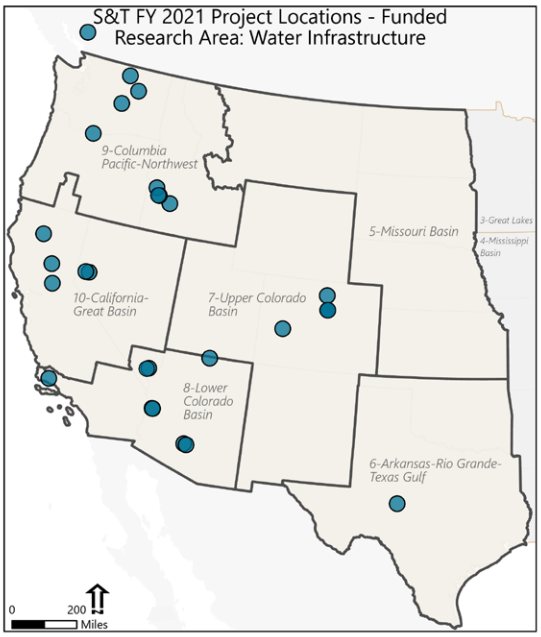
BUREAU OF RECLAMATION

Research Updates
R&D Office
Water Infrastructure

U.S. Department of the Interior

January 2021

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 FY21, S&T funded 32 projects in this area for a total of $2.6 M. This includes 6 new projects ($0.5 M) and 26 continuing projects ($2.0 M). S&T estimates a benefit-cost ratio (BCR) for two WI projects each year to demonstrate the value of this research. The BCR was 24.0 for Improving Seepage Measurements in the Truckee Canal and Developing a Framework for Data Collection, Modeling and Assessment of Unlined Canal Seepage. This project presents a framework for investigating seepage based on a broad range of techniques and the time sensitivity, concentration, and consequences of a seepage event. The BCR is primarily based on the relatively low-cost S&T investment and the probabilistic mean estimated for the cost of each technique; unquantified benefits include improved safety by decreasing diagnosis time, time spent on embankments, and probability of failure. Preliminary results indicated a BCR of 5.3 for Collaborative Studies of Hydraulic Concrete Surfaces to Reduce Concrete Damage for Water Resource Structures. This project evaluated approaches to improve design accuracy for concrete surfaces experiencing extreme hydraulic conditions. The BCR is primarily based on reduced field and material costs associated with new concrete placements. As demonstrated, WI research is extremely valuable to Reclamation, both by development of new design techniques and new O&M frameworks.

Science and Technology Program: Research Areas

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 research projects led by 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)

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

Water Infrastructure
Dams, Canals, Pipelines, and Miscellaneous Water Infrastructure

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

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

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

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Water Infrastructure

FY20 Completed Projects

19144: Improving seepage measurements in the Truckee Canal and developing a framework for data collection, modeling and assessment of unlined canal seepage - Evan Lindenbach

Canal seepage losses affect the ability of water conveyance structures to maximize efficiency and can be a precursor to canal failure. Identification and quantification of canal seepage out of unlined canals is a complex interaction of many factors: geology, operations, embankment geometry, etc. Coarse seepage estimation uses a mass balance-type approach (water in minus water out with the difference assumed to be a combination of seepage and evapotranspiration) while sophisticated methods quantify seepage in a specific location. This work provides a generalized framework for how and when to investigate seepage out of an unlined canal based on the type of seepage, level of understanding about the seepage locations, geology, and subsurface conditions. Various methods to locate seeps and quantify canal seepage are also described.

Installing field equipment in the Truckee Canal outside of Reno, Nevada.

1764: Determining Critical Crack Size and Water Pressure for Sealing Water Leaks using Electro-Osmotic Pulse - Daryl Little

Uncontrolled water seepage through Reclamation's concrete infrastructure can cause extensive damage to the structure and equipment and can necessitate expensive repairs. Grouting has historically been used to mitigate leaks but may only be a temporary fix and does not prevent seepage through the pores and very fine cracks. Electro-Osmotic Pulse (EOP) is a technology typically used in conjunction with grouting and concrete repair to be a long-lasting solution for water intrusion through concrete. A properly designed system and successful installation is critical in order to mitigate or reduce the water leakage. Data collected at one field installation showed that at a constant applied potential the resistance of the concrete increased indicating that the system was operating as intended by moving water through the concrete towards the cathodes.

Headgate shaft at Trinity Dam. Photo at left is before the EOP system was installed and the photo at right is after 12 months showing the system is reducing the water leakage.

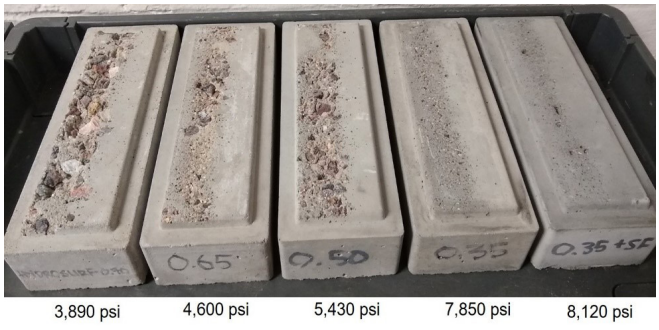
1884: Field Validation of Impedance Spectroscopy Coating Assessments - Bobbi Jo Merten

Traditional methods to inspect coatings on Reclamation structures use visual assessments, which identify only areas of coating that are visibly damaged. Evaluating undamaged areas of the coatings could help Reclamation to better plan the timing and approach for coating maintenance and lower overall costs. Traditionally a laboratory technique, Reclamation researchers demonstrated in previous research that electrochemical impedance spectroscopy (EIS) can also provide quantitative data on a coating's condition in the field. This study aimed to further the validity and usefulness of field EIS testing through laboratory and field experiments. The results showed good agreement between the laboratory and field data and made great strides toward refining the field method. The research also resulted in a draft ASTM international test method that may facilitate industry-wide adoption if approved.

Electrochemical impedance spectroscopy test cell set-up for coating evaluation near pipe crown in a large diameter pipe.

1885: Collaborative Studies of Hydraulic Concrete Surfaces to Reduce Concrete Damage for Water Resource Structures - Katie Bartojay

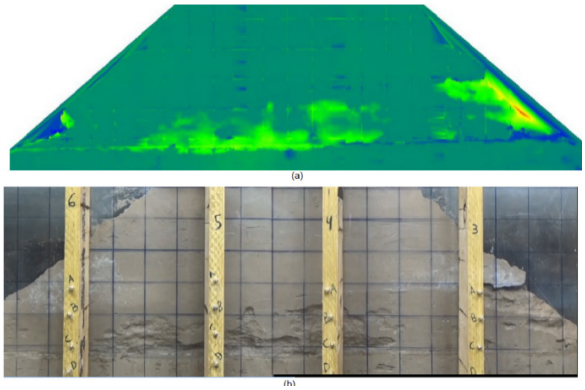
Cavitation and erosion damage on spillways and stilling basins are a problem for both the Brazilian Government and Reclamation. This study aimed to improve concrete design guidance by defining the complicated correlation of cavitation damage on concrete surfaces to material properties and localized hydraulic conditions which cause the damage. As a collaborative research study with the Brazilian Government, technical expertise and testing capabilities from laboratories in both Brazil and Reclamation were leveraged. The study included a literature review, analysis of damage in existing field facilities, and laboratory testing conducted by Brazilian and Reclamation engineers. To date, analysis of field data from several Brazilian spillways has been completed in Brazil and laboratory concrete damage testing has been completed at Reclamation.



Extent of cavitation damage with increasing concrete strength.

8284: Cracked Embankment Erosion Research - Peter Irey

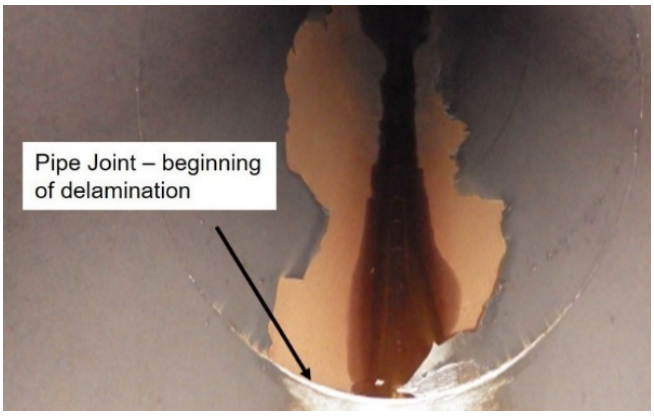
Embankment erosion causes a multitude of problems for Reclamation including water seepage, loss of material, and damage to surrounding structures. This study sought to determine the main causes of erosion to implement reduction methods. The structure of the soil was the most critical factor for erosion—fine-grained soils compacted wet of optimum are likely to have clay particles aligned, and soils compacted dry of optimum are likely to have unaligned clay particles. Alignment influences the size of the clods, with more aligned particles coming off in larger chunks while non-aligned particles are pulled apart easier. Testing found that erosion resistance increased with water content at the time of compaction and holding water content constant and increasing compactive effort.



Eroded surface constructed from photogrammetry (top), and image of the actual surface (bottom).

19122: Adhesion Strength of Protective Coatings – Test Method Development under Real-Life Hydraulic Conditions - Josh Mortensen

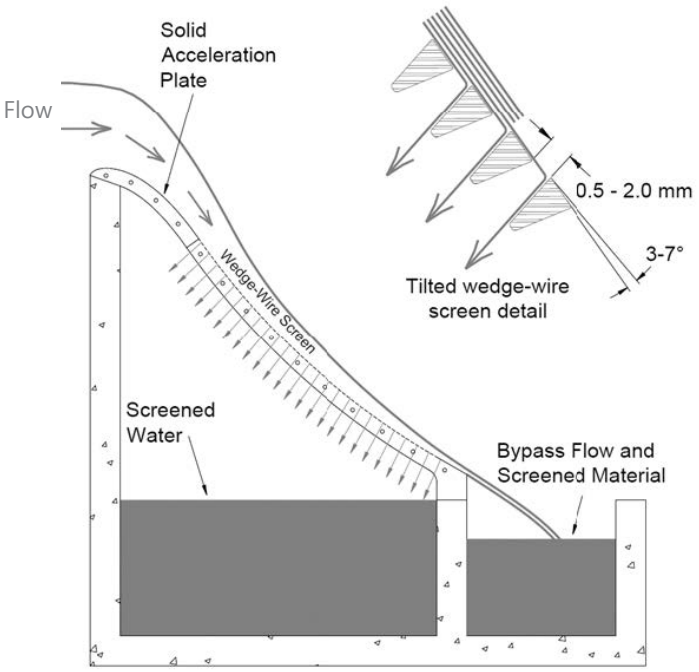
Recent field experience with modern protective coating systems in outlet works has shown traditional test methods for coating adhesion don't provide reliable results. Legacy coatings are reaching the end of their service lives in many Reclamation facilities and adhesion performance of modern replacement coatings are a concern. A test method was developed that simulates full scale hydraulic conditions present in the field to improve correlation between laboratory results and field experience. The test method, which exposes coating samples to the hydraulic uplift forces encountered in the field, has been implemented during initial laboratory trials and has shown success in correlating hydraulic conditions to coating failure.



Loss of the polyurethane lining in the Flatiron Penstock.

19233: Tools to Support Design of Coanda-Effect Screens for Debris Exclusion and Fish Protection - Tony Wahl

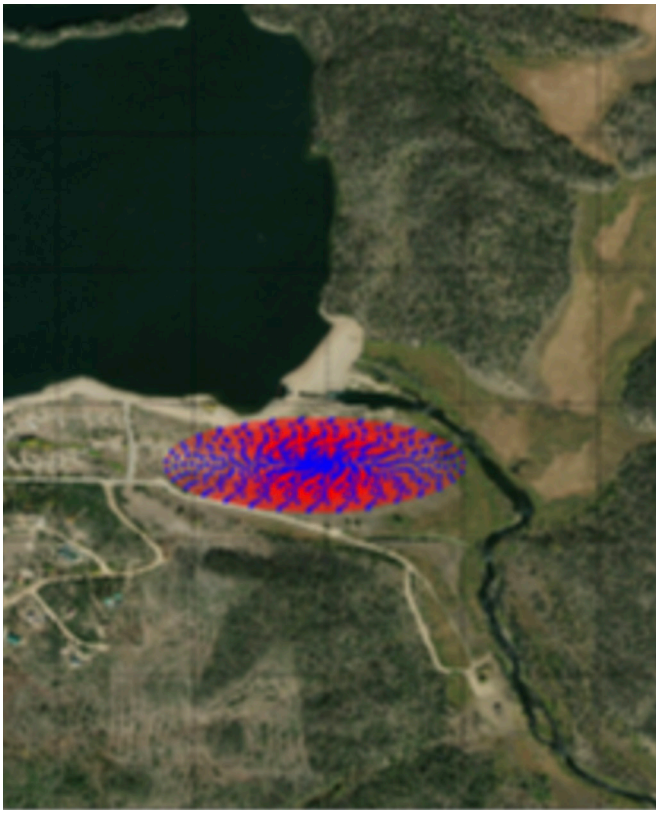
Removal of fine debris and screening of fish from water intakes are crucial for successful use of limited water resources. Coanda-effect screens offer a self-cleaning, high flow-capacity option for screening fine debris and fish from diverted waters. Testing of screens installed on relatively flat slopes showed that screen capacity was much higher than expected at low flow velocities because of surface tension forces on the flow as it passed through the narrow screen slots. Reclamation then developed better equations for predicting screen capacity which were incorporated into a computer program used to design screen structures. The uncertainty of predicted screen capacity has been reduced by a factor of 3 or more compared to earlier work.



Features and typical arrangement of a Coanda-effect screen structure.

20098: Internal Erosion Prize Challenge Competition Next Steps: Evaluating Distributed Acoustic Sensing (DAS) for Large Critical Infrastructure Imaging and Monitoring - Justin Rittgers

Reclamation has large earthen dams and other infrastructure in various states of deterioration, increasing the probability of failures. Typical assessment methods are often conducted by random placement of focused surveys and coreholes and can be time consuming and expensive for full coverage on large structures. There is the ever-present chance of entirely missing or underestimating the severity of structural health issues before they worsen. Distributed Acoustic Sensing (DAS) was one technology evaluated that could facilitate rapid and early identification of damage to critical infrastructure. DAS turns a single fiber optic cable into a massive seismic sensor array capable of continuously recording vibration signals at 25 cm increments for up to 50 km.



Schematic distributed acoustic sensor fiber for possible future installation at dam.

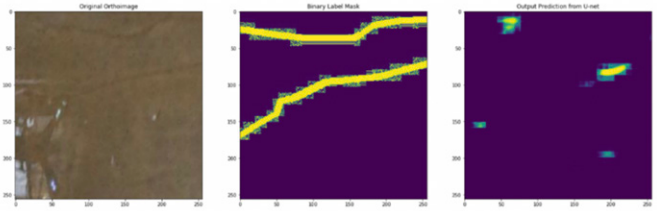
20102: Debris Clogging Assessment of Dams - Connie Svoboda

Debris such as trees, mats of connected wood pieces, and other items can travel through the reservoir to the dam and obstruct outflow structures, raising the water surface elevation and increasing the risk of dam overtopping. Information on debris clogging at various Reclamation dams was collected. Results showed that excessive debris occurs during flooding at 70% of facilities and during normal operations at 22% of facilities. In most responses, debris was reportedly small enough to pass through features but caused plugs when arriving in mats. Most Reclamation facilities with larger debris managed it through physical removal with a crane or by saw-cutting and removing debris by hand.

Debris removal at Buffalo Bill Dam, WY.

20105: Improving UAS-derived photogrammetric data and analysis accuracy and confidence for high-resolution data sets using artificial intelligence and machine learning - Matthew Klein

Traditional crack mapping is subject to many inaccuracies and, for some large data sets, can require up to a month to complete. Computer-based deep learning can be used to teach a computer to analyze data and images for cracks. The computer eventually finds cracks with greater precision and in less time than previous methods. Significant progress was made in producing a deep learning pipeline that can detect concrete cracks within Reclamation structures. The powerful and economically valuable tool could reduce future costs of concrete monitoring efforts and has the potential to enhance the safety and maintenance procedures around concrete infrastructure.



Example automatic crack mapping data set: input (left), label mask (middle), and output prediction (right).

FY21 New Research Projects

21045: Voids Behind Spillways, Conduits, Canals, Tunnels, and Siphons: Causes, Detection Techniques, and Repair Options, Funding - Evan Lindenbach

This project will determine the causes of voids, void detection methods, and void repair methods. Experts in hydraulics, geotechnical engineering, geophysics, and concrete repair will work together with the goal to improve our understanding of how voids form, how we can best detect voids, and how we can optimize the repair of identified voids.

21057: Instrumented Standard Penetration Testing (ISPT) to increase accuracy and reliability in penetration and delivered energy data for geotechnical analysis and liquefaction evaluation - Chris Haynes

This research looks to improve the Standard Penetration Test (SPT) analysis by digitally recording energy at the sampler and penetration per blow. According the Reclamation Geology Field Manual, the SPT was first created in 1927 as an in-situ geotechnical test for foundation design. The test has opportunities for error that can alter the results. This project proposes to take the lessons and technology developed in the Instrumented Becker Penetration Test (IBPT) program and transfer it to the SPT, with the end goal of developing an off-the-shelf Instrumented Standard Penetration Test tool.

21076: Concrete Cloth for Seepage Reduction – Field Demonstration - Shannon Harrell

This project will conduct a demonstration of concrete cloth. The goal will be to see if it can reduce seepage of unlined canals. Erosion reduction and reduced maintenance costs are other potential values.

21020: Methodology to Determine the Presence of Submerged Hydraulic Jumps at Low-Head Hydraulic Structures - Connie Svoboda

This project will investigate if known literature can be applied to determine the presence of a submerged hydraulic jump at Reclamation's low-head hydraulic structures. Near-term and long-term mitigation strategies for existing structures can be identified and "safe by design" standards can be created to ensure the new structures are not built that could cause a risk to the public.

21051: Hydraulic Concrete Surfaces for Water Resource Structures - Josh Mortensen

This research seeks to reduce concrete damage and improve concrete design for both repairs and new projects by evaluating flow interactions with the concrete surface with concrete material properties.

21096: Evaluation of Fiber Optic Technology for Use on Reclamation Critical Infrastructure - John Germann

This project will investigate the feasibility and potential use of fiber optic sensing for Reclamation applications with the goal of identifying specific applications for potential future Reclamation research and implementation.

21100: Standardizing Methods for Disaggregation of Slakable Rock and Fat Clay - Richard Bearce

This project will study the variables associated with ball mill processing on a variety of rock and clay materials obtained from active Reclamation projects. The researchers will study the effects of ball size and milling duration on estimated physical properties, study the effects of ball material (e.g., metal vs. rubber) on sand pulverization, and develop a standardized method to process slakable rock and desiccated clay to be adopted by TSC and regional geotechnical laboratories.

FY21 New and Continuing Research Projects

ID	Final Year	Title	Lead	FY21 Funding Amount
1765	2021	Truckee Canal Seepage Study	Evan Lindenbach	$107,482
7109	2021	Explore the Feasibility of using Unmanned Aircraft Systems in managing Rockfall Hazard Areas	Kevin Tibbs	$15,219
8126	2021	Chemical Compatibility Between Concrete Repair Materials and ASR Affected Concrete	Westin Joy	$44,604
19119	2021	Comparison of traditional and new testing methods for riprap material quality	Robert Rinehart	$51,100
19142	2021	Characterizing novel supplementary cementitious materials to reduce infrastructure costs and improve durability	Catherine Lucero	$112,234
19155	2021	Econometric Analysis and Forecast Model for Reclamation Corrosion Protection Costs	Bobbi Jo Merten	$130,062
19168	2021	Evaluation of corrosion inhibitive coatings	Stephanie Prochaska	$49,682
19170	2021	Uplift Pressure and Flow through Open Offset Joints in Spillway Chutes	Tony Wahl	$101,873
19182	2021	Facility Management of Reclamation's Dams - O&M Integration of the Unified Intelligent Model	David Winslow	$75,000

FY21 New and Continuing Research Projects

19188	2021	Feasibility of Autonomous Robotics for Relining Penstocks and Similar Structures	Allen Skaja	$21,208
19206	2021	Improved Prediction of Seismically Induced Hydrodynamic Loads on Dams and Spillway Gates	Josh Mortensen	$71,011
19227	2021	Polysiloxane and Vinyl coatings Comparison and Field Trial	Carter Gulsvig	$80,682
19242	2021	Algae Resistant Linings for Canals and Other Water Resource Structures	Scott Keim	$101,541
19275	2021	PCCP Inspection Truthing and Educational Demonstration	Matthew Jermyn	$77,240
19283	2021	Demonstration of USACE Corrosion Protection System Inspection and Monitoring Advancements	Grace Weber	$50,774
19317	2021	Field Implementation of Burrowing Animal Deterrents for Earthen Canal Embankments	Richard Bearce	$117,319
20020	2021	Geospatial Tool for Instrumentation Inventory and Collection and Evaluation of Readings	Matt Gappa	$66,999
20023	2022	Advancement of Cathodic Protection Monitoring and Control for Water Storage Tanks	Chrissy Henderson	$69,354
20024	2022	Laboratory Evaluation of Field Repairable Materials and Techniques for Cavitation Damage: Phase II	Chrissy Henderson	$126,562
20041	2022	Maintaining Canal Capacity and Delivery Feature Reliability Through the Use of Ultraviolet Aquatic Vegetation Control	Scott Fennema	$115,918
20056	2022	Exploring the Possibilities of Improving Flood Frequency Analysis in the West by Incorporating Paleohydrologic Reconstructions	Subhrendu Gangopadhyay	$138,872
20059	2021	Life-Cycle Costs of PCCP Maintenance	Matthew Jermyn	$80,765
20074	2022	Leak Repair Demonstrations for Pressurized Mechanical Systems	Grace Weber	$65,000
20081	2021	Internal Erosion: Laboratory Testing to Identify End States in Internally Unstable Soils	Carolyne Bocovich	$13,552
20096	2022	UAS Demonstration and Development for Inaccessible Features Inspections	Carter Gulsvig	$75,000
20200	2022	Gate Design Optimization and Composite Gate Lab Scale Testing	Eric Paquette	$100,000
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	$99,500
21020	2021	Methodology to Determine the Presence of Submerged Hydraulic Jumps at Low-Head Hydraulic Structures*	Connie Svoboda	$37,772
21045	2023	Voids Behind Spillways, Conduits, Canals, Tunnels, and Siphons: Causes, Detection Techniques, and Repair Options	Evan Lindenbach	$107,000
21096	2022	Evaluation of Fiber Optic Technology for Use on Reclamation Critical Infrastructure	John Germann	$97,629
21051	2022	Hydraulic Concrete Surfaces for Water Resource Structures – Continued Collaboration	Josh Mortensen	$86,000
21076	2023	Concrete Cloth for Seepage Reduction – Field Demonstration	Shannon Harrell	$110,986
21100	2023	Standardizing Methods for Disaggregation of Slakable Rock and Fat Clay	Richard Bearce	$69,677