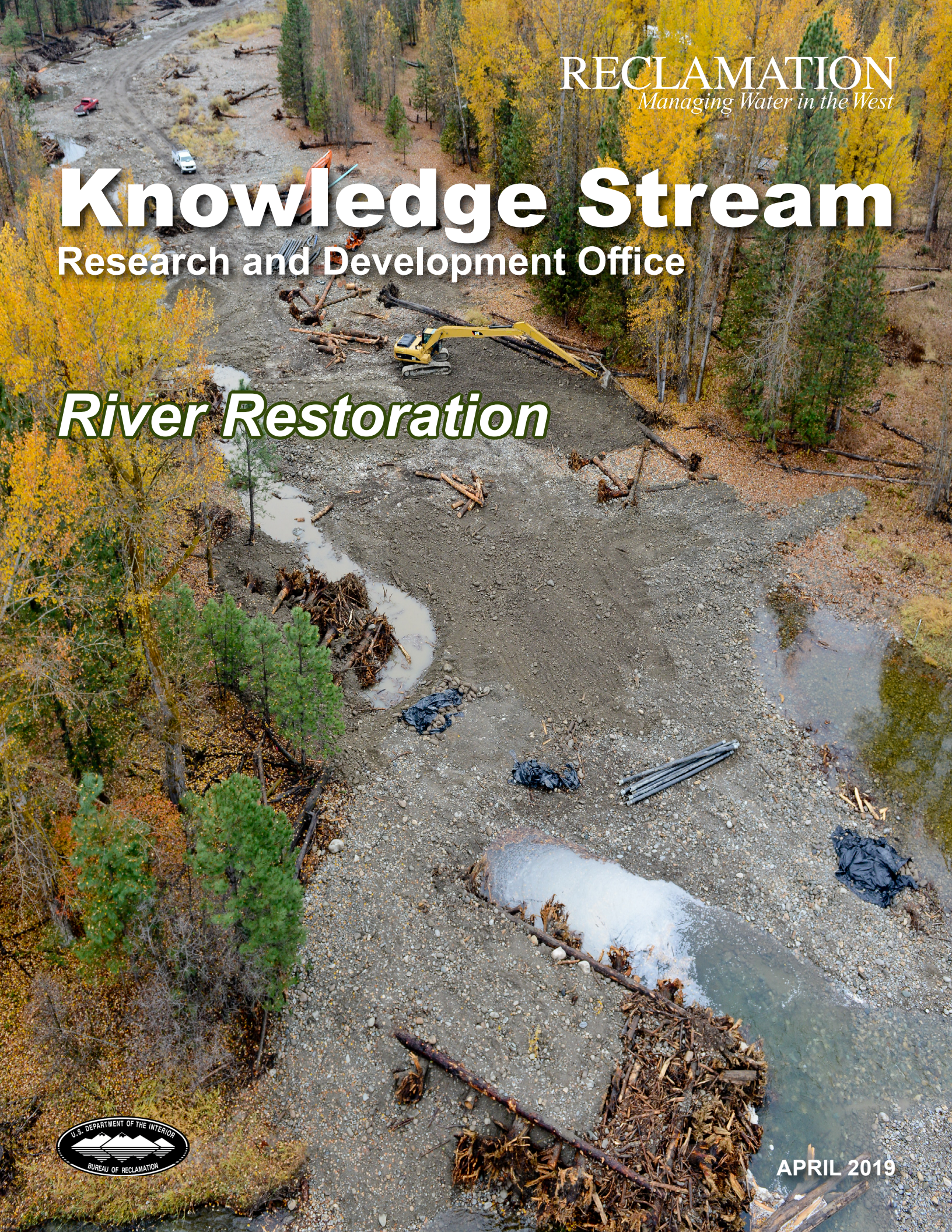

RECLAMATION
Managing Water in the West

Knowledge Stream

Research and Development Office

River Restoration

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

APRIL 2019

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Message from the Chief

Greetings and welcome to the April 2019 edition of the *Knowledge Stream* magazine! In this issue, you will learn about the Research and Development Office's (R&D) work in the field of river restoration aimed at helping Reclamation ensure adequate environmental compliance aligned with Reclamation projects. Reclamation conducts river restoration and enhancements on many of its water projects located throughout the West, often motivated by the goal of recovering threatened or endangered species located within these river systems. Activities may include species monitoring, habitat improvement, stream channel reconstruction, threat reduction, ecosystem health assessment, and more.

Inside, you will read about R&D projects designed to help Reclamation accomplish river restoration in a faster, cheaper, and more effective manner. Specifically, you will read about:

- Better ways to monitor and analyze river flow and sediment movement affecting aquatic and riparian habitats in the Trinity, San Joaquin, and Rio Grande Rivers,
- Fish migration and population studies on multiple species, including the Rio Grande Silvery Minnow, Pacific Lamprey, and various salmonids
- Piloting new methods for designing urban flood-control channels on the Los Angeles River in order to better account for ecosystem functions
- Research to better understand how channel and floodplain restoration projects affect river temperature regimes that control fisheries health, focusing on multiple Oregon rivers
- Developing advanced river hydraulic model tools that can be used by the technical community to support river restoration efforts in the West and beyond.

In addition, you will learn about R&D's efforts to bring together Reclamation's river restoration community through training events where participants are able to share activities and lessons learned, identify research needs, and enhance science partnerships that advance Reclamation's river restoration goals. We hope you enjoy, and as always, R&D welcomes your feedback and ideas for continual improvement on our dissemination strategies for transferring solutions to users!

Levi Brekke
Chief

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Jennifer Bountry, a Hydraulic Engineer in the Sedimentation and River Hydraulics Group, served as Content Lead for this issue.

She was awarded "Federal Engineer of the Year" in 2017.

Joel Sholtes, a former engineer with Reclamation, supported Jennifer with this issue.

He teaches at Colorado Mesa University, Engineering Department in Grand Junction, CO.

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Community Needs

River Restoration at Reclamation

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More Information
Reclamation Pacific Northwest Region Endangered Species Act Activities- Columbia/Snake Salmon Recovery Program
https://www.usbr.gov/pn/ccao/esa/index.html

Reclamation Mid-Pacific Region San Joaquin River and Trinity River Restoration Programs
https://www.usbr.gov/mp/programs.html

River restoration is a complex task, particularly in the Western U.S., where there are many competing demands for water and water supplies are highly variable. Reclamation supports river restoration efforts through several approaches, including large-scale river restoration and enhancement to ensure adequate environmental compliance aligned with Reclamation projects and by providing cost-shared financial assistance for restoration projects by local collaborative watershed groups.

Complexities of Restoration

Reclamation conducts extensive river restoration and enhancement activities on many of its projects throughout the West. In many cases, restoration activities are driven by the existence of federally listed endangered or threatened species in or associated with these rivers. Reclamation has identified 9 major river restoration efforts that are tracked for various reporting requirements, including:

- Columbia/Snake Salmon Recovery Program in Washington, Oregon, Idaho and Montana
- San Joaquin and Trinity Rivers Restoration Programs in California
- Lower Colorado River Multi-Species Conservation Program in Arizona and California
- Upper Colorado River Endangered Fish Recovery Program in Wyoming, Utah, New Mexico and Colorado
- Platte River Restoration in Colorado, Nebraska, and Wyoming
- Middle Rio Grande Endangered Species Collaborative Program in New Mexico; and Gila River Basin Native Fishes Conservation Program in Arizona.

Compliance with the Endangered Species Act is paramount to river restoration conducted by Reclamation. In other cases, Reclamation projects have authorizing legislation that includes benefits to fish and wildlife as one of the project purposes, such as the construction of fish passage facilities, fish barrier removal, or river and stream-bank protection and enhancement, among others.

Monitoring is conducted, and adaptive management implemented, as necessary, over time to ensure the long-term success of these restoration and enhancement activities. Success is most often measured in years or decades and so a commitment to long-term funding and ongoing monitoring is essential. Recently, Reclamation has developed internal measures to collect information on the planning and execution of the 9 major river restoration programs. These measures reflect a cross-section of our largest programs; represent each region; as well as consolidate some of our most common restoration practices (fish/stocking, water-for-fish, structural improvements, channel modifications, river miles of new/improved fish access, and habitat improvements). Each program reports under at least one of the measures. The measures are a coarse way to capture measures Reclamation-wide.

Importance of Partnerships

Most of Reclamation's river restoration and enhancement activities involve partnerships and cooperation with other Federal, state, and local agencies; tribes; and various non-profit environmental conservation organizations and stakeholders. These larger efforts include significant portions of river basins, cover numerous fish and wildlife species and their habitats, and are long-term, with planning, implementation and environmental compliance coverage spanning into the future as much as 10-50 years. Partnerships help to ensure successful implementation and allow for leveraging of funds through cost-sharing efforts that can run in the hundreds of millions of dollars. Federal grants, cooperative agreements, interagency agreements, contracts and service agreements with various entities are usually prepared as a part of these large restoration and enhancement efforts.

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River restoration reconstruction at Aravaipa Creek Fish Barrier, Arizona.

River Restoration at Reclamation

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Reclamation Cooperative Watershed Management Program
https://www.usbr.gov/watersmart/cwmp/

Boise River Enhancement Network
https://www.boiseriverenhancement.org/

Trout Unlimited - Abrams Creek Cutthroat Trout Project
https://vimeo.com/300398154

Every year Reclamation is required to report to the U.S. Fish and Wildlife Service an estimate of its annual expenditures on federally listed species. In 2017, Reclamation spent approximately $133,397,000 directly attributable to 60 different endangered or threatened species and their critical habitats. These costs do not represent other individual river restoration program costs such as staff time, program management or public involvement processes. Nor does it include costs borne by project partners such as other Federal and state agencies, tribes, municipalities or water districts.

Supporting Watershed Groups

Additionally, Reclamation supports stakeholder-driven restoration efforts through the Cooperative Watershed Management Program. Through this program, Reclamation provides funding to grassroots, local watershed groups to encourage diverse stakeholders to develop collaborative solutions to address their water management needs and avoid conflicts over water at the local level. Funding is provided for the support of watershed groups on a competitive basis for the development of watershed groups and watershed restoration planning (Phase I) and the implementation of on-the-ground watershed management projects (Phase II).

Watershed groups bring together a diverse group of stakeholders, some of which might otherwise be at odds, to provide a platform for collaborative, locally-led and community-based water resource management. Reclamation supports watershed groups and organizations sponsoring the development of watershed groups by providing funding for group development activities, such as stakeholder outreach, restoration planning, and watershed management project design (Phase I). Reclamation also provides cost-shared financial assistance to watershed groups to implement watershed management projects. These on-the-ground projects, collaboratively developed by members of a watershed group, will address critical water supply needs and water quality concerns, helping water users meet competing demands and avoid conflicts over water.

Since 2012, Reclamation has provided a total of $5 million in funding for the establishment or further development of 57 watershed groups across the west to accomplish over $7 million in watershed planning activities. In addition, since 2017, Reclamation has provided $560,000 in funding to watershed groups to implement 6 watershed management projects to accomplish over $2.6 million toward watershed management activities.

For example, the Boise River Enhancement Network works with stakeholders on the Lower Boise River in Idaho to promote the ecological enhancement of the Boise River. Through a 2014 CWMP Phase I grant, the Network developed the Boise River Enhancement Plan, focusing on stream channel function, fisheries and aquatic habitat, wetland and riparian habitat, and water quality concerns. The Network is currently working on a 2017 CWMP Phase II project to 'daylight' a previously buried section of Cottonwood Creek, which will improve habitat for Rainbow and Brown Trout. This project was identified as a priority in the Enhancement Plan.

Completed restoration at Aravaipa Creek Fish Barrier.

The Eagle River Watershed Council, in conjunction with Trout Unlimited, Colorado Parks and Wildlife, and Buckhorn Valley Metropolitan District (BVMD), works to improve instream flows in Abrams Creek, southwest of Eagle, Colorado. Abrams Creek, which supports a core conservation population of Green-Lineage cutthroat trout, suffers from low flows, affecting habitat for the trout and other aquatic species. The Council pipes a 21,790 linear feet section of the JPO ditch and uses the approximately 300 acre-feet of saved water for instream use. This increase to base flows in Abrams Creek benefits the target trout species, as well as other aquatic resources. This project, supported by the Eagle Creek Watershed Plan, has been endorsed by numerous elected officials, conservation groups, government agencies, and water users.

Current River Restoration Research and Future Needs

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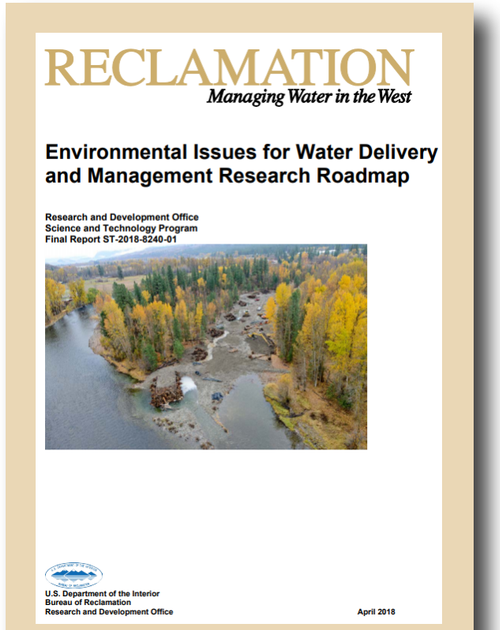
More Information
Reclamation Environmental Issues for Water Delivery and Management Research Roadmap
https://www.usbr.gov/research/st/docs/EN-roadmap.pdf

River restoration research falls under the environmental category within the Reclamation Science and Technology Program. River restoration refers to projects that improve target species habitat or physical processes in a river. This is in response to river habitat and processes that may have been altered by storage dams changing downstream river flows and sediment loads, operation of diversions, construction of levees, channel straightening or filling of floodplains and side channels, removal of vegetation and wood, mining of gravel, or other human impacts.

Habitat restoration locally improves or creates new physical habitat conditions in situ such as installation of engineered log jams. Process-based restoration includes small- and large-scale activities that restore the elements which create and maintain habitat over the long term. This includes restoring aspects of a natural flow and sediment regime on regulated rivers, as well as riparian re-forestation and bank armoring removal to allow for natural channel migration and large wood recruitment.

River restoration research at Reclamation has included development of new modules for in-house numerical models and guidelines to inform design. This research has tackled how to manage riparian vegetation with varying dam release flow scenarios, tools to predict water temperatures to support juvenile fish habitat, and design of large wood and rock grade control features. Research funding has also supported improvements to processing of hydraulic model output to look at fish habitat criteria from proposed designs.



Reclamation Environmental Issues for Water Delivery and Management Research Roadmap located at: https://www.usbr.gov/research/st/docs/EN-roadmap.pdf

A research roadmap was published in 2018 that identifies research needs for Reclamation in the environmental topic area, including river restoration. A comprehensive list of environmental needs are available in the roadmap as well. The roadmap will be updated periodically as new needs arise, especially the highest priority needs.

For FY 2020, the highest priority needs for new research proposals included:

1. Develop alternatives that eliminate need for fish screens; incorporate prize challenge outcome if applicable.
2. Improve upstream and downstream fish passage at dams.
3. Develop ecosystem health indicators throughout a watershed.
4. Evaluate post-construction habitat and design feature performance for rehabilitation projects.
5. Better understand effects of ecohydraulics on habitat availability, connectivity, and food webs for aquatic species.
6. Improve future channel change predictions in habitat rehabilitation areas and near Reclamation infrastructure.

Currently funded river restoration research includes the following topics, many of which are featured in this newsletter:

- Side channel evolution, geomorphic diversity, and sediment transport on the Bighorn River following larger dam releases between 2008 and 2018.
- Improving predictions of scour in the vicinity of vegetation in habitat rehabilitation areas.
- Side channel evolution and design: achieving sustainable habitat for aquatic species recovery.
- Technology Transfer: *Developing Tools for Efficient Handling of Data for Hydraulic Modeling and Habitat Analysis.*
- The potential for restoring thermal refugia for cold-water fishes.
- Measuring Gravel Bar Mobility in Large Rivers with Tracer Gravel.
- Coupling to Reclamation's Surface Water Model to a Groundwater Model.
- Measuring and Monitoring Sediment Transport in an Ephemeral Stream; Physical and Surrogate Data Collection.
- River restoration freeboard design requirements.
- Improvement in the accuracy and speed of riparian vegetation simulation.
- Representation of Large Wood Structures Using a Two-Dimensional Model.
- Robust Ecohydraulic 3D Modeling Tools for Rivers with Complex In-Stream Structures.
- Design of Low-Flow Ecosystem Features for Urban Flood Control Structures.
- Development of a new 2D structured and unstructured mesh generator for flow, sediment, temperature, groundwater, and vegetation modeling.
- Monitoring the Movements of Juvenile Pacific Lamprey in the Yakima River using Acoustic Telemetry.
- Quantifying Fish Biomass X Distance from Environmental DNA Samples in a Hydrodynamically Complex Environment.
- Seasonal/Temporary Wetland/Floodplain Delineation using Remote Sensing and Deep Learning.

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Current River Restoration Research and Future Needs

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River Restoration Workshops

In addition to funding research, Relclamation's Science and Technology Program has supported important workshops that bring together scientists working in river restoration to further research collaborations and proposal development.

- Stream Restoration Workshop (May 17-19, 2011; Sacramento, CA) attended by Bureau of Reclamation & U.S. Army Corps of Engineers technical staff. Specific objectives were to (1) review the state of science and engineering as practiced within each agency; (2) recognize pertinent science and technology gaps; and (3) identify opportunities for productive interagency cooperation and collaboration.

- River Restoration: Exploring Institutional Challenges and Opportunities (September 14 & 15, 2011, Albuquerque, New Mexico hosted by the Bureau of Reclamation and the Utton Center at the University of New Mexico School of Law. Brought together river restoration programs to discuss institutional challenges and possible solutions within the restoration and species recovery programs.

- Large Wood Workshop (February 14-16, 2012; Seattle, WA): Technical workshop on large wood applications and research needs in river settings. Individuals from federal, state, and local governments, tribes, universities, and private industry who research, design, and/or implement large wood in river restoration projects attended. A report documenting outcomes from the workshop and a subsequent large wood research roadmap can be found at *https://www.usbr.gov/research/projects/detail.cfm?id=3775*

- In May 2019 a River Restoration Training Workshop will bring together representatives of Reclamation's river restoration programs and researchers to share lessons learned in the areas of habitat, environmental flows, fish species, and adaptive management. The training workshop will include a technical field tour of the Fremont Weir project in collaboration with USACE. The outcome of the workshop will be a list of research topics and potential partnerships to inform upcoming FY 2020 research proposals at Reclamation.

River Restoration Partnership Highlights

Reclamation has an important partnership with the U.S. Army Corps of Engineers (USACE) in river restoration research referred to as the ecohydraulics theme area by USACE. Each year researchers from both agencies get together to share findings and explore opportunities to partner on upcoming research needs and river restoration studies along with infrastructure and invasive species. One major restoration project where Reclamation and USACE have worked together since 2017 is the Fremont Weir notch on the Sacramento River in California.

For this project a floodplain will be periodically inundated by overtopping the notch in the weir to improve rearing habitat for juvenile fish. The team is continuing their collaboration to complete the design and 3D modeling phases of the project. Reclamation and USACE have also collaborated on research related to large wood design guidelines.

Reclamation recovery programs also partner with local universities and other federal agencies in the area of river restoration. For example, there is a need to store design and monitoring data associated with river restoration to provide resources for future research that compare lessons learned and quantitative data across sites. In May 2019 Reclamation's Denver office will host a meeting being sponsored by the U.S. Geological Survey to look at options for developing an interagency river restoration database.

Participants in the River Restoration Training Workshop will complete a field tour of the Fremont Weir, shown above, to learn about the planning and evaluation process implemented to define the fish entrainment potential of 6 alternative notch designs evaluated as part of the EIS/EIR process.

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More Information

Fremont Weir Adult Fish Passage Modification Project - Revised Initial Study
https://water.ca.gov/LegacyFiles/environmentalservices/docs/yolo/yolo_R_is.pdf

Research and Partnerships

Modeling Hydraulics, Sediment Dynamics, and Vegetation Landscape in the Riparian Corridor

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S&T Project 6034
https://www.usbr.gov/research/projects/detail.cfm?id=6034

S&T Project 1778
https://www.usbr.gov/research/projects/detail.cfm?id=1778

Through several complimentary projects, Reclamation's Science & Technology Program has supported the development of modeling and analysis tools that support the Environmental Roadmapping priorities, including building an understanding of riparian vegetation lifecycle processes with linkages to water conveyance, sediment dynamics, and habitat availability.

Predicting the interacting effects of hydraulics, sediment dynamics, and evolution of the riparian landscape within managed riverine systems is a growing challenge due to the increasing priority of maintaining ecosystem function while sustaining water conveyance.

Questions pertinent to concern over managing conveyance, sediment, and habitat include the following:

- Conveyance: How can vegetation be incorporated into restoration projects without increasing flood risks?
- Sediment: How do varying riparian vegetation characteristics associated with restoration actions affect sediment transport dynamics within the system?
- Habitat: How will changes in riparian vegetation impact habitat for endangered and threatened species?
- Management: How do reservoir operations effect vegetation recruitment and survival?

Quantitative predictive tools are needed to aid the science, economics, and policy of establishing environmental flows by addressing questions regarding the physical interaction of flow, vegetation, and sediment in rivers and floodplains.

A quantitative two-dimensional model has been developed at the Technical Service Center for simulating the physical interactions of flow, vegetation, and sediment in rivers and floodplains. The model is based upon the SRH-2D package (Lai, 2010), which contains a two-dimensional flow and mobile bed sediment transport solver. The enhanced model is comprised of several computational modes that can be tailored to address commonly occurring questions pertaining to evaluation of alternative actions in river restoration design.

San Joaquin River restoration.

Vegetation Lifecycle Modeling: The model is capable of simulating the germination, establishment, growth, and removal of native and invasive vegetation in the riparian corridor. The model depends on rule-based algorithms that govern lifecycle processes as a function of dynamic hydraulic conditions.

Vegetation Resistance: The model predicts the hydraulic resistance associated with vegetated flow conditions as a function of vegetation characteristics. A spatially-distributed, dynamic roughness is computed using algorithms borrowed from an active body of research on the topic. The algorithms are tuned using species-specific parameters that are measured in the field or laboratory setting, or alternatively deduced from remotely-sensed (e.g., LiDAR) data.

Sediment Transport: The model simulates the effect of vegetated flow conditions on sediment mobility through a partitioned roughness that modifies the transport capacity calculations. The modified sediment transport capacity can provide more realistic predictions of sediment erosion and deposition under conditions in which vegetation causes a trapping effect on transported sediment.

The riparian vegetation modeling capabilities have been put to test supporting project work under the Trinity River Restoration Program and San Joaquin River Restoration Project; modeling work is currently under way supporting the Bosque Del Apache Channel Realignment Project on the Rio Grande.

San Joaquin channel realignment site riparian corridor.

Trinity River Restoration Project: The Trinity River Restoration Program Project Office requested the Bureau of Reclamation TSC to model the germination, establishment, and desiccation of riparian vegetation at the Lowden Ranch site. The approximately 3-mile long section of river, situated 7 miles downstream of Lewiston Dam, had previously received restoration treatment. The effects of changing key model parameters on the establishment rate and distribution of four vegetation types common to the Trinity River riparian zones were explored through a series of six simulations. Field data documenting the pre and post-restoration conditions along with hydrologic records provided a basis by which to evaluate model effectiveness.

San Joaquin River Restoration Project: The San Joaquin River Restoration Project Office requested the Bureau of Reclamation TSC to model several reaches within the project to assist in the planning of alternative designs. The utility of the vegetation lifecycle model was demonstrated by performing a dynamic simulation of six vegetation species (invasive and native) common to Western riparian zones. Comparisons of predicted vegetation distributions were made as a function of alternative proposed restoration flow hydrographs. Further modeling exercises were performed to analyze the hydraulics and sediment mobility effects as a function of proposed revegetation and channel design scenarios. The results predict how strategic revegetation can help stabilize sediment and sustain channel designs. Field work was performed to measure characteristics of the riparian vegetation which are necessary for parameterizing and comparing algorithms for computing flow resistance. Finally, a feasibility study was performed using readily available LiDAR data to gauge the efficacy deducing riparian vegetation characteristics. The study was motivated by the noted challenge in making comprehensive on-the-ground measurements.

Rio Grande Bosque del Apache Channel Realignment: The Bureau of Reclamation Albuquerque Area Office has requested the TSC to assist in analyzing riparian response to a channel realignment project currently under way in the Bosque del Apache reach of the Rio Grande. The project involves clearing of invasive vegetation (primarily Tamarisk) and rerouting the currently perched channel through an adjacent historic floodplain area. The existing channel configuration has been prone to sediment plugs forming, leading to loss of conveyance during high flow periods. Because the goals of the project are to improve both the reliability of water delivery and the vitality of native vegetation in the riparian corridor, modeling revegetation design alternatives represents a strategic approach to optimizing a solution.

Model Development: The vegetation modeling capabilities are undergoing active development and testing through project work, support from the Bureau of Reclamation Research Office, and collaborations with other organizations such as USACE, MIT, and UNM. It is anticipated that these additional efforts will result in improved capability to simulate the effects of stem-generated turbulence on sediment mobility, more appropriate scour modes, and more robust algorithms for estimating vegetation characteristics from LiDAR data.

Monitoring the Transport of Sediment in an Ephemeral Stream

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U.S. Army Corps of Engineers Albuquerque District
New Mexico Institute of Mining and Technology
Ben Gurion University
Yamma & Ayyeka Companies
CNRD France
German Research Center for Geosciences
U.S. Geological Survey

More Information
S&T Researcher
https://www.usbr.gov/research/projects/researcher.cfm?id=2351

Quantifying the mass, size, and frequency of sediment delivery from tributaries is requisite for understanding fluvial characteristics and geomorphic processes of a river reach. Perennial tributaries can be quantified fairly well using standard methods; ephemeral streams prove to be more difficult. These difficulties arise from: infrequency and flashy nature of events for obtaining measurements; varying cross sections shape during runoff events, where standard gaging methods cannot be utilized; and safety concerns in sediment laden water when a runoff event does occur.

A research station has been constructed on the Arroyo de los Piños, a tributary to the Rio Grande near Socorro, NM. The goals and methods deployed at this site have evolved over time, but the intent of this research is to: 1) develop a reliable relationship between surrogate signals coincident with physical sediment transport measurements contributing sediment to the mainstem; 2) identify channel and basin characteristics that generalize the results; 3) deploy a similar research facility within another ephemeral basin, using channel/basin characteristics to hypothesize surrogate-physical response, and; 4) test the research hypothesis by collecting coincident physical and surrogate measurements. The current status of the research is in the early phase, where physical and surrogate measurements are being made and the Arroyo de los Piños basin is being characterized. The ultimate goal is to deploy the surrogate methods in properly characterized basins so that sediment delivery will be reliably quantified at a reasonable cost.

This project has become a multi-agency effort with extensive collaboration. The interest generated by this research project is due to the data gaps recognized by hydraulic engineers, geomorphologists, biologists, and other researchers who work in the American Southwest and other arid regions. This project includes active participation and collaboration by Reclamation, Army Corps of Engineers, New Mexico Tech, and Ben Gurion University. There are many other collaborators on this project including Yamma & Ayyeka Companies, CNRS France, German Research Center for Geosciences, and United States Geological Survey.

The site was constructed and fully operational as of May 2018. The primary components of the site include: 3 Reid-type slot samplers, 2 active pipe microphones, 1 active plate with both a microphone and a geophone, vertical-horizontal duo pipe microphones, 4 passive hydrophones, seismometer, 2 ISCO pump samplers, 2 high-end turbidity sensors, 5 pressure transducers for stage, 4 rain gages throughout the basin, and a state-of-the-art signal processing/data storage system including cellular transmission, allowing monitored data to be viewed in real-time. These are supplemented by manual measurements of bedload, suspended sediment concentration, and velocity.

There have been a five runoff events during the 2018 monsoon season. Preliminary results for a variety of aspects of this research will be presented by research partners at the upcoming SedHyd conference this June: direct automatic, physical bedload monitoring and sampling; response of Japanese pipe and plate microphones (acoustic) to bedload; response of USGS-operated hydrophones to bedload; seismic response to bedload and turbulence; suspended sediment dynamics in a sand-rich arroyo, and; rainfall-runoff capabilities and dynamics within the Piños catchment.

Right: Research station viewed from right bank (flow direction is left to right). Three slot samplers across the width of the concrete sill, each with an acoustic sampler upstream of the inlet. Two blockouts downstream of the slot samplers are for future instrument deployments. Red stilling well on right bank includes protruding arms for suspended sediment sampling (not shown).

Left: Colleagues from New Mexico Institute of Mining and Technology sampling material collected in center slot sampler and preparing site for next event. Left to right: Madeline Richards (M.S. student), Dr. Daniel Cadol (advisor to both students), and Kyle Stark (Ph.D. candidate).

Pacific Lamprey Migration Study

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U.S. Department of Energy Pacific Northwest National Laboratory
https://www.pnnl.gov/news/release.aspx?id=4407

S&T Researcher
https://www.usbr.gov/research/projects/researcher.cfm?id=1465

The Pacific lamprey (Entosphenus tridentatus) is a migratory fish native to many rivers on the West Coast, including the Columbia River Basin. Adult lamprey spawn in fresh water rivers, where the juveniles may rear as filter-feeders buried in fine sediments for 4-7 years before becoming large enough to migrate to the ocean. In the marine environment Pacific lamprey are parasitic and feed on a variety of fishes including salmon, whales, rockfish, and pollock, and are preyed upon by sharks, sea lions, and other marine animals. After 1-3 years in the ocean, adult lamprey return to freshwater to spawn. Returning adult lamprey are an important food source for Native American tribes and are both culturally and ecologically significant. Since the late 1800's the distribution and abundance of the Pacific lamprey has been reduced dramatically in many river drainages where they were extirpated above dams and other impassable barriers, including many larger rivers throughout Washington, Oregon, and California. Range-wide restoration efforts are underway to improve lamprey abundance and distribution, but even basic life-history data such as migration timing for different populations is lacking.

Because lamprey are migratory, understanding their behavior and survival when they encounter irrigation and hydroelectric power projects is important for developing lamprey restoration strategies. Reclamation recently funded a Science and Technology grant to study migrating juvenile Pacific lamprey in the Yakima and Columbia rivers. Juvenile lamprey will be tagged with acoustic transmitters recently developed by the Pacific Northwest National Laboratory as part of an acoustic telemetry study being conducted in 2019-2020. The tags being used for this study are the smallest, lightest tags for use in fish and are not commercially available, thus part of the study will be evaluating acoustic transmitter performance. Fish will be released in the Yakima River and will migrate past a number of Reclamation diversion dams where they will be tracked with acoustic telemetry arrays to determine migration routes and survival. The results from the study will help managers learn more about the migration behavior of these juvenile lamprey in the mainstem and tributary environments as well as the potential impacts of various existing threats, including dam passage, diversion entrainment, predation, and impairment of water quality/quantity. Partners for this project include: Yakima Nation Fisheries, U.S. Bureau of Reclamation, U.S. Geological Survey, Pacific Northwest National Laboratory, and Kennewick Irrigation District.

An anaesthetized juvenile Pacific lamprey ready to be tagged.

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Collaborators

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Stillwater Sciences
Geosyntec Consultants
Council for Watershed Health
Southern California Coastal Water Research Project
Los Angeles County
The Nature Conservancy
Trout Unlimited
Arroyo Seco Foundation
Friends of the Los Angeles River
University of California Extension
U.S. Army Corps of Engineers

More Information

S&T Project
https://www.usbr.gov/research/projects/detail.cfm?id=1726

S&T Researcher
https://www.usbr.gov/research/projects/researcher.cfm?id=2801

Arroyo Seco Foundation
https://www.arroyoseco.org/fishreport180829.htm

EPA Urban Waters Partners
https://www.epa.gov/urbanwaterspartners

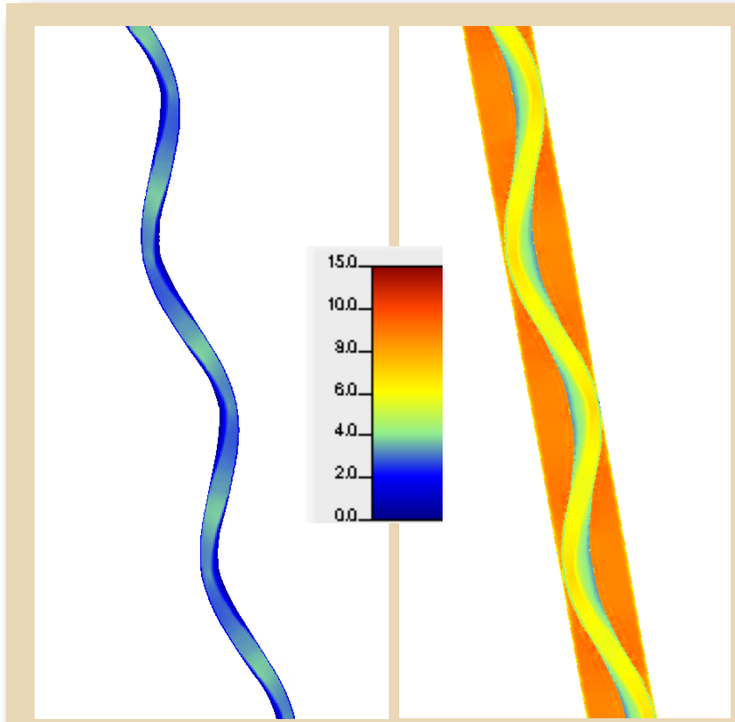
Los Angeles River Revitalization
https://www.lariver.org

Design and Analysis of Ecosystem Features in Urban Flood Control Channels

As watersheds throughout the western United States have become increasingly urbanized over the last century, Reclamation facilities and lands such as reservoirs, canals, and rivers have been impacted. Significant impacts include alterations to watershed hydrology, sediment yield, and imposed constraints that limit natural channel adjustment and floodplain access. Urban streams have perhaps suffered the greatest decline in biological habitat values and species diversity as rivers have been channelized and confined. Reclamation and the U.S. Department of Interior are participating agencies in the Urban Waters Federal Partnership. This program reconnects urban communities to their waterways and promotes collaboration to revitalize water systems by improving their economic, environmental, and social benefits. Additionally, Reclamation provided Title XVI funds to reuse some of the recycled water that currently makes up base flow for the Los Angeles (LA) River, where ESA-listed species such as the southern steelhead and Santa Ana sucker used to thrive.

Los Angeles River looking downstream from 1st Street.

In urban corridors such as the LA River, streams have been completely channelized and lined with concrete to efficiently convey floods and minimize erosion. These original goals have largely been accomplished but have resulted in degraded ecosystem services. Flow depths are uniform across the channel and velocities are increased with no refugia for aquatic species. Revitalization can be accomplished by considering channel functions over a range of low to high flows, thereby converting a single purpose (flood conveyance) waterway to a multi-purpose (flood control, habitat, aesthetics, and recreation) feature of the urban landscape. This research examines how to redesign the channel bed and banks to provide increased flow complexity and habitat heterogeneity within confined urban streams.



Velocity map for meandering low-flow channel design with pools and riffles (left) 150 cfs (right) 2,000 cfs.

As resources devoted to urban restoration, and the LA River in particular, increase, it is important to have performance data on various ecosystem features. This study evaluates methods that can be implemented within confined urban channels to improve ecosystem function without significantly raising flood stage at high flows. Using the LA River as a pilot site, conceptual designs are developed for the following features: meandering low-flow channel, variable width low-flow channel, pool-riffle sequence, flow deflectors (boulder clusters, transverse vanes), multi-thread flow paths, and variable roughness elements (cobbles, vegetation). Design concepts are tested and evaluated with a two-dimensional (2-D) numerical model and a physical model. Habitat suitability and effect on flood stage are assessed for each of the proposed ecological enhancement methods. Aquatic species habitat is improved by creating areas of low velocity refugia and adding diversity and complexity to the flow field. Results from this study provide tools for transforming urban flood control channels to multi-function streams with increased ecological and aesthetic values.

Radio-Frequency Gravel Tracking for Assessing Gravel Augmentations and Sediment Transport

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S&T Project 295
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S&T Researcher
https://www.usbr.gov/research/projects/researcher.cfm?id=2673

Dams reduce both the amount of transportable gravel and the frequency of transport episodes in the rivers downstream by disrupting the sediment supply from upstream and reducing the frequency and magnitude of peak flows.

Gravel transport is important to fish in several ways:

1. Salmonids and other fishes use gravel bars as spawning beds.
2. Gravel bars and other structural features composed of gravel are key components of the spatially complex channel morphology needed to support a diversity of physical habitats (e.g., juvenile rearing and adult holding).
3. Hyporheic flow through gravel bars moderates water temperatures, supplies nutrients, and alters water chemistry.

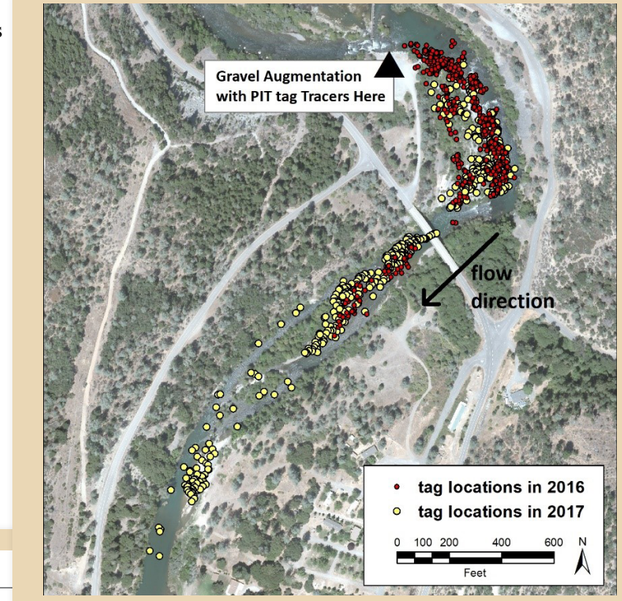
Adding mobile gravel downstream from dams (gravel augmentation) mitigates for the loss of upstream gravel trapped behind dams in a number of major streams within California's Central Valley Project, including the Trinity, Sacramento, and American Rivers, as well as in regulated tributaries such as Clear Creek and Grass Valley Creek.

Tracking gravel in the Trinity River with a large custom built antenna. The antenna can detect tagged gravel at distances up about 2 meters.

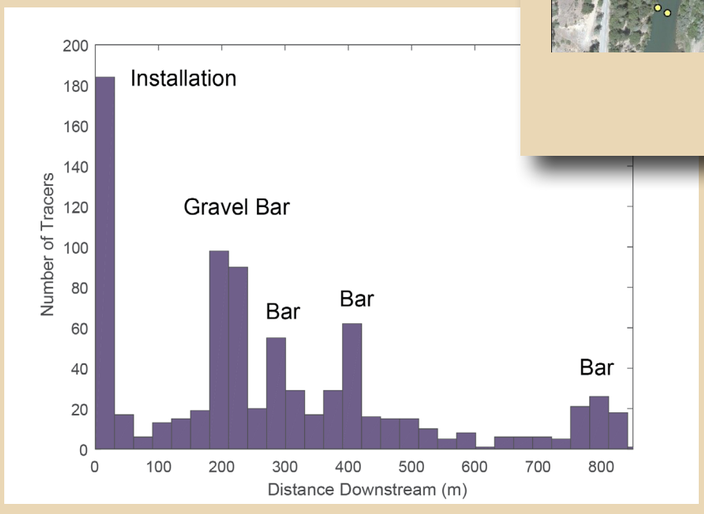
These projects require monitoring to assess the fate of the augmented gravel and the effectiveness of the gravel additions for improving habitat conditions. Monitoring techniques include bed load transport sampling to quantify gravel mobility and flux rates, repeated bathymetric surveys to assess changes in stream bed topography, and particle tracking to follow the trajectories of individual gravel particles. The trajectories identified by particle tracking are especially valuable for monitoring gravel augmentations because they allow scientists to observed precisely how far and fast augmented gravel travels in the stream and what types of topographic features they create.

Gravel particles with embedded passive integrated transponder (PIT) tags are a relatively new and particularly effective sediment tracking technology. The use of PIT tagged gravels to investigate gravel transport dynamics was introduced about a decade ago. Several pioneering studies in relatively small, wadeable streams produced tracer recovery rates above 90% for years after tracer installation. That early work included multi-year studies funded by the Research Office in California's Grass Valley Creek and in Halfmoon Creek near Leadville, Colorado. More recent work demonstrated the feasibility of tracking PIT-tagged gravel in much larger streams, such as the Trinity River where Reclamation scientists deployed a large custom-built antenna to search for tagged particles over several miles of a navigable river. In that Trinity study, a total of 2000 tracers were included in gravel augmentations at two locations during a 2016 spring flow release.

PIT tags can also be used to track the motion of natural gravels. The Methow River near Twisp, WA is confined by the Sugar Levee. By preventing channel migration, the levee appears to be creating a situation in which a large amount of natural gravel is routed rapidly through the levee reach and deposited on a large gravel bar downstream. Deposition on this bar appears to be forcing the river into the opposite bank, resulting in rapid erosion of private property. To test this hypothesis, Reclamation scientists, funded by the Research Office, deployed 600 PIT tagged clasts on gravel bars upstream of and across from the levee in the fall of 2018. By tracking the tracer motion over the next several years, we will gain information on sediment transport through this reach. Ultimately, this could lead to a decision to remove or relocate the Sugar Levee to create space for channel migration and sediment deposition and possibly reducing bank erosion downstream.



Distribution of tagged gravel in the Trinity River downstream of Lewiston Dam.



The peaks in PIT-tagged gravel tracer concentration in Halfmoon Creek correspond to the locations of gravel bars, highlighting the role stream morphology plays in modulating gravel transport.

In summary, gravel tracers studies using PIT tags are a powerful monitoring tool that can unequivocally demonstrate the geomorphic impact of specific management actions by directly linking sediment sources to specific transport characteristics and depositional features.

Novel Approaches to Restoring Rivers: Middle Rio Grande

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The Middle Rio Grande River (MRG) extends 286 miles from the mouth of Taos Box at Velarde, NM to Elephant Butte Reservoir. The MRG is wide and sandy, going from a trickle in winter to raging during spring. Due to the low gradient and high sediment load, coupled with periods of flooding and drought, various problems with drainage, sedimentation, flooding, and water delivery impacted the MRG valley.

These problems led to water resource development projects by Reclamation and the USACE involving river channelization, flood and sediment control dams, and irrigation and drainage improvements.

Newly constructed habitat feature that includes several connections to the main channel. The combination of embayments and a side channel is designed to maximize the conditions when habitat is created and reduce the likelihood of sedimentation that can eliminate the effectiveness of restored habitat.

This improved water delivery and impacted available habitat. Currently, there are endangered birds, plants, a mammal, and the Rio Grande Silvery Minnow in the valley. Channelization disconnected the river and floodplain, increased depth to groundwater, increased velocity, and reducing flow area.

Given Reclamation's mandate to deliver water and environmental stewardship, Reclamation is committed to performing river maintenance and habitat restoration for continued water delivery and ecological function. Due to the hydraulic and sediment regimes, bank lowering features have mixed success. The loss of restored habitat is due to continued channel degradation and/or accumulation sediment at channel margins, isolating habitat features by closing entrance/exit-ways. These challenges led to the investigation of optimizing these efforts.

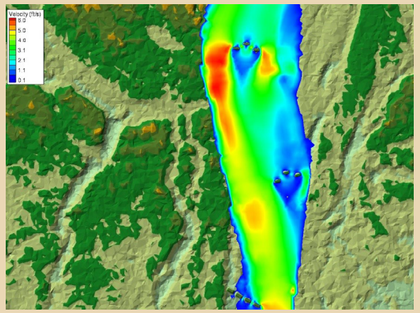
On-going investigations include:

1. Technical Services Center (TSC): We are investigating riverine aquatic habitat surfaces and their changes. This is being used to assess their configuration in the context of river hydraulics and sediment to determine their impact on project resilience. This will help develop design criteria for siting and designing future projects.
2. The University of New Mexico (UNM): We are collecting hydraulic and water quality characteristics, with biological richness and diversity to assess their relationships. We can then design projects to maximize biological production.
3. TSC, UNM, and Colorado State University: We are looking at larger temporal and spatial scales, attempting to correlate minnow population and geomorphologic data. These efforts will improve our understanding of Minnow biological success at different locations and times.
4. Divisions at the Albuquerque Area Office are working together to develop a monitoring program to ensure that new habitat features are surveyed so that we can detect and quantify physical changes over time. Additionally, a number of hydraulic measurements will be collected to validate design objectives for aquatic habitat creation.

Aerial photo of a bank lowered aquatic habitat feature (top) during peak runoff, and (bottom) after spring peak flow, illustrating sedimentation of feature connectivity to main channel. This feature was re-excavated to maintain functionality.

Currently, development of aquatic habitat is driven by some knowledge of characteristics favored by the Minnow. Changes in the system leave some projects not functioning as desired. Biologists identified the need for habitat during years with low spring runoffs. It is our challenge to ensure that we maximize efforts to benefit the endangered species we are mandated to protect.

Improved Numerical Modeling Techniques for Understanding Flows around Large Wood Structures

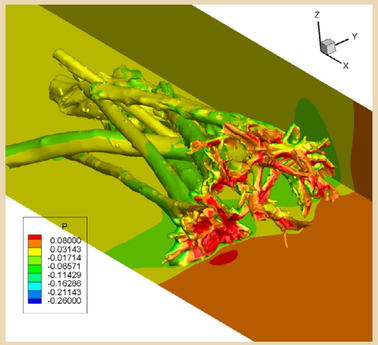


Predicted velocity magnitude affects near and around large wood structures.

Large wood structures have been widely used in stream and watershed restoration projects due to the many ecological benefits it offers. However, their use in streams have unresolved challenges with regard to their impact on stream morphology, safety and risk, as well as design and modeling uncertainties.

Large wood structures are being incorporated into project designs at a more frequent rate today than ever before. Hydraulic model results are instrumental in choosing structure type, placement, design parameters, and overall benefit. However, accurately representing the large wood geometry, force-balance equations, and structural evolution through hydro-dynamics modeling can be challenging. There are several ways to incorporate these structures into a hydraulic models, but the validation between what the model outputs and what is observed in the field is still being resolved through collaborative research.

Having a better understanding of the effects of implementing these types of structures through improved numerical model representation will aid in ensuring the design and effectiveness of stable wood structures. Increasing our confidence in how we numerically represent the hydraulic effects of large wood structures will help project managers and designers alike by driving down inflated factors of safety resulting in better, faster, and cheaper installations.



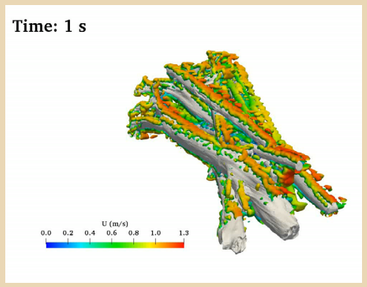
Predicted pressure distribution around an large wood structures using the 3D RANS model.

2D Numerical Modeling

This research is utilizing the SRH-2D hydraulics model to represent large wood structures using a selection of methodologies through a matrix of varying model parameters and techniques, essentially performing a sensitivity analysis.

Results from the sensitivity analysis that yielded the most reasonable foreseen modeling approaches are then being applied to data on existing field case studies through a partnership with the Sonoma County Water Agency.

Ideally, this evaluation of the representation effectiveness will lead to the best overall methodology while also gaining a better understanding of model limitations and uncertainty.



Predicted flow vortices around an large wood structures using the 3D RANS model.

3D Numerical Modeling

This current research is focusing on the development of a three-dimensional (3D) numerical model to understand the flow field around large wood structures (LWS). The results will allow a better understanding of the flow features created by LWS that may be beneficial for fish habitat; it also computes the force and moments acting on the LWS so that stability may be assessed with such structures. A high-fidelity numerical model can predict the flow and stability impacts of the installed LWS which will allow Reclamation to use LWS as a stream restoration technique responsibly and effectively.

Specifically, an automated 3D Reynolds-Averaged Navier-Stokes (RANS) solver is being developed with the immersed boundary method (IBM). This new IBM technique makes the flow field representation around LWS relatively simple: Only a simple background mesh and the scanned complex geometry of the LWS are used as inputs to the model and the rest of the modeling is carried out automatically by the software. Sample results are shown in sample images below in which the predicted pressure force distribution around a sample 6-piece LWS and the nearby flow vortices are displayed.

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S&T Project 1734
https://www.usbr.gov/research/projects/detail.cfm?id=1734

Large Wood Implementation: Lessons Learned from the Trinity River Watershed

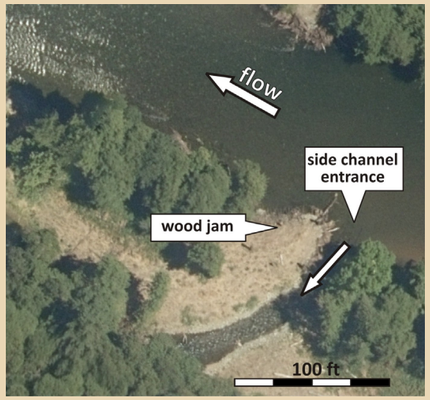
In 2015, the Bureau of Reclamation and the U.S. Army Corps of Engineers completed a *National Large Wood Manual* detailing the ecological functions of wood in rivers and guidelines for design and implementation. As described in the manual (see link for S&T Project 2754 below), wood in rivers increase trophic production, stores sediment and nutrients, and provides cover used by both juvenile and adult fish. Accumulations of wood known as wood jams are also important structural elements that promote hydraulic diversity and the development of pools, bars, side channels and other elements of habitat complexity. Since the release of the manual, additional techniques have been developed to improve implementation efficiency and ecological effectiveness.

Abundant Chinook fry using a constructed wood jam in the Trinity River.

Wood is being used extensively to improve aquatic habitat in the Trinity River watershed in Northern California. The Trinity River Restoration Program (TRRP) and its partners have constructed scores of wood features ranging from single pieces to engineered log jams containing in excess of 60 logs and trees over the past decade. These wood jams, which have been constructed using a variety of implementation techniques using only natural materials for ballasting and structural stability, have been monitored over the years to evaluate their evolutionary characteristics. Observations show that design architecture and geomorphic position in the river is more critical to their structural stability and longevity than the amount or type of ballasting.

Many of these wood structures are integral components of channel-scale features like constructed mid-channel islands or side channels designed to increase the availability of rearing habitat for juvenile salmon. Not only do these wood structures provide an abundance of cover habitat amid submerged logs, branches, and slash, but they also help to maintain adjacent habitats.

A recent example of an integrated wood structure and side channel complex was constructed as part of the Deep Gulch project on the Trinity River in 2017. That wood jam, denoted as IC-4 in project design documents, is located on the left bank of the river immediately downstream from the entrance into a constructed side channel. Its architecture consisted of over 50 logs and whole trees placed in horizontal and vertical arrangement with approximately 150 cubic yards of slash and 500 willow cuttings, and its foundation extends more than 10 feet below the river bed with pilings driven by an excavator outfitted with a modified rock hammer attachment. The ballasting consists of earthen materials only and does not use artificial anchoring materials like cables, rebar, or bolts. In addition, the construction was performed within a wild and scenic river corridor while maintaining turbidity and boater navigation requirements throughout the construction period.



The IC-4 wood jam at Deep Gulch is designed to improve the function of a constructed side channel.

Side channels habitats like the one adjacent to IC-4 are especially valuable restoration features because they add extra shore length where low flow velocities and proximity to riparian cover offer quality salmon rearing habitat. Side channels, however, often experience deposition in their entrance areas that blocks surface flow from the main channel during low flow periods. Designers of the Deep Gulch project hypothesized that the IC-4 wood jam would help prevent sediment deposition in the side channel entrance via two mechanisms. First, at 30 feet wide by 9 feet high, it has the potential to obstruct flood flows enough to create a small backwater zone that prevents sand and gravel from reaching the side channel entrance. Second, turbulence generated at the face of the jam is expected to cause local scour within the side channel entrance, further preventing sediment deposition in that area. In the year since construction, this side channel and wood jam complex has performed well and shows little or no evidence of deposition in the entrance area. Continued monitoring will establish whether this particular design functions as hypothesized during larger floods and maintains its structural stability over time.

One research area to be explored is how to better incorporate plant materials into the core of the structure in combination with design consideration for promoting internal hyporheic flows that promote root growth. Revegetation success in wood jams is critical for both habitat development and long term structural integrity.

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Trinity River Restoration Program
http://www.trrp.net/

Restoring Thermal Refuges for Cold-Water Fishes

Deep pool and high-degree of sinuosity in newly constructed channel of Catherine Creek promoting hyporheic exchange (inflow and outflow from channel into subsurface).

Human impacts to rivers have resulted in increased water temperatures threatening cold-water aquatic species such as salmonids. These include channel simplification, removal of riparian vegetation and the shading it provides, as well as global warming (Schindler, 1998; Caissie, 2006; Justice et al., 2016). Higher water temperatures in rivers can reduce cold-water fish viability by influencing fecundity and reducing food sources (Konecki et al., 1995). This can result in localized extirpation of certain species and overall reduction in habitat basin-wide (Batin et al., 2007; Ruesch et al., 2012; Justice et al., 2016). If cold-water aquatic species recovery programs are to meet their long-term goals, they must consider mitigating the impacts of warming waters with "thermal restoration" by both increasing riparian shade and by restoring thermal diversity that can provide thermal refuge.

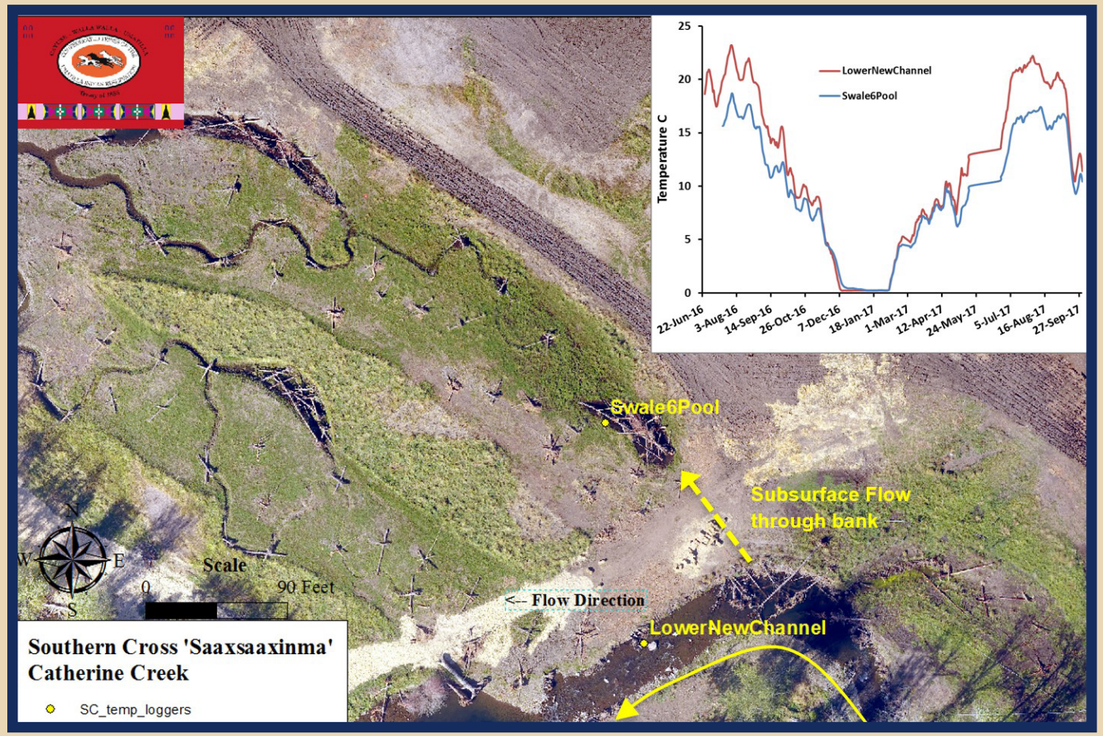
Thermal restoration refers to physical and biological river habitat restoration practices that result in restoring flow patterns and sediment processes of a river augmenting the ability of river water to interact and flow through with its bed and floodplain. When more river water flows through the bed and floodplain, water temperatures are buffered, lagged, and cooled (Arrigoni et al, 2008) resulting in areas where temperatures are out of sync with the main stem. Thermal restoration may involve enhancing connectivity between surface and groundwater systems at the hyporheic zone (the interface between surface and groundwater along a river bed and floodplain) through physical channel and floodplain manipulation. It may also involve re-vegetating the riparian zone to promote shading. Thermal refuges refer to areas within a river corridor where temperatures are more favorable than mainstem temperatures as a result of this buffering, lagging, or cooling (i.e., colder in the summer time and warmer in the winter time).

The Bureau of Reclamation and other federal agencies have devoted significant resources into river habitat restoration for threatened and endangered aquatic organisms. Much of this restoration has focused on constructing physical habitat. Restoring rivers to mitigate thermal impacts and create thermal refuges is a relatively novel objective for river restoration. Currently, there is little documentation of the ability of physical channel and floodplain restoration to mitigate the impacts of warming and create thermal refuges (Hester and Gooseff, 2008). We must develop a better understanding of what restoration techniques are effective at cooling water temperatures to better inform future efforts.

Several Reclamation designed channel and floodplain restoration projects having thermal restoration as a stated objective have been constructed or are actively under construction. A scoping proposal through the Science and Technology Program is funding the development of a full proposal evaluating if and how these projects influence temperature patterns within the restored reaches. This project is a partnership between the Technical Services Center, Sedimentation and River Hydraulics Group and the Pacific Northwest Region, River Systems Analysis and Restoration Group.

This scoping investigation focuses on projects on the upper Grande Ronde River and Catherine Creek in Oregon where restoration work includes the creation of perennial and intermittent side channels, multiple threads of the main channel, complexity in the pattern (sinuosity) and profile of the channels, installation of large wood features, and re-vegetation of the riparian area. These activities are hypothesized to enhance flow through and exchange of water between the surface and hyporheic zone over short (i.e., flow through a riffle) and longer (i.e., flow through the floodplain within a meander bend) flow pathways. When water moves through these features temperature is buffered and lagged over hours, days, and even months, potentially serving as thermal refuges at the points of outflow (Arrigoni et al., 2008; Poole et al., 2008). Extensive surface water temperature and groundwater level and temperature monitoring data collected at the restoration sites before and after restoration work will be analyzed to conduct this study.

A floodplain rearing channel ("blind channel"), constructed on Catherine Creek, is an example of a feature constructed to enhance this kind of hyporheic flow. Coarse cobble and gravel material are placed within a trench that connects with the main channel. Water flows through the trench as it would in a french-drain and connects with a side channel and pool system at its outlet. This feature mimics an abandoned channel that might play a similar role and provides water with buffered temperatures to off-channel habitat with the goal of providing more habitat for salmonids to rear over the winter.



7 day average daily maximum (7DADM) stream temperatures at a blind channel pool (blue line) and the main stem of Catherine Creek (red line) at the Southern Cross fish habitat restoration project for June 2016 through September 2017. Nearly a 5°C difference in 7DADM between pool and main channel in 2nd year of project (Jul-Sept 2017).

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Featured Faces

Highlighting Researcher Excellence

The following Reclamation researchers are critical to the success of the agency's work in River Restoration. Look for their contributions within this issue of the *Knowledge Stream*.

Michael Horn | mhorn@usbr.gov

Mike is a fisheries biologist with the Fisheries and Wildlife Resources Group at the Technical Service Center. His past work has involved cooperative studies using passive sonar technology (DIDSON, Split-Beam Hydroacoustics) to assess effectiveness of fish guidance structures on the Sacramento River in California, and fish passage over dams on the Yakima River in Washington. He is currently involved with a study to examine the effects of artificial night time lighting on predation rates in the Sacramento San Joaquin River basins, as well as examining ways to reduce the releases of suspended particulate matter in the tailwaters of Clark Canyon Reservoir MT.

Mike Knutson | mknutson@usbr.gov

Mike is the technical team leader for the River Systems Restoration Group in the Pacific Northwest Region. He has been in this position for eleven years and has lead several award winning habitat restoration projects throughout the Pacific Northwest. While he continues to lead teams on large restoration projects, he is focused on developing a better understanding of the outcomes of floodplain re-connections and their ecosystem benefits. He was recognized as a regional 2019 Reclamation Engineer of the Year. Mike is pictured with his team, third from right.

Mike Sixta | msixta@usbr.gov

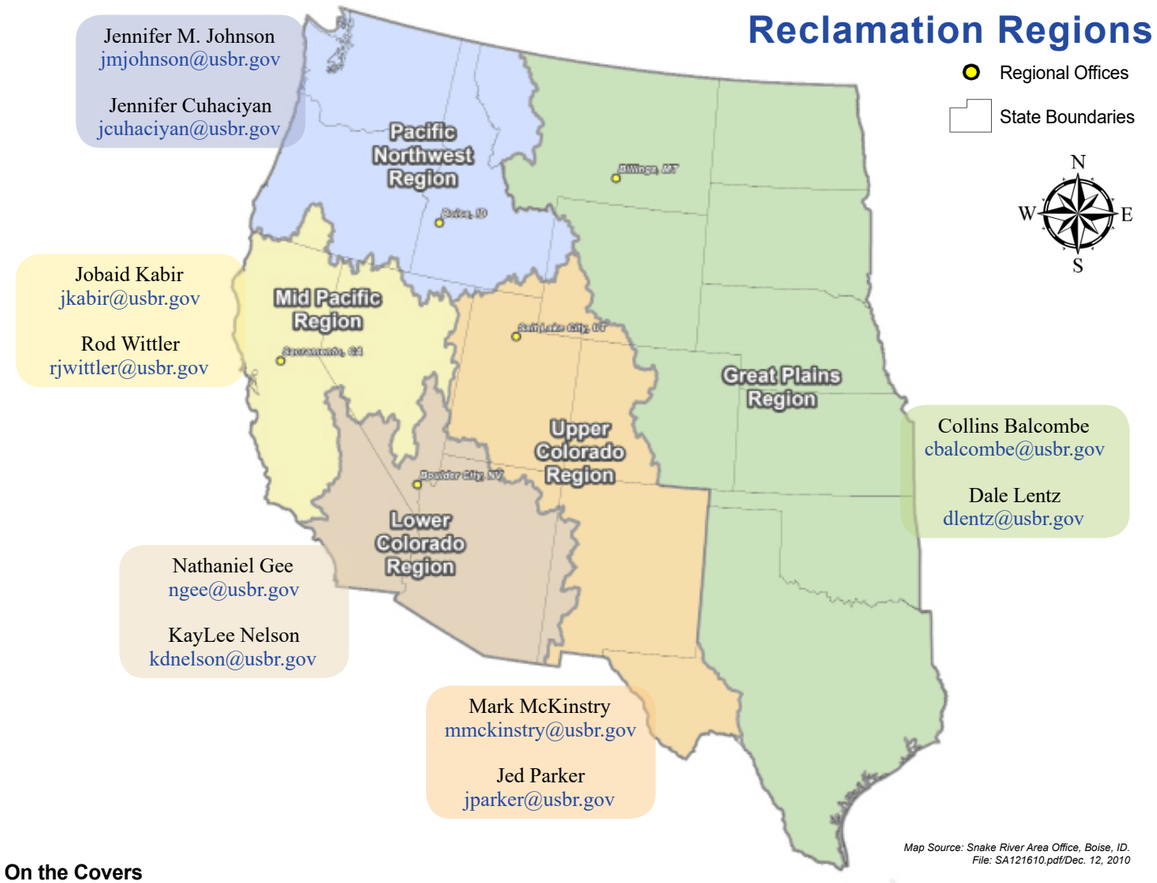
Mike is a hydraulic engineer in the Sedimentation and River Hydraulics Group. His past and current project work includes habitat restoration for endangered salmonids along tributaries of the Upper Columbia River Basin in the Pacific Northwest. He is currently researching the best way to represent large wood structures in a two-dimensional numerical hydraulics model.

About the *Knowledge Stream*

The *Knowledge Stream*, published by the Bureau of Reclamation's Research and Development Office, is a seasonal magazine bringing mission-critical news about the agency's research and science, as well as the many challenges associated with managing water and generating power in the West, including: projects, tools, methods, practices, results, innovation, prize competitions, publications, and more.

Regional Science and Technology Coordinators Contact Information

Whether you are a regional researcher, Reclamation partner or customer, or just have an idea for a project that can help your region, the Regional Science and Technology Coordinators can help you with your research ideas, proposals, and projects.



Map Source: Snake River Area Office, Boise, ID. File: SA121610.pdf/Dec. 12, 2010

On the Covers

FRONT: *Aerial image of Reclamation's restoration work along the Methow River, a tributary of the Columbia River in northern Washington.*
BACK: *Upper left - Reclamation's Susan Camp holds a lamprey. Bottom right - aerial view of Methow River restoration work, complements front cover. Upper right/lower left - juvenile salmon in a log jam restoration project of the Methow River, photo credit John Crandall, Methow Salmon Recovery Foundation.*