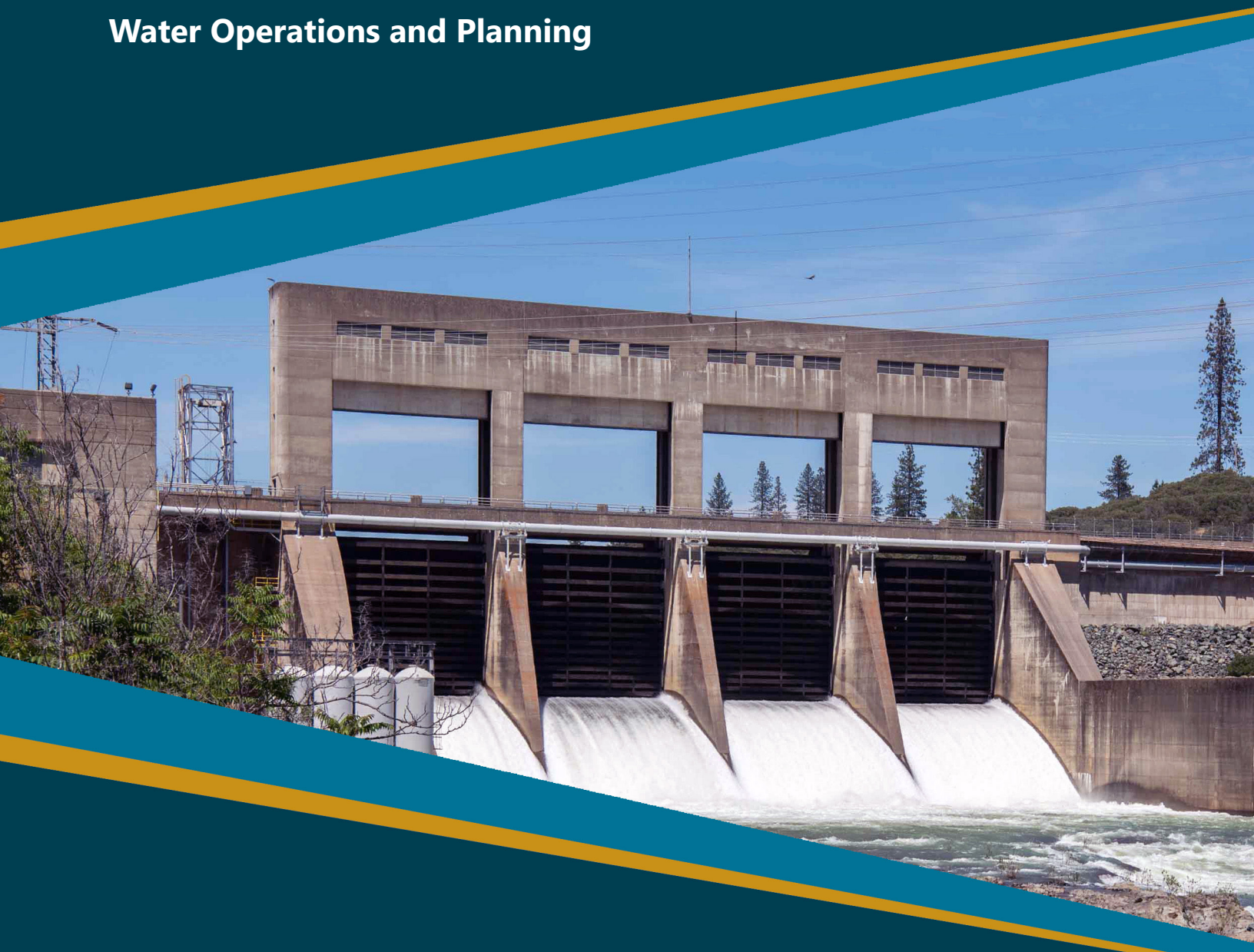
BUREAU OF RECLAMATION

R&D Office Research Updates

Water Operations and Planning



U.S. Department of the Interior

January 2022

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 FY22, S&T funded 24 WP Projects approximately totaling $1.6M: 9 were new totaling $0.86M and 13 were continuing totaling $0.734M. Benefit Cost Ratio calculations (BCR) are estimated for two WP projects each year to demonstrate the value of this research. A BCR of 8.7 was calculated for project 8116: Merging high-resolution airborne snowpack data with existing long-term hydrometeorological observations to improve water supply forecasting. The project developed statistical models that relate ground-based snow monitoring data to basin wide snow water equivalent (SWE) estimates derived from aircraft lidar surveys. The work demonstrated that with as few as 5 aircraft lidar surveys robust statistical relationships can be developed between the station data and the aircraft lidar data. These statistical estimates of basin wide SWE can complement and likely reduce the frequency of aircraft lidar snow surveys. These findings are notable as aircraft lidar surveys cost more than $100,000 per survey. The other BCR calculation was based on project 20047: Web-Based Decision Support System for the Upper Colorado River Basins. This work developed a collaborative tool that allows real-time exploration and sharing of proposed water operations in the Upper Colorado River. Reclamation's Eastern Colorado Area Office facilitates coordination meetings with stakeholders, supporting management and operations of storage reservoirs and irrigation diversions in the Upper Colorado River Basin. This project saves time and streamlines those efforts, while building trust and transparency. 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: 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

Front cover: Keswick Dam, California.

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Water Operations and Planning

FY21 Completed Projects

SENTINEL-1 satellite (image courtesy of the European Space Agency).

19258: Seepage Detection and Characterization in a Truckee Canal Site using L-band Synthetic-Aperture Radar (SAR) Technology - Jong Beom Kang

Reclamation alone holds 8,116 miles of in-service water conveyance canals within its infrastructure inventory. Many of these canal systems have aged beyond their original intended lifespan and are showing signs of aging and disrepair, extensive seepage and embankment failure events are becoming increasingly common, and consequences of canal failures within urban corridors are constantly increasing due to urban encroachment on these water conveyance structures. In addition to the problem of increased risk related to canal embankment failures, concentrated and distributed seepage poses a major challenge to water conservation due to significant water conveyance system losses.

As a result, there is an ongoing need to identify and comprehensively characterize canal seepage, both for safety-related and water conservation efforts and is the main motivation for this proposed research. The seepage detection and characterization in canal sites by means of the Synthetic-Aperture Radar (SAR) satellite remote sensing technology is an important research topic to evaluate suitable resolution and realistic limitations of the SAR to detect canal seepage and be used as a comprehensive monitoring technique for identification of potential seep locations at canal infrastructure. The InSAR data processing results at known seep locations indicate that corresponding dates of canal watering-up/de-watering correlate with the changes of SAR mean line-of-sight (LOS) velocity (mm/year) values obtain from timeseries analysis at known seep locations.

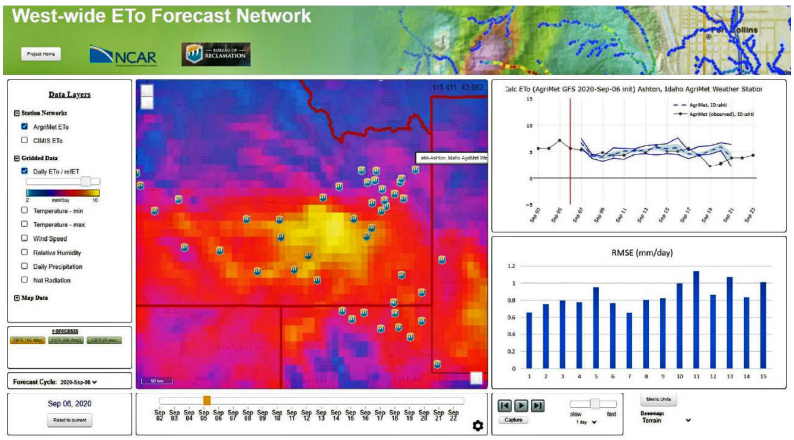
Snowpack in the mountains of Colorado.

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

Spring snowmelt helps recharge and contribute around 80% of water storage into Western reservoirs. It is a critical element to evaluate how much snowmelt will enter the reservoirs to estimate proper release of water from dams, mitigate potential floods, maintain conservation pool storage, and manage water delivery volumes for the Reclamation's water management (Reclamation 2006).

Thus, there is an ongoing need to evaluate the feasibility and value of using the Interferometric Synthetic-Aperture Radar (InSAR) technique to increase the detection accuracy of snow depth and density, quantify seasonal snow-melt water resources, and improve accuracy into river and reservoir operation models to better inform water allotments and planning efforts. Accurate understanding of seasonal snow cover is one of the most critical components in predicting water resources, supply planning, and parameters for hydrological water operation models.

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.



Screen capture of the WwET4Cast forecasting tool showing the 16-day forecast for September 06, 2020, for the Ashton, Idaho AgriMet station (ahi).

1763: West-wide Evapotranspiration Forecast Network - Michael Tansey

This project addresses forecasting of daily reference evapotranspiration (ETo) at agro-meteorological stations based on downscaled meteorological variables from 1) the NOAA Global Forecast System (GFS) model producing 16-day, daily ETo forecasts; and 2) the NOAA Climate Forecast System (CFS) model resulting in seasonal ETo forecast outlooks out 60-days (daily ETo) and 6 months (monthly ETo). The results of the project include the development of the West-wide Evapotranspiration Forecast (WwET4Cast) Network, which is a web-based service for generating and disseminating the forecasts at agro-meteorology stations and grid cells throughout the Western United States.

1845: Development of short-range forecasts of weather-driven channel losses and gains to support Reclamation water management - Hong Nguyen-DeCorse

Imperial Dam and the All-American Canal System near Yuma, Arizona.

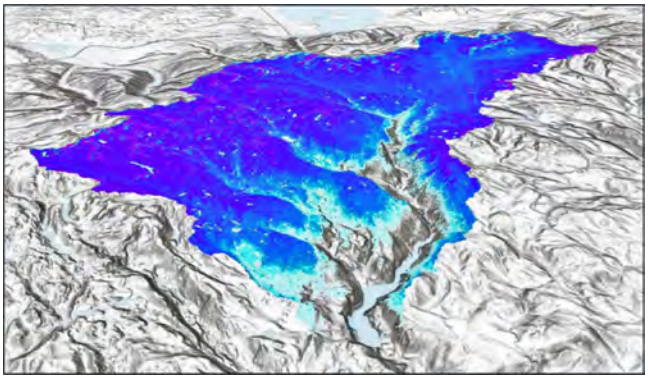
Unexpected water losses and gains on Lower Colorado River reach between Parker Dam and Imperial Dam challenge the Bureau of Reclamation's Yuma Area Office (YAO) daily operations, which aim at delivering water to irrigation districts while minimizing excess flow. This project investigated the origin of these losses and gains and explored the potential for calibrated precipitation forecasts to predict weather-related losses and gains at lead times of 1-5 days. Predictability was found to be low due to significant unexplained variance in the loss-gain time series unrelated to weather, as well as generally limited precipitation predictability in this area. However, probabilistic forecasts were found to skillfully predict increased odds for all gains and medium-size gains. While specific to the domain of YAO, these results might be transferable to other Reclamation operations in need of short-term loss-gain forecasts.

Delta Mendota Canal at milepost 64 near Santa Nella, California. (photo credit Laurel Dodgen)

7124: Improving Mid-Pacific Region Programs' water quality data management to enhance user access, analysis and decision-support - Laurel Dodgen

Following Executive Order 2013-13642 covering open data policy, the Department of the Interior – Bureau of Reclamation (DOI-BOR) has been developing efforts to build/modernize information systems to maximize interoperability and information accessibility, maintain internal and external data asset inventories, enhance information safeguards, and clarify information management responsibilities. In this context, the S&T Project 7124 intended to create and enhance DOI-BOR California-Great Basin Region capabilities to better integrate the BOR-wide data flow plans specifically related with data/documentation storage, database development/enhancement and data/documentation availability. Project 7124 efforts resulted in the development of a database schema, user requirements and reporting requirements. The new database infrastructure allows the incorporation of environmental data having in consideration data integrity and traceability. This report summarizes the activities developed.

8116: Merging high-resolution airborne snowpack data with existing long-term hydrometeorological observations to improve water supply forecasting - Lindsay Bearup



Tuolumne River Basin (CA) April 1, 2017, Snow Water Equivalent data from Airborne Snow Observatories.

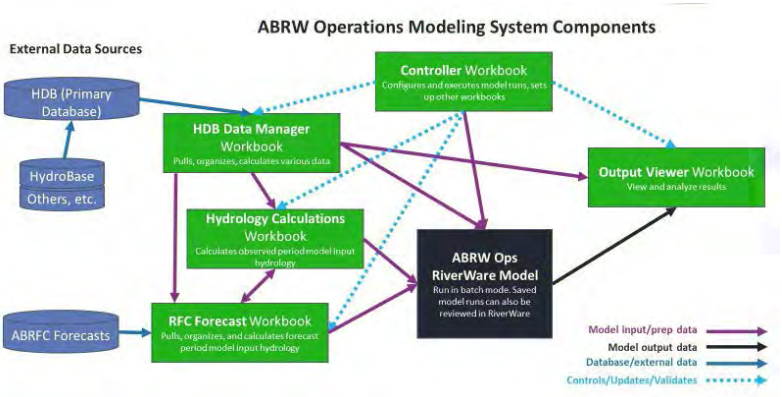
Mountain snowpack is a critical observation for seasonal streamflow forecasting in the Western United States. The Airborne Snow Observatory (ASO) methodology generates maps of snow depth, snow water equivalent, (SWE) and albedo from airborne lidar and spectrometer measurements that inform snowpack modeling. In this work, we evaluate how traditional snow pillow station-based estimates of basin-wide SWE compare to more spatially complete estimates from ASO, and the impact these differences have on streamflow modeling and forecasts. While the ASO flights provide excellent spatial resolution and coverage of high elevation areas, observations are limited to flight times. Assessing the relationship between stations, which monitor continuously, and ASO flights, which capture a snapshot in time, this project identified that approximately 5-10 ASO flights, combined with stations, are sufficient to define 95% of the variability in the remaining flights. The ASO data are also assimilated into SUMMA, or the Structure for Unifying Multiple Modeling Alternatives, to evaluate the potential improvement for water supply forecast models. Using several approaches for when flights were assimilated, results suggest that including ASO SWE estimates near peak SWE can substantially improve ensemble streamflow predictions by removing much of error that accumulated from uncertain precipitation through the winter season.

19264: Exploring the use of temperature to understand recent drought and project future conditions in the Colorado River Basin - Rebecca Smith

Glen Canyon Dam and Lake Powell near Page, Arizona.

Reclamation's midterm projections of Colorado River Basin reservoir operations are based on data that do not account for recent warming. This work demonstrates a proof of concept for using historical and predicted temperature information to improve skill of midterm streamflow forecasts and reservoir operations projections. It also contributes a novel application of random forests in the field of hydrologic forecasting. The moderate skill improvements resulting from this method suggest that it should continue to be evaluated using Reclamation's Colorado River Basin Operational Prediction Testbed.

20044: Adaptation of the Existing Fryingpan-Arkansas Project RiverWare Planning Model to Support Operational Modeling, Forecasting, and Probabilistic Decision-Making - Theresa Dawson



Fryingpan-Arkansas operations modeling system components.

A long term RiverWare planning model for the Fryingpan-Arkansas Project was converted for use as a short-term operations model. The updated modeling system uses data from Reclamation's Hydrologic Database (HDB) as input, performs necessary pre-processing of the data through a series of Excel workbooks, and uses RiverWare Data Management Interfaces (DMIs) to use transfer the data to and from the model. A controller workbook allows the model to be run with single or multiple trace runoff forecasts. Model results can be examined as charts and tables in an output viewer workbook. The system's directory structure is designed to allow users to easily compare different runs, store models for analysis and to archive data and results used to make decisions.

8117: Improving the robustness of southwestern U.S. water supply forecasting - Dagmar Llewellyn

Elephant Butte Dam and Rio Grande, New Mexico.

Recent decades have experienced strong trends in hydrometeorology in the western US with declining watershed runoff efficiency, which may be undermining the accuracy of conventional seasonal streamflow prediction methods that support water supply forecasts. There is a critical need to develop strategies to enhance the reliability of seasonal streamflow prediction methods so that they to continue to provide accurate, unbiased and reliable predictions by accounting for such variability. This project created a detailed modeling and ESP prediction (hindcast) resource that helped to understand new strategies for water supply prediction in the Upper Rio Grande River basin. It was generated to have specific relevance to the URGWOM management model. A key finding from the project analysis is that ESP-based approaches to water supply volume disaggregation is likely to be viable as an operational strategy for Reclamation, and that ESP-based sequences were more on average more skillful than analog based sequences. Additional analysis into climate predictability in the western US suggested that subseasonal to seasonal climate forecasts may have the potential to offset streamflow predictability losses due to warming trends and declining snowpack.

Final Version of the Collison Floating Evaporation Pan on Cochiti Lake, New Mexico.

8119: 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

This research tested a new method of estimating open-water evaporation, the Collison Floating Evaporation Pan (CFEP), on Lake Powell, UT-AZ and Cochiti Lake, NM between 2018 and 2020. The CFEP consists of an interior evaporation pan 2.44 m (8 feet) in diameter and 0.61 m (2 feet) deep surrounded by a vertical outer wave guard that is 6.1 m (20 feet) in diameter and 0.61 m (2 feet) tall. The CFEP also has a full micrometeorological instrumentation package with telemetry for remote, real-time access of data. The CFEP has the following two important improvements over land-based Class A Evaporation Pans: (1) the temperature of the water within the CFEP is nearly identical to the water temperature of the surrounding body of water; and (2) the atmospheric boundary layer over the CFEP is nearly identical to the boundary layer over the surrounding body of water. Results were compared to existing open-water estimation methods at both locations.

Snow blowing over a mountain.

20082: Assessing the impact of physically realized hydro-climate extremes on water supply - Marketa McGuire

The Bureau of Reclamation (Reclamation) Science and Technology (S&T) Program funded a scoping project (ID 20082) in October 2019 to develop a collaborative experiment to investigate atmospheric/climate drivers of hydrologic and land surface processes during drought periods and/or wet (i.e. pluvial) periods to understand the likelihood of acute or prolonged extremes and impacts on water management of Reclamation's reservoirs. The resulting project plan incorporates the approach of weather typing to understand atmospheric drivers of historical heavy snowfall events within four snowmelt-dominated watersheds that encompass a wide range of hydroclimate regions and have regional Reclamation partners who seek improved information and tools for streamflow forecasting.

Shasta Dam and Powerplant, California.

20071: Using "waste cold" from Liquid Air Energy Storage to achieve temperature objectives - Michael Wright

Liquid Air Energy Storage (LAES) uses the discharge through a turbine of air that has been liquefied to store and release energy. LAES has the potential to benefit Reclamation due to two outcomes of LAES operation: arbitrage on the power market offers the potential for profitable power operations, and the "waste cold" generated by the expansion of liquid air could allow for chilling of reservoir storage or releases. A feasibility analysis was conducted to determine potential benefits to Reclamation. Shasta Dam in Northern California was selected as the site for analysis due to its importance in both the Western power grid and as a temperature regulating facility for the upper Sacramento River habitat. After sizing a simulated plant through a literature review, a power and water temperature modeling effort was undertaken. Results indicate some potential for profitable power operations, but the temperature benefits accruing from operation of the plant at this scale were not sufficiently large to have a meaningful operational impact. A potential future scenario with currently unrealistically efficient operations did not offer major temperature improvements. This analysis finds that water temperature benefits are limited in scope for both a current technology and a potential future LAES plant.

21040: Yakima River Scoping Study to Assess Temperature and Dissolved Oxygen Levels to Inform Water Management Options - Kristin Mikkelson

Sockeye salmon. (photo courtesy of Tom Ring).

The purpose of this scoping study was to understand the data, tools and models currently available that describe Yakima river water quality, specifically temperature and dissolved oxygen. The Yakima River is a tributary of the Columbia River in Washington State and is the only migratory pathway for Yakima Basin juvenile salmonids migrating downstream to the ocean and adults returning to their natal streams to spawn. High water temperature and low dissolved oxygen levels in the lower Yakima River create migration barriers and become lethal for migrating salmon. The objective of this project is to help advise water managers when flow management options can be used to change water quality conditions and benefit salmonid migration. This scoping study gathered existing data and water quality models, reviewed previous and concurrent work being conducted in the basin and developed project partnerships to support the writing of a full research/conducting proposal for fiscal year 2022. The conducting proposal will create a predictive tool on how and when strategic flow releases at the upstream dams or other water management options might improve water temperature and dissolved oxygen levels in the lower Yakima River to allow adult salmon to migrate upstream and enhance juvenile salmon downstream migration survival.

Grand Valley Diversion Dam, Colorado River, Colorado.

20047: Web-Based Decision Support System for the Upper Colorado River Basins - Claudia Leon Salazar

To improve coordination and transparency of water management operations within the Upper Colorado River basin, Eastern Colorado Area Office developed a Web-Based Decision Support System that allows real-time sharing of a visual representation of the Upper Colorado River as it responds to actual and anticipated reservoir releases, diversions and return flows. As manager of Green Mountain Reservoir, ECAO facilitates coordination meetings with stakeholders responsible for the management and operations of storage reservoirs and irrigation diversions in the Upper Colorado River basin from the Colorado River headwaters to the confluence with the Gunnison River in Grand Junction, Colorado. Frequently, operation changes occur at multiple reservoirs and diversions. In the past, the projected flow at targeted locations based on these changes were roughly estimated by hand by the participants in the meetings. These estimates were difficult to determine in real-time due to the various reservoirs and diversions, numerous tributaries, and transit times and losses associated with long river distances. The DSS has improved the quality of discussion of the HUP meetings. The user-friendly web service allows to share modeling outputs in real-time, which has been extremely helpful to evaluate proposed operations.

FY22 New Projects

22041: Evaluation of file formats for storage and transfer of large datasets in the RISE platform - Drew Loney

The proposed effort is intended to examine large datasets produced by Reclamation and explore how they can be published through RISE.

22045: The development of a temperature and dissolved oxygen water quality model to inform water management options to benefit Yakima River salmon migration - Kristin Mikkelson

The goal of this project is to develop a predictive water quality model that can advise water managers when flow management options can be used to change or maintain water quality conditions downstream and enhance salmon migration and survival.

22050: Evaluating Water Temperature Modeling and Prediction in the Sacramento River Basin - Randi Field

This proposal supports the development of new meteorological datasets and inflow temperature predictions that can potentially improve Reclamation capabilities for stream temperature management in California's Sacramento River basin and communication with stakeholders.

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FY22 New Projects *-continued*

22055: Development of an integrated hydrologic model with high-resolution snow processes for water supply forecasting and forecast-based operations - Drew Loney

This effort expands the Adaptive Hydrology (ADHydro) model – a high-resolution, physics based, HPC capable hydrologic model – to include snow processes in collaboration with NOAA NWS Office of Water Prediction and the USACE Engineer Research and Development Center.

22056: Post-wildfire forecasting improvements using non-Newtonian flow processes with a high-resolution, integrated hydrologic model - Drew Loney

This effort will build an interagency model and model construction workflow to support post-wildfire water management. Reclamation will leverage the USACE ERDC investment into post-wildfire flow processes by incorporating their post-wildfire computational libraries into the ADHydro model.

22071: Characterizing Historical and Future Snowfall Events across the Western U.S. to Inform Water Resources Management - Kathleen Holman

This project will improve the understanding of synoptic weather conditions that result in heavy snowfall across four watersheds in the western US, knowledge that could help increase adaptive management and flexibility in the planning, design and operations of Reclamation's facilities in a variable and changing climate, including improved management during droughts and floods.

22072: PyForecast continued development – expanding PyForecast's reach and capabilities - Jonathan Rocha

This projrct will continue development and validation of the PyForecast statistical modeling software to incorporate additional modeling and analysis methods, and to allow the tool to satisfy more water supply forecasting use-cases within Reclamation.

22090: Favorably Stabilizing the Flow, Supply and Quality of Water from Public Lands During Forest Management - Dan Deeds

In collaboration with the Bureau of Land Management, the project proponents will use remote sensing data, state-of-the-science wildfire and watershed models and targeted monitoring efforts to study land based management practices and their impact on water supply and quality. This project will produce a planning process that will aid Reclamation, other reservoir owners and State and Federal land management agencies to better secure water supply in wildfire-prone regions of the West.

22108: Optimization of Water Management within the Colorado River Indian Reservation in Arizona - Meghan Thiemann

The intent of this project is to investigate methods to better integrate and simplify current processes to improve water ordering, accounting, and end user experience in terms of accuracy, transparency, accessibility and reliability. The main objectives are to develop a common operating picture across the participating organizations (CRIT, BIA, and Reclamation), simplify procedures for diversion management/water ordering, and build federal and Tribal confidence in water management systems and related decision-making, within the existing authorities and scope of responsibility for each agency.

FY22 Active Projects

ID	Final Year	Title	Lead
1881	2022	Risk-based decision making in reservoir operations	Jordan Lanini
1895	2022	Developing process-based and spatially consistent approaches for correcting streamflow biases in watershed hydrology simulations	Marketa McGuire
19132	2023	Using Remote Sensing and Ground Measurements to Improve Evaporation Estimation and Reservoir Management	Dagmar Llewellyn
19178	2022	Can better representation of low-elevation snowpack improve operational forecasts?	Dan Broman
19180	2022	Software Tool Development to Generate Stochastic Hydraulic Simulations using HEC-RAS	Ari Posner
19246	2022	Bio-physical Integrated Land Atmosphere Water Simulator (BI-LAWS)	Michael Tansey
19249	2022	Improving distributed hydrologic models using multiscale thermal infrared, near infrared, and visible imagery from sUAS and satellite-based sensors	Lindsay Bearup
20025	2022	Developing a holistic framework for evaluating system-wide groundwater surface water interaction and interconnected projects using system dynamics modeling methods	Jennifer Johnson
20032	2022	Characterizing the Predictability and Sensitivity of Streamflow to Monsoon Season Precipitation	Dagmar Llewellyn
20075	2022	Simulating California's water supply system under future climate stresses	Michael Wright
20093	2022	Dynamic Representations of Hydrologic-Irrigator Interactions in Planning Models	Kirk Nelson
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	Brett Mooney
21039	2022	A Collaborative Stochastic Weather Generator for Climate Impacts Assessment	Subhrendu Gangopadhyay
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
21048	2023	Assessing the impact of land use and land cover changes on river diversions in semi-arid river basins	Michael Poulos
21082	2023	Evaluating Big Thompson water supply modeling capability improvements from new model forcing and recalibration	Lindsay Bearup
22045	2024	The development of a temperature and dissolved oxygen water quality model to inform water management options to benefit Yakima River salmon migration.	Kristin Mikkelson
22050	2024	Evaluating Water Temperature Modeling and Prediction in the Sacramento River Basin	Randi Field
22055	2024	Development of an integrated hydrologic model with high-resolution snow processes for water supply forecasting and forecast-based operations	Drew Loney
22056	2023	Post-wildfire forecasting improvements using non-Newtonian flow processes with a high-resolution, integrated hydrologic model	Drew Loney
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