BUREAU OF RECLAMATION

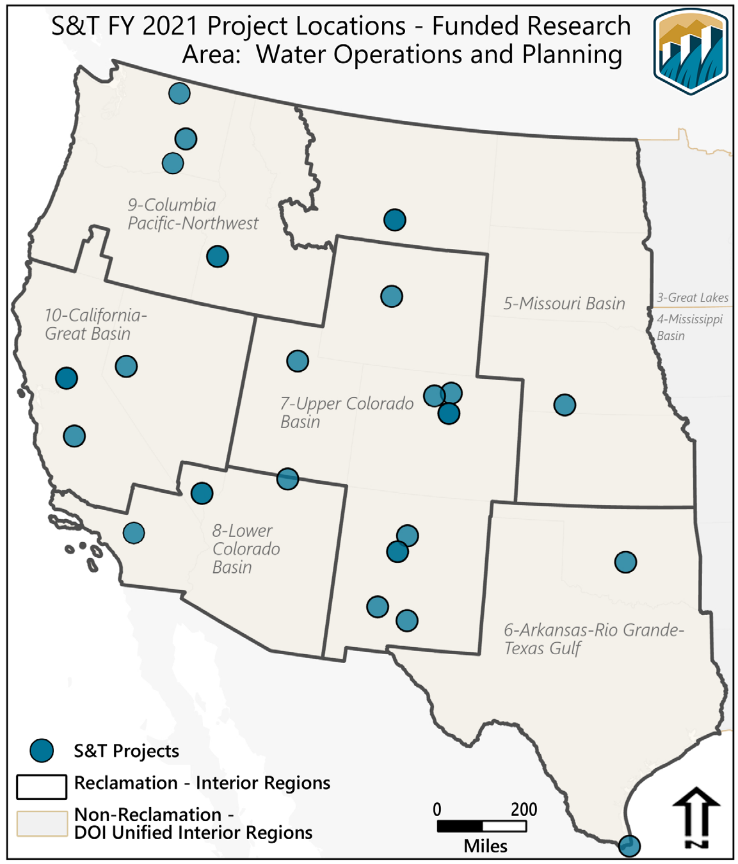
Research Updates R&D Office

Water Operations and Planning

U.S. Department of the Interior

March 2021

Executive Summary



The Water Operations and Planning (WP) Research Area of the Science and Technology Program (S&T) examines research in the following categories: Water Supply and Streamflow Forecasting, Water Operations Models and Decision Support Systems, Open Data, and Climate Change and Variability. In FY21, S&T funded 39 WP Projects approximately totaling $2.6M: 7 were new totaling $0.45M and 32 were continuing totaling $2.2M. Benefit Cost Ratio calculations (BCR) are estimated for two WP projects each year to demonstrate the value of this research. A BCR of 21.5 was calculated for project 1763: West-wide Evapotranspiration Forecast Network. This work developed a system that forecasts reference evapotranspiration (Eto) using temperature, solar radiation, humidity and wind speed from National Weather Service operational weather forecast models. These forecasts are bias corrected to agrometeorology stations relied on by irrigators. Washington State University supports the Irrigation Scheduler Mobile (ISM), an app used by growers in the northwest to inform data-driven irrigation scheduling. WSU has indicated they see demand and value for integrating these Eto forecasts into the ISM, where they would reach several hundred thousand acres of irrigated land. This information is likely to result in a range of benefits resulting from enhanced irrigation scheduling; high yields, lower pumping costs, and lower water costs are a few examples. As demonstrated, WP research is extremely valuable to Reclamation, by supporting development of tools and techniques to inform efficient water management and use.

Reclamation's Research and Development Office (R&D) manages the Science and Technology Program (S&T) and is focused on providing innovative solutions for Reclamation water and power facility managers and its western customers and stakeholders, primarily through competitive funding opportunities to Reclamation employees.

The S&T Program has five research areas (listed below) directly related to Reclamation's mission.
For more information, visit: https://www.usbr.gov/research/st/needs_priorities/index.html.

S&T Research Areas and Categories

Water Infrastructure (WI)
Dams, Canals, Pipelines, and Miscellaneous Water Infrastructure

Power and Energy (PE)
Hydro Powerplants, Energy Efficiency, Pumping Plants, and Non-Hydropower Renewable

Developing Water Supplies (WS)
Advanced Water Treatment, Groundwater Supplies, Agricultural and Municipal Water Supplies, and System Water Losses

Environmental Issues in Water Delivery and Management (EN)
Water Delivery Reliability, Invasive Species, Water Quality, Sediment Management, and River Habitat Restoration

Water Operations (WP)
Water Supply and Streamflow Forecasting, Water Operations Models and Decision Support Systems, Open Data, and Climate Change and Variability

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Water Operations and Planning

FY20 Completed Projects

1751: Impacts of Grade Control Structure Installations on Hydrology and Sediment Transport as an Adaptive Management Strategy - Deborah Tosline

Grade control structure installed at BSA HSP site.

First, innovative monitoring equipment was installed in the study drainage. This included a large-scale particle image velocimetry video camera and pressure transducers (to calculate discharge); digital terrain models, sediment samplers and sediment chains (to measure erosion and deposition); soil moisture sensors in monitoring wells (to document infiltration and potential recharge); and weather stations (to track temperature and relative humidity). Four small Unmanned Aircraft System (sUAS) surveys, a Terrestrial Land Survey, and a standard Land Survey were completed to monitor changes in cross-sections and geomorphology. Second, a two-dimensional (2D) mobile-bed hydraulics and sediment transport model for river systems was applied to predict sources and sinks of water and sediment yield, and predict impacts of GCS installations throughout the drainage. Third, GCSs were physically installed throughout the study area by a civil and environmental engineering consulting firm. Finally, results from the pre- and post-GCS installations monitoring were documented and compared. Despite drought conditions, small storm flow events provided enough data to model and analyze surface water conditions. Model analyses predicted the slight reduction and delay in peak flows for small events, consistent with the literature. The data collected for this Study agreed with model predictions and documented these effects, giving confidence for future modelling efforts. While data collection did not portray impacts on rainfall-runoff response from the installation of GCS, this is attributed to the dry antecedent conditions. The structures did reduce flashiness of peak flows though (which should limit erosion). The model estimates that the structures could increase the infiltration approximately 15% over time, slightly larger than average infiltration increases documented previously. Collected microclimate data demonstrate that GCS installations create roughly a three-degree microclimate cooling effect for at least two days following rainfall events, as compared with the untreated sites.

1735: Development of Web-based Stochastic Storm Transposition Toolkit for Physically-based Rainfall and Flood Hazard Analysis - Kathleen Holman

The research team combined output from RainyDay with a gridded, processed-based rainfall-runoff model, WRF-Hydro, to develop flood frequency estimates in the Big Thompson watershed above Olympus Dam, in Colorado. There are two clear advantages to coupling SST with a process-based FFA framework: First, the spatio-temporal structures of observed precipitation events are preserved, and second, the coupling enables the stochastic use of a hydrologic model that produces equally likely model output (i.e., streamflow peaks and volumes). The modeling framework started with the calibration and validation of the WRF-Hydro model between 1979 and 2018. The physical states from this long-term simulation were saved and later used as initial conditions in the stochastic simulations. A storm catalog was developed for the basin using a gridded precipitation dataset and SST technologies within RainyDay. Finally, 10 sets of 1,000 annual maximum streamflow events (for a total of 10,000) were simulated by sampling the RainyDay storm catalog and initial conditions from the long-term WRF-Hydro simulation. The 10 sets of annual maximum flow events can be used to estimate median and uncertainty estimates at return periods less than 1,000 years or to estimate a single frequency curve (without uncertainty) out to the 10,000-year return period. Simulated peak discharge estimates are shown in the figure below, along with observations from a USGS gage and a Log-Pearson Type III (LP-III) distribution fit to those observations. These results suggest that the process-based framework implemented can be used to estimate flood peaks at return periods up to and in some cases beyond the 1,000-year return period.

Big Thompson Canyon Damage from September 2013 Floods.

Eddy Covariance systems used in field sites for studies.

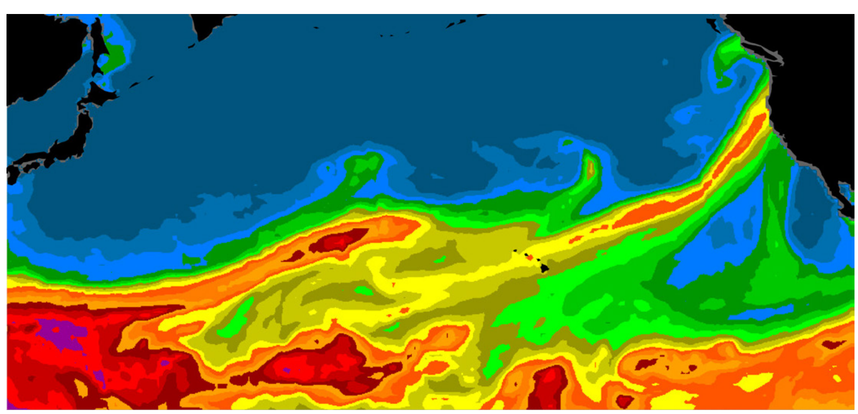
7107: Quantitative Assessment of Water and Salt Balance for Cropping Systems in Lower Colorado River irrigation Districts - Nohemi Olbert

The quantitative data achieved through this research will be directly used by stakeholders to examine and perhaps change their irrigation practices. Ultimately a mobile application to be finalized with the quantitative data will have practical application to assist stakeholders and Reclamation understand where and for what purpose water is diverted and what the consequences are of over and under irrigating. These apps would be useful anywhere that additional water is used to leach salts in the soil. Results also factor into the common summer fallow practice or even longer-term fallowing programs. Yuma Center of Excellence for Desert Agriculture (YCEDA) coordinated a large multi-institution cross-disciplinary project to quantitatively track water use and salt balance across typical crop production systems and rotations. Partners include the University of Arizona and USDA-ARS researchers, Irrigation Districts, United States Bureau of Reclamation, NASA, Arizona Commodity Councils, and others, including a group of University of Arizona-Yuma Systems Engineering seniors who completed a Senior Design project during the 2018-2019 academic year to support this project. Technologies such as electromagnetic surveys (EM38), Eddy covariance (ECV) and large aperture scintillometer (LAS) instrumentation, UAV with remote sensors, and satellites are being utilized to measure evapotranspiration (ET) and soil salinity levels at multiple scales. Data collection and analysis is ongoing beyond this S&T study. Ultimately, this unique data set will be used to develop irrigation management tools for most desert cropping systems that take into account actual crop ET and the needed leaching coefficient to assist growers to make an already efficient system even more efficient and sustainable. A summary of what was learned:

- Irrigation efficiencies for vegetables produced in the region exceed 90%.
- Required leaching for salt management is not achieved during the produce interval.
- The extent to which the rotational crop contributes to salt management is under investigation. Wheat irrigation efficiencies are high and this is not a net salt leaching practice. Sudan grass as a rotation does not seem to be a net leaching practice.
- In most situations pre-irrigation is crucial to salt management.

1816: Assessment potential future changes in atmospheric rivers over the western coast of the United States - Michael Wright

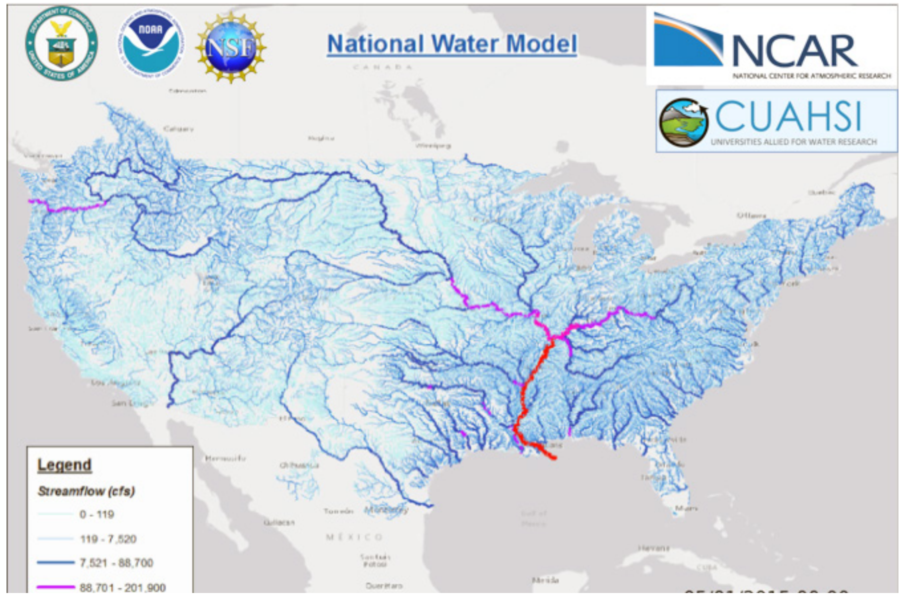
The NA-CORDEX model ensemble (Mearns et al. 2017) is composed of 6 regional climate models (RCMs), driven by one or more of six global climate models (GCMs; see https://na-cordex.org/.). For the historical period (1976 – 2005), precipitation values from the NA-CORDEX simulations are compared to values from two high-resolution precipitation datasets developed by Livneh et al. (2013) and Newman et al. (2015).Results indicate significant model spread in mean monthly precipitation in several key water-sensitive areas in both historical and future projections, but suggest model agreement on increasing daily extreme precipitation magnitudes, decreasing seasonal snowpack, and a shortening of the wet season in California in particular. While the beginning and end of the California cool season are projected to dry according to most models, the core of the cool season (December, January, February) shows an overall wetter projected change pattern. By the end of the century, extreme AR events increase in frequency whereas moderate AR events decrease in frequency. Projected precipitation changes during AR events also depend on event intensity. In the future, precipitation across the Sierra Nevada generally increases during extreme AR events and decreases during moderate AR events.



Satellite image of an atmospheric river in February 2017. Image Courtesy of NOAA.

1774: National Water Model Assessment for Reclamation's Water Management Needs - Ken Nowak

This project provides both a quantitative and reflective assessment of NOAA's new NWM for basins of interest to Reclamation. The assessment focuses on a range of forecast lead times, extending from weeks to seasons. This work evaluates the quality of those forecasts (and retrospective simulations), briefly discusses the water management value added by the resolution enhancements where possible, explores the hydrology processes of a snow-dominated watershed, and explores a potential methodology for generating ensemble NWM forecasts. The project was a collaboration between NOAA, NCAR, and Reclamation.



National Water Model simulation of streamflow across the contiguous United States

Island Park Dam, Idaho.

1794: Identifying Sources of Uncertainty in Flood Frequency Analysis - Amanda Stone

Two Reclamation dam watersheds in different regions were examined for this study: Island Park Dam, Idaho and Altus Dam, Oklahoma. Results from these two basins resulted in vastly different distributions of uncertainty (figure below) but similar generalized conclusions relevant to Reclamation work. There were four key takeaways from the results of this study. The first is that initial conditions and forcings are dominant components of the modeling chain in controlling uncertainty for more frequent and extreme events, respectively (figure below). The second is that model structure can be equally as important given a diverse set of model structures, particularly for multi-day volume flood metrics. This highlights the need to understand basin flood generation and couple that knowledge with an appropriate model structure choice. The third is that model parameter and model structure interactions may be important controls for model uncertainty if model calibration is not well constrained. And finally, comparison of calibration metrics for extreme events and volume-integrated floods revealed that Kling-Gupta Efficiency (KGE) is a more robust calibration metric than Nash-Sutcliffe Efficiency (NSE) in these applications.

FY21 New Projects

21041: Combining Physically Based Snow Modeling and Remote Sensing at High Spatial Resolution to Improve Snowmelt Runoff Forecasts in the Big Thompson and Willow Creek Basins – Claudia Leon Salazar

This project will enable Eastern Colorado Area Office and Northern Water to improve inflow forecasting to Lake Estes and Willow Creek reservoirs benefiting reservoir operations, water deliveries, hydropower production, balance of supply and demand, and other water management objectives. C-BT project users depend on these forecasts and available project water to plan operations.

Olympus Dam, Lake Estes, and Big Thompson River, Estes Park, Colorado.

21048: Assessing the impact of land use and land cover changes on river diversions in semi-arid river basins – Michael Poulos

The study proposes to evaluate historical land use and land cover changes (LULCC) by 1) delineating the lands irrigated by diversions based on water rights databases, 2) summarizing annual LULCC within the irrigated lands using historical satellite imagery, and 3) quantifying LULCC over time. The statistical models will be useful in the Boise Project for improving planning hydrology models that simulate water demands and diversions and provide an example of how the geospatial data could be used in other river basins. Better data and statistical models could help inform decision makers and potentially lead to improved system management.

New York Canal, Boise Project, Idaho.

21023: Measurement and modeling of effects of differential wind stress due to topography and wind sheltering elements on hydrodynamics of augmented lakes and reservoirs – Meghan Thiemann

This project intends to develop and test a protocol for long-term measurement and modeling of complex wind fields and water movement in augmented reservoirs using a dense network of meteorological stations, a 3D Computational Fluid Dynamics (CFD) wind model, two Acoustic Doppler Profilers (ADPs), and a 3D computational hydrodynamic model. Incorporating effects of spatially varying winds would improve accuracy of efforts to generate frequency distributions of travel time and attenuation needed for indirect potable reuse (IPR) surface water augmentation (SWA) projects. This will improve the body of information for planning as well as resiliency of drought-impacted water supplies. Lake Arrowhead, California, will be used as a case study to develop a varying wind field protocol for application to steep terrain reservoirs.

Olympus Dam, Colorado Big Thompson Project, Estes Park, Colorado.

21082: Evaluating Big Thompson water supply modeling capability improvements from new model forcing and recalibration – Lindsay Bearup

The Eastern Colorado Area Office (ECAO) is responsible for the management of the Colorado Big Thompson Project (C-BT), which imports water from the headwaters of the Colorado River on the west slope of the mountains to the Big Thompson River drainage on the east slope. Daily operations of the C-BT project require budgeting and management of inflow to the system reservoirs. To this end, ECAO forecasts inflows to Lake Estes daily to manage required reservoir releases, pool elevation and available reservoir storage for hydropower generation. This proposal investigates whether harnessing new meteorological data and analysis paired with recent advances in model calibration tools will improve ECAO hydrologic model performance for the C-BT system. Reclamation's Technical Service Center (TSC) and ECAO will partner with the National Center for Atmospheric Research (NCAR), Northern Water, and the Missouri Basin River Forecast Center (MBRFC) to address this research question by incorporating the EWS network into higher resolution gridded model forcing, and by improving and applying the Optimization Software Toolkit for Research Involving Computational Heuristics (OSTRICH, Mattot, 2017) to operational ECAO hydrologic model.

21040: Yakima River Scoping Study to Assess Temperature and Dissolved Oxygen Levels to Inform Water Management Options – Caroline Ubing

This scoping study seeks to understand the data, tools and models currently available that describe Yakima river water quality, specifically temperature and dissolved oxygen. Project goal is to help advise water managers when flow management options can be used to change water quality conditions to enhance juvenile migration survival and elicit an adult upstream migration response.

Sockeye Salmon. Image Courtesy of Tom Ring, Yakima Nation.

Snow near Boise, Idaho.

21108: Snow depth estimation using InSAR (Interferometric Synthetic-Aperture Radar) Technique – Jong Beom Kang

The purpose of this research is to evaluate the feasibility and effectiveness of using the InSAR technique as a tool for measuring seasonal snow depth and inform snow-melt water resources for the Reclamation water information system. Snow depth estimation is a critical component for quantifying seasonal Reclamation water resources at reservoir areas, expanding the use of the hydrologic database across Reclamation regions, assisting other water facility operational decisions for hydrological applications with real-time data, and informing recreational reservoir water users of reservoir water conditions.

21039: A Collaborative Stochastic Weather Generator for Climate Impacts Assessment – Subhrendu Gangopadhyay

As part of work in the Lower Santa Cruz River Basin, a weather generator was designed to characterize changes in the Basin's seasonal hydroclimate including: (1) spell characteristics of the premonsoon dry season; (2) length of the monsoon season; (3) precipitation amounts during the monsoon season; (4) precipitation amounts over the winter wet period; and (5) annual temperature variability. In order to finalize the weather generator tool, additional steps are necessary. These steps are: (1) adding functionality so that users can process climate projection data and define seasons based on their knowledge of updated understanding of seasonality from a changing climate or defining seasons as a suite of scenarios; (2) documenting the tool and publishing the methodology in a peer-reviewed journal; and (3) developing a package for the widely used statistical computing platform R.

FY21 New and Continuing Projects

ID	Final Year	Title	Lead	FY21 Funding Amount*
1845	2021	Development of short-range forecasts of weather-driven channel losses and gains to support Reclamation water management	Hong Nguyen-DeCorse	$ -
1881	2021	Risk-based decision making in reservoir operations	Jordan Lanini	$24,0000
1895	2021	Developing process-based and spatially consistent approaches for correcting streamflow biases in watershed hydrology simulations	Marketa McGuire	$140,020
8116	2021	Merging high-resolution airborne snowpack data with existing long-term hydrometeorological observations to improve water supply forecasting	Lindsay Bearup	$42,988
8117	2021	Improving the robustness of southwestern US water supply forecasting	Dagmar Llewellyn	$ -
8119	2021	Deployment of a floating evaporation pan on Lake Powell, UT-AZ, and Cochiti Lake, NM, to improve evaporation rate measurement accuracy and precision	Dagmar Llewellyn	$ -
19003	2021	Subseasonal Heatwave Prediction	Ken Nowak	$ -
20205	2023	Deployment of daily west-wide remotely sensed reservoir evaporation application	Dan Broman	$ -
19132	2021	Using Remote Sensing and Ground Measurements to Improve Evaporation Estimation and Reservoir Management	Dagmar Llewellyn	$69,000

ID	Final Year	Title	Lead	FY21 Funding Amount*
19178	2021	Can better representation of low-elevation snowpack improve operational forecasts?	Dan Broman	$26,065
19180	2021	Software Tool Development to Generate Stochastic Hydraulic Simulations using HEC-RAS	Ari Posner	$70,000
19246	2021	Bio-physical Integrated Land Atmosphere Water Simulator (BI-LAWS)	Michael Tansey	$102,465
19249	2021	Improving distributed hydrologic models using multiscale thermal infrared, near infrared, and visible imagery from sUAS and satellite-based sensors	Lindsay Bearup	$104,298
19256	2021	Improving volume forecasting tools for snow dominated basins	Joel Fenolio	$33,000
19258	2021	Seepage Detection and Characterization in a Truckee Canal Site using L-band Synthetic-Aperture Radar (SAR) Technology	Jong Beom Kang	$106,788
19264	2021	Exploring the use of temperature to understand recent drought and project future conditions in the Colorado River Basin	Rebecca Smith	$3,0000
20025	2022	Developing a holistic framework for evaluating system-wide groundwater surface water interaction and interconnected projects using system dynamics modeling methods	Jennifer Johnson	$68,866
20032	2022	Characterizing the Predictability and Sensitivity of Streamflow to Monsoon Season Precipitation	Dagmar Llewellyn	$94,994
20044	2021	Adaptation of the Existing Fryingpan-Arkansas Project RiverWare Planning Model to Support Operational Modeling, Forecasting, and Probabilistic Decision-Making	Theresa Dawson	$ -
20047	2021	Web-Based Decision Support System for the Upper Colorado River Basins	Claudia Leon Salazar	$64,000
20071	2021	Using "waste cold" from Liquid Air Energy Storage to achieve temperature objectives	Michael Wright	$98,000
20075	2022	Simulating California's water supply system under future climate stresses	Michael Wright	$31,701
20082	2021	Assessing the impact of physically realized hydro-climate extremes on water supply	Marketa McGuire	$20,000
20093	2022	Dynamic Representations of Hydrologic-Irrigator Interactions in Planning Models	Kirk Nelson	$55,000
20204	2022	Machine Learning for Improving Sub-Seasonal Forecasting	Ken Nowak	$250,000
21023	2023	Measurement and modeling of effects of differential wind stress due to topography and wind sheltering elements on hydrodynamics of augmented lakes and reservoirs	Meghan Thiemann	$100,000
21040	2021	Yakima River Scoping Study to Assess Temperature and Dissolved Oxygen Levels to Inform Water Management Options	Caroline Ubing	$29,792
21041	2022	Combining Physically Based Snow Modeling and Remote Sensing at High Spatial Resolution to Improve Snowmelt Runoff Forecasts in the Big Thompson and Willow Creek Basins	Claudia Leon Salazar	$97,500
21048	2023	Assessing the impact of land use and land cover changes on river diversions in semi-arid river basins	Michael Poulous	$73,960
21039	2023	A Collaborative Stochastic Weather Generator for Climate Impacts Assessment	Subhrendu Gangopadhyay	$47,080
21082	2023	Evaluating Big Thompson water supply modeling capability improvements from new model forcing and recalibration	Lindsay Bearup	$74,132
21108	2021	Snow depth estimation using InSAR (Interferometric Synthetic-Aperture Radar) Technique	Jong Beom Kang	$29,885
19042	2021	Developing a Collaborative Environment for Sharing Geographic Information Systems (GIS) Data Between Reclamation and Irrigation Districts	Paul Martin	$66,000
19210	2021	Leverage Existing Environmental Data for Improved Usability by Standardization and Migration to RISE-Compatible Database	Laurel Dodgen	$215,764
19221	2021	Reclamation Interactive Visualization and Exploration Resource (RIVER): A model scenario visualization tool for RWIS/RISE	Vanessa King	$100,000
20055	2021	Integration of invasive mussel detection data in RISE	Yale Passamaneck	$20,000
20077	2022	Open Data Pilot for Integrating BOR River and Reservoir topographic and sediment data into RISE	Jennifer Bountry	$12,000
20088	2021	Water Rights Information Management System (WRIM)	Ginger Dill	$134,425
7124	2021	Improving Mid-Pacific Region Programs' water quality data management to enhance user access, analysis and decision-support	Laurel Dogden	$ -

* For projects with no funding, these projects are nearly complete and received funding in past years for this work.