PROGRAM

76th Annual
Meeting Rocky Mountain Hydrologic Research Center
https://rmhrc.org/

Wednesday, 30 November 2022: 8 am to 3:00 pm
Boulder Jewish Community Center
6007 Oreg Avenue, Boulder, CO 80303

View of Black Hollow, Poudre River Canyon, Colorado following the 2020 Cameron Peak Fire and 20 July 2021 rainfall event. Photo: J. Kean

Purpose of the Meeting

To provide researchers, practitioners, and students an opportunity to share and discuss their research in a relaxed yet scientifically stimulating atmosphere. The meeting encourages interdisciplinary communication among a variety of investigators in the fields of hydrology, engineering, environmental sciences, water resources, and other related hydrological disciplines.

The RMHRC Board meeting will follow the technical session.

76th Annual Meeting Organizing Committee: Bob Milhous, Sandra Ryan, and Jason Kean with generous help from Debby Martin and John Moody.

Many thanks to Tracy Weber, Boulder JCC Event and Rental Director.

76th Annual Meeting of the Rocky Mountain Hydrologic Research Center 30 November 2022 Venue: Boulder Jewish Community Center, 6007 Oreg Avenue, Boulder, Colorado https://rmhrc.org/	
This is a hybrid meeting with in-person and virtual attendance conducted on the Zoom platform. Meeting link: https://us02web.zoom.us/j/82817785109?pwd=aWRKNlJVbGpSbiswTXdMZENCd2laQT09 Meeting ID: 828 1778 5109 Passcode: 472047 For questions during the meeting: Please text Debby Martin, 720-320-2113 or use Zoom chat window.	
Please note you will need to bring your own lunch.	
8:00-8:30	Registration, Coffee
8:30-8:50	*Debby Martin, President, Rocky Mountain Hydrologic Research Center* **Welcome, Introductions**
	**Presenting Author*
8:50-9:15	*John A. Moody*, Gino Ghinassi, and Riccardo* Maitan **Discharge Variability of Powder River and its Effects on the Sedimentary Record**
9:15-9:40	*Antonio Reveles-Hernandez*, Gabrielle Mather*, Sharon Bywater-Reyes, James Doerner* **Tree Core Analysis of Powder River Russian Olive**
9:40-10:05	*Kenneth R. Wright* **Droughts at Lake Titicaca and Mesa Verde**
10:05-10:30	**BREAK**
10:30-10:55	*Matthew A. Thomas* *[INVITED]* **The evolution of debris-flow hazard potential in the years following wildfire**
10:55-11:20	*Danielle W. vonLembke*, Matthew A. Thomas, Jaime Kostelnik* **Quantifying Trends in Vegetation Regrowth Following the 2020 Grizzly Creek Fire (Colorado, USA) Using Remotely Sensed**

	Vegetation Indices
11:20-11:45	*Natalie Collar*, Claire Vavrus*, Andrew Earles, Jeff Sickles, Chris Sturm, Katie Jagt* **Identifying post-fire debris flow hazards in a pre-fire context for the state of Colorado**
11:45-12:10	*Jason Kean** **Colorado's 2020 wildfires and 2021 debris flows**
12:10-1:00	**LUNCH**
1:00-1:25	*Peter Goble*, Becky A. Bolinger, Russ Schumacher, Colorado Climate Center, Colorado State University* **Colorado's Climate: Water Year 2022 in Review**
1:25-1:50	*Sara R. Warix, Alexis Navarre-Sitchler, Andrew H. Manning, Kamini Singha [INVITED]* **Local topography and hydraulic conductivity influence riparian groundwater age and groundwater-surface water connection**
1:50-2:15	*Sharon Bywater-Reyes*, Mimi Dunda, Keaton Macmillan, Sarah Holland, Nathan Duggins, Jeremey Burton, Antonio Reveles-Hernandez* **Evaluation of the Resilient St. Vrain Project with Implications for Ecogeomorphic Function and Flood Dynamics**
2:15-2:40	*Robert Milhous* **Environmental flows: research science versus applied science**
2:40-3:00	**MEETING DISCUSSION**
3:00	**Adjourn**

Discharge Variability of Powder River and
its Effects on the Sedimentary Record

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30 November 2022

Interannual peak-discharge variability of rivers is a current interest in the field of sedimentology because it can affect sedimentary features preserved in the rock record. Many tropical rivers, like the Amazon River, have a single, annual peak-discharge event; however, many rivers in the temperate zone, like Powder River, have an intra-annual variability characterized by multiple peak events per year associated with different climate phenomena. Powder River can have four types of peak events: (1) ice-breakup events in the late winter and early spring from runoff at low elevations, (2) snowmelt events generally in May and June from runoff at higher elevation, (3) flashflood events associated with convective storms during the summer months at low elevations, and (4) fall events from October-December associated with rain on early snowfall.

The discharge record for Powder River at Moorhead, Montana (USGS station 06324500), spans almost 100 years from 1930 to the present day and represents a short-term climatic record. After a 50-year flood in 1978, the interannual peak-discharge variability changed, caused by a decrease in the mean annual peak-discharge. We hypothesize that this may also reflect a change in the intra-annual discharge variability, and thus, a change in the short-term climate. We separated the discharge record into two-time intervals: 1930-1977 (46 years with no data in 1973 and 1974) and 1978-2022 (47 years). Events were identified as those discharges that exceeded the threshold of 12.7 $m^3 s^{-1}$ (equal to the mean annual discharge at Moorhead). Each event was characterized by: (1) the type of flood, (2) the peak discharge, and (3) the volume of water discharged while the flow was greater than the 12.7 $m^3 s^{-1}$ threshold. Sediment observations were made in September 2022 on two cutbank exposures of point bars dated from approximately 1930 through 1977 based on dendrochronology, and in one trench excavated along a point-bar axis to expose sediments deposited from 1978 through 2022 based on annual topographic surveys.

There was no statistical difference in the total number of events per year during 1930-1977 (6.4 events/yr) and 1978-2022 (5.8 events/yr). However, the difference in the number of flashfloods was statistically significant ($p < 0.008$; 1.8 and 1.0 events/yr, respectively). Flash floods commonly transport mud (silt and clay), which can vary in color depending on which tributary was exposed to the convective storm. The peak discharges of 10 flashflood events during 1930-1977 were greater than the peak discharges of the preceding snowmelt events, which is a necessary condition for depositing continuous mud drapes over sediments left by the preceding snowmelt event. In contrast, only 5 flashflood events met this condition during 1978-2022. The impact of this change in hydrology was that nine mud drapes were identified in the 1930-1977 stratigraphy, but only one was identified in the 1978-2022 stratigraphy. This documented change in the sedimentary record appears to reflect the variability in discharge associated with changes in the short-term climate over almost 100 years.

Tree Core Analysis of Powder River Russian Olive

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30 November 2022

Russian olive (*Elaeagnus angustifolia*) is an invasive species that was introduced to the Western United States. The distribution and spread of Russian olive on river processes and ecological community structure has been widely studied in the U.S. Southwest. However, the distribution and spread of Russian olive is unknown in northern regions. To study the distribution and spread of Russian olive, we focused on a reach within the Powder River, near the town of Broadus, Montana. We took tree core and tree rings samples. The tree ring samples will allow us to study the establishment year and spatial distribution of Russian olive in the Powder River, and to understand which environmental factors control Russian olive spread.

The samples of Russian Olive were retrieved between the 26th and 29th of July 2021 along a 15-kilometer reach of the Powder River. The collections were composed of disks from cut down trees, and cores from drilling samples. After sanding and prepping the material, we measured the length (micrometers) of each ring through Measure J2X. The data were then uploaded to xDateR to run introductory analysis and gather figures. This initial analysis allows us to cross-date our tree ring collection to statistically check for any missing or false rings to get an establishment year for each tree ring sample. We then used ArcGIS to conduct spatial analysis to understand how Russian olive is spatially distributed. We standardized the years using R to reconstruct streamflow of the area. During our analysis, we found that the oldest Russian olive that we sampled were established in the 1970s. Older Russian olives were along the bank of the river, whereas younger Russian olives were found in the floodplain under a canopy of cottonwood trees. This is consistent with other results from our study. Establishment occurs first near the river, and the river spreads Russian olive near the banks. Birds and other animals then spread Russian olive from the river into the floodplain.

Droughts at Lake Titicaca and Mesa Verde

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30 November 2022

Modern people can learn much through the study of how ancient civilizations dealt with climate change. The ancient Andean and Ancestral Pueblo people encountered much difficulty due to the vagaries of their altering environments. Details on both cultures, what they experienced, and how they addressed climate change can provide modern inspiration.

Through many decades of study, the scientific community has gained considerable insight into the environmental management techniques of ancient Andean civilizations These include the Tiwanaku Empire centered near the south shore of Lake Titicaca. The environmental stresses faced by the Tiwanaku Empire are examined as an example of the consequences of underestimating environmental risks.

The ancient Ancestral Puebloan people of Mesa Verde, popularly known as the Anasazi, reconciled their lifestyle to the semi-arid and changeable climate. These dryland farmers who lived at Mesa Verde from about AD 550 to about AD 1300 contended with periods of drought and occasional cool growing seasons. Dealing with climate variability was tough for people living in an already harsh environment with few resources. One of the ways the Ancestral Puebloans adapted to their difficult surroundings was by becoming reservoir builders.

Wright Paleohydrological Institute, a team of scientists, engineers, and archaeologists devoted to the study of prehistoric water use, began investigating Andean and Ancestral Puebloan water handling in 1995.

The evolution of debris-flow hazard potential in the years following wildfire

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[INVITED]

30 November 2022

Deadly and destructive debris flows often follow wildfire, but quantitative constraints on changes in hazard potential with time are lacking. I will present a new simulation-based framework that quantifies changes in the hydrologic triggering conditions for debris flows as postwildfire infiltration properties evolve through time. This approach produces time-varying rainfall intensity-duration thresholds for runoff- and infiltration-generated debris flows with physics-based hydrologic simulations that are parameterized with widely available hydroclimatic, vegetation reflectance, and soil texture data. When I applied the simulation framework to a test case in the San Gabriel Mountains (California, USA), the resultant thresholds were consistent with existing regional empirical thresholds and rainfall conditions that caused runoff-generated debris flows soon after the fire and infiltration-generated debris flows three years following the wildfire. This work demonstrates that the hydrologic triggering mechanisms for the two observed debris flow types are coupled with the effects of fire on the soil saturated hydraulic conductivity. Specifically, the rainfall intensity needed to generate debris flows via runoff increases with time following wildfire while the rainfall duration needed to produce debris flows via subsurface pore-water pressures decreases. These simulations also suggest that variations in soil moisture, rainfall climatology, median grain size, and root reinforcement could impact the median annual probability of postwildfire debris flows. This simulation-based method for calculating rainfall thresholds appears to be a tractable approach to improve situational awareness of debris-flow hazard in the years following wildfire. Further development of this framework will be important to quantify postwildfire hazard levels in variable climates, vegetation types, and fire regimes.

Quantifying Trends in Vegetation Regrowth Following the 2020 Grizzly Creek Fire (Colorado, USA) Using Remotely Sensed Vegetation Indices

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30 November 2022

On 10 August 2020, the Grizzly Creek Fire began burning in Glenwood Springs, Colorado. During the first monsoon season following the fire (June to September 2021), multiple rainstorms initiated debris flows, which damaged and temporarily closed Interstate Highway 70. Despite high-intensity rainfall in the second monsoon season following the fire (June to September 2022), no debris flows were observed. To better understand the state of vegetation recovery at these intervals, we used multiple remote sensing products to quantify regrowth. We used the Sentinel Hub EO Browser to acquire Landsat-8 (Collection 2 Level-2 processing) and Sentinel-2 (Level-2A processing) satellite imagery within the footprint of the fire. Landsat-8 has a spatial resolution of 30 m and a revisit time of 16 days. Sentinel-2 has a spatial resolution of 10 m and a revisit time of five days. Using ArcGIS Pro (version 2.9.2), we computed the normalized difference vegetation index, enhanced vegetation index, and the normalized burn ratio across the entire burn area for seasonally consistent dates before (as far back as four-years) and after the fire. To simplify the display and comparison of the indices, we computed the mean of each vegetation index for each basin in the burn area. We observed a sharp decline in vegetation reflectance followed by a generally monotonic increase in reflectance following the fire. On average, vegetation indices recovered to within approximately one-third and two-thirds of pre-fire levels by the beginning of the first and second monsoon season, respectively. We conclude that the Landsat-8 and Sentinel-2 imagery present consistent trends in post-fire vegetation recovery when averaged at the basin scale in our study region.

Identifying post-fire debris flow hazards in a pre-fire context for the state of Colorado

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30 November 2022

At the directive of Senate Bill 21-240, the Colorado Water Conservation Board (CWCB) initiated a statewide post-fire susceptibility study known as Wildfire Ready Watersheds (WRW). This initiative will assess the vulnerability of Colorado's water resources and critical infrastructure to post-wildfire impacts and advance a framework for communities to plan and implement mitigation strategies to minimize fire-exacerbated risks *before* wildfires occur. Post-fire hazards to be evaluated include potential hydrogeomorphological hazards like flooding and debris flows. However, no spatially continuous debris flow probability estimates currently exist for the entire state.

Over the last decade, the United States Geological Survey (USGS) developed logistic regression equations to estimate debris flow likelihood in burned catchments in the intermountain West for variable rainfall intensities (Staley et al., 2016, 2017). These models are typically employed in a post-fire context, such as when a multi-agency Burned Area Emergency Response (BAER) team is activated after fire impacts federally owned land or at the specific request of an agency. To meet WRW's need for predictive debris flow probability spatial data, the USGS's intermountain West M1 regression equation was applied to every Colorado watershed in the United States Environmental Protection Agency's (USEPA) Catchments data layer. Readily available gridded data products were used for terrain, soils, and rainfall model inputs. *A priori* burn severity estimates were inferred from the United States Forest Service's (USFS) FlamMap model, which were subsequently transformed to a numerically-continuous representation of burn severity by calibrating the inferential burn severity classes to Colorado-specific dNBR data broken out by arid and non-arid regions. Results were compared with USGS debris flow predictions for pre-existing burn scars and disagreement between the estimates and sources of uncertainty were explored. This work provides valuable insight into the methods and tools available to natural resource managers as they face increasingly severe and erratic wildfire behavior. Results and lessons learned are readily transferable to other small and large-scale pre-fire efforts in the arid, fire-prone West.

Colorado's 2020 wildfires and 2021 debris flows

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Following the worst wildfire season in history in 2020, Colorado was hit again by a series destructive flash floods and debris flows triggered by 2021 monsoon rains. The impacts of debris flow in Glenwood Canyon were especially severe and the threat of repeat events remains. I will discuss the science of predicting post-fire debris flows and outline the ongoing interagency work to identify these hazards and mitigate impacts. I will also describe the state of vegetation recovery and discuss the likelihood of events next year.

Local topography and hydraulic conductivity influence riparian groundwater age and groundwater-surface water connection

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30 November 2022

The western U.S. is currently experiencing changes in recharge patterns as a result of climate change leading to increasing rain to snow ratios. It is currently unclear how these changes are going to impact groundwater-surface water connection in montane headwater catchments. This study combines field observations to investigate the source and mean age of groundwater contributing to Hotel Gulch, a montane headwater stream in the Manitou Experimental Forest, CO, USA. We instrumented eight sites along Hotel Gulch and combined combine measurements of continuous stream discharge, groundwater level, stream and groundwater specific conductivity, groundwater residence times, and physical metrics of local slope and streambed hydraulic conductivity to identify correlations between groundwater residence time and the ability of that groundwater to contribute to streamflow. We observed the oldest groundwater in the catchment in the upper and lowermost watershed and that mean groundwater age ranged from 10-55 years. We found that local slope and streambed hydraulic conductivity are correlated with the age of groundwater and the amount of groundwater in streamflow. We hypothesize that where local slope is high, interflow contributes to riparian groundwater and that where alluvial sediment is present, it serves as a shallow alluvial aquifer and buffers seasonal change in groundwater age. We suggest that physical metrics can provide insight into how groundwater and streamflow may respond to shifts in recharge as a result of climate change and hypothesize that future stream drying is more probable in areas where local slope is relatively steep and mean groundwater age is young.

Evaluation of the Resilient St. Vrain Project with Implications for Ecogeomorphic Function and Flood Dynamics

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We are assessing the effectiveness of the Resilient St. Vrain Project (Longmont, Colorado) by characterizing: 1) the health of the riparian system in terms of vegetation-channel-flow relationships, 2) geomorphic condition in terms of complexity and bed mobility, and 3) the ability of the St. Vrain to withstand future 100-year flow events. As such, we collected physical and ecological parameters. Along transects, we identified and counted woody vegetation within 10x20m plots perpendicular to the river. We recorded functional traits such as height, diameter, number of branches, and flexibility, measured using a digital force gauge. Certain species demonstrated characteristics expected to enhance sediment aggradation. Plum required a two times higher force than sandbar willow to bend, indicating its potential to influence hydraulics through drag. Invasive Russian olive was observed (as was tamarisk) in restored reaches and is also rigid. In contrast, most native species are flexible (cottonwood, sandbar willow, and peachleaf willow) and are estimated to be low-influence on morphodynamics due to their minimal ability to cause sediment to drop out of suspension, but they have higher overall prevalence and densities. The downstream-most reach had the highest Shannon's Diversity Index and evenness. This reach was restored first and also has a wider floodplain, which may account for these results, but planting strategy likely also contributes.

To investigate whether grain-size distributions have changed since construction, grain size was collected with a gravelometer using the Wolman method. Samples were collected by randomly selecting grains while moving in a zig-zag pattern across the area, until 100 diameters

greater than 2mm were recorded. We found spatial variations in grain size, with finer grain sizes in depositional areas (Price Road and Dickens Farm). In upstream reaches, repeat measurements showed coarsening, whereas downstream showed fining. We surveyed topography (longitudinal profile, cross sections, and ground-control points) with RTK GPS. Slope was as designed (0.03) for the entire study area, but with some local variations (concave-up sections near Price Road and pools near Dickens Farm) likely responsible for grain-size patterns as the profile adjusts. High-resolution channel topography was constructed with Structure from Motion (SfM). A combination of Matrice 100 and Leptron RDASS with Rededge-M legacy 5-band sensor collected imagery post-processed in Agisoft Metashape to produce models with ~5cm resolution and accuracy. These will be used to compare to as-built surfaces and for input into a hydraulic model. This work contributes to our understanding of channel restoration techniques within urban areas.

Environmental flows: research science versus applied science

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30 November 2022

There has been considerable good work done by both researchers in an academic setting and in those in a non-academic setting where the issues are defined by policy questions. In an opinion article about optimization Thomas Walski (2014).made the following comment:

Usually a researcher in this area will define a problem, read the literature, select a method, modify the problem so that it fits the method, write a program, and publish a paper. The problem lies in the step of modifying the problem to fit the method. This usually involves some (often hidden) assumptions that can result in meaningless or even misleading solutions. This would not be problematic if the researcher carefully pointed out the limitations in the solution. Instead, the assumptions and limitations are incorporated in a publication and becomes the starting point for the next researcher, who has as little appreciation of the problem as the first researcher.

The problems identified by Walski appear to apply to environmental flow research as well. This paper investigates the issues by comparing the papers in proceedings of a symposium held by the Instream Flow Council in 2015 to the papers in the proceedings of two symposium of the Ecohydraulics Section of IAHR, one held in 2014 and the second in 2016. All three symposium proceedings have many good papers but there is significant differences in the focus between the researchers and the people actually establishing instream flow needs.

Reference, Walski, Thomas 2014. Consequential Research. Journal of Water Resources Planning and Management. MayASCE, Pages 559-561.DOI: 10.1061/(ASCE)WR.1943-5452.0000430