# Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin.

Submitted to: Department of the Interior Bureau of Reclamation WaterSMART Applied Sciences Program – Funding Opportunity No. R21AS00289

## Montana Department of Natural Resources and Conservation

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# LIST OF ACRONYMS

| Acronym | Definition |
|---|---|
| AMB | Arthur M. Blank Foundation |
| API | Application Programming Interface |
| DNRC | Montana Department of Natural Resources and Conservation |
| DRI | Desert Research Institute |
| ET | Evapotranspiration |
| FOA | Funding Opportunity Announcement |
| FWP | Montana Fish, Wildlife & Parks |
| GIS | Geographic Information Systems |
| MARS | Montana Aquatic Resources Services |
| MBMG | Montana Bureau of Mines and Geology |
| MCO | Montana Climate Office |
| METRIC | Mapping EvapoTranspiration at high Resolution with Internalized Calibration |
| NOAA | National Oceanic and Atmospheric Administration |
| NPS | National Park Service |
| NRCS | National Resources Conservation Service |
| PCA | Principal Component Analysis |
| PCEC | Park County Environmental Council |
| PKD | Proliferative Kidney Disease |
| USFS | United States Forest Service |
| USGS | United States Geological Survey |
| UYWG | Upper Yellowstone Watershed Group |

# TECHNICAL PROPOSAL AND EVALUATION CRITERIA

## 1. Executive Summary

**21- April 2021**

**Applicants:** John Lunzer, Sara Meloy, David Ketchum, Todd Blythe, Melissa Schaar, Montana Department of Natural Resources and Conservation – Water Management Bureau, Helena, Lewis & Clark County, Montana (Category A Applicant)

**Project Summary:**
Stakeholders and managers in the Upper Yellowstone Watershed, in south central Montana, are increasingly forced to balance the growing demand for water with uncertainty in water supply, the latter of which is primarily driven by climatic shifts towards earlier season snowmelt runoff, warmer temperatures, and persistent drought conditions. This complexity in water management has created tension throughout the community in recent years, but the turning point was in August of 2016, when low flows and warm water conditions led to a parasite outbreak that caused an unprecedented die-off of native mountain whitefish. The resulting temporary closure of a large stretch of the river and the associated economic and ecologic impacts underscored the need for a modern hydrologic toolset to forecast water supply conditions, enhance water management decision-making, and inform drought planning efforts. In response to this need and ongoing concerns from a wide variety of local stakeholders, the Montana Department of Natural Resources and Conservation (DNRC) will develop a robust water balance, precipitation-runoff hydrologic model, and water supply forecasting tools for the watershed. This suite of tools will use established methodologies to improve water supply decision-making and modeling capabilities for the watershed. Water supply forecasting will be enhanced by incorporating a physical precipitation-runoff technique, which will complement the existing statistical method. Evapotranspiration (ET) and crop consumption estimates will also be improved using remote sensing data and existing modeling software. This method has been applied by the principal investigators (PIs) in other parts of Montana, and it has been shown to improve modeling and forecasting accuracy, reduce error, and contribute to a better understanding of the watershed hydrology. Ultimately, the proposed project will provide stakeholders and managers with three distinct tools: (1) a water balance, (2) a precipitation-runoff hydrologic model, and (3) water supply forecasts. These tools will be implemented immediately by water managers to assess water management strategies, inform drought planning efforts, improve irrigation management, and inform fishery management in the Upper Yellowstone Watershed.

Funds received would be used to support equipment, travel, and a hydrologic technician. If selected, the project would begin when funds are distributed and conclude after two years' time. The proposed project is not located on a Federal facility.

## 2. Technical Project Description and Milestones

### *2.1 Overview and Objectives*

The Yellowstone River Basin (Figure 1) is renowned in Montana for its good water quality and ample water supply, both of which support local economies through activities like agricultural irrigation and recreation. However, in recent decades, flow volumes in late summer have become increasingly unreliable because of earlier spring runoff, variable winter snowpack, and warmer, drier summers with frequent drought events (Whitlock et al. 2017). This uncertainty is particularly acute in the Upper Yellowstone Watershed, in south central Montana, where flows are primarily snowmelt-driven and high demand from municipalities and domestic wells reflects the region's rapidly growing population. Water supply management decisions in the Upper Yellowstone are currently limited by the available hydrologic data, which lack the spatial and temporal detail necessary to understand the system's water balance and accurately model hydrologic processes. This basic, regional understanding of water supplies in the Upper Yellowstone fails to capture many of the intricacies of the complex hydrologic system, especially for irrigation use, which is the highest consumptive use in the basin and comprises the greatest proportion of the withdrawals from the watershed. We will address this deficiency by calculating a detailed runoff water balance and developing a hydrologic modeling and forecasting tool to help local and state water managers and hydrologists, as well as Yellowstone River users, address and adapt to water supply challenges in an uncertain and changing future.

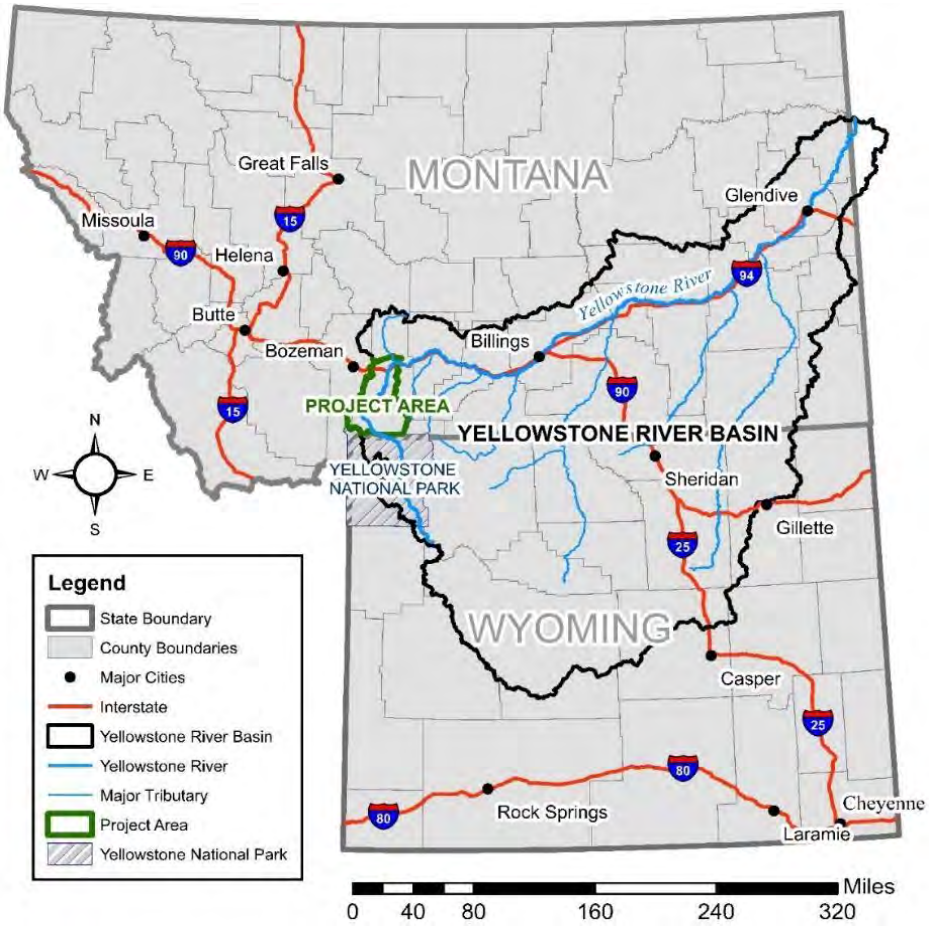



*Figure 1: Montana and Wyoming with Yellowstone River Basin, Yellowstone National Park and Project Area.*

***The goal of this project is to use existing methods to create a comprehensive modeling and water supply forecasting framework for adaptive management of water resources.*** To achieve this goal, we will combine remotely-sensed ET and irrigated lands mapping with telemetered streamflow and irrigation infrastructure data to improve existing DNRC systems models and calibrate a precipitation-runoff model for the study area. The resulting models will be used to support water management decisions and produce short- and long-term water supply forecasts for the region. Recent work by the PIs in other Montana watersheds show that hydrologic modeling and water supply forecasting can enhance water management decisions and drought resiliency on a watershed scale. Also, more spatially continuous water use data (particularly irrigation consumption and operation) could greatly improve DNRC's existing water balance models and provide detailed information on how changes in water use might affect hydrologic systems.

Recent advances in hydrologic and ET data have led DNRC to explore the use of more sophisticated techniques that could inform and improve water management in Montana. DNRC is collaborating with the Desert Research Institute (DRI) and Montana Climate Office (MCO) and has acquired access to an open-source remote sensing-based ET model implementation that can leverage Landsat optical and thermal imagery at the resolution necessary to describe the spatial and temporal variability in ET in agricultural regions.

The proposed work will build upon the previous efforts by the PIs and is the next logical step in DNRC's efforts to combine contemporary ET with irrigation monitoring, hydrologic modeling, and streamflow forecasting methods to form an improved, unified framework that meets the present and future surface water management challenges in Montana. The Project Team is uniquely qualified with expertise in large-scale hydrologic monitoring, analysis of high-resolution ET datasets, hydrologic model development, and on-the-ground knowledge of the challenges faced by water resource managers in the region. The following aims describe the steps required to complete this project:

**Aim 1. Calculate a comprehensive, runoff water balance.**

The Upper Yellowstone lacks a detailed water balance that includes watershed-scale information on crop consumption, irrigation systems, groundwater, and domestic water use. Runoff is the outflow component of the total water balance and consists of precipitation minus landscape evapotranspiration. Therefore, this portion of the project will quantify the fate of runoff water and associated consumption. We will focus on filling the hydrologic data gaps necessary to calculate this detailed water balance and incorporate new data sources available to DNRC (e.g., real-time streamflow, remotely-sensed ET, and improved mapping of irrigated lands). Data will be collected or acquired at spatial and temporal scales useful for management decisions (e.g., what is the seepage of canal X in July and what is the fate of that seepage?). The water balance will be used to construct an operational, systems model that allows the user to define inflows for specific locations, at specific times, and calculate resulting outflows. This is one of two models in the comprehensive modeling framework outlined in our overall goal and allows for scenario-based decision making by quantifying how changes in one system may propagate through the entire hydrologic system (e.g., if irrigation practices are altered on canal X, how does streamflow change downstream?).

**Aim 2. Develop a hydrologic modeling framework and water supply forecasts.**

The second model in our proposed hydrologic modeling framework is a precipitation-runoff model that will be calibrated using the improved data from Aim 1. DNRC currently does not use precipitation-runoff models and has identified a goal of employing this type of approach for quantifying surface water inputs and improving our ability to forecast streamflow or water supply. This physical model will define the total, watershed-scale water balance, including meteorological inputs, storage components, and landscape ET. The precipitation-runoff model will be used to estimate current natural streamflow and past streamflow at specific locations (as far back as available input data exist). Output from this model will serve as input to the systems model from Aim 1, such that a user could estimate streamflow under certain climatic conditions and then apply management scenarios to understand how to best distribute the available supply. The two-part modeling framework will also be used to develop water supply forecasts at specific locations and incorporate existing management or management scenarios.

**Aim 3. Engage irrigators, municipalities, and fishery managers to increase optimization and utilization of the resulting hydrologic model and water supply forecasts.**

Current relationships with the Upper Yellowstone Watershed Group (UYWG), City of Livingston, and Montana Fish, Wildlife & Parks (FWP), will be used to solicit input and feedback throughout the proposed work, which will ensure the hydrologic model and water supply forecasts meet end user needs.

The proposed work will directly address the goal of the current Funding Opportunity Announcement (FOA) to "develop hydrologic information and water management tools and improve modeling and forecasting capabilities" by leveraging recently-developed modeling approaches, forecasting methods, and data sources to develop a hydrologic model to support informed water management decisions and provide accurate water supply forecasts. Additionally, the project aims are well-aligned with the overall objective of the Bureau's WaterSMART Applied Sciences program to "be used by water managers to increase water supply reliability, provide flexibility in water operations, and improve water management". When the project is completed, we expect to be able provide: 1) enhanced hydrologic datasets, 2) a hydrologic watershed scale predictive model for managers, and 3) accurate water supply forecasts that can be used to improve decision making by surface water managers. The successful completion of the project will yield modeling and forecasting toolsets for improved water management in a snowmelt-driven, drought impacted watershed.

## *2.2 Significance*

The Upper Yellowstone Watershed has experienced significant drought in recent years, most notably in the summer of 2016. On August 19, 2016, in response to a rapid and unprecedented die-off of mountain whitefish, FWP closed the Yellowstone River and its tributaries to all water-based recreation from Gardiner, MT to the Highway 212 bridge in Laurel, MT (Figure 2). The

*Figure 2: Mountain whitefish in the wake of the 2016 fish kill (NPS 2016).*

cause of the fish kill was a microscopic parasite carrying Proliferative Kidney Disease (PKD) – a disease that impacts salmonid fish species and causes kidney swelling, loss of equilibrium, respiratory distress, and, eventually, death. In analyzing what has become known locally as the "fish kill," FWP identified low flow and warm water temperatures in the Yellowstone River as contributing environmental factors.

Likewise, these drought conditions have caused economic losses for local irrigators, ranchers, and recreational outfitters. Limited water supplies during drought seasons reduces crop growth and subsequent crop yields. Furthermore, low water conditions stress livestock that graze throughout the Watershed. Finally, these conditions can lead to state-enforced recreation restrictions prohibiting guides from taking clients out to fish, often with little to no warning.

Water shortages have also led to significant conflict between water users in the watershed. These conflicts include disputes among irrigators, irrigators and outfitters, and various local stakeholder groups. Many of these conflicts arise due to the lack of any hydrologic data to support sound decision making. Additionally, drought management or mitigation plans cannot be developed without detailed hydrologic data and a modeling framework.

Work performed by the PIs in other parts of Montana, including the Lolo Creek Watershed near Lolo, Big Hole River Watershed near Wisdom, and Teton River Valley near Choteau, has shown the effectiveness of data collection, hydrologic modeling, and water supply forecasting at promoting voluntary drought management plans, informing water management practices, and reducing local water user conflicts. Further implementation of these techniques in the Upper Yellowstone will continue to promote sound, science-based decision making at a watershed scale.

*The proposed work is significant* because its successful completion will result in a hydrologic model and water supply forecasting tool that can be utilized by local stakeholders, including municipalities, irrigation districts, and state agencies, to inform water management decisions. These water management decisions will improve sustainability and drought resiliency of operations in the watershed. Modeling will allow for simulation of potential future scenarios and proposed management plans. Water supply forecasts will provide early warning of water shortages and provide lead time for mitigation to be implemented. This lead time will allow stakeholders to avoid or minimize economic impacts, as well as reduce negative impacts on aquatic species.

### *2.3 Project Location*

The proposed work will focus on Upper Yellowstone Watershed defined as the portion of the Yellowstone River extending from the Yellowstone National Park boundary, downstream to the confluence of the Yellowstone and Shields Rivers (Figure 3). This stretch of the Yellowstone River contains roughly 70 miles of world class trout fishery, several feeder tributaries that are ideal Yellowstone cutthroat habitat, over 40,000 acres of productive agricultural land, and the municipalities of Gardiner, MT and Livingston, MT. Yellowstone National Park borders the project area to the south. Additional maps are available in Appendix A.

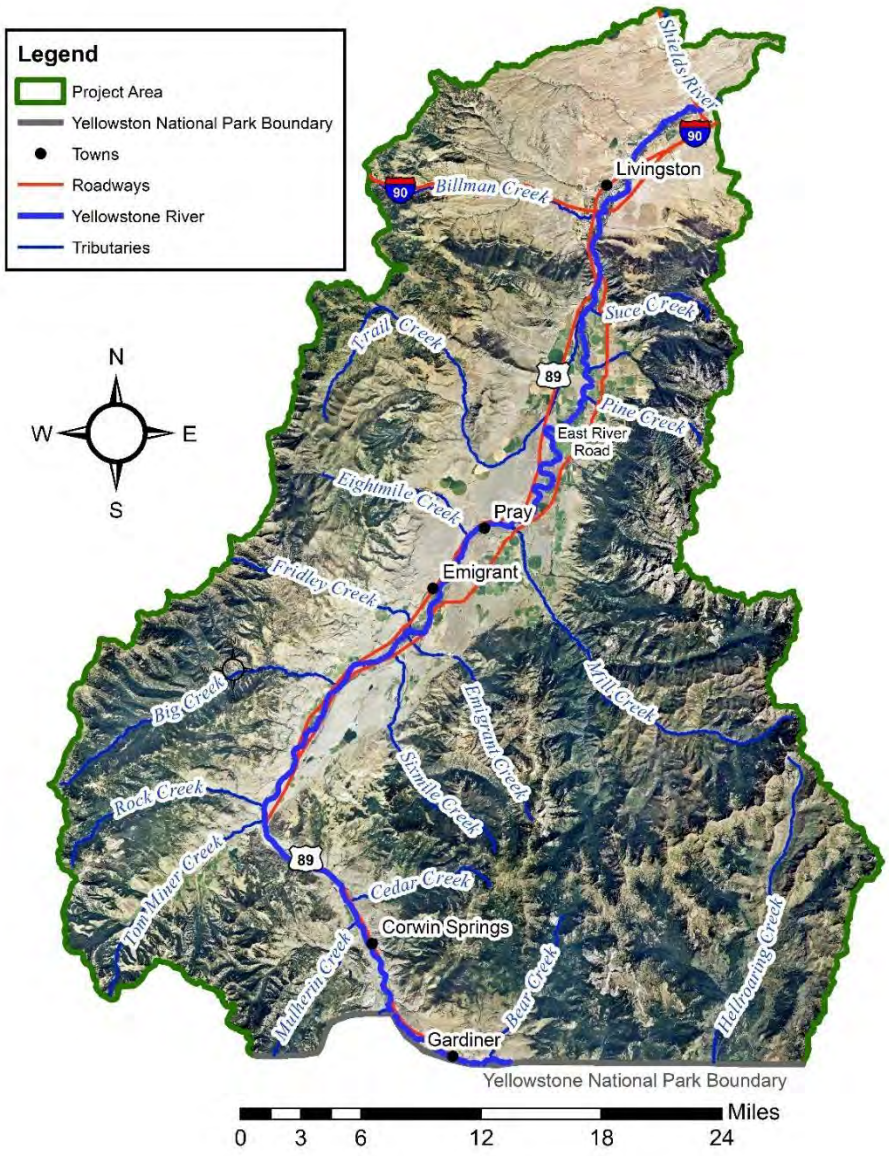



*Figure 3: Project area with Yellowstone River and significant tributaries.*

## *2.4 Preliminary Data*

A variety of agencies and groups currently operate monitoring equipment in the proposed study area. These include the United States Geological Survey (USGS), Montana Bureau of Mines & Geology (MBMG), Natural Resource Conservation Services (NRCS), MCO, National Park Service (NPS), United States Forest Service (USFS), UYWG, and FWP. These monitoring efforts measure streamflows, groundwater conditions, water quality, water temperature, snowpack, precipitation and soil moisture. Currently, the PIs manage several stream and canal gages within the project area. All these datasets will be incorporated into the proposed project through collaboration with all the groups listed above.

ET analysis will be performed using open-source processing and analysis software developed by Desert Research Institute and modified by DNRC hydrologists to automatically process the input

data for this study. Input data includes Landsat 30m resolution satellite imagery from Enhanced Thematic Mapper Plus (Landsat 7) and the Operational Land Imager and Thermal Infrared Sensor (Landsat 8), both of which are currently in operation. Meteorology data will include daily 4km resolution gridded inputs from GridMET (Gridded Meteorology; Abatzoglu, 2013), hourly 1/8th-degree grid North American Land Data Assimilation System (NLDAS; Mitchell et al., 2007), and 15-minute Montana Climate Office Mesonet weather station data. ET analysis will be summarized using geospatial data from the Montana Statewide Irrigation Dataset, which has partial coverage in the study region. PI Ketchum has experience using this software and has downloaded and processed data in the study region (2016 – 2019) for preliminary inspection.

### *2.5 Methods*

**Aim 1. Calculate a comprehensive, runoff water balance.**

The water balance for this project will follow DNRC's existing methods of quantifying the fate of streamflow, or runoff (Figure 4). These methods were developed by combining modern techniques with institutional knowledge acquired through dozens of similar projects over the last two decades (Blythe and Schmidt, 2018). To allow for more spatially explicit water balance calculations, we will split the Upper Yellowstone into Water Balance Regions. We will calculate separate water budgets for each Water Balance Region so that differences (i.e. some regions may have agriculture use, some may have no use, and some may have more domestic use) can be accurately represented and quantified separately from the aggregated basin-wide budget. We will compile all datasets and construct a systems model of the basin by categorizing input data by geographic location, upstream/downstream orientations, and as an input or output. ET is categorized by water source, rather than the physical location of the place of use (i.e. the field). Groundwater elevation data will be included to estimate and calibrate the surface water components of seepage, recharge, and streamflow loss. The groundwater balance will be calculated in the same way as the runoff water balance, after monitoring well data are converted into changes in aquifer storage over a specified time-step.

The interaction between the groundwater and surface water balances is calibrated by considering certain outputs of the surface water system as inputs to the groundwater system and vice versa. These interactions are quantified or verified by synoptic field surveys (longitudinal streamflow over a short time-period). We will combine the groundwater and surface water balance for each Water Balance Region to construct a comprehensive water budget for the basin in which inputs can be adjusted in real-time to explore scenarios of interest. Currently, the systems model is implemented using Geographic Information Systems (GIS) to construct the spatial categories and Python code to manage datasets and perform calculations. Individual input datasets (e.g. streamflow, groundwater levels, ET, domestic use, etc.) will be collected or produced independently and compiled in an input file for use in the systems model. Much of the data exists and will be requested from local municipalities or other agencies. Data gaps will be filled by collecting any additional data (primarily diversion rates) using standard DNRC field protocols. ET data used in the systems model requires its own set of methods because it is derived from operations on satellite data. It is our preference that the water balance be produced at daily time steps, but it could be monthly depending on the resolution of the input data. The final systems model can be packaged as a stand-alone python program or can be migrated to an easy to use Microsoft Excel spreadsheet (or any other requested platform).

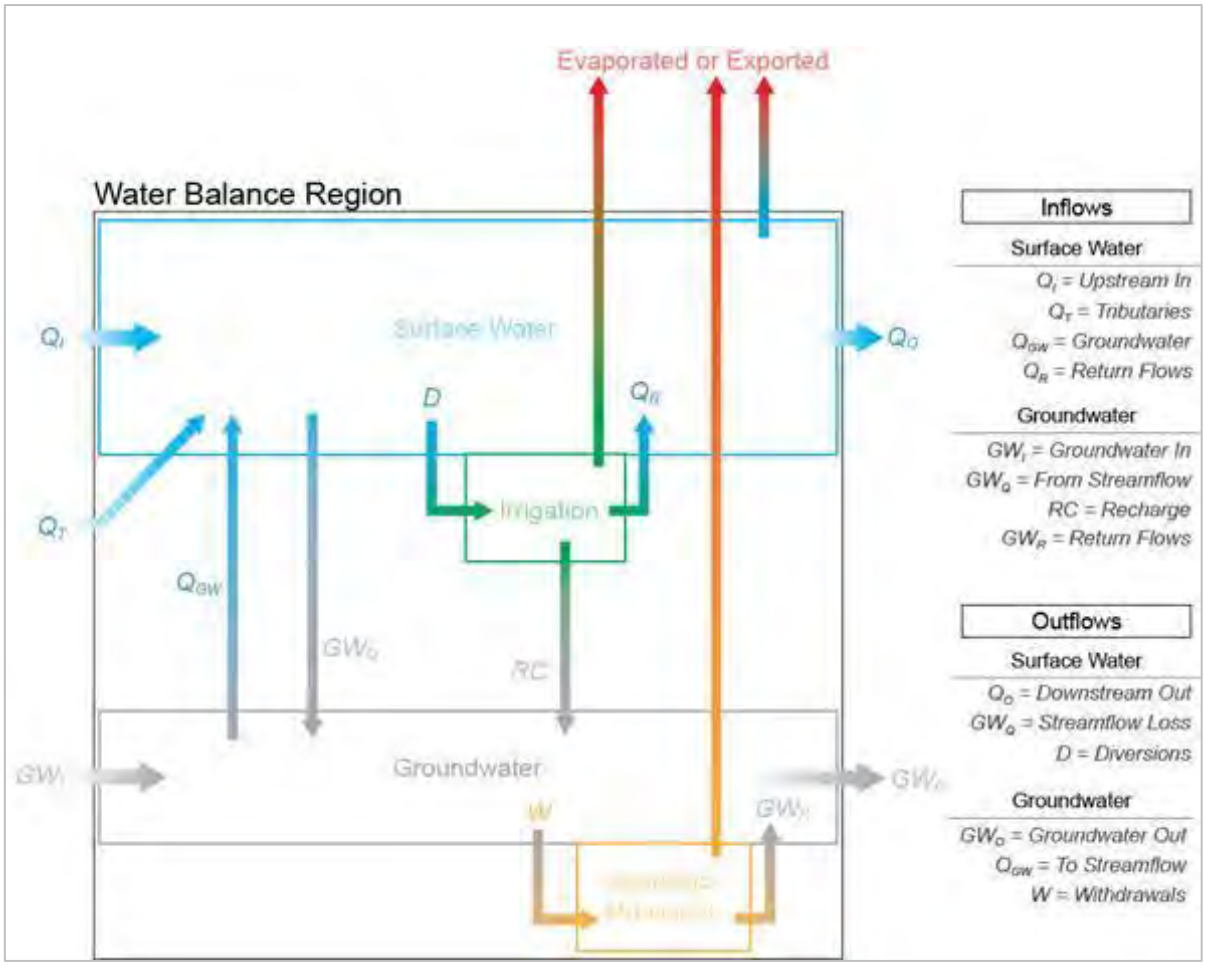



*Figure 4: Conceptual diagram of DNRC water balance model for a single Water Balance Region.*

ET and crop consumption (i.e., ET from irrigated water from crops) have historically been estimated in the Upper Yellowstone by calculating an idealized crop water demand using simple methods based on monthly meteorological means and agricultural statistics. These approaches ignore the considerable spatial and temporal heterogeneity in crop ET, which can vary greatly depending on many environmental and management factors not previously considered in our study area. Remote sensing-based ET estimates offer a solution to the distributed nature of this problem because images are captured repeatedly over the study area at resolutions that allow us to resolve individual fields. The images contain spectral information that is highly correlated with the crop growth stage and, thus, with the rate of ET. Further, modern meteorological stations, such as the Montana Mesonet, provide high-frequency observations of the full suite of meteorological variables affecting ET rates (e.g., temperature, humidity, incoming radiation, wind speed). Using remote sensing information (i.e., Landsat satellite images) to track changing crop conditions over space and high-frequency meteorology data to determine the potential for crop ET over time allows us to explicitly map ET over large areas with high accuracy.

Of several well-established remote sensing-based ET approaches, DNRC has found Mapping EvapoTranspiration at high Resolution with Internalized Calibration (METRIC; Allen, 2007) to be well suited to the geographic scope of the study area and to the geospatial, meteorological,

and satellite data we have available or propose to produce. METRIC uses optical and thermal satellite images, and ground-based meteorology data to calculate the residual of the energy balance at the Earth's surface. The residual surface energy is assumed to be 'lost' in the evaporation of water from bare soil and transpiration by plant tissue (i.e., latent heat of vaporization), and is converted to an estimate of ET in depth of water. Figure 5 depicts the type of processed images that will be used in this analysis (i.e., satellite imagery, surface temperature, ET pixels). METRIC ET estimates are constrained by a weather-based reference ET (ETr), a calculation of the atmospheric water vapor demand established as accurate and dependable. By using high resolution Landsat data, this image-processing approach allows us to map ET continuously over space, and periodically through time, to reconstruct the time-integrated consumption of water by crops over our study area. We will conduct our analysis using images of all Landsat 7 and Landsat 8 overpasses of the study area during the years 2022 and 2023. Not every image is usable, however, as clouds and smoke obscure the optical and thermal signal from the surface; obscured images must be masked or excluded from the analysis to prevent erroneous ET estimates. We will select usable images by manually sorting through each Landsat image.

Meteorology data for this project will be acquired from the GridMET archive (Gridded Meteorology; Abatzoglou, 2011), a gridded dataset consisting of 30+ years of daily, gridded, 4-km resolution meteorology data, including ETr, or the rate of ET from an idealized alfalfa reference crop given the current meteorological conditions (Allen, 1998). GridMET will be resampled to the Landsat resolution and used, pixel-by-pixel, to calculate ET. However, GridMET is known to provide ETr estimates that are biased high in agricultural areas, so local weather station data will be used to uniformly correct the GridMET data. This approach takes advantage of the continuous spatial coverage of GridMET and the local accuracy of Montana Mesonet meteorology data from our proposed stations.

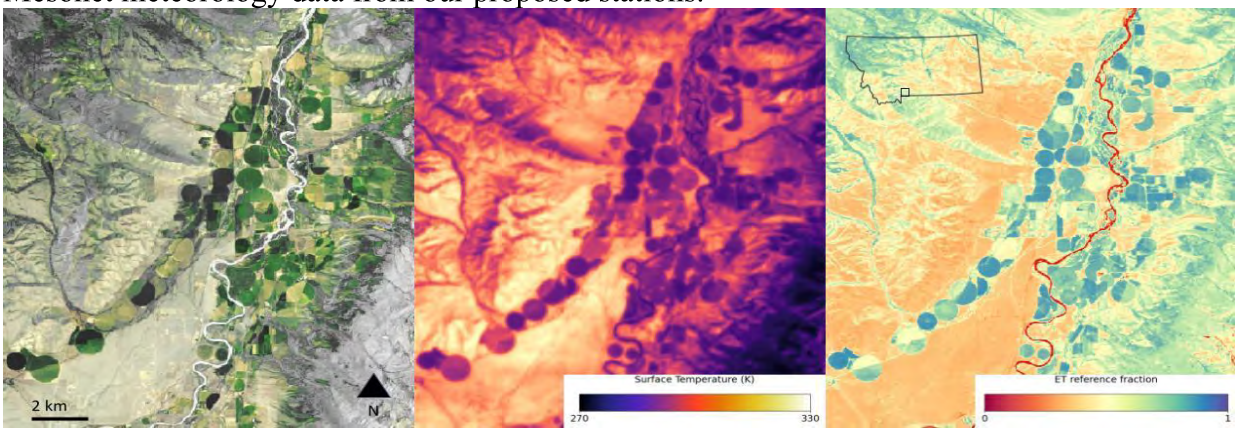


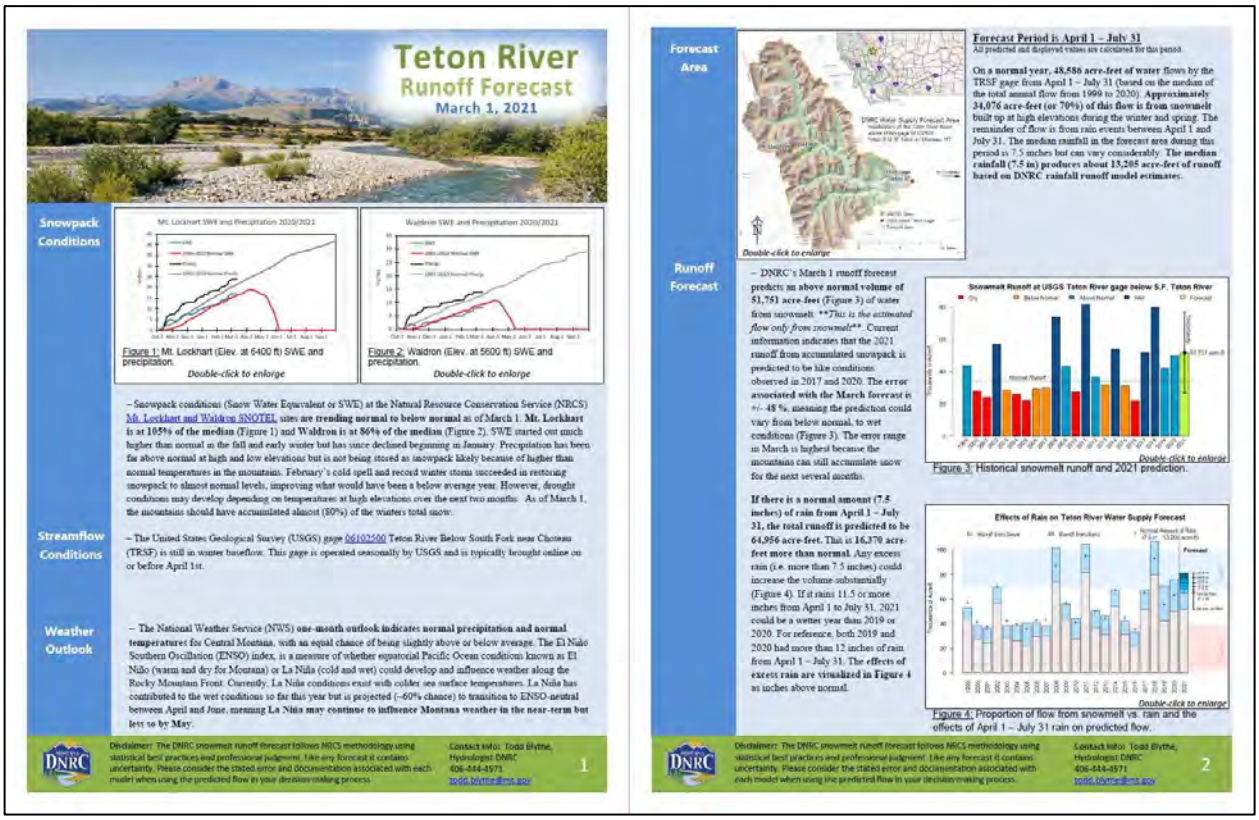

*Figure 5: Example ET processed images showing satellite imagery, surface temperature and ET reference fraction for a portion of the proposed project area.*

**Aim 2. Develop a hydrologic modeling framework and water supply forecasts.**

To develop the complete modeling framework, we will select from existing daily precipitation-runoff models. We will research the spatial and temporal limitations of several models to choose one that is most applicable to the Upper Yellowstone and can be calibrated with our input data (this may require calibration of one or more models). Calibration of the physical model will be primarily based on streamflow measured at USGS and DNRC gage stations. Additional validation of model components will be done using weather station (National Oceanic and

Atmospheric Administration - NOAA, SNOTEL, MCO Mesonet, Agrimet) data.

The calibrated precipitation-runoff model produced by this project will provide a tool for water users and managers to estimate streamflow resulting from certain climatic inputs. The output from the model will also be used as input for the systems model developed in Aim 1. The final component of developing the overall modeling framework proposed by this project is to develop a routine or method for the precipitation-runoff and systems models to communicate with each other. We will use model Application Programming Interface (APIs) or manually develop a work-flow to automate the modeling procedure and allow simplified user input of a single set of variables encompassing the entire hydrologic system.




Developing the comprehensive modeling framework proposed by this project will advance our forecasting capabilities by allowing the development of short- and long-term forecasts. Near-term forecasts could be developed by including forecasted weather data input into the precipitation-runoff model, similar to methods employed by NOAA. For long-term forecasts, we plan to continue using DNRC's existing methods but expand potential gaging stations where forecasts could be issued by using long-term simulated streamflow from the precipitation-runoff model to fit the Principal Component Analysis (PCA) regressions. This will allow for physically derived forecasts at DNRC gages, as well as expand the number of sites eligible for statistical methods. Management scenarios will be included in the short- and long-term forecasts using the modeling framework's systems component to predict water supply in the Upper Yellowstone with significant use. Figure 6 is an example of what DNRC produced monthly runoff forecasts look like for the Teton River Watershed.

**Aim 3. Engage irrigators, municipalities, and fishery managers to increase optimization and utilization of the resulting hydrologic model and water supply forecasts.**

The overarching goal of this project is to provide the Upper Yellowstone Watershed community with tools to support their water supply decision-making in the face of uncertainty from drought and climate change. To meet this goal, we are planning a robust outreach and communication effort that will be active throughout project implementation. Many local stakeholders are already engaged in the UYWG, and we will collaborate with them using a variety of approaches. Engagement will include:

- Regular (weekly) coordination with the UYWG leadership throughout the duration of the project.
- Regular conversations with key stakeholders (e.g. landowners, business owners) to communicate project updates and solicit input, such as suggestions for suitable monitoring sites and identification of key management questions that hydrologic modeling can help address.
- Presentations to and conversations with the Upper Yellowstone Drought Focus Group, a subgroup of UYWG to inform and support their ongoing drought planning work.
- Regular coordination with agency, nonprofit and university partners to leverage resources, share data and equipment and avoid duplication of efforts.
- Educate the public accessing available DNRC data, models, water supply forecasts and reports.
- Educate stakeholders on how to use the hydrologic precipitation-runoff model and water supply forecasts to be more efficient in water use, plan for drought, promote watershed health, and understand the watershed hydrology better.

## 3. Data Management Practices

Data used in this project will include Landsat-derived ET raster data in Tiff format, gridded meteorology data from GridMET and NLDAS (NetCDF), vector geospatial irrigation datasets (ESRI shapefile), and observed streamflow data collected by the USGS and DNRC (CSV spreadsheet). ET results will be presented as monthly and annual rasters representing ET (Tiff), and aggregated and tabulated using spatial statistics software to individual GIS polygon field boundaries (ESRI Shapefile and CSV spreadsheet). Model input files, calibration parameters, and output will also be generated and provided as CSV spreadsheets, as well as specific file types used by the precipitation-runoff model. These data will be stored in a OneDrive folder shared by the PIs, and backed up periodically by DNRC Information Technology Services. The source and collection date(s) of all data will be recorded in a separate document, as will metadata files describing the data and how they are being used. All data will be made available via download to the public upon publication of the final project report. Users will be able to access project information, final reports, and data via DNRC's website under a specific page created for this project. Geospatial data will be stored permanently and used in future development of a web-based mapping application for public access to project and download results. The DNRC will follow established agency data management protocols throughout the entire duration of the project.

## 4. Evaluation Criteria

### *4.1 Evaluation Criterion A - Benefits to Water Supply Reliability*

*1. Describe the water management issue(s) that your project will address. For example, will your project address water supply shortfalls or uncertainties, the need to meet competing demands for water, complications arising from drought, conflicts over water, or other water management issues? Describe the severity of the water management issues to be addressed through your project.*

This project will address a wide variety of complex water management challenges in the Upper Yellowstone Watershed. The region has experienced numerous water supply shortfalls in recent years, especially in late summer, when water is most critical to water users and aquatic species. The increase in drought frequency and intensity over the last 20 years has compounded this uncertainty in water supplies, and high rates of development and population growth in this region have also contributed to the difficulties of meeting competing demands for water. Water supply shortages threaten the local economy and livelihoods of water users, but they also foster increasing and more contentious conflict in the community, especially between irrigators and recreationists. Moreover, the low, late-season flows impair aquatic habitat and threaten the persistence of native species (e.g., the 2016 Yellowstone fish die-off). Despite differences of opinion, most water users agree that water supply uncertainty in the Upper Yellowstone is a severe problem that affects the entire community, and they expressed desire for better forecasting and management tools to aid in decision making.

*2. Explain how your project will address the water management issues identified in your response to the preceding bullet. In your response, please explain how your project will contribute to one or more of the following water management objectives and provide support for your response:*

*a. water supply reliability,*

*b. management of water deliveries,*

*c. water marketing activities,*

*d. drought management activities,*

*e. conjunctive use of ground and surface water,*

*f. water rights administration,*

*g. ability to meet endangered species requirements,*

*h. watershed health,*

*i. conservation and efficiency, or*

*j. other improvements to water supply reliability.*

This project will construct a water balance, develop a hydrologic model, and produce a water supply forecasting tool for the watershed, all of which directly support multiple water management objectives. The water balance will provide detailed data about inputs and losses to the system, which will help water managers make informed decisions in the operation and

management of water delivery systems. This will also improve the conservation and efficiency of these systems because managers will have specific information about issues, such as seepage loss and return flows, which they can use to direct resources for future upgrades.

The water balance and hydrologic model will improve our understanding of the complex interactions between the surface water and groundwater, and will have added benefits to the administration of water rights in the watershed. Surface water and groundwater are managed conjunctively in Montana, so new appropriations and change authorizations are evaluated in detail to ensure that users on either source type are not adversely impacted. However, many domestic wells are exempt from the permitting process because of their small volume, so the cumulative impacts of these wells on the hydrologic system are uncertain. The hydrologic model will address these gaps in our knowledge of the conjunctive use of groundwater and surface water while simultaneously improving the state's administration of water rights.

The hydrologic model and forecasting tool will contribute to drought planning and management activities in the region. Stakeholders have expressed interest in developing a drought plan, but the lack of data and understanding of the hydrologic system has hindered progress. The model development and supply forecasting tool will be used to solicit stakeholder engagement and can be incorporated into a formal drought contingency planning process, which will advance drought management activities and support overall watershed health. Moreover, by facilitating stakeholder collaboration, this project will promote positive interactions and reduce conflict.

*3. Describe to what extent your project will benefit one of the water management objectives listed in the preceding bullets. In other words, describe the significance or magnitude of the benefits of your project, either quantitatively or qualitatively, in meeting one or more of the listed objectives.*

This project will provide data, information, and tools to enhance our understanding of the watershed hydrology and develop forecasts for water supply in the Upper Yellowstone, all of which will significantly benefit water management objectives in the watershed. As we have seen in comparable watersheds, such as the Teton River watershed, when water managers are provided with detailed information about their delivery systems, they can make informed decisions about supply allocation, as well as direct resources to the areas where improvements will have the greatest benefit to water efficiency and conservation.

This project will also substantially advance drought management and planning activities in the region. The water balance will allow users to quantify components of surface water availability during drought years, which will promote collaboration and planning. The UYWG has a strong base of stakeholder support for these efforts, but they lack the resources and data to accurately assess vulnerabilities and develop a drought response plan. The hydrologic modeling and forecasting tools will provide the watershed group and other stakeholders with detailed information to initiate planning discussions and build critical momentum for plan development. The DNRC assisted with a similar successful effort in the Big Hole watershed in southwest Montana, which was in a comparable water supply situation in 1997. DNRC hydrologists provided water users and managers with support tools and data to help stakeholders develop a collaborative and effective drought contingency plan. Importantly, it is only with this improved understanding of management and climatic impacts to surface water that creative and cooperative management approaches be achieved.

*4. Explain how your project complements other similar applicable to 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? Applicant should make a reasonable effort to explore and briefly describe related ongoing projects.*

The Upper Yellowstone is the subject of various other scientific efforts that the proposed project will complement**.** The UYWG has initiated drought management and planning activities, and this project will complement these efforts and build group momentum by providing tools the group can use to assess and implement these efforts (see letter of support from UYWG). Fishery managers monitor tributary flow and water temperatures on several tributaries in the watershed, and the proposed work will complement these efforts by increasing the amount of available data and providing water supply forecasts that include early warning of adverse conditions. Current water supply forecasts performed by the NRCS are based off statistical methods; the proposed work will complement their efforts by implementing a physical precipitation-runoff method.

### *4.2 Evaluation Criterion B - Need for Project and Applicability of Project Results*

*Will the project result in an applied science tool(s) or information that is readily applicable, and highly likely to be used by water resource managers in the West?*

*a. Explain who has expressed the need and describe how and where the need for the project was identified (even if the applicant is the primary beneficiary of the project). For example, was the need identified as part of a prior water resources planning effort, determined through the course of normal operations, or raised by stakeholders? Provide support for your response (e.g., identify the entities that have expressed a need or cite planning or other documents expressing a need for the project).*

The need for a hydrologic toolset to aid water management decisions was expressed by local landowners, fly fishing outfitters, agricultural producers, fishery managers, local non-profits, county level government, municipalities, state agencies, and federal agencies. These stakeholders were brought together through the UYWG, where many group discussions led to a consensus that the watershed was in need of hydrologic based decision-making tools. Ultimately, DNRC's discussions with stakeholders about this need led to the proposed project for developing a water balance, hydrologic model and water supply forecasting tool.

*b. Will the results of your project inform water resource management actions and decisions immediately upon completion of the project, or will additional work be required?*

The results of this project will immediately be used to inform a variety of water resource management actions. The UYWG will be using the project results and tools to develop a drought management plan with irrigators and recreationists in the watershed. State agencies will immediately use the project results to improve fishery and water resource management. The City of Livingston will immediately use the project results to improve city planning and water resource management.

*c. If applicable, will the results of your project be transferrable to other users and locations? Note: not all water management solutions are transferrable.*

The water balance, hydrologic modeling and /water supply forecasting will be developed within a structure that builds on the PI's previous efforts in other basins. The PIs intend for this structure to be easily transferrable to other users and other watersheds in Montana.

*d. If the applicant is not the primary beneficiary of the project (e.g., Category B applicant), describe how the project beneficiaries have been or will be involved in planning and implementing the project?*

The project beneficiaries, including the UYWG, City of Livingston, state agencies and federal agencies, have held regular meetings over the past two years to discuss local needs, project objectives, and project planning. Effectively, these meetings have led to the development and planning of this project, and they will be continued throughout project implementation.

### *4.3 Evaluation Criterion C - Project Implementation*

*Briefly describe and provide support for the approach and methodology that will be used to meet the objectives of the project.*

**Aim 1. Calculate a comprehensive, runoff water balance.**

We will use the best-available data sources (e.g., GridMET, Landsat, USGS and DNRC surface water gages, MBMG groundwater monitoring data, and municipal water use data from communities within the study area) as input for a comprehensive runoff water balance, wherein each component is accounted for in the Upper Yellowstone Watershed (streamflow, diversions, return flows, crop ET, and change in groundwater storage). This water balance will be calculated using established DNRC methods and implemented using custom Python scripts. We will use specialized methods and software (METRIC) to calculate accurate crop water consumption estimates combined with accurate measurement of source water. Our approach builds off of our work in other watersheds, where enhancing available datasets and constructing a water balance showcased the applicability of established methods in developing state-level water management information and tools.

**Aim 2. Develop a hydrologic modeling framework and water supply forecasts.**

We will incorporate a physical, precipitation-runoff model into our existing water balance methodology. We will employ existing semi-distributed or distributed modeling software (e.g. PRMS, MIKE-SHE, Sac-SMA, SWAT, SMR, etc.) to construct the precipitation-runoff model. The calibrated physical model will provide the total landscape components of the hydrologic cycle that will be paired with our runoff water balance model via an automated or semi-automated routine (depending on which model performs best in the Upper Yellowstone). We will use existing DNRC statistical forecast methods (following established and documented NRCS PCA techniques) for long-term forecasting and adopt NOAAs ensemble streamflow prediction (ESP) methods, coupled with the calibrated physical model, for short-term streamflow forecasts.

**Aim 3. Engage irrigators, municipalities, and fishery managers to increase optimization and utilization of the resulting hydrologic model and water supply forecasts.**

Well-developed relationships with stakeholders by the PIs, as well as a strong presence in the UYWG, will be utilized to ensure regular and continuous engagement with project stakeholders.

The involvement of local irrigators, fishing outfitters, landowners, state agencies, municipalities, federal agencies, and non-profits in the UYWG will further ensure a high level of stakeholder engagement. Presentations by the PIs, and project updates will be distributed through the well-established stakeholder networks for the duration of the project. The project PIs will continually monitor stakeholder needs and ensure the project delivers sound results and tools to stakeholders.

*1. Describe the work plan for the project. Include an estimated project schedule that shows the stages and duration of the proposed work, including major tasks, milestones, and dates.*

Figure 7 below depicts the anticipated project work-flow, milestones, and major tasks.

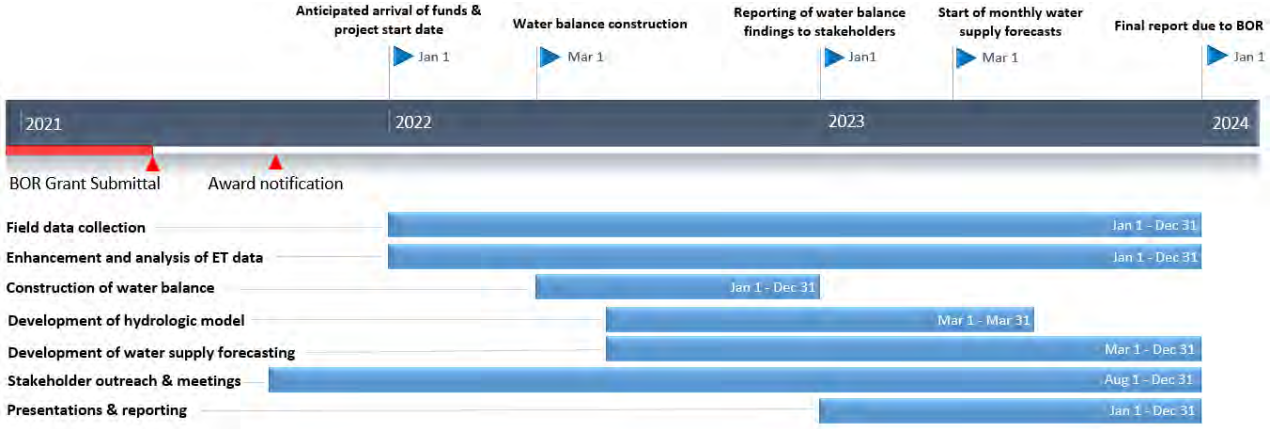



*Figure 7: Project work-flow, tasks and milestones.*

*2. 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.*

The development of the proposed water balance, hydrologic model and water supply forecasts will build upon recent work by the PIs. The methods and experience gained in other watersheds will streamline the process and facilitate the completion of the project in two years. Products are listed in Table 1 below.

**Table 1: Summary of Project Products**

| | | | |
|---|---|---|---|
| **Aim 1** | Enhanced hydrologic datasets, available publicly through the DNRC website. | Developed water balance that is continuously enhanced as data is collected. | Report describing water balance and subsequent findings. |
| **Aim 2** | Prepared hydrologic modeling and forecasting framework re-worked from previous projects. | Water supply forecasts which will be released to the public monthly (Mar. – Sep.). | Report describing hydrologic model and subsequent findings. |
| **Aim 3** | Outreach to stakeholders through group meetings and presentations. | Continued regular updates to stakeholders on a bi-monthly basis. | Presentation of model results to stakeholders, release monthly water supply forecast to public. |

3. *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:*

The project team will include five DNRC hydrologists, a water planner and a hydrologic technician. The following is a brief overview of the project team.

- John Lunzer, Co-Principle Investigator: Master's degree in Hydrogeological Engineering from Montana Technological University, 4 years' experience as a working hydrologist, DNRC Yellowstone River basin hydrologist.

- David Ketchum, Co-Principle Investigator: Master's degree in Hydrology from New Mexico Institute of Mining and Technology, in progress PhD in Systems Ecology from University of Montana, 8 years' experience as a working hydrologist, leads DNRC efforts to incorporate remote sensing techniques.

- Sara Meloy, Yellowstone Regional Water Planner: Master's degree in Natural Resource Management from the University of Idaho, five years' experience as a water resources planner, community engagement and education coordinator.

- Todd Blythe, Project Team Hydrologist: Master's degree in Watershed Sciences from Utah State University, 6 years' experience as a working hydrologist, DNRC basin hydrologist who developed original implementation of our water balance model in the Lolo Creek Watershed of Western Montana, DNRC hydro-science Upper Missouri and Clark Fork River basin hydrologist.

- Melissa Schaar, Supervisory Hydrologist and Hydrogeologist: Master's degree in Geological Engineering from Montana Technological University, 20 years' experience as a hydrologist, hydrogeologist, and geochemist, and now leading DNRC's hydrology team in basin hydrology, stream gaging and water measurement, and surface water and groundwater resource management.

- Jack Landers, Project Team Hydrologist: Master's degree in Environmental Science from the University of Montana, 4 years' experience as a working hydrologist, DNRC Regional Office Hydrologist/Water Resource Specialist.

A hydrologic technician will be hired to fulfill several tasks that support the aims of the project. They will collect field data throughout the two-year duration of the project. They will also be involved in data analysis, particularly analysis of ET datasets. The DNRC team has extensive experience in hiring and supervising such positions and will do so in a manner that meets DNRC human resource requirements. The applicant will be selected based on prior experience in similar type projects as well as their listed skillset.

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

Each project team member has participated in the development of water balance, hydrologic modeling, and water supply forecasting studies in Montana, or has participated in the planning and public communications surrounding such studies as either lead or team members.

*b. 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 prepared to begin work immediately upon entering into a financial assistance agreement.

### *4.4 Evaluation Criterion D - Dissemination of Results*

*Describe how the tools, frameworks, or analyses being developed will be disseminated, communicated, or made available to water resources managers who may be interested in the results.*

All associated project data will be publicly available through the DNRC's website. Additionally, all water supply forecasts will be publicly released on a monthly basis during the irrigation season. Water balance and hydrologic model results will be publicly available through the DNRC website, including the data outputs and associated reports from each. Presentations on about these tools and how to use them will be given to stakeholders and water managers, and the UYWG will help us publicize and promote them. DNRC will offer technical support on the tools to any interested user.

*a. 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.*

Project applicant is not the primary beneficiary of the project results.

*b. 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.*

Project results will be communicated to area stakeholders through presentations and a final technical report. Project geospatial data will be made available by DNRC on our website. Further, we plan on using project data in the future as we develop a modern web-based water resources information dashboard for public use.

## 5. Project Budget

### *5.1 Funding plan and letters of funding commitment*

The non-Federal portion of project costs will be provided by the FWP, Park County Environmental Council (PCEC), UYWG, Montana Aquatic Resources Services (MARS), and Arthur M. Blank Foundation (AMB). Additionally, funds will come from another Federal source as in-kind contribution (USFS). DNRC will provide a cost match using Project Team salaries plus fringe benefits. A letter of funding commitment can be found in Appendix C, letters of support from third parties can be found in Appendix D.

### *5.2 Budget proposal*

**Table 2. Total Project Costs**

| | |
|---|---|
| Costs to be reimbursed with the requested Federal funding | $119,009 |
| Costs to be paid by Montana DNRC | $178,553 |
| Value of third-party contributions | $107,573 |
| **TOTAL PROJECT COST** | **$405,135** |

**Table 3. Budget Proposal including all Tasks**

| | | | | |
|---|---|---|---|---|
| | | | | |
| John Lunzer, Hydrologist II | $28.00 | 1300 | Hours | $36,400 |
| Sara Meloy, Water Planner | $31.06 | 340 | Hours | $10,561 |
| David Ketchum, Hydrologist III | $31.54 | 770 | Hours | $24,286 |
| Todd Blythe, Hydrologist II | $29.50 | 770 | Hours | $22,715 |
| Melissa Schaar, Supervisory Hydrologist | $35.17 | 340 | Hours | $11,958 |
| Jack Landers, Hydrologist Specialist | $26.34 | 440 | Hours | $11,590 |
| Hydrologist Technician | $20.00 | 1920 | Hours | $38,400 |
| | | | | |
| | | | | |
| John Lunzer, Hydrologist II | $12.00 | 1300 | Hours | $15,600 |
| Sara Meloy, Water Planner | $13.13 | 340 | Hours | $4,465 |
| David Ketchum, Hydrologist III | $14.34 | 770 | Hours | $11,042 |
| Todd Blythe, Hydrologist II | $11.62 | 770 | Hours | $8,948 |
| Melissa Schaar, Hydrologist | $13.03 | 340 | Hours | $4,431 |
| Jack Landers, Hydrologist Specialist | $9.22 | 440 | Hours | $4,057 |
| Hydrologic Technician | $7.00 | 1920 | Hours | $13,440 |
| | | | | **$61,983** |
| | | | | **$217,893** |
| **Travel** | | | | |
| 1 person, 1 overnight stay | $224.50 | 52 | Trips | $11,674 |
| | | | | **$11,674** |
| | | | | |

| BUDGET ITEM DESCRIPTION | COMPUTATION | | Quantity Type | TOTAL COST |
|---|---|---|---|---|
| | $/Unit | Quantity | | |
| **Equipment** | | | | |
| Real Time Surface Water Gage plus two years maintenance | $30,000.00 | 1 | Gages | $30,000 |
| Real Time Irrigation Canal Gage | $6,500.00 | 1 | Unit | $6,500 |
| Real Time Satlink for Existing Canal Gages | $4,500.00 | 2 | Units | $9,000 |
| Trutracks (Surface Water Recorders + stilling well) | $500.00 | 10 | Gages | $5,000 |
| Transducers for GW Monitoring | $600.00 | 12 | Transducers | $7,200 |
| Flow Tracker II | $12,000.00 | 1 | Instrument | $12,000 |
| Field Toughbook Computers | $2,800.00 | 1 | Computer | $2,800 |
| Meters for City of Livingston Public Supply Wells | $2,000 | 3 | Meters | $6,000 |
| Mesonet station | $12,500 | 1 | Unit | $12,500 |
| | | | | |
| | | | | |
| Waders for Hydrologic Technician | $300.00 | 1 | Waders | $300 |
| Muck Boots for Hydrologic Technician | $150.00 | 1 | Boots | $150 |
| Misc. Field Supplies (Bear Spray, Tapes, Tools, etc.) | $1,000.00 | 1 | Unit | $1,000 |
| Installation material for FWP provided Trutracks | $200 | 5 | Unit | $1,000 |
| | | | | |
| | | | | |
| FWP Monitoring of Existing Surface Water Stations | $9,783 | 1 | Unit | $9,783 |
| FWP Trutracks (Surface Water Recorders) | $300 | 5 | Trutracks | $1,500 |
| Upper Yellowstone Watershed Coordinator | $25 | 400 | Hours | $10,000 |
| Two Mesonet stations from the UYWG | $12,500 | 2 | Units | $25,000 |
| PCEC Outreach/Communication Support | $35 | 624 | Hours | $21,840 |
| MARS Outreach/Communication Support | $75 | 20 | Hours | $1,500 |
| **TOTAL THIRD-PARTY (NON-FEDERAL) IN** | | | | **$69,623** |
| | | | | **$392,636** |
| **Third-Party Cash Contributions** | | | | |
| Upper Yellowstone Watershed Group/Arthur Blank Foundation Grant (Cash contribution not contributing to direct costs) | $37,950 | 1 | Unit | $37,950 |

| BUDGET ITEM DESCRIPTION | COMPUTATION | | Quantity Type | TOTAL COST |
|---|---|---|---|---|
| | $/Unit | Quantity | | |
| **TOTAL THIRD-PARTY CASH CONTRIBUTIONS** | | | | **$37,950** |
| **Indirect Costs** | | | | |
| Type of Rate | percentage | $base | 11.73 | $12,495 |
| **TOTAL ESTIMATED PROJECT COSTS** | | | | **$405,135** |

### *5.3 Budget Narrative*

**Salaries and Wages**

Sara Meloy, Regional Water Planner for DNRC, will coordinate outreach and stakeholder engagement. Melissa Schaar, Hydro-Science Supervisor will serve as technical support and assist in project management. Other personnel include the two PIs as well as two other staff hydrologists and one hydrologic technician who will all be involved in the data collection and analysis, water balance construction, hydrologic modeling, and forecasting efforts. Table 3 breaks out the respective salary and proposed hours for each member of the project team. All salaries of the project team, except for the hydrologic technician, are DNRC in-kind match. **The hydrologic technician salary, for which we are requesting Federal funding, is $38,400 over the two-year project duration.**

**Fringe Benefits**

Fringe rates vary for each employee and are computed hourly. Fringe benefits include health insurance and retirement. Amounts and percentages are determined by the State of Montana Legislature and are codified in statute. The total amount of fringe benefits is $61,983. All fringe costs of the project team, except for the hydrologic technicians, are DNRC in-kind match. **The hydrologic technician fringe costs are requested from Federal funding for a total of $13,440.**

**Travel**

The travel costs are based on one person traveling from Helena to the project area with per diem and one overnight stay at a hotel and is considered one trip. Round-trip mileage from Helena to Livingston is 247 miles. Round-trip mileage from Helena to the southern terminus of the watershed at Yellowstone National Park/Gardiner, MT is approximately 350 miles. The total project will require 52 trips with the number of trips for each task broken out in Appendix G. The cost of one trip is $224.50 which includes travel of 350 miles at the standard rate of $0.28 per mile, one daily per diems at $30.50 per person, and one hotel room at the state rate of $96.00 per night. **Federal funding is requested for travel for a total of $11,674 over the two-year project duration.**

**Equipment**

Equipment needed for the successful completion of the project include surface water and groundwater monitoring equipment and field computers. One real-time surface water gage that measures temperature and water height, equipped with telemetry for data transmission via satellite, will be installed in the watershed. One real-time irrigation canal gage that will measure water height, equipped with telemetry for data transmission via satellite, will be installed in the watershed. Additionally, two telemetry upgrades will be made to existing irrigation canal gages in the watershed.

The equipment, two years maintenance, permits, and installation of a real-time stream gage is $30,000. The equipment, two years maintenance and installation of a real-time irrigation canal gage is $6,500. The equipment and installation of real-time telemetry for existing irrigation gages will cost $4,500 a gage for a total of $9,000 for two gages. These gages will allow stakeholders easy access to data for forecasting efforts. DNRC hydrologists will install, operate and maintain the real-time surface water sites, the irrigation canal gaging sites, and will continue to do so after project completion as part of Montana's state stream gage network. AMB cash funds will cover $37,950 of the total cost. **Federal funding is requested for the remaining real time gages for a total of $7,550.** The installation labor and maintenance of these sites is DNRC in-kind match.

New surface water monitoring sites and existing surface water sites maintained by partner agencies will be retrofitted with continual recording equipment, Trutracks, in stilling wells. The Trutracks record temperature and water height. DNRC will operate, maintain, and download data on a monthly frequency from the Trutracks for the two-year duration of the project. The Trutracks and retrofitted gaging sites will be dismantled after project completion unless partner agencies volunteer to maintain the gaging site. The project will require 10 Trutrack installations on tributaries and diversions. Montana FWP will provide 5 Trutracks as direct contribution to the project. **Federal funding is requested for 10 Trutracks at $500 each for a total of $5,000.** The rate includes $300 for purchase of the instrument and $200 for the hardware and material for installation. The installation labor and maintenance of these sites is DNRC in-kind match.

Project hydrologists will install continual recording devices (transducers) in the existing groundwater well network maintained by the MBMG. The transducers measure pressure and temperature. The pressure changes can then be correlated to changes in groundwater levels. The installation labor is DNRC in-kind match. **Federal funding is requested for 12 transducers at $600 each for a total of $7,200.**

A Flowtracker 2 is a handheld stream wading measurement instrument. Along with continual recording devices, in-person wading measurements are required on the diversions and tributaries for the purposes of developing rating curves. A rating curve is a graphical representation of stage (height) vs. discharge over a period. DNRC will need one Flowtracker for project completion. **Federal funding is requested for a Flowtracker 2 at $12,000.**

One Toughbook field computer is required for downloading data from the continual recording field equipment (Trutracks and transducers). The Toughbook will be for use by the hydrologic technician. Additionally, initial data processing can be done remotely for project efficiency. **Federal funding is requested for one Toughbook computer made by Dell for a total of $2,800.**

The City of Livingston has three groundwater irrigation wells that are not metered for discharge. In order to understand the city's water demand and usage, the groundwater wells require metering. The City Engineers will install the equipment and manage the meter readings during the duration of the project and the equipment will be left in place after project completion. Their time and labor have not been calculated as in-kind contribution for the purpose of this grant. **We are requesting Federal funding of $2,000 for each meter for a project total of $6,000.**

Three Mesonet stations are proposed for the watershed at $12,500 each. These stations collect meteorological and soil moisture information at the same locations in order to support decision-making in agriculture, range and forested watersheds. All stations are solar powered and real time. Two of these stations will be paid for by the UYWG and one will be paid for as in-kind costs by the DNRC. The Mesonet stations will be installed by the MCO. The price includes the equipment, installation, and yearly operation and maintenance of the stations for three years. The stations will be maintained by the MCO after the completion of the project.

**Materials and Supplies**

Project hydrologists are equipped with waders and boots. We will employ two hydrology technicians for this project who will require waders ($300), muck boots ($150), and other field equipment such as bear spray, measuring tapes, and tools ($1,000). **We are requesting Federal funding for supplies and material for a total of $1,450.**

Montana FWP will be donating 5 Trutracks to the project. Installation of these Trutracks will require additional supplies and materials that cost $200 per Trutrack. These supplies include staff rods and steel pipe. DNRC hydrologists will install the Trutracks with labor costs included as in-kind. **Federal funding is requested for the installation material (e.g. steel pipes, staff gages and additional Trutracks) totaling $1,000.**

**Third-Party In-Kind Contributions**

Montana FWP operates existing surface water monitoring stations within the watershed. FWP hydrologists will help DNRC hydrologists maintain and upgrade existing surface water gaging stations. The in-kind staff time contribution equates to $9,783. FWP will additionally contribute five Trutrack continual recording instruments to the project at $300 each for a total of $1,500.

Ashley Lowrey, Upper Yellowstone Watershed Group coordinator, will provide 400 hours of in-kind contributions for outreach and coordination with local drought planning efforts in the watershed at $25/hour for a project total of $10,000.

The Upper Yellowstone Watershed Group will provide direct monetary contribution of $37,950 matching drought funds from the Arthur M. Blank Family Foundation which invests in education, green space and community transformation.

The Upper Yellowstone Watershed Group in conjunction with the Arthur M. Blank Family Foundation will also be contributing two Mesonet stations at a cost of $12,500 each for a total of $25,000.

Max Hjortsberg, Conservation Director of Park County Environmental Council will be provide 6 hours per week of in-kind contribution over the two year duration of the project to assist with

local outreach and communication at $35/hour for a project total of $21,840.

Wendy Weaver, Executive Director of Montana Aquatic Resources Services will be provide 20 total hours of in-kind contribution over the two year duration of the project to assist with local outreach and communication at $75/hour for a project total of $1,500.

**Indirect Costs**

The State of Montana's indirect cost rate is 11.73% (federal negotiated agreement is attached). The total direct costs requested for federal funding is $119,009 multiplied by 11.73% to compute the indirect costs, $12,495. **We are requesting Federal funding to cover the $12,495 in indirect costs (IDCs) in addition to direct costs.**

## 6. Environmental and Cultural Resources Compliance

***a.*** *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.*

The proposed work will require field installation of hydrologic monitoring equipment. Installation of real-time stream gages will require permits due to the need to slightly modify (i.e. hand-dig) the bed and banks of the Yellowstone River and tributaries. The installation of these gages involves burying piping within the stream bank and channel. This is done with a shovel and pickaxe, causes very little disturbance and typically within one season, the impacts of installation are not visible. Additionally, a metal box that houses the gaging equipment, satellite hardware, battery, solar panel and antenna will be installed on the bank above the high-water mark. These boxes require little ground disturbance to install as they simply rest on two shallowly anchored support beams.

***b.*** *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?*

Yellowstone River watershed is home to many native species including the Grizzly bear which is currently listed under the Endangered Species Act as threatened. We do not anticipate that this project will have any appreciable impacts on wildlife like Grizzly bears for various reasons. This project will involve computer modeling and data analysis, which will be done remotely. Due to the non-invasive nature of field work, we do not anticipate any impacts to wildlife species – aside from the occasional presence of field technicians at monitoring sites. Data collection will involve visiting field sites, installing monitoring equipment, downloading information from monitoring equipment and taking streamflow measurements by wading creeks or using a small, manually operated flotation devices using acoustic doppler equipment.

This project will not impact fish species of special concern (mountain whitefish, Yellowstone cutthroat trout, etc.) as disturbance to the riverbank is minimal and will only occur early on in the project at real-time gage sites.

***c.*** *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.*

There are wetlands within the watershed, but this project will not impact wetlands.

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

Not applicable.

***e.*** *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. 45 Notice of Funding Opportunity No. R21AS00289*

This project does not include widespread modifications to existing irrigation infrastructure – aside from potential installation of monitoring equipment (e.g. a flow meter) – but it may result in subsequent infrastructure repairs or upgrades through collection of more accurate monitoring data.

***f.*** *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.*

Several sites within Park County and the project area are registered with the National Register of Historic Places. An example is Carter's Bridge, which was constructed in 1921 and is a good representation of early highway construction in Montana. This project will not impact historic places as its footprint on the landscape is limited to minor bank modifications. There are no known archaeological sites within the study area.

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

Not Applicable

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

Not applicable.

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

Not applicable.

***j.*** *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?*

DNRC has established a protocol for decontaminating hydrologic field equipment (e.g. waders, boots, wading rods) to prevent spread of aquatic invasive species. These methods are consistent with Montana's "Clean, Drain, Dry" campaign to prevent spreading invasive mussels. There is potential to spread noxious weed seeds via field vehicles, however field vehicles are washed frequently to avoid this.

## 7. Required Permits or Approvals

Installation of temporary or real-time stream gages will require securing four different permits from local, state and federal agencies for each site. A joint Montana application can be submitted for all required permits for each site.

The four permits required for installing real-time stream gages include:

- Montana Stream Protection Act (SPA 124 permit)
- Montana Department of Environmental Quality 318 permit
- U.S. Army Corps of Engineers Section 404 permit
- Park County Floodplain Permit

DNRC regularly applies for these permits to support our state stream gage program, so this process is well-standardized and routine for certain DNRC staff.

The southern project boundary is Yellowstone National Park. Currently, we do not anticipate data collection within the Park boundaries. However, if data gaps are identified within the Park boundary that are essential for the successful completion of this project, a research permit will be submitted to Yellowstone National Park for purposes of collecting hydrologic data.

## Appendix A: Location Maps

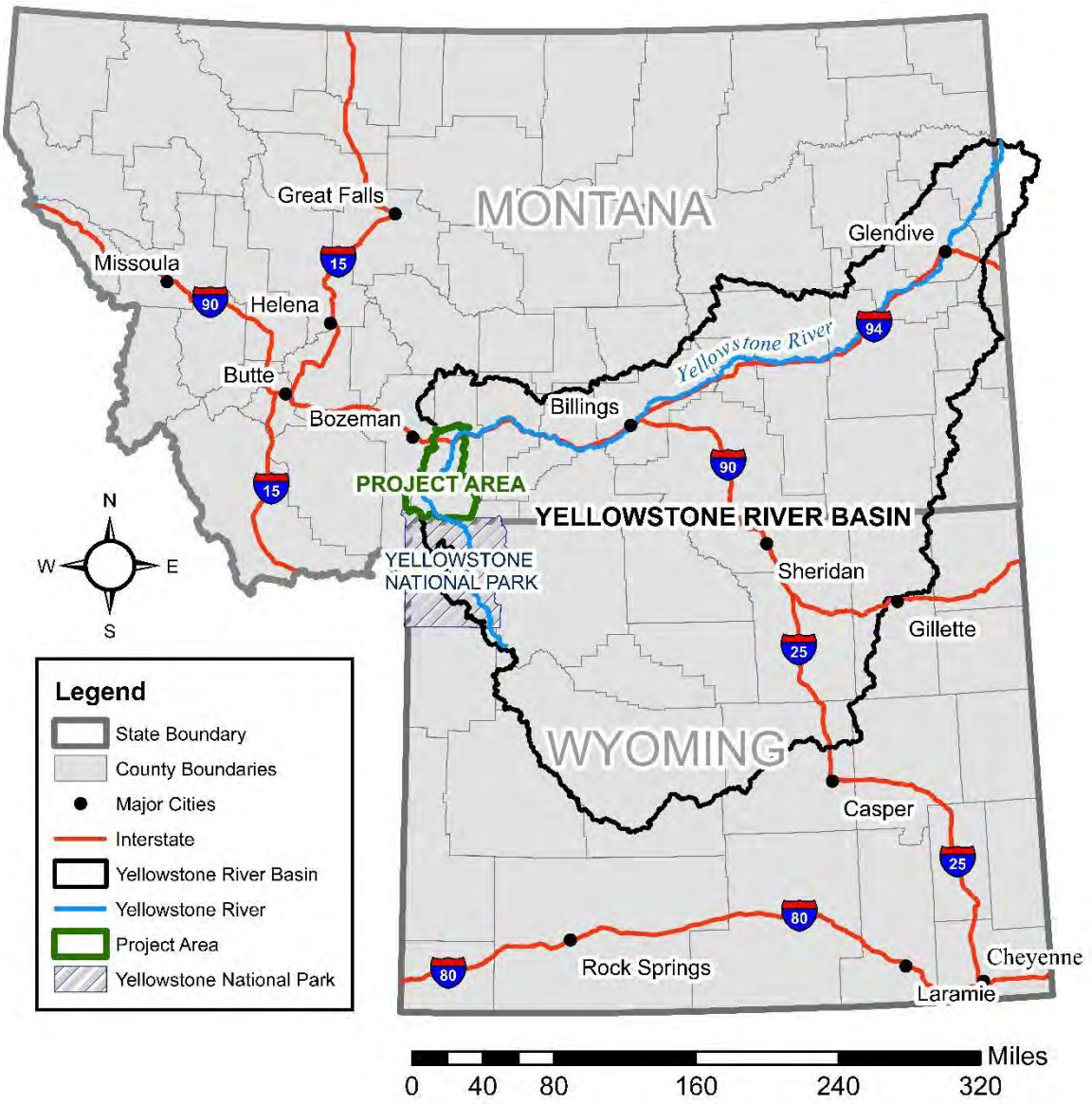



*FIGURE A-1: MONTANA AND WYOMING WITH YELLOWSTONE RIVER BASIN, YELLOWSTONE NATIONAL PARK AND PROJECT AREA.*

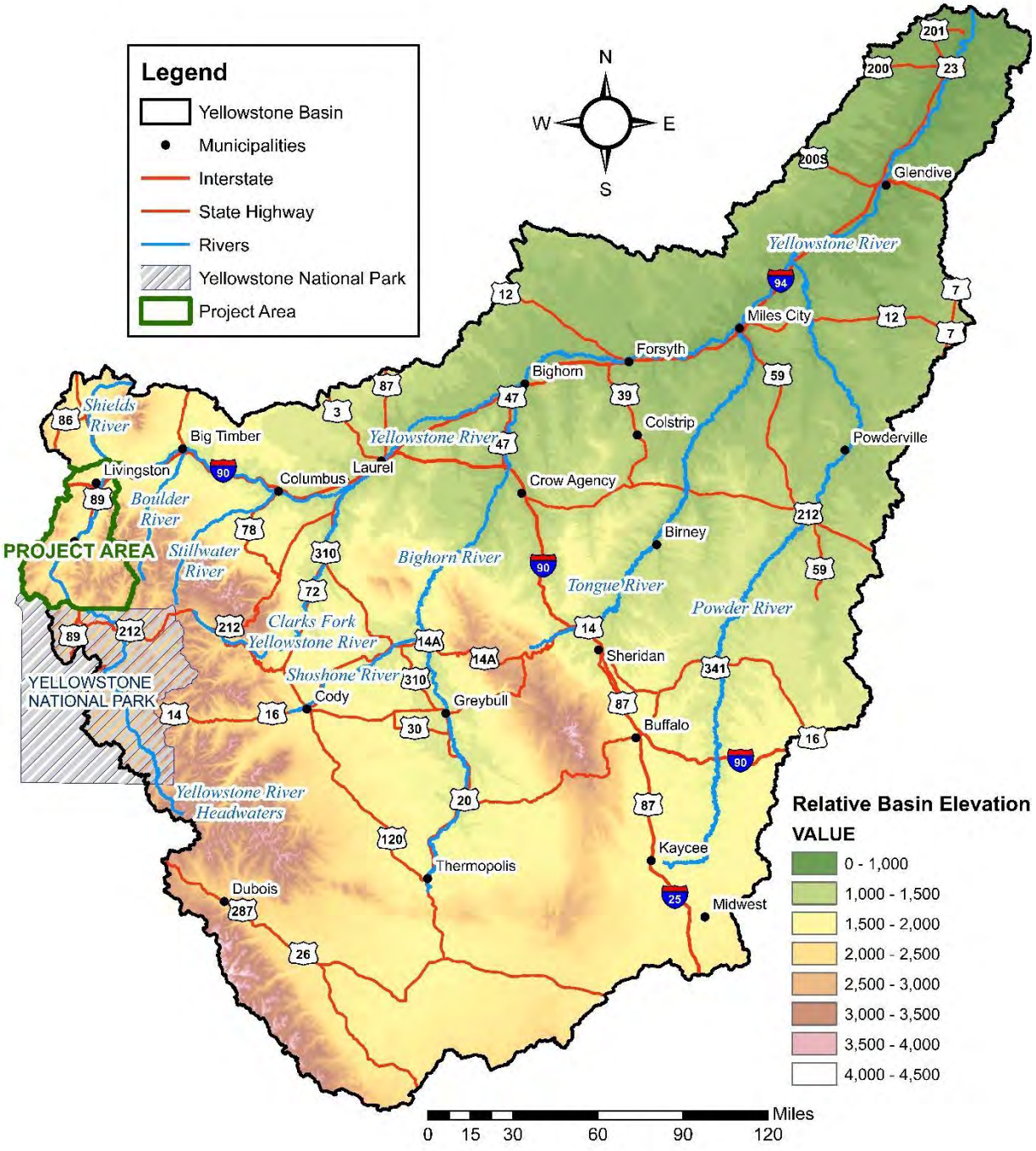



***FIGURE A-2:*** *YELLOWSTONE RIVER BASIN WITH SIGNIFICANT TRIBUTARIES, PROJECT AREA AND YELLOWSTONE NATIONAL PARK.*

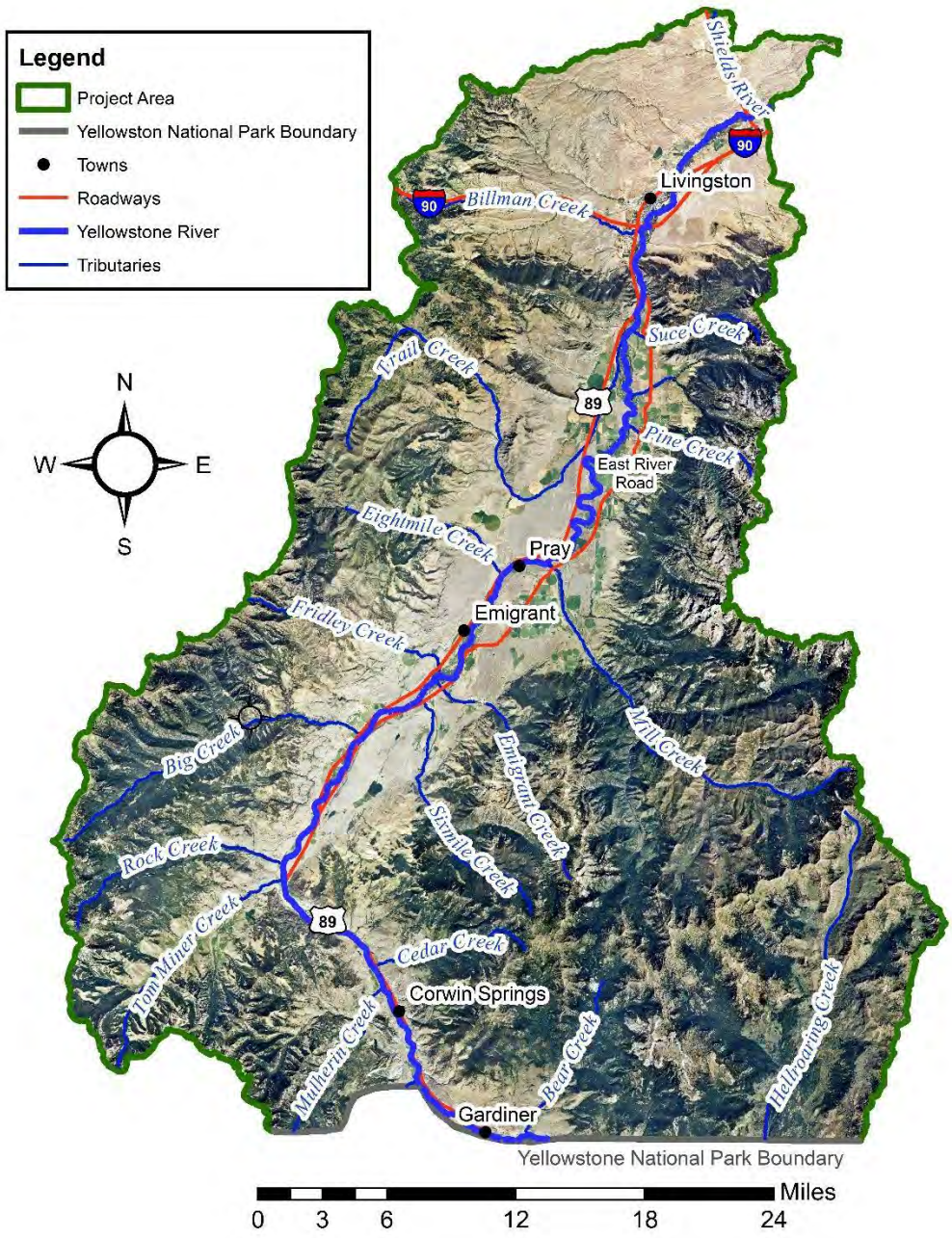



***FIGURE A-3**: PROJECT AREA WITH YELLOWSTONE RIVER AND SIGNIFICANT TRIBUTARIES.*

## Appendix B: References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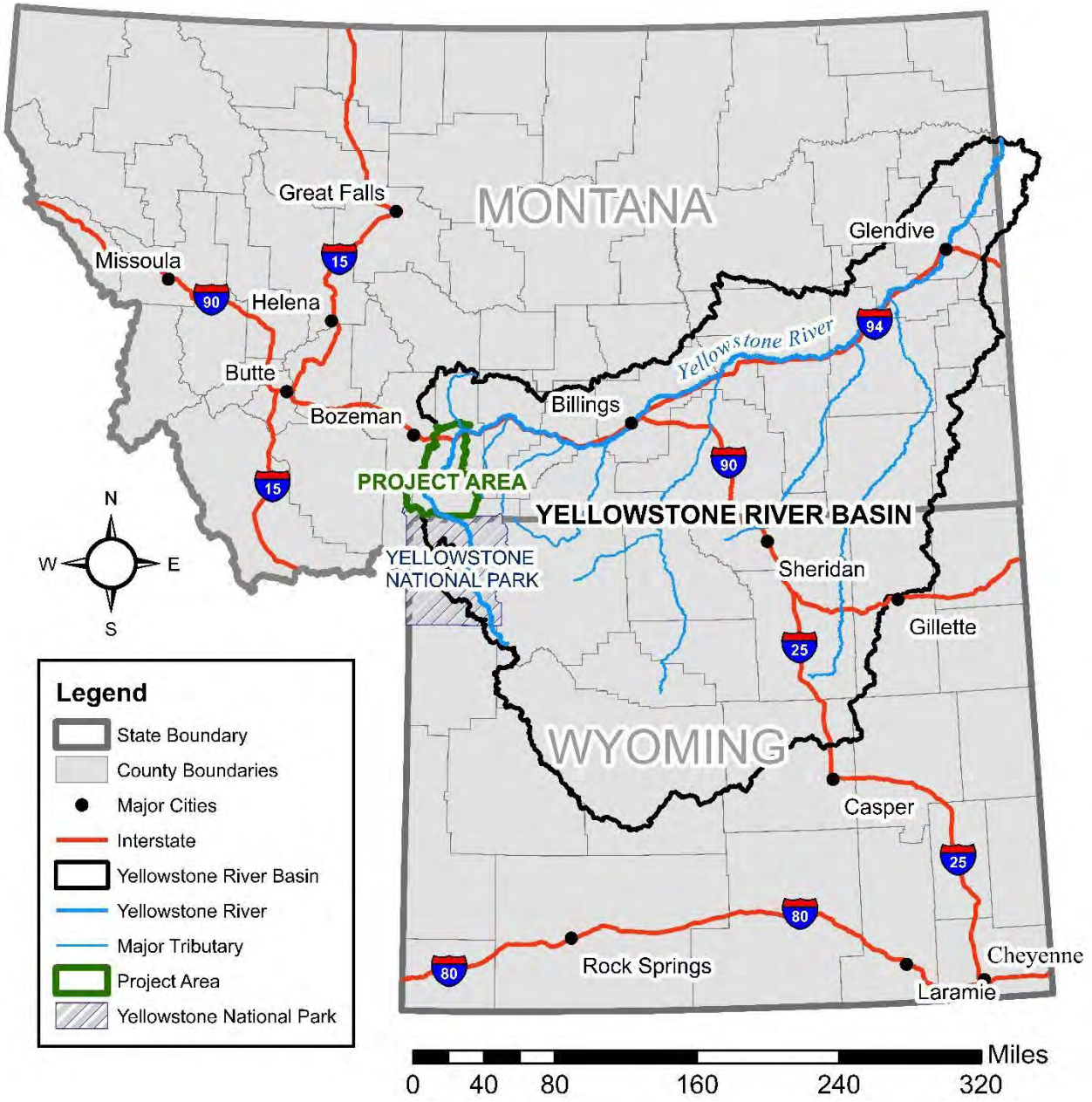



***FIGURE 1:*** *MONTANA AND WYOMING WITH YELLOWSTONE RIVER BASIN, YELLOWSTONE NATIONAL PARK AND PROJECT AREA.*

## Appendix C: Official Resolution

**DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION**

Water Resources Division
1424 9th Ave, Helena, MT 59620-1601 Phone: (406) 444-6601 Fax: (406) 444-0533

GREG GIANFORTE, GOVERNOR

1539 ELEVENTH AVENUE

**STATE OF MONTANA**

DIRECTOR'S OFFICE: (406) 444-2074
FAX: (406) 444-2684

PO BOX 201601
HELENA, MONTANA 59620-1601

April 20, 2021
Bureau of Reclamation
Water Resources and Planning Division
Attn: Ms. Avra Morgan
P.O. Box 25007, MS 86-69200
Denver, CO 80225

RE: WaterSMART Applied Science Grants for Fiscal Year 2021 (R21AS00289)
Montana DNRC – Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin - OFFICIAL RESOLUTION

Dear Ms. Morgan,

The Montana Department of Natural Resources and Conservation (DNRC) is pleased to submit a proposal for a Bureau of Reclamation Applied Science Project Grant. Staff from DNRC's Water Management Bureau, within the Water Resources Division (the Division), will be leading the effort to improve water measurement in Montana's iconic Upper Yellowstone River watershed with the goal of developing a water balance model that will deliver multi-functional drought planning tools to local stakeholders. This project is in direct support of ongoing, locally led drought planning in the area.

As the Water Resources Division Administrator, I have the legal authority to enter into a cooperative financial assistance agreement with the Bureau of Reclamation. The Water Resources Division has the capability to provide the in-kind and direct funding, along with third-party contributions, to meet the project objectives proposed. The Water Management Bureau will work with Reclamation to meet established deadlines for entering into a cooperative financial assistance agreement.

DNRC has reviewed this application and supports this project because it will help Montana community members in the Upper Yellowstone River watershed better understand water supply and determine management actions that will build drought resilience. Through the development of a water balance model that will examine predictive water supply and demand scenarios as well as refinement of stream forecasting and early warning tool for drought, this project will provide robust and replicable products that will help build drought resilience in other watersheds across Montana. Thank you for your thoughtful consideration of this project.

Sincerely,

Anna Pakenham Stevenson, Administrator
Water Resources Division, Montana DNRC

## Appendix D: Letters of Support

Shannon W. Holmes
*Public Works Director*

Martha O'Rourke
*Project Manager*

Almira Johansson
*Administrative Assistant*

Russell Smith
*Waste Reclamation Facility*

Hal Haefs
*Water / Sewer*

Craig Hahn
*Streets*

Rich Stordalen
*Solid Waste*

Eric Schneider
*Parks*

330 Bennett Street
Livingston, MT 59047
Phone: (406) 222-5667

www.livingstonmontana.org

March 22, 2021

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation
Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

Ms. Morgan,

I am writing on behalf of The City of Livingston to express my support for the Montana Department of Natural Resources and Conservation's (DNRC) application for a Bureau of Reclamation Applied Science grant for fiscal year 2021. The project, entitled "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin" would provide valuable tools in support of current locally led water management efforts. This grant would greatly benefit the City of Livingston to fund the monitoring, water balance, hydrologic modeling and water supply forecasting efforts for future growth in and around the city limits.

The Upper Yellowstone River is subject to frequent droughts due to increasingly earlier snowmelt runoff. Water availability has had negative impacts on irrigators, fishing outfitters, and aquatic species including the ever-threatened Yellowstone cutthroat trout. Several data collection efforts have taken place in the upper portions of the Yellowstone River however these efforts have fallen short in providing enough data for effective water management decisions to be made. Watershed residents have come together under the Upper Yellowstone Watershed Group to address drought through adaptation planning. The group has identified the need to better understand water use and availability in the watershed; this project would help them meet that goal.

Sincerely,

Shannon Holmes
Director of Public Works

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation
Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

Ms. Morgan,

I am writing on behalf of the USDA Forest Service to express my support for the Montana Department of Natural Resources and Conservation's (DNRC) application for a Bureau of Reclamation Applied Science grant for fiscal year 2021. The project, entitled "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin" would provide valuable tools in support of current locally led water management efforts.

The Upper Yellowstone River is subject to frequent droughts due to increasingly earlier snowmelt runoff. Water availability has had negative impacts on irrigators, fishing outfitters, and aquatic species including the ever-threatened Yellowstone cutthroat trout. Several data collection efforts have taken place in the upper portions of the Yellowstone River however these efforts have fallen short in providing enough data for effective water management decisions to be made. Watershed residents have come together under the Upper Yellowstone Watershed Group to address drought through adaptation planning. The group has identified the need to better understand water use and availability in the watershed; this project would help them meet that goal.

As a fisheries biologist with the Custer Gallatin National Forest, I am involved in the Upper Yellowstone watershed through informing multiple use land management decisions as they relate to aquatic resource protection and coordinating interagency native Yellowstone cutthroat trout habitat and population conservation and restoration efforts on National Forest system lands. The following project objectives would inform future aquatic habitat restoration and infrastructure designs and land management decisions on the Yellowstone Ranger District:

1. Identifying hydrologic data availability and gaps and establishing a monitoring plan to fill those gaps;
2. Installing monitoring equipment including stream gages, a weather station, piezometers and pressure transducers for surface and groundwater measurements;
3. Developing a water budget to help define water availability and use in the watershed, including quantifying the contributions from major, unmonitored tributaries and the depletions from large irrigation diversions;
4. Using cutting-edge remote sensing techniques to accurately assess crop demand;
5. Hydrologic modeling using predictive scenarios to understand the influence of driving forces such as climate change and increased water demand;
6. Establishing a water supply forecasting program to better predict streamflow into the future.
7. Develop and enhance modeling and forecasting tools available to water managers.

The Custer Gallatin National Forest is committed to supporting this project through communication and collaboration with data collection and data sharing and in-kind fisheries biologist and hydrologist time in support of objectives 1 and 2 above. The estimated in-kind contribution is 8 person days per year valued at $3,600.

I urge you to support local water management in the Upper Yellowstone Watershed by funding DNRC's grant application for "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin."

Sincerely,

Clint Sestrich

Absaroka Beartooth Zone Fisheries Biologist
Custer Gallatin National Forest

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation
Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

Dear Ms. Morgan,

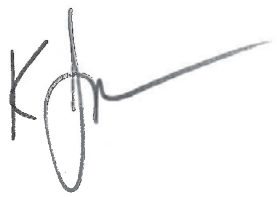
I am writing on behalf of the Montana Climate Office to express my support for the Montana Department of Natural Resources and Conservation's (DNRC) application for a Bureau of Reclamation Applied Science grant for fiscal year 2021. The project, entitled "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin" would provide valuable tools in support of current locally led water management efforts.

The Upper Yellowstone River is subject to frequent droughts due to increasingly earlier snowmelt runoff. Water availability has had negative impacts on irrigators, fishing outfitters, and aquatic species including the ever-threatened Yellowstone cutthroat trout. Several data collection efforts have taken place in the upper portions of the Yellowstone River however these efforts have fallen short in providing enough data for effective water management decisions to be made. Residents have come together under the Upper Yellowstone Watershed Group to address drought through adaptation planning. The group has identified the need to better understand water use and availability in the watershed; this project would help them meet that goal.

As the State Climatologist with the University of Montana's Montana Climate Office and as hydrology professor, I am involved in the Upper Yellowstone watershed through development of Montana's expanding Mesonet meteorological and soil moisture monitoring network and drought monitoring and reporting to the Lieutenant Governor's drought committee. This project would help support the work of my group through further development of precise Yellowstone basin water balance, understanding of agriculture's impact on surface water in the Yellowstone, and furthering our access to water supply forecasting products.

Montana Climate Office is committed to supporting this project through installation of Mesonet stations, meteorological data processing and delivery via our web-based database services, and expert advice on hydrological modeling and remote sensing analysis.

Sincerely,



Kelsey Jencso, P.h.D.
Associate Professor of Hydrology
Montana State Climatologist
Franke College of Forestry & Conservation
University of Montana

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation - Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

April 12, 2021

Dear Ms Morgan,

I am writing to express support from the Montana Bureau of Mines and Geology (MBMG) for the Montana Department of Natural Resources and Conservation's (DNRC) application for a WaterSMART Applied Science Grant for the Fiscal Year 2021. The project, entitled "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin" will support data-driven management of water resources in the Upper Yellowstone River basin. This proposed project will help the local watershed group, The Upper Yellowstone Watershed Group, meet their goal to manage the watershed during periods of drought, address drought-related impacts and develop strategies for resiliency during drought conditions. The watershed group has identified the need to better understand water use and availability in the basin.

The MBMG is involved in the Upper Yellowstone basin in a variety of ways. We monitor about 25 wells and springs in the watershed through our state-wide long term groundwater monitoring program and through monitoring activities associated with the Yellowstone Controlled Groundwater Area. If funded, this project will help support the work of MBMG by identifying and addressing gaps, if any, in the existing hydrologic monitoring networks within the basin. MBMG currently works cooperatively with the DNRC to collect and provide stream-flow measurements from Montana through our Surface Water Assessment Monitoring Program (SWAMP; https://www.mbmg.mtech.edu/mapper/mapper.asp?view=Swamp&).

If funded, the MBMG will support this project through several efforts. MBMG staff will support the DNRC's groundwater data collection efforts and host data from newly established monitoring sites in MBMG's Groundwater Information Center (GWIC) and SWAMP web portal. We anticipate coordinating with the DNRC to ensure complimentary efforts in the basin.

In summary, MBMG encourages funding of this DNRC grant application for hydrologic modeling and water supply forecasting in the Upper Yellowstone basin. Their proposed work compliments efforts by MBMG to provide Montana's citizens, businesses, and agriculturalists the hydrologic information and analysis needed in support of local planning efforts in the Upper Yellowstone basin.

Sincerely,

Madeline Gotkowitz

Madeline Gotkowitz
Research Division Chief

MARS
MONTANA AQUATIC RESOURCES SERVICES

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation, Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

Ms. Morgan,

I am writing on behalf of Montana Aquatic Resources Services (MARS) to express my support for the Montana Department of Natural Resources and Conservation's (DNRC) application for a Bureau of Reclamation Applied Science grant for fiscal year 2021. The project, entitled "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin" would provide valuable tools in support of current locally led water management efforts.

The Upper Yellowstone River is subject to frequent droughts due to increasingly earlier snowmelt runoff. Water availability has had negative impacts on irrigators, fishing outfitters, and aquatic species including the ever-threatened Yellowstone cutthroat trout. Several data collection efforts have taken place in the upper portions of the Yellowstone River however these efforts have fallen short in providing enough data for effective water management decisions to be made. Watershed residents have come together under the Upper Yellowstone Watershed Group to address drought through adaptation planning. The group has identified the need to better understand water use and availability in the watershed; this project would help them meet that goal.

As the Executive Director with MARS, I am involved in the Upper Yellowstone watershed as a member of the Steering Committee, and also as a volunteer to support efforts and projects as necessary. This project would help support the work of my organization by providing tools and resources to communicate and understand the complexities of the water budget and hydrology in the valley. MARS is committed to supporting this project through communication and collaboration of data collection and sharing. Also, we can help with in-kind support as necessary. We are able to contribute 20 hours x $75/hour, in the amount $1500.

I urge you to support local water management in the Upper Yellowstone Watershed by funding DNRC's grant application for "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin."

Thank you for your consideration of grant funds to support this study. If you have any questions, please feel free to contact me at 406-579-2355.

Sincerely,

Wendy Weaver, Executive Director
Montana Aquatic Resources Services

PARK COUNTY
ENVIRONMENTAL
COUNCIL

April 12, 2021

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation
Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

Dear Ms. Morgan,

I am writing on behalf of the Park County Environmental Council (PCEC), a local grassroots environmental organization based in Park County, Montana, with more than 500 members and 2,300 supporters, to express my support for the Montana Department of Natural Resources and Conservation's (DNRC) application for a Bureau of Reclamation Applied Science grant for fiscal year 2021. The "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin" project would provide valuable tools in support of current, locally led water management efforts.

PCEC sits on the Advisory Committee of the Upper Yellowstone Watershed Group (UYWG). The UYWG is an important and respected organizer of local stakeholders in Park County. Their goal is to provide dependable and accessible information through collection and dissemination of scientifically sound monitoring and assessment data, and to lead community education and outreach efforts on watershed-related issues, with the overall goal of maintaining and preserving the overall health of the watershed by developing best practices, seeking innovative solutions, and working to improve drought response and preparedness.

During the summer of 2016, an outbreak of proliferative kidney disease (PKD) caused a massive fish kill on the Yellowstone River. The near record low flows and high water temperatures on the river, the result of drought conditions, created this "perfect storm". 180 miles of the Yellowstone River were closed to all activities for five weeks, which sent a shock wave through our community, with an estimated $500,000 of lost revenue during the height of our summer season suffered by local businesses and fishing guides. Consequently, anxiety levels ran high and unnecessary finger pointing ensued.

In the spring of 2017 the UYWG convened the Yellowstone River Symposium, a two day conference in Livingston that brought together key stakeholders and constituents to discuss the state of the river and water use in the upper Yellowstone. Two important things came out of the meeting: one was a reinvigorated watershed group and the second was a participant survey that showed that drought and water resource availability/scarcity was one of the issues of greatest concern.

PCEC joined the UYWG Drought Focus Committee that was formed after the Symposium to address drought impacts within the upper Yellowstone watershed. Working with a diverse

group of local stakeholders and agency personnel, we have addressed drought vulnerabilities and adaptation strategies. We understand that water use and scarcity, when combined with drought conditions, creates conflict. Collecting data is the most critical component of moving forward for the Drought Focus Committee, and the why this grant will play a very important role in that effort.

The upper Yellowstone watershed is the headwaters of the Nation. Yellowstone National Park holds the upper most portion of the river's watershed. The Park is a nonconsumptive entity that protects the resource, while holding the snowpack that feeds the whole system. The residents of Park County are the most upstream users of the water resources of the Yellowstone River. While that provides us the benefit of clean cold water it also carries with it a great responsibility of stewardship for the resource and all downstream users.

Park County has seen an unprecedented surge in people moving to the area in the last year, fueled to a certain extent by the explosion of growth in the neighboring city of Bozeman, the fastest growing micropolitan city in the country. With the increase in development in Park County, as well as record numbers of visitors, the stressors on our water resources have grown acute and will only increase as these trends continue. This new pressure, combined with drought and the impacts of climate change, our stewardship of our local water resources is all the more essential.

My work with PCEC and involvement with the UYWG has reinforced the importance of sound data collection that this grant would support: stream flow monitoring, groundwater data, evapotranspiration rates, water delivery efficiency and loss, snowpack monitoring, building a water budget, and remote sensing. These tools provide the community we work with the needed data and information to respond and adapt accordingly to persistent drought and a changing climate.

As the leader in local grassroots conservation and community organizing, PCEC will help empower community leaders working on this project to help guide area residents in understanding and incorporating the information that this study produces to make sound decisions and act accordingly. We will help communicate and educate the community on this issue using the data that the study generates.

PCEC will continue to provide support in our advisory capacity, as an in-kind donation averaging approximately 10 hours/week, while also helping with communication and outreach, finding local volunteers when needed and any additional fundraising support identified by the UYWG.

I would like to thank you for your time and consideration, and encourage you to aid our community's local water management efforts in the upper Yellowstone watershed through supporting the DNRC's grant application for "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin."

Sincerely,

Max Hjortsberg
Conservation Director

14 April 2021

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation
Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

Dear Ms. Morgan,

I am writing on behalf of the Montana Water Center to express support for the Montana Department of Natural Resources and Conservation's (DNRC) application for a Bureau of Reclamation Applied Science grant for fiscal year 2021. The project, entitled "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin," would provide valuable tools in support of current locally led water management efforts and could demonstrate the importance of data collection for watershed planning across the state.

The Upper Yellowstone River is subject to frequent droughts due to increasingly earlier snowmelt runoff. Water availability has had negative impacts on irrigators, fishing outfitters, and aquatic species including the ever-threatened Yellowstone cutthroat trout. Several data collection efforts have taken place in the upper portions of the Yellowstone River; however, these efforts have fallen short in providing enough data for effective water management decisions to be made. Watershed residents have come together under the Upper Yellowstone Watershed Group to address drought through adaptation planning. The group has identified the need to better understand water use and availability in the watershed; this project would help them meet that goal.

The Montana Water Center is leading a project and working group to understand how shifts in irrigation method and practice affect water supply and what role irrigated agriculture can play in building a sustainable water future for Montana. As the effects of changing irrigation methodology are varied and site-specific, having local data is essential to understanding and predicting these impacts. The proposed project would support the Montana Water Center's work the following ways:

**Montana Water Center**
23 Faculty Court
Montana State University
Bozeman, MT 59717
www.montanawatercenter.org

Tel: 406-994-6690
Fax: 406-994-1774

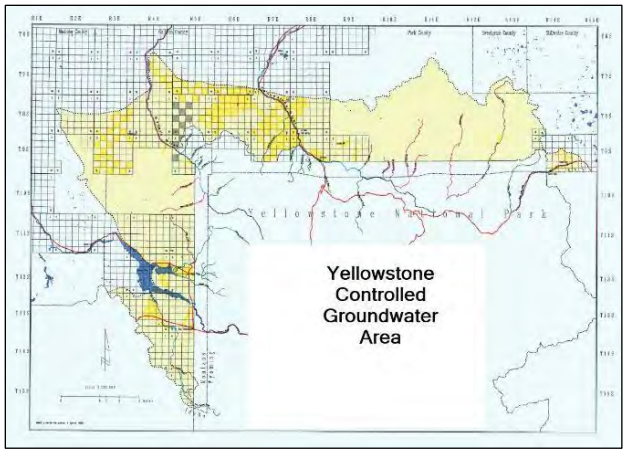
*turning science. . .*
*. . into solutions*

- The installation of monitoring equipment will help quantify how and where surface and groundwater interact in the valley, how changes in irrigation might affect these interactions, and what the subsequent impacts to streamflow and water supply might be.
- The development of a water budget and hydrologic model for the watershed will enable the use of predictive scenarios to understand how changes in irrigation, climate change, and development in the valley will affect water supply.
- Statewide investment in water monitoring and measurement is critical to planning for our water future in Montana. This effort will identify current gaps in water data and information and provide an important example of the value of accurate and timely water data.

The Montana Water Center is eager to see this work done in the Upper Yellowstone and is committed to supporting this project through collaboration and cooperation. I hope you will support local water management in the Upper Yellowstone Watershed by funding DNRC's grant application for "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin."

Sincerely,

Wyatt F. Cross
Director, Montana Water Center
Professor of Ecology
*montanawatercenter.org*
Montana State University
Bozeman, MT 59717




**Technical Oversight Committee Members**

Dr. Stephan Custer, Chair

Marvin Miller, Montana University System

John Kilpatrick, U.S. Geological Survey

David Susong, National Park Service

Attila Folnagy, DNRC

March 19, 2021

**To:** Ms. Avra Morgan, Bureau of Reclamation

**From:** Technical Oversight Committee for the Yellowstone Controlled Groundwater Area

**RE:** Enhancing Hydrologic Modeling and Water Supply Forecasting in Upper Yellowstone Basin

The Technical Oversight Committee (TOC) unanimously supports the Department of Natural Resources and Conservation (DNRC) proposal for the WaterSMART Applied Science Grant for their proposed project in the Upper Yellowstone Basin. The proposed project objectives of developing a water balance to understand water use and forecast modeling to aid in drought management will provide critical information to support the TOCs work. The TOC is committed to supporting this project through collaboration and communication with data collection, data sharing, and identifying data gaps.

The Yellowstone Controlled Groundwater Area was created by a compact between the State of Montana and the United States Government. "The parties agree that the goal of establishment and administration of the Yellowstone Controlled Groundwater Area shall be to allow no impact to the hydrothermal system within the reserved land of YNP" (Yellowstone National Park) p. 30). The TOC was established "to review scientific evidence related to the Yellowstone Controlled Groundwater Area; to advise the Department (ie., DNRC) on administration of the Area, including review of applications to appropriate water of 60$^{o}$F or more; to consult with the (Montana) Bureau (of Mines and Geology) on inventory and sampling; and to recommend modification of boundaries and restrictions."

In summary, the TOC looks forward to the wealth of information that this project will yield and how it will further our understanding of water use and water supply forecasting in the Upper Yellowstone Basin.

Ms. Avra Morgan
Program Analyst
Bureau of Reclamation
Water Resources and Planning Division
PO Box 25007
Denver, CO 80225

Ms. Morgan,

I am writing on behalf of the Upper Yellowstone Watershed Group (UYWG) to express my support for the Montana Department of Natural Resources and Conservation's (DNRC) application for a Bureau of Reclamation Applied Science grant for fiscal year 2021. The project, entitled "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin" would provide valuable tools in support of current locally led water management efforts.

The Upper Yellowstone River is subject to frequent droughts due to increasingly earlier snowmelt runoff. Water availability has had negative impacts on irrigators, fishing outfitters, and aquatic species including the ever-threatened Yellowstone cutthroat trout. Several data collection efforts have taken place in the upper portions of the Yellowstone River however these efforts have fallen short in providing enough data for effective water management decisions to be made. Watershed residents have come together under the Upper Yellowstone Watershed Group to address drought through adaptation planning. The group has identified the need to better understand water use and availability in the watershed; this project would help them meet that goal.

As Watershed Coordinator with the Upper Yellowstone Watershed Group, I am involved in the Upper Yellowstone watershed through working with a wide range of local stakeholders in water and other natural resource-based projects. This project would help support the work of my organization through identifying hydrologic data availability and gaps and establishing a monitoring plan to fill those gaps; installing monitoring equipment including stream gages, a weather station, piezometers and pressure transducers for surface and groundwater measurements; and developing a water budget to help define water availability and use in the watershed, including quantifying the contributions from major, unmonitored tributaries and the depletions from large irrigation diversions.

The Upper Yellowstone Watershed Group is committed to supporting this project through communication and collaboration with data collection and data sharing, as well as in-kind staff time to help bolster communication and outreach efforts for the project with local stakeholders throughout the watershed. The UYWG plans to give 200 hours (at $25/hour) a year as in-kind staff time to support this project.

I urge you to support local water management in the Upper Yellowstone Watershed by funding DNRC's grant application for "Enhancing Hydrologic Modeling and Water Supply Forecasting in Montana's Upper Yellowstone Basin."

Sincerely,

Ashley Lowrey

Watershed Coordinator, Upper Yellowstone Watershed Group