MONTANA NSF EPSCoR

# NEWSLETTER

**CREWS 2018-23 HIGHLIGHTS**

A scientist kneels on along the banks of the Upper Clark Fork River. Research on the Upper Clark Fork River (see page 4), Judith River Watershed (see page 5), and Powder River Basin (see page 6) under the Montana NSF EPSCoR RII Track-1 Consortium for Research on Environmental Water Systems (CREWS) project addressed the origin, persistence, and transformation of contaminants in water, and their impact on ecological and social systems. The vision of CREWS, outlined in the project graphic on the next page, was to create a collaborative network of interdisciplinary scientists to conduct cutting edge research, address water equality, and support Montana's economy. *Photo credit: Colton Kyro.*

# CREWS OUTCOMES

### MONTANA NSF EPSCOR RII TRACK-1 CREWS OUTCOMES

Montana's NSF EPSCoR RII Track-1 "Consortium for Research on Environmental Water systems, (CREWS) project has made substantial contributions to science, education, and engagement. Over the past five years, CREWS scientists and professionals have worked collaboratively to address water quality issues related to three important industries in the Montana economy: mining, agriculture, and energy. Researchers from institutions across the state explored how changing compositions and levels of nutrients and contaminants affect water quality, and the related impacts for local communities that rely on clean water.

CREWS field teams worked in three Montana landscapes where water systems and economic activity are inextricably linked: the Upper Clark fork River, the Judith River Watershed, and the Powder River Basin. In the laboratory, molecular scientists and engineers worked on new technologies to remediate contaminated water and developed and applied innovative sensing technologies to measure concentrations in environmental water systems. Social scientists linked the science to people by exploring community engagement, perceptions, and governance related to water quality.

Over the course of the project, CREWS strategically invested in Montana's research capacity and workforce. The project hired four new faculty, supported over 77 faculty and 102 postdocs and graduate students, and engaged over 190 undergraduate students in research activities and internships. CREWS researchers produced a diverse portfolio of over 165 peer-reviewed disciplinary and interdisciplinary publications that disseminated discoveries and outcomes. Over the course of the project, CREWS faculty leveraged over $82 million in new funding. Researchers partnered with 70 collaborating organizations across the state, and this partnership network will contribute to water quality research in Montana for years to come.

CREWS provided significant investments in K-12 outreach and education, diversity initiatives, and STEM opportunities for the general public (STEM: Science, Technology, Engineering, and Math). These activities and programming reached over 100,000 members of the public, K-12 teachers, students, and other stakeholders in Montana. Six substantial grants were made to tribal college faculty. CREWS supported Native graduate students in STEM disciplines, provided a research seminar for minority students, and supported summer STEM camps for middle school students from Montana's Tribal communities.

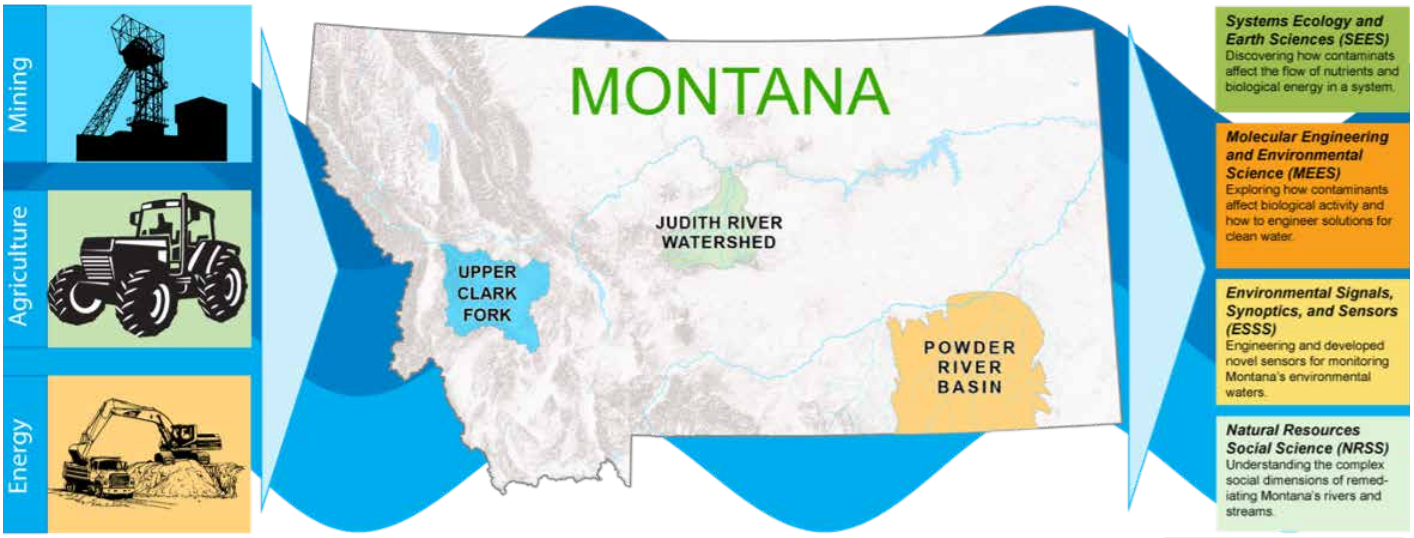
CREWS faculty, students, professionals, and partners have made outstanding contributions to Montana's research and education capacity. This publication highlights some of these achievements and provides a sampling of activities carried out over the 5-year CREWS project.

## VISION

Our vision is to create a collaborative network of interdisciplinary scientists to conduct cutting edge research, address water quality and support Montana's economy.

## CREWS — CONSORTIUM FOR RESEARCH ON ENVIRONMENTAL WATER SYSTEMS

CREWS' science focus is on water quality challenges related to hard rock mining, intensive agriculture, and energy extraction. The project brings together faculty and students from the earth sciences, molecular sciences and engineering, environmental science, synoptic signal and sensors technology, and natural resource social sciences to address National Research Council challenges to develop better understanding of how contaminants affect water quality.




## OUTCOMES

- Interdisciplinary Science Discovery
- Data Products
- Education and Diverse STEM Workforce Development
- Stakeholder Integration
- Innovation and Commercialization
- Economic Development
- Research Competitiveness


Graphic illustrating CREWS partner institutions. CREWS was developed as a partnership between the University of Montana (UM), Montana State University (MSU), Montana Technological University (MTU), Salish Kootenai College (SKC), and Little Big Horn College (LBHC). Through competitive seed funding opportunities, new higher education partners include Carroll College, University of Montana Western (UM-W), Montana State University-Billings (MSU-B), and Rocky Mountain College (RMC).

# CREWS BY THE NUMBERS

## OUTCOMES OF MONTANA NSF EPSCOR RII TRACK-1 PROJECT

**77** total faculty, **102** postdocs and graduate students, **192** undergraduate students, **32** technical support staff, and **42** non-technical support staff were involved with the CREWS project.

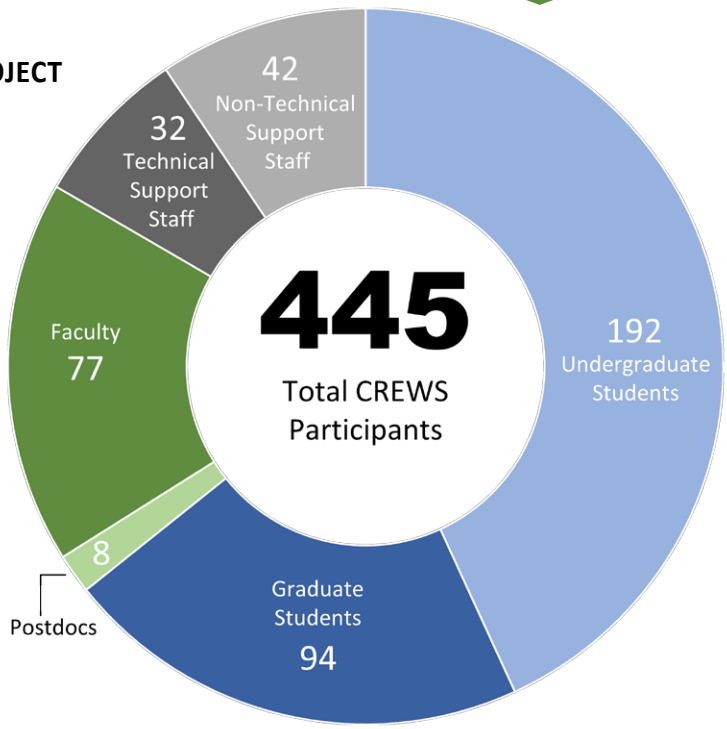
**214** individuals from **70** partnering organizations and institutions collaborated with CREWS researchers over the course of the project.

**$43M** in awards supported through NSF EPSCoR co-funding.

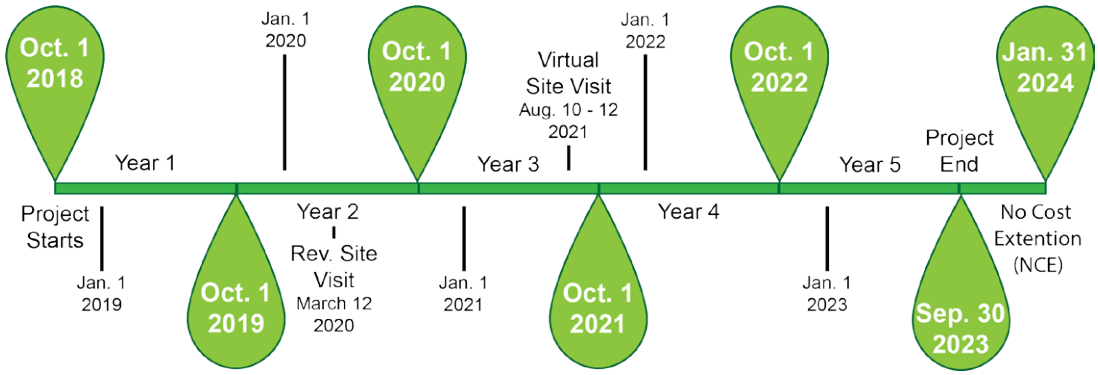
**165 PUBLICATIONS** - Cumulative total number of publications released by CREWS researchers by the end of the project.

**25 SEED FUNDED PROJECTS** - Total number of projects that received CREWS seed grants. These included 6 tribal seed funded projects, 7 research seed funded projects, and 12 workforce development seed funded projects *(see page 8 for highlights on these projects).*

**51 INTERNSHIPS** - Total number of internships funded through CREWS. These included 14 research internships, 12 commercialization internships, and 25 workforce development internships *(see pages 13-14 for highlights on these internships).*

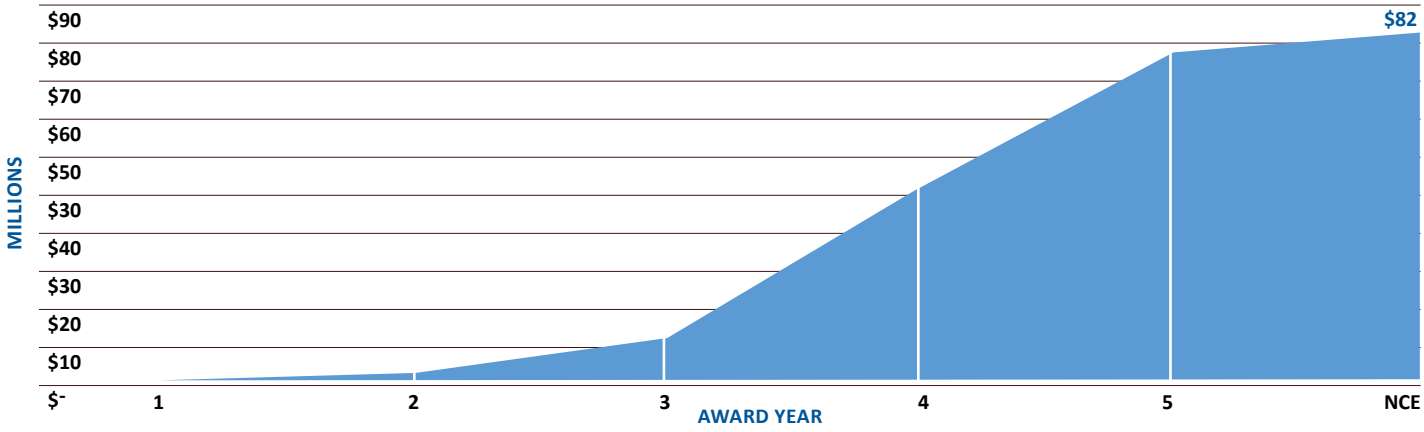



## MT NSF EPSCOR PROJECT TIMELINE



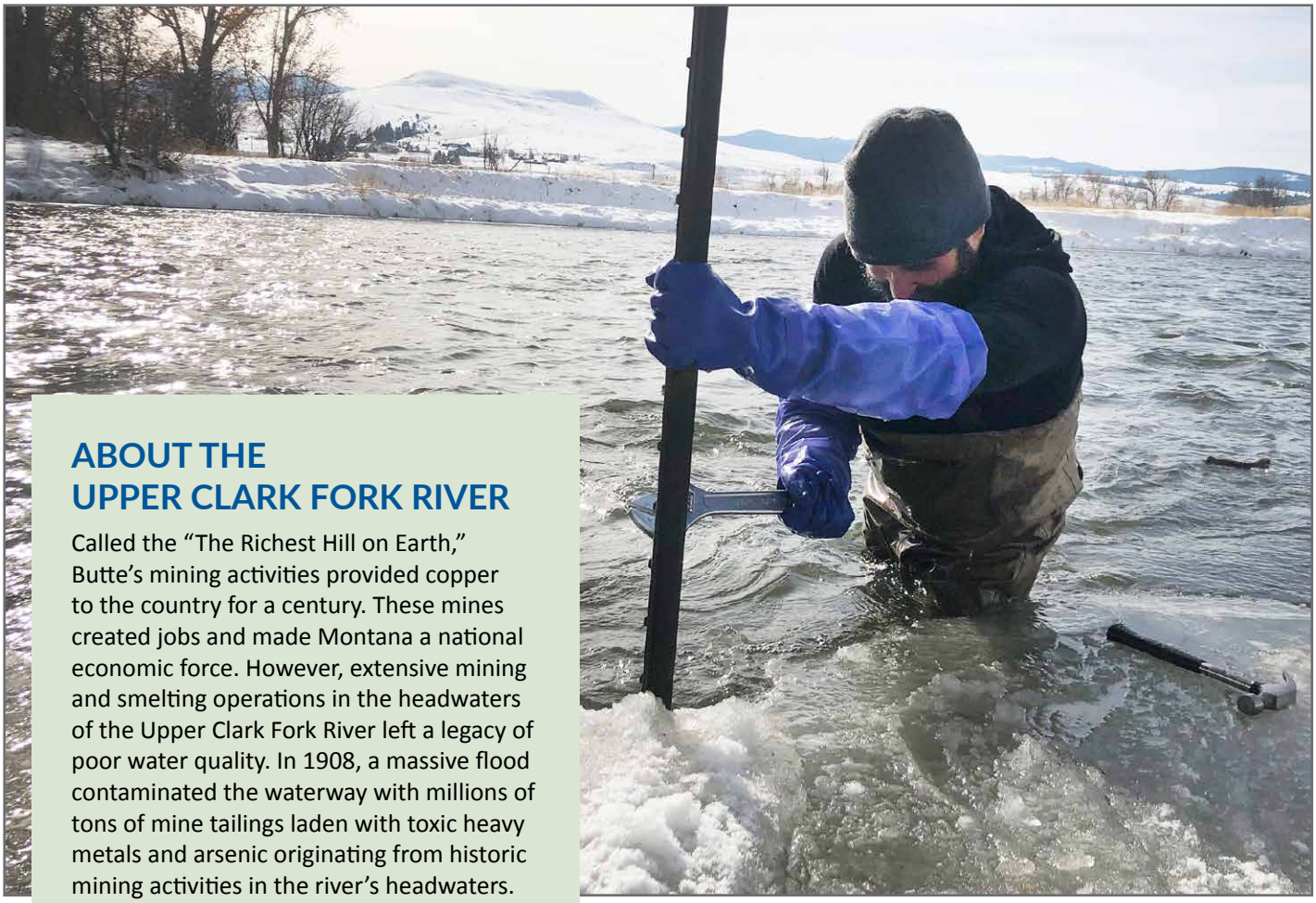

Timeline of the Montana NSF EPSCoR RII Track-1 CREWS project illustrating the major dates and milestones. This Special Issue newsletter highlights activities that occurred across all five years of the project (from 2018-2023, noted on the timeline).

## CREWS PROJECT GRANTS & AWARDS CUMULATIVE GROWTH




Cumulative total growth of CREWS project grants and awards between 2018 to 2023. Researchers leveraged CREWS work and support to secure major new grants and co-funding over the course of the project.

# UPPER CLARK FORK RIVER



## ABOUT THE UPPER CLARK FORK RIVER

Called the "The Richest Hill on Earth," Butte's mining activities provided copper to the country for a century. These mines created jobs and made Montana a national economic force. However, extensive mining and smelting operations in the headwaters of the Upper Clark Fork River left a legacy of poor water quality. In 1908, a massive flood contaminated the waterway with millions of tons of mine tailings laden with toxic heavy metals and arsenic originating from historic mining activities in the river's headwaters. Today the Upper Clark Fork River is part of the largest EPA Superfund complex in the U.S. and one of the focus landscapes of the CREWS project. A once ecologically vibrant stream providing fishing, wildlife habitat, and water for agriculture and growing communities needs cleanup and repair. The water contains heavy metals, and the problems these cause are compounded by nutrient enrichment from municipal and agricultural development interacting with naturally high phosphorus availability. The result? Striking geographic gradients in pollutants, changed ecological conditions, and complex social responses. Following decades of litigation, restoration efforts are now underway, including removal of contaminants and restoration of the river's floodplain.

CREWS postdoctoral researcher Rafael Feijo de Lima breaks the ice off of a sensor post in the Upper Clark Fork River before retrieving a submerged autonomous sensor bundle. *Photo credit: Claire Utzman.*

## CREWS RESEARCH ACCOMPLISHMENTS

Building on previous research projects developed at the University of Montana, the CREWS research team quantified and monitored river sediment metals (copper, arsenic, zinc, cadmium, and lead) and nutrients along 200 km of the river. Social science researchers studied how water quality issues and solutions are influenced by the people who live and work along the Upper Clark Fork River. CREWS also studied river productivity, algal blooms, ecological integrity, and developed the science needed for technical solutions that address the character of contaminants and the social and ecological systems that depend on the Upper Clark Fork River.

The CREWS Upper Clark Fork River team had several notable scientific accomplishments across the span of the project. First, researchers on the team published a conceptual model that

Students from Montana State University and the University of Montana work on the Upper Clark Fork River to assess algae levels, both through hyperspectral imaging with a drone and collecting algal samples directly from the river. *Photo credit: Lark Olson.*

Members of the CREWS Upper Clark Fork River team pose for a picture during the "Big Diel," a research campaign in which twelve researchers and students continuously sampled for 48-hours on the Clark Fork River. The goal of the campaign was to characterize diel cycles of nutrients and carbon dioxide alongside metals and arsenic in the river. *Photo credit: Ben Colman.*

looks at how snowmelt runoff impacts the Upper Clark Fork River. The development of this conceptual model was made possible by the existing collaboration between CREWS and the NSF Long Term Research in Environmental Biology (LTREB) project on the Clark Fork. Second, through CREWS, researchers were able to create a more rigorous metabolism model for carbon dioxide time-series data. This updated model, when combined with other data, provides powerful insights into the dynamics of carbon in rivers and streams. Finally, the CREWS Upper Clark Fork River team investigated the potential of a continuous flow material recovery system to remove contaminants from water. They found that the system effectively captured and removed magnetite and copper, with the potential for other contaminants like lead, phosphate, and rare earth elements.

Bob Hall, a CREWS researcher at the Flathead Lake Biological Station through the University of Montana, was recognized as a fellow with the Association for the Sciences of Limnology and Oceanography (ASLO) in 2021. *Photo credit: Bob Hall.*

## BOB HALL RECOGNIZED AS ASLO FELLOW

CREWS researcher Robert (Bob) Hall was recognized as an ASLO (Association for the Sciences of Limnology and Oceanography) fellow for the year 2021 for his sustained excellence in contributions to aquatic sciences. The Fellows program began in 2015 as a way for ASLO to acknowledge those members who consistently contribute to ASLO through their service to journals, conferences, and committees that advance the science of limnology and oceanography. Bob Hall is a professor of limnology at Flathead Lake Biological Station through the University of Montana, where he has worked since 2017. He has been interested in stream carbon cycling since attending graduate school at the University of Georgia. Hall's current work links geomorphology to stream metabolism and nitrogen cycling, time-series analyses of river metabolism, isotope tracers, and dissolved organic carbon (DOC) dynamics in streams.

# JUDITH RIVER WATERSHED

## ABOUT THE JUDITH RIVER WATERSHED

A tributary of the Missouri River, the Judith River runs through central Montana with its headwaters in the Little Belt, Highwood, and Big Snowy Mountains. The river's watershed is a productive agricultural region dominated by livestock, small grains, and forage production. Due to exceptionally shallow unconfined aquifers and gravelly soils, agricultural activities in the Judith River Watershed over the last century have gradually resulted in elevated levels of nitrate and low levels of herbicides in ground water, challenging farming communities to find workable solutions that address both water quality and soil health concerns while also sustaining local livelihoods. Researchers within the Montana State University Department of Land Resources and Environmental Sciences, Montana Agricultural Experiment Station, and Extension Service have worked extensively with local producers and stakeholders to complete initial research on water chemistry and quality in the Judith River Watershed.

A CREWS researcher records water sample data in the Judith River Watershed as part of the team's summer fieldwork campaign in Year 4.
*Photo credit: Rachel Anderson.*

## CREWS RESEARCH ACCOMPLISHMENTS

The CREWS project built upon these efforts with new scientific partnerships to determine key controls on movement of nitrate and residual herbicide through soils, groundwater, and streams. The team investigated these systems at scales ranging from molecular science to landscape studies to understand drivers of nitrate and herbicide levels in groundwater. Researchers and students contributed diverse understandings of how agricultural land use in Montana is connected to water quality across the realms of biogeochemistry, hydrology, and human communities. For example, team members looked at how riparian areas and groundwater inflows influence water

chemistry and the dynamics of compounds like nitrate in different hydrologic systems across the Judith River Watershed.

The team's important contributions are documented in a range of research publications and community conversations, as community partners helped to evaluate and communicate the results of their studies. Several graduate students completed their studies as part of CREWS and are now entering the research and regulatory community inside and outside of Montana. Ultimately, students and researchers benefited from the team's multidisciplinary dialog in details of non-irrigated agriculture, the complexity of soil-water interactions, photochemistry, membrane interactions, groundwater dynamics, plant community and geospatial assessment. These efforts have lead to innovative technologies for removing nitrate and other contaminants from water and a deeper understanding of the realities for local, rural communities that manage these environments.

CREWS graduate student Madison Foster processes water samples from the Judith River Watershed in the Environmental Analytics Lab at Montana State University. *Photo credit: Adrian Sanchez Gonzalez.*

A truck used for filling water sits in the town of Ryegate, MT. Members of the CREWS Natural Resource Social Science team working in the Judith River Watershed examined rural water infrastructure and the effects of a proposed regional drinking water system in towns like Ryegate as part of the project. *Photo credit: Grete Gansauer.*

## CREWS NATURAL RESOURCE SOCIAL SCIENCE TEAM PUBLISH ARTICLES EXAMINING RURAL WATER INFRASTRUCTURE, DECISION-MAKING, AND COMMUNITY RESILIENCE

CREWS Natural Resource Social Science (NRSS) and Judith River Watershed teams published two articles in Summer 2023. The first article, titled "Social memory and infrastructure governance: A century in the life of a rural water drinking system" was published in Environmental Research: Infrastructure and Sustainability. The paper examined how shared social memories of water hardship impact water governance decision-making in the town of Denton. Authors included NRSS leads Julia Haggerty and Libby Metcalf, JRW lead Stephanie Ewing, and graduate students Grete Gansauer and Jennifer Dunn. The second paper, "Beyond city limits: Infrastructural regionalism in rural Montana, USA," was published in Territory, Politics, Governance. Written by Gansauer and Haggerty, it analyzed the political geography of the Central Montana Regional Water Authority and its proposed regional water pipeline system. This article used region-wide interview data to articulate the community resilience dynamics associated with drinking water governance in the Judith region.

# POWDER RIVER BASIN

CREWS researcher Liddi Meredith and undergraduate student Allie Wolverton use their mobile lab during field work in the Powder River Basin. Wolverton assisted in monitoring well installation and surface and groundwater sampling. After receiving her degree in Geology from Rocky Mountain College, Wolverton went on to pursue a Master's degree from the University of Wyoming. *Photo credit: Stephanie Ewing.*

## ABOUT THE POWDER RIVER BASIN

The Powder River Basin is a geological region in southeast Montana and northeast Wyoming that includes the Powder River, Tongue River, and Rosebud Creek and is one of the world's largest deposits of low-sulfur coal. The area provides more than 40% of the nation's coal and is a major economic engine in Montana. The Powder River Basin broadly represents landscapes influenced by energy extraction associated with open-air coal mining. Open pit mining development in the Powder River Basin overlays extensive rangeland that needs high-quality water to be productive. Aquifer disruption and spoil heap processing from coal mining can create groundwater conditions that concern both the mining and agricultural communities. An important area for interdisciplinary research that can benefit the state is the interaction between mining and reclamation activities and sulfate concentrations in both surface and groundwater.

## CREWS RESEARCH ACCOMPLISHMENTS

Research in the Powder River Basin ramped up over the five-year project period. The CREWS research team focused on understanding the impacts of coal mining on ground and surface water exchange and surface water quality. CREWS aimed to understand the formation, transport, and transformation of sulfate compounds mobilized in coal-spoil aquifers. The team's findings at the end of the project clarified the results of previous year's fieldwork.

Researchers and students analyzed changing concentrations of sulfate, a focal contaminant compound, in water samples collected in the Powder to understand how sulfate is diluted and reduced. Based on this geochemical and physical evidence, as well further examination of the connection between groundwater and local streams near reclaimed mine sites, the team's findings suggest that these streams may be losing water to groundwater and not receiving contamination from the reclaimed sites.

Much of the Powder River Basin's team work was also based on the Crow Reservation, where CREWS researchers and students conducted cumulative health risk assessments of surface, groundwater, and public water supplies across the reservation and other watersheds in Montana. Several Crow undergraduate and graduate students assisted with water quality research and community engagement, and the team collaborated with a local project partnership, Guardians of the Living Waters, to engage at least 100 Crow youth in further hands-on water quality research.

Field trip attendees pose for a picture next to one of the Rosebud Mine's reclamation sites. On the field trip CREWS researchers and students were able to talk with employees of the Rosebud Mine and learn about their mining activities and reclamation efforts. *Photo credit: Madeline Gotkowitz.*

## CREWS RESEARCHERS AND STUDENTS TAKE FIELD TRIP TO ROSEBUD MINE

In June 2021, members of the CREWS-Powder River Basin team and staff from the Montana Bureau of Mines and Geology (MBMG) visited and toured the Rosebud Mine outside of Colstrip, MT. Field trip attendees, with the help of Rosebud employees, were able to learn about the history of the mine, view its active, on-the-ground operations, and see and discuss the various reclamation efforts of the mine. The field trip culminated with a visit to the team's research sites located in the area and around Rosebud Creek, including a visit to one of the wells the research team used to collect groundwater samples.

Student Tennison Big Day inspects the torch and nebulizer plumbing of the Environmental Analytical Lab's SpectroBlue ICP-OES. *Photo credit: Adrian Sanchez Gonzalez.*

## CROW WATER QUALITY PROJECT SELECTED BY URBAN INSTITUTE AS NATIONAL CASE STUDY

The Crow Water Quality Project, led by CREWS researchers John Doyle (Little Big Horn College), Mari Eggers (MSU), and colleagues, was selected by the Urban Institute as one of 15 U.S. case studies for their Advancing Contextual Analysis and Methods of Participant Engagement in OPRE (CAMPE) project. This project is a national review of participatory methodology being conducted for the Office of Planning, Research and Evaluation (OPRE) in the Administration for Children and Families. The project aims to advance knowledge of and capacity to employ innovative research and evaluation methods related to equity in projects overseen by OPRE.

# PROJECT HIGHLIGHTS

## THREE CREWS UNDERGRADUATE STUDENTS AWARDED PRESTIGIOUS GOLDWATER SCHOLARSHIPS

From left to right, CREWS graduate student Riley Logan and undergraduate students Madison Torrey and Shannon Hamp begin the process of packing up the drone after a flight on the Upper Clark Fork River in July 2021. The pictured drone carries the research team's hyperspectral imaging system, which is used to identify algal bloom and estimate water quality parameters. *Photo credit: Joe Shaw.*

CREWS undergraduate student Baylie Phillips, who received the Goldwater Scholarship while at MTU. The Goldwater Scholarship is one of the most prestigious awards given to undergraduate students in the natural sciences, engineering, and mathematics. *Photo credit: Baylie Phillips.*

Baylie Phillips, Shannon Hamp, and Madison Torrey, three CREWS undergraduate research students, were all awarded the Goldwater Scholarships over the course of the project. Baylie and Shannon were announced as recipients in 2022 while Madison received the award in 2023. The Goldwater Scholarship is the most prestigious award for undergraduates in the natural sciences, engineering, and mathematics in the United States and is given to sophomores and juniors who show exceptional promise to be the next generation of research leaders in their fields.

Baylie Phillips majored in metallurgical and materials engineering at Montana Technological University. Phillips worked with Dr. Jerry Downey in Fall 2021 as a CREWS undergraduate research intern, where she investigated selenium absorption and removal in Continuous Flow Metal Recovery systems. Phillips' research in her undergraduate studies encompassed a broad array of disciplines but focused mainly on exploring the life cycle of materials and ultimately removing materials from environmental systems.
She graduated in May 2023 and is now pursuing a master's degree in materials science at Montana Tech.

Shannon Hamp majored in electrical and computer engineering at Montana State University. Hamp became involved with CREWS through a Research Experience for Undergraduates project in Summer 2021 working in Dr. Joseph Shaw's lab. She assisted with drone-based hyperspectral imaging of algae in the Judith River Basin and the Upper Clark Fork River, while also developing a low-cost multispectral imager for river algae detection. Hamp was also awarded an NSF Graduate Research Fellowship (GRFP) in Spring 2023. With this fellowship, she will continue her graduate studies in the Shaw Lab at MSU, focusing on how hyperspectral imagers can collect data to calibrate how satellites measure light reflected from snow.

Madison Torrey majored in environmental engineering at Montana State University. Torrey also worked in CREWS researcher Dr. Joseph Shaw's Optical Remote Sensor Laboratory (ORSL) at MSU, where her work involved drone-based remote sensing via hyperspectral imaging to estimate pigments in river algae, which is indicative of stream health. Torrey, who will graduate in Spring 2024, plans to earn a doctorate in environmental engineering with a focus on optics, then teach at the university level, study the natural environment, and devise environmental remediation strategies.

## STEPHANIE EWING APPOINTED AS DIRECTOR OF THE MONTANA WATER CENTER

Stephanie Ewing was named the new Director of the Water Center in 2022. Ewing was appointed after Wyatt Cross, also a CREWS researcher, returned to his full-time faculty status after an impressive eight years leading the Water Center. Ewing was appointed to a three-year term as Director of the Water Center. She is a professor in Land Resources and Environmental Sciences at Montana State University (MSU) and was co-PI on CREWS as well as the Judith River Watershed research lead. With funding from the United State Geological Survey through the Water Resources Research Act, Ewing will lead Montana's Water Center to develop and support water research, outreach, and education across the Montana University System.

Stephanie Ewing, a co-PI on the Track-1 CREWS project and research lead for the Judith River Watershed team, was named as the new director of the Montana Water Center. *Photo credit: Montana State University*

## LIBBY METCALF NAMED INAUGURAL JOEL MEIER DISTINGUISHED PROFESSOR OF WILDLAND RECREATION AT THE UNIVERSITY OF MONTANA

Libby Metcalf, a CREWS project lead at the University of Montana who worked with the Natural Resource Social Science team, was named as the inaugural Joel Meier Distinguished Professor of Wildland Recreation in the W.A. Franke College of Forestry and Conservation. This honor recognizes Metcalf's exceptional leadership and accomplishments in research, teaching, and service in and beyond the Parks, Tourism, and Recreation Management arena. The endowed professorship was sponsored by Joel and Patti Meier, both active environmentalists and philanthropists who have supported many UM programs in the past.

Libby Metcalf, a CREWS project lead with the Natural Resource Social Science Team, was named the inaugural Joel Meier Distinguished Professor of Wildland Recreation at University of Montana. *Photo credit: University of Montana*

CREWS researchers Liddi Meredith (Montana Bureau of Mines and Geology) and Rob Walker (Montana State University) look at a map showing the locations of groundwater wells in the Powder River Basin. *Photo credit: Don Sasse.*

## ROB WALKER NAMED BOARD PRESIDENT OF TELLURIDE SCIENCE

Rob Walker, co-PI on the Montana NSF EPSCoR CREWS project and PI of the next Track-1 project, SMART FIRES, was named Board President of Telluride Science in January 2023. Telluride Science was founded in 1984 as an interdisciplinary think tank for science and engineering challenges. Currently, the Center enables leading scientists from around the world to convene workshops and summer schools in Telluride. Dr. Walker first joined the board in 2019 and shared, "I am a much better and more broadly knowledgeable scientist because of Telluride Science… I look forward to Telluride meetings immensely because they remind me that I am, at heart, a scientist, and science is fun."

# SEED GRANT HIGHLIGHTS


A screenshot of the Story Map created by Dr. Arica Crootof and her students at the University of Montana Western. The Story Map, titled "The Future Isn't Written," highlights survey findings that touch on how people use and view the Warm Springs Ponds outside of Anaconda, MT.

## ARICA CROOTOF AND UM WESTERN STUDENTS PUBLISH STORY MAP HIGHLIGHTING COMMUNITY PERCEPTIONS OF WARM SPRINGS PONDS

Dr. Arica Crootof, a CREWS seed grant recipient at the University of Montana (UM) Western, recently published one of her class's projects surrounding the contamination of the Warm Springs Ponds at the headwaters of the Clark Fork River. The project, a Story Map titled "The Future Isn't Written" involved 21 UM Western students and engaged with the Environmental Protection Agency, Atlantic Richfield Company (ARCO), the Citizen Technical Environmental Committee, and the Clark Fork Coalition.

Dr. Crootof received a CREWS workforce development seed grant in 2020 that supported the development of a survey by her class to understand the use and perceptions of the Warm Springs Ponds. The results showed that many respondents wanted to see the ponds cleaned up and preserved for their recreational uses. Using the survey's results, Dr. Crootof explained that because heavy metal reclamation is not simple, she wanted to find a way to explain the complexity of the issues while also creating information that was digestible for the public.

"The Future Isn't Written" began as a class project, which proved to be challenging, but it was a learning opportunity for students and faculty alike to rethink how to share information in an engaging way that the public could comprehend. Although there is still much to be done surrounding the Warm Springs Ponds, specifically concerning public health, impacts on wildlife, fish, and birds, research such as "The Future Isn't Written" project is important to continue to better know how bad the contamination truly is. Dr. Crootof shared that acquiring data about both health and environmental impacts would be valuable next steps to help answer questions for people who frequently use the area for recreation. Scan the QR code to access the Story Map.

## SALISH KOOTENAI COLLEGE RESEARCHER RECEIVES CREWS SEED GRANT TO TRAIN STUDENTS AND IMPROVE WETLAND CHARACTERIZATION

In Year 3 of the CREWS project, Georgia Smies, an instructor in the Fisheries and Wildlife Program at Salish Kootenai College (SKC) was awarded a CREWS workforce development seed grant to improve Category 1 wetland characterization using remote sensing tools and environmental DNA. Smies' research was centered around improving wetland characterization using remote sensing tools and environmental DNA. During this research, Smies and her students monitored select sites in the Flathead watershed. Scientists on the project selected three to five sites in the watershed and collected water samples there to analyze in order to determine the aquatic species composition. They also installed game cameras at each monitoring site in order to view animal activity. This work provided Salish Kootenai College students an opportunity to conduct undergraduate research and learn valuable workforce development skills.

Georgia was inspired to jumpstart this research because of her work with tribal natural resource managers from the Confederated Salish and Kootenai Tribes (CSKT) on the Flathead Indian Reservation. Her knowledge of and work with the CSKT Wetlands Program highlighted that there was a need for additional data to support their wetland water quality standards. This research allowed the CSKT access to additional important data, and upon the completion of the research, Smies advocated that the CSKT create wetland standards that match surface waters in the watershed. The most enjoyable aspect of this research project for Smies was working with her students and teaching them new field techniques. She was able to witness her students grow into their roles as researchers and was very pleased with their research results. Smies also received a CREWS tribal college seed grant with Janene Lichtenberg, Head of the Wildlife and Fisheries Department at SKC, in 2023, to support their work on researching the effect of elk feeding behavior on aquatic plants and macroinvertebrates.

Salish Kootenai College students being trained on-site by Dennis Lichtenberg (second person from right) and Tabitha Espinoza (middle) with the CSKT Wetland Program at Schwartz Lake. *Photo credit: Georgia Smies.*

## CREWS WORKFORCE DEVELOPMENT INTERN PARTNERS WITH CLARK FORK COALITION TO LOOK AT THE EFFECTS OF RIVER RESTORATION

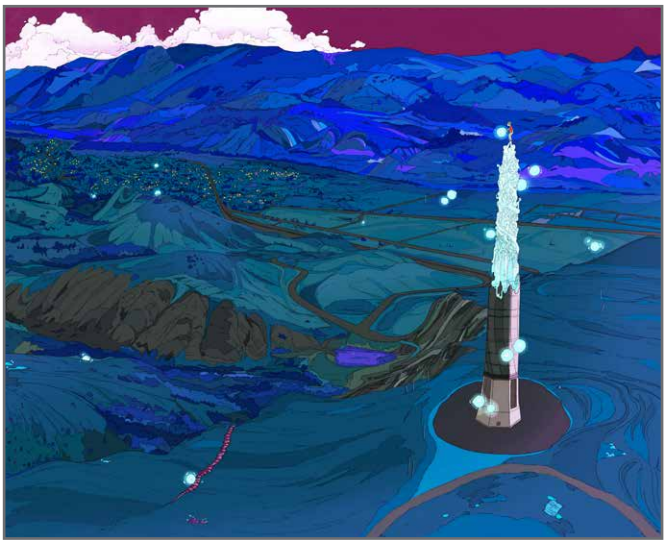

CREWS workforce development intern Morgan Schultz, who worked with the Clark Fork Coalition to analyze and interpret post-restoration stream bank habitat datasets from the Upper Clark Fork River. *Photo credit: Morgan Schultz.*

Morgan Schultz is from the Flathead Reservation in Northwest Montana. He received his bachelor's degree in Hydrology from Salish Kootenai College and his master's degree in Ecological Restoration from Montana Technological University. Schultz participated in the CREWS Workforce Development Internship program over Summer 2022. Schultz sought out the internship to help bridge the gap between science collection and management strategies, specifically regarding the Clark Fork River. He primarily worked with the Clark Fork Coalition but also reached out to people from Montana Fish, Wildlife, and Parks (FWP), the Natural Resource Damage Program (NRDP), and consultants at Applied Geomorphology, Inc. (AGI) and Geum Environmental Consulting. The project largely consisted of organizing and analyzing nearly 22,000 data points that looked at stream bank habitats following river restoration. In order to sort through this data, Schultz consulted with several agencies to develop meaningful approaches to interpret the seemingly overwhelming dataset and identify important information from it. He also conducted technical processes in ArcGIS to extract spatially explicit metadata and apply them to his research transects. Through the internship, CREWS also supported his travel expenses to the National American Fisheries Society Conference in Spokane, WA where he received feedback and advice to improve his project.

# INTERNSHIP HIGHLIGHTS

## CREWS NATURAL RESOURCE SOCIAL SCIENCE GRADUATE STUDENT PARTNERS WITH MSU STUDENTS TO TURN RESEARCH INTO ART

In Spring 2023, students at Montana State University (MSU) were given the opportunity to create art pieces that portrayed CREWS research. The idea to bring art and science together came from recently graduated University of Montana Ph.D. student Megan Moore, a member of the CREWS Natural Resource Social Science team. Moore wanted to communicate her results through storytelling and creative representations which offered a novel way to engage with community members. Moore worked with the student artists to share more information about her research, which focused on the intersection of community resilience, collective memory, and the Superfund process in the community of Anaconda, MT. The student artists then incorporated the information about Moore's research and data to interpret and create their own unique art pieces. Moore was also an intern with the CREWS Innovation and Commercialization Internship program, through which she worked to develop a resource for Anaconda community members that could help them learn more about their community and be informative moving into the future. Three MSU students applied and submitted art pieces as part of the project. Rachel Ingle, a Master of Fine Arts graduate student, used a copper printmaking medium to create a series of images representing Lost Creek, a tributary of the Upper Clark Fork River. Aria Dang, a Biochemistry graduate student, used a digital medium to create her art piece, titled "Survey." As Dang shared, the piece "was a fantastical representation of the Anaconda smokestack" and combines the themes from Moore's research, including "community identity", "resilience", "perception", and "uncanny", with "the literary style of magical realism [that] predominated Latin American and 20th-century literature. The third student, Athena Garron, in the Studio Arts program, created a series of sculptures to interpret and represent Moore's research, drawing on natural and manmade symbols and elements of the past and the future.



The art pieces developed in partnership with CREWS graduate student Megan Moore, whose research focused on community resilience, collective memory, and the Superfund process in Anaconda, MT. The pieces, from top to bottom, include Rachel Ingle's prints of Lost Creek, Aria Dang's digital painting of the Anaconda smokestack, and Athena Garron's sculpture representing natural and manmade elements. *Photo credits: Suzi Taylor; Aria Dang; Athena Garron.*

# EDUCATION, OUTREACH, & DIVERSITY

## CIRCLES ALLIANCE RECEIVES $10 MILLION NSF AWARD TO SUPPORT ALASKA NATIVE AND AMERICAN INDIAN STUDENTS IN STEM DISCIPLINES

Members of the six-state CIRCLES Alliance pose for a picture. The goal of the CIRCLES Alliance is to inform educational institutions and the NSF in Native cultural understanding and humility and to shift approaches toward AI/AN education. *Photo credit: University of Montana News.*

The National Science Foundation awarded $10 million to a six-state collaborative working to boost the underrepresentation of Alaska Native and American Indian (AI/AN) students in STEM disciplines and the workforce. The grant award funded Cultivating Indigenous Research Communities for Leadership in Education, or the CIRCLES Alliance. The alliance is led by principal investigator Aaron Thomas, Diversity and Inclusion lead on the current RII Track CREWS project, University of Montana (UM) chemistry professor, and director of UM Indigenous Research and STEM Education. Partners include universities and research institutions in Idaho, Montana, New Mexico, North Dakota, South Dakota and Wyoming. UM received $1.8 million of the total award to build a network for developing and disseminating science, technology, engineering and math educational resources, as well as implementing longitudinal programming, mentorship and teacher preparation in support of AI/AN student success. The CIRCLES Alliance launched in 2020 with support from NSF's EPSCoR and INCLUDES programs (INCLUDES: Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science).

## MONTANA GIRLS STEM COLLABORATIVE AWARDS EIGHT MINI-GRANTS TO HELP ORGANIZATIONS STATEWIDE ENCOURAGE YOUTH TO PURSUE CAREERS IN STEM

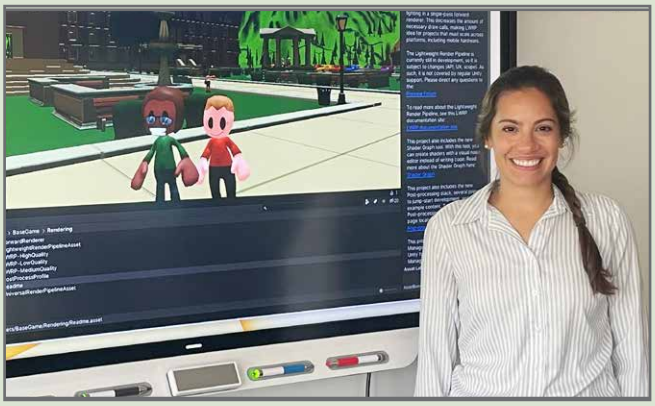
Eight Montana projects received mini-grant funding from the Montana Girls STEM Collaborative in 2021 to help develop and grow science, technology, engineering, and math programs that serve girls and youth. The Montana Girls STEM Collaborative, which was originally launched through Montana NSF EPSCoR as a chapter of the National Girls Collaborative, is a statewide network with hubs at Montana State University and the University of Montana. The mini grants ranged from $500 to $1000 and were given in partnership with Lyda Hill Philanthropies, which created an online database called the IF/THEN Collection that features women scientists and engineers. The database features profiles of 125 female ambassadors who serve as role models for young people, and all photographs, videos and text found on the site are free for educational use. Organizations that received the grants used the collection to encourage girls to pursue careers in STEM, which stands for science, technology, engineering and math. For example, Code Girls United Summer Camp, one of the mini-grant recipients, used the IF/THEN collection to help their students see other women utilizing similar coding and technology skills in their careers. Another recipient, Upward Bound in Missoula, used their award to help connect students learning about astronomy with IF/THEN role models who are astronomers. Further, they also provided the opportunity for Native scholars to share star stories with students in Browning to help inspire a new generation of scientists.

Middle and high school girls learn about computer science and information technology at the STEM Girls in Government Camp in Fall 2019. The Montana Girls STEM Collaborative supports events and programs like this that aim to develop and grow science, technology, engineering, and math programs that serve girls and youth across the state. *Photo credit: Suzi Taylor.*

Group photo of students in the Montana American Indian in Math and Science (MT AIMS) program at the final day of the 2021 MT AIMS Gatherings. The MT AIMS program is supported by UM's Indigenous Research and STEM Education (IRSE) program, which is led by Aaron Thomas, Diversity lead on the CREWS project. *Photo credit: Stephan Chase.*

## CREWS RESEARCH, STORIES USED TO CREATE VIRTUAL COLLEGE SIMULATION GAME

With support from Montana NSF EPSCoR and the Science Math Resource Center, faculty and graduate students in the MSU Department of Education developed a virtual college simulation that introduces players to various STEM concepts and pathways. The game, called Crash Course, is meant to promote STEM major exploration for pre- and first-year college students. The game connected with CREWS researchers, students, and staff by integrating several water-related themes into course content, dialog between players and non-player characters (NPCs), social meetups, university clubs, and the history of the campus lake. For example, players may take courses in Water Chemistry, Hydrology, Water Policy, and Ecology and speak with NPC professors and graduate students to learn about a variety of research possibilities and careers within STEM specifically related to water research and sustainability. Additionally, NPC friends highlight water-related research projects, many of which were based on CREWS research. While fictional, these NPC characters are a conduit to the authentic stories, research, and advice of CREWS faculty and student researchers. Ultimately the goal of Crash Course is to let students engage with the stories and activities related to CREWS research and encourage young players, especially those from underrepresented groups, to cultivate a vision for themselves in a STEM career.



Tasha Striker, a graduate student in the Department of Education at Montana State University, poses with a developer version of the virtual College Simulator game. With support from Montana NSF EPSCoR, the game will allow high school students to engage in a virtual college experience and introduce them to various STEM concepts and pathways. *Photo credit: Suzi Taylor.*

## A LOOK BACK AT SPECTRUM'S CREWS ENGAGEMENT

Youth on the Flathead Reservation engage with CREWS-funded exhibits, activities, and role model engagement as part of spectrUM's Science Learning Tent, which travels to communities and events across Montana. *Photo credit: spectrUM Discovery Area.*

spectrUM Discovery Area, UM's hands-on science center, played a key role in CREWS's broader impacts efforts, focusing particularly on fostering K-12 students' curiosity and sense of belonging in STEM education and career pathways.

**Through CREWS, spectrUM:**

- Positioned water and environmental science education in the heart of Missoula at spectrUM's location within Missoula Public Library. At this new site, which opened in 2021, spectrUM now sees an estimated 115,000 visits annually, a fivefold increase from our former location. Visitors can immerse their hands in two Clark Fork River water tables against the backdrop of a mural depicting the local ecosystem and community; explore with and deploy sensors, as well as try out other CREWS-based activities; and "meet" CREWS graduate student role models featured in museum signage.
- Rotated exhibits, hands-on activities, and role signage to EmPower Place, a free family learning center inside Missoula Food Bank and Community Center, collaboratively operated by the Food Bank, spectrUM, and Missoula Public Library.
- Distributed over 21,000 take-home science kits during the pandemic, when in-person programming was on hold. Instructions for many of these fun, user-friendly activities are now also on Instructables, reaching audiences worldwide.
- Engaged children and families in rural and tribal Montana communities—including at summer powwows, free meal sites, and other community events on the Flathead Reservation and at rural libraries across Missoula County—with CREWS-based activities and role models. While many of these community programs were paused for 2020 and into 2021, in-person programming ramped back up for the final years of CREWS.

While CREWS has ended, the resources and partnerships developed through this project persist, not only in permanent and rotating exhibits and activities at spectrUM and in our mobile programming, but also in collaborations with researchers, educators, and community partners who continue to shape our ongoing efforts to inspire Montana youth about STEM and the world around them.

# PROJECT HIGHLIGHTS

## MONTANA STATE RESEARCH TEAM RECEIVES FUNDING TO CONTINUE STUDYING NITROGEN PROCESSING IN RIPARIAN AREAS

With recent funding from the U.S. Department of Energy, a team of scientists at Montana State University will examine a group of unique organisms that consume the gas methane while simultaneously removing forms of nitrogen linked to agricultural fertilizers from their environment. Anthony Bertagnolli, a senior research scientist at MSU, will lead the project. Bertagnolli is a part of the team in the laboratory of Frank Stewart at MSU, and the two will collaborate with Stephanie Ewing and Rob Payn, who were both CREWS researchers. Exploring nitrogen's impact on water quality in Montana's Judith Basin watershed has been a key element of ongoing water quality research by Ewing and Payn, and the new exploration will dovetail with that work. Supported by a three-year grant of just under $1 million from the Department of Energy, the MSU project is one of 17 nationwide to be funded by the federal program. Preliminary work that initiated Ewing's and Payn's exploration was funded by the National Science Foundation's EPSCoR Track 1, the Consortium for Research in Environmental Water Systems (CREWS), and included collaboration with MSU's Central Agricultural Research Center in Moccasin and MSU Extension.

Montana State University researchers (from left to right) Rob Payn, Anthony Bertagnolli, Stephanie Ewing, and Frank Stewart. Building off CREWS research, the group received funding to study organisms that process nitrogen and produce oxygen along waterways. *Photo credit: MSU photo by Colter Peterson.*

## MONTANA TECH AWARDED $24M GRANT TO DEVELOP MATERIALS TECHNOLOGY FOR RARE EARTH ELEMENT PROCESSING RESEARCH PROGRAM

Montana Technological University (MTU) was awarded a five-year, $24M research and development grant from the Army Research Laboratory (ARL) in 2022 to develop a research program called "Materials Technology for Rare Earth Elements Processing." Dr. Jerry Downey, a CREWS research lead at MTU, is the PI for the award, and Dr. Grant Wallace, a Research Associate in Dr. Downey's research group, will act as co-PI. The program, developed in partnership with the Montana Bureau of Mines and Geology (MBMG), built on the advances in the Continuous Flow Metal Recovery (CFMR) system developed during the CREWS project and will include analysis of large waste systems of the Butte-Anaconda mining complex and Montana coal mines. The goal of the program is to develop innovative, environmentally friendly, and industrially viable methods for recovering and separating rare earth elements (REE), and ultimately help lay the groundwork for economically and environmentally-sound utilization of REE sources in the United States.

Teagan Leitzke, who was a CREWS graduate student at Montana Tech, pours a slurry of magnetite and water into the continuous flow metal recovery system. The slurry flows through the static mixer column to a magnet, where the magnetite is collected, and water continues to flow out of the system. *Photo credit: Amanda Badovinac.*

## MONTANA NSF EPSCOR SUPPORTS FIRST CLARK FORK SCIENCE FORUM

The first Clark Fork Science Forum was held at the Holiday Inn Downtown Missoula in 2023. Continuing the tradition of a recurrent meeting to address the status of the Clark Fork River and its floodplain, the meeting was a research-focused forum intended to foster the exchange of data, ideas, and interpretations. The Clark Fork Science Forum was a joint effort among the Montana University System, Montana NSF EPSCoR CREWS, the Montana Natural Resource Damage Program, and the United States Geological Survey. Researchers both presenting and in attendance represented multiple CREWS-funded state universities, as well as state and federal agencies, nonprofit organizations, and industry organizations. The forum was possible due to the groundwork efforts of the Upper Clark Fork Working Group (UCFWG).

Members of the Upper Clark Fork Working Group survey a section of the Upper Clark Fork River as part of a field workshop in 2021. The Upper Clark Fork Working Group, which was supported by Montana NSF EPSCoR CREWS, supports workshops like this and meetings like the Clark Fork Science Forum to inform research and restoration efforts on the Clark Fork River. *Photo credit: Taylor Gold Quiros.*

From the bottom of our hearts, thank you to everyone who was involved with CREWS. Whether you were a researcher, part of the EPSCoR office, or collaborating partner, your dedication, time, and energy made CREWS a truly special and unique team and project of which to be a part. We're excited to see how the work that began in CREWS, ranging from the science to broader impacts to workforce development, continues to evolve and grow, and to recognize the many important impacts this project will have on our state, both now and into the future.

**Montana NSF EPSCoR**
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