30 – 4:00 PM	**Alan Vajda,** L.B. Barber, D.O. Norris, J.H. Writer **Fish endocrine disruption responses to a major wastewater treatment facility upgrade**
4:00 – 4:30 PM	**Open**
4:30 – 6:00 PM	**ADJOURN** Meeting of the Trustees of the Rocky Mountain Hydrologic Research Center

Effective Discharge (Magnitude - Frequency Analysis) typically not at bankfull for coarse-bedded Rocky Mountain streams

Kristin Bunte[1a], Kurt W. Swingle[b], Dan A. Cenderelli[c] and Steven R. Abt[a]

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[b] Boulder, CO
c Stream Systems Technology Center, USDA Forest Service, Fort Collins, CO

Effective discharge (Q_{eff}) computed from a magnitude-frequency analysis (Wolman and Miller 1960) is often reported to correspond with bankfull or the 1.5-year return flow $Q_{1.5}$. Because Q_{eff}, by definition, transports the majority of all bedload, it is considered a design flow for stream restoration and flow management. This study investigates the relationship between Q_{eff} and $Q_{1.5}$ for gravel bedload in 17 Rocky Mountain coarse gravel-bed streams with 30-50 year flow records.

Power functions describe both the flow frequency distribution ($F_Q = c\ Q^{-a}$) where Q is discharge class, and the bedload transport (Q_B) rating curve ($Q_B = d\ Q^{b}$). The product $F_Q \cdot Q_B = (d \cdot Q^{-a+b})$ is positive if $b + -a > 0$, and negative if $b + -a < 0$. In log-log plotting scale, power function flow-frequency distributions F_Q exhibit a breakpoint and steepen in the vicinity of $Q_{1.5}$. If the bedload rating curve exponent is small, e.g., =3 as is typical of Helley-Smith bedload samples, $b + -a$ shifts from >0 to <0 at the breakpoint, causing $F_Q \cdot Q_B$ to peak, and $Q_{eff,HS} \cong Q_{1.5}$. More representative measurements of gravel transport obtained from bedload traps and similar devices indicate much larger rating curve exponents of 6-18. In this case, $b + -a$ remains >0 over the entire range of Q, and $F_Q \cdot Q_B$ reaches its maximum near the highest flow on record.

Q_{eff} occurred within 46-149% $Q_{1.5}$ for all study streams when computations were based on Helley Smith samples. By contrast, the steeper rating curve exponents typical of bedload trap samples shifted Q_{eff} to Q_{max}. The results suggest that the often-quoted similarity of Q_{eff} and $Q_{1.5}$ is an artifact of using Helley-Smith measurements in mountain streams, and that flow much higher than "bankfull" transport the majority of longterm gravel transport.

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Wildfire impacts on dissolved and particulate organic matter quality in a sub-alpine stream

Kaelin M. Cawley *[1] Amanda Hohner[1] and Fernando Rosario-Ortiz[1]
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The Cache La Poudre (CLP) watershed has been severely impacted by the High Park wildfire that burned approximately 87,284 acres from June 9 to July 1, 2012. The CLP River is located within a heavily forested watershed and serves as the source water for three major water districts in northern Colorado. The main objective of this study is to evaluate the forest fire impact on and seasonal variability of the concentration and composition of dissolved and particulate organic matter (DOM/POM) in the CLP River. Organic matter plays an important ecological role in the environment due to its ability to attenuate light, complex trace metals, and serve as an organic carbon source to microorganisms. For this study, surface water samples were collected at a reference site above the burned area, a downstream fire-impacted site, and at the Fort Collins drinking water intake (also impacted by the fire) bi-weekly during snowmelt and monthly for a year following the fire. Samples were analyzed for DOC concentration, total suspended solids, fluorescence, and UV-Visible absorbance properties. During the storm events DOC concentration increased relative to baseflow or snowmelt. Differences between the reference and burned sites were not detected for DOC concentration or most characteristics, but were observed for POM. Interestingly, the one difference between the reference and burned sites for DOM was the FI, a measure of terrestrial v. microbial contributions, which was more microbial for the burned sites; indicating that there may be sorption of terrestrial organic matter to burned particulates at the fire impacted sites. The POM at the reference site had no visible ash or charred pieces, a more microbial FI, and higher abundance of protein-like fluorescence compared to the burned sites. Our results from the first year following the fire show little difference in the DOM concentration and quality, but mobilization of terrestrial POM in the burned areas is apparent. This may have implications for downstream reservoirs or stream reaches that receive this POM as its fate and transport is not well understood.

Isotopic and geochemical approaches to characterizing water movement through abandoned mine workings, Nelson-Wooster-Humphrey Tunnel Creede, Colorado

Rory Cowie, University of Colorado, Boulder, CO; Garrett Rue, University of Colorado, Boulder, CO; Mark W. Williams, University of Colorado, Boulder, CO; Mike Wireman, Region 8, U.S. EPA, Denver, CO

Long term acid mine drainage (AMD) discharging from the portal of the Nelson Tunnel near Creede, CO is currently impacting water quality in West Willow Creek and the Rio Grande River. We are using established isotope and geochemical tracer techniques to quantitatively determine the sources, ages and pathways of waters in the mine.

Preliminary results indicate that waters draining the mine are well mixed and composed to some degree of old groundwater not just meteoric inputs. The stable isotope (^{18}O) of the mine water is steady at -15 ‰ throughout the year, suggesting a well-mixed groundwater system composed of equal parts winter snow (-20 ‰) and summer monsoon rain (-10 ‰). Tritium (^{3}H) values within the tunnel are primarily "tritium-dead" indicating water that is at least older than the "bomb-spike" waters of nuclear weapons testing in the 1960s. Additionally, dissolved inorganic carbon (DIC) $\delta^{14}C$ testing indicates mine water on the order of hundreds to thousands of years of age. Results therefore suggest that mine waters are largely not directly connected to surface waters, or to the shallow groundwater (sampled from springs and domestic wells), but rather are likely entering the tunnel at intersections with a system of watershed-wide faults.

To provide age verification for the DIC $\delta^{14}C$ results the mine water samples were also analyzed for the $\delta^{14}C$ of dissolved organic carbon (DOC). To isolate the aquatic humic components of the DOC, the XAD Chromatographic technique was employed. This method involves first passing an HCl-acidified sample through a column packed with XAD-8 resin to selectively sorbs hydrophobic (fulvic) weak acids. Followed by an elution with sodium hydroxide and a rinse with DI water to remove chloride. Salts are then removed in the final step using a cation exchange resin-filled column, leaving only these isolated organic carbon constituents. Due to the high iron content of the mine waters, samples were passed through the columns several times to further isolate the humic components of the DOC. Additionally, fluorometer analysis of the final isolates resulted in fluorescence index values indicative of terrestrial carbon sourcing and minimal microbial influence.

The results from this study have been used to develop a hydrogeologic conceptual model of the mine complex, which will aid in the development and feasibility analysis of targeted remediation strategies.

Ice Effects On Stream Channels In The Rocky Mountains

Robert Ettema[1] and Edward W. Kempema[2]

[1]College of Engineering and Applied Science, University of Wyoming, Laramie, Wyoming, USA; Visiting Professor, Colorado State University, Fort Collins, CO

[2]Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming, USA

Fluvial ice forms seasonally, but can exert long-term effects on stream morphology and sediment transport in regions experiencing frigid periods such as the Rocky Mountains. Our presentation briefly describes ice formation and its effects in terms of time, length, and dynamic scales associated with thermal and fluvial processes in streams.

The effects encompass altered dynamics and thermodynamics of flow, the direct entrainment and transport of bed sediment by ice, adjustments in the transport capacity of ice-covered flow, localized increase in bed-material transport when and where ice accumulations increase local flow velocities, and ice gouging of channel bed and banks. The effects also have consequences for channel bank strength and loading, floodplain erosion, riparian vegetation and the winter ecology of fish.

We use fieldwork observations from the Laramie River in Wyoming, and other streams rivers in the Rocky Mountain region, to illustrate several of these processes. Long-term effects on channel planform have not been ascertained, though the seasonal instabilities are shown to pose problems for engineered structures, such as bridges, and for fish.

A particular focus of our presentation is on frazil and anchor ice which can form large masses covering 100's of m^2 of a streambed, and stick tenaciously to the bed for as long as the water remains supercooled. Although frazil and anchor ice usually form at night when conditions typically are more frigid, incoming solar radiation during daylight hours usually warms the water to the freezing point in the morning. When this occurs, anchor ice releases from the bottom and floats to the surface carrying entrained sediment that can potentially be ice rafted long distances downstream. The processes involved really are rather fascinating – they can be very delicate yet surprisingly robust – and require considerable further research. Their consequences for stream biota also require more research.

Flow Reconstruction from Riparian Cottonwood Trees

Jonathan M. Friedman, Jesse R. Edmondson, Eleanor R. Griffin, David M. Meko, Michael F. Merigliano, Julian A Scott, Michael L. Scott, Ramzi Touchan

In dry landscapes of the interior western US, seedling establishment of cottonwood (*Populus* spp.) often occurs only close to river channels after floods. Where winter is cold enough, cottonwoods also have distinct annual rings and can live up to 370 years, allowing reconstruction of the long-term history of river flows and channel locations. We have analyzed the annual rate of cottonwood establishment along streams in Montana, Wyoming, Colorado, North Dakota and Idaho. The upper Snake, Yellowstone and Green rivers all show a strong decrease in cottonwood establishment beginning in the late 1800s and continuing to the present, indicating a decrease in peak flows prior to flow regulation by large dams. In contrast, beginning in the late 1800s cottonwood ring widths along the Little Missouri River, North Dakota show an increase in annual growth that continues into the present. Because annual growth is strongly correlated with April-July flows (r=0.69) the ring-width data suggest an increase in April-July flows at the same time tree establishment dates suggest a decrease in peak flows. These results suggest that while increases in low temperatures have decreased snowpack, summer precipitation has increased.

Integrated hydrometeorological modeling in the Colorado Front Range using a multi-scale, multi-physics platform for hydrologic research and prediction

David Gochis, National Center for Atmospheric Research, Boulder, Colorado

Increasingly, Earth system science is integrating process information across spatial and temporal scales and across disciplines. From short-term high-impact weather events to long-term climate change users of Earth system models are demanding more flexibility in terms of process representation, spatial resolution and computational infrastructure. The WRF-Hydro modeling architecture, released in April 2013 was designed to help bridge the gap between traditional atmospheric and hydrological modeling communities. It provides a multi-scale/multi-physics platform for linking atmospheric models with physics-based, spatially-distributed hydrological models in a flexible, mass-conservative and parallel computing modeling architecture. In this presentation we will provide a brief synopsis of some recent applications of the modeling architecture for the research and prediction problem of flash flooding in the Colorado Front Range region. We will focus on two recent high-impact weather events, namely the 2011 Fourmile Canyon flash flood and the Great Flood of 2013. In addition to demonstrating the functionality of the modeling architecture, a number of hydrologic research issues will be discussed including the impact of burned landscapes on hydrologic response and the importance of high quality, spatially-distributed precipitation information.

Trends in snow accumulation and melt in Rocky Mountain National Park, Colorado, USA

Glenn G. Patterson
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Steven R. Fassnacht and Amanda Weber
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The seasonal snowpack in Rocky Mountain National Park is critical to the local and downstream water supply and the ecosystem of the park, and is important for winter recreational opportunities. Recent regional studies have illustrated that snow accumulation is decreasing, averaging on the order of -2 to -4 cm/decade; snowmelt is tending to be earlier, averaging on the order of -2 to -4 days/decade. Trends specific to Rocky Mountain National Park, on the other hand, appear to be less specific. From 30+ years of daily snow water equivalent (SWE) data collected at thirteen NRCS Snowpack Telemetry (SNOTEL) stations in and near the park, April 1 SWE has been changing by -4.7 to +1.1 cm/decade, with most stations slightly decreasing yet many of the changes being statistically significant. Trends in date of peak SWE were also increasing and decreasing, ranging from -4.4 to +3.2 days per decade. Monthly records from longer-term NRCS snow courses suggested that some declining trends began as early as the late 1930s, while other decreasing trends did not start until the late 1970s. Trends in April 1 SWE at snow courses ranged from -<1 to ->4 cm/decade.

The Bees' Needs: a Citizen Science Project of the University of Colorado Museum of Natural History

Alexandra P. Rose, Virginia L. Scott and M. Deane Bowers
University of Colorado

The Bees' Needs is a citizen science project designed to study the abundance and diversity of solitary wood-nesting bees and wasps in Colorado's Northern Front Range and to explore relationships of these metrics to surrounding landscape attributes. The large volunteer workforce behind this project not only allows us to survey a greater study area and increase sample sizes, it also provides us with an avenue to educate and inspire members of our community by helping them to better understand and conserve native pollinators. Volunteers are issued a standard bee block that they monitor throughout the summer. Data on completed nests are submitted every two weeks via our website, which not only acts as a portal to submit data, but is also being developed as an educational resource. During 2013, our pilot season, we partnered with 250 volunteers to provide 10,000 potential nesting sites for solitary wood-nesting bees and wasps. A preliminary summary of our pilot season findings will be presented along with plans for increased development of the project for 2014.

Review of the 2013 Water Year, including a closer look at the September 2013 storm rainfall totals

Zach Schwalbe and Nolan Doesken
Colorado Climate Center
Dept of Atmospheric Science
Colorado State University

This presentation will provide a descriptive summary of climatic conditions affecting precipitation and runoff during the 2013 Water Year (October 1, 2012 - September 30, 2013). An in depth look at the September storm that caused major flooding will also be presented. With a persistent drought in the 2012 Water Year, the start of the 2013 Water Year was looking to be a similarly dry year. The start to winter was very shaky, with much below average precipitation and snowfall leading to a much below average snowpack in the mountains. November 2012 was particularly dry and warmer than average. Colorado stayed dry for the Water Year going into March 2013 where it was looking like the dry pattern would continue. After the very warm November average temperatures where near to slightly cooler than average. Finally, late March snow storms started hitting Colorado. However, mostly the northern half of the state was the largest beneficiary of these storms. This pattern lasted into mid-May, allowing near average peak snowpack. Although the southern half of the state saw beneficial snow storms through April, the peak snowpack was still much below normal. Even with these late season snow storms, overall precipitation in Colorado for the water year remained below average through Ma y. June turned hot and dry, especially in the southeast portion of the state, causing severe drought and dust storms. Cooler temperatures and lively storms arrived to most of the state in July, thanks to a monsoonal flow that lasted into mid-August. The end of August and beginning of September were hot and dry through the state. Then, during the week of September 8th, monsoonal flow returned to Colorado causing large rainfalls of 17 plus inches along the Front Range, leading to the major flooding. Thanks to these storms, and over 600% of average precipitation for September, the Water Year precipitation for much of Colorado ended near to above average, with the exception of the drought stricken areas in southern Colorado which remain below 70% of average water year precipitation.

Fish endocrine disruption responses to a major wastewater treatment facility upgrade

Alan M. Vajda[1], University of Colorado Denver; L.B. Barber, U.S. Geological Survey

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The urban-water cycle modifies natural stream hydrology, and domestic and commercial activities increase the burden of endocrine-disrupting chemicals, such as steroidal hormones and 4-nonylphenol, that can disrupt endocrine system function in aquatic organisms. This paper presents a series of integrated chemical and biological investigations into the occurrence, fate, and effects of endocrine-disrupting chemicals in the City of Boulder Colorado's WWTF and Boulder Creek, the receiving stream. Results are presented showing the effects of a full-scale upgrade of the WWTF (that treats 0.6 m3 s−1 of sewage) from a trickling filter/solids contact process to an activated sludge process on the removal of endocrine-disrupting compounds and other contaminants (including nutrients, boron, bismuth, gadolinium, and ethylenediaminetetraacetic acid) through each major treatment unit. Corresponding impacts of pre- and post-upgrade effluent chemistry on fish reproductive end points were evaluated using on-site, continuous-flow experiments, in which male fathead minnows (Pimephales promelas) were exposed for 28 days to upstream Boulder Creek water and WWTF effluent under controlled conditions. The upgrade of the WWTF resulted in improved removal efficiency for many endocrine-disrupting chemicals, particularly 17β-estradiol and estrone, and fish exposed to the post-upgrade effluent indicated reduction in endocrine disruption relative to pre-upgrade conditions. Endocrine disruption responses of wild fish in Boulder Creek to the WWTF upgrade will be discussed.

Andean Hydrologic Research at Prehistoric Water Temple in Peru

Kenneth R. Wright, P.E., Ruth M. Wright, J.D.

The Inkamisana is a masterpiece of Inka civil engineering and construction for religious ceremonies and offerings focused on water. The architecture and hydraulic works define Inkamisana, built by Pachacuti, as a high-status temple for worship of water. Studies of the Inkamisana and mountain water supply were undertaken by Wright Paleohydrological Institute supported by a team from the University of Virginia.

The ancient temple has fourteen ceremonial fountains with three additional ones under construction at the time of abandonment. The water temple's mountain collection system, canals, fountains, and conduit/distribution system were painstakingly executed and represent exquisite Inka design and construction. Extensive rock carving on the adjacent cliff represents classic Inka religious and ceremonial displays.

Eight terraces lie northwest and immediately adjacent to the Inkamisana. The terrace complex was adopted by the Inka from earlier people and rebuilt as their own. Water was derived from two sources, a mountainside Quebrada and the Rio Patakancha, but not a spring as expected.

Intricate and carefully executed cliff carvings that parallel the water temple add an important dimension to this spectacular Inka temple for the worship of water.