BUREAU OF RECLAMATION

R&D Office Research Updates

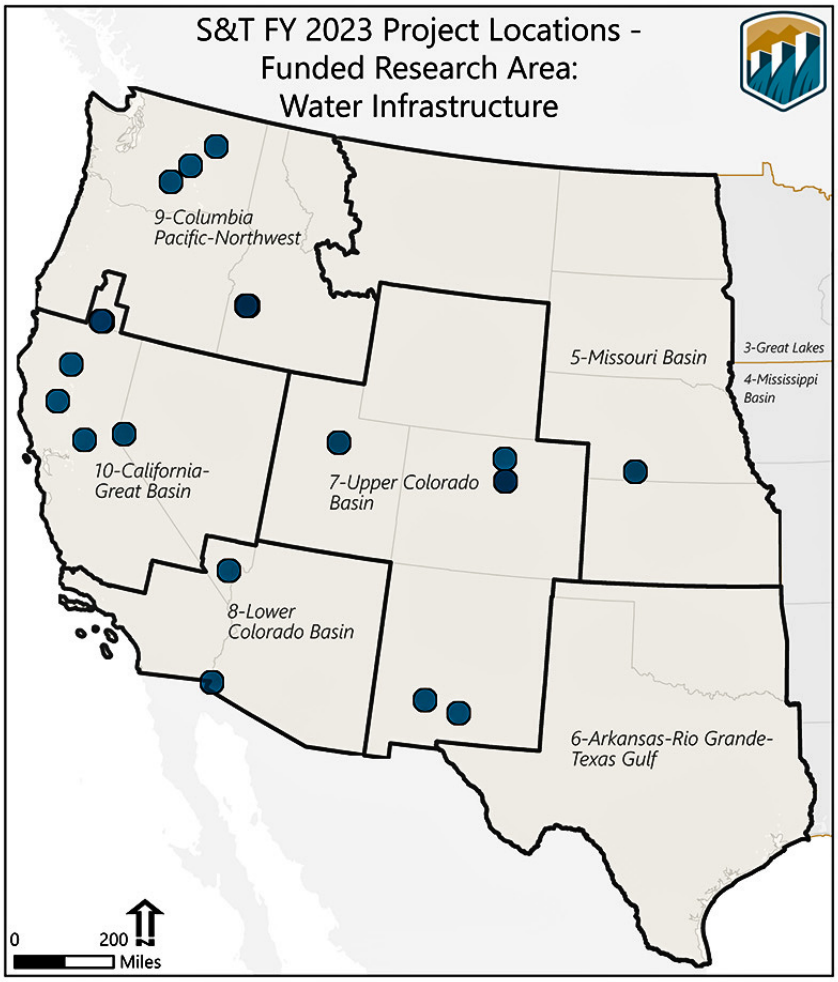
Water Infrastructure

U.S. Department of the Interior

January 2023

Executive Summary

The Water Infrastructure (WI) area of the Science and Technology Program (S&T) examines research in the following categories: Dams, Canals, Pipelines, and Miscellaneous Water Infrastructure. In FY23, S&T funded 35 Water Infrastructure projects for a total $2.1 M. This includes 8 new projects ($0.7 M) and 27 continuing projects ($1.4 M). S&T estimates a benefit-cost ratio (BCR) for two WI projects each year to demonstrate the research value. The results of the analyses and respective BCRs will be available in the spring. WI research is extremely valuable to Reclamation, as demonstrated by the development of new and improved solutions to support Reclamation's mission.



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

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Water Infrastructure

FY22 Completed Projects

21105: Hoover Dam Cylinder Gate: Stoplog Sealant Alternatives – Alexander Smith

Sealing the intake towers at Hoover Dam is a labor-intensive process. A 1:1 mixture of bentonite and stag manure is filled into a cannister, submerged to the elevation of the bulkhead gates and released. This takes about three sealant deployments per gate, 720 labor-hours, and four hydroelectric mechanics to complete. This study evaluated materials and methods used at other facilities in hopes to improve the Hoover Dam sealing process. The findings show that most facilities do not have metal seals like Hoover and do not deploy sealants or deploy them on the water surface to sink to the gate elevation—Hoover Dam has tried many of the "dump and drift" sealants. Grand Coulee Dam is the only facility that uses a submersible cannister. Davis Dam and Parker Dam use preformed flexible gasket strips to augment their bulkhead's sealing capabilities as necessary. The study concluded that an engineered solution specific to Hoover Dam is recommended to reduce the effort needed to seal its intake towers.

Hoover Dam's sealant deployment device.

Grand Coulee Unit G8 penstock newly applied lining, from the concrete/steel transition to scroll case.

19188: Feasibility of Autonomous Robotics for Relining Penstocks and Similar Structures – Allen Skaja

Improved materials and application methods are needed for penstock relining at hydropower facilities, as evidenced by several lining failures and safety incidents over the past two decades. This report documents joint efforts since 2016 between the Bureau of Reclamation and other government agencies, professional organizations, contractors, and coating manufacturers to advance technologies and promote information sharing to achieve long term corrosion protection of penstocks and other critical piping. The collaborations helped Reclamation identify three areas in need of future research and development: 1) increase reliability and effectiveness during autonomous (unmanned) robotic relining operations by improving equipment monitoring capabilities, 2) improve existing robotic technology for autonomous, non-structural pipe relining of small diameter pipes (e.g., less than 18 inches diameter), and 3) perform economic study targeting robotic relining technologies.

20023: Advancement of Cathodic Protection Monitoring and Control for Water Storage Tanks – Chrissy Henderson

Reclamation oversees more than a thousand water tanks on hundreds of projects in the Western United States. These include storage and regulating tanks, air chambers, and elevated tanks. Tank interiors can be expensive to reline, so for tanks with aging linings or for new facilities being designed, cathodic protection systems can be beneficial to extend the service life of the tank, as well as the protective coating by decreasing the frequency of the need for coating maintenance and replacement. This research sought to investigate different anode configurations for tank cathodic protection systems, namely by using surface-mounted magnesium ribbon anodes arranged in rings. While the anodes themselves are not novel, their use to protect tank interiors differs from Reclamation's traditional hanging rod system design. This research also investigated the performance of a polysiloxane coating system in immersion service.

Laboratory water storage tank filled with water and in-place at the Technical Service Center, Hydraulics Laboratory.

19144: Improving Seepage Measurements in the Truckee Canal and Developing a Framework for Data Collection, Modeling and Assessment of Unlined Canal Seepage – Evan Lindenbach

Quantifying seepage losses from unlined irrigation canals is necessary to improve water use and conservation. The use of heat as a tracer is widely used in quantifying seepage rates across the sediment-water interface. In this study, field observations and two-dimensional numerical models were used to simulate seepage losses during the 2018 and 2019 irrigation season in the Truckee Canal system. The results demonstrate the value of long-term datasets that illustrate the seasonality of groundwater levels, siltation, stage, and temperature on seepage rates. The seepage losses estimated by this study account for 32% to 41% of the inflow volumes. Regression models were able to reproduce seepage time-series simulated by the numerical models reasonably well.

Unlined section of Truckee Canal from the heat-as-a-tracer seepage investigation. Photo credit David Smith, USGS.

PCCP educational demonstration virtual model created by photogrammetry.

19275: PCCP Inspection Truthing and Educational Demonstration – Matthew Jermyn

Two distressed sections of pre-stressed concrete cylinder pipe (PCCP) that had been removed from service were brought to the Denver Federal Center for inspection truthing and to be a resource for hands-on educational demonstration. Visual inspection found extensive damage to the bell and spigot joints, exterior gouging, staining, and delamination. Photogrammetry was used to create a virtual model of the pipe sections. The educational material will be debuted at the Spring 2023 Corrosion School, taught by the Reclamation Technical Service Center Materials and Corrosion Laboratory Group.

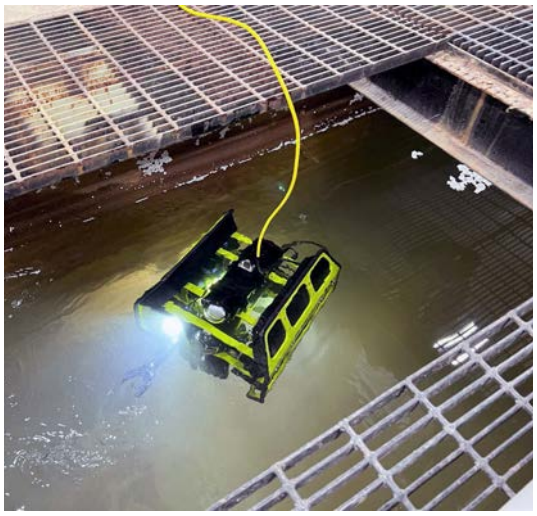
7109: Explore the Feasibility of using Unmanned Aircraft Systems in managing Rockfall Hazard Areas – Matthew Klein

Rock fall events at Reclamation facilities can disrupt water and power deliveries, cause costly damage, and result in severe injury or death. This project explored the application of unmanned aerial systems, or UAS, to inspect rock fall hazard areas, with focus on: 1) determining the approval process for operating UAS at Hoover Dam's rockfaces, 2) using the UAS to collect high-resolution photogrammetric data, and 3) performing preliminary analysis of the data for change detection and geologic rock fall potential. Research findings showed that UAS can be safely and reliably operated at complex locations, as well as that the data collected by UAS for photogrammetry is robust and measurable. The research also determined that the return-on-investment for using UAS to help manage rock fall hazards is 12.2 percent.

Uncrewed aerial system (UAS) collecting data on Hoover Dam rockfaces to identify rock fall hazards has a 12.2 benefit-cost ratio.

21060: Underwater Remotely Operated Vehicle (ROV) Data Collection at Reclamation Sites – Matthew Klein

ROVs, or remotely operated vehicles, are a type of robot that is typically operated underwater. This research focused on identifying the current equipment and applications of ROVs within Reclamation, as well as researching current ROV technology. The research also sought to identify gaps in Reclamation's current use of ROVs and the state-of-the-art to make recommendations for future upgrades and capability. The research findings point to three recommendations based on consideration of issues related to ROV piloting expertise, comparison to unmanned aerial system technology, and costs. These are: 1) replacement of older, less powered, lower resolution ROVs with higher and more modular capabilities; 2) high-resolution sonar for inspection and mapping; and 3) autonomously controlled unmanned surface vessels for hydrographic and bathymetric surveys with the ability to merge underwater data with shoreline data.



Operation of the UNRD Prosecutor Gen 2 ROV at the Hydraulics Lab sump pool.

19242: Algae Resistant Linings for Canals and Other Water Resource Structures – Scott Keim

Each year irrigation districts treat their canals with 140,000 pounds of copper sulfate to reduce the algae that stick to the canal sides and reduce the flow of water, thus slowing down deliveries and causing other operation issues. This research aimed to better understand chemical and physical characteristics of concrete and concrete surfaces that would inhibit algae growth on canal linings and other water resource structures by evaluating various changes to the concrete canal system. The research team included the Reclamation Concrete and Structural Laboratory and the Quincy-Columbia Basin Irrigation District (QCBID). The study tested several integral products, a topical product, and a smoother finish technique using concrete panels placed into a QCBID canal. The findings recommended a scale-up to a full concrete canal panel for the topical product.

Coated concrete panels in canal during testing.

FY23 New Research Projects

23008: Refurbishment of Small Diameter Embedded Pipes in Powerplants and Dams – Allen Skaja

Much of Reclamation's infrastructure exceeds 70 years of age. Refurbishing small diameter embedded piping, such as to repair corrosion damage, is notoriously challenging. For example, the 10- to 12-inch diameter bypass filling, air vent, and drain pipes are currently being repaired at the John Keys Pump-Generating-Plant (JKPGP). Water leaking back into the pipes made them impossible to reline. This scoping-level research will identify and evaluate potential refurbishment solutions for small diameter embedded pipes. The project team includes TSC specialists and is in partnership with JKPGP. Solutions may be applicable to all facilities with small diameter embedded piping.

23009: Investigating Rubberized Polysiloxane Coating Formulations to Improve Durability and Long-Term Performance – Allen Skaja

The United States Army Corps of Engineers (USACE) and the Bureau of Reclamation began a collaboration in 2015 to investigate alternative corrosion-resistant coatings to vinyl for impacted immersion service of hydraulic infrastructure. Reclamation recently found several polysiloxane coating products to have excellent corrosion-prevention properties that are lacking in durability, impact resistance, flexibility, and erosion resistance—essential characteristics for long-term corrosion protection of immersed infrastructure. This research will seek a polysiloxane formulation that is suitable for field trials in collaboration with USACE as a funding partner.

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FY23 New Research Projects – *continued*

23012: Investigation of Innovative Exposed Lining Systems – Brian Baumgarten

Geomembrane liners have been in use dating back to the 1960's, with HDPE currently being the liner type that is overwhelmingly specified in exposed liner applications. Although HDPE is very durable and high performing, no long-term field or laboratory study has compared HDPE to the new advanced liner technologies available today. This study will evaluate a flexible Geo-Form Ethylene Propylene Diene Monomer, a polyurea impregnated geotextile, a bituminous geomembrane, and a reinforced polyethylene to determine whether HDPE is still the preferred exposed liner material or if there are other more durable and economical options for the end user.

23014: Long-Term Coatings Lab Testing Data Analysis for Service Life Correlations and Evaluation of New Testing Methods – Bobbi Jo Merten

Reclamation has been working to find replacement coatings for the long service lifetimes provided by coal tar enamel and solution vinyl coatings. To do so, there is first a need to determine which laboratory tests best predict field performance and to find new or improved test methods to fill gaps left by traditional testing approaches. The research team will analyze existing large datasets from Reclamation's Materials and Corrosion Laboratory and the U.S. Army Corps of Engineers Paint Technology Center to identify correlations and statistical significance. The expected research outcome is improved coating laboratory evaluation techniques and increased correlation of laboratory performance to field performance.

23020: Ground Modification using Microbially Induced Desaturation (MID) for Liquefaction Interim Risk Reduction – Angel Gutierrez

Many of Reclamations' dams and canals are founded on potentially liquefiable materials and will require further investigation and, potentially, modification. Microbially induced desaturation and microbially induced desaturation/precipitation (MID/P) are emerging technologies that offer the potential for sustainable, cost-effective liquefaction mitigation for existing structures. This project will evaluate the benefits of MID/P to provide a draft risk analysis of its implementation and will develop a bio-geotechnics testing program at Reclamation's Technical Service Center Geotechnical Lab for testing liquefaction resistance of MID/P treated soils.

23024: The Effect of Large Earthquake Loading on Fine-grained Foundation Materials: Determining Residual Undrained Strengths at Large Strains and Corresponding Embankment Deformations – Carolyne Bocovich

Deformation analysis due to earthquake loading relies on well-defined residual undrained strengths. However, there is not an industry-accepted standard to determine this value, meaning no clear method to incorporate these strengths into deformation analyses. This research utilizes laboratory tests and numerical modeling to: 1) determine earthquake induced residual undrained strengths of fine-grained embankment and foundation soils and 2) inform deformation analyses of embankments. Results from this research will allow for increased confidence in geotechnical design and have the potential to greatly decrease the amount of time, material, and funding required for seismic modifications.

23036: System Commissioning for Topical Concrete Coatings used for Algae Resistant Linings for Canals – Jeffery Keim

Alternatives to the chemical treatments currently used for algae control in canals are needed to reduce environments impacts. This research will confirm if products identified during small-scale field trials for a preceding S&T research project are capable of reducing algae growth when applied to full-size concrete canal lining panels that are in-service over multiple irrigation seasons. Successful products from the previous study will be trialed on full-size concrete canal lining panels within the Quincy-Columbia Basin Irrigation District that are in-service. The panels will be observed and photographed monthly to track algae growth.

23050: Reducing Reclamation's Carbon Footprint Through Modernizing Concrete Materials, Specifications and Construction Practices – Catherine Lucero

The concrete industry has been targeted for its contribution to global warming due to the high levels of carbon emitted by cement production and the concrete construction process. There is a great push for the concrete community to become carbon neutral by 2050. Through this project, researchers will collaborate with other high-level concrete industry leaders to develop guidance for reducing Reclamation's carbon footprint in concrete materials and construction. The team will review recently published documents on concrete carbon neutrality, attend meetings and workshops, identify new research areas related to sustainable concrete, and perform outreach to Regional engineering and construction staff. Potential solutions include modernizing concrete materials, specifications, and construction practices.

FY23 New and Continuing Research Projects

ID	Final Year	Title	Lead
19119	2023	Comparison of Traditional and New Testing Methods for Riprap Material Quality	Robert Rinehart
19142	2023	Characterizing Novel Supplementary Cementitious Materials to Reduce Infrastructure Costs and Improve Durability	Catherine Lucero
19182	2023	Facility Management of Reclamation's Dams - O&M Integration of the Unified Intelligent Model	David Winslow
19206	2023	Improved Prediction of Seismically Induced Hydrodynamic Loads on Dams and Spillway Gates	Josh Mortensen
19317	2023	Field Implementation of Burrowing Animal Deterrents for Earthen Canal Embankments	Richard Bearce
20041	2023	Maintaining Canal Capacity and Delivery Feature Reliability through the Use of Ultraviolet Aquatic Vegetation Control	Josh Voorhees
20074	2023	Leak Repair Demonstrations for Pressurized Mechanical Systems	Grace Weber
20081	2023	Internal Erosion: Laboratory Testing to Identify End States in Internally Unstable Soils	Carolyne Bocovich
20096	2023	UAS Demonstration and Development for Inaccessible Features Inspections	Carter Gulsvig
20200	2023	Gate Design Optimization and Composite Gate Lab Scale Testing	Eric Paquette
21030	2023	Dam Incident Investigations: Determining Best Practices for Investigations that Can Improve Future Performance of Dams	Rich Eastland
21045	2023	Voids Behind Spillways, Conduits, Canals, Tunnels, and Siphons: Causes, Detection Techniques, and Repair Options	Evan Lindenbach
21049	2023	Improving Reclamation’s Geologic and Geotechnical Investigations with Drill Parameter Recorder Technology	Evan Lindenbach
21051	2023	Hydraulic Concrete Surfaces for Water Resource Structures – Continued Collaboration	Josh Mortensen
21057	2023	Instrumented Standard Penetration Testing (ISPT) to Increase Accuracy and Reliability in Penetration and Delivered Energy Data for Geotechnical Analysis and Liquefaction Evaluation	Chris Haynes
21062	2023	Atmospheric Plasma Coating Removal	Kevin Kelly
21067	2023	Investigating Newly Formulated Polysiloxane Coating Systems with Improved Erosion and Impact Properties	Brian Baumgarten
21076	2024	Concrete Cloth for Seepage Reduction – Field Demonstration	Caleb Nickel
21096	2023	Evaluation of Fiber Optic Technology for Use on Reclamation Critical Infrastructure	John Germann
21100	2023	Standardizing Methods for Disaggregation of Slakable Rock and Fat Clay	Richard Bearce
22004	2024	Evaluation of Plunger Valves as a New Technology for Improved Water Delivery at Reclamation Dams and Hydropower Facilities	Josh Mortensen
22017	2024	Evaluate and Model Economical, Safe and Effective Methods to Mitigate and Remove Debris from Dam Intake Structures	Juan Luna
22039	2024	Boundary Layer and Aerated Flow Effects on Hydraulic Jacking in Spillway Chutes	Tony Wahl
22048	2023	Development of Facility Corrosion Inspection Templates & Planning for a Central Database	Bobbi Jo Merten
22081	2024	Utilization of Trained Canines to Detect Leaks in Water Pipelines	Daryl Little
22086	2024	Evaluation of Acoustic Emission Sensing Technologies for Pressurized Buried Water Pipeline Leak Detection	Atousa Plaseied
22096	2023	Alternative Methods for Collecting Data for Photogrammetric Crack Mapping of Interior Cavities of Buttress Dams: Development of Methodology and Demonstration at Stony Gorge Dam	Matthew Klein
23008	2023	Refurbishment of Small Diameter Embedded Pipes in Powerplants and Dams	Allen Skaja

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Truckee Canal structure - Photo credit Ramon Naranjo, USGS.

Front cover photo: Unlined section of Truckee Canal from the heat-as-a-tracer seepage investigation. Photo credit Ramon Naranjo, USGS.