

Project A: Streamflow, Water Quality, and Sediment Transport and Budgeting in the Colorado River Ecosystem

This project collects the physical data that directly link dam operations to the downstream Colorado River; all other GCDAMP-funded projects use these data to link dam operations to their resources of interest. The data collected by this project are used to implement the High-Flow Experiment (HFE) Protocol (i.e., trigger and design HFE hydrographs), to evaluate the reach-scale sand mass-balance response to the HFE Protocol, and to evaluate the downstream effects of releases conducted under the Long-Term Experimental and Management Plan (LTEMP) Environmental Impact Statement (EIS; [LTEMP](#)). Full Description on page 80 of the [FY21-23 TWP](#).

- A.1 Stream gaging and hydrologic analyses
- A.2 Continuous water-quality parameters
- A.3 Sediment transport and budgeting

Project B: Sandbar and Sediment Storage Monitoring and Research

The purposes of this project are to: 1) track the effects of individual HFEs on sandbars and campsites, 2) monitor the cumulative effect of successive HFEs and intervening dam operations on sandbars and sand conservation, 3) investigate the interactions between dam operations, sand transport, and channel dynamics, and 4) develop and apply predictive models for streamflow and sandbar changes that can be used for evaluating dam operations scenarios. It directly relates to the LTEMP Record of Decision (ROD; [LTEMP](#)) to "increase and retain fine sediment volume, area, and distribution...for ecological, cultural, and recreational purposes." Full Description on page 106 of the [FY21-23 TWP](#).

- B.1 Sandbar and campsite monitoring with topographic surveys and remote cameras
- B.2 Bathymetric and topographic mapping for monitoring long-term trends in sediment storage
- B.3 Control network and survey support

Project C: Riparian Vegetation Monitoring and Research

The purpose of this project is to monitor the status and trends of riparian vegetation, examine mechanisms behind trends in riparian vegetation change as they relate to LTEMP flows, and apply existing and new knowledge to LTEMP vegetation management. The four elements of this project assess riparian vegetation status in the Colorado River Ecosystem (CRe), test mechanisms by which flow regime impacts species of interest, synthesize data to anticipate changes to vegetation, and assist nonflow management actions directed by the LTEMP. Full Description on page 135 of the [FY21-23 TWP](#).

- C.1 Ground-based riparian vegetation monitoring
- C.2 Determining hydrological tolerances and management tools for plant species of interest
- C.3 Predictive models and synthesis
- C.4 Vegetation management decision support

Project D: Effects of Dam Operations and Vegetation Management for Archaeological Sites

The LTEMP goal for Archaeological and Cultural Resources is to maintain the integrity of potentially affected National Register of Historic Places (NRHP)-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis. Project D monitors and quantifies changes in the physical condition of river corridor archaeological sites in Grand Canyon as a function of ongoing and experimental dam operations and vegetation management actions of the LTEMP ROD ([LTEMP](#)), in keeping with the mandates of the Grand Canyon Protection Act (GCPA) and consistent with the monitoring plan developed in 2015 and Reclamation's 2017 Historic Preservation Plan. Description on page 164 of the [FY21-23 TWP](#).

- D.1 Dam operations, vegetation management, archaeological sites

Project E: Controls on Ecosystem Productivity: Nutrients, Flow, and Temperature

This project aims to disentangle some of these drivers by combining the highly resolved long-term information about riverine turbidity, silt and clay concentrations, solar inputs, discharge, and gross primary productivity via continuous oxygen and temperature measurements— data that are collected as parts of the Interagency Lake Powell Water Quality Monitoring project. Project E is designed to capture and link changes in productivity to changes in bottom-up drivers such as light, flow, and nutrients and to further develop links between these bottom-up drivers and higher trophic levels. Full Description on page 189 of the [FY21-23 TWP](#).

- E.1 Phosphorus budgeting in the Colorado River
- E.2 Rates and composition of primary producers in the Colorado River
- E.3 Productivity at higher trophic levels

Project F: Aquatic Invertebrate Ecology

The primary focus of Project F is continuation of long-term food base monitoring needed to track ecosystem response to “Bug Flows” and other LTEMP experiments. Additionally, this project supports other projects within the TWP such as: Project E, Project G, and Project H. Full Description on page 214 of the [FY21-23 TWP](#).

- F.1 Aquatic invertebrate monitoring in Marble and Grand Canyons
- F.2 Aquatic invertebrate monitoring in Glen Canyon
- F.3 Aquatic invertebrate monitoring of Grand Canyon tributaries
- F.4 Fish diet studies

Project G: Humpback Chub Population Dynamics throughout the Colorado River Ecosystem

This project is mandated by the [2016 Biological Opinion](#) associated with the [LTEMP](#), while focusing research on improving our understanding of abundance and the drivers of humpback chub population dynamics throughout the lower CRE. Full Description on page 231 of the [FY21-23 TWP](#).

- G.1 Humpback chub population modeling
- G.2 Annual spring/fall HBC abundance estimates in the lower 13.6 km of the LCR
- G.3 Juvenile chub monitoring near the LCR confluence (JCM-East)
- G.4 Remote PIT-tag array monitoring in the LCR
- G.5 Monitoring humpback chub aggregation relative abundance and distribution
- G.6 Juvenile chub monitoring - West (JCM-West)
- G.7 Chute Falls translocations

Project H: Salmonid Research and Monitoring

Rainbow trout were an important component in the development of LTEMP for GCD operations, and thus were a major consideration in the flow decisions in the selected alternative in the LTEMP ROD. This study focuses on how experimental flows will influence recruitment, growth, survival, and dispersal of rainbow trout in Glen and Marble canyons. Full Description on page 257 of the [FY21-23 TWP](#).

- H.1 Rainbow trout monitoring in Glen Canyon
- H.2 Experimental flow assessment of trout recruitment
- H.3 Brown Trout Early Life Stage Survey in Glen Canyon
- H.4 Salmonid modeling

Project I: Warm-Water Native and Non-Native Fish Monitoring and Research

Maintaining self-sustaining native fish populations within the Colorado River and minimizing the presence and expansion of aquatic invasive species are two specific resource goals outlined in the [LTEMP](#) and associated [2016 Biological Opinion](#) for the operation of Glen Canyon Dam. These two resource goals are closely linked together in that introduced warm-water fish are largely incompatible with Colorado River native fish and pose a direct risk to native species like the Humpback Chub. This project will help to monitor those risks. Full Description on page 291 of the [FY21-23 TWP](#).

- I.1 System-wide native fish and invasive aquatic species monitoring
- I.2 Invasion and colonization dynamics of warm-water invasive fish
- I.3 Impacts of channel catfish on native fish in the LCR

Project J: Socioeconomic Research

Project J contains research elements that collect and integrate socioeconomic information with data and predictive models from ongoing long-term physical and biological monitoring and research led by the USGS GCMRC. The project elements improve the ability of GCDAMP resource managers and stakeholders to evaluate management actions and prioritize monitoring and research. The proposed project elements address the LTEMP ROD resource goals related to humpback chub, sediment, invasive fish, and hydropower, as specified in Section 4. Full Description on page 291 of the [FY21-23 TWP](#).

- J.1 Predictive models for adaptive management
- J.2 Brown trout incentivized harvest

Project K: Geospatial Science, Data Management, and Technology

This project provides high-level support to GCDAMP-funded science efforts in the disciplines of geospatial science, data management, database administration, and emerging information technologies. Full Description on page 326 of the [FY21-23 TWP](#).

- K.1 Enterprise GIS, geospatial analysis, and processing
- K.2 Data management and database administration
- K.3 Remote monitoring and advanced technology support

Project L: Overflight Remote Sensing in Support of GCDAMP and LTEMP

This project seeks to acquire and analyze high-resolution multispectral imagery and digital surface models (DSM) of the Colorado River and riparian area from the forebay of Glen Canyon Dam downstream to Lake Mead, and along the major tributaries to the Colorado River. Data derived from the 2021 and previous overflights are used either directly or indirectly by every science project to address every resource goal of the LTEMP. Full Description on page 346 of the [FY21-23 TWP](#).

- L.1 Overflight remote sensing

Project M: Leadership, Management, and Support

The Leadership, Management, and Support budget covers salaries for a budget analyst, librarian, a part-time library assistant, three members of the logistics support staff, as well as leadership and management personnel for GCMRC. Full Description on page 359 of the [FY21-23 TWP](#).

- M.1 Leadership, management, and support
- M.2 Logistics staff
- M.3 IT

Project N: Hydropower Monitoring and Research

The LTEMP states that the objective of the hydropower and energy resource goal is to, “maintain or increase GCD electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.” Project N will identify, coordinate, and collaborate with external partners on monitoring and research opportunities associated with operational experiments at GCD designed to meet hydropower and energy resource objectives, as stated in the LTEMP EIS and its ROD, and guided by the memorandum (Guidance Memo) from the Secretary's Designee, dated August 14, 2019. Full Description on page 360 of the [FY21-23 TWP](#).

- N.1 Hydropower monitoring and research
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Table 2. Project elements in the FY2021-23 Triennial Work Plan that address some aspect of the Long-Term Experimental and Management Plan (LTEMP) Resource Goals relative to LTEMP dam operations and experimental actions. Gray boxes indicate no relevance. Full Description on page 69 of [FY21-23 TWP](#).

LTEMP General Dam Operations & Experimental Actions	Archeological and cultural resources	Natural Processes	Humpback chub	Hydropower and energy	Other native fish	Recreational experience	Sediment	Tribal resources	Rainbow trout fishery	Nonnative invasive species	Riparian vegetation
General dam operations	D.1/D.2	A.2 E.1-3 F.1-4	G.1-6 I.1 J.1	N.1	G.1-6 I.1	A.1/A.3 B.1/B.2 J.1/J.3	A.1/A.3 B.1/B.2/B.3 D.3	D.3	H.1/H.2/H.4 I.1	H.3 I.1-3	C.1/C.2/C.3
Fall High Flow Experiments (HFE) > 96-hr ≤ 45,000 ft ³ /s, in Oct. or Nov.	D.1/D.2	A.2 E.1-3 F.1/F.2	G.1-6 J.1	N.1	G.1-6 I.1	A.1/A.3 B.1/B.2/B.6 J.1/J.3	A.1/A.3 B.2/B.6		H.1/H.2/H.4	H.3 I.1-3	C.1/C.2/C.3
Fall HFE ≤ 96-hr ≤ 45,000 ft ³ /s, in Oct. or Nov.	D.1/D.2	A.2 E.1-3 F.1/F.2	G.1-6 J.1	N.1	G.1-6 I.1	A.1/A.3 B.1/B.2/B.6 J.1/J.3	A.1/A.3 B.2/B.6		H.1/H.2/H.4	H.3 I.1-3	C.1/C.2/C.3
Humpback chub translocation			G.7								
Larval humpback chub head-start program			G.7								
Macroinvertebrate production flows		F.1/F.2/F.4	F.4 G.1-6 J.1	N.1	F.4 G.1-6 I.1	J.3			F.4 H.1/H.2/H.4	I.1-3	
Mechanical removal of invasive fish											
Mechanical removal of rainbow trout from LCR reach											
Proactive spring HFE ≤ 45,000 ft ³ /s, in April, May, or June	D.1/D.2	A.2 E.1-3 F.1/F.2	G.1-6 J.1	N.1	G.1-6 I.1	A.1/A.3 B.1/B.2/B.6 J.1/J.3	A.1/A.3 B.2/B.6		H.1/H.2/H.4	H.3 I.1-3	C.1/C.2/C.3
Riparian vegetation restoration	D.1/D.2					C.4 J.1/J.3					C.4
Spring HFE ≤ 45,000 ft ³ /s, in March or April	D.1/D.2	A.2 E.1-3 F.1/F.2	G.1-6 J.1	N.1	G.1-6 I.1	A.1/A.3 B.1/B.2/B.6 J.1/J.3	A.1/A.3 B.2/B.6		H.1/H.2/H.4	H.3 I.1-3	C.1/C.2/C.3
Trout management flows				N.1					H.1/H.2/H.4	H.3	C.1/C.2/C.3