BUREAU OF RECLAMATION

River Restoration Research Needs

Science and Technology Program

U.S. Department of the Interior

April 2020

Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acknowledgements

The authors are grateful for funding provided by the Bureau of Reclamation's Science and Technology Programs. We thank everyone for all of their input and work. (Please see Appendix: Attendees for this list). This workshop was a success because of the dedicated participants that not only took the time to attend but actively engaged in developing the product presented in this report. Without the participants' involvement and dedication during the workshop, this product would not have been possible. We would also like to thank all of the participants who provided presentations. We thank Dave Smith from USACE and Ben Nelson from the Reclamation Bay-Delta office for hosting a field tour to the Fremont Weir restoration site. We thank the California-Great Basin Reclamation office for hosting the workshop. We would like to thank the Reclamation Science and Technology Office for providing funding to accomplish the workshop. We would also like to acknowledge Dr. Joel Sholtes of Mesa State University for co-facilitating the workshop and keeping us all on course!

Cover: Before and after spawning and rearing habitat constructed in 2014 below Nimbus Dam, American River (Reclamation)

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River Restoration Research Needs

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Acronyms and Abbreviations

2D	two-dimensional
API	Application Programming Interface
CAP	Central Arizona Project
CDEC	California Data Exchange Center
CVP	Central Valley Project
DOI	Department of the Interior
EIS/EIR	Environmental Impact Statement/ Environmental Impact Report
ELAM	Eulerian Lagrangian Agent Method.
ERDC	USACE Engineering Research Development Center
ESA	Endangered Species Act
FCRPS	Federal Columbia River Power System
FWUA	Friant Water Users Authority
HEC-RAS	Hydrologic Engineering Center's River Analysis System
LiDAR	light detection and ranging
NRDC	Natural Resources Defense Council
O&M	operations and maintenance
qPCR	quantitative polymerase chain reaction
Reclamation	Bureau of Reclamation
RGSM	Rio Grande Silvery Minnow
S&T	Science and Technology
SFM	Structure for Motion
SJRRP	San Joaquin River Restoration Program
SWP	State Water Project
TRD	Trinity River Division
TRRP	Trinity River Restoration Program
TSC	Technical Service Center
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

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Introduction

The Bureau of Reclamation (Reclamation) conducts extensive species recovery and river restoration activities on many of its projects throughout the Western United States to support mission goals of securing America's energy resources and managing water in a sustainable manner. Reclamation carries out these activities through partnerships and cooperation with other Federal, State, and local agencies; tribes; and various non-profit environmental conservation organizations and stakeholders. Sample activities include: the construction of fish passage facilities, removal of fish barriers, vegetation management, river and stream-bank protection and enhancement, floodplain restoration, increased or improved water supply, wetlands construction, propagation of fish and the installation of water temperature control devices. Much of this activity occurs with the context of collaborative species recovery or river restoration programs, which are collectively supported by more than 20 percent of Reclamation's annual budget.[1] Additional activities occur within the context of project-level environmental mitigation.

Many of these recovery and restoration programs have been up and running for at least 15 years and have gained valuable expertise and lessons learned. Reclamation hosted events to promote implementation and technology sharing among the programs and partners. In 2011, a workshop was held to share institutional challenges and provide an overview of 16 restoration program activities within Reclamation (Reclamation, 2011). A second workshop with U.S. Army Corps of Engineers (USACE) was held May 17-19, 2011 in Sacramento, California, to identify eco-hydraulic research needs common to both Federal agencies. In 2012, a workshop specific to large wood restoration research needs was sponsored by Reclamation's Science and Technology Office.[2] This effort led to the funding and development of a National Manual for Large Wood Design.[3] Annual meetings since 2015 have been held with Reclamation and USACE Engineering Research Development Center (ERDC) to identify collaboration opportunities in eco-hydraulics.

In 2018, we interviewed several people working in the recovery programs, and conducted a technical workshop in 2019 to capture highlights and lessons from the Reclamation river restoration programs, as well as identify research needs. We hope that this collaboration will foster new partnerships and continued sharing of research and information as we move forward in the future. The summaries represent personal opinions of the participants, not Reclamation, and have been compiled to help foster a constructive dialogue regarding research opportunities.

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[1] Reclamation. 2011. Bureau of Reclamation River Restoration Programs: A Summary of 16 Programs and Shared Institutional Challenges, prepared for River Restoration: Exploring Institutional Challenges and Opportunities, September 14 & 15, 2011, hosted by the Bureau of Reclamation and the Utton Center at the University of New Mexico School of Law.

[2] Reclamation and USACE. 2012. Large Wood Research Workshop Summary Report, February 2012, Seattle, WA. https://www.usbr.gov/research/projects/detail.cfm?id=3775

[3] National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. March 15, 2016 https://www.usbr.gov/research/projects/detail.cfm?id=2754.

Workshop Overview

The River Restoration Science Training was held in Reclamation's California-Great Basin[4] Regional Office in Sacramento from May 1 to May 3, 2019. In this training, participants:

- Shared technical information related to river habitat restoration, fish monitoring, environmental flows, and adaptive management projects and research. Presentations were provided by experts working on the ground in Reclamation's recovery programs and from Reclamation's Technical Service Center on active river restoration research and tools being developed.

Participants shared river restoration experiences and strategies for success.

- Identified technical knowledge and research gaps to inform future proposals to Reclamation research programs such as the Science and Technology Program, the training sponsor.

- Reviewed a river restoration project in the field. Reclamation and the California Department of Water Resources are planning a notch in the Fremont Weir on the Sacramento River to provide access to the Yolo Bypass floodplain for juvenile salmon across a range of flows. The field tour of the Fremont Weir covered the planning and evaluation process to define the fish entrainment potential of six alternative notch locations/designs evaluated as part of an Environmental Impact Statement/ Environmental Impact Report (EIS/EIR) process. Analysts developed two-dimensional (2D) hydraulic models and fish movement models, each calibrated to data, to help define the entrainment potential.

Participants toured the Fremont Weir river restoration project.

[4] Then the Mid-Pacific (MP Region).

Strategies for Restoration Project Success

Participants shared wisdom gained from their experiences in conducting river restoration projects. Key ideas are captured here.

Communication

Effectively communicating project outcomes (dynamic or static) results in greater team, partner, management, stakeholder, and public buy-in. Communicate project designs as clearly as possible—upfront and often during the process. Improving the communications for the project design and potential evolution may help improve project acceptance and appearance. If participants have multiple interpretations of outcomes, and if the implementation does not match these multiple interpretations, the project can appear to be a failure.

Set Clear and Agreed-on Goals and Data Needs

Prioritize and focus efforts at the outset—and refine and communicate these goals throughout the process. Some goals are shorter term and some are longer term, so set time frames and schedules for revisiting goals and evaluating them with updated information and analyses. Determine what the ultimate goals are and clearly delineate what can and cannot be accomplished with available resources. Design projects that can fit budget rather than trying to design project and then find the money. Ask: Are we trying to restore a function, process, or a product of that process?Once project goals are set, determine data needs.

Ask decisionmakers what information would be helpful: what questions do you want to answer, who needs to know the answers, and what will be done with the information. Determine the big questions and track answers to inform actions and measure whether objectives are met. For example, the Platte River Recovery Implementation Program asked:

Do program management actions in the central Platte River cumulatively

> *1) produce detectable changes in the physical environment (i.e., habitat) and*
>
> *2) result in a detectable increase in tern, plover, and whooping crane use of the associated habitats?*

We cannot collect all the data all the time. Determine the most effective use for your data collections to help inform actions. For example, monitoring is a status effort, so do we invest in the top 10 sites or monitor some sites periodically? Refine data collection processes by asking:

- What data can we collect?
- What do you want to know?
    - Numbers
    - Growth
    - Condition

  - Habitat Use
  - Migration
  - Predation

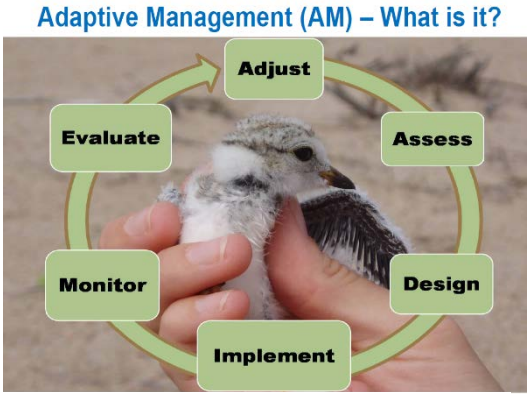
- How do you want to test it?
  - Models (which type, limitations)?
  - Field Data (what kind, limitations)?
  - Adaptive Management Framework?

Use Science Wisely

Make Science Useful

River restoration is not a big science project but is using science to inform actions:

- Avoid the "science pile" of information—synthesize the data to tell the story.
- Science must feed into the decision-making—it informs but does not control.



Adaptive management is a cycle: Adjust, Assess, Design, Implement, Monitor, Evaluate, Adjust. . .

Consider the Entire System

Consider the entire system when designing a restoration project and use integrated designs. Model interactions of flow, vegetation, and sediment for improved river system management.

Sediment dynamics and vegetation are important to restoring ecosystem processes, but must be integrated with water conveyance and flood protection.

Projects can be dynamic, and site or reach specific river restoration actions can be a moving target within the context of the overall system restoration goals. Incorporating the potential for dynamism ultimately adds another layer of interpretations of the project evolution.

Use a Flow, Form, and Function Framework

Before designing a project, determine the river's hydrological, geomorphic, and ecological characterization. Determine goals for flow regimes, river corridors, and ecosystem processes as an integrated whole. Use these goals to assess the final design: Will the as-built restored system meet these goals?

With LiDAR and photogrammetry data, we are able to collect near-census scale geomorphic data of a restoration site. These data can be used to directly inform design rather an basing design on regional relations or a sampling of geomorphic variables from a site. This provides "a comprehensive, spatially explicit, process-based paradigm for assessing and restoring landscapes—emphasizing the 1-meter scale as the basic building block for geomorphic processes

and ecological-function endpoints. By eliminating all decisions that go into sample selection upfront, it is possible to analyze the totality of a landscape in fine detail with no compromises" (G. Pasternack, 2019 presentation at workshop, see also Brown and Pasternack, 2019[5] and Schwidnt et al., 2020[6]).

Determine Decision-making Structures

Clarify your decision-making structures (governance) up front (get the people part right at first). Collaborative decision-making helps ensure actions are agreed on and taken. For example, stakeholders sit on the Governance Committee for the Platte River Recovery Implementation Program.

Case Studies

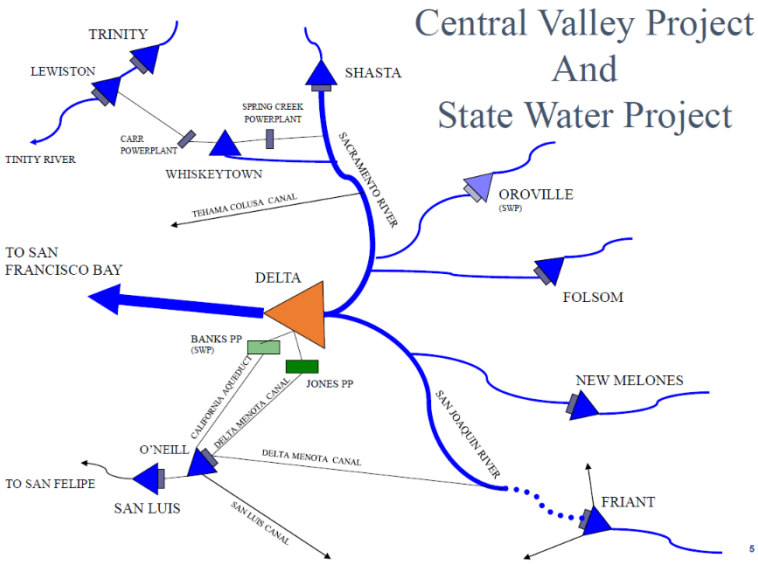
Participants shared various case studies, and the studies below show a range of Reclamation experiences.

Fish and Wildlife Project Purposes in Central Valley, California

Presented by Dave Mooney, Bay-Delta Office Area Manager, Bureau of Reclamation

California's cycle of water supply and demand is full of contradictions: most of the precipitation falls in the north while most demand occurs in the south, rain and snow fall primarily during the winter and spring, but the water is needed more in the summer, and precipitation amounts vary from year to year, but demands vary little.

Questions for fish flows in the Central Valley Project (CVP) and State Water Project (SWP) include:



Flow map for CVP and SWP, California.

[5] Brown, R.A. and Pasternack, G.B., 2019. How to build a digital river. *Earth-Science Reviews*.

[6] Schwindt, S., Larrieu, K., Pasternack, G.B. and Rabone, G., 2020. River Architect. *SoftwareX*, 11, p.100438.

- How do CVP and SWP exports influence routing, entrainment, and survival?
- How do salmon select different routes through the Delta?
- What is the survival of salmon along different routes?
- What factors explain the differences in survival?
- What can we do to balance all project purposes?

Monitoring can provide some answers.

CVP and SWP actions include:

- California EcoRestore, a companion program to California WaterFix, which is restoring 30,000 acres of habitat by 2020 to address the legacy of development and invasive species and CVP and SWP impacts. The program incorporates adaptive management.
- Facility modifications such as fish passage, inlet construction, intake fish screens, barriers, and the Shasta Dam temperature control device.
- Hatchery management to mitigate the effects of dams on the ocean fishery, preserve wild stocks from the effects of hatchery practices, and provide refugia and supplement stocks for listed species.
- Status and trend monitoring. Current initiatives include enhanced Delta Smelt monitoring and acoustic tag salmon monitoring.

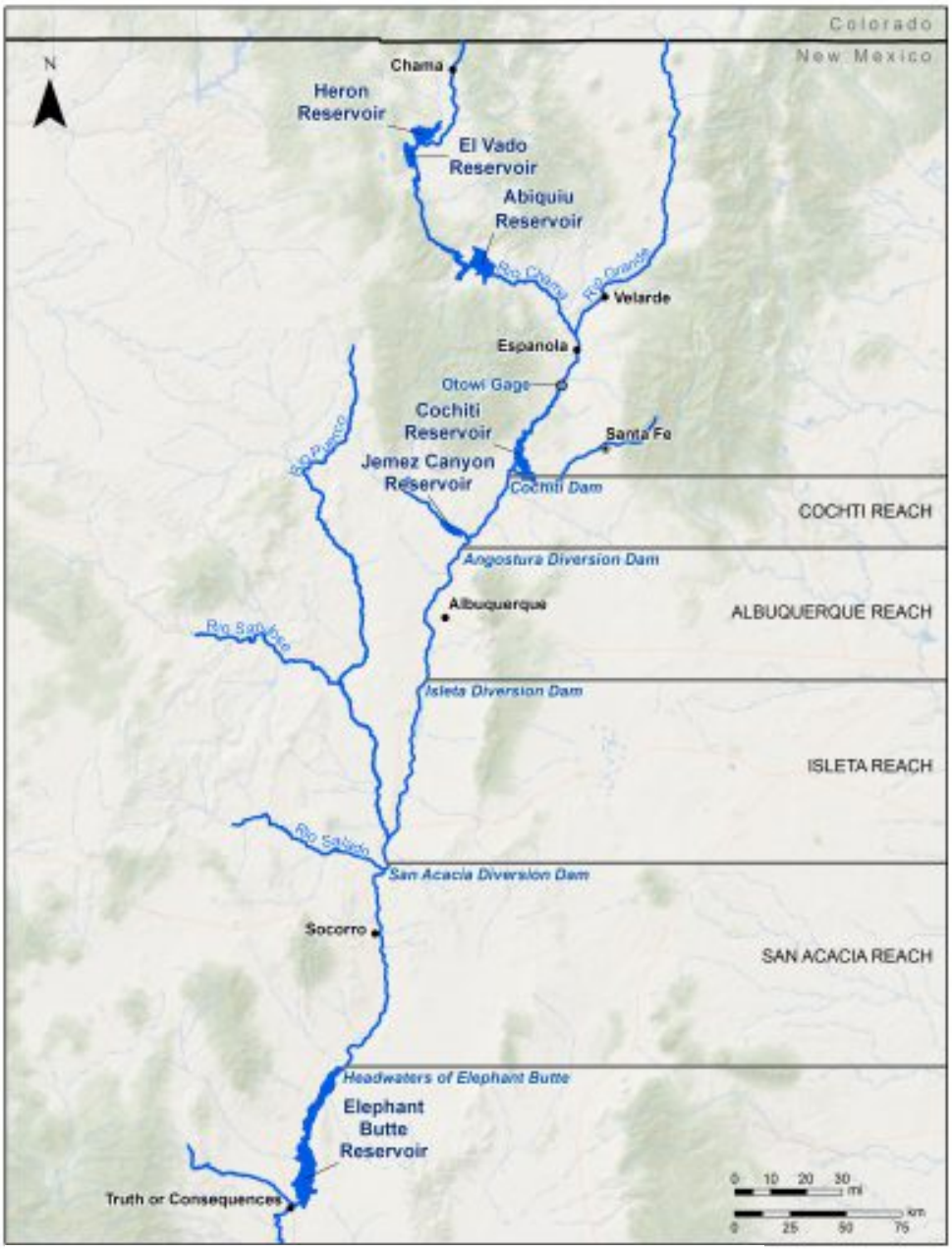
For more information, see https://www.usbr.gov/mp/cvp/.

Rio Grande Silvery Minnow, New Mexico

Presenter: Drew Baird, Hydraulic Engineer, Sedimentation & River Hydraulics, Technical Service Center (TSC), Bureau of Reclamation

To help determine biology, monitoring, and habitat needs for the Rio Grande Silvery Minnow (RGSM), several Reclamation Science and Technology (S&T) projects were conducted, including:

- Field Deployment of Continuous Sediment Load Surrogate deployed instruments in lieu of physical measurements. This reduced cost for determining suspended sediment load. (Ari Posner partnered with the U.S. Geological Survey [USGS]).



Rio Grande Reaches, New Mexico.

- Stochastic Hydraulic Simulations using Hydrologic Engineering Center's River Analysis System (HEC-RAS) developed software tool for performing Monte Carlo simulation on input parameters for HEC-RAS. Developed processes for uncertainty estimates stemming from large uncertainties with input parameters and conducted stochastic simulations to provide probabilities associated with input parameters. (Ari Posner)

Arroyo de los Piños Research Station

- Arroyo de los Piños Research Station constructed and operated total sediment load (bed and suspended load) measurements at a gaging station near Socorro, New Mexico. (Dave Varyu)

Reclamation's Albuquerque Area Office also funded projects, including:

- Linking Morpho-dynamics with Biology to improve understanding of changing morpho-dynamics of the Middle Rio Grande between Bernalillo New Mexico and Elephant Butte Reservoir for RGSM habitat.

- RGSM Minnow Population Monitoring . This long-term systematic monitoring from 1993 to the present compares changes among years; correlation between spring runoff flows, overbank flows, and fall populations; and assesses available habitat sites.

- Post project morphological changes used 2012-13 light detection and ranging (LiDAR) and 2017 high flow and low flow LiDAR to determine depositional patterns in habitat restoration features. (Nathan Holste)

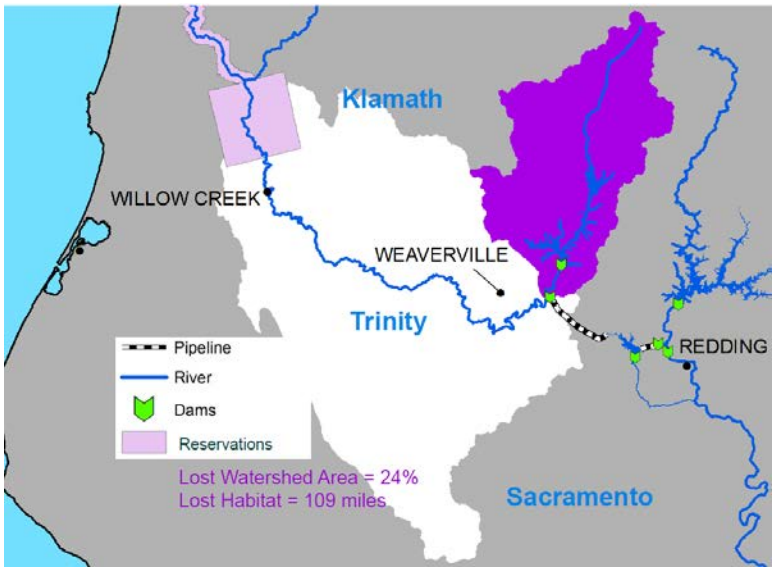
Habitat restoration objectives are to:

- Increase floodplain connectivity
- Provide heterogeneity of velocity and depth
- Improve bankline complexity

For more information, see https://webapps.usgs.gov/mrgescp/.

Adaptive Management on the Trinity River, California

Presenters:
David J. Bandrowski P.E., Watershed Restoration Program Engineer, Yurok Tribal Fisheries
Michael Dixon, Implementation Branch Chief, Trinity River Restoration Program
Logan Negherbon, P.E., Acting Implementation Branch Chief



Trinity River, California.

The Trinity River Restoration Program (TRRP) is a multi-agency program with eight Partners forming the Trinity Management Council, plus numerous other collaborators. The TRRP implements the 2000 Department of Interior (DOI) Record of Decision, which directs DOI to restore the fisheries of the Trinity River impacted by dam construction and related diversions of the Trinity River Division (TRD) of the Central Valley Project.

Sawmill Rehabilitation site, 2009.

Approximately one-fourth of the Trinity River basin and 109 miles of in-stream habitat have been cut off due to dams. TRD water diversions initially diverted 80 to 90 percent of the Trinity River flow, and still take over 50 percent of the flow. These diversions compounded impacts to the river that occurred from hydraulic and dredge mining that buried floodplains and obliterated the channel, and logging that increased fine sediment and reduced wood recruitment.

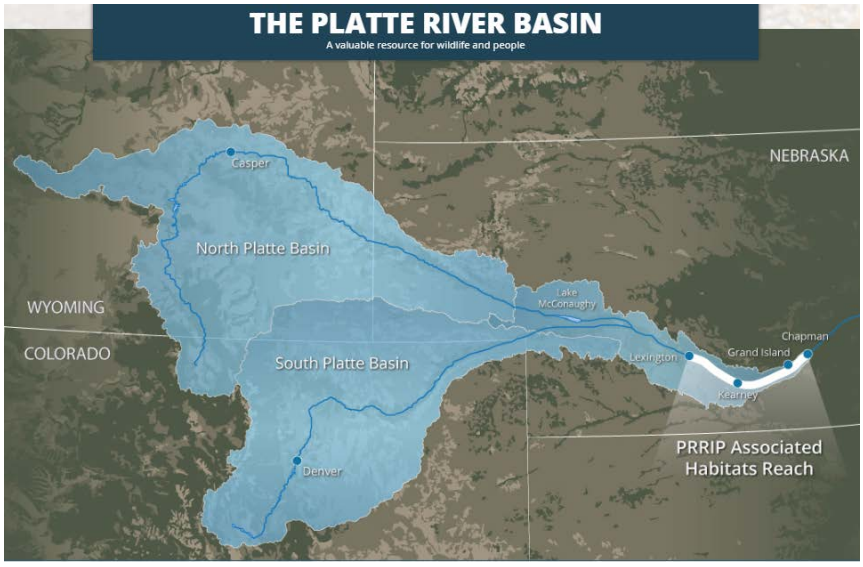
The TRRP's goal is to restore and maintain the trinity River's anadromous fishery resources by rehabilitating the river itself, restoring the attributes that produce a healthy, functioning alluvial river system. Lessons learned from TRRP actions were discussed at the workshop including:

- Watershed restoration using gravel augmentation, large woody debris, and channel rehabilitation
- Restoration flows for steelhead and Chinook Salmon released from the Trinity hatchery, supporting adult spawning, encouraging cottonwood seedlings, and discouraging willows
- Adaptive management

For more information, see https://www.trrp.net/.

Platte River Recovery Implementation Program, Colorado, Wyoming, and Nebraska

Presenter: Chad Smith, Deputy Executive Director, Platte River Recovery Implementation Program



Platte River, Colorado, Wyoming, and Nebraska.

This program is a cooperative effort between the Department of the Interior, Colorado, Wyoming, Nebraska, and stakeholders. The goal is to improve and maintain habitat for target species: the interior least tern, piping plover, whooping crane, and Pallid Sturgeon. The first increment's objectives were to improve 10,000 acres of land and to provide 130,000 - 150,000 acre feet of target flows per year. This first increment, from 2007 -2019, had a budget of $325 million and was extended to 2032 with an additional $106 million.

Management actions include:

- short duration high flows,
- sediment augmentation,
- mechanical island building,
- channel widening,
- vegetation clearing, and
- developing off-channel habitat.

Mechanical creation and maintenance.

This program has completed a full loop of adaptive management (assess, design, implement monitor, evaluate, and adjust). After monitoring determined how the target species responded to program management actions, the Governance Committee decided to change the management approach to a mix of on-channel and off-channel tern and plover nesting habitat and provide guidance on flow releases. The program is considering how to improve resiliency in the system in response to climate change, hydrological variability, and operational flexibility.

For more information see https://platteriverprogram.org/.

San Joaquin River Restoration Program, California

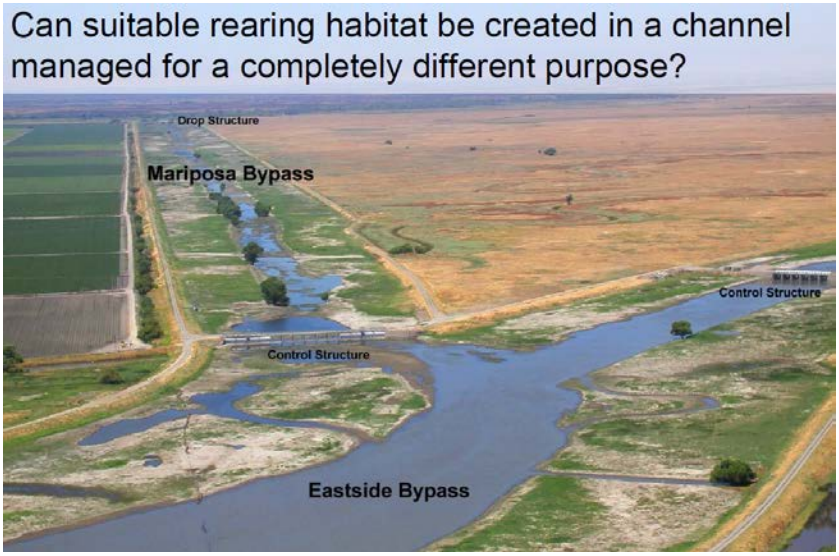
Presenters: Adam Nickels, Deputy Program Manager - Water Management Goal, San Joaquin River Restoration Program, Bureau of Reclamation
Chad Moore, Flow and Science Coordinator
Emily Thomas, Hydraulic Engineer

The San Joaquin River Restoration Program (SJRRP), a multi-agency effort to restore Chinook salmon to 150 miles of river. The SJRRP is the direct result of the San Joaquin River Restoration Settlement reached in September 2006 by the U.S. Departments of the Interior and Commerce, the Natural Resources Defense Council (NRDC), and the Friant Water Users Authority (FWUA). The Settlement, which followed an 18-year lawsuit, received Federal court approval in October 2006. Federal legislation, the San Joaquin River Restoration Settlement Act, was passed in March 2009 authorizing Federal agencies to implement the Settlement. The Program has two goals:

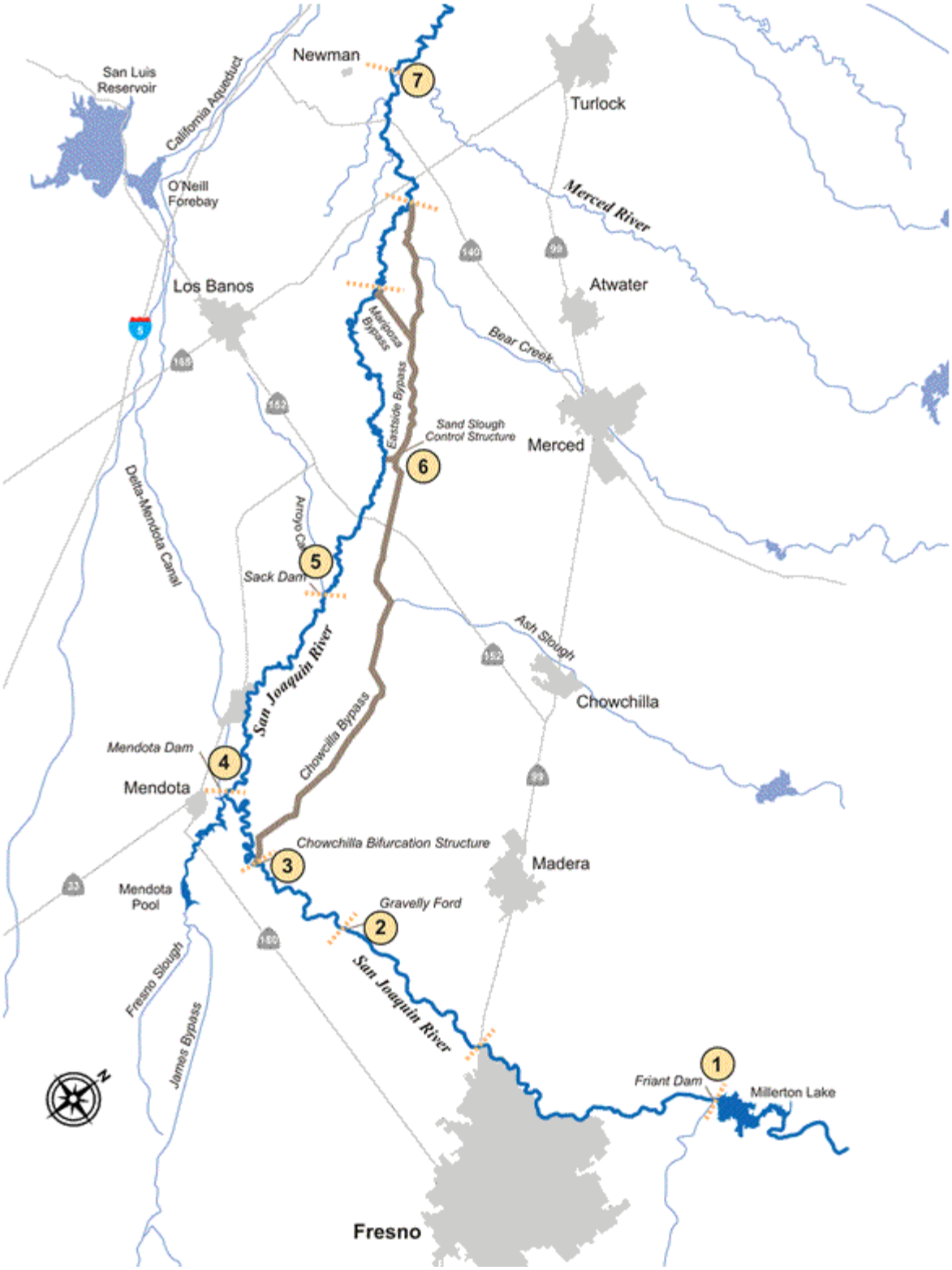
- **Restoration Goal.** To restore and maintain fish populations in "good condition" in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- **Water Management Goal.** To reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows provided for in the Settlement.

The SJRRP may be a forerunner of river restoration projects that seek to blend not just a better river but also a better water project for all. However, the main question is "What does restoration look like in the highly modified landscape of the San Joaquin Valley?" As the root cause (dams, etc.) cannot be removed, what should the reference condition be for the San Joaquin?



Eastside Bypass, and Mariposa Bypass Channel in the SJRRP.



San Joaquin River, California. Monitoring Points: 1 Friant Dam Releases – Millerton Lake Daily Operations Report. 2 Gravelly Ford (California Data Exchange Center [CDEC]), 3 Below Bifurcation Structure (CDEC), 4 Mendota Pool (CDEC), 5 Sack Dam (CDEC), 6 Washington Road, 7 Confluence of Merced River (USGS).

The SJRRP faces many challenges (e.g. subsidence, inadequate channel capacity, dewatering in flood systems). Projects like SJRRP may become the rule rather than the exception for resuscitating rivers in working landscapes. These projects increasingly integrate economic infrastructure restoration with environmental restoration. Actions may fall short of restoring natural processes and full biotic function yet are still an important evolutionary phase in conservation. So, how does this potential future affect our research needs? Considerations include:

- Using advancing technology such as NASA's Airborne Snow Observatory for better forecasting.

- Designing pulse flows with a limited channel capacity (e.g., levee stability, freeboard, seepage issues).

- Developing strategies for moving juveniles out through a river that is strongly affected by ambient temperature. Would adding banked groundwater confuse fish? Would it benefit fish by cooling temperatures?

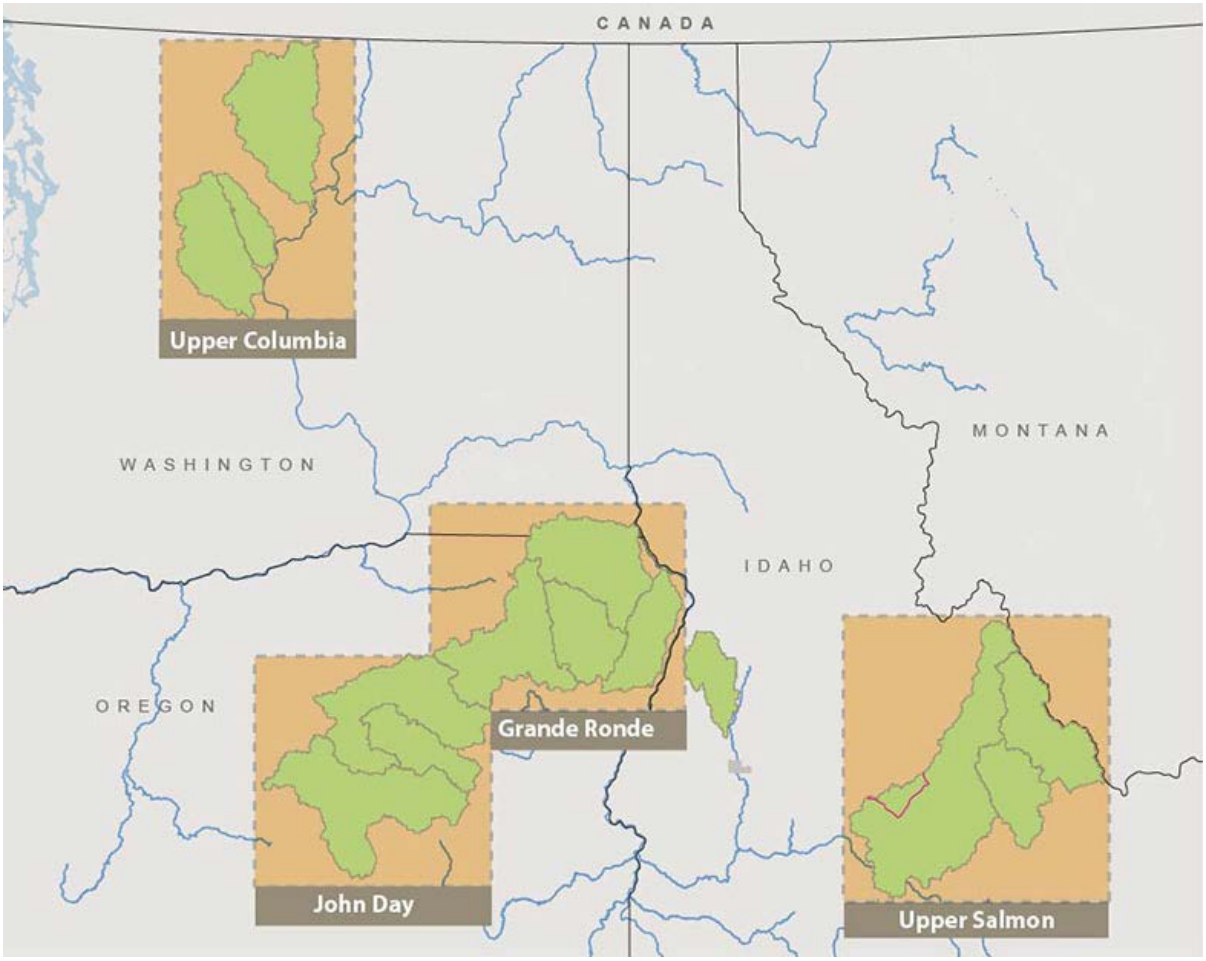
- Determining whether suitable rearing habitat can be created in a channel managed for a completely different purpose. SJRRP is currently routing flows through the Eastside Flood Bypass in lieu of the historic channel. This may become a permanent solution due to the limited capacity and cost associated with the historic Reach 4B channel.

For more information see http://www.restoresjr.net/.

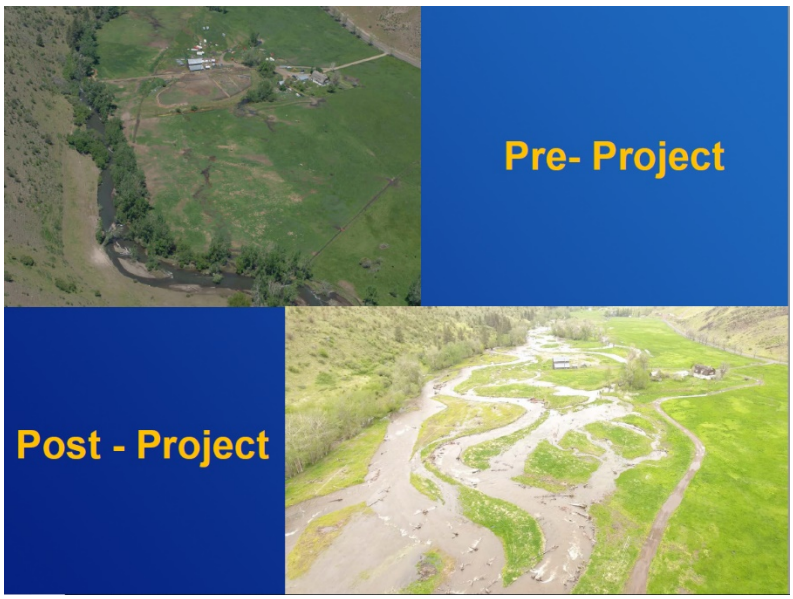
Federal Columbia River Power System (FCRPS) Tributary Habitat Program

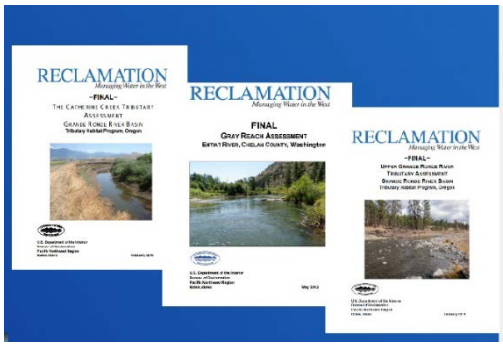
Presenter – Michael Knutson, P.E., Lead Hydraulic Engineer River Systems Restoration Group, Columbia Pacific Northwest Region

The Pacific Northwest Region provides technical assistance within the region for habitat restoration to the FCRPS. The program works with project sponsors, Bonneville Power Administration, National Oceanic and Atmospheric Administration, and permitting agencies to provide technical assistance for implementation of habitat improvement projects. FCRPS objective is to mitigate impacts to Endangered Species Act (ESA) listed spring Chinook and Steelhead. Example projects include fish passage, instream flow and diversion improvements, and habitat complexity. Basins where work occurs are shown in the map below and includes the Upper Columbia, Grand Ronde, John Day, and Upper Salmon. A recent project example was highlighted on Catherine Creek in the Grande Ronde River Basin where a successful effort was implemented to improve habitat complexity by reconnecting the floodplain to the main channel.



Projects in the Columbia Pacific Northwest Region





For more information see http://www.usbr.gov/pn/fcrps/habitat/index.html.

Gila River Restoration Program, Arizona

Interviewee: Bill Stewart, Reclamation (May 2018)

The geographic extent of the Gila River Basin Native Fish Conservation Program covers the entire Gila River basin—which extends from the confluence of the Gila River and Colorado River upstream to the headwaters of the Gila in Western New Mexico. There are five priority fish species that are the focus of conservation /restoration for this program.

Additionally, the program has provided funding for Chiricahua Leopard Frog recovery efforts, and in the near future will be re-initiating consultation to address the northern Mexican and the Narrow-headed Gartersnake.

Gila Topminnow
Poeciliopsis occidentalis
1999 Recovery Plan - Draft

Spikedace
Mefu fulgida
1991 Recovery Plan

Loach Minnow
Tiaroga cobitis
1991 Recovery Plan

Razorback Sucker
Xyrauchen texanus
2002 Recovery Goals

Gila Chub
Gila intermedia
2015 Recovery Plan - Draft

Five main conservation measures guide this program:

1. Construction of native fish barriers
2. Native fish monitoring
3. Native fish conservation
4. Nonnative fish eradication
5. Information and Education

There are over 100 streams, tributaries and springs in the Gila River basin. Project scope can vary in size from stocking and monitoring small springs with Gila Topminnow to larger scale efforts like building a barrier, removing nonnatives, and stocking with priority species in the Blue River. Examples of the types of restoration projects implemented include:

- Native fish barrier construction
- Long term monitoring
- Invasive species monitoring of the Central Arizona Project (CAP) canal
- Hatchery construction and operations and maintenance (O&M)
- 10+ stockings/year of priority species
- Post stocking monitoring
- Nonnative fish removals
- Information and education (native fish in the classroom)
- eDNA sampling
- Nonnative control research (YY male, supraverm study)
- Genetics monitoring (Gila Topminnow, Spikedace, and Loach Minnow)
- Fish habitat investigations

Because of the large stream network and difficulties in selecting projects for the 5 priority species, most of the work has been for on the ground management actions (e.g., stocking and removals). The Gila River program would like more research to help inform where and how management actions take place.

Research has largely been focused on genetics or investigating new techniques for nonnative fish control. The program is currently working with the University of Arizona on investigating the use of YY male fish to control nonnatives. Another research need of this program is investigating ways to improve propagation in the hatchery for Spikedace and Loach Minnow. The Gila River funds the only facility that holds these species and would like to get more and consistent production from the various lineages of fish. Additional research needs of interest include:

- New nonnative control methods, preferably something that is species specific (e.g., controlling for sea lamprey (lampricide) in the Great Lakes)

- Improving nonnative control methods (e.g., pheromone development to improve trapping success)

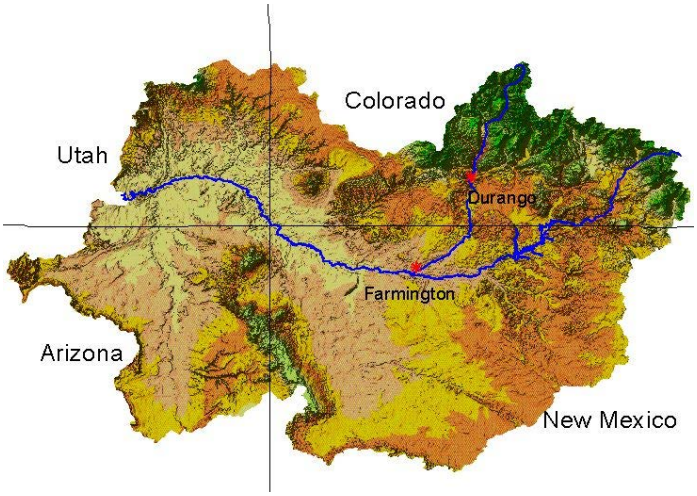
- Genetics
- Hatchery propagation
- Improving post stocking survival

For more information, see https://www.usbr.gov/lc/phoenix/biology/azfish/index.html.

San Juan River Recovery Program, Utah, New Mexico, and Colorado

Interviewees: Mark McKinstry (Reclamation); Nathan Franssen, Eliza Gilbert, Melissa Mata (U.S. Fish and Wildlife Service), September 2018

The San Juan River Restoration Program focuses on the endangered Colorado Pikeminnow and Razorback sucker. The San Juan Recovery Program assists in recovery of endangered species for over 300 water development projects in Utah, Colorado, and New Mexico. In addition, actions under this program benefits other native fishes in the San Juan Basin, in-stream flow protection, and habitat restoration. Recovery actions involve restoring and managing stream flows and habitat, boosting wild populations with hatchery-raised endangered fish, and reducing negative interactions with non-native fish species.



San Juan River, Utah, New Mexico, and Colorado.

Habitats are no longer created during high flows due to regulation by upstream dams—thus reducing habitat complexity and availability in the system. There are over 180 river miles to be addressed, and large-scale restoration has not yet occurred. The Colorado Pike Minnow and Razorback have been extirpated from the system. The current strategy is to reintroduce hatchery fish until enough adults are present to be self-sustaining. The current system is thought to lack sufficient backwater, slow velocity habitat important for larval and juvenile stage. The San Juan River is vastly different than historical conditions when it was braided with a high gradient. The current river has extensive Russian olive invasion that has armored banks and unnaturally limits lateral movement. Existing research has focused on:

- habitat monitoring,
- Russian Olive response to wetting and drying with variable stream hydrology,

- impacts to secondary channels surface water connectivity after non-native vegetation encroachment, and

- availability of food web productivity in backwater areas (proposal submitted for funding)

The San Juan Recovery Program puts a high priority on improving fish population numbers of wild fish. Habitat metrics of importance include area of backwater low-velocity habitat, length of connected river channels for fish passage, and total wetted area of habitat availability. The program is interested in doing future research in:

- Evaluation of effectiveness of pilot projects using machinery to remove Russian Olive

- More cost-effective methods for removal of Russian Olive to keep open secondary channels

- Improved understanding of role of geomorphic and flow drivers to keeping secondary channels open longer without invasive vegetation closing off again after removal

- Sedimentation study on how to address impacts on habitat from sediment originating from Marble Canyon or tributaries

- More cost-effective ways to accomplish non-native fish removal

- Alternatives to stocking programs for reintroducing native fish back in river

- Interdisciplinary geomorphic and habitat planning that involves novel or recent learning and ideas

- Improving tools to better inform dam operation decisions for base flows to create maximum low velocity, backwater habitat that is optimized spatially and temporally

- Primary and secondary productivity differences in mainstem backwaters versus productivity in secondary channel backwaters at base flows

- Developing physical or field tests to assess whether larval stages drift a lot and potential implications to flow release recommendations

For more information, see https://www.usbr.gov/uc/wcao/rm/sjrip/index.htmlResearch.

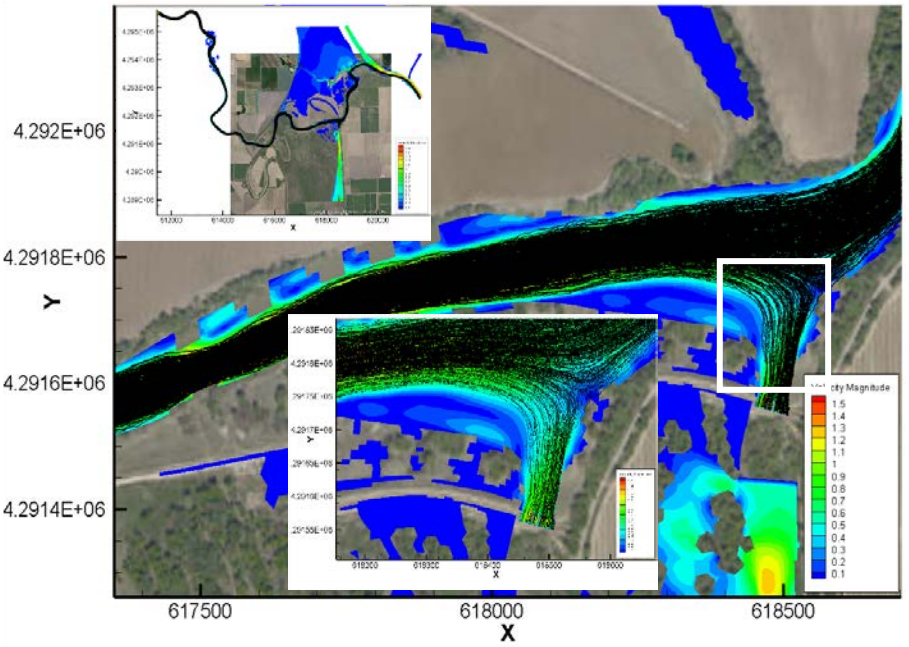
Fremont Weir, California

Presenter, Dave Smith, ERDC USACE.

Floodplains are recognized as a vital component of a juvenile salmon's life cycle. On the Sacramento River, floodplains are largely inaccessible to fish because of the economically vital flood risk management infrastructure such as levees, bypasses, and weirs.

An innovative project is developing an approach to provide access to floodplains for fish while preserving the vital role of levees in managing flood risk. The Fremont Weir is an approximately 2 mile-long structure that regulates flood flows into the Yolo Bypass. It is infrequently overtopped. The objective of this project is to provide fish access to floodplains was to notch the Fremont Weir, providing a flow path from the river to the Yolo Bypass. The stage at which the notch begins to flow and the maximum notch discharge were balanced against existing agricultural and recreational needs and the need to entrain as many fish as possible.

Questions of notch entrainment rates for fish, the notch location and configuration were addressed through a combination of high resolution fish telemetry in the existing river and a fish movement model, the Eulerian Lagrangian Agent Method (ELAM). The ELAM represents fish as a mathematical point embedded in a 2D or 3D hydraulic model. The modeled fish are parametrized with size and swim speeds and the resulting movement is calibrated using speed and position estimates from real fish. Hydraulic models are then developed for proposed notch locations, sizes, and configurations to estimate the notch entrainment rates.



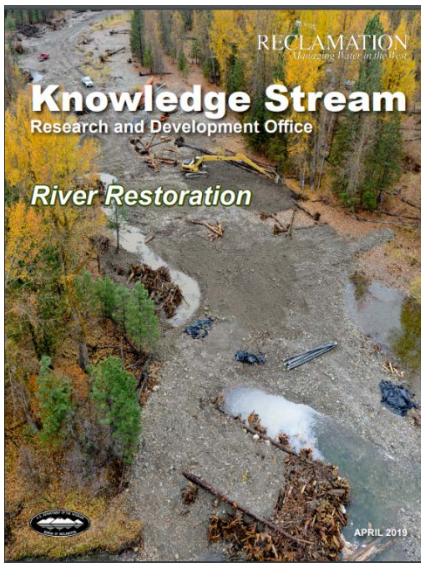
The Fremont Weir reach showing 2D hydraulic model, modeled fish tracks, and one example of a proposed notch.

We compared predicted entrainment as a function of the ratio of notch flow to river flow to other diversions in the Sacramento River by modeling over 16 notch configurations and found that predicted entrainment rates at the Fremont Weir are similar to what is measured elsewhere. This suggest that the ELAM approach was making reasonable estimates and adds confidence to the modeling results.

The notch is not yet built, and actual entrainment rates have not been measured. Once the new notch is built, we expect that we can compare measured entrainment rates and consider approaches to improving them if needed.

Next Steps

We hope this report will foster research proposals for FY2021 and beyond. We have also started sharing additional case studies in webinars hosted by the Science and Technology Research Office. If you are interested to give a webinar on a river restoration or environmental research topic, please contact Jennifer Bountry, Environmental Research Coordinator at Reclamation, jbountry@usbr.gov. We plan to host future workshops as funding is available, rotating the location to different geographic regions accomplishing restoration. We will continue to include a field trip, technology sharing presentations and further discussion on research opportunities in the workshops.



Reclamation's Research and Development Office's Knowledge Stream focused on River Restoration. See https://www.usbr.gov/research/docs/ks/ks-2019-02.pdf.

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

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.

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Table 1 summarizes the research needs proposed during the 2018 interviews and 2019 workshop. We encourage readers to partner to work on the research needs listed in Table 1. Assistance with connecting to recovery programs or other Reclamation partners is always available from the Science and Technology Office (email: research@usbr.gov).

Table 1. River Restoration Research Needs

Area	Research Question	Importance	Successful Outcome	Collaborations and locations for research
Physical Systems				
Vegetation management	How do reservoir operations affect vegetation recruitment and survival in the downstream riparian corridor? How can vegetation be incorporated into restoration projects without increasing flood risks? How do varying riparian vegetation characteristics associated with restoration actions affect sediment transport dynamics within the system?	Rule-based methodology for coupling hydraulics to riparian response can determine vegetation life cycles Quantitative predictive tools are needed in order to systematically evaluate management options Sediment-vegetation interaction is complex and introduces additional challenges to making quantitative predictions	Spatially and temporally distributed model for predicting fluid and sediment dynamics as influenced by vegetation characteristics—and for predicting riparian vegetation evolution as influenced by local hydraulics.	
Sediment	How can we most efficiently create semi-continuous habitat features on sediment laden rivers? How can we project and model sediment deposition patterns? How do restoration projects effect sediment dynamics of the system? Do we need to reduce uncertainty in design with better measurement/modelling of sediment transport and morphodynamics? How can we better embrace and consider uncertainty in design?	Help predict the longevity of future restoration sites. Identify where heavy modeling and design efforts are and are not warranted based on potential project longevity.	2D model that can predict sediment deposition patterns and testing and optimal design	People who work on sand bed and sediment laden rivers Middle Rio Grande, San Juan, and Platte Rivers.

Area	Research Question	Importance	Successful Outcome	Collaborations and locations for research
Gravel augmentation	What are the criteria for implementing beneficial gravel augmentation in lieu of self-sustaining restoration projects and, more generally, for sediment starved systems (e.g., downstream of dams)?	Sediment is often an overlooked, but a significant driver of geomorphic processes and form which also relates to quality habitat. Understanding where systems are limited, but could be improved through gravel augmentation could mitigate negative impacts.	Agency Report, but initially a scoping exercise with summary that assimilates available information and brings together a strong literature review of what has been done.	Subject matter experts (academia, Federal agency research divisions)
Habitat	How will restoration actions impact quality, quantity, and distribution of habitat? What are effective methods to answer:			
	How does habitat availability vary with discharge in the river (instream and floodplain habitats), and how do flow-habitat relationships influence the recruitment? How have flow-habitat relationships changed relative to historical conditions?	Understand flow habitat relationships		University of New Mexico/Colorado State University Rio Grande for the RGSM in the Middle Rio Grande
	How does longitudinal dis-connectivity (i.e., diversion dams) affect the distribution, abundance, and genetic viability for target fish species?	Improve longitudinal connectivity		
	How does one design lateral habitat features that may function at low flows?	Many systems no longer maintain their own lateral habitat and flows are often low in these systems due to storage and withdrawals.	Strategies for connected, low-flow habitat that will be easy to maintain or have longer lifespan given propensity to aggrade.	

Area	Research Question	Importance	Successful Outcome	Collaborations and locations for research
Habitat Restoration Site Usage	What is the target fish usage of created habitat? What life stages use created habitat? Is there a correlation between RGSM use of created habitat and the numbers of fish at the population monitoring sites?	Understand the effectiveness of created habitat and identify areas for further study and improved designs.		Rio Grande
Thermal refugia	What are the best ways to collect temperature data over time and locations? What restoration practices enhance or create thermal refuges at water scales and timeframes? What are different hyporheic signatures we can consider to identify thermal refugia?	To ensure restoration projects are targeted in optimal locations for realizing the benefits of thermal refugia. Ultimately, restoration projects want to avoid developing river features that are not utilized by fish or to some other benefit. If optimal hyporheic conditions can be identified to aid in temperature control, designs can be optimized with that information.	Guidance document that summarizes methods (e.g., temperature strings and loggers, fiber optic cable, drones), level of effort and costs required, pros and cons of each method,	Collaborate with different agencies, academia, researchers. Many areas could benefit. Projects with identified interest include the SJRRP and Bird Track Springs.
Environmental flows for fish	1. What are the important spawning cues, rearing habitat, and adult life history? 2. How does geomorphology support riverine fish habitat?	Allocation of limited resources to support fish life history	Well-defined hydrograph (volume, magnitude, duration, chemistry, timing, temperature) to complete life history. More big fish, rising water tables, reduced depletions.	Municipalities, irrigation districts, other water managers with biologists. San Joaquin River.

Area	Research Question	Importance	Successful Outcome	Collaborations and locations for research
Instream fish habitat	What does mesohabitats look like to fish? What is the mesohabitats preference / use by target species?	Is current instream mesohabitats sufficient to achieve population targets?	A better understanding of fish habitat preference and availability.	Need interdisciplinary collaboration among biologists, geomorphologists, engineers.
Data Collection and Analysis				
Fish	What are the best practices for coordinating data collection for integrated model efforts across disciplines? How can we improve efficiency of data capture and spatial and temporally alignment in order to maximize value for each model? What metadata standards and open data principals should be used to maintain data for present and future use cases?	Modeling is a cost-effective approach to evaluate alternatives and quality data is often the limiting factor. Coordination will reduce the occurrence of opportunities missed due to lack of communication about data needs, improving the information gained from integrated modeling.	A process document outlining approaches that will assist interdisciplinary teams better coordinate their data collection methods for integrated modeling.	Hydraulic engineers, geomorphologists, biologists, data scientists, environmental planners ...
eDNA	How can we use eDNA to monitor fish? What are the limits for eDNA and meta-eDNA analyses—how far can they be detected (distance/flow)? Can we use qPCR to get better quantification?	May provide a cost-effective way to get information	Tools that could be incorporated into study efforts.	Partner with universities and labs that can analyze genetics and DNA. Gila River

Area	Research Question	Importance	Successful Outcome	Collaborations and locations for research
Remote Sensing Drones	How can we incorporate drone technology into an existing Reclamation Structure for Motion (SFM) post-processing workflow?	Reduce risk of having people in field hard to reach areas are highest return on investment, hard to put price on safety and access Floodplain analysis, reduce uncertainty by having more density of data in time and space	Point cloud classifications and tools that are easy to use and robust Having IT systems in place to support them DOI pilot program Work flow of getting drone data, and post processing to get it in hands of modelers and decision makers to make more use of it	DOI pilot programs, IT (for storage of all the data generated). Focus on areas that require humans for survey yet pose safety risks for human inspections. Drones could reduce these risks by eliminating the need for human access.

Area	Research Question	Importance	Successful Outcome	Collaborations and locations for research
Data integration	What data integration systems are available that meets our data needs, but also adhere to our IT restrictions, and which existing data sources are not working and how do we improve them?	By having this program available, the repository would provide continued value to people in the future. Participating in a centralize data repository encourages people to collaborate with one another, yielding more potential solutions from different perspectives. Exposing more people to these data sets will open the data to criticism, providing the opportunity to improve data quality.	A data portal that also provides meta-data that can be successfully harvest. Having an Application Programming Interface (API) associated with the repository for computer programs to easily query the data. Having a citation metric tied to the dataset.	IT, 508 Compliance Specialist, Contracting Officer or Contracting Officer Representative. The person who actually needs the data should become the principal investigator rather than contracting this work out.
Communication, Design, and Decision Processes				
Dynamism	How does dynamism play a role in design? How do we communicate dynamism?	Improving the communication of the project design and potential evolution may help improve project acceptance and appearance.	Framework for developing communication strategies dependent on target audience and product the yields the most effective method of communicating the product	Visual artists, 3d rendering technicians, landscape architects, etc.

Area	Research Question	Importance	Successful Outcome	Collaborations and locations for research
Spatial Temporal Scale	How do we determine the extent and period for restoration efforts? Are we trying to restore a process or a product of that process? How do we balance restoration objective will available budgets?			
	How can we move from the paradigm of statistical sampling to near-census river science?	Overhaul and automate how river restoration designs are developed to achieve mechanistic, sustainable outcomes.	1-m map of USA with aquatic bathymetry Objects for every single tree, downed wood, and stream wood Objects for all large riverbed elements (boulders, bedrock outcrops, etc.) LSPIV for 2D water velocity maps Sediment facies & mineral maps	
Sustainability	What features, geometries, and topography should be included in floodplain projects to improve sustainability?			
Economics	What is the economic value of better forecasting?	Determine the cost efficiencies with modeling, satellite data, Airborne Snow Observatory, etc.		

Resources

Several resources presented at the workshop are highlighted below.

River Restoration Webinars

Webinars hosted by the Science and Technology Office will be posted to the following site under "TSC Environmental Research Webinar Series."

https://www.usbr.gov/tsc/training/training.html

Models and Software Programs

Sediment River Hydraulics Models incorporating Vegetation

Reclamation has developed models that are currently used, including:

SRH-1D. One-dimensional (1D) flow, sediment transport, and vegetation simulation tool

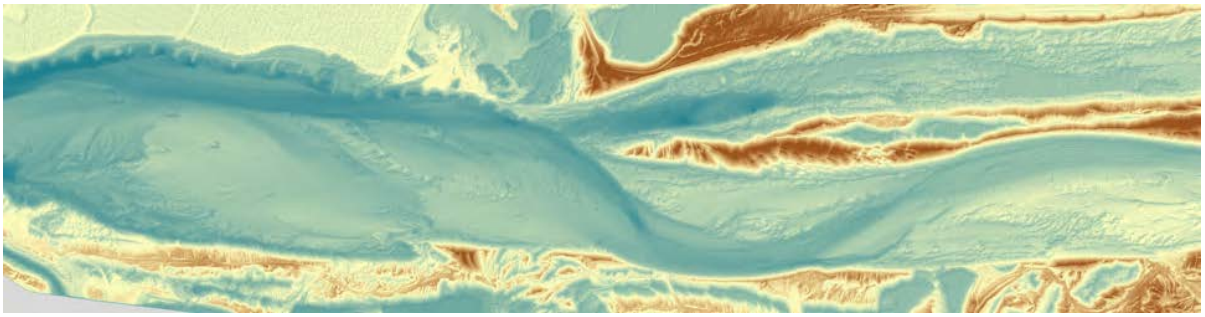
SRH-2D. Two-dimensional (2D) flow, sediment transport, and vegetation simulation tool

- Solves the depth-averaged 2-D dynamic wave or St. Venant equations
- Computes variables over an unstructured hybrid mesh
- Features an automatic wetting-drying algorithm
- Uses a spatially distributed Manning's n roughness as the primary tuning parameter

For more information on the full suite of SRH-D modeling, see https://www.usbr.gov/tsc/techreferences/computer%20software/compsoft.html. For a list of current research and future needs related to eco-hydraulics and sediment modeling at Reclamation see the newly posted roadmap at https://www.usbr.gov/research/st/roadmaps/EcoHy-Sediment-Modeling.pdf.

River Builder and Feature Lifespan Mapping

Dr. Gregory Pasternack, Professor, Department of Land, Air, and Water Resources, University of California, Davis discussed using near census 2D hydraulics model. For example, these one-meter scale maps have a high benefit cost ratio, as they can be used for many purposes.



Lower Yuba Map

Algorithms for fluvial geomorphic and ecological assessment are rapidly growing and increasing in sophistication. These models provide spatially distributed point set of water surface elevation, depth, velocity magnitude & directional components, and bed shear stress in velocity (ft/s) and depth (ft) at a sufficiently accurate level for river analysis and project-design analysis (Brown et al. 2014).

- Synthetic River Valley (SRV) Models use geometric modeling to create river and floodplain topography. River Builder is a free and open source SRV model.

- River Architect is a Python3-based open-source package GUI modules supporting stream design
    1. Lifespan mapping of design features
    2. Simple auto-mod terrain and compute terraforming mass differences
    3. Evaluate habitat quality for various aquatic species
    4. Investigate functional flows related to geomorphologic features
    5. Compute project cost-benefit economics

For further information, see Brown, R.A., G.B. Pasternack, and W.W. Wallender, 2014. Synthetic River Valleys: Creating Prescribed Topography for Form-Process Inquiry and River Rehabilitation Design. Geomorphology 214: 40-55.

Reclamation Programs and Activities

Native American Affairs Program

Presenter Kelly Titensor, Reclamation Native American Affairs

The Native American Affairs Program, which is a formal program funded through the Native American Affairs line item in Reclamation’s budget, is a small but integral part of the overall Native American Program. The Native American and International Affairs Office in the Commissioner's Office serves as the central coordination point for the Native American Affairs Program and lead for policy guidance for Native American issues in Reclamation.

Reclamation is committed to being respectful of Tribal sovereignty and to upholding its overarching Indian policy, which states that it will "comply with both the letter and the spirit of Federal laws and policies relating to Indians; acknowledge and affirm the special relationship between the United States and Federally recognized Indian tribes; and actively seek partnerships with Indian tribes to ensure that tribes have the opportunity to participate fully in the Reclamation Program as they develop and manage their water and related resources."

See https://www.usbr.gov/native/.

Science and Technology Program

Presenter: John Whitler, BOR Science and Technology Program: S&T Overview

Reclamation's Research Office Science and Technology (S&T) Program addresses technical issues through innovative solutions, using research projects, technology transfers, and water and power technology prize competitions. S&T serves Reclamation resource managers, facility managers, customers, and stakeholders as well as the broader water and power resources community. S&T provides funding for Reclamation employees as principal investigators to study problems, develop new or adapt technology to solve problems, and to field test and demonstrate solutions.

The Call Schedule is

- April–Calls for proposals
- June –Proposals Due
- June-August –Proposal Review
- September –Commissioner Concurrence
- October –Awards Announced

Get involved in the S&T Program?

- Submit a proposal
- Volunteer to be on a project team
- Volunteer to be a technical reviewer
- Communicate research needs identified as part of regular work

https://www.usbr.gov/research/st/index.html

Motivation

During the workshop we also talked about what motivates us to work in river restoration and watched an inspiring video about cleaning up the Mississippi River, *Why we do River Restoration*: https://www.youtube.com/watch?v=7h2aSPA0Gcc.

Keynote Speaker Chad Pregracke is proof that one person can make a difference. What started as one man's crusade has become an ever-evolving worldwide movement to educate people and connect them with their environment.

Appendix A: River Restoration Science Training Workshop Agenda

Sponsored by Reclamation Science and Technology Program

Dates: May 1 to May 3, 2019

Location: The May 2 and 3 sessions will be held at: *Room W-2617, Sequoia Room, Federal Building, 2800 Cottage Way, Sacramento, CA.*

Overview: The focus of this training will be to share technical information related to river habitat restoration, fish monitoring, environmental flows, and adaptive management projects and research. While learning about the latest developments in these areas, participants will also have the opportunity to identify technical knowledge and research gaps. This discussion will inform future proposals to Reclamation research programs such as the Science and Technology Program, the training sponsor. Additionally, this training will include a field tour and a technical presentation of a river restoration project. Presentations will be provided by experts working on the ground in Reclamation's recovery programs and from Reclamation's Technical Service Center on active river restoration research and tools being developed.

Wednesday May 1 – Fremont Weir Field Trip (12:00 to 5:30p)

Tour Guides: Ben Nelson, BOR; David Smith, USACE

Reclamation and the California Department of Water Resources are planning a notch in the Fremont Weir on the Sacramento River. The notch is intended to provide access to the Yolo Bypass floodplain for juvenile salmon across a range of flows. We will visit an existing fish passage structure at the Fremont Weir and as well as the area of the planned notch. If time permits, we will also visit a habitat restoration site on the American or Sacramento Rivers before heading back to the regional office. The field tour of the Fremont Weir will cover the planning and evaluation process implemented to define the fish entrainment potential of six alternative notch locations/designs evaluated as part of the EIS/EIR process. We developed 2D hydraulic models and fish movement models, each calibrated to data, to help define the entrainment potential. The field tour will cover how these engineering tools were used in a planning context including objectives and evaluation metrics.

For more information on the aquatic habitat values in the Yolo bypass, visit this Reclamation website: https://www.usbr.gov/mp/bdo/yolo-bypass.html

For more information on the Fremont Weir Adult Fish Passage Project, visit:

- https://www.usbr.gov/mp/bdo/fremont-weir.html
- https://water.ca.gov/Programs/Environmental-Services/Restoration-Mitigation-Compliance/Yolo-Bypass-Projects
- DWR video with aerial footage - https://www.youtube.com/watch?v=WtEpdaE8HMY

Thursday May 2 – Restoration Science Training Workshop

8:00a to 5:00p Sequoia Room (Federal Building, 2800 Cottage Way, Sacramento, CA)

Workshop Objectives: 8:00a to 9:00a

- Jennifer Bountry and Joel Sholtes and Rod Wittler: Welcome and introductions (30 minutes)
- Kelly Titensor, BOR American Affairs (15 minutes)
- John Whitler, BOR Science and Technology Program: S&T Overview (15 minutes)

Session 1: Keynote speaker, 9:00a to 9:45a

- David Mooney, Bay-Delta Office Area Manager, Bureau of Reclamation (45 minutes)

Session 1: Fish Biology and Monitoring, 10:00a to 12:00p

- 10:00 to 10:30 Presentation: Mike Horn, Group Manager, Fisheries & Wildlife Resources, Technical Services Center, Bureau of Reclamation
    - *Challenges of Monitoring Fish*
- 10:30 to 11:00 Presentation: Drew Baird, Hydraulic Engineer, Sedimentation & River Hydraulics, Technical Service Center, Bureau of Reclamation
    - *Middle Rio Grande Geomorphology & Habitat for Silvery Minnow*
- 11:00 to 11:30 Small Group Breakouts on Research (each group gets 1 topic)
    - What is the research question?
    - Why is it important to restoration recovery programs?
    - What would a successful outcome or product look like?
    - Who can we collaborate with (who does this, champion or SMEs)?
    - Where can we conduct the research?
- 11:30 to 12:00 Large Group Discussion on Research
    - Small groups report back to large group

Lunch and Poster Session, 12:00p to 1:00p

Session 2: Project Lifespan - Adaptive Management Implementation, 1:00p to 2:45p

- 1:00 to 1:30 Presentation: Chad Smith, Deputy Executive Director, Platte River Recovery Implementation Program
    - *Adaptive Management on the Platte River Recovery Implementation Program*
- 1:30 to 2:00 Presentation: David Bandrowski, Watershed Restoration Program Engineer, Yurok Tribe and Michael Dixon, Implementation Branch Chief, Trinity River Restoration Program
    - *Adaptive Management on the Trinity River Restoration Implementation Program*
- 2:00 to 2:30 Small Group Breakouts on Research (each group gets 1 topic)
- 2:30 to 3:00 Large Group Discussion on Research

May 2 – Restoration Science Training Workshop, *continued*

Session 3: Habitat Rehabilitation and Design, 3:15p to 5:00p

- 3:15 to 3:45 Presentation: Michael Knutson, Technical Lead Hydraulic Engineer, River Systems Analysis and Restoration Group, Pacific Northwest Region, Bureau of Reclamation
    - *Designing and monitoring complex channel and floodplain rehabilitation projects*
- 3:45 to 4:15 Presentation: Dr. Gregory Pasternack, Professor, Department of Land, Air, and Water Resources, University of California, Davis.
    - *River Builder and Feature Lifespan Mapping*
- 4:15 to 4:45 Small Group Breakouts on Research (each group gets 1 topic)
- 4:45 to 5:00 Large Group Discussion on Research

Friday May 3 – Restoration Science Training Workshop

8:00a to 12:00p Sequoia Room (Federal Building, 2800 Cottage Way, Sacramento, CA)

Session 4: Environmental Flows, 8:00a to 10:00a

- 8:00 to 8:30 Presentation: Daniel Dombrowski, Sedimentation and River Hydraulics, Technical Service Center, Bureau of Reclamation
    - *Modeling Interactions of Flow, Vegetation, and Sediment for Improved Riverine System Management*

- 8:30 to 9:00 Presentation: Emily Thomas, Hydrologic Engineer; Adam Nickels, Deputy Program Manager - Water Management Goal, San Joaquin River Restoration Program, Bureau of Reclamation
    - *Flow Management, Forecasting, and Flow Guideline Development*
- 9:00 to 9:30 Small Group Breakouts on Research (each group gets 1 topic)
    - What is the research question?
    - Why is it important to restoration recovery programs?
    - What would a successful outcome or product look like?
    - Who can we collaborate with (who does this, champion or SMEs)?
    - Where can we conduct the research?
- 9:30 to 10:00 Large Group Discussion on Research
    - Small groups report back to large group

Restoration Science Training Workshop Wrap Up and Next Steps, 10:15a to 12:00p

- 10:15 to 11:00 Group discussion: Potential FY2020 Research Proposals
- 11:00 to 12:00 Group discussion: Next steps BOR river restoration community dialogue and institutional framework

Adjourn! 12:00p

Appendix B: Attendees

Reclamation

Drew Baird, dbaird@usbr.gov, Denver
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Non-Reclamation

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Dave Smith, USACE ERDC