Water Resources Operations Forecasting Tool for the Yampa River Basin

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Table of Contents

Executive Summary

The applicant is the Upper Yampa Water Conservancy District (UYWCD), Steamboat Springs, Routt County, Colorado, which is a Category A applicant (Water District). The UYWCD is a Water Conservancy District, formed under the Colorado Water Conservancy Act. This grant proposal is applying for $249,625 in Federal support, which is matched by $254,471 in cash and in-kind contributions from the UYWCD for a 50.5% match from non-federal funding sources.

This grant will deploy a by-reach river administration forecasting tool for the Yampa River basin that will produce a variety of metrics like projected reservoir contents, supply and demand, and streamflow conditions. The project team will leverage the State of Colorado's StateMod water rights and demands dataset, alongside a state-of-the-art deployment of the Weather Research Forecasting Hydrologic Model (WRF-Hydro) to project both streamflow forecasts as well as the impact of those streamflows on river operations throughout the basin. The project will provide river administration projections to smaller users that lack the resources to interpret existing forecasts or run systems operations forecasts of their own. Additionally, the UYWCD and project team will engage with water users throughout the basin to gather feedback on additional useful metrics for different sectors of water use.

This project extends an existing 18 month proof-of-concept effort that tested the feasibility of combining the component models and delivering useful river administration metrics. Forecast results will be delivered through a web-based interface and made freely available to all users in the basin. Project implementation will take place over a 2 year period for development, calibration, testing and stakeholder engagement. It is anticipated that this model will be completed and available for broad use by the end of runoff season 2025.

There are no USBR projects within the Yampa River Basin, though water from the Yampa River is counted towards Colorado's obligations under the Colorado River Compact. Contract releases are also made from multiple reservoirs throughout the basin to support the US Fish and Wildlife Service's Upper Colorado River Endangered Fish Recovery Program.

Technical Project Description

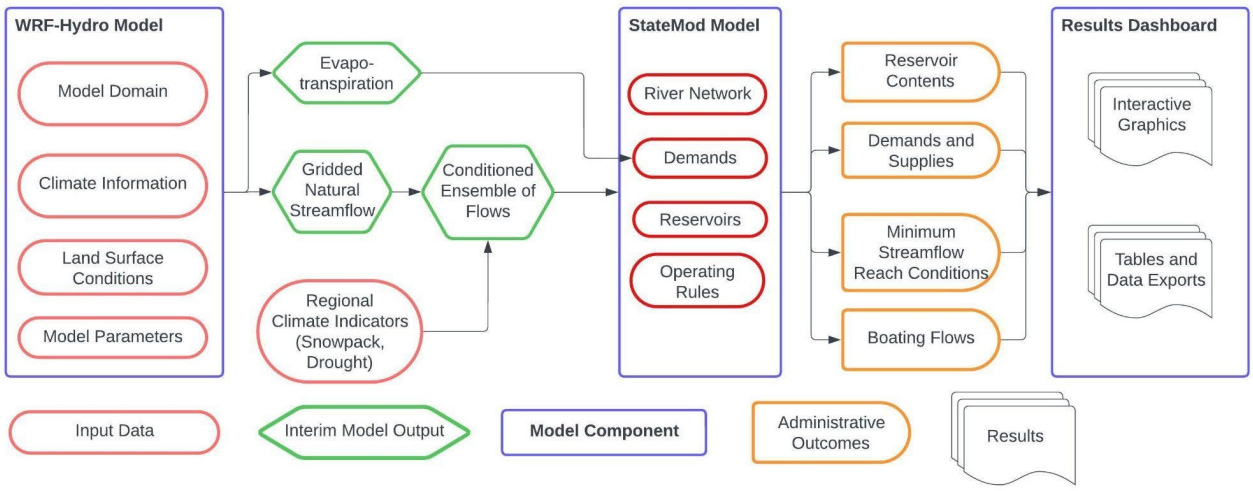
The primary goal of this project is to create a forecasting tool for the Yampa River Basin that provides not only projected streamflow conditions, but also administrative outcomes like expected reservoir yields, impacts to environmental flows, water rights availability, and others. This goal will be achieved through the integration of a robust streamflow forecasting framework with a well established water resources allocation systems model, and delivery of model results through a publicly accessible web-based dashboard. The Weather Research and Forecasting Model Hydrological modeling system (WRF-Hydro), deployed by Scripps CW3E will be used to generate an ensemble of daily streamflow forecasts at points throughout the Yampa River Basin. These streamflow forecasts will be integrated into a modified version of the State of Colorado's StateMod river administration and water rights model. Administrative outcomes for each major river reach, and the associated uncertainties on those outcomes, will be made publicly available to all water users throughout the Yampa River basin.

The model will cover the drainage of the Yampa River basin upstream of the Utah State Line, including tributary areas within Colorado and Wyoming. In all, the model domain encompasses ~8,000 square miles. The model will be run on a daily time step though forecast results will only be produced on a biweekly or monthly basis, depending on the season.

Figure 1 below shows the general architecture for the proposed tool. In general, the completed tool will operate in the following way:

(1) The WRF-Hydro streamflow forecast model is used to produce an ensemble of streamflow forecasts at all relevant locations in the Yampa River basin
(2) Regional climate indicators like drought and snowpack will be used to adjust the ensemble of streamflow forecasts to better represent the current year based on locally observed conditions
(3) StateMod will be run with the updated streamflow forecast ensemble to generate a set of administrative outcomes for key locations throughout the basin
(4) Model results will be delivered via web dashboard allowing public users access to forecasted water availability

Figure 1: Overall Tool Architecture



Existing Efforts

The Upper Yampa Water Conservancy District (UYWCD) continues to modify and improve their Yampa River StateMod model to understand different water resources scenarios. The Yampa River basin StateMod model has nearly 500 model nodes representing stream gages, agricultural and municipal diversion structures, minimum streamflow reaches, surface water reservoirs, wells, and others. Additionally, the existing model has more than 1500 active water rights associated with a specific diversion amount and priority date.

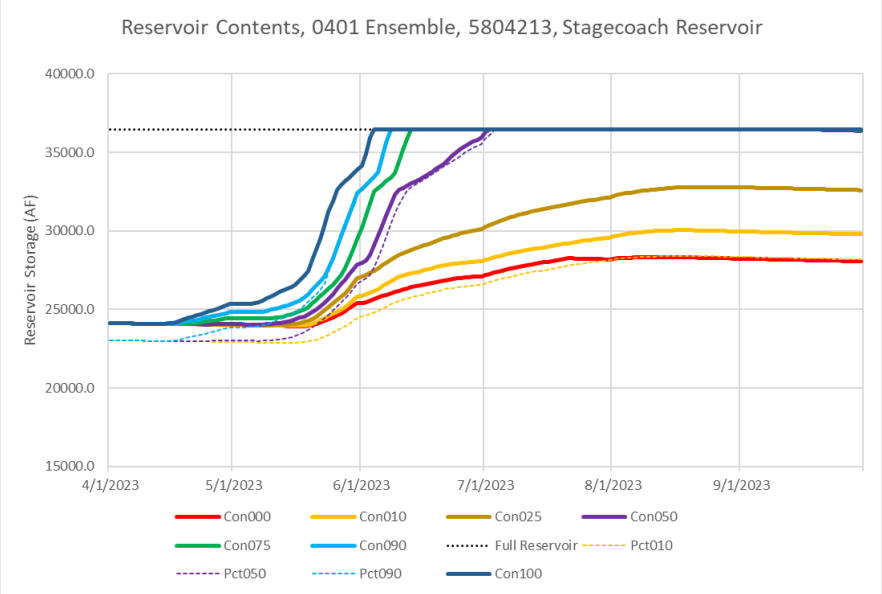
Beginning in 2022, the UYWCD funded the project team (CW3E and LRE Water) to develop a proof-of-concept integration between WRF-Hydro and their StateMod model. Several forecasts of river outcomes were made on March 1st, April 1st, May 1st, June 1st, July 1st, and August 1st 2023. During this testing phase, LRE Water was contracted to build a proof of concept around how streamflow

forecasts could result in different administrative outcomes for key reservoirs or diversions in the basin including:

- Probability and timing of reservoir fills/spills
- Timing of periods of “Free River” with no active water rights calls
- Timing of water availability for specific water users
- Use of various augmentation plans and contracted supplies
- Occurrences of minimum streamflow conditions
- Timing of major river calls

Figure 2 shows a range of projected reservoir contents from the proof-of-concept project. In this graphic, the colored lines represent reservoir contents occurring when streamflow conditions are in a certain percentile of the ensemble. For example, the purple line shows the median (50th percentile) ensemble member and the reservoir filling on July 1st. Its important to note that ensemble is continually updated with observed streamflows and reservoir contents, resulting in more accurate forecasts and a smaller range of results as the season progresses. Metrics like these will provide good value to all stakeholders with contract water in Stagecoach Reservoir.

Figure 2 Example Figure Showing Range of Likely Reservoir Contents, Stagecoach Reservoir



There were many lessons learned during this pilot project that will be addressed in the technical scope below including:

- Better calibration of the WRF-Hydro model to conditions in the Yampa River Basin
- The need for additional natural flow locations and key diversion nodes within the StateMod model
- More seamless integration of WRF-Hydro and StateMod
- The value and need to improve the ensemble conditioning method to narrow the range of output uncertainty

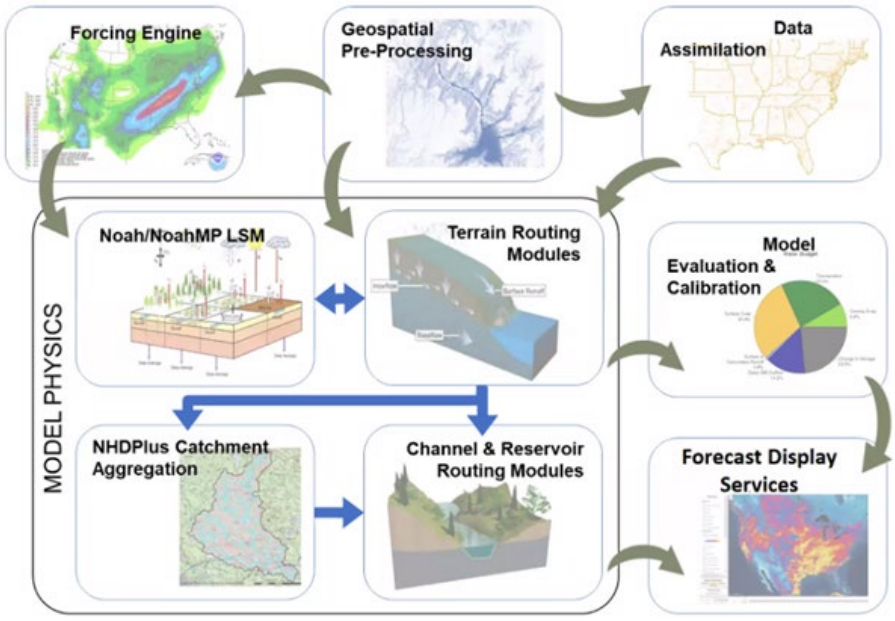
- Identification of several forecast metrics of interest, but the project team recognized the need for more stakeholder input in this area

Natural Flow Forecasting with WRF-Hydro

The first key component of this forecast tool is the deployment of CW3E's WRF-Hydro model to support refined daily natural flow forecasts in the Yampa River basin. Currently, CW3E delivers forecasts supporting stakeholders throughout the Colorado Nevada River Forecast Center domain, including the State of California.

The most recent version of the WRF-Hydro model (version 5.2.0), will be used as the main hydrologic forecasting tool. WRF-Hydro is a full-featured hydrologic model developed at the National Center for Atmospheric Research (NCAR) and it is regionally calibrated. The WRF-Hydro model consists of three major modules: (1) the land surface model, a 1-D vertical model to simulate the moisture and energy fluxes between the atmosphere and land surface as well as in the soil layers, (2) the terrain routing model, which simulates the 2-D overland flows across hillslopes, and (3) the channel routing model, which calculates the 1-D flow of water in the river network. **Figure 3** shows the WRF-Hydro model components and their combined architecture.

Figure 3: WRF-Hydro Model Components and Architecture



WRF-Hydro requires forcing inputs at 1-km, 1-hourly scale and a forcing engine has been developed at CW3E for this purpose that combines/downscales various operational data products. These operational data products include various meteorological data sets ranging in duration from hourly (High Resolution Rapid Refresh from NOAA, or HRRR) to daily and longer (PRISM[1], developed by Oregon State).

[1] https://prism.oregonstate.edu/

An elevation (topography) based downscaling and merging procedure is established for all input forcing variables (precipitation, temperature, humidity, short-/long-wave radiation, pressure, and wind) according to the existing literature[2]. This forcing engine ingests a series of inputs from different sources with different temporal/spatial resolutions, domains, reliability, period of coverage, and lag time (see **Table 1** below for non-forecast sources of data).

Table 1 Procedures and Data Sources for WRF-Hydro Model Forcing Data

Variable	Sources	Downscaling/Merging Procedures
Precipitation	Stage-IV, NLDAS-2, PRISM, HRRR	1) Merge NLDAS-2 (for gap fill) and Stage-IV at 4 km 2) Constrain daily total to match PRISM 3) Bilinear interpolation to 0.01° (~1 km)
Temperature	NLDAS-2, PRISM, HRRR	Elevation based downscaling with a lapse rate of -6.5°C/km
Pressure	NLDAS-2, HRRR	Elevation based downscaling with hydrostatic atmosphere
Shortwave	NLDAS-2, HRRR	Bilinear interpolation
Specific Humidity	NLDAS-2, HRRR	1) Back out relative humidity at 0.125°, interpolate to 0.01° 2) Re-calculate specific humidity using temperature, pressure, and relative humidity at 0.01°
Longwave	NLDAS-2, HRRR	1) Back out emission temperature at 0.125° 2) Apply lapse adjustment to emission temperature at 0.01° 3) Apply emissivity adjustment at 0.01° 4) Re-calculate longwave emission
Wind (U, V)	NLDAS-2, HRRR	Bilinear interpolation

The WRF-Hydro modeling is divided into several time horizons according to the data availability/reliability as well as the purpose of a particular forecast. **Figure 4** shows the various time horizons and how they range from hindcast (using climatology), to short term (based on forecasted weather data), to seasonal (derived from seasonal forecasts). For this project, the project team may use some or all of these forecast products, depending on the timeline.

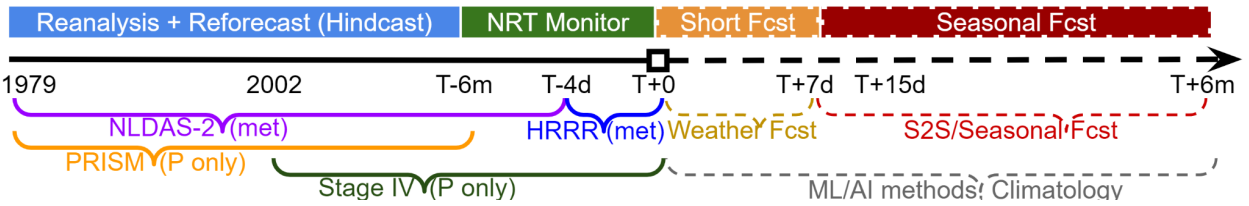


Figure 4 Separation of modeling time horizons: (1) retrospective period: 1979 to 6 months behind real time, for reanalysis and re-forecast, (2) near real time: 6 months behind real time to real time for monitoring purposes, (3) future: lead time 0 to 6 or more months for forecast.

[2] Cosgrove, Brian A., et al. "Real-time and retrospective forcing in the North American Land Data Assimilation System (NLDAS) project." *Journal of Geophysical Research: Atmospheres* 108.D22 (2003).

Given the challenging nature of meteorological forecasting at subseasonal and seasonal (S2S) scales, an include-all forecasting strategy is adopted. Multiple forecast time scales are combined to generate the best possible forecast across the entire ensemble:

0 to 7 Days: Weather forecast from West-WRF weather model

8 Days to 3 Months: Statistical S2S forecast from Canonical Correlation Analysis (CCA)

3 Months to end of Water Year: Past climatology, to enable Ensemble Streamflow Prediction (ESP)

As a practical matter, the forecast portion farther out than 3 months uses historical climatology and can therefore be compared to historical physical conditions in the basin (like SWE and soil moisture). This will enable an ensemble conditioning approach that will narrow the range of uncertainty in the forecast. Ensemble conditioning is discussed in more detail below.

WRF-Hydro Model Output Post-processing
The model-predicted streamflow will very likely be biased even if it is driven by observed forcing (e.g. in the reanalysis period) and after calibration. To minimize the biases in the streamflow predictions, we apply a CDF matching procedure that converts predicted value to a quantile (CDF) and finds the observed value of the same quantile in the observed climatology. Due to the small sample size of monthly data, (only 42 observed historical samples in 1979-2020), we apply an interpolation procedure between discrete points on the CDF curves to handle the data sparsity issue.

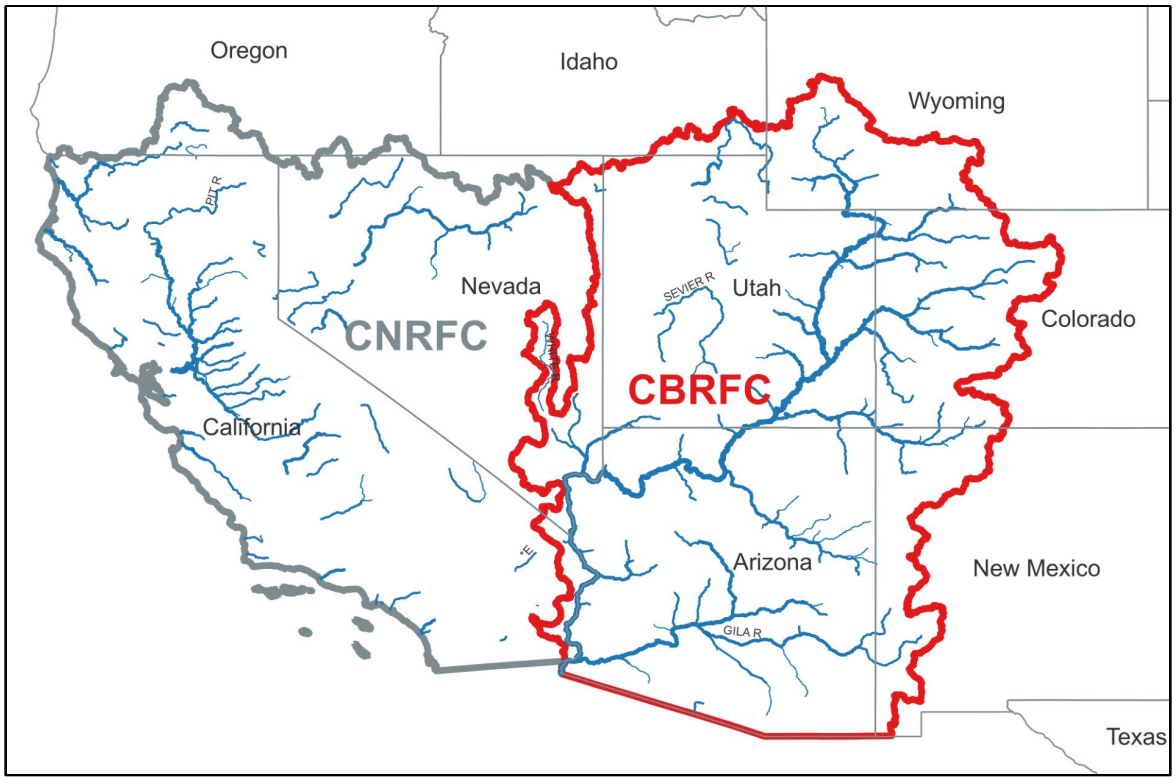
The existing WRF-Hydro deployment is able to produce forecasts for locations within the Yampa River basin, but there are several upgrades and improvements that will be addressed by this project which are described below:

- Expand the model domain to all of Western Colorado
- Calibrate the WRF-Hydro model parameters to local conditions
- Improve the representation of late-season baseflows
- Incorporate better representations of snowpack, soil moisture and other measurements

Expand and Improve the WRF-Hydro Forecast Domain

Currently the CW3E WRF-Hydro model generates forecasts for the Yampa River Basin on an experimental basis. While this particular project is focused on delivering administrative forecasts for the Yampa River basin, the eventual goal of this project is to eventually expand to the portion of Colorado west of the Continental Divide. It is efficient to expand the WRF-Hydro domain to cover a broader area than just the Yampa River basin portion used in the pilot project. **Figure 5** shows the existing (CNRFC in gray) and proposed domain (CBRFC in red) of the WRF-Hydro Streamflow forecast model. This figure shows how the model domain will be expanded to cover all of the Western Slope of Colorado to deliver future forecasts for additional basins. The specific application of these expanded forecast areas depends on engagement with additional stakeholder groups. This new domain

Figure 5 - Current and Expanded WRF-Hydro Forecast Domain



CNRFC - California Nevada River Forecast Center
CBRFC - Colorado Basin River Forecast Center

Parameter calibration to local natural flows

The CW3E WRF-Hydro model has been calibrated to conditions in the CNRFC and other parts of the Western US, but not Colorado or the Yampa River Basin specifically. During the initial investigation period to determine the suitability of the WRF-Hydro model for this effort, biases were identified wherein the WRF-Hydro hindcast showed higher total runoff, and a mean runoff date that was later in the season. As part of this effort, the WRF-Hydro model will be calibrated to existing datasets of monthly "naturalized" flows, to improve the forecast performance. These datasets have been derived from streamflows and observed diversion data within the StateMod dataset and are described below.

Address late season baseflows

One key upgrade to the WRF-Hydro platform will be better representation of late season low flows, through calibration or other means. Low flow periods are the time of the year when reservoir storage and carefully negotiated water rights operations become relevant since there is insufficient water to meet all demands, and water rights seniority begins to matter. It is important to capture these low flow periods for effective forecasting of both seasonal runoff totals and likely river operations.

Potential further improvements through ingesting additional data (snowpack, streamflow, etc.) and Machine Learning (ML) techniques

CW3E is supported through other projects and programs to develop ML techniques for improving hydrologic forecasting with the help of additional data. Here we will explore the tools and techniques developed in those external efforts to:

- Improve snowpack dynamics (snowpeak and snowmelt amount/timing) through ingesting of snow water equivalent (SWE) and fractional snow covered area (fSCA) data from NRCS, SNODAS, and USGS.
- Improve short-term streamflow forecasts through ingesting gauge observed and calculated natural flow data.
- Improve runoff calculations through Long Short Term Memory (LSTM) techniques

River Administration Model (StateMod)

The other key component of this tool is the integration of a river administration model to represent water rights, supplies, demands, reservoirs and other river operations. This project will use the State of Colorado's StateMod model (https://cdss.colorado.gov/software/statemod) to represent these operations. The StateMod platform is part of an effort to develop integrated hydrologic models throughout the State of Colorado as part of the Colorado Decision Support System (CDSS). StateMod analyzes water supplies and water demands and allocates available supply based on water rights, locations of demands, operational protocols and other factors. Per the attached letter of support from the Colorado Water Conservation Board, the agency responsible for developing and maintaining StateMod, LRE Water's implementation of StateMod as a forecasting tool is first of its kind.

StateMod operates in two key modes relevant to this effort: baseflow mode and simulation mode. In baseflow mode, "naturalized" flows are calculated by taking first stream gage data, and backing out any upstream operations like diversions, subsurface return flows after diversions, reservoir operations and evaporation, and transbasin imports/exports. This "naturalized" flow data will be used to calibrate the WRF-Hydro model outputs.

In StateMod's simulation mode, the priority and amount of all water demands, reservoirs, minimum streamflows, and other operations compete against one another so water users receive their legal entitlement of water. When there is insufficient flow available, the most junior water rights have shortages where they are not able to meet their demands. All StateMod models in Colorado have been initially developed using monthly calculations to generate naturalized flows. In simulation mode, various disaggregation methods are applied so the model is run on a daily timestep. Simulation mode is what will be used to generate the final set of forecasts produced in this project.

The existing UYWCD StateMod model runs on a daily timestep, but needs some improvements to better represent water rights administration on key stream reaches. Several changes will be made to the existing StateMod model as part of this tool development to improve the quality and resolution of the forecast product:

- Addition of more natural flow locations
- Refinement of existing natural flow locations
- Representing key diversion structures explicitly

- Development of daily demand datasets

WRF-Hydro/StateMod Integration

In order to use WRF-Hydro and StateMod seamlessly to generate an administrative forecast, some amount of software development must be done to link the two models together. StateMod is run using a compiled FORTRAN executable that does not allow for direct integration with WRF-Hydro. StateMod uses a scripting language called TSTool (https://cdss.colorado.gov/software/tstool) to develop text-based input files for each model run. As part of the initial testing period, some proof-of-concept scripts have been developed to take WRF-Hydro model output and generate StateMod input files, though these scripts need to be improved and their execution automated.

Ensemble Conditioning

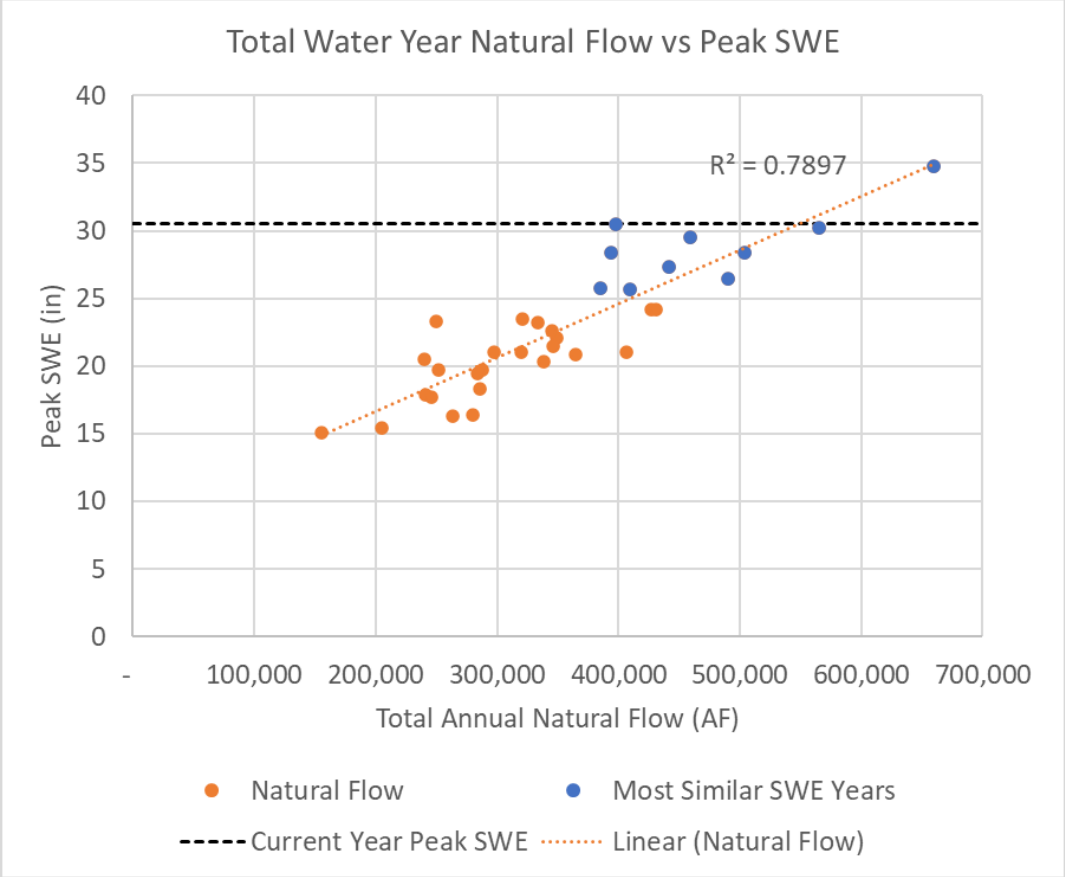
Regardless of forecast lead time, WRF-Hydro model results are delivered in an ensemble fashion, with each ensemble member representing one possible daily streamflow realization for the remainder of the season. Traditionally, each trace in an ensemble forecast is weighted the same, which makes the implicit assumption that climatology from any year in a historical record is equally as likely to occur. From a recent paper on ensemble forecasting:

"Results show that conditionally resampling from a set of traces based on large-scale climate information can greatly improve forecast skill, and has the potential to narrow the spread of ensembles produced at longer lead times.[3]"

Several studies have validated the importance of Snow Water Equivalent (SWE) information in predicting seasonal total runoff across the Western US[4,5,6]. **Figure 6** below shows an example relationship between Peak SWE and Naturalized flow data at a key gage in the Yampa River basin. There is a strong relationship between peak SWE and total annual runoff. This is just one of many relationships that will be tested to condition the ensemble of streamflows to improve the river administration forecast.

[3] Middleton, Brennan, Balaji Rajagopalan, and Shane Coors. "Conditionally Resampling from Ensemble Streamflow Forecasts Using a k-Nearest Neighbor Bootstrapping Approach."
[4] Modi, Parthkumar A., et al. "Investigating the role of snow water equivalent on streamflow predictability during drought." *Journal of Hydrometeorology* 23.10 (2022): 1607-1625.
[5] Li, Dongyue, et al. "How much runoff originates as snow in the western United States, and how will that change in the future?." *Geophysical Research Letters* 44.12 (2017): 6163-6172.
[6] Llewellyn, D., A. Wood, and F. Lehner, 2018: Runoff efficiency and seasonal streamflow predictability in the U.S. Southwest . Bureau of Reclamation Final Rep. ST-2015-8730-01, 63 pp., https://www.usbr.gov/research/projects/download_product.cfm?id=2760.

Figure 6 - Peak SWE vs Total Natural Runoff, Yampa River at Steamboat Springs, CO



To deliver an improved forecast and reduce uncertainty beyond the range of the full ensemble, this project will test different variables including SWE and soil moisture, to evaluate the ideal variables to condition the WRF-Hydro ensemble. The end result of the ensemble conditioning project component will be a process by which WRF-Hydro ensemble members are weighted and a “most likely” range of outcomes for the Yampa River basin are generated for the upcoming forecast period, prior to being run through the StateMod model.

Public Dissemination of Forecast Results

The end goal of this project is to provide a range of likely administrative forecasts to water users throughout the basin. This goal is only achievable if results are useful, shared publicly, and presented in a user friendly understandable fashion.

During the initial testing phase of this project, the project team received feedback from local stakeholders on ideal metrics they could use to guide their decision-making. Specifically, these metrics were identified and tested:

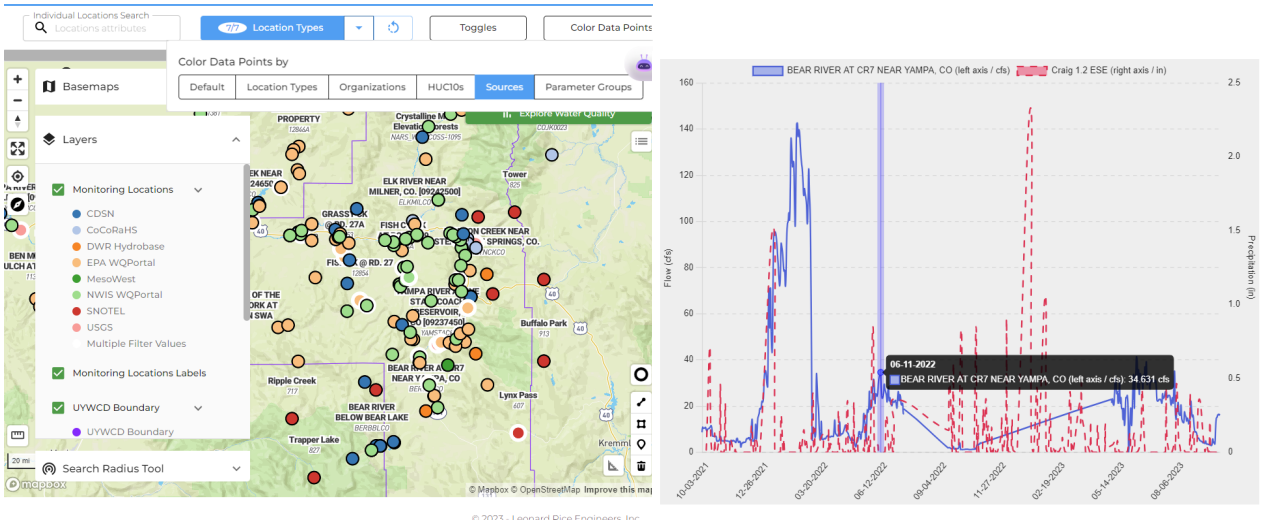
- Priority Date of Active Calling Right (What seniority of user can legally divert water)
- Date range of free river (What is the time range where river supplies exceed all demands)
- Reservoir filling likelihood/date estimates for key reservoirs

- Timing of minimum streamflow exceedances
- Peak and seasonal total streamflow on key subreaches
- Timing and amount of the use of reservoir contract water to augment direct flow water rights
- Other key metrics requested by stakeholders

Through a stakeholder engagement process, the project team will fine tune the selection and presentation of these metrics and forecasted results, as well as the best way to represent uncertainty around them. American Whitewater, the CWCB, and other local entities representing municipal and agricultural interest have agreed to participate in this process and identify relevant metrics, as well as help us present the data in a way that helps them make informed decisions for their users.

The UYWCD currently hosts a publicly accessible (https://uywcd-ops.lre-up.com/, free signup required) data dashboard for streamflow, water quality and meteorological data throughout the basin. Additional pages will be added to this dashboard to host administration forecasted results on the platform that is already used by stakeholders throughout the basin. **Figure 7** shows two example screenshots of the dashboard, with a map and timeseries viewer shown.

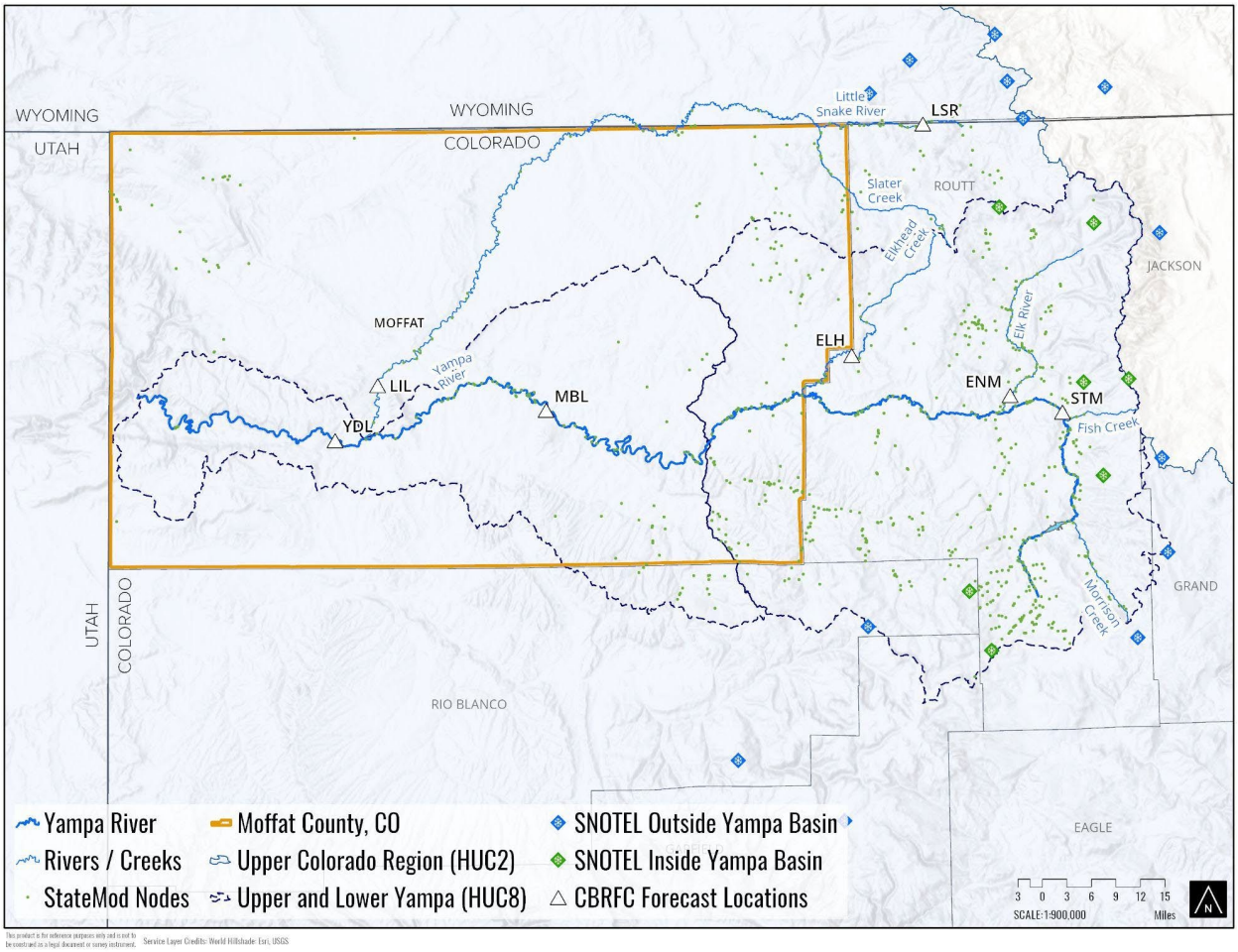
Figure 7 - UYWCD Data Dashboard, Map and Time Series Viewer



Project Location

The map below summarizes the domain of this project. **Figure 8** shows the Yampa River Basin within Colorado. This map also shows the relatively limited number of CBRFC seasonal streamflow forecast locations and NRCS SNOTEL sites, compared to the thousands of water user locations within the StateMod dataset (“StateMod Nodes”). Also highlighted on this map is Moffat County, which is listed as an economically disadvantaged community according to the Council on Environmental Quality’s interactive Climate and Economic Justice Screening Tool.

Figure 8 - Project Location and Key Geographies



Data Management Practices

CW3E will make our data from modeling and forecasting publicly available in order to support further research, including the reanalysis, and forecast data. The sharing of research results will be consistent with USBR and other related policies governing intellectual property, copyright and the dissemination of research products. The investigators are committed to upholding the highest standards for transparency and allowing the research to be reproduced by others. Results obtained during the proposed research will be summarized and shared with other researchers through presentations at scientific conferences and publication in international peer-reviewed journals.

StateMod was originally developed by the State of Colorado, and all model inputs were subject to a rigorous peer review process as part of the Colorado Decision Support Systems (CDSS) initiative and the Colorado Water Plan. The core StateMod deployment used in this tool will be made publicly available as part of our commitment to transparency. Similarly, the results from the completed forecast tool, all forecast output will be archived and made available to the general public.

Evaluation Criteria

At its core, this forecast tool is designed to provide valuable decision-making insight to water users of at multiple scales; from reservoir operators down to individual ditch users. This project is eligible for funding based on multiple water management objectives identified in the NOFO including, water supply reliability, drought management activities, water rights administration, and ability to meet endangered species requirements. This tool combines a state-of-the-art water resources forecasting model and a detailed ditch-level water rights and operations model to provide robust forecasts to enhance management of water supplies and reservoir operations.

A. Water Management Challenge

The Yampa River, one of the last predominantly free-flowing rivers in the Western US, serving as a lifeline for Northwest Colorado residents (Routt and Moffat County combined population ~40,000) and vast acres of farming and ranching. Municipal water supplies, industrial uses, environmental, and recreation uses all depend on Yampa River flows. The Yampa River also delivers approximately 1.3 million Acre-Feet annually across the Utah border, constituting approximately 17% of Colorado's obligations under the Colorado River Compact. The Yampa River is also one of a few river homes to four endangered fishes – the humpback chub, bonytail, colorado pikeminnow, and razorback sucker.

1. Describe the water management challenge(s). Describe in detail the water management challenge is occurring within your project area.

In 2022, the Colorado Division of Water Resources declared the majority of the Yampa River basin as over-appropriated for the first time (Letter on Jan 19, 2022 from Erin Light to Kevin Rein, Colorado State Engineer). This situation has raised concerns among stakeholders who anticipate increased water rights administration and usage restrictions.

The water management challenge facing the Yampa Basin is twofold:
1. Large portions of the river are undergoing administration for the first time in its history.
2. Existing forecasting tools lack the necessary resolution for many stakeholders to make informed decisions about their water resources.

Streamflow forecasts in the Yampa River Basin, and across Colorado, are typically only available at major watershed boundaries, and do not provide information about the impact those streamflows will have on local water users. In Colorado, water rights operate under a carefully monitored version of the prior appropriations system, meaning that water availability for individual users is driven by numerous factors beyond seasonal streamflow. Additionally, small water users typically do not have the manpower, resources, or technical expertise to forecast water availability for their particular ditch, reservoir or other system.

Water users often possess diverse portfolios of water rights, reservoir contracts, and other sources, all varying in seniority and quantity. These complexities, coupled with the influence of other river users, make it challenging to project when their water rights can be used. As climate change continues to

impact the Western US and the operating regime of the river changes, it is important to provide local stakeholders with reliable forecasting tools to allow them to understand, within a range of uncertainty, when they are likely to need additional water supplies beyond their direct flow water rights.

Traditionally, water users in the Yampa River have relied on "rules of thumb" such as the duration of the irrigation season, peak flows in specific subbasins, and NRCS basin snowpack estimates. These approximations are loosely correlated with actual river conditions but fail to provide precise insights. This project aims to address this issue by integrating the detailed StateMod model database with a distributed WRF-Hydro streamflow forecasting model, enabling water users to navigate the basin's uncertainty sooner and more effectively.

The work conducted under this grant will address these challenges in three principal ways:
1) by improving the quality and spatial resolution of streamflow forecasts through the deployment of a WRF-Hydro model that is calibrated for conditions in the Yampa River,
2) by leveraging the State of Colorado's water rights modeling framework (StateMod) to project water availability on a by-reach scale throughout the basin
3) by delivering useful forecast metrics, and associated uncertainties, in a dashboard format so local stakeholders who lack resources to run their own forecast tools can be aided in their decision making.

2. Describe the concerns or outcomes if this water management challenge is not addressed?
As administration expands in the Yampa Basin, and as the climate continues to change, traditional "rules of thumb" for how the river operates will no longer be relevant. Forecast tools that are based on the best available science, and those that provide a forecast of operating conditions, are a key climate change adaptation strategy. Without tools like this one, water users will continue to be at risk, reducing their ability to proactively plan for a changing water future, and potentially impacting important financial decisions around their use of water with limited information.

3. Explain how your project will address the water management issues identified in your response to the preceding bullets and provide support for your response.

This tool addresses the needs of water administrators for making informed decisions as well as a mode of communication to broadcast these decision-making parameters to water users. The water users from a variety of sectors will benefit from the forecasts produced by this tool. A few examples include:

- Reservoir operators will be able to understand the likelihood and timing of reservoir fill
- Agricultural and municipal users will be able to assess the likelihood and timing of when their water rights are in priority, or when augmentation from other sources may be required
- Environmental groups can decide on the use of water leases for stream health based on projections of minimum streamflow conditions
- Recreational groups can use the results to project the range of boatable conditions on the many heavily-boated river reaches throughout the Yampa River basin.

B. Project Benefits

The Upper Yampa Water Conservancy District (UYWCD) provides water to thousands of people and businesses through over 100 (total number varies annually) separate water storage contracts representing a wide range of use types (environmental, agricultural, M&I, augmentation).

Upon the full deployment of the forecasting tool, users will gain the ability to make more informed decisions about their water resources, aided by the results and associated uncertainties. Given the intricate nature of water rights and water usage, users from various sectors will derive multiple benefits.

Several water management entities, including municipal, industrial, agricultural, and environmental interests such as the Colorado River District, American Whitewater and the Colorado Water Conservation Board, have expressed interest in using the tool. Each group requires specific administrative metrics relevant to their practices, including drought resilience planning, water security, supply security, and stream health enhancement. The stakeholder engagement process will refine these metrics by location, use type, and uncertainty presentation. Each of these users has a different set of water administration metrics that are relevant for their practice areas including, for example:

- **Municipal:** Projected dates when they will need augmentation water, to plan around drought resilience and their water security
- **Agricultural**: Priority Date of Active Calling Right, Date range of free river, so water users know when or if they need reservoir water to meet their needs
- **Industrial:** Reservoir filling likelihood/date estimates so contractees can understand the security of their supply
- **Environmental:** Timing of minimum streamflow exceedances and when reservoir water may be required to enhance flows

Existing Efforts

Although the Colorado Basin River Forecast Center (CBRFC) issues water supply forecasts for the Yampa River Basin, those forecasts are limited in spatial resolution and do not incorporate the administration of diversions and reservoirs. Additionally, these forecasts focus on total streamflow volume and do not project water availability for individual water users or key structures in the basin. **Figure 8** above shows the relatively small number of CBRFC forecast locations throughout the Yampa River basin. Additionally, these official forecasts have limitations: they operate at a basin scale, do not account for diversions and reservoirs, and do not project streamflow impacts on individual water users. This project aims to provide a "last mile" solution, offering small users the tools to assess the priority and allocation of their water rights.

The administrative component of this tool, StateMod, is a model developed by the State of Colorado. StateMod's datasets encompass water rights priorities and amounts, reservoir accounting, water demands, and system operations. In its current form, StateMod is used as a planning tool which operates over multi-decadal timescales to estimate water rights yield and overall risk. This project will leverage the detailed information in StateMod, combined with improved streamflow forecasting, to produce administrative forecasts on a by-reach scale.

Regarding result delivery, many water management stakeholders in the Yampa River basin already utilize the UYWCD's Data Dashboard for tracking various datasets. By integrating this tool with an existing portal, the project will reach a wider audience of engaged stakeholders.

C. Project Implementation

Pending the award of this grant, the project team is targeting completion of the tool by spring 2025, with a test period of administrative projections issued and usable starting in runoff season 2025. Stakeholder engagement and education will be conducted throughout the project to inform users about the availability of the tool as well as how to interpret the associated uncertainty.

This project will be executed in the phases listed below, though the precise dates depend largely on the award timeline, and post-award contracting processes. The project phases and timeline are described in **Table 3** showing the project schedule.

Table 3: Project Schedule

Project Phase	Task	Responsible Team Member	Months Post-Award
Project Administration	UYWCD - Contracting with Project Team	UYWCD	0-3
Phase 1b - Core Model Development (WRF-Hydro)	Expand WRF-Hydro Domain	CW3E	3-6
	Build Meteorological Forcing Datasets	CW3E	3-6
	Retrospective Analysis and Calibration	CW3E	6-12
	WRF-Hydro/StateMod Integration	CW3E	6-12
	ML Techniques for Forecast Improvement	CW3E	12-15
Phase 1b - Core Model Development (StateMod)	Ensemble Conditioning Research	LRE Water	3-6
	Model Improvements for Forecast Mode	LRE Water	6-12
	WRF-Hydro/StateMod Integration	LRE Water	6-12
Phase 2 - Stakeholder Engagement	Facilitate Local Stakeholder Engagement	UYWCD	12-15
	Identify Additional Forecast Metrics	LRE Water	12-15
Phase 3 - Model Deployment and Testing	Test Year of Administrative Forecast Delivery	LRE Water	12-15
	WRF-Hydro Model Feedback and Improvement	CW3E	15-21
	StateMod Model Feedback and Improvement	LRE Water	15-21
Phase 4 - Dashboard Development	Develop Dashboard Specifications	LRE Water	12-15
	Deploy Data in UYWCD Dashboard	UYWCD/LRE Water	12-24

Final Model Output

After each forecast is produced, model output will be available in both raw CSV formats as well as delivered on the UYWCD data dashboard. These model outputs will include:

- Daily/Seasonal streamflow forecasts for many locations throughout the Yampa River
- River administration metrics at those locations

- Forecasted reservoir metrics including reservoir contents, fill dates
- Timeseries data of Demands and Available supplies for water users at critical locations

The data dashboard will show forecasts of river metrics at a range of locations, how those forecasts change over time, and showing ranges of uncertainty on those metrics.

Development Team

The technical team for this project consists of expert staff from UYWCD, CW3E, and LRE Water. Over the last 18 months, the UYWCD has worked closely with LRE Water and CW3E to test a proof of concept of this tool. Given their deep familiarity with this work, as well as the nuances of the various tool components, UYWCD will continue to engage with both groups to execute this project.

UYWCD: The UYWCD's mission is to lead water resource management within the District's boundaries by responsibly conserving, protecting, developing, providing and enhancing the water resources of the Yampa River Basin. The UYWCD initiates and participates in projects that embody and promote the protection of water rights, provide broad benefits to UYWCD constituents, and develops projects that provide responsible conservation, responsible growth, beneficial water storage and usage, and public awareness within the Upper Yampa Water Conservancy District. Short bios for UYWCD staff are listed below

Andy Rossi, PE: Andy Rossi is the General Manager of the Upper Yampa Water Conservancy District (UYWCD). Prior to taking on this leadership role in 2019, Mr. Rossi worked as a water resources consulting engineer and the UYWCD District Engineer. Mr. Rossi has 20 years of experience in the water resource engineering and management industry. This experience, coupled with excellent project management skills, great attention to detail, and enthusiasm to expand the understanding of hydrologic systems have built a platform of technical knowledge for the UYWCD's many accomplishments.

Emily Lowell, PE: Is the District Engineer at the Upper Yampa Water Conservancy District (UYWCD). Ms. Lowell joined the UYWCD in 2020 in a continuation of her successful water resources engineering career. Ms. Lowell serves as the engineering and operations manager for the UYWCD's water storage and conveyance facilities. In addition to operations management duties, Ms. Lowell conducts and manages complex hydrologic and hydraulic engineering analyses to support UYWCD activities.

CW3E: The Center for Western Weather and Water Extremes at the Scripps Institution of Oceanography (CW3E, https://cw3e.ucsd.edu/) focuses on research on extreme weather and climate in the Western US and their effects on water supply and flooding, as well as providing operational services in weather, climate, and hydrologic forecasting for government agencies and a wide range of stakeholders. The center has established the most recognized research program on Atmospheric Rivers (modeling, forecasting, air reconnaissance, ground monitoring, verification, etc.) that play a dominant role in the water supply and flooding in the region. Particularly, CW3E has been tasked by the California Department of Water Resources (CA DWR) to develop, implement, and operate a seasonal hydrologic monitoring and forecast system in support of the agency's Bulletin-120 water supply forecast services. This WRF-Hydro based experimental seasonal forecast system has been serving CA DWR

since 2022, the skill of which has been well verified through long-term re-forecast and near real time comparisons. Short bios for key CW3E staff members are listed below

Ming Pan, PhD: Dr Pan received his PhD degree in hydrology from Princeton University in 2006 and has been conducting hydrologic modeling/forecasting, remote sensing, and climate impact research in the past 20+ years in institutions like Massachusetts Institute of Technology, Princeton University, and Scripps Institution of Oceanography. His work is widely recognized and cited in the research community (100+ journal publications and Google Scholar H-index 56). He is currently a senior hydrologist at CW3E, specialized in hydrologic modeler and forcing data production, leading developer of CW3E's seasonal water supply forecast system that provides inflow forecast for a series of important reservoirs in California. He is the hydrology team lead at CW3E, overseeing the hydrologic research and operation activities at the center.

Qian Cao, PhD: Dr Cao received her PhD degree in hydrology from University of California Los Angeles (UCLA) in 2020 and served as a postdoc researcher at UCLA and later at CW3E. She has extensive experience in hydrologic modeling and its applications in short- and long-term forecasting, retrospective analysis, and climate impact projections. She is currently a staff hydrologist, specialized in modeling and forecasting with WRF-Hydro and other models (calibration, NRT operation, bias correction, verification, etc.), main contributor to CW3E's seasonal water supply forecasting effort.

LRE Water: Since its founding in 1970, LRE Water (https://lrewater.com/) has provided leadership in environmental consulting and engineering services related to planning, managing, and developing water resources throughout the Rocky Mountain West. For more than three decades, LRE Water has been developing decision support and modeling tools for water resources. We have expertise in GoldSim, Colorado's Decision Support System tools (StateMod, StateCU, Hydrobase, etc.) as well as other recognized decision support tools and modeling programs such as ModSim, WEAP, and HecRas. Our vast modeling experience allows us to design innovative combinations of existing tools, leverage new technology where it makes sense, and customize modeling and decision support solutions to exactly fit the task at hand. Short bios for key LRE Water staff members are listed below

Page Weil, PE: Page Weil is a water resources engineer with 14 years of experience in water resources engineering and water supply planning. Mr. Weil's municipal water resources expertise includes planning for supply, demand, changing operations and infrastructure development. His work in water demand includes calculations on water efficiency, changing patterns in indoor and outdoor use, demand growth and municipal buildout. For raw water supply, he has several projects that include water resources modeling, climate change and drought impacts to water supply, Colorado water rights rules and regulations, and augmentation requirements. Mr. Weil has supported several municipal entities in the Western US in modeling and optimizing the use of their various water sources to maximize yield and reliability. His work includes water rights accounting, developing water court and storage applications, and providing general guidance on basin-wide water rights issues including trans-mountain diversions, and major river administration policies and climate change impacts.

Kelly Close, PE: Kelly is the Chief Technology Officer at LRE Water. Kelly's passion is finding ever-better ways to turn data into information, to streamline reporting, analytics and modeling, and to support

efficient day to day water operations. Her background includes water rights engineering and accounting, surface, ground water and watershed modeling, water quality data collection and analysis, and environmental permitting. With this broad foundation, Kelly leads LRE's development of client-facing technologies company-wide, pulling in expertise from all LRE's service areas to find the best fit and deliver intelligent and long lasting data management, visualization and analytical solutions.

D. Dissemination of Results

As described in the Technical Project Description above, the forecast results themselves will be delivered via the existing Upper Yampa Data Dashboard tool, and will be shared publicly. The UYWCD is a beneficiary of these results, since they manage Stagecoach Reservoir and deliver water contract supplies for many users in the basin. Results of this project will be available for many locations across the Yampa River basin.

Stakeholders and other groups with river administration interests in the Yampa River basin can use the results as soon as they are published to improve their decision-making. Throughout the development and implementation of this forecast tool, the project team will hold several educational sessions to help stakeholders understand the benefits and limitations of the forecast tool. Additionally, the project team will engage closely with stakeholders to ensure results are presented in a way to maximize adoption of the tool:

- Clear timelines of forecast delivery and regular updates
- Simple and intuitive results graphics
- Education around the projected range of uncertainty for a particular metric

As this project progresses and improvements are made, it may be possible to expand the model domain to include other parts of Colorado with existing StateMod models, or other water resources administration models like RiverWare. The lessons learned on forecast performance and improvement will be broadly applicable for basins throughout the West that function on the prior appropriations system, and have existing water rights models. There are several aspects of this work that will be useful to water managers beyond the Yampa River, including:

- The use of ensemble conditioning to reduce uncertainty in streamflow forecasts
- Methods and results of calibration of the WRF-Hydro model for Colorado watersheds
- The linkage of daily streamflow forecasting models and water rights/river operations models
- Which metrics and results presentation methods identified during the stakeholder engagement process are found to be useful to smaller water managers.

These findings will be summarized in a series of task memos as the project progresses.

E. Presidential and Department of the Interior Priorities

Climate Change Benefits: Advanced forecasting models like the one proposed here, can provide improved predictions of river flow and water availability, empower policymakers, water managers, and

stakeholders with the information they need to make more informed decisions. This enhanced situational awareness enables proactive responses to the impacts of climate change, ranging from prolonged droughts to erratic precipitation patterns. Without tools like this one, that provide detailed water operations at the river-reach scale, water resources managers are beholden to historical “rules of thumb” for decision making, and will make poor estimates of river outcomes. By analyzing historical data and climate indicators, these models can identify early warning signs of impending drought conditions. This early recognition allows communities, farmers, and policymakers to implement drought response plans, secure emergency water supplies, and mitigate the potential economic and environmental impacts of prolonged water shortages. As climate change continues to reshape the region's hydrological patterns, tools like this one will play an increasingly crucial role in building resilience and ensuring the sustainable use of this precious resource.

Underserved community benefits: This project will provide benefits to water users in **Moffat County, Colorado**, a Disadvantaged or Underserved Community, per the Council on Environmental Quality’s interactive Climate and Economic Justice Screening Tool. The project map shows the location of Moffat County within the project area. There are many water users in Moffat County who can use this tool to estimate their water availability and the impacts to their local river systems. There are significant economic benefits to making more reliable estimates of water availability. The Yampa River is also a major recreation hub with thousands boater days per year on various river reaches, from Steamboat Springs down to Dinosaur National Monument. Better forecasting of river flows will expand boating opportunities throughout the Yampa River basin, as well as the associated economic benefits of more boatable days.

Project Budget

Table 4 below shows the budget breakdown table as required by the NOFO. Submitted with this proposal is a completed Budget Detail and Narrative Spreadsheet (Attachment B to the NOFO). Additionally, since there is one source of contract labor that represents 35% or more of the total project cost, this proposal includes a separate attachment for the budget breakdown from LRE Water.

Table 4 - Summary of Non-Federal and Federal Funding Sources

FUNDING SOURCES	AMOUNT
Non-Federal Entities	
1. Upper Yampa Water Conservancy District	$ 254,471
Non-Federal Entities	
REQUESTED RECLAMATION FUNDING	**$ 249,625**

Budget Narrative

No salaries and wages of staff within the applying agency (UYWCD) will be paid for by this Financial Assistance Agreement. All contributions by UYWCD staff for project management and stakeholder engagement will be treated as in-kind contributions.

Costs for the University of California, San Diego, where CW3E staff are employed, operates under a Negotiated Indirect Cost Agreement (NICRA) with the US Department of Health and Human Services (DHHS). This NICRA serves as guidance for all cost components below and is included as an attachment to this grant application.

Costs for LRE Water staff are on a contractual basis and are summarized below

Salaries and Wages: The in-kind contribution value of salaries and wages for UYWCD was determined by using each employee's 2022 hourly labor rate and multiplying it by the number of estimated hours contributed to the project. Salaries, wages, and estimated total effort for CW3E staff are detailed in the attached budget narrative. This includes salaries for Ming Pan and 3 other labor categories where specific individuals have not yet been identified.

Fringe Benefits: Fringe benefits for CW3E staff are included in the attached budget narrative and include scaling by year. The attached NICRA details the calculation of fringe benefits.

Travel: Travel costs for CW3E staff include one trip per year for one staff member from San Diego to Steamboat Springs, where the UYWCD is located. The cost estimate for this trip is included in the attached budget narrative.

Equipment - One laptop is included for CW3E staff and the cost is included in the attached budget narrative.

Materials and Supplies - Miscellaneous communication costs as well as the use of the UCSD supercomputing facilities are included in the attached budget narrative.

Indirect Charges - Per CW3E's NICRA, indirect charges are 58% for FY22 and future work by CW3E staff. The attached NICRA details the allowable indirect costs.

Contractual - LRE Water will be hired on a contractual basis for this work. LRE Water provided detailed cost estimates during development of this submission, included as an attachment. These detailed cost estimates are based on existing rates between LRE Water and UYWCD, and conform to industry standards.

If awarded this grant, UYWCD intends to issue a contract to LRE Water for the Contractual portion of the technical work without a competitive bid process. This noncompetitive procurement is justified based on LRE Water's development of the proof-of-concept project, technical skill set, and the unique implementation of the tools proposed. The UYWCD as a Water Conservancy District is not subject to

statutory publication or bidding requirements for the purchases of advisory and professional services. The UYWCD did complete a comparative review of the availability of the unique and specialized skill set required to complete the proposed project tasks in the determination of LRE as the preferred entity for the contractual portion of the technical work.

Per CFR §200.320(c)(2) on noncompetitive procurement. *"Noncompetitive procurement can only be awarded if…(2) The item is available only from a single source;"*

The partners on this project, CW3E and LRE Water, have been engaged in an 18 month pre-grant pilot project to develop a proof-of-concept of the forecasting framework proposed here. This combined forecasting framework lies in the way it combines the outputs of CW3E's distributed daily streamflow forecasts with the river administration components of the StateMod model. Per the attached letter of support from the Colorado Water Conservation Board, the agency responsible for developing and maintaining StateMod, LRE Water's implementation of StateMod as a forecasting tool is first of its kind. Although the scientific concepts involved may be understood by other firms, the specific manner in which these elements have been merged through the proof-of-concept phase is unique.

Entrusting another firm to execute this work within the available budget would be technically unfeasible, considering the advanced state of progress achieved by the current partners. The continuity and expertise of the existing team are essential for the successful execution of this pioneering forecasting tool, ensuring its alignment with the specific goals and needs of the Yampa River Basin and the wider Western US context.

While the process may not be competitive, UYWCD remains firmly committed to delivering the highest level of quality and technical excellence, ensuring that the project outcomes provide exceptional value for the Federal funding support allocated. This approach is justified by UYWCD's proven track record in overseeing and executing similar engineering projects. UYWCD's long history of effectively managing complex, water-related initiatives, along with its stringent internal policies and procedures, affirms its capability to engage contractors that consistently provide cost-competitive services while maintaining an unwavering commitment to technical expertise. This experience ensures that the project is in capable hands, with a demonstrated ability to deliver on its objectives with efficiency and effectiveness.

This project aligns with UYWCD's established procedures, which do not mandate a competitive bidding process for engineering projects of this nature. This project's specialized requirements and the unique collaboration between CW3E and LRE Water necessitate this sole-source approach. In essence, while the procurement process may not be competitive, UYWCD's unwavering commitment to excellence and its institutional experience make it a worthy partner for Federal funding, poised to deliver maximum value for the project.

Recommended Application Components

Environmental and Cultural Resources Compliance (as applicable to the project)

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. - **No impacts**

Are you aware of any species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat in the Project area? If so, would they be affected by any activities associated with the proposed Project? **- No**

Are there wetlands or other surface waters inside the Project boundaries that potentially fall under Clean Water Act (CWA) jurisdiction as “Waters of the United States”? If so,please describe and estimate any impacts the proposed Project may have. - **The project area represents the entire river basin of the Yampa River Basin, which does include significant areas that would classify as “Waters of the United States”. However, this project is entirely conducted using desktop modeling techniques, there is no expected impact on those waters due to this project.**

When was the water delivery system constructed? - **N/A**

Will the proposed Project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)? If so, state when those features were constructed and describe the nature and timing of any extensive alterations or modifications to those features completed previously. - **No**

Are any buildings, structures, or features in the proposed Project area 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 - **The project area represents the entire river basin of Yampa River, which does include significant areas that would fall under the National Register of Historic Places. However, this project is entirely conducted using desktop modeling techniques, there is no expected impact on those waters due to this project.**

Required Permits or Approvals

None required

Overlap or Duplication of Effort Statement

None

Conflict of Interest Disclosure Statement

At the time of this application, UYWCD has no known conflict of interest with this grant submittal.

Uniform Audit Reporting Statement

The UYWCD did not expend more than $750,000 of federal award funds and was not required to submit a Single Audit report for the most recently closed fiscal year.

University of California, San Diego (CW3E parent organization, EIN: 1956006144A1) has provided this documentation which is attached as an appendix.

Disclosure of Lobbying Activities (if Applicable)

UYWCD has no lobbying activity to disclose.

Letters of Support

Below, please find letters of support from these stakeholders agencies representing a wide range of water interests:

- American Whitewater
- Colorado Water Conservation Board
- Colorado River District

Official Resolution

This document is in process with the UYWCD board and will be completed pre-award.

Letter of Funding Commitment

UYWCD has provided a letter of funding commitment, attached to this application

Other Attachments

Letter of Funding Commitment
Letters of Support
Detailed Budget from LRE Water
UCSD NICRA Doc
UCSD Audit Statement

UPPER YAMPA WATER
CONSERVANCY DISTRICT

10/16/2023

Bureau of Reclamation
Water Resources and Planning Office
Attn: Ms. Avra Morgan
Mail Code: 86-63000
P.O. Box 25007
Denver, CO 80225-0007

RE: NOFO R23AS00446 Funding Commitment

To Whom it May Concern:

This letter of funding commitment is submitted by the Upper Yampa Water Conservancy District (UYWCD) in support of our WaterSMART-Applied Science Grant. (Notice of Funding Opportunity R23AS00446).

The UYWCD has committed $254,471 of matching funds to this project, available on the following schedule:

1. $14,350 in cash was spent on development of the project proof-of-concept between the opportunity posting date of 6/29/2023 and submittal.
2. $100,000 from approved and adopted budget of the UYWCD for the fiscal year of 2024, available January 1st, 2024.
3. $100,000 from approved and adopted budget of the UYWCD for the fiscal year of 2025, available January 1st, 2025.
4. $40,121 is included as in-kind matching funding through UYWCD staff hours engaged in the technical and stakeholder management aspects of this project.

The funds for line items 2 and 3 will be made available subject to the approval of annual budgets by the Board of Directors of the UYWCD in accordance with the Local Government Budget Law.

The UYWCD is excited to continue the development of this novel and useful forecasting tool and looks forward to future collaboration with the Bureau of Reclamation.

Thank you for your consideration,

Andy Rossi
General Manager
Upper Yampa Water Conservancy District
arossi@upperyampawater.com

COLORADO
Colorado Water Conservation Board
Department of Natural Resources
1313 Sherman Street, Room 718
Denver, CO 80203

October 4, 2023

Re: WaterSMART-Applied Science Grants for Fiscal Year 2023 (Funding Opportunity Number R23AS00446) Upper Yampa Water Conservancy District

To Whom It May Concern,

The Colorado Water Conservation Board (CWCB) would like to express our support for Upper Yampa Water Conservancy District's grant proposal for the following USBR program: WaterSMART-Applied Science Grants for Fiscal Year 2023 (Funding Opportunity Number R23AS00446). If funded, this grant will build upon the extensive work done by the Upper Yampa Water Conservancy District (UYWCD), and its stakeholders, to develop administrative forecasts for the Yampa River basin.

The project proposed by the UYWCD will provide a unique product of a high-resolution streamflow forecast from WRF-Hydro utilizing the StateMod water rights database developed by the CWCB. As the primary developer of StateMod, the CWCB sees this as an innovative application of this dataset that will give water resources managers in the Yampa basin a unique toolkit to manage their systems.

We recognize that many smaller water users, like those whose ditches and reservoirs are represented in StateMod, typically rely on historical operations and other "rules of thumb" to estimate their water rights yield for the coming year. Most of these groups do not have the resources to take official forecast products, like those from the Colorado Basin River Forecast Center (CBRFC), and develop an estimate of the supply available. This forecast tool will give a variety of water resources managers insight into how their systems may function in the coming year.

We are committed to engage with the UYWCD and other stakeholders over the course of this project to help pilot the end product, as well as identify water resources metrics that will be useful to as broad an audience as possible throughout the basin.

We emphasize that delivering this kind of administrative forecast across the Yampa River basin will have benefits for many major water sectors and stakeholders.

Sincerely,

Brian Macpherson, P.E., Senior Colorado River Technical Specialist, CWCB

COLORADO RIVER DISTRICT
PROTECTING WESTERN COLORADO WATER SINCE 1937

October 16, 2023

Via electronic mail to:
Bureau of Reclamation - Attention: Nathan Moeller (CPN-7309)
Columbia-Pacific Regional Office
1150 N. Curtis Road
Boise, Idaho 83706

Re: ***Letter of Support for Upper Yampa Water Conservancy District WaterSMART-Applied Science Grants for Fiscal Year 2023 (#R23AS00446) Application***

Dear Mr. Moeller:

On behalf of the Colorado River District (CRD), I am writing to express support for the Upper Yampa Water Conservancy District's (UYWCD) WaterSMART-Applied Science Grants for Fiscal Year 2023 (#R23AS00446) Application. We urge you to support the expansion of the innovative work performed by the UYWCD, and its stakeholders, to develop administrative forecasts for the Yampa River basin.

The CRD is a public, regional, water planning, and policy agency with a mission to "lead in the protection, conservation, use, and development of the water resources of the Colorado River Basin." We have a long and successful partnership with the UYWCD, which is within our District and downstream in Yampa River Basin, we operate and maintain the Elkhead Dam and Reservoir; and this project will provide actionable information for us and our stakeholders.

Our planning and operations rely on a variety of traditional forecast tools and products. The innovative work proposed by UYWCD bridges the gap between these traditional streamflow forecasts and water rights administration. Funding is needed to develop the "last-mile" between old and new methods to get beyond "rules of thumb" to more accurately estimate water yields for key water rights (agricultural, municipal, industrial), and the natural environment.

As this project pairs streamflow forecasts from WRF-Hydro with the Colorado Decision Support System (CDSS) water rights databases and water rights allocation model ("StateMod"), it will create an end-to-end forecast tool, giving stakeholders a new cutting edge, real-time tool to better inform water resource decisions, honoring senior water rights and helping reservoir operators, ultimately optimizing the limited water resources across the basin.

We are committed to continued engagement with the UYWCD and participating stakeholders to help pilot this project, to help ensure its application, and benefit by delivering a first-of its-kind administrative forecast across the Yampa River basin. Eventually, it is hoped that this will have broad implications across our District and even the state for all water use sectors.

Thank you for your consideration.

Sincerely,

Andrew A. Mueller
General Manager

Hattie Johnson, S. Rockies Stewardship
Director
hattie@americanwhitewater.org
395 S 2nd Street
Carbondale, CO 81623
970.456.8533

October 16, 2023

To Whom It May Concern:

American Whitewater would like to express our enthusiastic support for Upper Yampa Water Conservancy District's grant proposal for the following USBR program: WaterSMART-Applied Science Grants for Fiscal Year 2023 (Funding Opportunity Number R23AS00446). If funded, this grant will build upon the extensive work done by the Upper Yampa Water Conservancy District (UYWCD), and its stakeholders, to develop administrative forecasts for the Yampa River basin.

The innovative work proposed by UYWCD bridges the gap between traditional streamflow forecasts and actual river operations and administration. As a boating advocacy group, we help educate the recreational boating community in Colorado on tools to make better water resources decisions. Our stakeholders rely on a variety of forecast products including the Colorado Basin River Forecast Center (CBRFC), the Natural Resources Conservation Service (NRCS) SNOTEL network and other smaller-scale products. The groups we work with do not typically have the resources to interpret official streamflow forecasts to plan around optimal boating conditions. Our stakeholders typically rely on historical year types and "rules of thumb" to estimate flows and timing on the rivers they enjoy and operate on. On a river system like the Yampa, where variable flow conditions, especially low flow seasons that can shut down recreational river uses, steps towards refined forecasting tools can make significant differences in seasonal planning for our stakeholders.

The project proposed by the UYWCD will provide a unique combination of a high-resolution streamflow forecast from WRF-Hydro, paired with the carefully curated StateMod water rights database from the State of Colorado. When combined into an end-to-end forecast tool, smaller groups like ourselves will have a forecast at our fingertips that helps us make real-time water resources decisions. This forecast tool will provide a numerical answer around the implications of forecasts on specific infrastructure (eg, will a reservoir fill and what does that mean for recreational releases?).

We are committed to engage with the UYWCD and other stakeholders over the course of this project to help pilot the end product, as well as identify water resources metrics that will be useful to us and smaller groups throughout the basin.

We emphasize that delivering this kind of administrative forecast across the Yampa River basin, and more broadly across the state, will have benefits for many major water sectors and stakeholders—municipal, environmental, recreational, agricultural, and industrial sectors can all benefit from the additional forecast information.

Hattie Johnson, S. Rockies Stewardship Director
hattie@americanwhitewater.org
395 S 2nd Street
Carbondale, CO 81623
970.456.8533

We fully support this grant application and look forward to using the data to improve our water resources decision making.

Sincerely,

Hattie Johnson
Southern Rockies Stewardship Director
PO Box 1540
Cullowhee, NC 28806
hattie@americanwhitewater.org
970.456.8533