

## Roaring Fork Watershed: Improving soil moisture data validation and access



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# 1. Technical Proposal and Evaluation Criteria

## 1.1. Executive Summary

October 17, 2023

Aspen Global Change Institute

City of Aspen, City of Glenwood Springs, Town of Basalt, Pitkin County, Eagle County, and Garfield County, Colorado

Over the last 12 years, Aspen Global Change Institute has worked with local partners to establish an *in situ* soil moisture observing network to better understand mountain hydrologic processes and potential implications of climate change. The network, named the Roaring Fork Observation Network, or iRON, was initiated in 2012 and consists of 10 stations that span the elevation gradient of the Roaring Fork Watershed. The Roaring Fork Watershed is a microcosm of the larger system and contains complex water processes characteristic of many Colorado River headwater catchments. As a result, this decade-plus of iRON data has unique potential to contribute to a deeper understanding of the role of soil moisture measurements in water forecasting and management in the Colorado River Basin. Through this project, Aspen Global Change Institute, in partnership with the Colorado River District and the Ruedi Water and Power Authority, will improve the quality, accessibility, and usability of the iRON dataset. The project will provide capacity to develop standardized quality assurance/quality control measures, automate data feeds, and build data dashboards and tools to guide data accessibility and use. These improvements will support uses of iRON data that serve ongoing investigations into the role of headwater catchment soil moisture in watershed processes. This project will also support water forecasting and modeling efforts by refining a valuable decadal-scale headwaters soil moisture dataset to be more accessible and robust. This project will be completed in two years with an estimated completion date of March 31, 2026. While not located directly on a federal facility, the project is located just downstream of Ruedi Reservoir and upstream of the Glen Canyon Dam which are both federal facilities.

## 1.2. Technical Project Description

**Applicant category:** Aspen Global Change Institute is a Category B applicant working in partnership with the Colorado River District and the Ruedi Water and Power Authority, Category A applicants.

The Colorado River supplies water to an estimated 40 million people across the arid southwest. Its water supply is stretched thin across municipal, agricultural, and in-stream uses, and water managers are pressed to accurately predict water supply from snowmelt to optimize reservoir management. However, in some recent years traditional runoff estimation techniques have overestimated runoff, leading to non-optimized runoff delivery and storage. One possible process impacting the difference between estimated runoff and actual runoff may be soil moisture. The role of soil moisture in runoff volume and timing is poorly understood, and few Colorado River headwaters catchments have long *in situ* monitoring records. However, the role

of soil moisture processes in water management is gaining focus as the Colorado River system continues to respond to prolonged and severe drought.

To fill this need, Aspen Global Change Institute (AGCI) has worked alongside local partners in the Roaring Fork Watershed to install and maintain the Roaring Fork Observation Network (iRON), an *in situ* soil moisture and meteorological monitoring network. The first station was installed in 2012. The network has since been expanded to include 10 soil moisture monitoring stations. These stations are located across the elevational gradient of the Roaring Fork Watershed, ranging from 6,200 ft to 12,080 ft in elevation. Data from this network have not been used to inform runoff prediction to date; however, given the recent widespread interest in using soil moisture in runoff prediction in the Colorado River headwaters, these data have enormous potential to help understand the value of this type of measurement prior to expending the energy and resources to install new long-term monitoring stations in the Colorado River Basin. Yet to uncover this value, further efforts are required to ensure data quality and accessibility including improving and standardizing quality control measures, data validation, expanding data accessibility, and designing more intuitive data platforms.

This project brings together efforts and advances ongoing work funded by the Colorado Water Conservation Board and the Colorado River Water Conservation District (often referred to as the Colorado River District) to improve access to and understanding of iRON data. This grant will allow for the further development this data resource through:

1. Improved validation and quality control/quality assurance (QA/QC) procedures
2. Streamlined access to iRON data through internal data dashboards and data hosting on pre-existing data repositories appropriate for these data
3. Curation of an online tool pointing data users to relevant uses of iRON data and other complementary Roaring Fork data sources
4. Sharing and promotion of iRON data to new, relevant partners in the stakeholder and research communities

The outcome of this project will be a robust, usable, and accessible dataset for water managers, runoff forecasters, and watershed researchers.

For over 30 years, AGCI has been a community partner in the Roaring Fork Watershed and worked across private, research, government, and public partners to better connect decision makers and stakeholders with reliable, reputable, interdisciplinary science they are seeking at local, global, and regional scales. AGCI is a 501(c)(3) non-profit organization and a Category B applicant. As a Category B applicant, AGCI will partner with the Colorado River District and the Ruedi Water and Power Authority for this project to ensure that the outcomes are applicable to the needs of water management entities and other stakeholders in the water resources community.

The Colorado River District is the primary water policy and planning agency for 15 counties across the Upper Colorado River Basin and works to protect water rights and water use for multiple entities. For this project, AGCI will work closely with the Colorado River District for (a) advice on effective approaches to platforms and tools for data access for Colorado River

District staff and other partners going forward and (b) identify other entities with potential interest in iRON's refined dataset and/or data quality and validation methods.

Ruedi Water and Power Authority is a regional water agency in the Roaring Fork Watershed, directed by a board with an elected official from each local government in the watershed. Ruedi Water and Power Authority has expressed a need for better access to soil moisture data and context around how runoff forecasts are generated. In this project, AGCI will partner with Ruedi Water and Power Authority to (a) identify effective tools and practices for data accessibility for local soil moisture data, (b) obtain insight into what context is most helpful to provide alongside the data, and (c) understand potential applications for local soil moisture data to inform water management and planning.

### 1.2.1. Detailed Project Description

The primary objective of this project is to transform a 12-year monitoring record of soil moisture data in an upper Colorado River headwaters catchment into a robust, cleaned, validated, and readily usable dataset to help inform water managers, runoff forecasters, and watershed researchers. Key elements of this project include:

- Task 1: Project management and meetings
- Task 2: Data validation and QA/QC
- Task 3: Automated data feed from stations and web server hosting
- Task 4: Data Dissemination
- Task 5: Development of a web-based iRON soil moisture guide and tool

Measurements collected at the 10 iRON stations include: soil moisture data at two inches, eight inches, and 20 inches below the surface; rain; soil temperature at eight inches below the surface; air temperature; and snow depth. Stations collect data on twenty-minute to hourly intervals and stations have periods of record ranging from three to 12 years. This network was built with support from local partners, including municipality, county, non-profit, and water management collaborators. Increasing data accessibility is a key step in allowing iRON data to be better used by the research, management, and user communities in understanding the role of soil moisture in mountain hydrology.

The iRON dataset has, on a case by case basis, helped inform water managers and other decision makers within the Roaring Fork Watershed, and lightly processed versions of the dataset have been used for academic investigations into soil moisture processes in the southwestern United States (Feng et al., 2022; Al-Yaari et al., 2017). However, current uses of the iRON dataset are restricted due to limited quality assurance and data availability. Two peer reviewed papers incorporating iRON data both found the current quality assurance and data flagging standards to be inadequate for comparison of iRON data to satellite-derived data (Feng et al., 2022; Al-Yaari et al., 2017). Local stakeholders have also mentioned difficulties in accessing, using, and interpreting data. Application of iRON data is, therefore, limited by pathways through which the data can be accessed, inadequate dissemination of the dataset to modeling and forecasting entities, and a lack of more stringent and standardized data quality controls. There is strong interest from both water management and research communities in increasing the quality of the iRON dataset. Years of extensive field notes, metadata, and

contextual information are available, but to-date there has been limited funding available to apply these resources to further process and more broadly disseminate the dataset.

There is also growing interest in incorporating soil moisture data into watershed models and management decisions. New deployment of soil moisture monitoring efforts in headwaters catchments in the southwestern United States include: (1) deployment of cosmic ray sensors in the Roaring Fork Watershed by the USGS; (2) establishment of a new sensor network (currently with one live station) in the upper Yampa River Watershed by the Center for Western Weather and Water Extremes; (3) the Logan River Observatory managed by Utah State University, (4) the ongoing development of four soil moisture sensing stations in the upper Dolores River Watershed managed by Mountain Studies Institute, and (5) addition of soil moisture measurements at many NRCS SNOTEL sites. These initiatives follow on the heels of previous soil moisture monitoring networks in the Colorado River headwaters including the PBO\_H2O network (2012-2017). As the number of networks including *in situ* soil moisture grows, utility of these data will be dependent on easily navigable, reliable data dissemination platforms and robust, well-validated datasets. The data refinement process carried out by this project will demonstrate one possible pathway to improving data robustness and useability. Further, the iRON data have potential to provide context for and lengthen the period of record for many of these other newly installed soil moisture monitoring efforts. Taking steps to improve the quality and accessibility of the iRON dataset will contribute to the ongoing, growing need for robust soil moisture data from headwaters catchments and ensure the data continues to contribute to water management and research needs in the future.

This project will build upon ongoing work to transform the iRON data record into a publicly accessible, robust, and usable dataset for both stakeholders and the research community. Current efforts to QA/QC and clean the iRON data are funded by local (Colorado River District) and state (Colorado Water Conservation Board) partners. A grant from these partners provides much of the cost-share for the proposed project. The remaining cost share will be contributed by AGCI. Some initial data screening and analysis supported by Colorado River District and Colorado Water Conservation Board in 2023 has highlighted important additional steps needed for better quality control, which would only be possible with the additional funding from this proposal. This proposal will expand the iRON network capacity to include a comprehensive data management system with automated QA/QC, a publicly accessible database with data formats in both common (e.g., CSV) and research specific (e.g., NetCDF) formats, and the dissemination of the network data record with an emphasis on both public and research audiences. The technical aspects of the project are completed in Tasks 2-5 as outlined below:

### **Task 1: Project management and meetings**

Task 1 includes administrative tasks including communication, coordination, scheduling, budget tracking, invoicing, and project reporting and will be completed throughout the project.

### **Task 2: Data validation and QA/QC for the complete iRON soil moisture record**

As interest in and installation of *in situ* soil moisture networks expands, ability to compare datasets across sensor types and across basins becomes increasingly critical. To help address this need, the National Coordinated Soil Moisture Monitoring Network (NCSMMN) is currently facilitating a soil moisture community-driven effort to define standards for quality

assurance and quality control. Working with guidance from the developing NCSMMN standards, a process in which AGCI is participating, this project will apply up-to-date QA/QC methods to ensure that data publicly available from the iRON network is high quality. QA/QC methods in this project will focus on data that exceed the physical limits of the system, such as extreme values and extreme rates of change.

Data validation and QA/QC will be undertaken for all sensor data across the entirety of the past iRON data record and will be applied to automated QA/QC practices for ongoing data collection. The target outcome of Task 2 will be for the iRON dataset to meet the NCSMMN's forthcoming identified criteria for data quality, robustness, and QA/QC.

### *Task 2 Approach*

Pre-existing data will be reviewed for inconsistencies, sensor changes, field-based errors, extreme or physically improbable values, and extreme rates of change. Data from each sensor at every station will be reviewed during Task 2. In addition to pre-existing data, QA/QC thresholds and metrics will be applied to ongoing data collection. These methods will be applied in real time to prevent additional QA/QC backlogs preventing data use. Method development will be closely tied to emerging soil moisture community standards.

### **Task 3: Automated data feed from stations to web server hosting**

Sensor data are collected autonomously at each field site on 20-minute to hourly intervals. These data are stored on a field collection drive, which can connect via cellular or satellite network to a remote server. Currently, data from stations are pushed to platforms hosted by the associated manufacturer of the logger box deployed. Downloadable data are made available on the International Soil Moisture Network and the CUAHSI databases; however, these data must be manually uploaded in a time-intensive process that is only carried out annually. Furthermore, both sites can be challenging to navigate for data users from the stakeholder community.

The target outcome for Task 3 is for quality-controlled data to be accessible in both stakeholder oriented (e.g., CSV) and research oriented (e.g., NetCDF) formats via a web downloader with a graphical user interface (GUI) capable of plotting parameters and mapping stations for quick-view data. Improving data accessibility in this manner will benefit the research community by making the most recent data available and will benefit the non-research community by providing more easily accessible datasets in a format where context about the data being downloaded can also be provided.

### *Task 3 Approach*

This project will review data hosting opportunities, data feed techniques, and possible third-party collaborations for establishing reliable, near real-time data feeds from soil moisture stations to a remote server. The QA/QC process developed in Task 2 will be implemented on this server for reviewing and flagging ongoing data feeds.

### **Task 4: Data Dissemination**

To disseminate these data beyond AGCI's project partners, the project will implement multiple strategies to publicize the iRON dataset, data access, and soil moisture data tools. These strategies include co-hosting data on partner sites and data platforms (e.g., National Mesonet,

CoAgMet, and CW3E networks), hosting updated data on research-oriented platforms (e.g. CUAHSI HydroShare), presentation of data at relevant gatherings, and promoting the revised dataset in relevant publications. The iRON dataset offers continuous soil moisture data from 2012: this is a relatively early and long monitoring record for a soil moisture record in a headwaters catchment and has immense potential for the research community. The target outcome for Task 4 is for the iRON dataset to be utilized as a robust, long-term soil moisture dataset in the Colorado River headwaters catchments by the research community. The foundations for this outcome will be set in place throughout the project, although the outcome may take place following official project completion.

#### *Task 4 Approach*

Strategies will be reviewed for efficacy, and selected data sharing strategies will be implemented. Sharing strategies will incorporate a combination of published and in-person approaches. The target audiences for these approaches include both resource managers and forecasting researchers.

#### **Task 5: Development of a web-based iRON soil moisture guide and tool**

Despite a multi-decade track record of research on soil moisture processes, soil moisture data remains complex and interpreting data can be nuanced. While interest in soil moisture data continues to grow, misperceptions remain around soil moisture data type, units, and application.

Task 5 focuses on developing tools and resources that clarify data access and provide context for the role of *in situ* soil moisture data in understanding mountain hydrologic systems. The target outcome for Task 5 is a web-based soil moisture guide and tool integrating: a data downloading platform for iRON data, additional relevant monitoring datasets in the Roaring Fork Watershed, a “lessons learned” guidance review for future soil moisture observation networks, and materials to help clarify different uses of soil moisture data.

#### *Task 5 Approach*

The project will include the development of a web resource highlighting points of access to iRON soil moisture data, companion climate datasets, and other soil moisture resources across the region such as SNOTEL, USGS, and state sensor networks in the Roaring Fork Watershed. This resource will be a curation of both iRON and other data sources in the Roaring Fork Watershed and will act as a pilot project integrating a small-scale monitoring network into larger monitoring efforts. This approach, if successful, has myriad potential applications across other, often isolated, small-scale monitoring efforts in the Colorado River headwaters catchments.

#### **Project Goals**

This project seeks to advance the appropriate use of soil moisture data in water resource strategy and runoff forecasting. One of the major limitations in utilizing *in situ* data in Colorado River forecasts has been the lack of long-term monitoring data. This project seeks to provide a dataset with which water managers and researchers can explore how robust *in situ* soil moisture data could help inform runoff forecasts and possibly reduce error. Moreover, this project acts as a pilot project for integrating small-scale monitoring projects into the larger Colorado River



Basin monitoring programs; similar strategies may be employed for other monitoring projects across the Colorado River headwaters catchments.

### 1.3. Project Location

The project will take place within the Roaring Fork Watershed in Pitkin and Garfield Counties in Colorado. The watershed is located in the central Colorado Rocky Mountains and spans nearly 9,000 vertical feet from its headwaters along the Continental Divide at 14,235 ft to its confluence with the Colorado River at an elevation of 5,717 ft. A PDF version of the project location is shown in Figure 1; a SHP file has been uploaded separately through the SF-424.

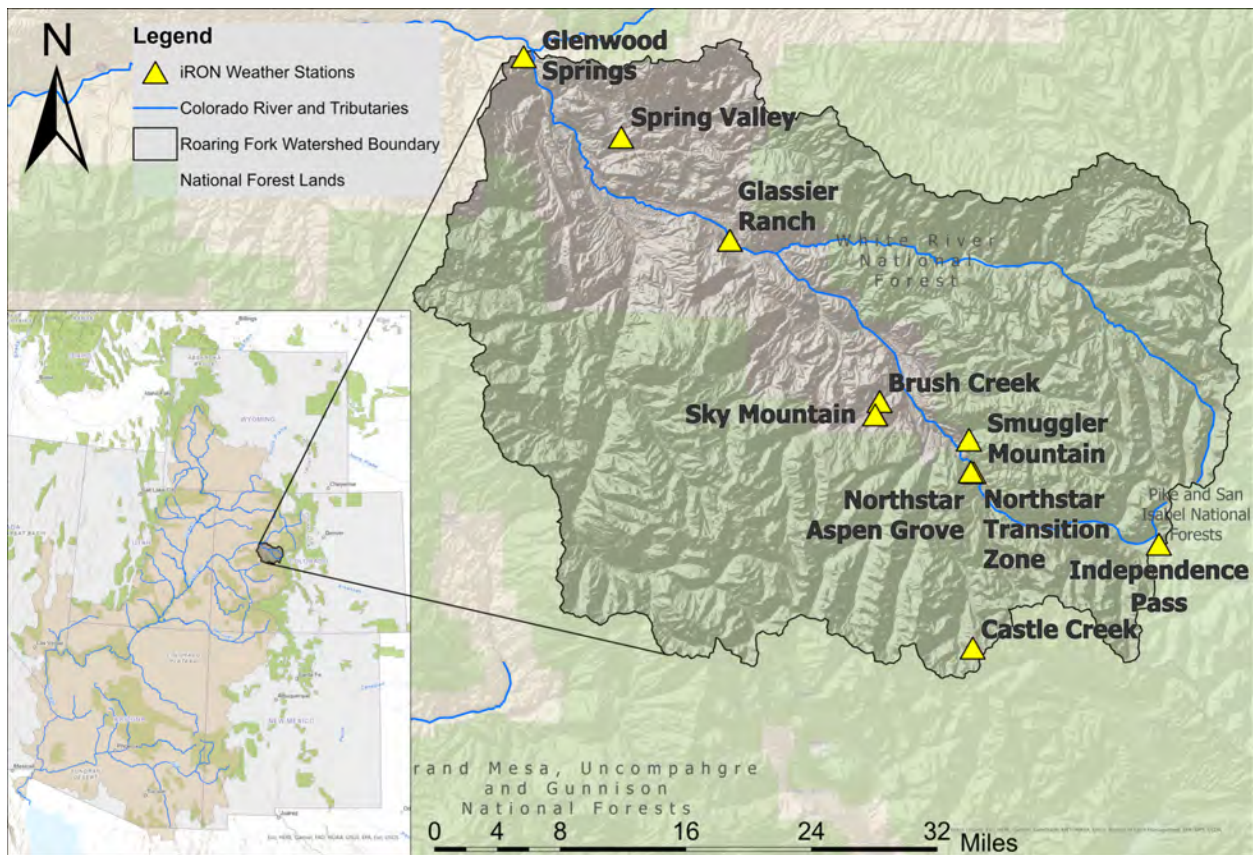


Figure 1. Project Location (PDF format). The Roaring Fork Watershed is located in western Colorado in the Upper Colorado River Basin.

## 2. Data Management Practices

Data management is a key focus of this project. All spatially explicit data and tools developed in the project will be compatible with Geographic Information System (GIS) platforms and developed in industry standard formats. Data records will be backed up on secondary servers. Current data management practices are reviewed in Osenga et al. (2021). This project will build upon these initial QA/QC strategies and enhance data management practices.

## 3. Evaluation Criteria

### 3.1. Water management challenge (30 points)

- 1. Describe the water management challenge(s). Describe in detail the water management challenges occurring within your project area. Describe the severity of the challenge to be addressed with supporting details. For example, will your project address water supply shortfalls or uncertainties, the need to meet competing demands for water and the lack of reliable water supplies for municipal, agricultural, tribal, environmental or recreational water uses, complications arising from drought, conflicts over water, or other water management issues?**

An estimated 70% of the Colorado River’s water is derived from mountain headwater catchments. An estimated 40 million people in the American West are reliant on this water supply. These snowpack hydrology-dominated catchments are characterized by a large increase in runoff during spring snowmelt followed by receding runoff back to “baseflow” by the fall and winter months. Water management in these catchments relies on robust runoff forecasts to optimize reservoir management and support municipal, agricultural, and ecological water needs throughout the year. Robust runoff forecasts are paramount in the management of headwaters reservoirs. Yet, in recent years such as 2020 and 2021, runoff forecasts estimated by the Colorado Basin River Forecast Center overestimated headwater Colorado River runoff by 20% and 40%, respectively, as compared with measured flows at USGS gages. The large disparity created critical challenges for water management and is indicative of an urgent need for higher quality data to input into forecasts.

Locally, AGCI’s partners, including the Colorado River District and the Ruedi Water and Power Authority, have expressed interest in actions such as adding direct observations to forecast models or adding soil moisture processes to help address concerns regarding the water supply and water forecasts in the Roaring Fork Watershed including:

- Timing water releases from reservoirs to account for fish habitat needs, water user needs, prevention of environmental degradation (e.g., anchor ice), and storage optimization
- Reducing uncertainty in water supplies
- Meeting downstream calls for water from more senior water rights

This project seeks to address these needs by providing a unique, 12-year and ongoing soil moisture record for both water manager and researcher communities that can provide additional context for runoff estimates and enhance understanding of soil moisture processes in these complex, impactful headwater regions.

- 2. Describe the concerns or outcomes if this water management challenge is not addressed?**

The water management system of the southwest is reliant upon reservoirs to help smooth water supply to meet user needs throughout the year, despite most of the water availability coming during spring runoff. Without accurate runoff forecasts, water managers are unable to

optimize reservoir operations, either risking over or underfilling reservoirs. Impaired reservoir operations have repercussions for agricultural, economic, and recreation success, as well as having environmental consequences (e.g., build-up of algae, inability to regulate temperatures for fish population health). Moreover, these 12 years of data can help inform and improve future investments in understanding soil moisture. Lessons learned from this existing effort can contribute to more strategic future investments in soil moisture research in the Colorado River Basin.

3. **Explain how your project will address the water management issues identified in your response to the preceding bullets and provide support for your response. For example, will your project improve water management by supporting:**
- **water supply reliability for municipal, agricultural, tribal, environmental or recreational water uses,**
  - **management of water deliveries,**
  - **water marketing activities,**
  - **drought management activities,**
  - **conjunctive use of ground and surface water,**
  - **water rights administration,**
  - **ability to meet endangered species requirements,**
  - **watershed health,**
  - **Restore a natural features or use a nature-based feature to reduce water supply and demand imbalances, the risk of drought or flood, or to increase water supply reliability for ecological values,**
  - **conservation and efficiency, or**
  - **other improvements to water supply reliability?**

The iRON dataset is unique in its spatial coverage (across the elevational gradient of a tributary) and its period of record (decade-plus). Validating, formalizing, and disseminating this dataset supports water management decisions in several ways.

(1) This project enhances data useability for decision makers in the Colorado River headwater catchment of the Roaring Fork Watershed by providing locally specific hydrologic data. Reservoir planning must meet the needs of local water users, downstream compacts, and **endangered species requirements**. Understanding the role of soil moisture in headwaters catchments provides additional information to reservoir managers as they work to time releases to augment streamflow and meet these myriad needs.

(2) Increasing the robustness and accessibility of the dataset advances its utility for validating and improving soil moisture models to decrease uncertainty in runoff forecasts. Better runoff forecasts may contribute to improved **management of water deliveries** and help optimize **water rights administration**.

(3) Dissemination of information about the role of *in situ* soil moisture in the water cycle, improved quality control and validation approaches, and the iRON dataset itself create a knowledgebase to support water managers in relating soil moisture data to urgent challenges, such as drought. Soil moisture values are often low during drought periods, increasing the pertinence of soil moisture in runoff efficiency and creating a potential for ecological drought

conditions that persist across multiple years. Improved understanding of soil moisture processes as they relate to *in situ* data can support water management decisions around scarce water resources during droughts and enhance **drought management activities**.

### 3.2. Project Benefits (30 points)

**1. Describe how the need for the project was identified. Was the proposed project identified using a collaborative process with input from multiple and diverse stakeholders?**

Members of both the stakeholder and research communities have expressed a desire for a more streamlined approach to access quality controlled historic and current iRON data for multiple uses. These communities have expressed interest in both better access to iRON soil moisture data and improved QA/QC procedures.

Researchers have expressed interest in comparing the iRON dataset to other network data but are uncertain about how and where to access the most current data. Stakeholder interest in accessing the iRON dataset increased markedly following the over-estimates of runoff in 2020 and 2021 for the Colorado River and its headwaters since soil moisture was identified as a potential factor influencing runoff efficiency. This interest is illustrated by our cost-sharing and project partners. AGCI participates in gatherings and targeted conversations with stakeholders from municipal, county, water management, recreation, agriculture, and conservation communities within the Roaring Fork Watershed, and, starting in the 2021 water year, several stakeholders expressed concern regarding the discrepancies in runoff efficiency and curiosity regarding the role soil moisture might play in improving understanding of the local water cycle and water forecasts. These partner groups identified the iRON as a possible dataset to help investigate the role of soil moisture in runoff and support their decision-making around water-related issues. However, the iRON data record is currently not in a readily applicable or accessible format for use by the non-research community or for use in runoff forecasts.

**2. Describe how the tool, method, or information will be applied and *when* will it be applied. Will the tool or information be used immediately, or will additional work need to be done before the tool will be used?**

This project will yield four key deliverables: (1) a cleaned dataset that meets the NCSMMN's forthcoming identified criteria for data quality, robustness, and QA/QC that can be used as a reference dataset for 12+ years of soil moisture records across the elevational gradient of the Roaring Fork Watershed (2) access to the historic and ongoing iRON dataset in formats acceptable for management and research communities, (3) a web tool for interfacing with and downloading the iRON data, and (4) integration of the iRON data with other data aggregation and soil moisture monitoring networks such as the National Mesonet, CoAgMet, and CUAHSI. These deliverables will be complete at the end of this project period (March 31, 2026). However, access to the iRON data will continue in perpetuity while the iRON network continues to operate. Dissemination of this tool and other information about the project are anticipated to continue after the final project completion date.

Moreover, the iRON monitoring network represents one of many individual and isolated monitoring efforts in the larger Colorado River Basin which are currently underutilized. Focusing resources on transforming these previously overlooked data sources into robust, high-quality datasets would help to identify the value and need for additional long-term *in situ* soil moisture monitoring for use in research, model validation and development, and water management decision making. This project would serve as a pilot project for optimizing utility of small-scale monitoring networks across the larger watershed.

The web-based tool made accessible during the project will be usable after the completion of the project. The tool will provide access to a cleaned soil moisture dataset, interactable quick-view plots of the data, and written guidelines for how data may be used in real time.

**3. Describe, in detail, the extent of benefits that can be expected to occur upon implementation of the project, and provide support for your responses.**

The dataset and tool developed in this project will provide a foundational dataset for soil moisture data in Colorado River headwaters catchments. While there are many immediate benefits from curation of this dataset (e.g., informing real time soil moisture conditions, integration of soil moisture data into runoff prediction), there is also the possibility for these data to have longer-lasting benefits. For instance, the iRON data record is well positioned to develop decadal and multi-decadal averages for headwater catchment soil moisture conditions, something that is currently hard to estimate from *in situ* data measurements due to limited periods of record.

- **Who will use the tool or data developed under this proposal and how will they benefit from the project? Support could include but is not limited to letters from stakeholders expressing support for the project and explaining how they will benefit.**

The tool and dataset developed in this project will benefit both water managers and researchers. The dataset and tool will help shed light on the role of soil moisture processes of the water balance in headwater catchments of the Colorado River, which is relevant to both researchers refining water forecasting models and to water managers making management decisions. In addition, this tool will provide decision-relevant information on opportunities and challenges for utility of installing in-situ soil moisture stations in mountainous terrain.

Project partners for this proposal include the Colorado River District and Ruedi Water and Power Authority. Partners contributing the cost-share for this project are the Colorado Water Conservation Board and the Colorado River District. Additional support for this project comes from the Colorado River Basin Forecast Center, City of Aspen, Roaring Fork Conservancy, and Colorado State University's Integrated Rocky Mountain-region Innovation Center for Healthy Soils (IN-RICHES). Other partners working with the iRON team include the Yampa Basin Sustainability Council, the National Resource Conservation Service, and others from the municipal, agricultural, recreational, and conservation communities. Each of these user groups has expressed an interest in being able to access the iRON dataset more easily for uses such as comparisons to their own datasets or providing context for water planning decisions.

Additionally, some partners have conveyed a need for explanatory resources that clarify how to interpret soil moisture data, its relationship to other components of the water-cycle, and more.

- **How will the project improve *water management decisions*?**

Soil moisture acts like a sponge which has the capacity to change snowpack-driven runoff timing and magnitude. Despite the recognized importance of soil moisture in runoff estimates and, consequently, management of reservoirs in snow dominated watersheds, satellite imagery-based and model-based soil moisture estimates often struggle in mountainous terrain. Making the current soil moisture monitoring efforts usable and accessible for water managers could help bridge this gap. This project will make the iRON data more accessible for water managers: for instance, the City of Aspen uses iRON data in their decision-making processes, but the Ruedi Water and Power Authority has found the data too complex to access and use. This project seeks to create a robust, high quality, and accessible dataset which is usable by all water managers across the Roaring Fork Watershed.

- **Describe if the results of your project will be *applicable elsewhere*. What additional work would need to be done to make the project results transferable to others?**

Results will be applicable to other watersheds in two primary ways. First, these data have been collected in an archetypal headwaters catchment of the Colorado River. As such, these data could help improve soil moisture modeling in mountainous terrain across the Southwest by providing an example of measured soil moisture across an elevation gradient. Second, the iRON is one of many small-scale soil moisture monitoring efforts ongoing in headwaters catchments in the southwestern United States. Other examples of soil moisture monitoring in the region include a new sensor network (currently with one live station) in the upper Yampa River Watershed by the Center for Western Weather and Water Extremes, the Logan River Observatory managed by Utah State University, the burgeoning soil moisture monitoring efforts in the upper Dolores River Watershed led by Mountain Studies Institute, the addition of soil moisture measurements at many SNOTEL sites, and the PBO\_H2O network managed by the university of Colorado at Boulder from 2012-2017.

Many of these efforts, including the iRON, operate on small budgets (the iRON project has never received Federal funding) and struggle with standardizing data quality control and broadening accessibility. This approach, if successful, could be implemented with other soil moisture monitoring networks to ensure improved data accessibility to these pre-existing datasets and to help support more distributed future monitoring that could be, similar to iRON, led by local communities and organizations.

- **To what extent will the project address the water management challenges described in E.1.1.?**

This project will address the water management challenges described in E.1.1. in two ways. First, this project will provide access to a valuable, pre-existing dataset that may further the understanding of the role of soil moisture in modeled runoff by modeling and forecasts. The extent to which *in situ* soil moisture data can be of value in validation and comparison with the

models used to generate runoff forecasts is currently under-explored, in part because of the lack of access to multi-year soil moisture datasets in mountain catchments. Second, the tool developed by this project, which provides contextual information about soil moisture, will support water managers in the Roaring Fork Watershed by generating resources highlighting use and interpretation of soil moisture data and providing access to the iRON dataset.

- 4. Explain how your project complements other similar efforts in the area where the project is located. Will your project complement or add value to other, similar efforts in the area, rather than duplicate or complicate those efforts? Are there other similar efforts in the area that have used a similar methodology successfully which can be complimented? Applicants should make a reasonable effort to explore and briefly describe related ongoing projects. Consider efforts by any Federal, state, local agency, or non- governmental organizations.**

In response to the growing interest in the role of soil moisture in water management and forecasting capabilities, there are a growing number of soil moisture monitoring networks launching in the Colorado River headwater catchments. These new deployments include: (1) deployment of cosmic ray sensors in the Roaring Fork Watershed by the USGS; (2) establishment of a new sensor network (currently with one live sensor) in the upper Yampa River Watershed by the Center for Western Weather and Water Extremes group, (3) development of a new four-station soil moisture monitoring effort in the upper Dolores River Watershed led by Mountain Studies Institute, and (4) addition of soil moisture measurements at many SNOTEL sites, including at two SNOTEL sites in the Roaring Fork Watershed. This project will generate and host “lessons learned” from the iRON for burgeoning soil moisture monitoring networks. The Colorado River District and Colorado State University have called for better coordination of soil moisture monitoring efforts at regional and state-wide scales respectively. The tools and quality control approaches developed for the iRON during this project will be shared broadly, so that others seeking guidance on data management and outreach approaches have resources specific to *in situ* soil moisture data. Importantly, iRON data can also help inform these new efforts by providing a glance back at the last 12 years of soil moisture data in the region, highlighting lessons on ways to improve these monitoring efforts from lived experiences.

### 3.3. Project Implementation (20 points)

- 1. Briefly describe and provide support for the approach and methodology that will be used to meet the objectives of the project. You do not need to repeat the full technical project description included in *Section D.2.2.4* under the Technical Project Description. However, you should provide support for your chosen methodology, including use of any specific models, data, or tools.**

This project will use AGCI’s iRON dataset. This dataset will be validated, QA/QC checks will be developed using statistical analyses, and data will be flagged for any QA/QC checks that the data does not pass. The dataset will be hosted in collaboration with a public-access data hosting platform, such as Synoptic Data. A data dashboard will be developed using modern scripts to interface with data in a “quick view” format. A web tool will be developed with text to help users understand the data, possible uses of the data, incorporation of additional

data monitoring efforts in the Roaring Fork Watershed, and instructions on how to download the data.

**2. Describe the work plan for implementing the proposed scope of work. Such plans may include, but are not limited to:**

- **an estimated project schedule that shows the stages and duration of the proposed work,**
- **milestones for each major Task,**
- **start and end dates for each Task and milestones, and**
- **costs for each Task**

Tasks included in the project work plan are summarized in **Table 1**. The project is estimated to cost \$247,217 and be completed by March 31, 2026. Work on Tasks 1-4 is anticipated to start on April 1, 2024; work on Task 5 will start in 2025. Much of the internal work to be completed by AGCI is tied to data management needs which are reflected in Tasks 1, 2, and 4. Additional internal work with the data technician will result in the tool described in Task 4. Task 3 will be carried out in partnership with AGCI and an external partner. Major milestones for each Task are listed below:

- Task 1: Project management and meetings
  - Milestones: Continued collaborative efforts on dataset generation, dissemination, and product development
- Task 2: Data validation and QA/QC
  - Milestone: Have a robust, NCSMMN criteria validated dataset
- Task 3: Automated data feed from stations and web server hosting
  - Milestone: Live data hosted on the web; data is downloadable by any user
- Task 4: Data Dissemination
  - Milestone: Complete a short, publicly accessible communications document
  - Milestone: Present data at academic conferences and seek partners (e.g., mountain and soil hydrology, climate science, hydrologic modeling, and/or water forecasting researchers) for possible future integration of iRON data into runoff prediction
- Task 5: Construct tools and develop resources capturing the potential of the iRON soil moisture monitoring network as a tool for improved runoff forecasting
  - Milestone: Develop a web-based tool highlighting iRON data alongside other Roaring Fork observations
  - Milestone: Integrate clear instructions on downloading and using iRON data for users
  - Milestone: Host iRON data on partner web tools
  - Milestone: Generate and host “lessons learned from the iRON” for burgeoning soil moisture monitoring networks



<b>Task</b>	<b>Start Date</b>	<b>End Date</b>	<b>Costs</b>
Task 1: Project management and meetings	Apr 1, 2024	Mar 31, 2026	\$45,638.33
Task 2: Data validation and QA/QC	Apr 1, 2024	Apr 1, 2025	\$29,409.92
Task 3: Automated data feed from stations and web server hosting	June 15, 2024	Feb 15, 2026	\$63,452.61
Task 4: Data Dissemination	July 1, 2024	Mar 1, 2026	\$50,013.77
Task 5: Construct tools and develop resources capturing the potential of the iRON soil moisture monitoring network	Feb 15, 2025	Apr 1, 2026	\$58,702.81
<b>Total</b>	<b>April 1, 2024</b>	<b>March 31, 2026</b>	<b>\$247,217</b>

**Table 1.** Summary of the project work plan and Tasks.

- 3. Provide a summary description of the *products* that are anticipated to result from the project. These may include data, metadata, digital or electronic products, reports, and publications. *Note: using a table to list anticipated products is suggested.***

A summary description of the anticipated products that will be produced by the project are listed in **Table 2**.

<b>Product</b>	<b>Explanation</b>
NCSMMN quality iRON dataset	Development of a robust dataset with adequate QA/QC monitoring flags that meets the NCSMMN’s forthcoming identified criteria for data quality, robustness, and QA/QC. This dataset will incorporate iRON data through the initiation of its record (2012) through present day.
iRON data web tool	Development of a remote server, web dashboard, and data downloader for iRON data. This tool will integrate iRON soil moisture data, point to additional monitoring efforts in the Roaring Fork Watershed,

	provide contextual lessons learned for setting up and maintaining soil moisture monitoring networks, and help clarify use cases for soil moisture data.
iRON data on external sites	In addition to development of an iRON data web portal and tool, updated and cleaned iRON data will be hosted by additional relevant data hosting sources such as: CUAHSI, CoAgMet, and NCSMMN.

**Table 2.** Summary of the anticipated products produced by this project.

**4. Who will be involved in the project as project partners? What will each partner or stakeholder’s role in the project be? How will project partners and stakeholder be engaged in the project and at what stages? If you are a Category B applicant, be sure to explain how your Category A partners will be engaged in the project.**

Project partners are Ruedi Water and Power Authority and the Colorado River District. Both partners have been previously involved with the iRON and are motivated to improve the quality of the dataset to ensure high quality, relevant, and reliable data for information and decision-making purposes.

For this project, AGCI will build upon prior collaborations with the Colorado River District and work in partnership with them for (a) advice on effective approaches to platforms and tools for data access for River District staff and other partners going forward and (b) identify other entities with potential interest in iRON’s refined dataset and/or data quality and validation methods.

AGCI will partner with Ruedi Water and Power Authority to (a) identify most effective tools and practices for data accessibility for local soil moisture data, (b) obtain insights into what context is most helpful to provide alongside the data, and (c) understand potential applications for local soil moisture data to inform water management and planning.

**5. Identify staff with appropriate credentials and experience and describe their qualifications. Describe the process and criteria that will be used to select appropriate staff members for any positions that have not yet been filled. Describe any plans to request additional technical assistance from Reclamation or via a contract. Please answer the following:**

- **Have the project team members accomplished projects similar in scope to the proposed project in the past either as a lead or team member?**

This work will be led by the research team at AGCI. The team has supported the development, installation, and management of the iRON soil moisture monitoring network since its conception. In addition to its expertise with regards to soil moisture, the research team at AGCI has developed web-based tools, user guides, and data products related to climate change in the Colorado River Basin.

Staff working on this project include Tanya Petach, Ph.D. Principal Investigator; Julie Vano, Ph.D., Co-investigator; Elise Osenga M.A., Co-investigator; as well as a data technician and a science fellow (comparable to a postdoctoral researcher). Additional expertise will be provided by data management contractors. These contractors will bring experience working with environmental datasets, data piping, and data management issues similar to those encountered with the iRON dataset.

Dr. Petach has previously worked to clean and publish complex environmental datasets relevant to water management decisions in the Colorado River Basin and has experience working in R, Python, and MATLAB. Dr. Vano has worked with southwestern United States drought and hydrology models and data for over a decade and will provide key insight and direction for the development and dissemination of a robust, readily usable dataset. Dr. Vano directs the research branch of AGCI and has led and completed numerous multi-faceted projects targeted at improving the connection between Colorado River science and stakeholder communities. Ms. Osenga has extensive experience managing the iRON network, which she installed and has operated for the last decade. She has also developed strong working relationships with numerous local partners and stakeholders. She will aid in data management, tool development, and stakeholder integration. The data technician has worked with SQL databases and has constructed data management scripts in R and Python for a variety of data needs. As part of this project, a science fellow will assist with data QA/QC, data validation, tool development and data integration in the research community.

- **Is the project team capable of proceeding with Tasks within the proposed project immediately upon entering into a financial assistance agreement? If not, please explain the reason for any anticipated delay.**

The project team is ready to move forward when funding is awarded. Match funding has been secured and is in place.

### 3.4. Dissemination of Results (10 points)

**Explain how project results will be disseminated, including:**

1. **Describe how the tools, frameworks, or analyses developed under the proposed scope of work will be disseminated, communicated, or made available to water resources managers who may be interested in the results.**
  - **If the applicant is the primary beneficiary of the project, explain how the project results will be communicated internally and to interested stakeholders and interested water resources managers in the area, if appropriate.**
  - **If the applicant is not the primary beneficiary of the project (e.g., universities or research institutes), describe how project results will be communicated to project partners and interested water resources managers in the area.**

Key users of the iRON dataset include the City of Aspen, the Ruedi Water and Power Authority, the Colorado River District, academic researchers, and snow hydrology research and forecasting communities. We will meet annually with representatives from each of the

stakeholder groups and engage with the research community through conferences and meetings. This project will also result in a report and online web tool which will include: (1) a data downloading platform for iRON data, (2) links to additional relevant monitoring datasets in the Roaring Fork Watershed, (3) a “lessons learned” guidance review for future soil moisture observation networks, and (4) materials to help clarify different uses of soil moisture data. These data and tools will be presented at relevant conferences alongside academic partners working in the mountain and soil hydrology, climate science, hydrologic modeling, and water forecasting fields.

**2. Describe how the project results will be shared with other water managers in the West that could use the information to support water management objectives.**

This project will work with partners to identify and participate in webinars to share project results with other water managers in the West. AGCI will present on the dataset itself, possible uses of the data, and potential impacts of the iRON dataset. Moreover, these data will be provided to stakeholders including local water utilities in western Colorado. These presentations will be open to the public, and AGCI will work to provide outreach to other water managers in the West prior to these events. The project will also be presented at relevant academic conferences and/or be published in a journal with a focus on water in the West.

### 3.5. Presidential and Department of the Interior Priorities (10 points)

- **Climate Change: E.O. 14008 emphasizes the need to prioritize and take robust actions to reduce climate pollution; increase resilience to the impacts of climate change; protect public health; and conserve our lands, waters, oceans, and biodiversity.**
- **If applicable, describe how the project addresses climate change and increases resiliency. For example, does the project help communities respond to or recover from drought or reduce flood risk?**

Negative impacts of climate change include increased extreme events, increased temperatures, and less predictable water supplies. Understanding the mechanisms driving water supply, runoff timing, and predictions of water availability are critical aspects of climate resilience, especially in the arid southwestern United States where water demand is already stressing available water supply. Soil moisture remains a poorly understood mechanism in terms of influence on runoff timing and magnitude. The proposed project will provide a key dataset to advance understanding of the role of soil moisture in runoff prediction.

- **How will the project build long-term resilience to drought? How many years will the project continue to provide benefits? Please estimate the extent to which the project will build resilience to drought and provide support for your estimate.**

The project builds resilience to drought by contributing to our understanding of the role of soil moisture in water availability. First, 12 years of headwater catchment, mountainous terrain soil moisture data will be made accessible and usable for water researchers and managers in the southwestern United States. Second, these data will continue to be collected, reviewed, and

posted to a publicly accessible site in real time. Third, a resource will be curated to help stakeholders and researchers alike use and understand these data. This project will increase resilience efforts around climate change impacts by curating a resource to integrate *in situ* soil moisture data into runoff prediction and water availability estimates. Most notably, these efforts will allow Colorado River Basin users to make more informed water management decisions to sustain populations, ecosystems, and federal projects along the water-stressed river corridor.

- **Will the proposed project reduce greenhouse gas emissions by sequestering carbon in soils, grasses, trees, and other vegetation? Does the proposed project seek to reduce or mitigate climate pollutions such as air or water pollution? Does the proposed project contribute to climate change resiliency in other ways not described above?**

This project does not directly contribute to carbon sequestration; however, this project will contribute a key data record to the scientific community with potential applications beyond the drought resilience and water forecasting scope.

## 4. Cited References

Al-Yaari, A., Wigneron, J. P., Kerr, Y., Rodriguez-Fernandez, N., O'Neill, P. E., Jackson, T. J., ... & Yueh, S. (2017). Evaluating soil moisture retrievals from ESA's SMOS and NASA's SMAP brightness temperature datasets. *Remote sensing of environment*, 193, 257-273.

Feng, S., Huang, X., Zhao, S., Qin, Z., Fan, J., & Zhao, S. (2022). Evaluation of Several Satellite-Based Soil Moisture Products in the Continental US. *Sensors*, 22(24), 9977.

Osenga, E. C., Vano, J. A., & Arnott, J. C. (2021). A community-supported weather and soil moisture monitoring database of the Roaring Fork catchment of the Colorado River Headwaters. *Hydrological processes*, 35(3), e14081.

## 5. Project Budget

The total project budget is \$247,217 to complete Tasks 1-5 between April 1, 2024 - March 31, 2026. AGCI is requesting \$123,608 from Reclamation under this NOFO. The remaining funds will be split between AGCI internal funds, a Colorado Water Plan grant, and a grant from the Colorado Water District. The project cost estimate listed by Task is included in Table 1(section 3.3).

A description of the project budget is described below, including details on funding already secured from the Colorado Water Plan, AGCI internal funds, and the Colorado River District to meet the non-federal cost share requirement.

### **Budget Proposal**

The breakdown of costs between the three non-federal cost sharing partners and Reclamation is highlighted in Table 3.

<b>Funding sources–Non-Federal Entities</b>	<b>Amount</b>
Colorado Water Plan (CWCB) grant funds	\$79,109
Colorado River District grant funds	\$29,666
AGCI internal funds	\$14,833
<b>Requested Reclamation Funding</b>	<b>\$123,608</b>

**Table 3.** Summary of Non-Federal and Federal Funding Sources

The cost share represents a 50% contribution. The full project budget is summarized in Table 4. For additional budget information, please refer to the budget and budget narrative attachments.

<b>Summary</b>			
<b>Figures in this summary table are calculated from entries made in subsequent categories, only blank white cells require data entry.</b>			
<b>6. Budget Object Category</b>	<b>Total Cost</b>	<b>Federal Estimated Amount</b>	<b>Non-Federal Estimated Amount</b>
<b>a. Personnel</b>	<b>\$106,948</b>		
<b>b. Fringe Benefits</b>	<b>\$24,299</b>		
<b>c. Travel</b>	<b>\$5,108</b>		
<b>d. Equipment</b>	<b>\$0</b>		
<b>e. Supplies</b>	<b>\$0</b>		
<b>f. Contractual</b>	<b>\$40,000</b>		

<b>g. Construction</b>	<b>\$0</b>		
<b>h. Other Direct Costs</b>	<b>\$1,500</b>		
<b>i. Total Direct Costs</b>	<b>\$177,854</b>		
<b>i. Indirect Charges</b>	<b>\$69,363</b>		
<b>Total Costs</b>	<b>\$247,217</b>	<b>\$123,608</b>	<b>\$123,609</b>
<b>Cost Share Percentage</b>		<b>50%</b>	<b>50%</b>

**Table 4.** Summary of budget object categories, total costs, and federal/non-federal cost breakdowns.

## 6. Environmental and Cultural Resources Compliance

**6.1. Will the proposed project impact the surrounding environment (e.g., soil [dust], air, water [quality and quantity], animal habitat)? Please briefly describe all earth-disturbing work and any work that will affect the air, water, or animal habitat in the project area. Please also explain the impacts of such work on the surrounding environment and any steps that could be taken to minimize the impacts.**

There are no construction aspects to this project; this project will not affect the air, water, or animal habitat in the project area.

**6.2. Are you aware of any species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat in the project area? If so, would they be affected by any activities associated with the proposed project?**

No activities in the project affect habitat, as no earth-disturbing activities or disruptive transport across sensitive habitat regions are proposed in the project.

**6.3. Are there wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as “Waters of the United States”? If so, please describe and estimate any impacts the proposed project may have.**

No activities in the project will affect any wetlands or surface waters that potentially fall under the Clean Water Act jurisdiction of “Waters of the United States” as there will be no earth disturbing activities.

**6.4. When was the water delivery system constructed?**

No activities in this project will affect conveyance infrastructure because there will be no earth disturbing activities.

**6.5. Will the proposed project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)? If so, state when those features were constructed and describe the nature and timing of any extensive alterations or modifications to those features completed previously.**

No activities in this project will affect any aspect of an irrigation system because there will be no earth-disturbing activities as part of the project.

**6.6. Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places? A cultural resources specialist at your local Reclamation office or the State Historic Preservation Office can assist in answering this question.**

No activities in this project will affect any buildings, structures, or features listed or eligible for listing on the National Register of Historic Places because there will be no earth-disturbing activities as part of the project.

**6.7. Are there any known archeological sites in the proposed project area?**

No activities in this project will affect any aspect of an archeological site because there will be no earth-disturbing activities as part of the project.

**6.8. Will the proposed project have a disproportionately high and adverse effect on low income or minority populations?**

The impacts of this project will have no negative impacts on low income or minority populations.

**6.9. Will the proposed project limit access to, and ceremonial use of, Indian sacred sites or result in other impacts on tribal lands?**

There are no tribal lands in the project area. Additionally, no activities in this project will affect access to lands.

**6.10. Will the proposed project contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area?**

No activities in this project will affect introduction, continued existence, or spread of noxious weeds or non-native invasive species because there will be no earth-disturbing activities as part of the project.



## 7. Required Permits of Approvals

This project does not require any permits or approvals.

## 8. Overlap of Duplication of Effort Statement

This proposal aligns with ongoing work funded through the cost share. This was our first opportunity to apply for WaterSMART funds since securing matching funds from Colorado Water Conservation Board and the Colorado River Water Conservation District. The addition of WaterSMART Applied Science funds will add value to the overall co-shared project by:

- Contributing to more robust data hosting with an external partner
- Increasing data quality and robustness
- Contributing towards an enhanced data portal and use tool
- Reaching a wider audience with a more robust dataset

This effort is not duplicative of any other projects.

## 9. Conflict of Interest disclosure statement

There are no conflicts of interest to disclose.

## 10. Uniform Audit Reporting Statement

AGCI was not required to submit a Single Audit report for the most recently closed fiscal year.

## 11. Letters of Support

Letters of support for the project were provided by the Colorado State University's IN-RICHES program, the Colorado Basin River Forecast Center, the Roaring Fork Conservancy, and the City of Aspen and are attached in Appendix A.

## 12. Letter of Partnership

A letter of partnership for the project was provided by the Ruedi Water and Power Authority and Colorado River District and are attached in Appendix B.

## 13. Letters of Funding Commitment

Letters of funding commitment for the project were provided by the Colorado River District and the Colorado Water Conservation Board and are attached in Appendix C.

# Appendix A

Letters of support

U.S. DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
National Weather Service  
Colorado Basin River Forecast Center  
2242 West North Temple  
Salt Lake City, Utah 84116-2919



October 13, 2023

To Whom It May Concern:

The Colorado Basin River Forecast Center (CBRFC) supports Aspen Global Change Institute's grant proposal to the WaterSMART Applied Sciences Program for the grant proposal: "Roaring Fork Watershed: Improving soil moisture data validation and access."

The Colorado Basin River Forecast Center is interested in improved access to the Aspen Global Change Institute's "IRON" soil moisture dataset for possible comparisons to our existing modeled soil moisture data. The proposed project would both improve ease of access to this dataset and would improve the quality of the data themselves.

For these reasons, we are in favor of the Aspen Global Change Institute's request to fund "Roaring Fork Watershed: Improving soil moisture data validation and access."

Sincerely,

A handwritten signature in black ink, appearing to read "John D. Lhotak".

John Lhotak - Development and Operations Hydrologist  
on behalf of Michelle Stokes - Hydrologist in Charge

Colorado Basin River Forecast Center, NOAA



Re: Aspen Global Change Institute Application to WaterSMART Applied Sciences NOFO, Fiscal Year 2023

Dear Stephanie Micek,

On behalf of Colorado State University's (CSU) Integrated Rocky Mountain-region Innovation Center for Healthy Soils (IN-RICHES), I submit this letter of support in favor of funding Aspen Global Change Institute's grant proposal to the WaterSMART Applied Sciences Program for the grant proposal: "Roaring Fork Watershed: Improving soil moisture data validation and access."

Recently established, IN-RICHES is part of CSU's Agricultural Experiment Station and is tasked with improving and sustaining soil health in the state of Colorado. From farms to forests, our mission is to create systems level change that scales regenerative soil health systems in the Rocky Mountain region and beyond. Soil moisture plays an important role in soil health, ecological health, and the health of our state's water systems. However, there is a need for greater coordination across soil moisture monitoring networks in Colorado and more simplified access to data from these networks for multiple data users.

We are currently in the process of facilitating collaboration across existing soil moisture networks within Colorado and have hosted several meetings with partner and stakeholder groups to this end. In this work, Aspen Global Change Institute is an active partner, and we see a powerful opportunity for Colorado's soil moisture monitoring community to benefit from the lessons learned around data quality control, data sharing, and data management that would come out of the "Improving soil moisture data validation and access" project.

Properly shared, soil moisture data have a real potential to advance our understanding of water processes and water management practices. But to do so, we will need shared demonstrations of effective data practices, and we strongly support Aspen Global Change Institute's request to fund "Roaring Fork Watershed: Improving soil moisture data validation and access."

Any questions may be directed to myself at [helene.d.silver@gmail.com](mailto:helene.d.silver@gmail.com) or Megan Machmuller at [megan.machmuller@colostate.edu](mailto:megan.machmuller@colostate.edu).

Thank you for your consideration,

Helen D. Silver

A handwritten signature in black ink that reads "Helen D. Silver". The signature is written in a cursive style.

Co-director  
IN-RICHES  
[inrichsoil.com](http://inrichsoil.com)



WaterSMART Applied Sciences  
Attn: Stephanie Micek  
P.O. Box 25007  
Denver Federal Center  
Denver, CO 80225

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*Education Program Coordinator*  
Chad Rudow  
*Water Quality Program Manager*  
Sheryl Sabandal  
*Development Director*  
Andrea Tupy  
*Ecologist*  
Matthew Anderson  
*Water Quality Technician*

Dear Ms. Micek,

Roaring Fork Conservancy (RFC) is writing to express strong support for Aspen Global Change Institute's (AGCI) grant proposal to the WaterSMART Applied Sciences Program for the grant proposal: "Roaring Fork Watershed: Improving soil moisture data validation and access."

Roaring Fork Conservancy is an independent, not-for-profit 501(c)(3) organization and one of the most respected watershed organizations in Colorado through its focus on water quantity, water quality, and riparian habitat preservation.

RFC has been a long-time partner of AGCI and would benefit from its proposed work to improve soil moisture data access and quality. As a key provider of public information about stream health conditions in the watershed, RFC is interested in including data from AGCI's soil moisture network as part of its weekly river reports. These are Stream Flow and Snowpack Reports that provide significant outreach to the public by alerting local residents to snow, water, drought, and other conditions in their watershed.

RFC is a small non-profit that collects extensive amounts of data locally on water quality and stream conditions and substantial staff time is used conducting necessary quality control checks on data prior to publication and/or public dissemination. AGCI's WaterSMART proposal includes sharing methods and approaches for data management with partner organizations in the community. Having access to AGCI's data cleaning processes, quality control checks, and learning about their approach to data sharing has the potential to help revise RFC's own data quality approaches, without the intensive time and effort of developing programs from scratch.

For these reasons, please give the highest consideration to Aspen Global Change Institute's application to fund "Roaring Fork Watershed: Improving soil moisture data validation and access."

Sincerely,

Chad Rudow  
Water Quality Program Manager





Attn:  
Grants Support Officer  
WaterSMART Applied Sciences  
Fiscal Year 2023

To Whom It May Concern:

The Water Department of City of Aspen submits this letter in support of Aspen Global Change Institute's (AGCI) grant proposal to the WaterSMART Applied Sciences Program for: **Roaring Fork Watershed: Improving soil moisture data validation and access.**

City of Aspen is tasked with ensuring a safe and reliable water supply for our residents and visitors. In the face of changing climate conditions, we cannot rely solely on historic patterns to assist in our planning and management strategies. We additionally need access to current, rigorous, and locally-relevant data from multiple sources.

The WaterSMART project proposed by AGCI includes tasks to improve the rigor and accessibility of the dataset for the Roaring Fork Observation Network (iRON). Improvements to the dataset are of high interest to City of Aspen's Water Department, which already references the iRON dataset for local information about soil moisture and weather conditions. City of Aspen would directly benefit from advancements in ease of access to and additional context for these data. Additionally, the project's efforts to improve data quality in alignment with national soil moisture standards would allow for broader comparison of the iRON dataset to other soil moisture and hydrologic datasets both within the Roaring Fork Watershed and across other basins experiencing similar water management challenges.

City of Aspen has a long-standing relationship with AGCI, including initial and ongoing support of an iRON station in the Castle Creek basin, a critical source of water supply for the City. Our relationship has been one of mutual learning across the boundaries of scientific research and societal application.

For these reasons, we support funding AGCI's proposal **Roaring Fork watershed: Improving soil moisture validation and access.**

Thank you for your consideration. Any questions may be directed to Steve Hunter PE, PH, Utilities Resource Manager, City of Aspen, Colorado, [steve.hunter@aspen.gov](mailto:steve.hunter@aspen.gov)

# Appendix B

Letters of partnership



**COLORADO RIVER DISTRICT**  
PROTECTING WESTERN COLORADO WATER SINCE 1937

October 5, 2023

*Via electronic mail*

Bureau of Reclamation  
ATTN: Ms. Stephanie Micek  
PO Box 25007  
Denver Federal Center  
Denver, CO 80225-0007

RE: Support Letter: Aspen Global Change Institute Application

Dear Ms. Micek:

The Colorado River Water Conservation District ("River District") is pleased to support Aspen Global Change Institute's ("AGCI") 2023 WaterSMART Applied Sciences application regarding the project: *Roaring Fork Watershed: Improving soil moisture data validation and access*. The River District is a local government that serves as a leader in the protection, conservation, use, and development of water resources of the Colorado water basin for the welfare of the District. In this effort, the District views soil moisture data collection as imperative in the District's ability to adapt to a hotter and dryer climate.

The project will build upon AGCI's existing work to improve access to in situ soil moisture data from the Roaring Fork basin, provide contextual information about soil moisture data, and support coordination of soil moisture research across headwater basins in the Upper Colorado. Currently, in situ soil moisture data can be challenging to access and utilize in a timely manner. Yet, this data is urgently needed to help address the challenges of growing water demand alongside a shrinking water supply. Funding from the WaterSMART Applied Sciences grant would support the accessibility and utility of the soil moisture data.

In October 2022, the River District granted \$60,293 to AGCI's project to respond to a community need to understand how soil moisture data can support drought-ready, climate-adaptive water management. Their work over the past year and half has gained strong support from partners across Colorado. The River District is dedicating a portion of the grant to serve as a match towards AGCI's WaterSMART application to support their work to further disseminate their soil moisture data to partners in our community.

We strongly support the AGCI's project: *Roaring Fork Watershed: Improving soil moisture data validation and access* and their application for the WaterSMART Applied Sciences funding and ask that you look favorably upon their WaterSmart application.

Thank you for your consideration.

Sincerely,

Andrew A. Mueller  
General Manager

☎ 970.945.8522

📍 201 Centennial Street | Suite 200  
Beverly Springs, CO 81601

🌐 [ColoradoRiverDistrict.org](http://ColoradoRiverDistrict.org)



  
Ruedi Water & Power Authority

Ms. Stephanie Micek  
PO Box 25007  
Denver Federal Center  
Denver, CO 80225-0008

Subject: AGCI Grant Proposal: WaterSMART Applied Sciences Grant Program

Dear Ms. Micek and Staff of Reclamation,

I am writing to express Ruedi Water and Power Authority's (RWAPA) full support in favor of funding the Aspen Global Change Institute's grant application to the WaterSMART Applied Sciences Grant Program, Fiscal Year 2023, *Roaring Fork Watershed: Improving soil moisture data validation and access*.

RWAPA is a regional water agency in the Roaring Fork Watershed, directed by a board with an elected official from each local government within the watershed – City of Aspen, Town of Snowmass Village, Town of Basalt, Town of Carbondale, City of Glenwood Springs, Pitkin County and Eagle County. We work to facilitate cross-jurisdictional policies and programs that protect and support communities and waterways across our watershed.

Recent years of drought in the Roaring Fork and across the West have increased the challenge of finding approaches that both meet in-basin water needs and fulfill downstream water rights. AGCI's project *Improving soil moisture data validation and access* proposes several actions that we believe would benefit RWAPA and our stakeholder communities.

The improved dashboards and tools for viewing and understanding soil moisture data would be of direct utility to RWAPA and others by reducing our burden of time for accessing and interpreting local soil moisture data. The advancements to data validation and adherence to data quality standards would (1) allow comparison of iRON data to other datasets being collected in this watershed, such as the USGS NGWOS soil moisture data, helping to create a more complete picture of soil moisture across our basin and (2) expand opportunities for comparison of local on-the-ground soil moisture conditions to the modeled soil moisture data and runoff forecasts used by RWAPA and other agencies in reservoir management and planning.

RWAPA would directly benefit from this project and strongly recommends this proposal for funding through the WaterSMART– Applied Sciences program.

If you have any further questions, please contact me at [april@rwapa.org](mailto:april@rwapa.org).

Sincerely,

*April B. Long*

April B. Long  
Executive Director, Ruedi Water and Power Authority

P.O. Box 565  
Basalt, CO 81621

