RECLAMATION *Managing Water in the West*

November 2012
Research and
Development Office
Newsletter 2013-01

The Knowledge Stream

Research Updates Issue

"Desalination technology offers the potential to convert the almost inexhaustible supply of seawater and apparently vast quantities of brackish groundwater into a new source of freshwater."
Desalination: A National Perspective, Report in Brief, National Academy of Science, 2008

Our Denver labs support a wide range of research, including desalination using renewable energy. (see page 10)

Research and Development Director's Message

Our research aims to provide practical solutions to the many technical and scientific challenges Reclamation faces as the nation's largest wholesale water provider and the second largest producer of electric power in the western United States. Meeting the increasing water and energy demands of the West while protecting the environment and the public's investment in our infrastructure is a challenging business. The following are a sample of investigations being undertaken by Reclamation scientists, engineers, and technical specialists to help us be successful in this mission.

Adapting technology to meet Reclamation's unique requirements:
- Ultrasound to protect fish (page 24)
- LiDAR to track historic sites (page 28) and ecosystems (page 26)
- Acoustic hydrophones to track river bedload movement (page 22)
- Determining the best type of rock ramps and weirs (page 34)

Providing tools for Reclamation managers, powerplants, and irrigation districts:
- Electro-osmotic pulse technology to stop water seepage (page 38)
- Power system stability improvements (page 50)
- Overshot gates irrigation districts can make themselves (page 46)

Developing methods of using data to predict potential consequences of:
- Predatory, non-native fish entering waters below dams (page 4)
- Canal embankment breach flows (page 40)
- Impacts of climate variability on complex habitat interrelationships (page 14)

Optimizing Reclamation's operations:
- Finding the most economical way to generate hydropower (page 42)
- Improving power system performances (page 50)

Denver's Technical Service Center's Water Treatment Engineering Research Team includes: (left to right) Dan Gonzáles, Andrew Tiffenbach, Valerie Batista-Garcia, Katharine Dahm, Michelle Chapman, Yuliana Porras, Katie Guerra, Frank Leitz, shown with Kevin Price, Research and Development Office's Advanced Water Treatment Research Coordinator.

Print Options and Instructions

This document is designed to be read either electronically via PDF or printed in color or black and white. Please forward it to your colleagues and friends.

You have three options for printing parts or all of this document:

1. Print individual research updates on one sheet of paper, print double-sided for the two-page updates.

2. Print the whole document double-sided, corner stapled on 8.5” x 11” paper.

3. For magazine-style, instruct your print professional to print the document double-sided, head-to-head, saddle-stitched on 11” x 17” paper.

Your suggestions for improvements are always welcome.
Please email them to jakervik@usbr.gov.

Thanks

Jake Akervik
Communication and Information Systems Coordinator, Research and Development Office

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RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Coatings for Invasive Mussel Control

Evaluating foul-release coatings to protect Reclamation infrastructure

Bottom Line

Researchers at the Technical Service Center in Denver, Colorado, have identified foul-release coatings that prevent attachment of invasive quagga and zebra mussels.

Better Control

Environmentally friendly, prevents mussel attachment, minimizes maintenance. While silicone foul-release coatings can be nearly three times as expensive as conventional epoxy, the long-term preventative maintenance of the foul-release coatings must be considered. Savings in operation and maintenance, safety considerations, and flow may make it more economical to use foul-release coatings to control mussels.

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Problem

Invasive quagga and zebra mussels have the potential to disrupt water delivery and hydropower generation functions, as well as to create long-term economic impacts. These mussels are capable of attaching to nearly all submerged surfaces and thus can clog pipes, trashracks, and cooling water and fire suppression systems; among other infrastructure. In addition, the mussels build up on gates and gate seats. All of these structures are critical to the reliability of Reclamation's mission of delivering water and generating hydropower.

Historically, mussels have been controlled by chlorinating water systems. This requires discharge permits to release into open waters, and are not practical in all situations. However, foul-release coatings could deter mussel attachment without releasing toxins into the water. These types of coatings do not depend on water chemistry, pH, temperatures, or flow rates. Commercial foul-release products thus far have been marketed for fouling control in the shipping industry. Yet the service environment at Reclamation facilities presents some unique challenges for a fouling control coating.

Solution

This Science and Technology Program research project works with manufacturers to evaluate the performance of a range of commercial coatings to reduce biofouling by mussels. To determine if these coatings could meet Reclamation's needs, we evaluated over 50 coatings and metal alloys in six broad categories:

- Conventional epoxies (which do not have any mussel control)
- Antifouling coatings (which use a biocide to prevent mussel settlement)
- Foul release coatings (which rely on physical properties to make it difficult for mussels to strongly attach)
- Fluorinated powder coatings
- Metallic coatings
- Metal alloys

Prior to this study, Reclamation did not have a strong need for coatings to address biofouling problems.

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Coatings are tested in waters at Reclamation's Parker Dam on the Lower Colorado River, California where mussels reproduce almost year round. We are able to test coatings here in both still and moving water.

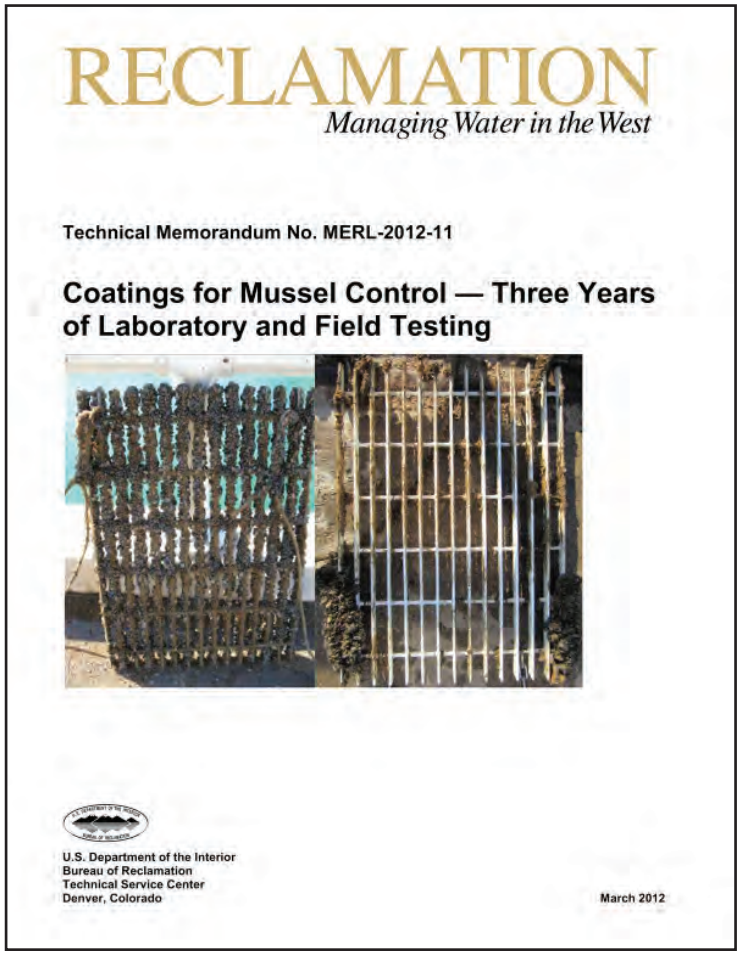
After immersion in the reservoir for several months, the coated metal grates are examined to determine the extent to which mussels have attached, and also the force required to remove the attached mussels. At this time, the data indicate that the silicone foul-release coatings are the most promising at deterring mussel attachment in both static (non-flowing) and dynamic (flowing) conditions. This finding was surprising, because the quagga mussels did not attach to the silicone surfaces at all. This contradicts what manufactures have found in the shipping industry, that marine fouling organisms attach weakly to silicone surfaces.

Unfortunately, the majority of these coatings are soft and not very resistant to abrasion or gouging. Nevertheless, for conditions that do not expose structures to heavy debris impacts, these coatings may perform well. Surprisingly, although they are soft, the silicone foul release coatings have superior erosion resistance than epoxy coatings for sediment and silt-laden waters and, in this respect, are comparable to abrasion-resistant ceramic epoxies.

Future Plans

Future research is needed to further identify and evaluate new commercially available foul release technologies that will hopefully exhibit desirable abrasion and gouge resistance properties while maintaining foul-release performance. As technology advances, there may eventually be a durable foul-release coating that prevents mussel attachment. Additional research is needed to determine the critical flow rates required for self cleaning of durable foul release, fluorinated powder, and elastomeric coatings.

Reclamation anticipates that its first opportunity to install foul-release coatings will be in fiscal year 2013 at Parker Dam in California as part of the rehabilitation of a trashrack structure.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Managing Water in the West

Technical Memorandum No. MERL-2012-11

Coatings for Mussel Control — Three Years of Laboratory and Field Testing

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

March 2012

"The silicone and fluorinated silicone foul release coatings have been successful thus far in preventing or minimizing fouling. The limitations will be when debris is present in the water that will rub, abrade, or gouge the coating. These coating systems should work well on infrastructure that is free of debris."

Allen Skaja,
Principal Investigator

More Information

Coatings for Mussel Control — Three Years of Laboratory and Field Testing. **Technical Memorandum No. MERL-2012-11, Reclamation, 2012.**

This report combines all the knowledge gained in the past three years of Reclamation research on coatings for mussel control.

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

San Joaquin Selenium Solutions: From Research to Reality

Research provided innovative alternatives to address selenium in irrigation drainage

Bottom Line

The biotreatment pilots provided data for feasibility-level designs and cost estimates of full-scale biotreatment plants to remove selenium in the San Joaquin Valley.

Faster, Better, Cheaper

The pilot-scale testing showed that this technology can successfully remove selenium to below 10 micrograms per liter (µg/L) from the DP-25 drainage water significantly faster than other competing technologies.

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Collaborators

- **San Luis Unit Irrigation Districts**
- **California Department of Water Resources**
- **Other Reclamation Programs**

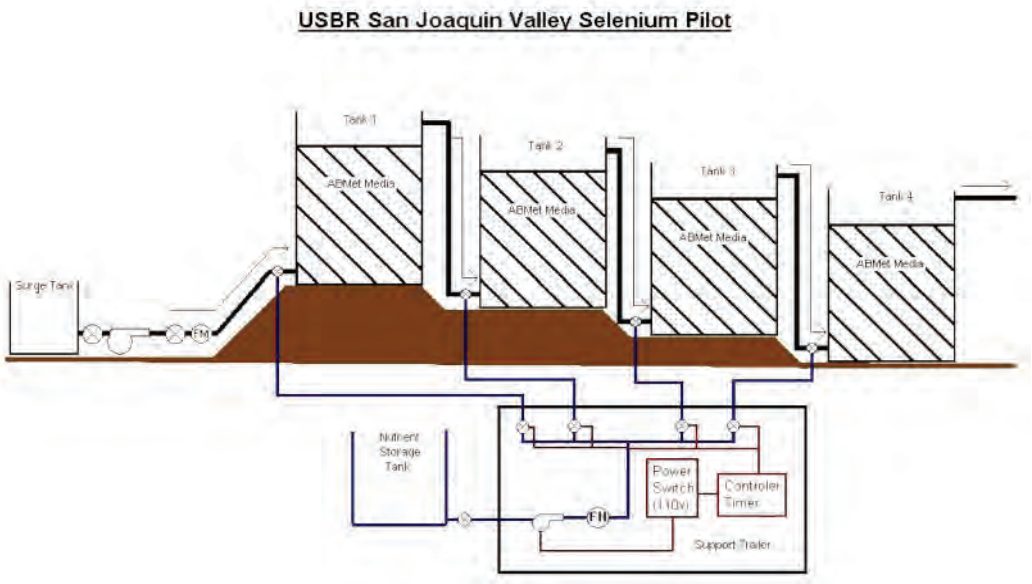
Problem

Selenium concentrations in irrigation drainage can lead to serious environmental problems. High selenium concentrations transported via the San Luis Drain into the Kesterson National Wildlife Refuge were linked to reproductive problems, deaths, and deformities of waterfowl. These findings led to closing the San Luis Drain and the Kesterson Reservoir in 1985. Currently, irrigation districts in the San Luis Unit, including the Panoche Drainage District and Westlands Water District in the San Joaquin Valley near Firebaugh, California, have drainage effluents containing elevated levels of selenium. The search continues for viable and long-term ways to dispose of or treat this effluent.

Solution

This Science and Technology Program research project supported a patrnership among Reclamation's Technical Service Center and Mid-Pacific Region with the San Luis Unit irrigation districts and the California Department of Water Resources. We contracted with Applied Biosciences (now part of Zenon Membranes Solutions, a division of GE Water) to conduct pilot studies at Panoche Drainage District and Westlands Water District (at Red Rock Ranch) to determine the cost and performance of the Advanced Biological Metals Removal Process (ABMet®) technology to remove selenium from agricultural drain water. Applied Biosciences initiated a pilot-scale study to test the removal of selenium from the district's drainage water. The initial testing was from June to October 2003.

The biotreatment technology used micro-organisms to reduce dissolved selenium to insoluble elemental selenium, which is removed from the water in the bioreactor tanks.



Schematic for the San Joaquin Valley Selenium Pilot Plant.

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The tanks are filled with granular activated carbon (GAC) media, which provides a surface area for the microbes to attach to and come into contact with the dissolved selenium. The reduced selenium is retained and accumulates within the biological film and GAC media until the tanks are backwashed weekly at a high flow rate.

The selenium biotreatment pilot consisted of two bioreactor tanks operating in series, with a capacity of 1-3 gallons per minute (gpm) to treat raw drainage or concentrate from reverse osmosis treatment. The bioreactor pilots operated periodically in phases from June 2003 until September 2006. During each phase of operation, Reclamation and the contractor (Zenon-GE) made modifications to the pilot equipment and operations in response to observed flow and performance. These modifications included design and operational changes to all facets of the system including tanks, plumbing, nutrient dosage, flow distribution, instrumentation, pumps, backwashing flow rate and frequency, data acquisition, etc. The modifications resulted in greater process control, more stable operation, and improved selenium removal performance. Both pilots operated for about 3 months after the final equipment modifications.

Results

Data collected in the biotreatment pilot studies were used to develop designs and cost estimates for full-scale treatment plants. Design assumptions derived from the pilot studies included:

- Selenium can be removed to 10 µg/L or less within about 6 hours of residence time in the bioreactors.
- Downward flow through the bioreactor tanks is required to avoid gas binding in the GAC media.
- Two-stage bioreactor design: Stage 1 bioreactor is designed to remove nitrate, and the Stage 2 bioreactor is designed to remove selenium.
- Weekly backwash of bioreactors is required to remove accumulated biosolids and avoid flow blockage.

A feasibility-level design was developed for three biotreatment plants in the San Joaquin Valley by Zenon-GE. The design inflows and influent concentrations represent the concentrate flow from a co-located reverse osmosis treatment plant.

The heart of the full-scale selenium treatment plant is the Zenon ABMet® biotreatment train. A train consists of two bioreactors operating in series. Each train will treat a maximum feed flow of 285 gpm. Each bioreactor tank will be constructed of reinforced concrete approximately 40 feet long x 16 feet wide x 32 feet high and contain a 22-foot bed of GAC media.

The biotreatment plant will include a feedwater tank, bioreactor trains, and a post-treatment oxidation tank(s) to convert any residual selenium in the effluent back to its oxidized soluble form. The backwash system will include a backwash water storage tank and backwash clarifier(s). Ancillary systems include nutrient feed and sludge dewatering. One of the more important of these ancillary systems is the nutrient that is used as a carbon source for the micro-organisms in the bioreactors. Since the molasses-based nutrient is quite viscous and injected into the bioreactors at periodic intervals, the nutrient system is designed to maintain continuous flow circulation through the plant.

"This is an excellent example of some of the many ways Reclamation and innovators can approach seemingly intractable problems and provide a larger suite of potential solutions for decisionmakers rather than being limited to off-the-shelf solutions. This project shows the research process of problem identification, testing of conventional alternatives and research of new and unproved techniques, followed by pilot-scale testing, extensive internal and external technical review, and now demonstration leading to full-scale implementation."

Kevin Price,
Advanced Water Treatment Research Coordinator

More Information

San Luis Drainage Feature Re-evaluation Feasibility Report. Appendix E: Selenium Biotreatment Pilot Reports
www.usbr.gov/mp/sccao/sld/docs/sldfr_report/Appendices/AppE-Final.pdf

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Reverse Osmosis Energy Savings for Seawater and Brackish Water

Equipment and process design improvements reduce desalination energy usage and associated costs

Bottom Line

The cost and energy needed to purify seawater through reverse osmosis can be reduced.

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Reclamation:

- **Science and Technology Program**
- **Technical Service Center**

Affordable Desalination Collaboration (ADC)

The majority of project funding came from the California Department of Water Resources for seawater testing and the Texas Water Development Board for brackish water testing.

Problem

The need for more water continues to grow as populations increase, droughts occur, climate change effects escalate, and other factors pressure existing water supplies. Reverse osmosis (RO) membrane technology can provide purified water from seawater and inland brackish waters but with higher costs and more energy use than using non-saline sources.

Energy use is the most expensive and environmentally taxing component of desalination operations. To reduce both costs and environmental impacts, the energy required for desalination operations must be reduced. Isobaric energy recovery devices can reduce desalination energy use and associated costs.

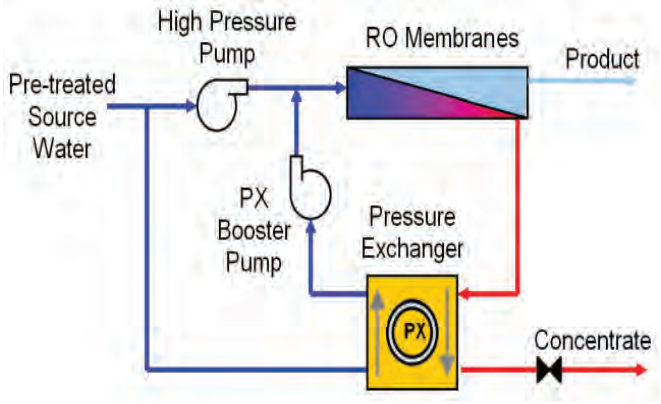
Isobaric energy recovery devices have been widely used in seawater, and optimizing the latest RO technology lowers energy use and costs. However, the industry and public are often unaware of this and may still believe that this is as cost prohibitive for most applications as it has been in the past. In brackish water treatment, the use of isobaric energy recovery devices to reduce desalination energy use and associated costs has not been widely implemented and demonstrated to the industry.

Solution

To demonstrate how the cost and energy needed to purify seawater through RO can be reduced, this Science and Technology Program research project provided a demonstration of the most efficient combination of the latest commercially available equipment (including a full-size 8-inch RO membrane, high-efficiency pump, and energy recovery devices).

Seawater RO

Seawater RO using an optimized process creates an optimal cost point at 6.81 kilowatthours per thousand gallons (kW-hr/kgal) with a 50-percent recovery and a flux of 9 gallons per square foot of membrane per day. Alternatively, an optimal energy point of 5.98 kW-hr/kgal (1.58 kW-hr/m^3) is achieved with a 42.5-percent recovery.



Seawater desalination pilot components and test schematic.

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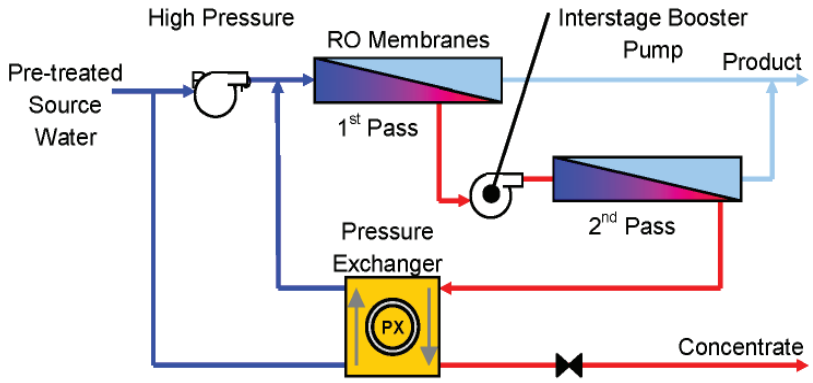
Brackish Water RO

Since brackish water RO treatment requires less energy than treating seawater, net energy usage and cost benefits attained are modest by comparison. Net benefits are most promising for water with low levels of silica as scaling of pressure exchangers limits recovery.



Brackish water desalination pilot components and test schematic.

The innovative flow regime shown above did not produce a significant energy benefit, and an increased recovery was not possible due to silica scaling. Standard process configurations along with pressure exchanger technology showed both an energy benefit over other energy recovery devices and a projected positive net decrease in the cost of water produced.

Future Development Plans

There are no specific future development plans for this research. Further reduction in RO energy use will likely come from small incremental improvements driven by public research funding and competition between equipment manufacturers. The technology is approaching thermodynamic limits that cannot be improved upon.

More Information

The brackish water project has two main sources for additional information:

- Report: Energy Optimization of Brackish Groundwater Reverse Osmosis Desalination from the Texas Water Development Board (TWDB)
- Conference Proceedings of the American Membrane Technology Association's 2011 Annual Conference (July 17 - 20, 2011 Miami, Florida)

The seawater project has two primary sources for additional information:

- Report: Optimizing Seawater Reverse Osmosis for Affordable Desalination from California Department of Water Resources (forthcoming)
- Conference Proceeding of the International Desalination Association World Congress in 2009

"Desalination technology benefits all water managers and agencies that need to use saline water sources to minimize the risk of water supply shortages. Seawater and some brackish water sources are more reliable than many freshwater sources."

Kevin Price,
Advanced Water Treatment Research Coordinator

Where Have We Applied This Solution?

A unique collaboration of leading government agencies, municipalities, RO membrane manufacturers, consultants, and others formed the Affordable Desalination Collaboration (ADC) in 2004 with the goal of reducing seawater desalination energy usage and associated costs. The ADC developed a multi-phased effort that built and operated a demonstration desalination pilot at the U.S. Navy's Seawater Desalination Test Facility in Pt. Hueneme, California. Following the pilot seawater desalination project success, the ADC reconfigured the pilot for brackish RO energy recovery and mobilized at the Kay Bailey Hutchison Desalination Plant in El Paso, Texas.

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Renewable Energy Options for Desalination

Using renewable energy to reduce desalination costs

Bottom Line

Reclamation is exploring the use of renewable energy sources for the desalination process.

Better, Faster, Cheaper

We are working to reduce costs and address environmental impacts to use renewable energy to provide sustainable water supplies in the future.

A solar still.

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Problem

Desalination by any process requires energy. The amount of energy needed depends on the amount of salt in the water—in general, the higher the salt concentrations, the more energy is needed. Other factors include source water salinity, required product water salinity, composition of the salinity in both streams, amount of desalinated water to be produced, the desalination process used, temperature of source, and the quality of the product and reject water. Renewable energy increases the sustainability of desalination processes, but research is needed to reduce overall costs and environmental impacts. Reclamation has funded several studies to investigate ways to use renewable energy for desalination.

Solutions

Solar

A variety of solar collection systems can power a variety of desalination processes.

- **Solar stills** allow sunlight to pass through a transparent material and be absorbed by a dark surface behind it. This heated dark surface helps evaporate the salty water. The vapor rises into tubes where it condenses, drains down, and is collected. Tubes rather than walls provide additional surface area for water to condense. Suns River Solar Still

- **Photovoltaic systems** can convert solar energy to electricity for an electrodialysis or reverse osmosis desalination system. Photovoltaic Reverse Osmosis Desalination System

- **Salinity gradient ponds** (also called salt gradient ponds) trap heat as the stratified water contains various levels of salt concentrations. The higher the salinity concentrations in the water, the more heat the water can store. Hot, salty water from the bottom of the solar pond heats the feed water to raise the vapor pressure. Cooler, less salty water from the surface of the solar pond cools the water vapor into distillate.

  ◊ **Membrane distillation** operates best at very low pressures, allowing for less expensive piping materials and fewer problems with leaks and pump failures, thus lowering capital and operational costs. Solar and Waste Heat Desalination by Membrane Distillation *(for further membrane distillation work, see Desalination and Water Purification Reports #87, #96, #99, and #134)*

  ◊ **Multi-effect, multi-stage (MEMS)** flash distillation uses energy from the salinity gradient pond as a heat source to the MEMS systems. This small pilot system showed the potential for reducing operation, maintenance, and concentrate disposal costs in treating reverse osmosis or nanofiltration concentrate. Thermal Desalination Using MEMS & Salinity-Gradient Solar Pond Technology

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- **Solar concentrating sand beds** may further reduce the volume of concentrate from desalination processes. This study demonstrated that halophytes (salt-loving plants such as *A. nummularia*) combined with sand beds can be used in a concentrated disposal process. Halophyte Crops and a Sand-Bed Solar Concentrator to Reduce and Recycle Industrial, Desalination, and Agricultural Brines

Wind

Wind turbines supply both mechanical and electrical energy sources. Mechanical power may be supplied to either mechanical vapor compression or reverse osmosis desalination processes. Electrical power may be used for the desalination processes, including electrodialysis.

- Renewable energy sources can be combined: a windmill to power a reverse osmosis system and solar energy to drive the system's instrumentation. Wind-Powered Reverse Osmosis Water Desalination for Pacific Islands and Remote Coastal Communities

- A wind turbine array and intelligent control systems can reduce overall energy costs. Wind Power and Water Desalination Technology Integration

Wave

Ocean waves are becoming a more popular source of renewable energy in areas such as the northwestern U.S. coastal regions. Ocean wave technologies vary in location from nearshore to far offshore. Mechanisms applied to convert wave power to energy are also diverse. As wind blows over the surface of the ocean, waves are formed and energy may be extracted using wave power devices. Reclamation has recently funded a project with Resolute Marine Energy to design, build, and test a pressure and flow rate regulation system in conjunction with a seawater reverse osmosis system powered by wave energy. Design and Testing of a Pressure Regulation Subsystem for a Wave-Driven Desalination System

Geothermal

Geothermal resources provide electricity or thermal energy to power various desalination processes. Reclamation has sponsored a pilot test project in California to demonstrate the technical and economic feasibility of using geothermal energy. Vertical Tube Evaporator Thermal Desalination Pilot Test

Collaborators

- **CalEnergy Operating Corporation**
- **Resolute Marine Energy**
- **Sephton Water Technology**
- **Suns River**
- **Texas Tech University**
- **University of Arizona**
- **University of Hawaii at Manoa**
- **University of Texas at El Paso**

Photos (left to right): Nanofiltration concentrate may be recycled through the process of evapotranspiration utilizing halophyte shrubs such as A. nummularia *halophyte shrub, Reclamation-sponsored pilot test project in California to demonstrate the technical and economic feasibility of using geothermal energy, and harnessing power for a reverse osmosis system with a windmill in Seminole, Texas.*

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Renewable Energy Assessment for Reclamation

Determining ways to use renewable energy on Reclamation lands

Bottom Line

These tools provide a way for Reclamation managers to determine the potential for renewable energy at their facilities and lands.

Better, Faster, Cheaper

In some locations, wind and solar energy can cost-effectively augment Reclamation's hydroelectric power as sustainable non-polluting sources of energy.

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Collaborators

- **Phoenix Area Office, Reclamation**
- **National Renewable Energy Laboratory (NREL)**
- **Central Arizona Water Conservation District**
- **Bureau of Land Management**

Problem

As environmental concerns over carbon-based power generation increase, Reclamation is exploring the possibilities of adding solar and wind energy to its renewable hydroelectric generation portfolio. Solar and wind could be used to generate power for the overall electric grid (utility scale) or just to meet the power needs of an individual building or plant (facility scale).

To analyze the potential for energy use in our system, we need consistent, accurate, and reliable methods. Determining the potential, suitability, and costs for renewable energy depends on many factors such as slope, insolation (the amount of sunlight), wind resource potential, proximity to power transmission, access to roads, adjacent public or state lands, and regional market potential. Undertaking these investigations will help Reclamation make informed decisions about wind and solar energy.

Solution

In 2011, Reclamation's Phoenix Area Office initiated a study to assess the economic feasibility and technical suitability of renewable energy use at its facilities. To assist in this effort, the Research and Development Office established an Inter-Agency Agreement with the National Renewable Energy Laboratory (NREL) to assess and analyze renewable energy generation opportunities within Reclamation. The Reclamation-NREL Team:

- Used geographic information system (GIS) technology to identify and rank the potential for solar and wind energy development on Reclamation lands
- Conducted detailed technical and economic assessments of these potentially suitable lands
- Identified Reclamation facilities with the best potential to deploy facility-scale solar and/or wind energy resources
- Conducted a technical and economic study of deploying wind or solar energy at three Reclamation sites north of Reclamation's Hayden-Rhodes Aqueduct right-of-way
- Examined the possibility of installing solar energy at the Phoenix Area Office building

Conclusions and Recommendations

The team has developed a methodology to examine the opportunities for developing renewable energy on Reclamation properties. This method uses GIS overlays to examine slope and insulation as well as other suitability factors, and then uses financial analyses to determine feasibility.

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NREL has released a final report detailing the potential for renewable energy in the Phoenix Area Office service area. Recommendations include:

- Revisit cost analyses if solar prices continue to drop and the cost of power from the Navajo Generating Station increases
- Pre-qualify the development potential of the most promising sites, especially in areas that are near transmission lines that have capacity, and areas with the potential for very low environmental and cultural impact
- Once Reclamation determines that a site has strong potential for development, they consider issuing a competitive lease solicitation that can be used to evaluate industry interest in moving forward with a project at that site

NREL recommends that Reclamation further study the Hassayampa and other regional sites as the most suitable locations for possible replacement project power. NREL further recommends that the Phoenix Area Office consider installation of additional photovoltaic panels because of the high cost of energy, dropping cost of photovoltaics, excellent solar resource, and excellent incentives.

Project team identifying renewable energy opportunities at Hassayampa, Arizona.

"Reclamation has several cost-effective opportunities to integrate renewable energy sources into its facilities as well as along existing right-of-ways for water supply projects such as the Central Arizona Project. Integration of renewable energy technologies with critical water supply infrastructure will allow Reclamation to be at the forefront of meeting national and regional sustainability and critical infrastructure goals."

Mitch Haws,
Program Development Division,
Phoenix Area Office, Reclamation

More Information

Haase, S., K. Burman, D. Dahle, D. Heimiller, and O. Van Geet. 2012, Assessment for the Bureau of Reclamation. www.nrel.gov/docs/y12osti/53697.pdf

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Effects of Climate Change on Riparian Vegetation Structure, Water Uptake, and Dependent Pollinators

How could climate change affect semiarid riparian habitats, and what measures can we take?

Bottom Line

Reclamation needs to understand how the environmental costs and benefits of its water management operations will change as local and regional environmental conditions change.

Better, Faster, Cheaper

Understanding the relationships between Reclamation's operations and ecological change enables Reclamation to develop strategies that can maximize benefits and avoid or minimize undesirable effects while meeting water and power delivery and other obligations.

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Questions

Riparian ecosystems (already greatly altered by water management, land development, and biological invasion) are being further altered by increasing atmospheric carbon dioxide (CO_2) concentrations and climate change, particularly in arid and semiarid (dryland) regions. Reservoir inflow timing and quantity, evaporative losses, and the timing and amount of downstream demand are also affected by this climate change. Thus, it is important for water resource managers to understand how climate change and climate-driven changes in streamflow are likely to affect habitat and what operational measures we can take if necessary to mitigate those impacts.

Analyses

This Science and Technology Program research project reviewed the scientific literature concerning likely effects of rising atmospheric CO_2 concentrations and climate change on riparian ecosystems in semiarid and arid Western North America.

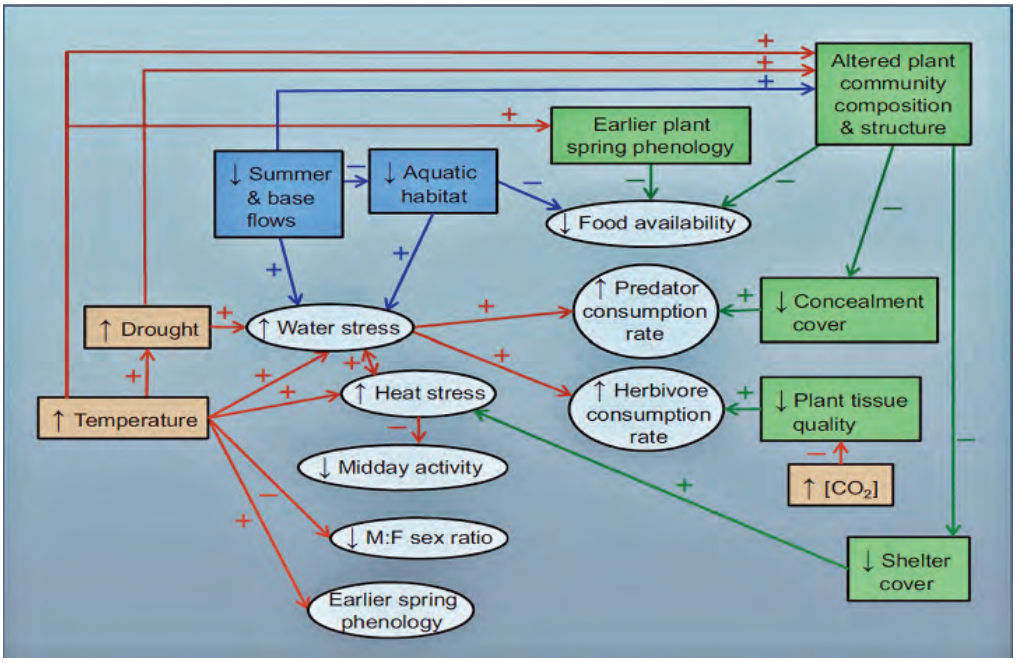

Image shows the potential effects of elevated CO_2, climate change, climate-driven streamflow, and plant community changes (rectangles) on riparian animals (ovals). Not all potential linkages discussed in the text are shown. Together, these effects will have complex, species-specific and community-specific impacts on riparian animal survival, recruitment, population dynamics, geographic distributions, community composition and structure, and trophic and symbiotic interactions.

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Reclamation and U.S. Geological Survey researchers:

1. Summarized expected changes in climate, hydrology, and water management.
2. Considered likely effects of those changes on riparian plants, animals, biotic interactions, and soil processes.
3. Identified knowledge gaps that hinder predictions of riparian ecosystem responses and sound water management planning and adaptation measures.

Answers

Together, climate change and climate-driven changes in streamflow are likely to:

- Reduce the abundance of dominant, native, early-successional tree species
- Favor herbaceous species and both drought-tolerant and late-successional woody species (including many introduced species)
- Reduce habitat quality for many riparian animals
- Slow litter decomposition and nutrient cycling

Potential Actions

Climate-driven changes in human water demand and associated water management may intensify these effects. On some regulated rivers, however, reservoir releases could be managed to protect riparian ecosystems. Outcomes of adaptation measures can be predicted by linking models of future climate scenarios, land cover, water demand, and water management.

Human adaptation measures—actions that increase resilience and reduce vulnerability of natural and human systems—will also shape riparian ecosystem responses to climate change. Adaptation options for riparian ecosystems will vary across watersheds and may include both proactive and reactive approaches. Proactive management is aimed at maintaining or increasing system resilience to climate change in advance of changes occurring. Examples include:

- Increase the scale of protected area networks and connected private lands
- Secure water rights for environmental flows
- Implement water conservation measures or cropping pattern adjustments
- Restore riparian vegetation to increase habitat connectivity
- Promote linkages between aquatic and terrestrial ecosystems
- Expand thermal refugia for wildlife
- Protect genetic diversity

"Semiarid and arid Western North America is environmentally diverse. However, many climate-change effects will vary in size or direction across the region. Immediate research priorities include determining riparian species' environmental requirements and monitoring riparian ecosystems to allow rapid detection and response to undesirable ecological change."

Perry et al. 2011

More Information

Perry, L.G., D.C. Andersen, L.V. Reynolds, S.M. Nelson, and P.B. Shafroth 2012. Vulnerability of riparian ecosystems to elevated CO_2 and climate change in arid and semiarid western North America. Global Change Biology 18(3): 821-842.

www.fort.usgs.gov/Products/Publications/pub_abstract.asp?PubID=23228

Collaborators

U.S. Geological Survey

RECLAMATION Managing Water in the West

June 2012
Research and Development Office
Bulletin 2012-15

The Knowledge Stream
Research Update

Establishing Swimming Performance Criteria for Fish

Using fish swimming performance data to improve the design and operations at Reclamation facilities

Bottom Line

These studies provide data for improved design and operation of fish screens and fish passage structures.

Better, Faster, Cheaper

This field-based fish holding and experimental setup can be used for projects Reclamation-wide.

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Collaborators

Reclamation:

- **Montana Area Office**
- **Klamath Basin Area Office**
- **Tracy Area Office**
- **Pacific Northwest Region**

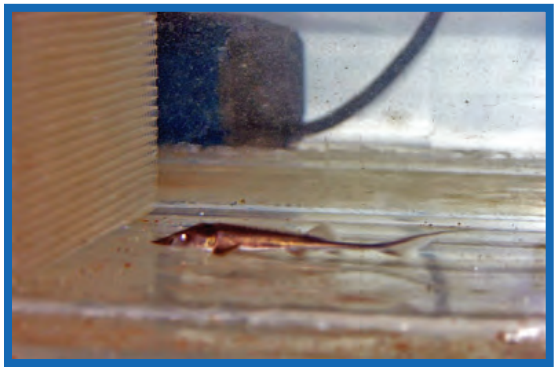
Confederated Tribes of the Umatilla

Problem

Understanding how well various species of fish swim under varying flow velocities is crucial for the design and operations of Reclamation's fish passage and fish screening facilities. For example, flow velocities near intake structures that are higher than a fish can handle could contribute to entrainment losses. However, if we know the swimming performances for particular life stages of a fish, we can identify appropriate locations to apply innovative fish barrier technologies such as non-physical barriers that use light, sound, and bubble curtains to limit potential entrainment loss. Moreover, by understanding swimming performances we can develop effective procedures, facility components, and equipment that will improve fish survivability. Similarly, experimental methodology, such as tagging or marking procedures used in mark and recapture studies, that affect the swimming performance of fish can contribute to biased test results (see Sutphin et al. 2007). Thus, a clear understanding of the effects of experimental methodology on fish swimming performance is also key to analyzing fish and potential effects on fish for Reclamation decisions related to operations, maintenance, new projects, and more.

Solution

To help provide these data for Reclamation analysts, engineers, and decisionmakers, this Science and Technology Program research project conducted multiple independent fish swimming studies on fish at Reclamation facilities. We worked with regional managers and biologists to identify the specific information about swimming performance needed to improve Reclamation's procedures or operations. The type of swimming performance evaluated was targeted to meet the demands of the particular species tested and regional science needs.



Late-larval pallid sturgeon in one of our fish swimming flumes.

Larval Pacific lamprey being inserted into our fish swimming flume for testing. The fish swimming flume is inside our mobile testing laboratory.

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Our three fish swimming chambers were designed, built, and calibrated by Reclamation's Technical Service Center's (TSC) Model Construction Group and Machine Shop. Some of these studies were conducted under laboratory conditions at the TSC.

However, most of species tested were species which are of special concern and/or are threatened and endangered (Pacific lamprey [*Lampetra tridentate*], Klamath River Basin suckers, and Chinook salmon [*Oncorhynchus tshawytscha*]). Tests on these species were undertaken at or near fish collection sites using Reclamation's Mobile Testing Laboratory. This new and innovative method minimizes fish handling and transportation; tests fish using their native waters with a natural temperature regime, photoperiod and water chemistry; and typically permits return of test fish to their natural system (thus minimizing mortality of threatened and endangered species). Field-based testing can also provide a cost savings to Reclamation, because it reduces the need to secure fish transportation permits and employee time necessary to transport fish.

More Information

Please see the more comprehensive discussion of our research results in the following reports.

Fin clipping, visual implant elastomer, and photonic marking solution, commonly used to mark fish for mark and recapture experiments, have no negative impact on a fish's ability to swim:

- Portz, D. and Z. Sutphin. In Draft. Effects of Fin Clipping for DNA Sampling on Physiological Stress, Swimming, and Survival of Chinook Salmon. Tracy Fish Collection Facility Studies. Volume X. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.

The tested vacuum pump could be used at hatcheries and other Reclamation facilities to efficiently move fish into tanks:

- Portz, D. and Z. Sutphin. In Draft. Evaluation of Fish-Friendly Vacuum Pump Systems to Remove Salvaged Fish from Recessed Cylindrical Holding Tanks at the Tracy Fish Collection Facility. Tracy Fish Collection Facility Studies. Volume X. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center.

A mobile, field-based laboratory can be employed in an efficient manner to measure the swimming performance of fish:

- Sutphin, Z., C.A. Myrick, and M.M. Brandt. 2007. Swimming Performance of Sacramento Splittail Injected with Subcutaneous Marking Agents. North American Journal of Fisheries Management 27:1378–1382.

- Sutphin, Z. and C.D. Hueth. 2010. Swimming Performance of Larval Pacific Lamprey (*Lampetra tridentata*). Northwest Science, Vol. 84, No. 1, 2010.

- Sechrist, J. and Z. Sutphin. 2010. Effects of Non-Physical Modalities at Preventing Entrainment of Klamath Basin Suckers, 2010 Annual Progress Report.

- Mefford, B. In Draft. Intake Diversion Dam Fish Screens. Evaluation of Fish Screens for Protecting Early Life-Stages of Pallid Sturgeon. Hydraulic Laboratory Report HL-200X.

"Reclamation engineers can use these data, particularly the swimming endurance curves, when designing screens and barriers for fish. These curves, which define the burst, prolonged, and sustained swimming performance, can be used to predict the approach velocities at Reclamation structures and screens that are likely to result in impingement or entrainment."

Zachary Sutphin,
Principal Investigator

Future Development Plans

We have developed the mobile fish testing laboratory and multiple fish swimming chambers and have this equipment available for testing. However, there are no current studies identified that will use this equipment.

RECLAMATION Managing Water in the West

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Research and Development Office
Bulletin 2012-12

The Knowledge Stream
Research Update

Radio Telemetered Flow Monitoring and Canal Control Technologies

Accelerating adoption of canal modernization technologies by using hands-on demonstration sites

Bottom Line

Radio telemetered monitoring and control of canals can be cost effective for irrigation districts.

Better, Faster, Cheaper

Irrigation districts can improve service while using staff and equipment resources more efficiently.

Principal Investigator

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Collaborators

Reclamation:

- **Science and Technology Program**
- **Dakotas Area Office**
- **Nebraska-Kansas Area Office**
- **Oklahoma-Texas Area Office**
- **Yuma Area Office**

Colorado Water Conservation Board

Problem

Integrating electronic control and communication technologies into irrigation districts' operations can enhance system performance and help use districts' staff and equipment resources more efficiently. Irrigation districts typically operate under differing site-specific conditions and under a wide range of institutional requirements and constraints. Moreover, they often employ unique operational strategies that have evolved in response to unique characteristics of each district.

Therefore, a generic or "one-size-fits-all" approach to integrating electronic technologies into an irrigation district delivery system's operations may yield limited returns on resources invested. Reclamation researchers have encountered multiple cases in which an irrigation district's initial efforts at using electronic technologies have fallen short of expectations and, in some cases, the equipment has been abandoned. Factors contributing to project shortcomings include limited ability to customize system functions, excessive need for technical support to maintain the system, poor performance reliability of equipment and, in some instances, high and recurring communication system costs.

Solution

This Science and Technology Program has partnered with Reclamation area offices and cooperating water districts to set up demonstration sites in areas that have had limited opportunity to implement canal modernization techniques. This provided prospective users with knowledge and experience with these technologies before decisions were made to purchase canal modernization equipment. It has also enabled Reclamation researchers to develop system components and operating functions that can significantly enhance the value a district may realize from the equipment.

Science and Technology Program funding has been leveraged by support from Reclamation's Dakotas, Nebraska-Kansas, Oklahoma-Texas, and the Yuma Area Offices. Additional cooperative support has included grant funding from the Colorado Water Conservation Board as well as extensive in-kind services provided by cooperating irrigation districts. At each site, existing equipment has been used to the extent possible. Tasks such as motorizing existing gates were performed using tools and metal fabrication skills irrigation districts typically use for regular maintenance tasks. District personnel assisted with equipment installation, which served to provide districts with a degree of in-house familiarity with operation and maintenance of the equipment. In all projects, district management and/or staff have provided input on the functions they want the electronic system to perform.

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Applications

Demonstration sites have been established at the Buford-Trenton Irrigation District in North Dakota; Angostura Irrigation District in South Dakota; Ainsworth, Twin Loups, and Bostwick Irrigation Districts in Nebraska; South Platte Ditch Company in Colorado; Tom Green County Water Control and Improvement District in Texas; and the Unit B Irrigation and Drainage District and at the Yuma County Water Users Association in Arizona.

In the left photo, Buford-Trenton ditch-riders are installing a gate motor at the end of system spill site.

In the bottom right photo, Bostwick personnel are installing an overshot gate that was fabricated in the district's shop as part of the demonstration.

Workshops that focused on operation and maintenance tasks associated with equipment installed at the demonstration sites were held in Hot Springs, South Dakota, and in Red Cloud, Nebraska, in February 2009. Approximately 20 participants attended each workshop.

A paper on the Ainsworth and Twin Loups Projects was presented at the June 2009 U.S. Committee on Irrigation and Drainage (USCID) conference in Reno, Nevada. Papers on the South Platte Ditch and Nebraska Bostwick Projects were presented at the September 2010 USCID conference in Fort Collins, Colorado. These papers may be accessed at:

- www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-0986.pdf
- www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-1048.pdf
- www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-1047.pdf

Future Plans

The Reclamation project team is currently working with the Nebraska-Kansas Area Office in planning a demonstration system at the Mirage Flats Irrigation District in Nebraska and with the Yuma Area Office in planning a demonstration system at Coachella Valley in California.

"The most important aspect of the workshop was to provide an exposure that was unavailable anywhere else.

Now our employees are wanting to make improvements faster than we can fund them."

Mike Delka,
Nebraska Bostwick Irrigation District Manager

RECLAMATION Managing Water in the West

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Bulletin 2012-11

The Knowledge Stream
Research Update

Trinity River Restoration Program's Online Data Portal (ODP)

New website allows agencies to share data for improved river system management efficiency and productivity

Bottom Line

ODP provides a framework for a multidisciplinary scientific database.

Better, Faster, Cheaper

Users can quickly retrieve and share scientific data needed on a daily basis without having to repeatedly search for the same data.

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Collaborators

Reclamation:

- **Science and Technology Program**
- **Mid-Pacific Region: TRRP, SJRRP, and Klamath Basin Area Office**

Utah State University's Water Research Laboratory

ESSA Technologies

Problem

The Trinity River Restoration Program (TRRP) is a collaborative program among Federal, State, County, and Tribal government agencies that work to restore the Trinity River and its associated Tribal and non-Tribal fisheries. These agencies must work together to share and analyze data. The TRRP is designed to adaptively manage the Trinity River restoration actions as scientific knowledge of the river advances.

Adaptive management is a systematic process of learning from the outcomes of management actions, making adjustments based upon new data, and thereby improving management. For effective adaptive management, technical analysts and decisionmakers must evaluate enormous amounts of data and information. Managing data involves much more than organizing numbers into tables. The significance and meaning of data depend on collection purposes and methods and the sampling design. This information about the data is referred to as the "meta-data" and is critical to understanding and using the data for management purposes.

Too often, however, data are stored on individual computers inaccessible to team members or cooperating agencies and do not have the associated meta-data. Given these weaknesses, and the need to efficiently maintain data quality and share the data, centralized information systems and active data management are needed for most large river restoration programs.

Solution

This Science and Technology Program research project partnered with Reclamation's TRRP Office, Klamath Basin Area Office, San Joaquin River Restoration Program (SJRRP), and other staff of the Mid-Pacific and Pacific-Northwest Regions, plus Utah State University's Water Research Laboratory and ESSA Technologies to develop an integrated information management system (then known as IIMS). Founded upon IIMS, but more flexible to the varied needs of collaborative adaptive management, the system has become the ODP. This web-based system allows all members of the TRRP to:

1. **Store data.** The ODP is a flexible information repository with storage and search capabilities for data packages, reports, meeting minutes, and other information.

2. **Share data.** The ODP enables all TRRP member agencies and organizations to access the program data within a secure and quality-controlled system.

3. **Inform the public and stakeholders.** The ODP (in conjunction with the TRRP website) provides an access point for stakeholders and the public to obtain information about TRRP and its activities.

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The ODP includes data visualization, summary statistics, and regulatory compliance tools. The ODP is a web-based suite of tools including a data package library, document library, meeting materials library, time-series data modules for point and depth data, an online map driven by ArcServer, web services for automated data queries, and a search interface that includes searching meta-data. Internal data structure is flexible to the addition of further data modules.

Benefits

Scientific analysis and decisionmaking in TRRP will improve as a result of more accurate and timely information available to water and natural resource science staff and managers through the ODP. Program stakeholders and the general public will also benefit from the easy access to information. The benefits reach far beyond the TRRP; the ODP system and protocols can be used for many river restoration and other adaptive management programs.

Application

This ODP is being used extensively for the TRRP (http://odp.trrp.net). The ODP is highly portable, and Reclamation is considering using the system for other river systems. The ODP is based upon general modules that are independent of location and, thus, can be applied to any river basin.

Future Development Plans

Additional planned data modules include a simple but flexible table for reporting performance metrics and a project proposal and management tool. Further planned extensions of ODP capabilities include data viewing for river and reservoir depth-related data as well as longitudinal changes along river courses.

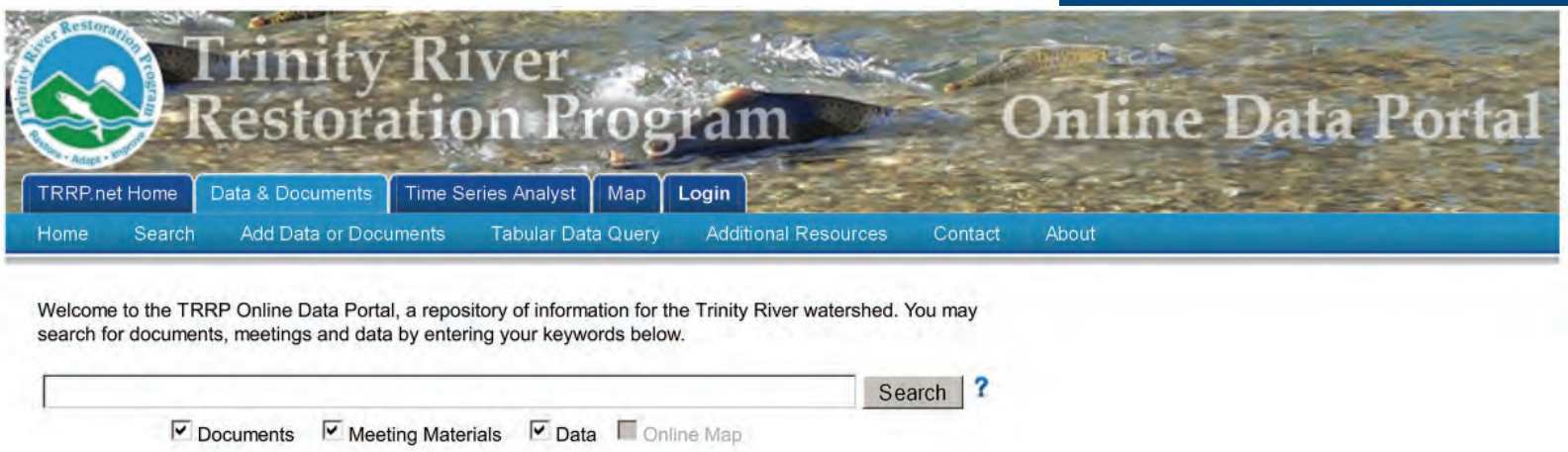
"The TRRP has been successful in linking the theory and practice of data stewardship in an efficient data portal. The TRRP system documents, preserves, and makes available valuable data collected by the program. By doing so, in a manner that is both user friendly and accessible to all interested parties, it has increased the value and utility of the datasets now and for years to come."

Eric Peterson,
Data Steward for the Trinity River Restoration Program

More Information

Trinity River Restoration Program: www.trrp.net

Online Data Portal: http://odp.trrp.net



RECLAMATION Managing Water in the West

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Bulletin 2012-22

The Knowledge Stream
Research Update

Acoustic Hydrophones to Measure Sediment Transport

Measuring underwater sounds of moving sediment can help quantify sediment in rivers

Bottom Line

Passive acoustic hydrophones can track sediment movement on a riverbed.

Better, Faster, Cheaper

Existing passive hydroacoustic technology holds promise to consistently provide reliable bedload measurements at a lower cost to better manage gravel-bed rivers.

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Collaborators

- **National Center for Physical Acoustics (NCPA) at the University of Mississippi**
- **Agricultural Research Service (ARS) in Oxford, Mississippi**
- **Trinity River Restoration Program (TRRP)**

Problem

Quantifying sediment transport in rivers and streams is important for understanding and managing regulated rivers. Sediment accumulations and deficits can adversely affect infrastructure such as levees, bridges, and wastewater treatment plants, as well as riparian and aquatic habitats. Sediment can also accumulate in reservoirs, reducing capacity. Thus, understanding how sediment moves within a river (both sediments suspended in the flow and bedload sediment, larger material that rolls along the bed of a river) is vital to managing river channel morphology, habitats, and infrastructure.

Bedload sediment (larger sand and gravel not suspended in the water) moves along the river bottom during high flows or floods and is difficult to track. Conventional methods samples isokinetically (collecting sediment when the velocity in front of the collected is the same as the adjacent velocity in the river) to collect a sample of moving bedload. Humans must operate the sampler for each test from a bridge or boat. However, these conventional sampling methods provide samples only one time and in one place. These discrete, infrequent measurements make it difficult to quantify sediment transport loads and understand how coarse sediment moves through a river system. During high flows, samplers can be difficult or even unsafe to operate, making it problematic to obtain data during floods (when most of the sediment is transported). Moreover, conventional methods have high costs for labor and lab analysis.

Solution

Underwater gravel collisions make noise, which hydrophones (microphones for underwater recordings) can measure as acoustic energy. Prior research has indicated that passive hydroacoustic technology shows great promise to obtain quantifiable measurements of coarse bedload in rivers (Barton 2006, Barton et al. 2010). Additionally, Mason et al. (2007) showed that it may also be possible to obtain information regarding sediment size from the frequency distribution of sounds. Thus, recording the sounds that gravel makes when moving along the riverbed might be used to measure the total sediment transport for different size classes of gravel. Hydrophones also may detect when bedload transport initiates. Understanding when the gravel bedload starts to move is important for calibrating sediment transport equations and for managing riverflows, particularly where causing or avoiding movement of gravel is an important goal of river restoration projects.

This Science and Technology Program research project is determining whether placing acoustic hydrophones in a river channel can provide quantitative, accurate, and continuous bedload measurements. The hydrophones use materials that produce electricity when subjected to water pressure changes (sound in water) and are widely used for military, geophysical, and marine biology applications. Hydrophones can be securely placed so that they can safely record data even during high flows. Thus, hydrophones can be programmed to provide continuous data about the bedload movement or be programmed to sample periodically. This research is in the first year of a 3-year effort with planned laboratory and field experiments.

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Application

The first field deployments of hydrophones took place on the Trinity River near Weaverville, California, in early May 2012. The Trinity River Restoration Program (TRRP) is a partnership of Federal, State, Tribal, and local government agencies, collaborating with river stakeholders to rehabilitate the managed river to the dynamic state needed to restore the world class salmon and steelhead fishery.

We are using concurrent measurements to correlate the acoustic energy from hydrophones with the measured bedload transport. During this study, the TRRP has collected bedload data using conventional methods (a TR-2 bedload sampler deployed from a cataraft collecting physical samples of moving bed material). Our hydroacoustic sampling used six hydrophones and pre-amplifiers connected to laptop PCs running LabVIEW software. The photograph below shows both methods of measuring bedload sediment at Lewiston, California, with the cataraft in the background and hydrophones (shown in circles) in the foreground, deployed at 5 and 10 meters apart.

Lab tests are also taking place at the National Sediment Lab (USDA-ARS, Oxford, Mississippi) in a 30-x 1.2-meter flume capable of transporting and recirculating gravel up to 80 millimeters. Ongoing tests explore ways to mount the hydrophone in a manner that will minimize flow noise, which could obscure the collection of sounds from gravel impacts on the channel bed. An anechoic (no echo) underwater chamber has been developed to examine the sound of individual gravel strikes with varying momentum.

Future Plans

Future field deployments of the hydrophones to obtain more calibration data are planned on the Trinity River and Elwha River in Washington State. The Elwha River study will provide information on bedload movement in a different environment and will focus on sediment changes resulting from the current dam removal projects.

Future lab tests in a model flume will measure sounds that different sized gravels make over a range of flow velocities in a controlled environment. To minimize ambient flow noise during flume experiments, gravel particles will be tethered to a variable-speed carriage to be towed over a gravel bed. Water will not be in motion during these tests.

"The Trinity has variable flows throughout the year that create dynamic geomorphic change; support fish, wildlife, and riparian vegetation; and attract rafters, guides, birders, and other outdoor enthusiasts.

Collaborative efforts such as this hydroacoustic study that help develop methods for real-time river monitoring make the Trinity River a destination for scientists and science-based adaptive management, too."

Robin Schrock,
TRRP Executive Director

RECLAMATION Managing Water in the West

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Bulletin 2012-13

The Knowledge Stream
Research Update

Using Ultrasound as a Tool for Fish Research and Management

Ultrasound provides non-invasive methods to assess fish

Bottom Line

Ultrasound is an accurate non-lethal way to identify gender, determine reproductive maturation, and assess the body condition of fish.

Better, Faster, Cheaper

Reclamation managers and researchers can use ultrasound rather than more expensive and more invasive techniques.

Principal Investigator

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More Information

Broderick, S., 2012. Using Ultrasound as a Tool for Fish Research and Management, Reclamation.

This final report has an in-depth literature search for more information.

Problem

To effectively manage our facilities and water operations, Reclamation needs methods to assess fish health for a range of project operations and restoration programs, including:

- **Dams and reservoir operations.** Managing Reclamation's facilities requires understanding potential fish issues (e.g., scope of predation, flows, and interactions with facilities) to assess these impacts and determine the most effective designs to avoid impacts.
- **Reclamation fish facilities.** Reclamation needs methods to ensure that facilities such as diversions, ladders, and counting stations can safely and effectively handle large numbers of fish, including threatened and endangered (T&E) species.
- **Habitat restoration programs.** Accurate methods to determine the benefits for fish and wildlife species from these programs are needed to ensure effective adaptive management.

Solution

Ultrasound is a well-developed technology with broad application to Reclamation resource management and research endeavors. Some advantages of the new generation of ultrasound machines are:

- Analysis and results are rapid, providing more timely information
- Methods are non-invasive and non-lethal
- Machines are portable and rugged
- Resolution is high
- Analyses are accurate (reproductive maturity and gender determination with over 90-percent accuracy)
- Analysis can reduce the number of handling events (maturity sorts) from four to two
- Ultrasound can effectively determine body fat and muscle thickness for body condition determination
- Technology can be used with a wide variety of species such as salmon, steelhead, sturgeon, and non-game fish species as well as wildlife species

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Benefits for Reclamation Researchers and Managers

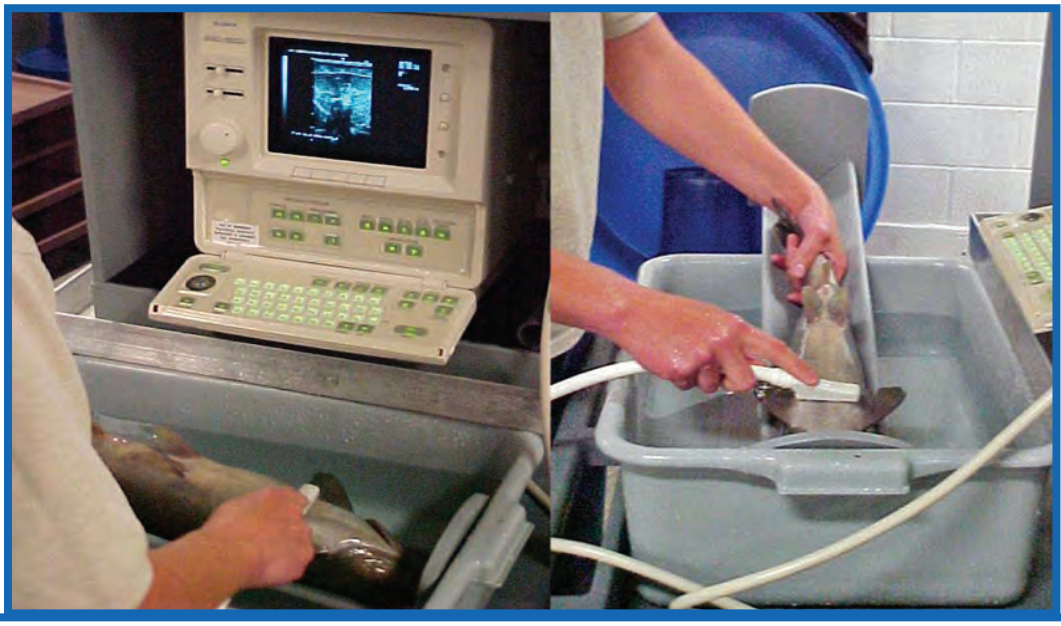
Reclamation facilities and operations can benefit from ultrasound investigations in areas of:

- **Gender and reproduction.** Ultrasound imaging is a non-invasive method to determine gender that is more accurate that visual methods. Egg development within the ovary can be measured non-invasively by measuring egg diameter on the screen. Knowing the sex and reproductive condition of fish would allow Reclamation to better manage fish facilities (e.g., diversions, ladders, and counting stations). It provides a good tool for broodstock selection for captive rearing programs.

- **Species determinations.** This technique could be used to determine the difference between resident rainbow trout and anadromous steelhead, which can assist in recovery and management efforts for T&E steelhead stocks.

- **Habitat restoration.** Ultrasonic imaging could be used in conjunction with habitat restoration efforts to measure the response of many T&E species in terms of reproductive condition. It is extremely difficult to monitor the response of populations of many T&E species such as sturgeons. Ultrasonic imaging allows direct assessment of reproductive stages of sturgeons and other species in the field with minimal impacts to the fish. This technology is minimally invasive, yet it is sufficiently sensitive to allow investigators to track the progress of individual fish through the reproductive cycle and to determine whether spawning has occurred. Fecundity of fish in restored areas can be measured and compared against fish in adjacent areas to determine if environmental cues needed to trigger development and release of eggs are present in newly restored habitats.

- **Fish handling.** Reclamation fish facilities routinely handle a large number of fish, including T&E fish species. Injury assessment is currently done using visual estimates, which are often inaccurate, resulting in an underestimation of delayed mortalities. Ultrasound would allow rapid non-invasive, non-lethal imaging to detect internal injuries so that the causes of any such injuries can be more readily identified and rectified. Conversely, ultrasonic imaging could be used to demonstrate to regulatory agencies (U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration [NOAA] Fisheries) that fish emerging from Reclamation fish facilities are uninjured and in good health.



"Ultrasound techniques can help us assess fish conditions and provide the information we need for effective facility operations with a minimal risk to critically imperiled species."

Susan Broderick,
Principal Investigator

"Ultrasound is a rapid and non-invasive technique for fish. We can identify maturity and gender in less than 5 seconds per fish. Ultrasound is extremely accurate (greater than 90%) for both maturity status and gender determination, reducing our handling events from four to just two. Ultrasound models are both inexpensive and durable. I would highly recommend investigating this technology for your use."

Carlin McAuley,
Fisheries Biologist,
NOAA Fisheries,
Manchester Research Station

Photo at left:
Applying a 7.5-megahertz linear ultrasound probe to examine a fish.

See C. McAuley, M. Chaney, and G. Baesler, 2010. Peeking at gonads. The use of ultrasound technology in a threatened Snake River Spring Chinook salmon* Oncorhynchus tshawytscha *captive broodstock program. Presentation at the World Aquaculture Society, 2010. www.was.org/documents/MeetingPresentations/AQ2010/AQ2010_0172.pdf.

RECLAMATION Managing Water in the West

June 2012
Research and Development Office
Bulletin 2012-04

The Knowledge Stream
Research Update

Using USGS LiDAR for Aquatic Habitat Mapping and Hydraulic Modeling

USGS LiDAR can measure channel depths to provide accurate representations of aquatic environments

Bottom Line

Using an airborne green laser to map terrain below water surfaces allows us to quantify physical conditions in the riverine environment. This project allows us to accurately map large areas of shallow streams with good water clarity.

Bigger, Better, Cheaper

Providing these data in any other way would be cost prohibitive or physically impossible in rugged and non-navigable streams. The airborne EAARL can cover much larger areas than sonar and using airborne mapping solves legal access problems.

Principal Investigator

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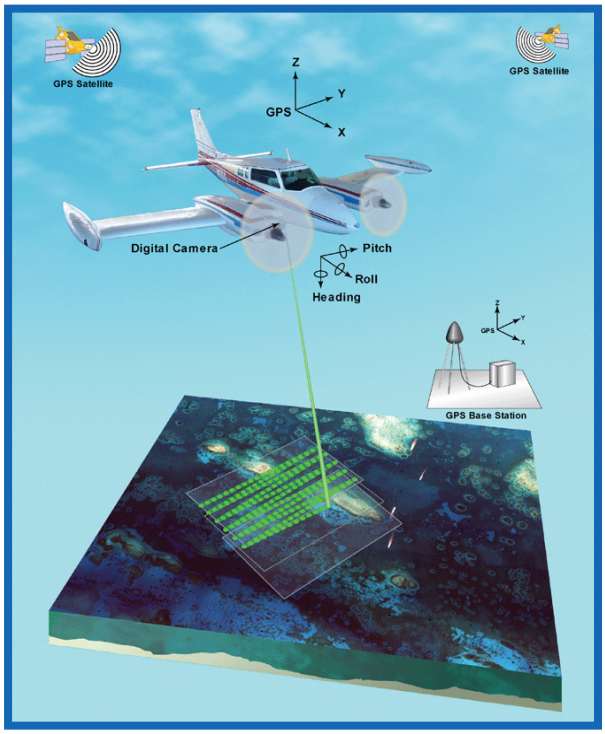
Collaborators

- **Reclamation**
- **U.S. Geological Survey**
- **U.S. Forest Service**
- **University of Idaho**
- **NASA**

Problem

Maps of the topography of streambeds are essential tools for analyzing most river management activities. These maps support habitat measurement, streamflow, temperature studies, and flow and sediment transport modeling.

Traditionally, river maps were made by field surveys. However, the costs and logistics of these field campaigns severely limit the spatial extent of the maps to very short samples of the full river domain. The larger the mapped area, the more accurate the analysis can be. Thus, methods are needed to map kilometer-scale river segments with high resolution and accuracy to assess the response of these critical environments to both management and natural disturbances.



Aerial mapping provides data for EAARL.

The Experimental Advanced Airborne Research LiDAR (EAARL) is an emerging technology that uses a green laser that can penetrate water to map the streambed and banks. However, EAARL hardware and data processing software are currently optimized for shallow marine surveys—rather than streams and rivers.

Solution

Reclamation has been collaborating with U.S. Forest Service scientists at the Boise Aquatic Sciences Lab, the U.S. Geological Survey (USGS), and University of Idaho scientists to adapt the EAARL system to mountain stream environments. We have compared EAARL data with aquatic physical habitat data collected in the field to test EAARL's capabilities. We also used EAARL data to support a one-dimensional hydrodynamic model with a water quality module and a two-dimensional aquatic habitat model. Developing the unique topographic dataset and this full suite of models greatly improves Reclamation's ability to quantify conditions and ecological responses in the riverine environment.

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Application

To assess environmental conditions and biologic interactions with Reclamation dam and reservoir operations, Reclamation and USGS collected and processed EAARL data, covering a total of 146 river miles in three streams in southern Idaho. This information is being used to help investigate flexibility in operating Deadwood and Anderson Ranch Reservoirs to improve conditions for bull trout in the river below these two dams.

Future Plans

The information gained in this research is being used to guide construction of a new EAARL sensor, custom-designed for riverine applications. In addition, the information gained from this research will be shared with peers and stakeholders through presentations at public and professional meetings, journal publications, and reports.

More information

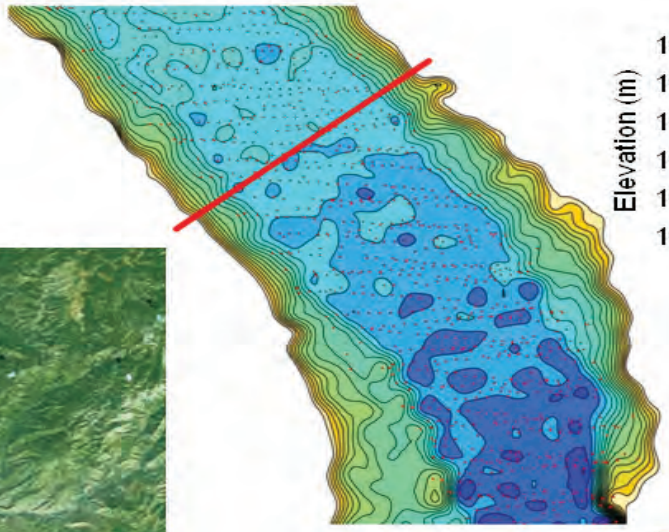
USGS LiDAR for Science and Resource Management website at:
http://ngom.usgs.gov/dsp

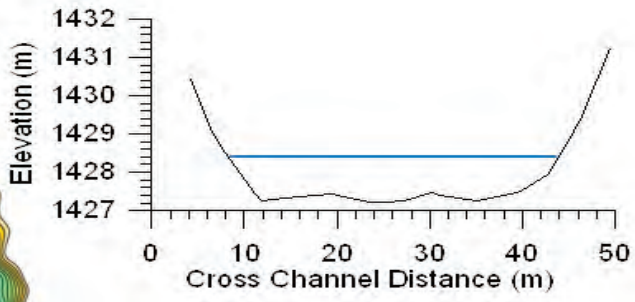
USGS, 2011 and 2009 Evaluation of LiDAR-Acquired Bathymetric and Topographic Data Accuracy in Various Hydrogeomorphic Settings in the Deadwood and South Fork Boise Rivers, West-Central Idaho, 2007 Scientific Investigation Reports 2011-5051 and 2009-5260.

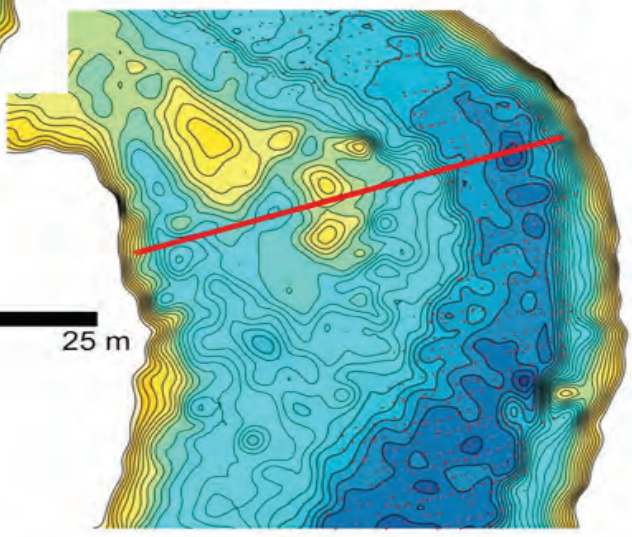
"We can use these advanced tools and practices for increasing our knowledge base to help inform our water management decisions on other rivers where we have facilities."

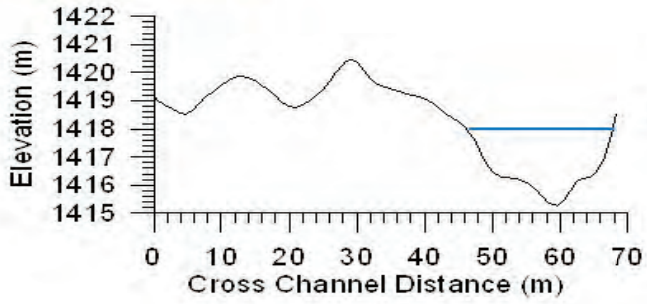
Allyn Meuleman,
Principal Investigator

Figure below: Topographic and schematic analysis for the Deadwood Reservoir and Deadwood River. Dots show bathymetric data from EAARL.









RECLAMATION Managing Water in the West

June 2012
Research and
Development Office
Bulletin 2012-29

The Knowledge Stream
Research Update

Tracking History with LiDAR

Using LiDAR to assess Reclamation's priceless and irreplaceable heritage assets

Bottom Line

LiDAR is a new tool for rapid archaeological site condition assessment.

Better, Faster, Cheaper

When applied at regular time intervals, LiDAR can provide very precise measurements of changes at archaeological sites, furnishing management with information to make informed decisions at reduced expense.

Principal Investigator

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Collaborators

- **Bureau of Land Management**
- **Idaho State Historical Preservation Office**
- **Idaho State University**

Problem

The American Falls Archaeological District in eastern Idaho is listed on the National Register of Historic Places. The district contains important archaeological sites that represent the entire span of human occupation in southern Idaho. From Paleoindians to modern Indians to pioneers on the Oregon Trail, people have always valued this area just north of the Snake River for its natural resources, spirituality, and beauty. The district contains 158 archaeological sites (131 on Reclamation land and 27 on Bureau of Land Management land) and represents almost continuous human occupation spanning more than 9,000 years.

These assets are non-collectable—they must stay in place. However, these sites are now threatened as shifting ground surfaces can cover and uncover the archaeological resources. When sites are uncovered and exposed, they can be vandalized, washed away, or removed. They are exposed to wind and water erosion, off-road vehicle use, and cattle trampling. Understanding both the natural forces and human activities that impact these sites is critical to managing and preserving these invaluable cultural resources.

Example of the detrimental effect that off-road vehicles have on an area.

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Solution

Tracking changes in the Archaeological District requires a data collection method that can cover a huge area and yet provide enough detail to determine the condition of specific features (which may be as small as a single campfire ring or as large as a 476,000 square-meter prehistoric habitation site).

This Science and Technology Program research project uses a light detection and ranging (LiDAR) system mounted on an aircraft to create finely detailed mapping of this vast area. LiDAR is a remote sensing system that collects topographic data using laser light. LiDAR can provide highly detailed three-dimensional imagery of cultural resources such as rock art and archaeological features. Archaeologists can use these data to document the baseline condition of these resources at a very fine scale. Collecting these data in the same area over a span of years can provide an understanding of erosional patterns and rates that Reclamation can then use to assist management with decisions that could alleviate–or possibly eliminate–the existing causes of deterioration.

Research to Date

The project team first assessed conditions at four important archaeological sites. The team then compared these conditions with the last survey from 20 years ago. This comparison provided a baseline to indicate the rate of change for the last 20 years. In 2011, the team flew a LiDAR flight over the entire district, including the four sites that were inventoried on the ground, to provide a comprehensive picture of current ground conditions.

The team quality controlled the data and developed a method for future comparative analysis. This methodology include three parts:

- Experimental uncertainty analysis used to "define an objective representation of the bounding limits distinguishing areas of measured change from differences potentially introduced through data collection and post-processing techniques" (Reclamation 2012)
- Data processing to process LiDAR point cloud data into three-dimensional surfaces and two-dimensional grid surfaces to calculate surface change
- Surface model comparison that will essentially subtract the second-year surface from the first-year surface to determine areas of change.

Future Plans

The team plans on conducting another LiDAR flight in 2013 and then comparing the two datasets. This will help identify specific areas within the Archaeological District that are more subject to erosion—"red flag" areas. The LiDAR comparison will also provide specific data to help determine the causes of this erosion and to help focus management's attention on addressing these causes to preserving the heritage assets. The team also plans on performing a ground survey in the "red flag" areas and setting up a monitoring system after this comparison. The amount of changes shown in the comparisons will help determine how much and how often monitoring, including future LiDAR flights, would be needed.

"This study represents a significant step in cultural resources management using a recently developed digital imaging tool and could be an enormous boon for Reclamation in both its fiscal and legal responsibilities to heritage preservation. Reclamation will likely garner national attention with this project."

Tom Lincoln,
Archaeologist, Reclamation

More Information

Reclamation, 2012
Proposed Methodology for the Application of LiDAR Technology to Improve the Management and Protection of Heritage Assets: American Falls Archaeological District, Idaho, Pacific Northwest Region. Available on request.

Future Applications

The methodology for surface model comparisons with LiDAR could be an enormous help in future applications in areas with similar geology. Comparing the surface models from LiDAR data taken over a period of years can help determine the amount of degradation and if the degradation stems from erosion.

RECLAMATION Managing Water in the West

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Bulletin 2012-02

The Knowledge Stream
Research Update

Chemical Metering and Control System

Delivers a constant, monitored flow of chemicals where needed—especially over fluctuating flow systems

Bottom Line

This patented method provides a constant concentration of a chemical, regardless of changes in water flows, in a cost-effective and reliable way.

"We are looking for partner companies to expand this prototype for a wide range of applications. Opportunities to use this system to more precisely measure chemicals in fluctuating flows are endless."

David Sisneros
Principal Investigator

Faster, Better, Cheaper

This system provides immediate feedback and can control injection rates based on flow amounts. It is accurate, uses little power, is self-contained, easy to install, and can run unattended.

For More Information

Sisneros, D., M. Lichtwardt, and T. Greene 1998. Low-Dose Metering of Endothall for Aquatic Plant Control in Flowing Water, J.Aquat. Plant. Manage. 36:69-72.

Chemical Metering Patent
www.google.com/patents/S5902749

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Problem

Releasing chemicals into a fluctuating flow system is complicated, as the ratio of chemicals to flow needs to remain the same. If the chemical is either over or under applied, problems ranging from label violations to lower effectiveness can result. Even small differences in flows and chemical concentrations can impact how well the chemical application will work. Controlling the concentrations of chemicals injected into flow streams usually requires directly measuring the chemical concentration or the flow rate.

However, measuring these concentrations in real time is impossible with some chemicals or under some conditions. Sometimes, it may be necessary to take multiple water samples, analyze the water outside of the stream, and extrapolate results—which gives a reading of past events rather than present conditions. Further, it may not be possible to accurately measure the flow rate of the stream. For example, closed channel flows may require a straight section of full flowing pipe, while open channels may require expensive weirs or gates.

Chemicals may need to be injected into flowing water for many applications including controlling aquatic weeds or algae in a canal, treating storm or wastewater, injecting nutrients or antibiotics to ensure fish health, detecting seepage from one water source to another, analyzing flow patterns, or reducing toxic metals in drainage. Similar injection systems can even help maintain nutrients in large systems like aquariums or be used in food processing and health care.

Solution

We developed and patented the Chemical Metering and Control System (patent no. US5902749), which can automatically control the injection of any chemical into any flow stream—regardless of the stream characteristics or the ability to detect and measure the injected chemical. The system adds non-toxic, fluorescent dyes to the injected fluid to monitor chemical concentrations in real time. This system can tell the exact composition of the chemicals based on the correlation with the dye indicators (e.g., if the chemical is 2 parts per million [ppm], then the dye is 0.2 ppm).

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This system offers many advantages, such as:

- **Environmentally safe.** The system ensures that the correct amount of chemical is injected, according to specified label rates or Environmental Protection Agency regulations.
- **Automated.** The system automatically compensates for changes in chemical properties and can be left to operate unattended for extended periods of time.
- **Durable and low maintenance.** The system can operate from a battery power, DC power, and solar panels.
- **Portability.** The system can be installed and activated in less than 30 minutes.

Application

We have successfully used a prototype system for aquatic weed and algae control in the Salt River Project, Arizona; the Northside Canal near Jerome, Idaho; and the Farmer Independent Ditch near LaSalle, Colorado.

Benefits

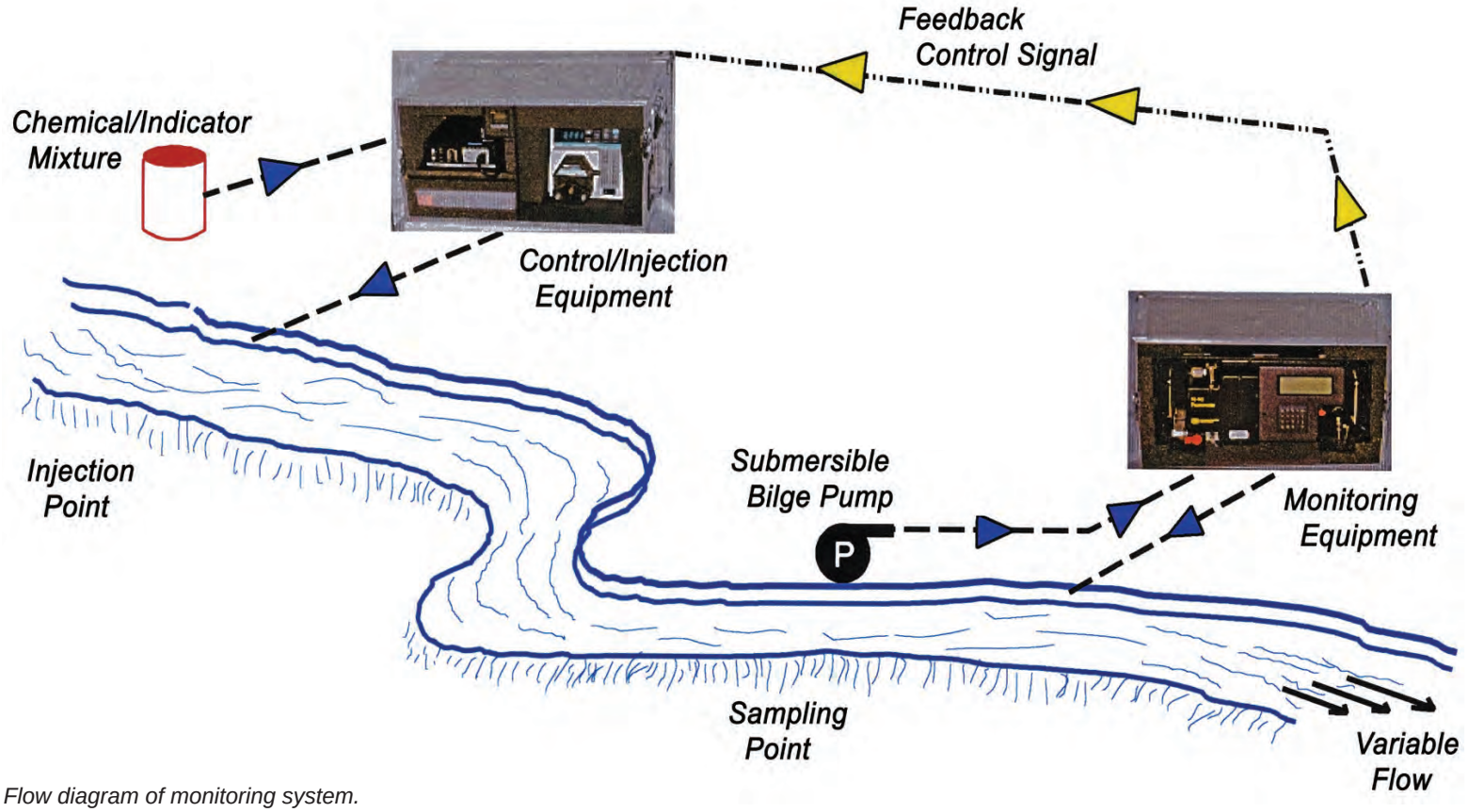
Reclamation has advanced the state-of-the-art for automated control and measurements of injected chemicals into open or closed flow streams. Reclamation can use this system for more effective operations, environmental restoration, and canal and facility maintenance.

Future Plans

This system is now patented and available for licensing. Reclamation is seeking companies interested in licensing and commercializing this technology.

"The control system in conjunction with the pumping system has excellent potential for precision delivery of herbicides in linear flow systems. The ability to deliver these defined doses should spur future studies with which to determine the minimum rates and exposures needed to control given nuisance species."

David Sisneros,
Principal Investigator



Flow diagram of monitoring system.

RECLAMATION Managing Water in the West

June 2012
Research and Development Office
Bulletin 2012-14

The Knowledge Stream
Research Update

Hydroacoustic Surveys of Pelagic Fishes in the Glen Canyon Dam Forebay

Conducting research to help manage endangered species

Bottom Line

To help understand the potential for entrainment of warm-water, non-native fish into the Colorado River below Glen Canyon Dam, this field study was conducted (2007 - 2009) to help establish base-line data for monthly density and distribution of pelagic fishes within the dam forebay.

Better, Faster, Cheaper

This research allows Reclamation to proactively evaluate potential impacts to endangered species for better decisionmaking.

Principal Investigator

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Collaborators

Reclamation:

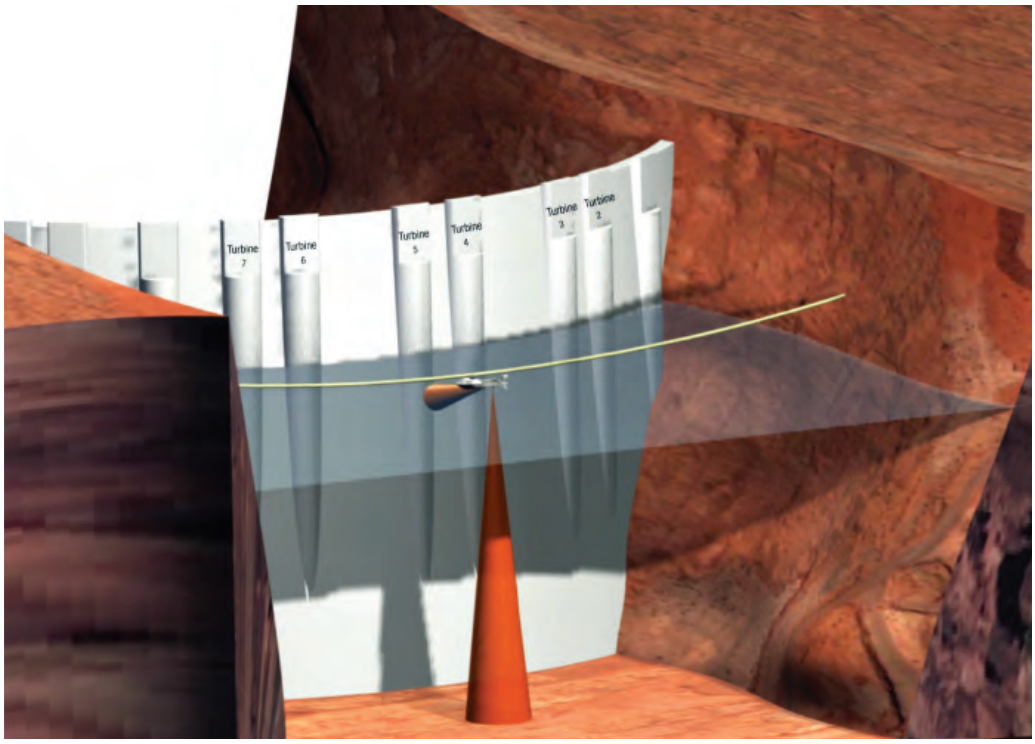
- **Science and Technology Program**
- **Upper Colorado Area Offices**

Problem

As an element of the reasonable and prudent alternative set forth in the 1995 Biological Opinion on the operation of Glen Canyon Dam, Reclamation was directed to implement a selective withdrawal program for Lake Powell to determine the feasibility of releasing warm, epilimnetic water below Glen Canyon Dam.

As part of this program, Reclamation conducted a 2-year field investigation from June 2007 through June 2009 to establish baseline data for monthly density and distribution of pelagic fishes within the Glen Canyon Dam forebay. The study improved Reclamation's understanding of the potential for entrainment of warm-water, non-native piscivorous fish into the Colorado River below the dam. These fish (if entrained into the river) could potentially complicate recovery of the humpback chub through predation or competition and negatively impact other native fish.

Other study objectives included monitoring water quality parameters and far-field velocity profiles within the forebay, documenting species composition within the forebay, and determining the Glen Canyon forebay water surface elevation where entrainment of pelagic fish could become problematic if epilimnion withdrawal occurs.



Schematic of the sample vessel attached to the Kevlar line (yellow) within the Glen Canyon Dam forebay. This figure shows the ensonified volumes of water as cones for both down- and side-looking transducers.

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Analysis/Methods

This Science and Technology Program research project partnered with Reclamation's Upper Colorado Area Offices for researchers to conduct research, including monthly surveys from July 2007 to June 2009. Volumetric hydroacoustic surveys were conducted at predetermined stations in the forebay on the Kevlar line (see figure). The stations were located so that the transducers were oriented downstream (toward the dam) and inline with the turbine being sampled. Turbines 2 through 7 were selected for volumetric density estimation. Turbines 1 and 8 could not be sampled effectively from the survey line because of the curvature of the dam and the interference caused by the forebay canyon walls. Volumetric data were collected to document fish density and distribution by depth.

Water quality parameters were recorded monthly. An acoustic Doppler velocimeter was used to measure point velocities at the centerline elevation of the penstock intakes (elevation 3,470 feet) and an occasional vertical temperature profile. An acoustic Doppler current profiler was used to measure velocity profiles in front of penstock intakes (turbines) 2 through 7.

Attempts to identify species composition in the forebay included midwater icthio-trawls, vertical gill-netting, electrofishing, and direct observation.

Results and Conclusions

1. The density and distribution of fish within the forebay varies with light versus dark periods, month of the year, and depth, with more fish present during dark periods from June through September.

2. Regardless of reservoir elevation, fish in the Glen Canyon Dam forebay were most abundant in the top 14 meters of water during the study period, which overlapped largely with the epilimnion during periods of thermal stratification. Fish were especially abundant in the top 4 meters of the water column.

3. Fish entrainment through Glen Canyon Dam penstocks during the course of the study was likely low, based on densities of fish at water elevations where they would be entrained.

4. Entrainment would likely be via a selective withdrawal system operating at 40' below the surface or during periods of extremely low reservoir elevations (about ≤ 3,516 feet mean sea level) even without a selective withdrawal.

Management Implications

This study used hydroacoustic methodologies to provide critical information about temporal and spatial patterns of pelagic fishes proximate to Glen Canyon Dam. This information will be important to Reclamation managers who have a responsibility to deliver water and power while minimizing environmental impacts to recovery activities associated with the endangered humpback chub.

"This study is an important component of the knowledge base that Reclamation will use for future determination of the feasibility of releasing warm, epilimnetic water below Glen Canyon Dam through a selective withdrawal, particularly with regard to impacts on native and non-native fish species."

Dennis Kubly,
Program Manager,
Environmental Resources Division,
Upper Colorado Region

Future Development Plans

These data and methods will be used in future evaluations of a selective withdrawal system in the Glen Canyon Dam Forebay.

More Information

Reclamation 2012: Hydroacoustic Surveys of Pelagic Fishes in the Glen Canyon Dam Forebay, 2007-2009.

RECLAMATION *Managing Water in the West*

January 2012
Research and
Development Office
Bulletin 2012-05

The Knowledge Stream

Research Update

Evaluation of River-spanning Performances: Rock Ramps

Design guidelines for rock ramps will improve performance and reduce repairs and replacement costs

Future Development Plans

The rock ramp research is part of a larger effort to evaluate the use of natural materials in many types of water engineering projects. Results from the rock ramp research will be incorporated into a river-spanning rock structure design guidance document.

More Information

Additional information on river spanning rock structures research and associated physical modeling and field performance reports are available at: www.usbr.gov/pmts/sediment/kb/SpanStructs/index.html

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Collaborators

Reclamation:

- **Science and Technology Policy and Administration Programs**
- **Pacific Northwest Region**
- **Great Plains Region**
- **Albuquerque Area Office**

Problem

River-spanning rock ramps help meet water deliveries in an ecologically sound manner. They function as low-head diversion dams, permitting fish passage, create habitat diversity, stabilize streambanks and profiles, and more. As widespread use of rock ramps increases, the need for reliable design methods with a broad range of applicability at individual sites grows as well. However, guidance for sustainable construction and retrofit techniques is lacking for instream rock ramps.

During low streamflows, rock ramps must convey enough surface flow to meet passage requirements. Designing ramps to ensure sufficient surface flow is not well understood. The current state of the art does not provide the designer with adequate guidelines to establish a low flow limit of operation for rock ramps.

Solution

Reclamation formulated a study combining field investigations and laboratory physical modeling to investigate the:

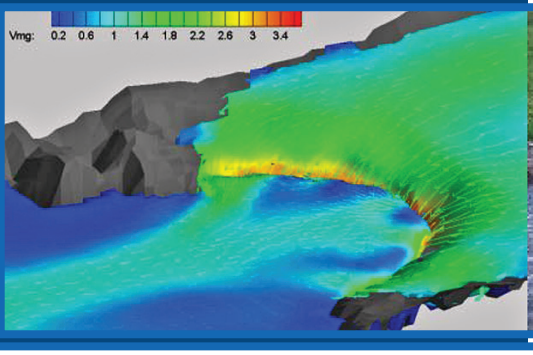
- Ratio of interstitial flow to surface flow passing down rock ramps as a function of ramp material gradation
- Effectiveness of "choking" treating the finished rock ramp surface with choke material designed to reduce surface permeability.

Design guidelines generated from this study will provide information for the development of sustainable construction and retrofit techniques—minimizing the structure lifecycle costs and maximizing their ability to reliably meet management objectives.

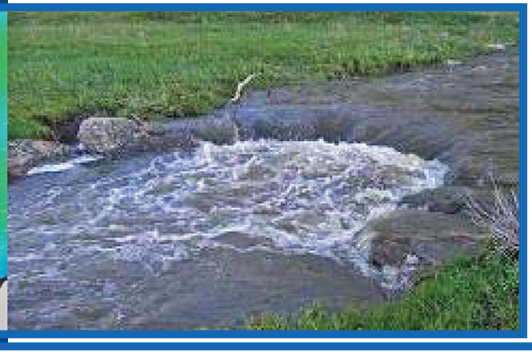
Results of field investigations and physical modeling showed that choking of the rock ramp reduced the percentage of subsurface flow by as much as a factor of four.

Benefit

Natural resource managers with a need for aesthetic river structures composed of natural materials for diversion, fish passage, channel stabilization, etc., will benefit from the results of this research. The design guidelines will be used by project engineers to design rock ramps to meet their intended objectives.



Modeling the velocity of bankful flow at a U-weir.



Application

Research on the selection of a ramp gradation and choking material gradation and placement has been applied to rock ramps on the Colorado River near Palisade, Colorado. Results from this research are currently being used in the design and physical testing of a large rock ramp on the Yellowstone River, near Intake, Montana.

RECLAMATION Managing Water in the West

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Bulletin 2012-06

The Knowledge Stream
Research Update

Evaluation of River-spanning Performances: Rock Weirs

Design guidelines for rock weirs will improve performance and reduce repairs and replacement costs

Future Development Plans

The rock weir research is part of a larger effort to evaluate the use of natural materials in many types of water engineering projects. Results from the rock weir research will be incorporated into a river spanning rock structure design guidance document.

More Information

www.usbr.gov/pmts/sediment/kb/SpanStructs/index.html

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Collaborators

Reclamation:

- **Research and Development Office**
- **Pacific Northwest Region**
- **Albuquerque Area Office**

Colorado State University's Engineering Research Center

Rock weir structure.

Problem

River-spanning rock weirs are constructed for water delivery, bank stabilization, grade control, fish passage, and to improve aquatic habitat for endangered fish species. Current design methods are based upon anecdotal information applicable to a narrow range of channel conditions. The complex flow patterns and performance of rock weirs is not well understood. As a result of minimal design guidance, many rock weirs do not function as intended and need frequent repairs or replacement.

Field investigations of 127 rock weirs found that failures were most commonly caused by development of downstream scour holes and the subsequent slumping of the rock components. Guidance is needed to define the analysis required for structure design and construction to better predict scour patterns and to minimize the likelihood of structure failure.

Solution

Reclamation and Colorado State University are combining field investigations, physical modeling, and computer simulations to develop design guidelines and countermeasures for avoiding failure of river-spanning rock weirs. Using the design guidelines and countermeasures will result in more robust structure design or retrofits based upon predictable engineering and hydraulic performance criteria.

Results of laboratory tests and numerical modeling show that scour depths below rock weirs are significantly deeper than typical foundations designed for rock weirs. Empirical methods for scour prediction were analyzed with respect to rock weirs. Also, design techniques to reduce the likelihood for failure were investigated through physical models, field studies, and numerical models, including Reclamation-developed models SRH-2D and U2RANS. These techniques may include deep foundations to protect against scour, grouted weir crests, using multiple structures in series, and using interlocking and block-shaped rocks.

Benefit

Natural resource managers with a need for aesthetic river structures composed of natural materials for diversion, fish passage, channel stabilization, etc., will benefit from the results of this research. The design guidelines will be used by project engineers to determine the suitability of using rock weirs to meet their objectives and to construct rock weir structures that perform as intended.

Application

The findings of this research thus far have been applied to develop plans for repairs and retrofits of rock weir diversion structures on the Lemhi River in Salmon, Idaho; Beaver Creek near Twisp, Washington; and Entiat River near Entiat, Washington. Repairs and retrofits of these structures incorporated design guidelines and countermeasures to protect the structure against common failure mechanisms.

RECLAMATION Managing Water in the West

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Bulletin 2012-16

The Knowledge Stream
Research Update

Best Practices for Preparing Concrete Surfaces for Repairs and Overlays

Providing guidance for effective concrete repairs

Bottom Line

This research developed performance criteria for surface preparation of existing concrete prior to repair and overlay.

Better, Faster, Cheaper

The more effective preparation, the better and more long-lasting the concrete repair will be.

Principal Investigator

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More Information

Bissonnete, B., A.M. Vaysburd, and von Fay, K., 2012. Best Practices for Preparing Concrete Surfaces Prior to Repairs and Overlays. Reclamation, Report No. MERL 12-17.

Problem

Repair and strengthening of existing concrete structures are among the biggest challenges civil engineers face today and will face in the years to come. Concrete repair can prolong the useful service life of a deteriorated or distressed structure, restoring the load carrying capacity and strengthening the structure. To be successful, the repair and the substrate need to act as one unit. Repair material cracking and debonding from the concrete substrate is one of the biggest problems impacting the long-term performance of concrete repairs and bonded overlays.

Despite the relatively large pool of theoretical knowledge, the practical issues related to surface preparation of existing concrete to achieve a long-lasting bond are still inadequately addressed. Thus, repairs and overlays continue to perform poorly.

Solution

To promote more effective concrete repairs, this Science and Technology Program research project identified the key physical characteristics of a concrete substrate needed to ensure successful, long-term repairs and overlays. In conjunction with our research partners, we developed practical guidelines in the form of a Suggested Guide Specification based on results of the International Research Project, "Development of Specifications and Performance Criteria for Surface Preparation Based on Issues Related to Bond Strength," a review of best practices, and the authors' knowledge of concrete repair.

The Suggested Guide Specification contains recommendations for surface preparation of concrete prior to repair and overlay. The document summarizes current knowledge, best practices, and results of research concerning the surface preparation of concrete prior to application of repair/overlay materials.

Results

In addition to verifying some standard industry practices, we identified other factors for successful concrete repair, including:

Planning the Repair

The success of concrete repairs depends on determining the cause and extent of concrete distress or deterioration, establishing realistic repair objectives, and developing a repair strategy to address repair needs.

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Properly Removing the Concrete

The effectiveness of various concrete removal techniques may differ for unsound and sound concrete, and a combination of techniques may be necessary. Success depends on:

- Removing unsound (and, if necessary, sound) concrete and foreign materials that inhibit bonds from the concrete and reinforcement surfaces, opening the concrete pore structure, and preparing and repairing damaged reinforcement.
- Avoiding the use of methods to remove concrete or to prepare the concrete and reinforcement to receive the repair material that weakens the remaining sound concrete and reinforcement.
- Reviewing the effect of concrete removal on the structural integrity of a structure prior to removal of existing concrete.
- Monitoring concrete removal to ensure minimal impact on the surrounding environment. Primary issues are noise, dust, and flying debris.

Treating Reinforcing Steel

Corrosion of embedded reinforcing steel is the most frequent cause of concrete deterioration. Proper evaluation of the condition of reinforcing steel exposed in the repair area and proper reinforcement treatment steps will ensure that the repair will not fail prematurely. Site welding of reinforcement should be avoided if alternative methods of repair are available. Repairs of corrosion-related concrete deterioration are usually performed in the areas where the corrosion activity is at its worst—at "hot spots." After these areas are repaired, the "hot spots" can move to the areas adjacent to repair areas. To protect such areas, consider using sacrificial galvanic anodes.

Preparing the Surface

Surface preparation is important to remove deteriorated concrete and to create a good interface texture. Adhesion depends as much on good surface preparation as on repair material characteristics. Regardless of the cost, complexity, and quality of the repair material and application method selected, the care with which concrete is removed and concrete reinforcement surfaces are prepared will often control whether a repair project will be successful.

Concrete removal methods may leave the surface to receive the repair material too smooth, too rough, too irregular, and without open pores. In these cases, procedures specifically intended for surface cleaning are necessary, including secondary cleaning in some cases.

Place repair materials as soon as possible after concrete removal and cleaning is completed or protect the cleaned and prepared concrete and reinforcement surfaces from contamination. If too much time passes after cleaning and before placing the repair, additional cleaning to remove the carbonated surface may be needed.

Future Research

The Suggested Guide Specification should be modified by the results of further research and field trials. Investigating different substrate concretes, interface textures, and various repair materials would be helpful. In addition, further research will be necessary to develop a practical methodology for optimum moisture conditioning of the concrete substrate's surface prior to repair.

"Regardless of the cost, complexity, and quality of repair material and application method employed, the quality of the surface preparation of the substrate prior to repair will often determine whether a repair project is a success or a failure, and whether a repaired structure meets the design objectives."

Vaysburd, A.M., G.M. Sabnis, P.H. Emmons, and J.E. McDonald, "Interfacial Bond and Surface Preparation in Concrete Repair," Indian Concrete Journal, No. 15, January 2001, 27-33.

RECLAMATION *Managing Water in the West*

June 2012
Research and Development Office
Bulletin 2012-19

The Knowledge Stream

Research Update

Electro-Osmotic Pulse (EOP) Technology

Adapting EOP technology to handle water seepage problems at Reclamation's unique facilities

Bottom Line

EOP prevents water from leaking through concrete, thus preventing structural damage, corrosion, and other issues—including potential dam safety concerns.

Better, Faster, Cheaper

EOP can be installed without interruptions in water or power delivery, reducing operations and maintenance costs. Also, EOP has a lower life-cycle cost than grouting or concrete repair alone.

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Collaborators

- **Reclamation's Northern California Area Office**
- **U.S. Army Corps of Engineers**
- **Electro Tech**

Problem

Reclamation has many older dams and associated structures with massive amounts of concrete. These structures play a critical role in the United States' water and power infrastructure, and any type of failure could be severe and costly. Water seepage through concrete can cause extensive damage, including corrosion of the reinforcing steel, cracks and potential structural failure, and corrosion of nearby equipment (e.g., gate operating motors, pipelines). Extensive maintenance is required to mitigate the corrosion damage to equipment, remove calcite deposits, and mitigate safety issues due to inoperable equipment and poor air quality. Grouting cracks and leaks may be only a temporary fix and often takes a significant amount of time. Also, grouting does not prevent seepage through the concrete pores.

Solution

Electro-Osmotic Pulse (EOP) technology can mitigate many water-related problems from the interior of affected areas without the cost of excavation. EOP prevents corrosion and water/moisture-related damage to equipment and reduces humidity. Thus, EOP technology can address issues that could affect dam safety or operations.

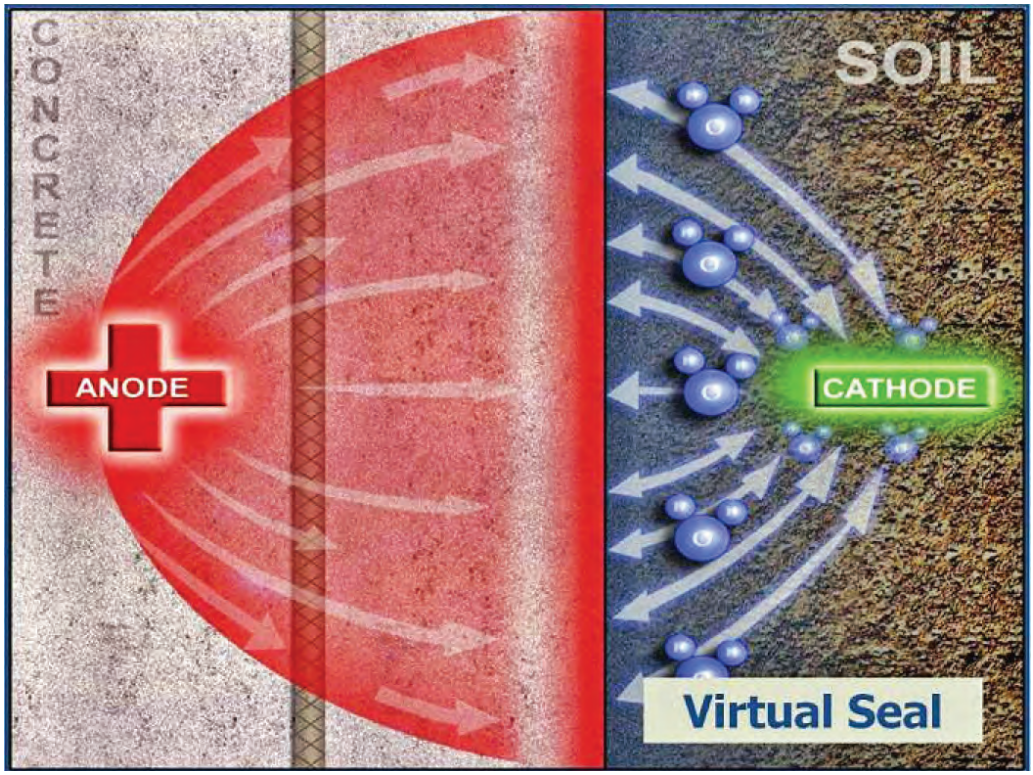

Illustration of the effects of the application of EOP technology to create a virtual seal or barrier to prevent water from entering the concrete on a macro scale (image from Electro Tech).

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Reclamation tested the EOP technology at Trinity Dam near Redding, California. Trinity Dam has water leaks through the bonnet chamber shaft, which leads to several maintenance problems in the shaft and bonnet chamber. The walls of the shaft and bonnet chamber are covered with calcite from seepage over time. The extent of the calcite deposits prevents the door from sealing. If there is a failure in the chamber, this door is the only thing that would stop water from the reservoir flowing through the door, down into the penstock tunnel, and then out into the powerplant yard.

An EOP system involves inserting anodes (positive electrodes) into the concrete wall or floor on the inside of the structure and placing cathodes (negative electrodes) in the water or soil directly outside the structure. A commercial system was developed to apply EOP technology using a pulsating direct electric field to reverse the flow of water seepage and create a barrier to prevent further water coming in. The pulse sequence consists of a pulse of positive voltage (as seen from the dry side of the concrete wall), a period of rest when no voltage is applied, another positive pulse, and then a pulse of negative voltage. The negative voltage pulse prevents the alteration of the chemical composition of the pore solution due to the application of the current. This prevents the system from losing efficiency and prevents damage to the concrete.

Reclamation installed an EOP system in a 12-foot-wide by 6-foot-high wall in the bonnet chamber shaft. Measurements determined that this first phase worked to dry out the concrete. The next phase test section will include concrete that contains leaking cracks.

Benefits

This is a common problem throughout Reclamation, and savings from an EOP system will allow more money to be used for other structure maintenance and issues to improve operations.

An analysis can be used to determine the cost/benefit of installing an EOP system compared to continual repairs. Installing an EOP system to dry out a concrete structure can provide the highest return on investment if, as expected, it:

- Prevents new cracks that could compromise the system, which can lead to dam safety or other issues.
- Costs less than other options over time. Extensive excavation is not required to install an EOP system, and an EOP system needs minimal maintenance.
- Avoids costs of service disruption and lost productivity.
- Prevents structural degradation of the facility from water penetrations.

Future Development Plans

This successful test section was small, and a larger installation should be tested. For the larger test section, an EOP system should be installed in the bottom 10 feet of the shaft around its entire circumference. For this test, leaking cracks would be included in the test section. If the technology works for this larger test, then it would likely work for the entire area of the gate shaft.

However, the success of the pilot test at Trinity Dam strongly suggests that an EOP system could work to address the problems Reclamation faces in its other facilities. Mount Elbert Powerplant, for example, faces similar water seepage problems. Reclamation managers are looking at applying an EOP system to other structures.

"EOP technology can mitigate many water-related problems from the interior of affected areas without the cost of excavation. Corrosion damage to equipment and reinforcement can be mitigated and reduce O&M costs."

Daryl Little,
Principal Investigator

More Information

Reclamation, 2012.
Technical Memorandum No. MERL-2012-10 Electro-Osmotic Pulse Leak Repair Method: Evaluation in Trinity Dam Bonnet Chamber

U.S. Army Corps of Engineers Construction Engineering Research Laboratory
www.cecer.army.mil

RECLAMATION Managing Water in the West

June 2012
Research and Development Office
Bulletin 2012-18

The Knowledge Stream
Research Update

Projecting Economic Consequences of Urban Canal Breaches

Adapting risk management techniques for dams to canals

Bottom Line

This research project adapted HAZUS software to determine potential economic damages from canal breaches.

Better, Faster, Cheaper

We can now provide information to local Reclamation offices to help prioritize preventative maintenance and resources. Previous damages from a canal breach have reached over $10 million dollars. Using this method could help minimize future canal breach losses.

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Problem

Reclamation is responsible for managing more than 8,000 miles of canals. As the population of the West has grown, many miles of these canals have been incorporated into urban areas. While an irrigation canal breach in an originally unpopulated area might have caused little damage, recent canal breaches have flooded new residential developments. Reclamation managers need current and comprehensive information about the potential consequences of a canal breach in these urbanized areas so that maintenance and repair operations can focus on areas of greatest risk. Economic consequences typically include downstream property damages, lost water delivery benefits, repair/replacement costs, and secondary or indirect impacts.

Evaluating the potential property damages due to a canal breach is a good first step in determining the overall economic consequences. Reclamation's Dam Safety Program has developed procedures for calculating consequences of dam failure and resulting floods. However, canal breach floods are different in several important ways and, therefore, require new procedures.

Landside, left canal bank, about 240 feet downstream from the Truckee Canal breach. Collapse feature associated with downhill sediment transport. Three muskrat burrows on the canal side of the embankment near high water line. See the Truckee Canal breach information on the following page.

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Solution

This Science and Technology research project developed a method to identify and quantify potential downstream property damages due to a canal breach scenario. We use damage parameters that are less like a dam failure and more like a rapid rise river flood to simulate the potential damages from a canal breach.

Our analysis adapts the Federal Emergency Management Agency's (FEMA) HAZUS-MH software now being used to estimate economic consequences for dam failure scenarios. HAZUS is a nationally applicable standardized methodology and risk assessment software program for analyzing potential losses from floods, hurricane winds, and earthquakes. HAZUS reports the locations and types of major infrastructure that would be inundated by the flood as well as the estimated damages. The Technical Service Center's Economic and Resource Planning Team can now use these data, together with a Geographic Information System (GIS) to produce a report that shows potential damages for canal breaches. For any urbanized canal system, tools are used to:

1. Perform an infrastructure inventory and economic value analysis of the area surrounding the canal system

2. Determine valuations for the affected infrastructure

3. Create a geospatially referenced economic value database of the information

We use the HAZUS-MH database along with the Homeland Security Infrastructure Program (HSIP Gold) database as sources of infrastructure information.

Application

As a proof of concept, this Science and Technology research project analyzed a hypothetical situation based on previous canal breaches. We examined:

- Essential facilities (e.g., fire stations, hospitals, police stations, and schools)
- Transportation lifelines (e.g., roads, bridges, airports)
- Utility infrastructure (e.g., water, wastewater, power, communications)
- Buildings and infrastructure (e.g., residential, commercial)
- Agriculture (i.e., exposure and potential losses)

Future Development Plans

Reclamation is inventorying our canals and identifying canals in urban areas. This first step can lead to an overall estimation of economic consequences, including lost benefits, repair/replacement costs, and indirect impacts due to a canal breach scenario. We can use this information to further pinpoint areas of potential significant economic consequences.

More Information

HAZUS software is available at www.fema.gov/hazus.

"We can use this analysis to help our efforts to protect the public and the environment from the risks posed by potential canal breaches."

Bill Goettlicher,
Co-Investigator

Canal Breach Example

At approximately 4:30 a.m. on Saturday, January 5, 2008, a breach occurred in the Truckee Canal, a Newlands Project facility in northern Nevada, owned by Reclamation and operated and maintained by the Truckee Carson Irrigation District. As a result of the breach, an uncontrolled release of water flowed into irrigated lands and a portion of the city of Fernley, located some 30 miles east of Reno. About 590 homes were flooded.

For more information about this canal breach, see Truckee Canal Breach Hydraulic Model Results for Truckee Canal Breach Evaluation, Fernley, Nevada. January 5, 2008. www.usbr.gov/mp/truckee_canal.html

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Advanced Algorithms for Hydropower Optimization

Determining the most economic way to operate generator units

Bottom Line

Although computationally intensive, these methods can solve difficult constrained optimization problems, like the dynamic economic dispatch problem, quickly and reliably.

Faster, Better, Cheaper

Improved dispatching efficiency will result in the generation of more electric power using less water—benefitting all water and power users.

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Collaborators

- **Colorado State University**
- **U.S. Bureau of Land Management**
- **Argonne National Laboratory**

Problem

On many of the large river systems in the West, Reclamation operates multiple hydroelectric powerplants, each with several electrical generators powered by the release of water from reservoirs. Every hour, night and day, Reclamation's powerplant operators must decide which powerplants and generators to operate and how much water should be released for each. Even small improvements in powerplant operations can provide substantial gains. For example, increasing the generation efficiency at Glen Canyon Dam by only 2 percent would yield approximately $4.5 millon (in 2010 dollars) annually.

Improving operations requires us to solve a mathematical problem known as the "constrained dynamic economic dispatch" problem. Stated in words, this problem is:

How much water should the hydropower plant release each hour through each generator to maximize the economic value of the electricity produced, given the amount of water available for release, the anticipated hourly price of electricity, and all of the other constraints (e.g., physical, environmental)?

This problem has universal, practical, everyday management applications at Reclamation hydropower plants. At least hourly, Reclamation's powerplant operators must solve this problem and decide how to operate the plant. The constrained dynamic economic dispatch problem is quite complicated and is shaped by a number of factors. It can be discrete, discontinuous, and non-convex—characteristics that preclude the use of traditional, calculus-based solutions.

Solution

This Science and Technology research project identified, assessed, and applied advanced optimization approaches to this problem, focusing on new optimization heuristics. Although computationally intensive, these methods can solve difficult constrained optimization problems quickly and reliably. This research project identified three promising evolutionary algorithms: the real coded genetic algorithm (RGGA), differential evolution (DE), and particle swarm optimization (PSO). Heuristic optimization approaches are based on applying rules and logic that reduce the search space, facilitating solving complex optimization problems.

These innovative search techniques are drawn from biological and physical processes. Evolutionary algorithms are based on the concept of biological evolution. These approaches are based on calculating the performance of a population of algorithms over a series of generations or iterations. Each algorithm provides one solution to the optimization problem. At each iteration, the algorithms producing the best solutions are carried forward, while the less optimal algorothms drop out. The quality of the solutions found thus improve over time. This ongoing process ultimately identifies the optimum solution. Current software can evaluate a very large number of "generations" in a short period of computation.

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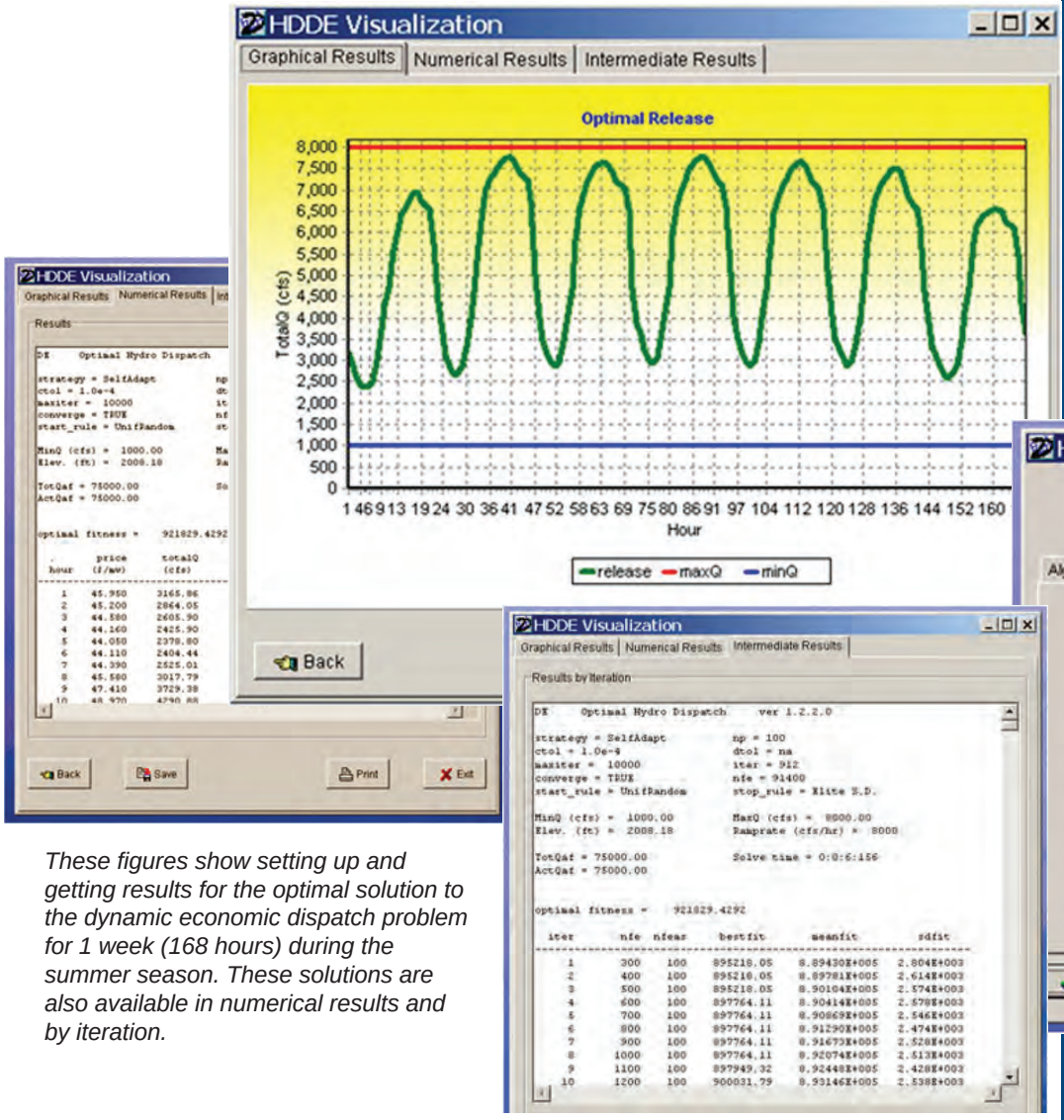
Advantages of these approaches include:

- Uses simple mathematical structures
- Allows concise, straightforward coding
- Easily accommodates many-dimensional problems
- Allows non-linear, continuous, discrete, or complex problems
- Can represent most types of constraints
- Provides a higher probability of identifying the overall optimum solution

Results

We applied these three evolutionary algorithms to the constrained dynamic economic dispatch problem and conducted multiple trials to gauge their success and compare their performance characteristics. The results indicate that these algorithms are able to accurately and reliably solve the constrained dynamic economic dispatch problem for a generic powerplant. For the test problems examined, these algorithms have longer solution times than calculus-based approaches.

However, the strength of these evolutionary algorithms is their ability to successfully solve more complicated problems, which cannot be solved with traditional, calculus-based approaches. Using these approaches can help guide Reclamation's hydropower economic dispatch decisions and improve efficiency, generating more electric power with less water.



These figures show setting up and getting results for the optimal solution to the dynamic economic dispatch problem for 1 week (168 hours) during the summer season. These solutions are also available in numerical results and by iteration.

"Improved efficiency will result in the generation of more electric power using less water, benefitting water and power users as well as the American taxpayer."

Dr. David Harpman,
Principal Investigator

Future Research

We are now applying these evolutionary algorithms to the hydropower unit commitment problem in a follow-on research effort, Phase 2–Advanced Optimization Algorithms for Hydropower Dispatch, Science and Technology Program, Project 3906. This will help operators of a multiple-unit powerplant determine the best combination of generator units to bring online, and at what levels, given the existing load demands and other operating costs and constraints.

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Reducing Noise Exposure in Powerplants

Providing engineering solutions to reduce noise to help ensure employee health and safety

Bottom Line

Reclamation's powerplants can be noisy places. This study explores sources of noise and possible engineering solutions.

Better, Faster, Cheaper

Engineering solutions to reduce noise can help protect employees from hearing losses.

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Collaborators

Reclamation:
Pacific Northwest Region and Great Plains Region Powerplant Employees

External Partners:

- **Office of Naval Research (ONR)**
- **U.S. Army Corps of Engineers (USACE)**
- **U.S. Department of the Interior (DOI)**

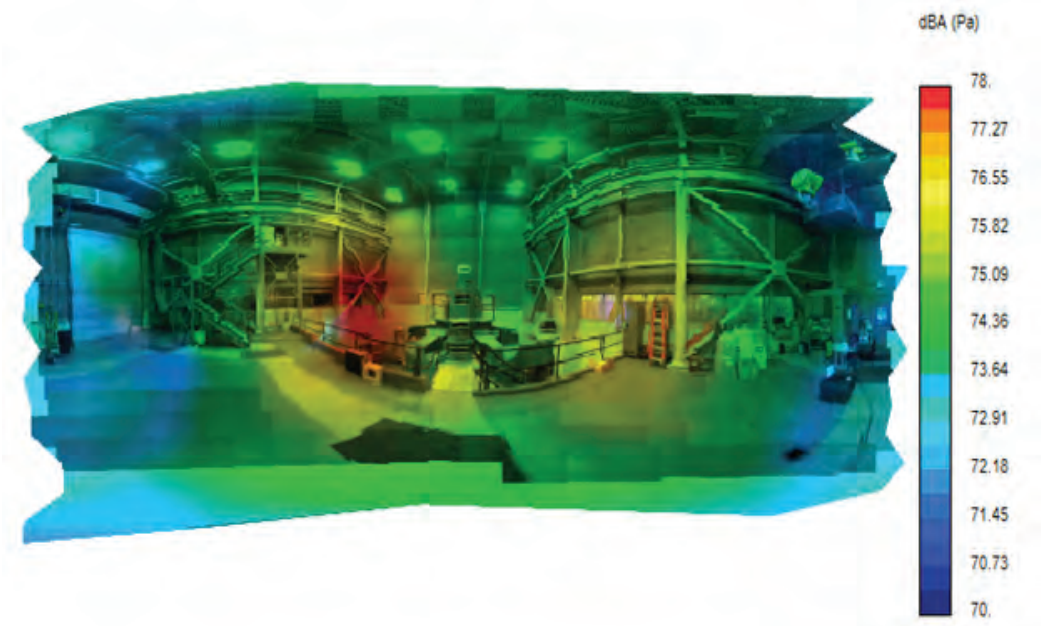
Problem

Noise is often overlooked as a hazard because there are no obvious indicators of acute or chronic exposure. However, noise-induced hearing loss is one of the highest worker's compensation expenses that agencies have for non-traumatic injuries. The noise standard for hazardous noise exposure is 85 decibels over a day (about the same sound level as a bulldozer idling). The Occupational Safety and Health Administration requires eliminating or reducing a hazard through engineering controls, if feasible, as the first priority, before relying on administrative and personal protective equipment strategies. Hearing loss from noise is preventable by reducing noise at the source, treating the path of noise transmission, limiting the frequency and duration of employee exposure, and providing effective hearing protectors.

Most of Reclamation's powerplants are over 40 years old and were constructed before many modern noise control technologies were developed. We can now incorporate noise reduction technologies when we replace and refurbish equipment, or modernize powerplants.

Solution

This Science and Technology Program research project seeks to understand the common sources and characteristics (such as frequency and intensity) of noise in Reclamation's hydroelectric powerplants. We can then evaluate the range of cost effective engineering solutions that can be implemented to eliminate the noise or reduce it to levels below the industrial standard for hazardous noise.



Acoustic array plot showing hot spot from cooling fan at Roza Powerplant, Washington.

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Reclamation contracted with an Office of Naval Research's (ONR) contractor, Noise Control Engineering, Inc., to identify noise sources and propose engineering controls at Reclamation and U.S. Army Corps of Engineers' (USACE) hydroelectric powerplants. The ONR applied its insights from research designed to protect warfighters from noise-induced hearing loss in the navy. The research team:

- Identified the most significant noise sources at nine Reclamation and USACE powerplants.
- Developed and evaluated engineering controls to reduce noise in the powerplants.
- Researched the technical and economical feasibility of implementing the engineering controls and compared this to the potential benefit.

Applications

We evaluated a wide range of powerplants to identify noise sources and consider possible engineering solutions:

- Green Springs, Oregon (small, Reclamation)
- Mary's Lake, Colorado (small, Reclamation)
- Roza, Washington (medium-small, Reclamation)
- Chandler, Washington (medium-small, Reclamation)
- Dalles, Oregon (large, USACE)
- Chief Joseph, Washington (large, USACE)
- Estes, Colorado (medium-large, Reclamation)
- Flatiron, Colorado (medium-large, Reclamation)
- Grand Coulee, Washington (very-large, Reclamation)

The field measurements included acoustic octave band analysis and vibration analysis surveys. The ONR contractor also used an acoustic array to help verify the acoustic "hot spots" and provide insights into possible treatment methodologies. Suggested engineering controls included:

- Fan silencers
- Tuned resonance sound absorbers for hard surfaces, such as in turbine pits
- Redesigned turbine pit access door with fan
- Damping treatment on the ventilation ducts, generator housing, and/or electrical cabinet
- Space closure or sound absorption treatment under pumps

This study can be used as the basis for further noise reduction studies in Reclamation, USACE, and throughout the hydropower industry.

"Of our worker's compensation costs, about 20 - 25 percent is due to hearing loss compensation. Dollar-wise, it's the largest single component of claims that we have. This project is an opportunity to protect our employees. Changing the infrastructure protects this and future generations of powerplant employees."

James Meredith,
Safety and Occupational Health Program Manager, Reclamation

More Information

Noise Control Engineering Inc., 2012. Engineering Controls for Hydroelectric Powerplants: Preliminary Recommendations. Technical Memo 2012-44.

Future Plans

The next steps at these powerplants are to:

- **Determine the feasibility of the recommended engineering controls and the impact on employees hearing loss prevention**
- **Recommend designing, purchasing, and installing engineering controls that are determined to be cost effective and feasible**
- **Verify the effectiveness of any control measures that were installed**

RECLAMATION Managing Water in the West

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Bulletin 2012-17

The Knowledge Stream
Research Update

Simplified Overshot Gate Development

Overshot gates that irrigation districts can construct themselves

Bottom Line

Irrigation districts can construct these gates and maintain them using commonly available tools and techniques.

Better, Faster, Cheaper

These overshot gates are less expensive than commercially available gates and can be tailored to an irrigation district's needs and fabrication capabilities.

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Collaborators

Reclamation:

- **Science and Technology Program**
- **Nebraska-Kansas Area Office**
- **Dakotas Area Office**

External:

- **New Mexico State University**
- **Buford-Trenton Irrigation**
- **Nebraska Bostwick Irrigation**
- **South Platte Ditch Company**
- **Tucumcari Irrigation District**
- **Carlsbad Irrigation**

Problem

Control structures in irrigation canals raise the upstream water surface elevation to deliver water into lateral canals or farm turnouts. Irrigation districts have historically preferred stoplog controls (wooden planks) as control structures. As flows pass over the top, stoplog controls enable floating debris to pass on downstream, reducing maintenance. They also provide for better control of flows than controls structures pass flows under the structure (such as sluice gates), as there is less variation of the upstream water level as the flow rate moving through the canal changes.

In typical control operations, stoplogs are stacked in slots up to a height that will raise the water level to a desired elevation. The portion of flow continuing downstream past the check passes over the stoplogs. Since stoplogs must be physically installed or removed, this type of control is not readily adaptable for automated or remote control operations.

As water districts seek to adopt modernized canal operating technologies, they commonly face the need to upgrade stoplog controls. Stoplogs must be replaced with gates that can be readily motorized to be compatible with automated or remote control operation. Overshot gates offer a way to maintain the advantages of over-the-top flows offered by stoplogs. However, the various commercially produced overshot gate systems available represent a level of investment that can prevent many irrigation districts from considering adoption of modernized canal technologies beyond anything more than a demonstration-level scale.

Solution

This Science and Technology Program research project is partnered with cooperating irrigation districts and the Water Conservation Programs at Reclamation's Dakotas and Nebraska-Kansas Area Offices to establish field demonstration sites for self-constructed overshot gates. Each of the prototype overshot gate installations in this project have been configured for simple construction and installation at the existing structures. Additionally, we used differing gate operating mechanisms at the various sites to suit the cooperating districts' preferences and fabrication capabilities.

Application

We constructed and installed prototype overshot gates at:

- South Platte Ditch Company near Merino, Colorado
- Nebraska Bostwick Irrigation District near Red Cloud, Nebraska
- Buford-Trenton Irrigation District near Trenton, North Dakota

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At all the demonstration sites, overshot gates were fabricated for installation in existing stoplog bays. All gates are powered by solar-charged 12-volt DC motors. All of the demonstration site gates are set up for local manual operation and for automated/remote operation. The remote terminal units can be programmed to adjust a gate automatically or for a gate to be operated.

Figures 1, 2, and 3 show overshot gates installed at Buford-Trenton Irrigation District, at Nebraska Bostwick Irrigation District, and at the South Platte Ditch Company, respectively. These overshot gates, which were built using in-house capabilities and equipment at the respective districts, are able to fully meet operational objectives of the cooperating districts.

In figures 1 and 2, rubber belting is attached to the sides of the overshot gate leaf to seal against concrete piers on each side of the bay of the control structure. The overshot gates at these sites are simply a steel gate leaf with the upstream edge hinged to the floor of the structure and a lifting system attached to the downstream gate edge. The existing control structure in figure 3 features wide flange steel sections installed vertically to form the stoplog slots. Bottom and side sheets constructed of steel plates were required for this overshot gate, which was designed as a "drop-in" structure to install in the existing stoplog slots.

These overshot gates are a cost-effective option for districts. For example, the "drop-in" style 4-foot-wide gate shown in figure 3 was constructed and installed (including the 12-volt DC actuator) for approximately $3,000, or about $750 per foot of width. This compares with commercially produced overshot gates in the cost range of $2,500 per foot width.

Figure 1: Burford-Trenton Irrigation District.

Figure 2: Nebraska Bostwick Irrigation District.

Figure 3: South Platte Ditch Company.

"The overshot gate on our spill structure fully meets our needs at a fraction of the cost of a commercially built gate. With the linear actuator, the gate is SCADA ready and will be automated for upstream level control."

Charlie Bartlett,
South Platte Ditch Company
Board Member

Future Plans

Reclamation researchers are working to develop a "standardized" materials list and general design methodology that will be suitable for fabricating overshot gates over a range of gate sizes for "drop-in" installations in existing stoplog bays in irrigation canal check structures. We are working in cooperation with a research team from New Mexico State University to further refine the overshot gate design concept with planned demonstration sites at Tucumcari Irrigation District and Carlsbad Irrigation District.

RECLAMATION Managing Water in the West

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Bulletin 2012-30

The Knowledge Stream
Research Update

Using Metalized Thermal Spray Coatings on Reclamation's Infrastructure

Evaluating corrosion protection for Reclamation equipment

Bottom Line

Metalizing may provide a coating that will protect infrastructure such as intake structures, canal gates, and trashracks from corrosion in environments with changing levels of freshwater.

Better, Faster, Cheaper

Although metallizing has an initial cost premium over a comparable polymer coating system, life-cycle costs may be substantially lower.

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Problem

Many of the coating systems that Reclamation has used in the past to prevent corrosion of its water control infrastructure (such as vinyl resins, lead-based paint, or coal tar enamel) can no longer be used due to stricter environmental and health regulations. However, many of the modern coatings systems are more expensive to apply and, if applied incorrectly, are prone to premature failure. Furthermore, modern coating systems have expected service lives of 15 to 20 years in contrast to the older coatings, which had over 50 years.

Solution

We continue to evaluate many kinds of coatings as we search for economical and effective means of corrosion protection. One alternative approach is to coat structures with a very thin layer of metal (metalizing). This study compares polymer coatings, metalized coatings, and metalized coatings with a polymer topcoat.

Figure 1: Unsealed aluminum thermal spray systems tested after 5,040 hours under different conditions: (a) a dilute Harrison solution, (b) accelerated weathering test (QUV) and salt fog test chambers (Prohesion cycle), and (c) QUV, salt fog, and immersion testing (Reclamation cycle). The "Xs" show bare metal exposure, and the panels show how well the metalized spray coatings worked.

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Our results suggest the best use of metalizing at Reclamation is on radial gates, stoplogs, partially exposed trashracks and other equipment subjected to fluctuating water immersion. Furthermore, metalizing can be applied under a variety of environmental conditions, whereas other types of coatings specify a narrow range of humidity and temperature for proper curing. Although metalizing has an initial cost premium over a comparable polymer coating system, life cycle costs may be substantially lower. Other applications where metalizing should be considered include severe atmospheric service environments such as bridges and above-ground piping.

While metalizing is not a new technology, technological advances have increased reliability and spray rates.

Advantages include:

- No cure time. The structure can be placed in service immediately following the conclusion of the application.
- No production of volatile organic compounds (VOC).
- Good impact resistance (compared with epoxy).
- Good ultraviolet (UV) light resistance (compared with epoxy).
- No temperature restrictions for application.
- No humidity restrictions for application.
- Increased service life (up to two times), with less downtime for coating maintenance.
- Passive cathodic protection when substrates are coated with metals that are more active on the galvanic series (aluminum, zinc, and magnesium in the case of steel).

Disadvantages include:

- Not compatible with impressed current cathodic protection systems found on many structures such as buried pipe.
- Initial costs are 15 to 40 percent higher, depending on the system specified.
- Metalizing heats the substrate, which may be unacceptable in certain situations.
- Fast-flowing water can decrease coating life.
- Service life in immersion can vary significantly depending on water chemistry and coating material.

Testing revealed that alloy composition and exposure condition significantly affect corrosion protection performance. Of the systems tested, the pure aluminum system is believed to offer the best combination of corrosion protection and expected service life in immersion or fluctuating immersion. The system works well if the water has a pH between 4.0 and 8.5. In addition, aluminum is easy to apply, relatively low in cost, and exhibit greater adhesion strengths compared to the other alloy systems. Aluminum-sprayed panels tested under several conditions are shown on the figure.

"Metalized coatings are provide an alternative to polymer coatings in fluctuating immersion service when rapid return to service is needed, during cold weather applications, or where VOC emissions are restricted."

Reclamation, 2012

More Information

Reclamation, 2012 Laboratory Evaluation of Metalized Coatings for Use on Reclamation Infrastructure. Technical Memorandum No. MERL-2012-14

Future Plans

Further research and evaluation is needed to determine an expected service life, determine ease to repair defects, and a method to deal with crevice corrosion. Because the service life of metalizing coatings depends highly on localized conditions such as water chemistry, it is recommended to perform a small field trial using the results from the current study as a basis.

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Power System Stability Improvements

Improving generator controller and power system performance through improved data analysis

Bottom Line

Improved generator/controller simulation models will improve power management and reduce the potential for blackouts.

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Collaborators

Reclamation:

- **Science and Technology Program**
- **Upper Colorado Regional Office**
- **Western Colorado Area Office**

Future Plans

These methods for establishing generator/controller parameters for improving simulation models will be refined continuously as technologies advance and experience is gained. They are planned for implementation at all large Reclamation powerplants during the next sequence of routine tests in 2012 - 2016.

Generator testing and monitoring at Crystal Powerplant, Colorado

Problem

Turbine-driven "synchronous" generators are the heart of the interconnected power system in the United States, and they supply over 95 percent of the nation's electricity. Dynamic computer models that simulate these generators and their controllers (voltage regulators, power system stabilizers, and speed governors) are used to predict and plan for abnormal occurrences within the power system. Modeling the generator being used with up-to-date controllers and other correct parameters is crucial—in the same way that modeling the behavior of a 747 airplane will not be much help if you are flying a 737 airplane. Inadequate models can lead to unforeseen system behavior, which may lead to significant problems such as regional blackouts.

Traditionally, severe, sudden, short-circuit tests are performed on synchronous generators to get the information needed to develop these models. These tests are costly, time consuming, and potentially dangerous. These tests require the generator to be disconnected from the power system and to have specialized control and monitoring circuitry connected. New methods are needed to retrieve this information while the generator is still operating normally. Moreover, severe tests only show extremes, so we need to improve the quality of generator parameter data under smaller disturbances.

Solution

Reclamation's Hydropower Technical Services staff has developed computer software to identify generator/controller characteristics, dynamic parameters, their effects on the power system, and any unusual operations. The software is used in concert with normal routine test results (with the generator connected normally to the power system) to develop the required simulation model parameters. This new model identification capability, based on data acquired during either staged tests or via continuous monitoring, improves the understanding of the impact of generator controllers on power system stability in a more efficient way. It also adds the ability to monitor the impact of long-term power system operation on powerplant equipment life. Individual generator governors and voltage regulators can be better integrated with regional automatic generation control systems and voltage controllers when improved parameter data are incorporated into generator/controller simulation models.

These model identification methods provide more accurate data for the prevention of power system problems such as blackouts. Moreover, they can save several days of test preparation and set up and reduce the possibility of a failure during testing. Reducing the number of testing days gets the generating units back in normal production faster.

Application

We have used these new methods at Reclamation's Crystal, Glen Canyon, Shasta, and Parker Powerplants. We improved generator/controller simulation models by using parameters that were established through these applications. Reclamation test procedures and model parameter development procedures have been modified to incorporate the new techniques, and publications in technical journals are pending.

Recent Research Projects

To get information generated by research quickly into the hands of end users and the broader public, our researchers and partners publish their results in peer-reviewed journals, technical memoranda, research reports, and other venues. We also present our results at conferences and workshops. Below is a list of reports published since the previous edition of the Knowledge Stream Newsletter.

Bandrowski, David, Jock Conyngham, Zac Corum, Kendra Russell, Connie Svoboda, and Michael Sixta. *Large Wood Research Workshop Summary Report*, February 2012, Seattle, Washington. (interim) (Project 3775).
Contact: Jennifer Bountry, jbountry@usbr.gov, 303-445-3614

Technical Workshop on Large Wood Applications and Research Needs in River Restoration, (February 14 - 16, 2012) Seattle, Washington.

Chugh, Ashok. *Discussion of Earth Pressure Measurements on Buried HDPE Pipe.* (interim) (Project 4292).
Contact: Steve Robertson, srobertson@usbr.gov, 303-445-3123

Gault, Greg. *Linking Documents and Information Stored in Sharepoint Libraries to Geospatial Representations of Reclamation Features.* (interim) (Project 2998). Documents are:

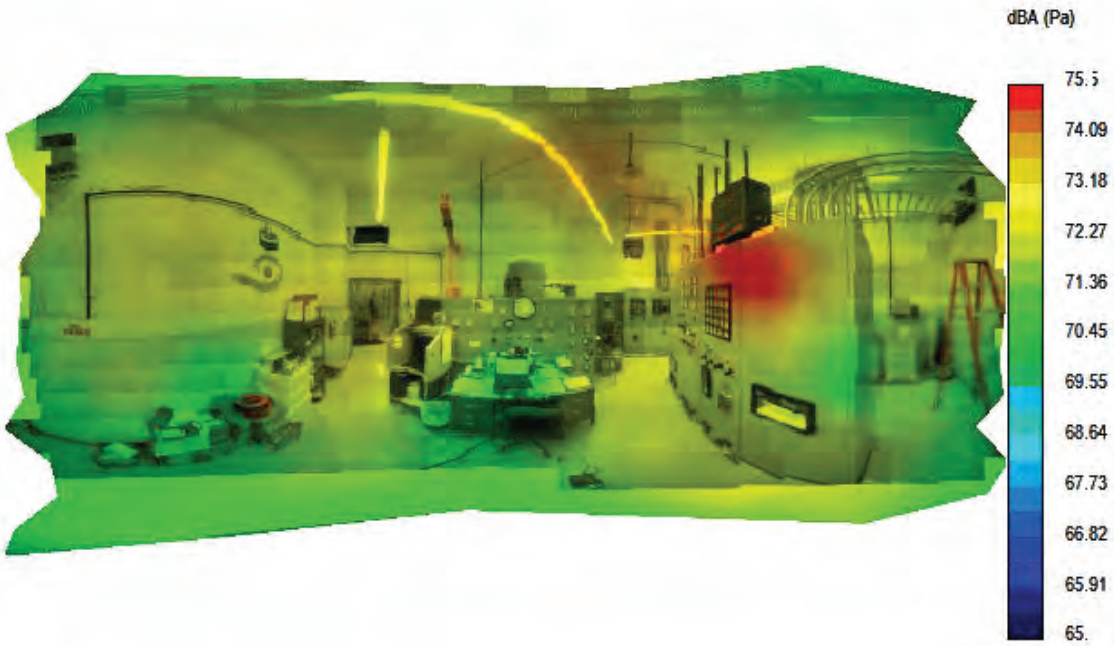
- Recommendations, Best Practices, and Guidelines for Link Documents in SharePoint
- Conceptual Model Report
- Implementation Manual
- Prototype

Contact: Greg Gault, ggault@usbr.gov, 208-378-5325

Heiner, Bryan J. *Measurement Device Calibration with Light Detection and Ranging and Computational Fluid Dynamics - Scoping Summary Research Project #5505*. (interim) (Project 5505). Contact: Bryan Heiner, bheiner@usbr.gov, 303-445-2140

Heiner, Bryan J. and Tracy B. Vermeyen. *Laboratory Evaluation of Open Channel Area-Velocity Flow Meters.* (interim) (Project 6578). Contact: Bryan Heiner, bheiner@usbr.gov, 303-445-2140

Quinn, Nigel. *Slideshow of Simulation Modeling Results using Mike-SHE and Mike-11.* (interim) (Project 947).
Contact: Michael Eacock, meacock@usbr.gov, 559-487-5133



Acoustic array plots showing (in red) areas generating greater noise in Reclamation powerplants. (See page 44)