BUREAU OF RECLAMATION

Knowledge Stream

Research and Development Office

Innovation in Sustainable Reservoir Sediment Management

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Message from R&D

Welcome to the Fall 2022 issue of the *Knowledge Stream*! In this issue, we highlight research and innovation activities related to sustainable reservoir sediment management. Reservoirs provide a buffer to hydrologic variability both within a given year and across years, helping to reliably meet downstream demands. However, as decades go by, reservoirs are steadily losing water storage capacity, with sediment filling space once reserved for water. This presents significant challenges for reservoir operation and maintenance in addition to supply reliability impacts associated with lost storage capacity. Reservoir sedimentation is complex. Monitoring an underwater process occurring over significant space and time is not trivial. Management may involve moving tons of material from difficult to access locations. Finally, aging facilities coupled with increasing frequency of extreme precipitation events and wildfires will continue to make sedimentation an important topic for Reclamation, today and going forward. Included in this issue you'll find articles about:

- Challenges and opportunities related to reservoir sedimentation
- Post wildfire sedimentation
- Water quality and sedimentation
- Guardians of the Reservoir prize competition
- The researchers behind sedimentation work at Reclamation

About the *Knowledge Stream*

The *Knowledge Stream*, published by the Bureau of Reclamation's Research and Development Office, is a quarterly magazine bringing mission-critical news about the agency's innovations in the following:

- Science and Technology Program
- Desalination and Water Purification Research Program
- Prize Competitions Program
- Snow Water Supply Forecast Program
- Open Water Data Program
- Reclamation Geographic Information System Program
- Technology Transfer...and more

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Will Recent Trends in Wildfires Cause Reservoir Sedimentation Issues?

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Assessing Mercury Release from Contaminated Sediments During Dredging

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Front Cover: Willow Creek Reservoir near Granby, CO in 2021 showing reservoir delta with recent sedimentation effects from the East Troublesome Creek fire being studied by researchers at Reclamation. (photo credit Luke Javernick, River Science).

Back Cover: Aerial view of sediment delta formed in Elephant Butte Reservoir in New Mexico. (photo credit Nathan Holste, Bureau of Reclamation)

Community Needs

Recognizing Reservoirs as Assets

By Dan Staton & Jenn Bountry
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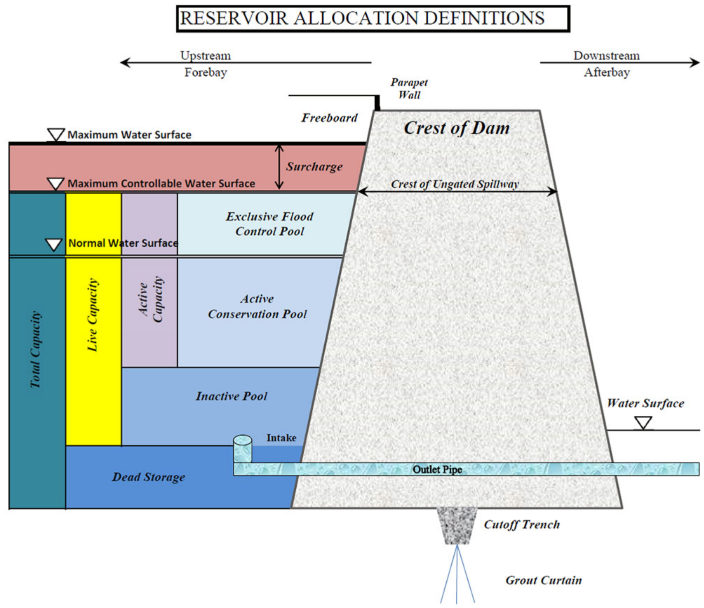
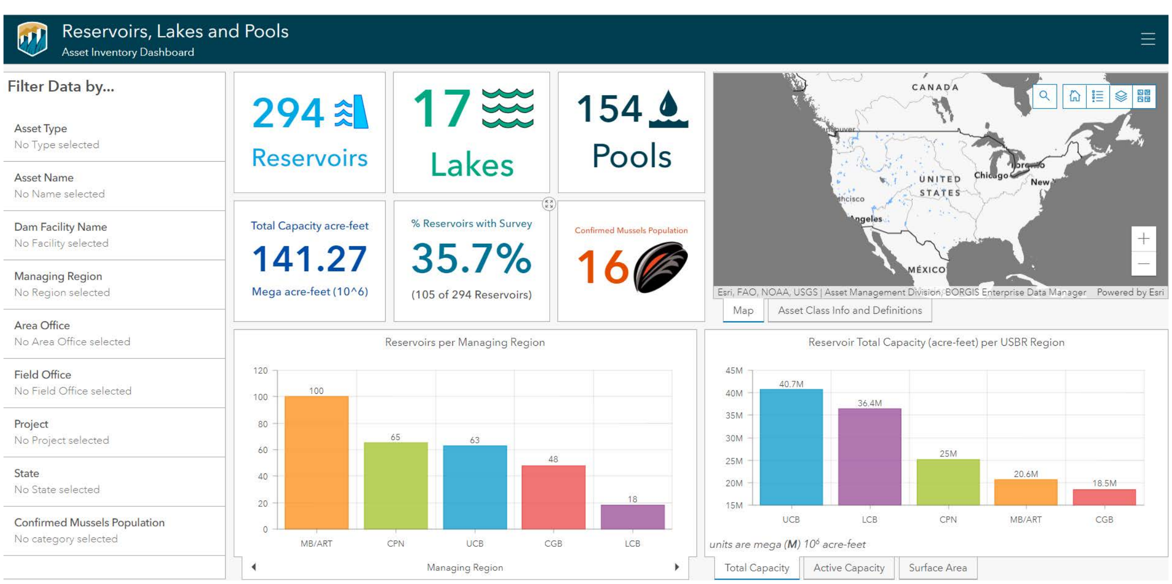


The Asset Management Division at the Bureau of Reclamation has embarked on the Enterprise Asset Registry Project to coordinate with asset class subject matter experts (SMEs) across Reclamation, develop requirements and processes for data stewardship, establish an inventory, and publish asset class data and editor applications across the organization for over 18 asset classes. Recently added is the Reservoirs Asset Class that now provides a single authoritative source in Geographic Information System format for Reclamation's entire inventory of natural or man-made water impoundments. The Asset Registry includes processes and procedures for maintaining the inventory over time in order to keep a record of changes (e.g., reduced storage capacity due to sediment load). The current asset class includes 294 reservoirs with a total capacity of 141.2 million acre-ft and provides a single resource to obtain information on any Reclamation reservoirs.

An important part of the asset class is recognizing how storage levels in our reservoirs are categorized and how sedimentation may be reducing various storage areas and reservoir operations and benefits. As sediment begins to build in reservoirs, it initially fills dead storage. Over time, sediment can build up in the active pool and result in release of sediment downstream. Sediment connectivity through dams encourages natural sediment transport processes and can be beneficial to downstream ecosystems, coastal areas, and riparian zones, but it must be carefully managed to not cause unintended impacts. Research to help with sediment monitoring, removal, and management tools will help Reclamation in the coming decades to optimize multipurpose operations and continue to meet our mission of delivering water in an environmentally responsible manner.



The new reservoir asset class dashboard here provides a single source in geospatial environment for tracking information about the Bureau of Reclamation's reservoirs.

Building Survey Capacity for Monitoring Sedimentation

By Andrew Geister, Darion Mayhorn, & Jenn Bountry
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Over half of the Bureau of Reclamation's (Reclamation) reservoirs are over 60 years old, about 20 percent are over 80 years old, and 7 reservoirs are over 100 years old, which means many reservoirs are reaching the end of their original sediment-design life. In addition to sedimentation infilling caused by normal operations, wildfire – particularly the production of ash and a decrease in erosion resistance caused by destruction of vegetation – and changes in the hydrologic regime are exacerbating the issue. Reservoir surveys are needed to estimate when sedimentation impacts will impair reservoir function and to properly plan sediment management actions or operations to encourage sediment continuity through the watershed.

Conducting a reservoir bathymetric survey on Palisades Reservoir in June 2022. Photo taken by Travis Hardee, June 30, 2022.

A new reservoir survey data repository (RESDATA) is being built to house all surveys and area-capacity tables in one unique place! If you have surveys or data to contribute, please reach out to Melissa Foster via TSCreservoirsurvey@usbr.gov. To date, only approximately one-third of Reclamation reservoir assets have been resurveyed since original construction, and many of these resurveys are outdated, as the mean time since the most recent resurvey is 25 years. A new requirement was recently incorporated into Reclamation Manual Directive and Standard (D&S) FAC 02-01, Operating Practices and Procedures for High and Significant Hazard Potential Dams (and other facilities, as applicable), to address the current deficit. Regional directors are now required to "coordinate, schedule, and budget for Reclamation's costs in the development of reservoir sedimentation plans for storage reservoirs at high and significant hazard potential facilities that do not have a reservoir sedimentation monitoring plan in place." To support the regions in fulfilling this D&S, a Reclamation-wide Reservoir Sedimentation Survey Team (Sedimentation Survey Team) is proposed. The Sedimentation Survey Team will help to foster regional cooperation, meet region-specific needs, and share resources and training, thus significantly increasing Reclamation's capacity to survey its reservoirs. Research is one important way to support the new Sedimentation Survey Team and share knowledge in advancements in data collection and processing technology and best practices. Check out the Fall 2022 issue of the Water Operations and Maintenance Bulletin for more information about development of the Sediment Survey Team and efforts funded by WATERSMART to further RESDATA and sediment yield prediction capability.

Collaboration on Reservoir Sedimentation: The Importance of Partnerships

By Tim Randle & Jenn Bountry; with partner, U.S. Geological Survey & U.S. Army Corps of Engineers

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The Bureau of Reclamation (Reclamation) is, and has been, actively collaborating with the U.S. Army Corps of Engineers (USACE) on the technical aspects of reservoir sedimentation. Interagency collaboration between the two agencies includes research, training, and specific projects. Collaboration brings together the best expertise from both agencies and improves the quality and efficiency of results. Examples include the recent Guardians of the Reservoir research prize competition that helped find better ways to remove sediment from reservoirs. The agencies have shared methods of numerical sediment transport models they have developed (e.g., SRH-1D, SRH-2D, and HEC-RAS). The agencies jointly provided training on reservoir sedimentation in Vietnam and Laos and invited international governments to send engineers and scientists to Denver, Colorado, for training. The USACE invited Reclamation to participate in training presented by their Regional Sediment Management Team. Project collaboration examples include sedimentation investigations at Big Horn Reservoir in Montana and Wyoming and Lewis and Clark Reservoir in South Dakota and Nebraska.

To better understand reservoir sedimentation processes, measurements of incoming sediment loads to reservoirs, characterization of sediment deposits in reservoirs, and released sediment loads are critical. Interagency collaboration on sediment measurements has existed since 1939 under the Inter-Departmental Committee. The project later became known as the Federal Interagency Sedimentation Project (FISP) (https://water.usgs.gov/fisp/). Since then, the FISP expanded to include collaboration on all sedimentation topics (including reservoirs) and included representation by nearly all Federal agencies concerned with water and sediment. Reclamation uses FISP research and development on sediment measurement methods and devices for quantifying incoming sediment to reservoirs and sediment released from dams.

Bureau of Reclamation and U.S. Army Corps of Engineers scientists working collaboratively on research to determine sediment thickness in reservoirs.

Another long-standing interagency collaboration since the 1940s is the Advisory Council on Water Information's (ACWI) Subcommittee on Sedimentation (SOS), which promotes collaboration on sediment issues; and advances in information gathering, storing, and sharing; for decision making about natural resources management and environmental protection. The SOS, along with many other advisory committees, was retired in December 2019. However, FISP continues as a separate project and collaboration among Federal agencies continues with universities and scientific organizations under the SEDHYD organization.

SEDHYD provides a forum to foster knowledge transfer and collaboration. Reclamation, the USACE, and the USGS have been very active in the planning of the periodic SEDHYD Conference. This conference brings together Federal and non-Federal scientists, engineers, and managers from various natural resources disciplines. Proceedings from the past conferences dating back to 1947 are available at www.sedhyd.org/. Papers include recent accomplishments and progress in research; technical developments in the physical, chemical, and biological aspects of sedimentation; and the development and use of computer models that simulate surface water quality and quantity as well as sediment erosion, transport, and deposition. The 12th SEDHYD Conference is scheduled for May 8–12, 2023, in St. Louis, Missouri.

Key Perspectives

Reservoir Sedimentation Challenges and Opportunities

By Carolyn Gombert, Jenn Bountry, & Tim Randle
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Water storage reservoirs in the arid Western United States are getting on in their years. Unfortunately, they are not aging with grace. As decades go by, reservoirs are steadily losing water storage capacity, with sediment filling space once reserved for water. Presently, remaining storage capacity in reservoirs is about the same as capacity in the 1970s. Reversing this trend demands critical thought and intentional action. Coupling shifts in design and management will be key to ushering our reservoirs into the decades yet to come. As noted in a recent article on how to manage sediment, "Fundamentally, achieving sustainable reservoir management requires acknowledging that sediment is not a pollutant, but is, instead, like water, often a beneficial resource that must be wisely managed."

Today, reservoirs and their dams are critical components of our infrastructure. By capturing, storing, and regulating water, reservoirs provide water for agricultural, industrial, and municipal use; allow for the generation of hydropower; and serve as a destination spot for recreation. The rivers that transport water to our reservoirs also naturally transport sediment. Depending on different hydrologic, geologic, and biological factors, rivers can carry material ranging in size from very small clay particles to large boulders bigger than one's fist. A river's ability to transport sediment changes drastically after construction of a dam. Particles that once easily made their way downstream instead accumulate in the stagnant reservoir pool. Over time, this sediment accumulates – a process known as reservoir sedimentation.

Historically, reservoir sedimentation was only considered for the 50 or 100 years of the reservoir life. Designers planned for accumulation of sediment over this time period, a concept known as the sediment-design life. Design plans then placed the elevation of key features, such as dam outlet structure, above the estimated sediment level associated with the sediment-design life.

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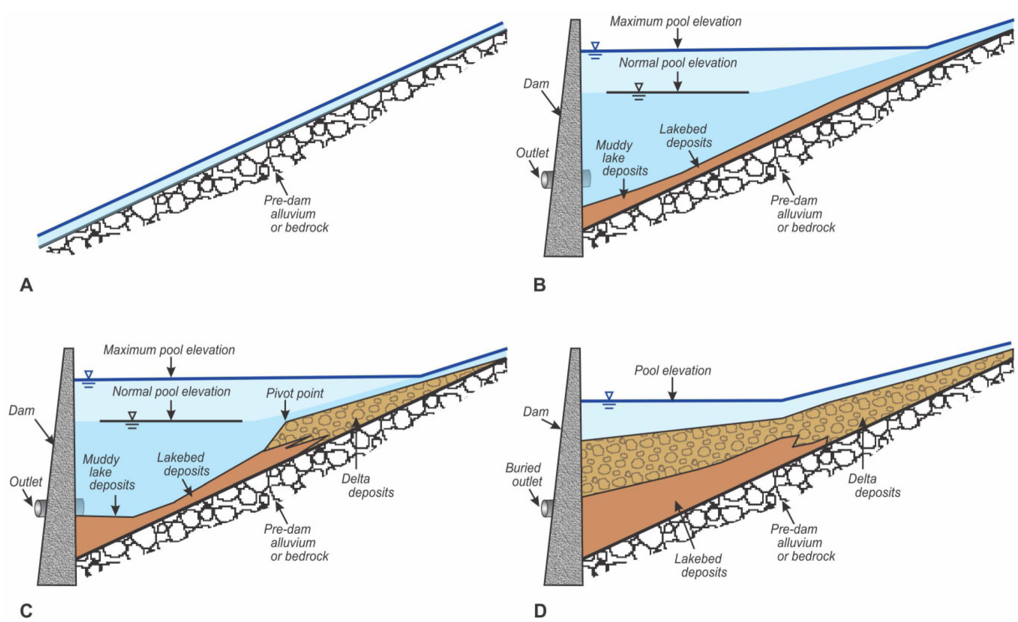

Process of reservoir sedimentation:
A) original riverbed,
B) new dam construction,
C) sedimentation that is near the "sediment-design life," and
D) dam outlet works burial.

Schematic of locating the outlet works intake to account for reservoir sedimentation at Sumner Dam near Fort Sumner, New Mexico. Photo captures the same outlet works, 65 years later, after sediment-design life has been reached.

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For example, the predicted sedimentation level at the dam, over the sediment-design life, was used to determine the elevation of the dam's outlet works.

Now, a significant number of reservoirs are close to or have already reached their sediment-design life. Sedimentation and debris can plug dam outlets, deposits choke water supply intakes, and boat ramps lead to sand instead of water. Sedimentation extends along the upstream river channel while the downstream channel erodes. All these symptoms of sedimentation come with a fundamental shift in reservoir function: loss in storage capacity.

Constructed reservoir storage capacity peaked in the United States around 2000, but sedimentation has been reducing this capacity since the dams were built. Today, remaining storage capacity is about the same as it was in the 1970s. Since the 1990s, sedimentation has led reservoir storage capacity to decrease faster than capacity has been added by new dam construction. Furthermore, taking population growth into account, the current per-capita reservoir storage in the United States has declined to storage volumes available during the mid-20th century during the heyday of dam construction.

Reservoir sedimentation is difficult to detect without dipping below the water surface to get the real story. Often, a reservoir's level of aggradation sedimentation will go undetected unless the sediment accumulation interferes with dam infrastructure (i.e., outlet structure), buries boat marinas, or impedes fish passage or access. To quantify sediment deposition in a reservoir, it is best to complete a bathymetric, or below water, survey. During bathymetric data collection, crews operate a boat equipped with a Global Positioning System unit and depth sounding equipment. Presently, much less than half of the reservoirs in the Western United States have been surveyed since being built. Current efforts to construct a database of reservoirs, coupled with survey data, will streamline efforts to prioritize reservoirs that are most at risk and will require surveys sooner.

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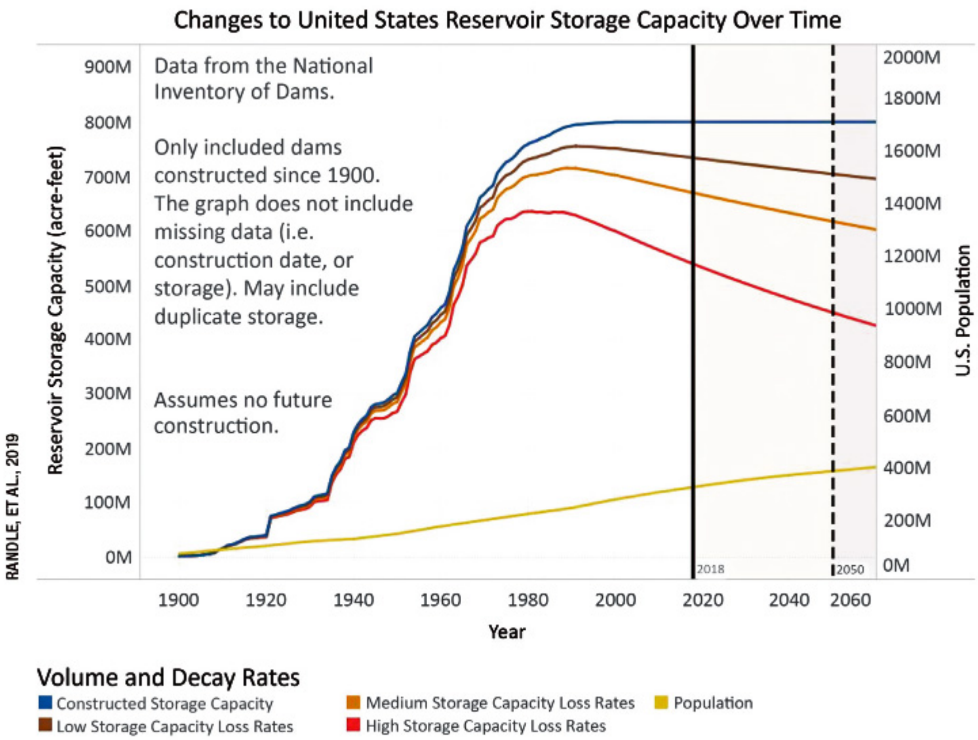
To move forward, it is imperative to reframe our relationship with reservoirs and look beyond their sediment-design life. Climate change is predicted to accelerate rates of reservoir sedimentation. With the backdrop of climate change, the possibility that the severity and frequency of droughts and floods could increase lends urgency to a need for a shift in approach. Research into processes linked to reservoir sedimentation is already underway and will likely support future sediment management decisions. A better understanding of the impact of wildfire on sediment delivery, research into the source of sediments, efforts to shed light on water quality, and habitat impacts of sedimentation are all key pieces of the reservoir sedimentation puzzle.



Changes to United States reservoir storage capacity over time due to dam construction and reservoir sedimentation. Randle, et al. 2019

Heavy sedimentation in Basin 3 of the All American Canal desilting works has required sediment removal with heavy equipment.

New Tools on the Block

Evaluation of Subbottom Profiling Technologies for Measuring Reservoir Sedimentation Stratigraphy

By Dan Dombroski; with partners, U.S. Geological Survey & U.S. Army Corps of Engineers
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EdgeTech CSS-200 subbottom profiling instrument in tow at Cherry Creek Reservoir in Colorado.

Reservoir sedimentation varies in space (geography) and time (events), creating great uncertainty in the useful lifespan of water infrastructure projects. Many of the Federal dams are beyond the latter half of the design lifespan without having received sufficient study and monitoring to establish sediment management plans. As reservoir sedimentation is an interagency issue, the Science and Technology Program is supporting collaborative efforts aimed at developing and adopting methodology for characterizing deposited sediments. A team of experts from the Bureau of Reclamation, U.S. Army Corps of Engineers (USACE), and U.S. Geological Survey (USGS) will compare the effectiveness of different subbottom profiling instruments in characterizing deposited sediments and determining pre-impoundment (before dam closure) surfaces at a reservoir with well-studied geomorphic conditions.

Subbottom profiling systems use high-powered acoustic pulses over a range of relatively low frequencies to penetrate up to tens of meters into sediments for remote characterization of stratigraphy. Variation in sediment density due to compositional nonuniformities cause unique reflections of the transmitted acoustic signal, which can then be interpreted to generate maps of stratigraphy. The information garnered is more robust and cost effective than what can be collected through traditional methods alone, such as sediment core sampling. The study, anticipated in early 2023, will build off the success of a scoping-level effort that demonstrated the feasibility of using acoustic technology for characterizing deposited sediments at two reservoirs in Colorado: Cherry Creek, near Denver and Shadow Mountain Lake, near Grand View.

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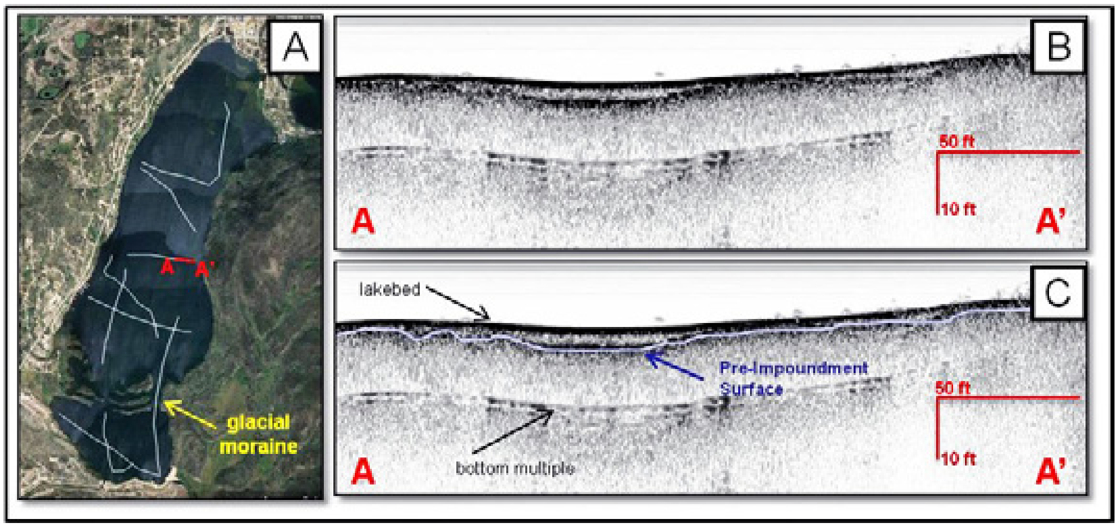

(A) Map view of Shadow Mountain Lake reservoir (Colorado), with subbottom track lines plotted in white. The location of the cross-sections in (B) and (C) are noted by the red A- A′ line on plot (A). The glacial moraine is noted by the yellow arrow and text. (B) Example of uninterpreted and (C) interpreted subbottom profiles.

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The mapped subbottom surface elevations (as derived from the study results) were consistent with known pre-impoundment surfaces prior to dam construction, and the data supported inferences regarding sediment stratigraphy. Overall, the results were useful in demonstrating the capability of the shallow acoustic technique in imaging pre-impoundment surfaces and assessing geomorphic conditions.

The USACE and USGS are jointly interested in working with other governmental agencies to further evaluate the capabilities and limitations of subbottom profiling technology in reservoir settings. Acoustic subbottom systems come in a wide range of stratigraphic resolution and penetration capabilities, and not all systems will yield similar data, nor are all easily portable and manageable in shallow reservoirs or reservoirs with restricted access. With instrumentation largely untested in applications to reservoir sedimentation studies, a thorough assessment of a variety of subbottom profiling systems is needed. This next phase of study aims to elucidate the effects of differential instrument characteristics on interpretation of results and develop guidelines concerning the selection and operation of subbottom profiling instruments. The study will be conducted at a single reservoir in California containing varied, yet well-documented, sedimentological conditions over the extent of the reservoir basin to allow for accurate and independent verification of the different subbottom systems.

Predicting Reservoir Drawdown Flushing to Improve Reservoir Sustainability

By Victor Huang
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Drawdown flushing can be used to remove reservoir sediment in small gorge-shaped reservoirs and to extend the reservoir lifespan. During a drawdown flush, a reservoir is drawn down to establish flow conditions through the reservoir that mimic flow along the river prior to dam construction. With its flow configuration, a drawdown flush is able to release both water and sediment from behind a dam. The efficiency of the sediment removal during drawdown flushing depends on many factors, including timing, duration, and reservoir shape, among others.

This study will look at the efficiency of reservoir drawdown flushing with different reservoir shapes using a two-dimensional hydraulic and sediment transport model. The research includes two parts:
(1) calibration of the numerical model to a real reservoir sediment flush event and
(2) application of the calibrated numerical model to a set of reservoir types modified from the real reservoir geometry.

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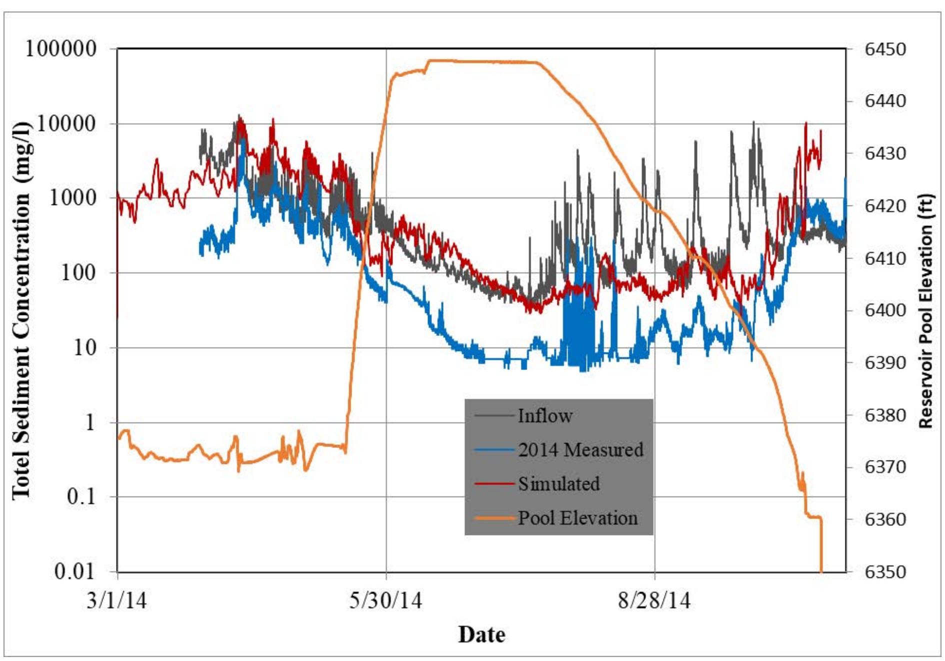
For the first task, Paonia Reservoir will serve as the example case. Paonia Dam and Reservoir are located on Muddy Creek, a tributary of the North Fork Gunnison River in western Colorado. Based on the bathymetric survey of the entire reservoir conducted in June 2013, the estimated average annual rate of sedimentation has been 101 acre-feet per year. The as-built storage capacity of Paonia Reservoir is 20,950 acre-feet, meaning nearly 25 percent of the reservoir's original capacity has been lost. During spring 2014, drawdown flushing was performed at Paonia Reservoir. The SRH-2D numerical model will used to simulate this drawdown flushing event. During model calibration, sediment concentration from the reservoir release will be used for comparison.

Paonia Outlet structure during emergency actions to maintain diversion, November 11, 2014.



Paonia Reservoir pool elevation and release sediment concentration during 2014 drawdown flushing.

For the second task, a set of reservoir types will be created to study the effects of reservoir types on the efficiency of reservoir drawdown flushing.

Reservoir sediment flushing provides a proactive approach to preserving reservoir capacity and minimizing downstream impacts. Failing to take actions with reservoir sedimentation will result in a loss of project benefits and expensive reservoir retirement options. This proposed research will provide a numerical algorithm to simulate scouring and resuspending sediment deposited in the reservoir and transporting it downstream. Methods and alternatives identified by this research will help determine the state of Bureau of Reclamation (Reclamation) facilities relevant to reservoir sedimentation impacts and will provide Reclamation and other Federal agencies with an application framework for taking a proactive planning approach to best manage reservoir sediment in a sustainable manner. This research will provide a scientifically sound method and guidance for reservoir sediment flushing. Failure to understand the fundamental characteristics of reservoir sediment flushing would result in usage of it in the ill-suited reservoir types, incorrect times of action, wasting of water, and adverse impacts to downstream ecosystems.

Abrasivity of Slurry-Transported Sediment: Development of Laboratory Test Systems

By Evan Lindenbach, PE, PG; Richard Bearce, PhD, PE; Mikayla Oligney, & Zachary Hein
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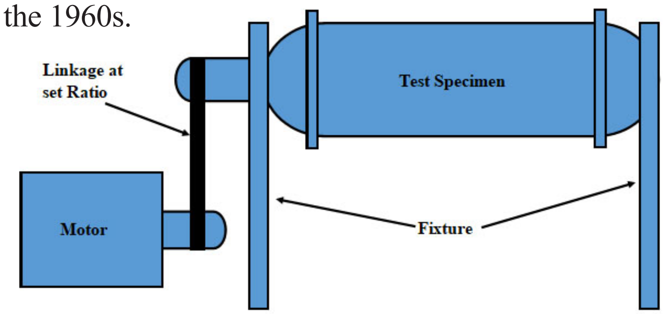
Sediment mobilized in flowing water is abrasive and can cause damage to the reservoir pumping structures, outlet works, gates, penstocks, and dredging systems. The Science and Technology Program has funded a multiyear, laboratory-scale research project to investigate slurry abrasion to inform reservoir sedimentation removal and future operations.

The thrust of this research is to develop laboratory-based systems to evaluate the abrasive potential of slurry-mobilized sediment to monitor damage, predict failures, and estimate the effect an abrasive slurry would have on the service life of reservoir infrastructure. The results will be used to optimize design and selection of materials of future infrastructure repairs and modifications. A multidisciplinary team, including mechanical, hydraulic, and geotechnical engineers, along with sedimentation and dredging experts, has been assembled to lead this collaborative effort.

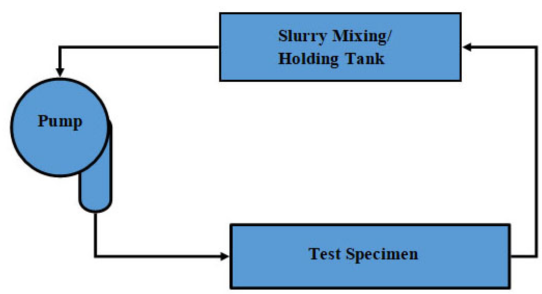
The research is being conducted in two phases: Phase I comprises a series of comparative tests using standardized bench-scale instruments with reservoir sediment and common pipe materials to elucidate on the state of the practice for evaluating slurry abrasivity and wear resistance of materials. The slurry abrasivity tests include the Miller Number test, Cherchar Abrasivity Index (CAI) testing, and petrography, and have utilized materials from Imperial Dam and Strontia Springs Reservoir. High-density polyethylene, concrete, polyvinyl chloride, coated mild steel, and stainless steel have been evaluated for their relative erosion resistance using the Slurry Abrasion response Number test, the underwater concrete abrasion test, and a coatings test designed by the Technical Service Center's (TSC) Coatings and Corrosion Group. The data collected during Phase I provide the underpinning for our understanding of the testing currently available to evaluate sediment abrasivity and the relative resistance of common pipe materials.

Phase II is an upscaling effort designed to evaluate the resistance of the common pipe materials using sediment from a subject reservoir. Phase IIa, recently constructed with commissioning occurring this fall, utilizes a rotating 6-inch-diameter pipe filled with a slurry comprising a sediment of interest at a known water content. The pipe is rotated with the mass loss over time documented; this approach builds on one developed by Bureau of Reclamation engineers in the 1960s.



Rotating pipe test conceptual layout.

Phase IIb is the design and construction of a large-scale abrasion test located in the Hydraulics Laboratory at the TSC. This system will consist of a large pump, or set of pumps, that will push a pre-mixed, site-specific slurry at a controlled velocity for a set amount of time through a test section of interest in what is termed a "Dirty Pump" hydraulic circuit. After conducting the test, the mass loss will be calculated and the wear pattern analyzed using high-precision surface scanning. The Phase IIb device design is complete, and construction will occur in fall/winter 2022.



"Dirty Pump" hydraulic circuit.

The final report for this research will touch on several concepts, including how the data collected from the different test types compare, which materials were more or less resistant to erosion, what operational conditions (velocity, solids content, duration, etc.) had the strongest effect on wear, and it will provide comments on considerations for future designs in which slurry abrasion is of concern. Please reach out to the lead author if you are interested in collaborating on this research. A specific need is to tie our laboratory data to wear documented in the field.

Moving Research to Application: New Facilitated Adoption

By Ken Nowak
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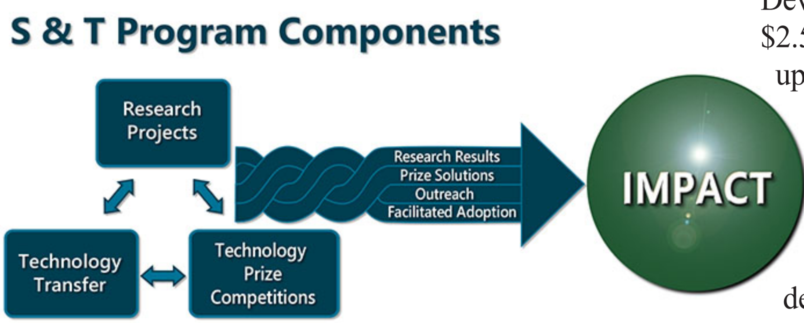
The Science and Technology (S&T) Program funds research projects and prize competitions that lead to promising solutions that can enhance the delivery of the Bureau of Reclamation's (Reclamation) mission by addressing known challenges. Currently, there is not an efficient process to support transitioning promising outcomes to implementation at Reclamation. This is a gap for Reclamation in which promising information, technologies, or other types of research results may not be utilized to their fullest extent.



Facilitated Adoption is a new program element for fiscal year 2023 that aims to take high-impact potential research results and prize solutions from completed activities and support further evaluation and implementation at Reclamation through demonstrations and knowledge transfer. Successful Facilitated Adoption projects will: (1) transfer knowledge and/or technologies to end users such that mission outcomes are enhanced and (2) integrate technologies/knowledge into processes and practices, thereby ensuring their use beyond the life of the Facilitated Adoption project.

Facilitated Adoption will use a competitive, merit-based selection of projects while offering proposal and review efficiency. The Research & Development (R&D) Office is planning to make $2.5 million available. Proposed projects must build upon completed S&T projects or solutions from prize competitions. This new program element will officially be launched in fall 2022. Lead researchers of completed S&T projects and members of prize competition teams will be notified of their eligibility to apply and process details. Stay tuned for future updates on this new R&D activity to help bring innovation to enhancing the delivery of Reclamation's mission.

For fiscal year 2023, $2.5 million for this program element was included in the President's Budget Request.

Rocks, Rivers, and Reservoirs: Can Long-Term Erosion Rates be used to Inform Modern Rates of Sedimentation?

By Melissa Foster
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Rivers transport sediment sourced from the upstream watershed. When rivers are impounded by dams, this sediment is trapped and accumulates through time. The volume of sediment in a reservoir indicates the average rate at which the contributing drainage basin delivered or produced sediment on a decadal to 100-year timescale. In reality, the rate of sediment delivery varies from year-to-year, as infrequent events such as drought, floods, landslides, and fires affect the rate of sediment delivery. In some cases, the life of a reservoir is too short to capture how rare rare events may affect long-term sedimentation rates; therefore, historic reservoir-sedimentation rates may not always accurately project future reservoir sedimentation, especially when the record of sedimentation is short. Predicting future sedimentation at Bureau of Reclamation reservoirs is further complicated by an overall lack of reservoir-survey data, which are used to quantify the volume of sediment accumulated in a reservoir.

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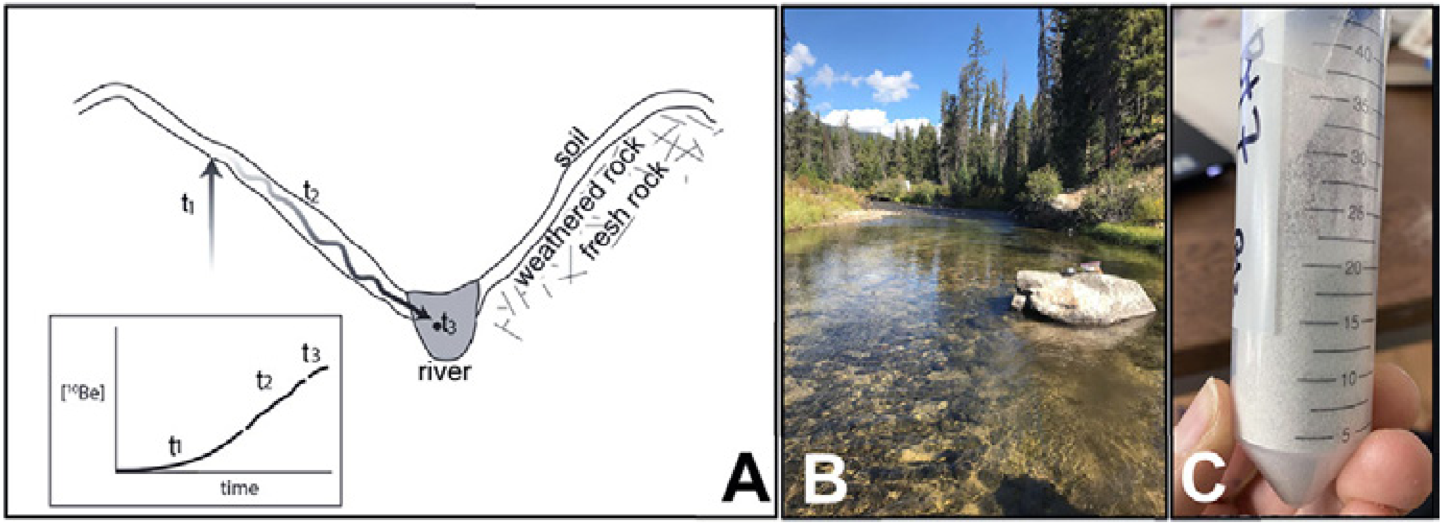

A. Conceptual model of how beryllium-10 accumulates during exhumation of rock, residence time on hillslopes, and residence time in a stream (adapted from Foster and Anderson [2016]). B. Example sample site on the Deadwood River where sands were recently deposited behind a larger boulder. C. Quartz, isolated from other minerals within sand.

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To address the data gaps in reservoir sedimentation, we proposed a study to determine whether we can use long-term basin erosion rates to inform modern rates of reservoir sedimentation. We use the concentration of beryllium-10 in river sands to calculate a basin-averaged erosion rate. Beryllium-10 is a cosmogenic radionuclide produced within an atom's nucleus when it interacts with a high-energy particle; these particles are originally sourced from cosmic rays entering the Earth's atmosphere. Within quartz, a common mineral found in river sands, beryllium-10 is produced within both silica and oxygen atoms. The concentration of beryllium-10 in quartz river sands represents the accumulation of beryllium over thousands to tens of thousands of years, including: (1) the time (t1) the quartz minerals spent within bedrock near the surface of the Earth, (2) the time (t2) the quartz minerals spent in soils on hillslopes, and (3) the time (t3) the quartz minerals spent in the river (figure 1). This method assumes that quartz is well-distributed throughout the watershed and that river sands are well-mixed, containing grains sourced throughout the watershed.

We selected study sites with repeat reservoir surveys, quartz-rich rocks throughout the drainage basin, and also tried to avoid sites with large upstream dams. Eleven sites are Bureau of Reclamation reservoirs, and three reservoirs are located in the eastern United States. To calculate the modern rate of basin erosion, we used the total capacity loss in a reservoir to infer the mass of sediment delivered from the upstream basin to the reservoir between surveys. Study reservoirs have between 30- and 80-year records of reservoir sedimentation. To calculate long-term basin erosion rates, we collected samples from 19 rivers upstream of the reservoirs; at 4 of the reservoirs, we sampled multiple rivers because each river drained a large portion of the reservoir's contributing drainage area.

Our preliminary results show that there is good agreement between modern basin erosion rates and long-term basin erosion rates at many of the sites. Most interesting are the variations in long-term erosion rates between subbasins at the four reservoirs where multiple rivers were sampled. Two reservoir sites yielded similar erosion rates for sampled subbasins, while the subbasin erosion rates at the other two reservoir sites varied by a factor of 2 and 4. This type of subbasin analysis could inform future sediment management plans at reservoirs, allowing reservoir managers to specifically target the input from subbasins with high erosion rates.

Sedimentation in Action

A Closer Look at the East Troublesome Fire and Willow Creek Reservoir

By Carolyn Gombert & Jenn Bountry
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East Troublesome Fire in Grand County, burned 192,560 acres, the wildfire is the second largest in recorded Colorado history.

The occurrence of a wildfire within a watershed has the potential to significantly increase the rate of sedimentation, effectively reducing its useful life and negatively impacting the Bureau of Reclamation's water management and water delivery mission. With climate change, the risk of wildfires and extreme hydrological events is increasing. As hydrology becomes less predictable, water resources become less reliable. Reclamation needs to plan for increases in sediment loads due to wildfire in their design and operations. In April 2021, the Science and Technology Program sponsored a workshop where researchers had an opportunity to listen in for new challenges and research needs due to wildfire. Speakers from partner agencies, the new Reclamation Wildland Fire Program, and Reclamation facilities shared concerns and effects experienced firsthand from wildfires. Important questions about how to predict and, if needed, manage changing hydrology, sedimentation, and debris loading to reservoirs prompted numerous researchers to develop proposals, several of which focused on Willow Creek Reservoir.

Willow Creek Dam and Reservoir are located on Willow Creek in Grand County in north-central Colorado approximately 2.5 miles upstream of the confluence of Willow Creek with the Colorado River and 5 miles north of the town of Granby, Colorado. Operated by Northern Water as part of the Colorado-Big Thompson Project, Willow Creek Dam captures about 33,700 acre-feet of excess Willow Creek flows annually for diversion to Lake Granby for storage (Reclamation 2013). In October and November 2020, the East Troublesome Fire burned 193,812 acres surrounding Willow Creek Reservoir, including more than 91 percent of the watershed that feeds the reservoir. It was the second largest fire in Colorado history (www.thedenverchannel.com/news/wildfire/east-troublesome-fire-second-largest-in-colorado-history-declared-100-contained), growing more than 150,000 acres in a single 24-hour period, driven by near-hurricane-force winds as it burned the majority of the 55-percent forested watershed. Read below for highlights from these new research projects to learn more!

Post-Wildfire Increases in Sediment Loading to Willow Creek and Willow Creek Reservoir

By Kent Collins
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Monitoring sediment deposition in a reservoir over multiple years is underway to determine, and possibly predict, watershed and reservoir responses to large-scale wildfires. Repeat hydrographic surveys (including above and below water data collection) and sediment sampling following spring runoff are being used to measure the volume and distribution of sediment deposits in Willow Creek Reservoir from the East Troublesome Fire burn area and assess the effectiveness of sediment management activities undertaken prior to runoff. A watershed analysis is underway to characterize sediment properties, describe the increase in sediment available for transport, and assess the risk of debris flows and/or landslides due to wildfire. Potential impacts to the Colorado-Big Thompson Project and operations at Willow Creek Reservoir will be identified through this research.

Sediment and debris deposited in Willow Creek upstream of the reservoir following the East Troublesome Fire. (photo courtesy of Nate Bradley)

This research effort will also support ongoing water quality and watershed sediment yield research projects at Willow Creek.

PONAR sampler used to collect surface sediment samples from the bottom of Willow Creek Reservoir. (photo courtesy of Rob Hilldale)

The Bureau of Reclamation's Sedimentation and River Hydraulics (Sedimentation) Group has conducted repeat hydrographic surveys of Willow Creek Reservoir following the 2021and 2022, spring runoff and will continue this effort in 2023 and 2024. The Sedimentation Group is collecting the bathymetry using multibeam sonar integrated with RTK Global Positioning System while Northern Water contractor River Science repeats November 2020 and fall 2021 and 2022 Unmanned Aircraft System (UAS) surveys to capture the above water changes, anticipated to be primarily in the upper delta. The Sedimentation Group will then process the bathymetry data and combine it with the UAS data to generate a continuous surface of the reservoir bottom up to the dam crest elevation. Surface and core samples are also being collected in the reservoir delta to determine the thickness, gradation, and source of sediments delivered to the reservoir.

Will Recent Trends in Wildfires Cause Reservoir Sedimentation Issues?

By Ben Abban
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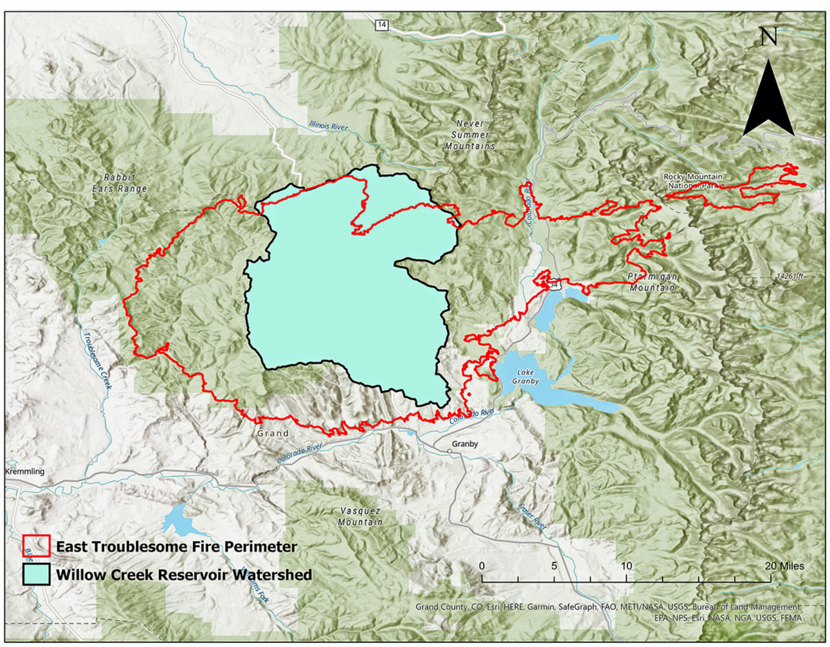
The recent increase in the number and extent of wildfires across the West has put a spotlight on the question as to whether there is a risk of increased sediment delivery to reservoirs post-wildfire due to increased hillslope and channel erosion. Increased sediment delivery results in a decline in available storage capacity in affected reservoirs and a need for costly sediment management to maintain operations. However, increased erosion potential does not always translate to actual sediment delivery to reservoirs; global observed post-fire loads have been noted to vary widely between 1 to 1,500 times pre-fire loads. Factors affecting actual delivery include watershed precipitation patterns, connectivity of fire-impacted areas to reservoirs via drainage networks, and storage potential along the networks. Management of reservoir sedimentation risk (probability times consequence) requires the ability to predict the probability of sediment delivery to reservoirs so the potential consequence of reservoir sediment management can be quantified. This necessitates a numerical model capable of predicting physical processes and fluxes from the hillslope scale up to the watershed scale at which delivery to reservoirs occurs. Most models developed to simulate wildfire impacts on sediment delivery are limited to hillslope or catchment scales (< 100 square kilometers) due to the neglect or rudimentary treatment of channel drainage networks and processes. A couple models have been developed for large watersheds, but they either average landscape properties over the watershed or use simple empirical approximations of soil erosion and sediment processes. Moreover, they rely on an empirical specification of sediment delivery, which places a severe limitation on their predictive capability to how sediment delivery may impact Bureau of Reclamation (Reclamation) reservoirs. These models are beneficial as planning tools to identify watersheds that need more refined modeling/prediction for developing management strategies; their inability to explicitly capture spatial connections/interactions as well as soil erosion and channel sediment transport physics prevents their use as predictive tools for evaluating alternative wildfire scenarios and watershed management actions.

There is a pressing need for a model capable of predicting wildfire and management impacts on sediment delivery in large watersheds that contribute to reservoirs, especially given the recent increase in wildfires in the Western United States and uncertainty related to climate change. A physically based, mesh-distributed watershed modeling tool, SRH-W, has previously been developed by Reclamation that can predict hillslope soil erosion processes and in-channel sediment transport and delivery to reservoirs. Its primary application is predicting sediment loads to reservoirs and evaluating watershed management actions.



The East Troublesome Fire burned over 90% of Willow Creek Reservoir's watershed, raising the question of whether or not there will be increased sediment delivery to it over the next few years.

However, SRH-W is currently limited to watersheds that have not been impacted by wildfires because it does not simulate wildfire effects on land cover and soil properties. Our interagency team from Reclamation, U.S. Department of Agriculture –Agricultural Research Station, U.S. Army Corps of Engineers, and U.S. Geological Survey is

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collaborating on how to extend SRH-W's capability to include wildfire impact prediction and evaluation of related management efforts. The SRH-W improved model will be tested in the Willow and North Inlet Creek watersheds, Colorado, recently affected by the East Troublesome Fire. Our work aims to provide Reclamation resource managers a tool with the following capabilities: (1) predictions of reservoir sediment loading post-wildfire and evaluation of alternative management actions in gauged and ungauged watersheds, (2) predictions of increased volume of dam flows (bulking) that results from significant sediment loads, and (3) forecasting to identify critical Reclamation facilities that are susceptible to future wildfire.

Potential Impacts of Phosphorous Loading from the East Troublesome Fire on Surface Water Quality

By Lindsay Bearup
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S&T Project page:
www.usbr.gov/research/projects/detail.cfm?id=22019

The East Troublesome Fire ignited in Grand County, Colorado, on October 14, 2020, at the end of a drought season and spread rapidly over 9 days, burning 193,812 acres. Due to the accelerated spread of the fire, emergency responders fought to protect human structures and the town of Grand Lake, including dropping fire suppressing agents. The summer after the fire, an intense rainstorm resulted in a flush of sediment into Willow Creek Reservoir. Several days later, the reservoir experienced a harmful algal bloom driven in part by nutrients that accompanied the sediment. Earlier modeling of the Three Lakes system, where Willow Creek water is pumped, suggests much of the algal growth in these reservoirs is limited by the amount of available phosphorous. Adding to the problem, phosphorous is also a primary ingredient in many fire-fighting foams used to slow the spread of wildfires.

Willow Creek after the East Troublesome fire. (photo compliments of Alexis Navarre-Sitchler)

Algal bloom in Willow Creek Reservoir the summer after the East Troublesome fire. (photo compliments of Rob Hilldale)

The Bureau of Reclamation is partnering with researchers at the Colorado School of Mines to better understand the complex biogeochemical processes that determine how phosphorous is stored and moves through a system after a wildfire. Starting this water year, researchers are sampling water, soil, and sediment to determine where the nutrient is stored and its form, which will help improve our understanding of phosphorous behavior. This work will help produce a conceptual model of phosphorous input into, and behavior, in Willow Creek Reservoir. This model can inform any potential actions to address increased phosphorous loading and provide guidance on future nutrient modeling in the Three Lakes system. Over 3 years, this work will evaluate the potential environmental impacts on water quality in Willow Creek Reservoir from the East Troublesome Fire and help to understand the impacts of phosphorous-containing fire retardant in similarly affected watersheds.

Post-Wildfire Forecasting Improvements Using Non-Newtonian Flow Processes with a High-Resolution, Integrated Hydrologic Model

By Drew Loney
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Wildfires fundamentally alter the ecology and hydrology of watersheds, testing the skill of post-wildfire water management. The Bureau of Reclamation (Reclamation) uses hydrologic models prior to a wildfire in water management to support release planning, water quality, and environmental compliance. These models do not apply post-burn due to the changed watershed properties and the different physics of post-burned runoff and flows.

Kent Walker, a Hydraulic Engineer with Reclamation, is seen testing settlement and flow with sediment using one of the dam models.

Wildfires will generally reduce vegetation and infiltration, thus increasing sediment yield and runoff volume. While basin properties such as these can be re-estimated, hydrologic properties have high uncertainty and change over time with basin recovery. However, existing Reclamation hydrologic models currently lack sufficient spatial resolution to capture the variability of post-wildfire conditions. As the sediment load in the post-wildfire overland flow increases, runoff transitions from Newtonian to non-Newtonian physics.

This process is not captured in current Reclamation models because the existing models lack non-Newtonian process representations and have a coarse resolution that cannot capture the fine-scale flow regime transitions. The absence of appropriate parameter estimates, physical process representations, and a high-fidelity modeling capability limits the ability of Reclamation to operate its facilities in post-wildfire conditions by eliminating the utility of computational modeling until the basin stabilizes and recovers.

This effort will build an interagency model and model construction workflow to support post-wildfire water management. The effort builds upon the Adaptive Hydrology (ADHydro) high-fidelity hydrologic model jointly managed by the National Oceanic and Atmospheric Administration Office of Water Prediction-National Weather Service, the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC), and the Technical Service Center (Reclamation, Denver Office). ADHydro is a high-fidelity, parallelized model that can simulate hydrologic processes at meter level resolutions using physics-based process representations. Reclamation will leverage the USACE ERDC investment into post-wildfire flow processes by incorporating their post-wildfire computational libraries into the ADHydro model. The resulting capability will be validated at post-burn sites to determine model skill. Additionally, the modeling capability will be supported by model construction workflows that simplify and accelerate both burn hydrologic modeling, making it straightforward to build from burn maps and incorporate wildfire best practices. This effort will result in a faster, more accurate post-wildfire hydrologic modeling capability that is simpler to deploy and adapt as basins recover to achieve Reclamation's water management mission. Research work will begin in earnest in fiscal year 2023.

Impacts of Sediment Removal on Water Quality

Assessing Mercury Release from Contaminated Sediments During Dredging

By Dan Deeds & Angela Paul
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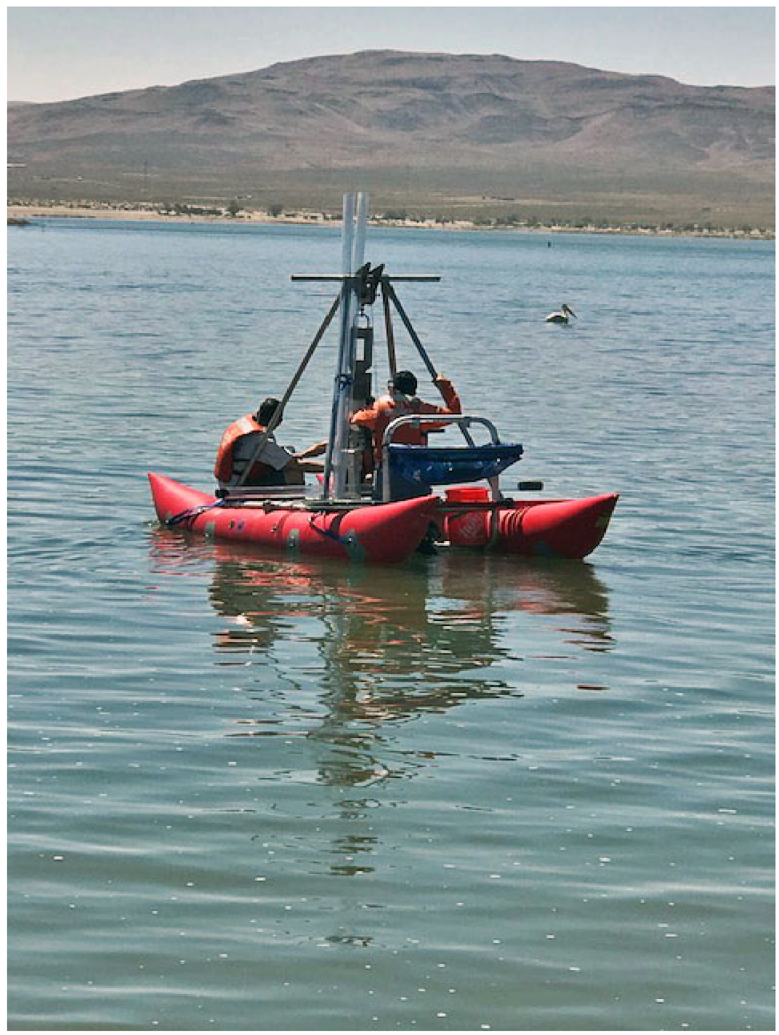
Long-term sedimentation in Lahontan Reservoir threatens to block the dam outlets and thereby prevent water delivery to downstream communities and agriculture. These sediments can contain high levels of mercury from historical pollution associated with silver mining in the Comstock Lode. Dredging Lahontan Reservoir to restore reservoir capacity will resuspend some of these sediments, potentially impacting water quality and releasing mercury into the surround water. Released mercury would enter the local ecosystem, concentrating in fish and threating recreational and subsistence anglers.

In collaboration with the U.S. Geological Survey Nevada Water Science Center, we have collected cores from sediments near Lahontan Dam to perform laboratory-based dredging simulations. These simulations will evaluate mercury release during any future dredging activities. In June 2022, dredging simulations were performed on freshly collected cores, and water quality samples from simulations were collected for analysis. Water quality impacts will be addressed in fiscal year 2023 and communicated to Lahontan Basin Area Office management. The results are expected to have direct pertinence to reservoirs dependent on inflows from watersheds containing historical mercury, gold, or silver mining sites.



U.S. Geological Survey staff collecting sediment cores from Lahontan Reservoir for dredging water quality impact simulations.

Beyond Storage: A Look into the Reservoir Delta Story

Investigating the Physical Processes that Impact Reservoir Delta Fish Passage and Evaluating Potential Solutions

By Colin Byrne
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S&T Project page: www.usbr.gov/research/projects/detail.cfm?id=22065

All rivers carry sediment downstream, especially during flood events, which are associated with greater water depths and velocities. When a river meets the pool of a reservoir, velocities slow, and the sediment the river was carrying, particularly the larger sediment sizes, can be deposited at the mouth of the river. As more and more floods occur, the delta can continue to grow. These delta surfaces then become highly dynamic during flood events, and poorly defined channels may change course due to erosion of new paths or blockage of previous channels due to sediment deposition. While the formation of deltas within lakes is a natural process, deltas in reservoirs are also subjected to large fluctuations in the reservoir pool water level. Because the deltas do not often have a deep, reliable channel connection between the upstream river and the downstream reservoir pool, flow paths often become very shallow or nonexistent, as water can infiltrate into the large delta sediments.

In the Yakima River basin in Washington, the Endangered Species Act-listed bull trout (*Salvelinus confluentus*) and other salmonids are prevented or impaired from migrating between the reservoirs and upstream spawning habitat because of the delta dynamics described above. These fish passage issues include partial or complete dewatering of the delta stream channels; wide channels with insufficient flow depths for fish passage; lack of channel cover, leading to increased

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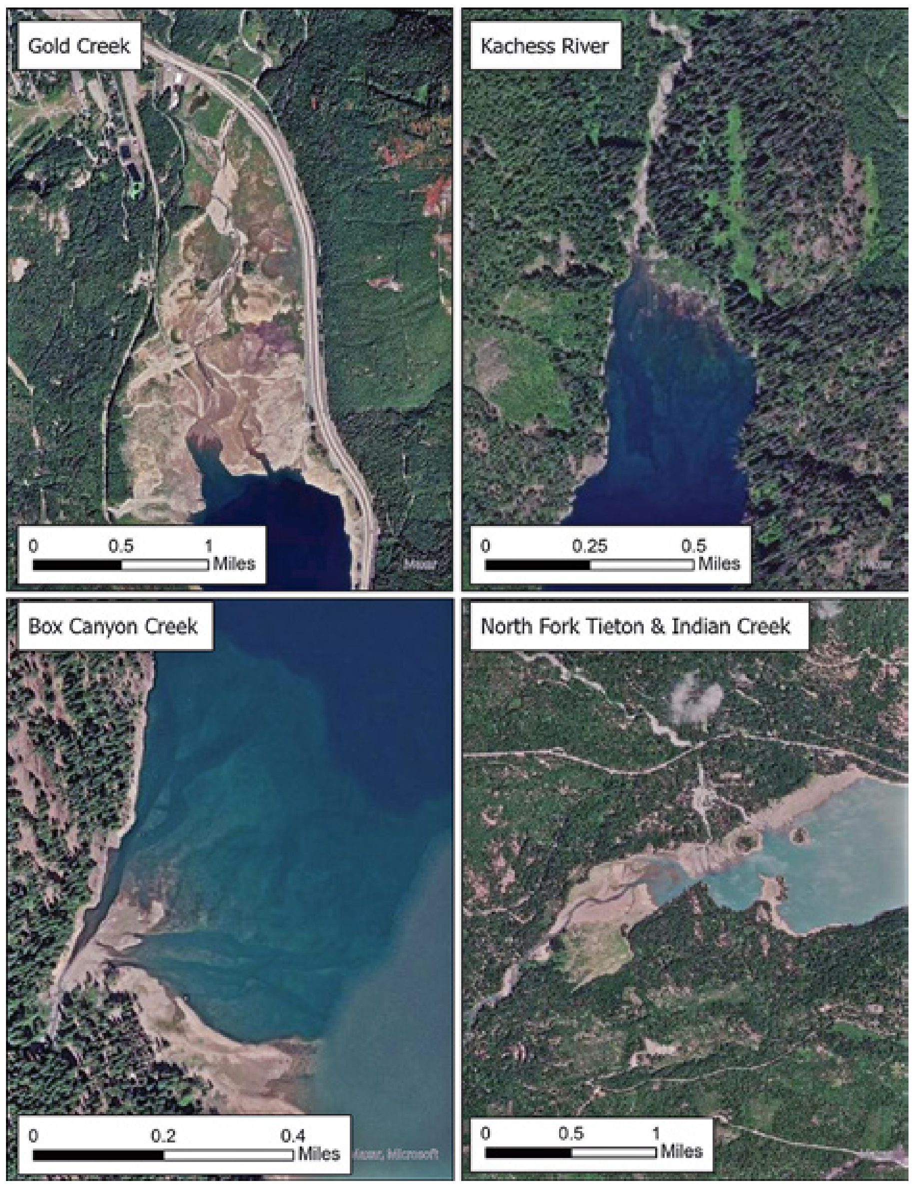

Aerial images of deltas on four different reservoirs in the Yakima River Basin.

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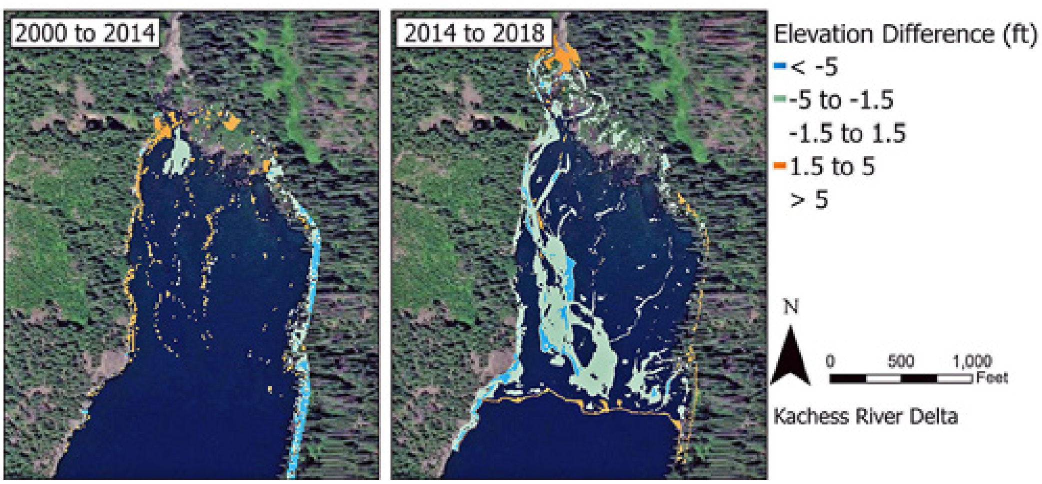
predation; and channels flowing over bedrock ledges, creating large hydraulic drops that fishes are unable to jump over. In the Western United States, where climatic variability is common, these conditions are even more pronounced during dry years. Efforts are currently being made to promote fish passage on an annual basis in the Yakima basin, but the present solutions are labor intensive and unsustainable.

This study has two main research objectives to address fish passage problems on reservoir deltas: (1) develop a conceptual understanding of the geomorphic processes that contribute to reservoir delta evolution, including how channel flow depth, sedimentation patterns, and inundation dynamics impact fish passage and (2) use the conceptual model to formulate and evaluate solutions that promote sustainable fish passage across reservoir deltas. Two types of delta stream channels important to fish passage have been identified and are the focus of the research: (1) mainstem alluvial streams that enter the reservoir at the upstream extent and (2) lateral tributaries that are smaller and likely have steeper entry slopes. Initial efforts are focused on site visits and data collection to better understand the sediment sizes and the longitudinal channel slopes of the delta surfaces. Initial comparison of elevation changes and inundation frequency are also being assessed. Figure below shows an example of the elevation analysis and shows that considerable channel changes occurred between 2014 and 2018 at the Kachess River Delta, but the surface was more stable over a longer period between 2000 and 2014. Years two and three of the study will focus on numerical modeling of the delta surfaces and solution development.



Differences in elevation from 2000 to 2014 and 2014 to 2018 at the Kachess River delta at the upstream end of Kachess Lake, Washington.

Reservoir Delta Vegetation and Wetlands

By Nathan Holste
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The Bureau of Reclamation has constructed hundreds of dams throughout the Western United States. Dams are structures that block the flow of river channels and store water upstream; therefore, they alter the environment by transforming a free-flowing river system into a reservoir. Dams provide essential services such as water storage, flood control, and hydropower. However, dams cause downstream and upstream effects to native species and their habitats. Downstream effects are well documented and include lowering of the channel bed (incision) because much of the upstream sediment supply is trapped behind the dam. Upstream effects are less understood and depend on sediment characteristics and fluctuations in the reservoir pool elevation.

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Matilija Dam in Ventura County, California (Surfrider Foundation/Paul Jenkin). Reservoir upstream of dam is transitioning to a wetland marsh and will eventually become riverine.

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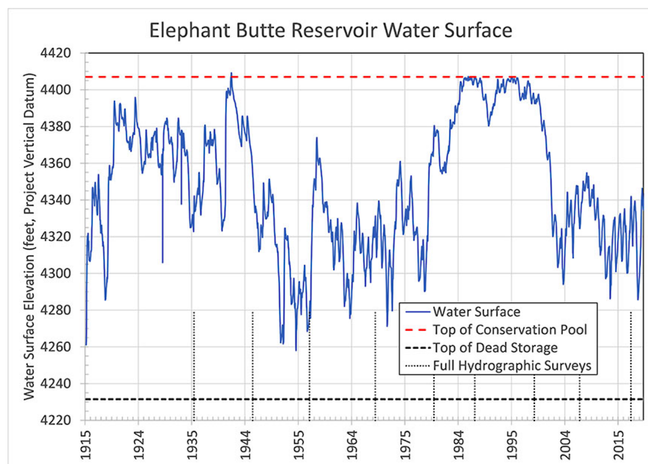
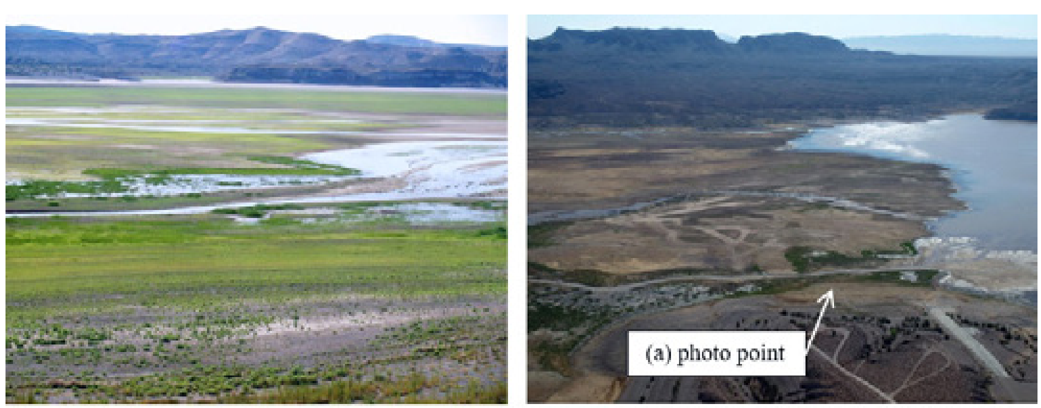
As a river flows toward a dam, the velocity decreases and sediment is deposited. The transition zone between the river and reservoir, where most sediment deposition occurs, is known as a delta. Sediment deltas are frequently changing in response to the water and sediment supply from the river and the pool elevation of the reservoir. These changes in the delta fluctuation zone provide opportunities for new and dynamic riparian and wetland habitats to develop. Many bird species rely on a dense vegetation mosaic that consists of different characteristics and age classes. Under static conditions, where there is little erosion or deposition, vegetation tends to age without being rejuvenated and becomes less suitable habitat over time. In the dynamic zone where a river enters a reservoir, decadent vegetation is more easily scoured by floods, and emergent vegetation can become established on fresh delta sediments.



Fluctuations in Elephant Butte Reservoir water surface elevation since storage began in 1915 (Randle and Benoit 2020).

Elephant Butte Reservoir in New Mexico provides an informative case study. The reservoir pool water surface has fluctuated historically in response to climatic wet and dry cycles. During the onset of the most recent drought period, the pool elevation dropped about 100 feet between 1998 and 2003. This reservoir lowering exposed acres of delta sediments that were formerly inundated and colonized by riparian and wetland vegetation. The new vegetation quickly became suitable habitat for the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), and the number of territories rapidly increased. Reservoir pool elevations have remained low while the drought has continued for over 20 years. Vegetation in the former delta headwater area has become less suitable with a corresponding decline in territories. The low reservoir elevation has caused a more static delta environment where there has been relatively little erosion, deposition, or emergence of new vegetation. Periodic reservoir pool fluctuations and the associated sediment and vegetation dynamics are an important and often overlooked riparian habitat zone.



(a) (b)

Downstream view of Elephant Butte Reservoir delta (a) from ground and (b) from airplane (Reclamation/ Nathan Holste). A recent decline in the pool elevation has exposed delta sediments that are being colonized by emergent riparian vegetation.

Groups and Resources to Know

Reservoir Sedimentation Information Resources

By Tim Randle
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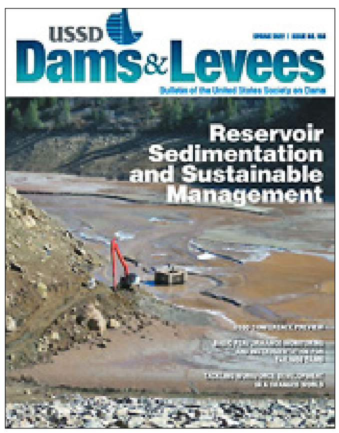
Bureau of Reclamation (Reclamation) staff have worked hard to collaborate with professional groups and colleagues in the area of reservoir sedimentation from across the globe. Efforts have resulted in numerous helpful guidelines, videos, and education resources to promote knowledge transfer and documentation important to continue working on better ways to monitor and address reservoir sedimentation. Resources available on the topic of reservoir sedimentation include newsletters, videos, webinars, white papers, and journal articles.



The U.S. Society on Dams supports a reservoir sedimentation technical committee through which, Dams and Levees Bulletin, Spring 2022 issue, highlighted an overview article on "Reservoir Sedimentation and Sustainable Management." www.ussddamsandleveesbulletin-digital.com/damq/0122_spring_2022/

The Federal Interagency Sedimentation and Hydrologic Modeling (SEDHYD) Committee's National Reservoir Sedimentation and Sustainability Team provides several resources on reservoir sedimentation. (www.sedhyd.org/reservoir-sedimentation/) This national volunteer team is comprised of engineers and scientists from multiple Federal and local agencies, universities, consultants, and industries. The types of available resources are listed below:

- Introductory 6-minute video about sedimentation
- White paper
- Journal articles
- Recorded webinars (7 webinars, 1-hour each)
  Answers to frequently asked questions

Development of Basic Cost Model for Removal of Sediment from Reservoirs

Reclamation staff partnered with colleagues through a technical committee at the Western Dredging Association (WEDA) to produce a guideline on reservoir sediment management. This guideline provides an overview of the dredging process as applied to reservoirs: the unique technologies and respective capabilities, challenges, and engineering and environmental considerations that apply. WEDA also has links to webinars on reservoir dredging and the Guardians of the Reservoir prize competition. www.westerndredging.org/reservoir2

Reclamation published the Erosion and Sedimentation Manual (2006) (www.usbr.gov/tsc/techreferences/mands/mands-pdfs/Erosion%20and%20Sedimentation%20Manual.pdf) and several technical guidelines related to reservoir sedimentation and bathymetric survey reports of Reclamation reservoirs. www.usbr.gov/tsc/techreferences/reservoir.html

The International Hydropower Association, together with the World Bank, hosts the Hydropower Sediment Management Knowledge Hub to promote strategies and case studies for effective sediment management. www.hydropower.org/sediment-management/resources

iha international hydropower association

BUREAU OF RECLAMATION

WEDA Western Dredging Association

SEDIMENTATION AND HYDROLOGY Joint Federal Interagency Conference FISC FIHMC SEDHYD.org

Science & Technology Prize Competitions Overview

Guardians of the Reservoir

By Jennifer Bountry & Tim Randle; with partners, U.S. Army Corps of Engineers
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www.usbr.gov/research/challenges/

The Bureau of Reclamation (Reclamation) uses prize competitions to spur new ideas and innovation in areas of water supply, infrastructure, and environment – areas that can help us fulfill our mission effectively and efficiently. We have awarded more than $45000,000 in prizes and launched 32 competitions in the past 6 years! The Guardians of the Reservoir Sediment Removal Competition (Competition) put out an important challenge to spur innovation for more efficient ways to remove sediment through reservoirs, with $550,000 in prize money over three stages. The goal of the competition was to encourage development of technology that can be implemented to help us maintain water storage and reservoir function into the future. In some cases, the technology can also provide ways to route sediment into downstream areas to benefit ecosystems.

The authors of the most compelling submissions to Competition had the opportunity to develop and demonstrate their technologies at increasing scales throughout the competition. The approximately 2-year challenge kicked off in July 2020, and final judging was just wrapped up in August 2022. The competition has been a huge success. Between July and October 2020, teams created a written proposal highlighting their specific ideas on how to improve reservoir sediment management. Five very qualified teams were selected to compete in Phase 2, each receiving $75,000 to further developing their approach, build prototypes, and perform laboratory-scale demonstrations between December 2020 to March 2022. Three teams were selected to compete in Phase 3 to conduct a lab- or field-scale demonstration, with the top performing team winning $100,000.

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Teams receiving honorable mention for their efforts in Phase 2 of the competition were:

- Wing Marine Team composed of Doug Thompson, John Crowson, Mel Friedman, Peter Crossland, Bryan Longhurst, James Coats, and Joel Friedman from Texas, ***"A Cure for Ailing Reservoirs"***

- Peter Murdoch and John Newport from Pennsylvania, ***"Air Bubble Suction Pipe with Water Recirculation"***

Video from Research & Development Office Prize Competitions website "Sediment Removal Techniques for Reservoir Sustainability" www.usbr.gov/research/challenges/sediment-removal.html or [watch on YouTube](#).

Teams receiving honorable mention for their efforts in Phase 3 of the competition were:

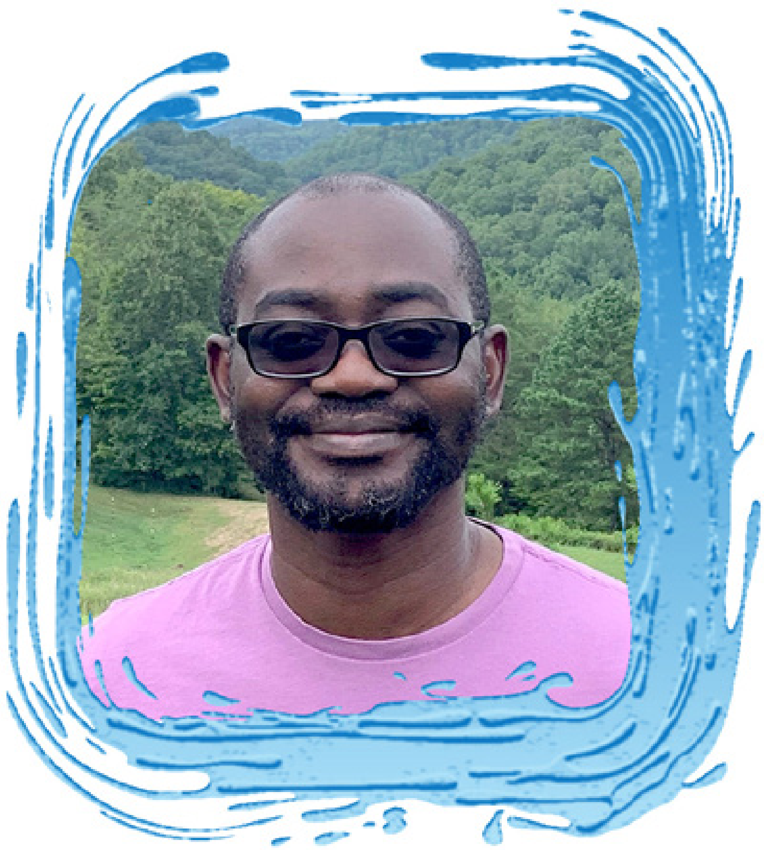
- Honorable Mention for Versatility: Nicholas LaBry and Kenneth LaBry of Prometheus Innovations, LLC, and Bartolomeo Mongiardino of Hydro Maintenance Service, Louisiana, ***"3 D DREDGER™: Complete Sediment Management"*** (3DD): The 3DD Team is developing a fully autonomous dredging system designed to handle sediment and larger debris using three dredging attachments. The system is designed for deployment in any environment, without impacting operation or recreation.

- Honorable Mention for Innovation: Baha Abulnaga, Washington, ***"High Volume Deep Dredging for Low Water De-silting:"*** Mazdak International is developing a new technology based on three steps: (1) a deep dredging slurry piston pump engine, (2) dewatering sediments in settling ponds, and (3) hydraulic capsule pipelines to transport dewatered sediments in dry or semi-dry form. The technology is based on minimizing water and power consumption and reducing abrasion in pumps and pipelines.

The overall winner of the Competition was awarded to D-Sediment. Dr. Michael Detering, Laura Backes, and Joana Kueppers, Germany, ***"Sediment Continuity and Restoration":*** The D-Sediment Team developed the SediMover technology as an autonomous vessel for efficient 24/7 sediment transfer from reservoirs. The patented and scalable, modular technology can be used for downstream river sediment continuity or sediment land processing. There are generally no limits in control, transfer range, or scope. The transfer is measured constantly onboard and is documented. The D-Sediment Team has been active in sediment consulting and removal systems for several years.

The success of the Competition was only possible with important partnerships. Reclamation teamed up with the U.S. Army Corps of Engineers as a key Federal partner to help improve reservoir sediment management solutions. We also had amazing support from Hero-X and NASA Tournament Labs, who facilitated the prize competition design, solver team communication, and project management. For the Competition, we brought in a new partner, Fed Tech, who helped teams build industry relationships and business plans to improve potential for future implementation. We also appreciate our collaboration with the World Organization of Dredging Associations and the Western Dredging Association who helped advertise the Competition and provided platforms for sharing progress with industry.

Featured Faces



Ben Abban
babban@usbr.gov

Dr. Ben Abban has worked with the Sedimentation and River Hydraulics Group at the Technical Service Center (TSC) since 2019. His work focuses on hydrodynamic modeling. Ben's research also encompasses watershed modeling, including watershed model development. He has been able to leverage his unique knowledge and skill set to advance research involving predicting post-wildfire effects on sediment delivery.

Ben holds a doctorate in water resources engineering from the University of Tennessee. Prior to beginning work on his Ph.D., Ben was a National Science Foundation Geoinformatics (NSF GEEMaP) Fellow at the University of Iowa. Ben also spent time working as a water resources engineer for Aurecon before returning to graduate school.

Previously, Ben's research sought to characterize an appropriate scale unit for the prediction of water and sediment fluxes at the level of the watershed. He has also spent time thinking about spatiotemporal changes in sediment sources within watersheds. His Water Resources Research publication, "An enhanced Bayesian fingerprinting framework for studying sediment source dynamics in intensively managed landscapes," captures his contributions on estimating both sediment sources as well as their associated uncertainties. Ben's past research also includes dam break and flood line analysis, modeling of flow around instream hydraulic structures, and development of software to manage environmental release flows from Berg River Dam.

Ben's current research and interests at the TSC include work with Yong Lai on the development of a watershed extension for the Sedimentation and River Hydraulics model (SRH-W). Ben is also working on hydrodynamic modeling and habitat suitability studies in the San Francisco Bay/Sacramento-San Joaquin River Delta. In addition to Ben's aforementioned work on predicting effects of wildfire on reservoir sedimentation, he is also investigating factors affecting thermal stratification in riverine pools. Additional information on Ben's present research efforts may be found in his recent publications: "A process-based mesh-distributed watershed model for water runoff and soil erosion simulation" and "Two-Dimensional Numerical Modeling of Flow in Physical Models of Rock Vane and Bendway Weir Configurations."

In his free time, Ben loves spending time with his wife Donna and their child Rowan. He also loves traveling to new places and trying new things. If Ben is not at his computer, you may find him tinkering with electronic gadgets or out riding his motorcycle.

Featured Faces *–continued*

Colin Byrne
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Colin Byrne joined the Technical Service Center (TSC) in 2020 as an engineer in the Sedimentation and River Hydraulics Group. Before moving to Denver, Colin graduated from the University of Wisconsin-Madison with a B.S. in Zoology and a M.S. in Biological Systems Engineering. His PhD in Civil Engineering is from the University of New Mexico, where he studied flood wave attenuation and channel-floodplain hydrodynamics along the Middle Rio Grande. Prior to joining the Bureau of Reclamation, Colin was a postdoc at the University of California, Davis where he studied California's diverse river channel morphology as well as pool-riffle dimensionality and formational processes. Colin's favorite (and shortest) paper he has authored is titled "Channel constriction predicts pool-riffle velocity reversals across landscapes," which was published in Geophysical Research Letters.

Colin's work at the TSC is focused on hydraulic and sediment transport modeling of rivers. While at Reclamation, Colin has completed modeling for flood inundation along Lake Fork Creek near Leadville, Colorado, and has assessed the ability of a numerical, sediment transport model to predict similar transport and depositional patterns as compared to a physical laboratory model.

Currently, Colin's Science & Technology research project focuses on alleviating fish passage problems at reservoir tributary deltas in the Yakima River basin. In addition to this undertaking, he is also investigating the pre-Klamath Project surface water interaction between the Klamath River and Lower Klamath Lake and assisting on other portions of the Klamath Revised Natural Flows Study. Colin's current project list is rounded out by modeling along the Methow River near Twisp, Washington, in support of river restoration efforts to improve salmon habitat. Upcoming projects include a Stage-0 restoration modeling effort in Oregon and a reach assessment of the Chewuch River in Washington.

In his spare time, Colin enjoys spending time with his wife and two dogs. His favorite hobbies include hiking, mountain biking, skiing, and, when he makes return visits to Wisconsin, sailing.

Featured Faces *–continued*

Dan Deeds

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Dan joined the Bureau of Reclamation (Reclamation) in 2019. He is the Branch Chief for the Environmental Monitoring and Assessment branch in the California-Great Basin (CGB) Region.

Dan was the Regional Water Quality Coordinator for Reclamation in the CGB region from 2019 to 2021. Before that, he worked as a Research Hydrologist with the U.S. Geological Survey California Water Science Center in San Diego from 2011 to 2013 and as a Postdoctoral Researcher at McGill University from 2008 to 2011. He obtained a PhD in Earth Science from Scripps Institution of Oceanography (University of California San Diego) in 2008 and a BS in Chemistry (minor in Earth Science) from the University of California Berkeley in 2001.

Dan's previous research has spanned multiple domains, including greenhouse gas geochemistry, ground water quality and management, mercury speciation, and the development of novel methods to detect ultra-trace concentrations of pollutants in air and water. He is interested in how water quality monitoring can inform water supply and watershed management and in assessing how changes in watershed health impact downstream water quality.

Dan's current projects/research of interest include:

* Development of low-cost UV-spectrophotometers for real-time algal bloom detection (funded through WaterSMART Internal Applied Science funding opportunity; collaboration with University of California Davis
* Chemical Fingerprinting of Delta Smelt for Sensitive Detection in the Environment (Science and Technology (S&T) Project 21078; collaboration with University of California Davis)
* Evaluation of Mercury Release from Sediment and Dredging to Lahontan Reservoir Waters (S&T Project 22088; collaboration with U.S. Geological Survey Nevada Water Science Center)
* Favorably Stabilizing the Flow, Supply and Quality of Water from Public Lands During Forest Management (S&T Project 22090; collaboration with the Bureau of Land Management)

Dan is the father of three children ages 17, 12, and 5. His 17-year-old is starting at the University at Concordia University in Montréal, Québec this fall! While he doesn't have any pets, Dan constantly fights to keep their two chickens from destroying the family garden. When not busy with research, Dan enjoys camping, hiking, cooking new recipes, and brewing beer. He used to box (wow!) but hasn't been in the ring since undergraduate school. Dan also plays the alto saxophone and clarinet. We hope to get a concert soon Dan!

Featured Faces *–continued*

Melissa Foster

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Melissa Foster is a fluvial geomorphologist with the Sedimentation and River Hydraulics Group at the Technical Service Center (TSC). Since joining the Bureau of Reclamation (Reclamation) in 2016, Melissa has developed a keen interest in reservoir sedimentation. Specifically, she seeks to couple modeling and remote sensing to constrain sediment production and yield rates in basins. She developed and now maintains the new Reservoir Survey Data (ReSurveyD) Repository. Melissa sees the ReSurveyD Repository as a crucial tool to support reservoir survey prioritization as well as a means of improving Reclamation's understanding of a key asset, available reservoir capacity. At the TSC, Melissa also enjoys one-on-one mentoring and working with Reclamation interns on research projects.

Melissa earned her B.A. and M.S. in geology from Humboldt State University, where she dove into research on propagation of knickpoints in the South Eel Fork River in northern California. Between earning her bachelor's degree and returning for graduate work, Melissa joined an environmental consulting firm in Arcata, California, working on erosion control projects aimed at improving salmonid habitat. In 2010, Melissa moved to Colorado to pursue her Ph.D. in geological sciences at the University of Colorado at Boulder (CU Boulder). Her doctoral research focused on landscape evolution in Colorado's Front Range.

Melissa's past projects at the TSC include both geomorphic analysis as well as hydraulic modeling. Her collaborative research with Reclamation colleagues on long-term disconnection of side channels on the Bighorn River in Montana leveraged both satellite imagery as well as field mapping to evaluate geomorphic diversity. A publication detailing the findings of this study, "The Bighorn River: declining geomorphic diversity and adaptive management opportunities," is now in preparation. Melissa has also worked on modeling projects below Glen Canyon Dam. Specifically, this work assessed the effect of potential rock fall or sediment excavation on the tailwater surface elevations at the dam.

Currently, Melissa is focused on bringing new methods to our understanding of sedimentation. She is using concentrations of beryllium-10, a cosmogenic radionuclide found in river sands, to calculate basin-averaged erosion rates. Melissa is also engaged with WaterSMART applied research that looks to correlate sediment yield rates with environmental parameters, a project she has taken on with CU Boulder Ph.D. student and Reclamation intern, Abigail Eckland. Another project Melissa has underway is her work with Aaron Hurst on rock erosion and sediment transport in an unlined spillway. A publication detailing the three-tiered approach employed in this research is now in the works.

When Melissa is not knee-deep in sediment at work, she enjoys open water swimming. In her free time, she also does a lot of gardening. Melissa and her husband have two daughters. They all look forward to spending time outdoors as a family and camping with their dog, Toast.