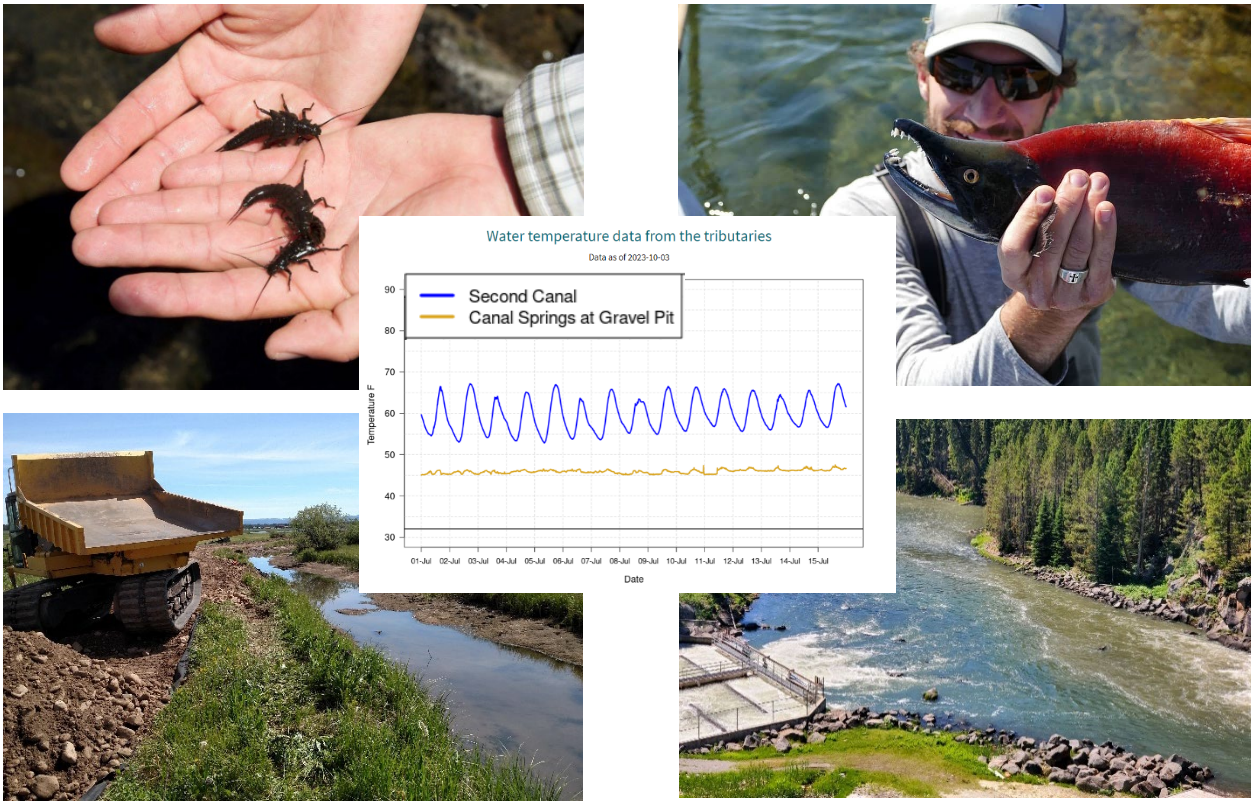
The DIRTT Plan: Developing Infrastructure to Reduce Temperature and Turbidity in the Henrys Fork Snake River Watershed



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List of Abbreviations and Acronyms

HFF	Henrys Fork Foundation
IDFG	Idaho Department of Fish and Game
Reclamation	US Bureau of Reclamation
IDPR	Idaho Department of Parks and Recreation
IDEQ	Idaho Department of Environmental Quality
FRREC	Fall River Rural Electric Cooperative
USFS	US Forest Service
NOFO	Notice of Funding Opportunity
FMID	Fremont-Madison Irrigation District
USEPA	US Environmental Protection Agency
AMSL	Above Mean Sea Level
HSP	Harriman State Park
REACT	REmote Aquatic Chlorophyll-a Tracker
NGO	Non-Governmental Organization
HFWC	Henrys Fork Watershed Council
NTU	Nepholometric Turbidity Unit
HAB	Harmful Algal Bloom
HUC	Hydrologic Unit Code
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
DMP	Drought Management Plan
HOA	Homeowners Association
RFP	Request For Proposal
TBD	To Be Determined
CWA	Clean Water Act

Technical Proposal

Executive summary

PROPOSED PROJECT DURATION: Oct. 1, 2024–Sep. 30, 2027

The Henry's Fork Foundation (HFF), a nonprofit watershed conservation organization, proposes to partner with Idaho Department of Fish and Game (IDFG) on a three-year collaborative planning and assessment project to develop a "water quality basin plan" across multiple subbasins of the Henrys Fork watershed, Idaho and Wyoming. A water quality basin plan is a suite of nature- and evidence-based project designs to restore water quality, build resilience to drought, climate change, aging infrastructure, and human population growth, and thereby protect regional fish, wildlife, and aquatic habitat and associated economic resources. The Henrys Fork watershed is part of the Greater Yellowstone Ecosystem; its unique fisheries, wildlife, and aesthetic qualities support a world-renowned recreational tourism industry worth $30 million annually. At the center of the Henrys Fork watershed is Island Park Reservoir, a US Bureau of Reclamation (Reclamation) facility and the lynchpin of regional water quality, fish, wildlife, and aquatic resources. Drought, climate change, aging infrastructure, and human population growth have increased water temperatures, harmful algal blooms (HABs), and fine sediment transport, and reduced spring-fed thermal refugia and dissolved oxygen concentrations within Island Park Reservoir and the Henrys Fork River. Poor water quality has reduced the resilience of threatened fish and wildlife populations, aquatic macroinvertebrate community health, and the recreational fishing experience. The water quality basin plan will develop designs that 1) address aging facilities with new or retrofit infrastructure in Island Park Reservoir, 2) restore degraded tributaries with watershed-scale, nature-based stream, wetland, and aquifer restoration projects. Projects will be prioritized for implementation after collaborative evaluation, data collection, and stakeholder outreach in partnership with IDFG, Idaho Department of Parks and Recreation (IDPR), Idaho Department of Environmental Quality (IDEQ), Fall River Rural Electric Cooperative (FRREC), the US Forest Service (USFS), and Reclamation. This project is an outgrowth of previous work; our proposal supports water quality and fish and wildlife habitat objectives detailed in the 1992 Henrys Fork Basin Plan, 2005/2018 Henrys Fork Drought Management Plan, 2015 Henrys Fork Basin study, 2019-2024 IDFG Statewide Fisheries Management Plan, and the 2022 HFF Strategic Plan.

Technical project description

Partners

The HFF's expertise, skills, focus on science-based collaboration, and extensive existing hydrologic, ecologic, and geomorphic datasets make it uniquely positioned to effectively accomplish this project. Our key partner is IDFG. The IDFG's mission is to protect, preserve, perpetuate, and manage Idaho's wildlife resources and is the managing agency of fish and wildlife resources in the project area.

The HFF and IDFG, along with supporting partners IDPR, IDEQ, FRREC, and the USFS, have facilities, management, or mission nexus with the planned outcomes of this project. Some of the planning and design tasks as well as data collection will affect lands or facilities owned and operated by IDPR, FRREC, and USFS. These partners allow us to harness existing infrastructure and stakeholder connections to effectively plan and design water quality improvement projects. The outcomes of this project will help IDEQ meet its mission of ensuring Idaho's surface, ground, and drinking water resources meet statutory water quality standards. Finally, the primary focus of this planning and design project centers around Island Park Dam and Reservoir, a Reclamation facility.

Location

The Henrys Fork watershed is located in the Greater Yellowstone Ecosystem in Idaho and Wyoming. This project focuses on the headwaters area of the Henrys Fork within the Upper Henrys Fork Subbasin (Figure 1). The Henrys Fork is dammed to form Island Park Reservoir (Table 1). Reclamation manages Island Park Reservoir to meet downstream irrigation supply needs, in coordination with Fremont-Madison Irrigation District (FMID), the sole storage spaceholder in the reservoir. Water is stored in Island Park Reservoir during the winter and spring and is drafted during the summer and fall. Island Park Reservoir stores about 1/3 of its watershed's total annual yield in a water year (October 1–September 30), so the reservoir is drawn down and refilled to capacity on an annual basis. Annual drawdown in Island Park Reservoir is a function of the difference between irrigation-season outflow and inflow, the latter of which partially consists of outflow from Henrys Lake, a private storage reservoir located upstream. At the watershed scale, outflow from these two reservoirs and Grassy Lake, another Reclamation facility, is managed to meet total irrigation demand and streamflow targets at the bottom of the irrigation system. "Carryover" is the minimum amount of water in Island Park Reservoir at the end of irrigation season, and "drawdown" is the difference between full pool and carryover.

Island Park Reservoir consists of two semi-independent basins. The western basin of the reservoir contains the majority of Island Park Reservoir's surface area (24.7 km^2, 79%) and 40% of the reservoir's total volume. This western basin is shallow (max. depth = 14.6 m, mean depth = 2.61), and wide (fetch = 12 km, average width = 2.2 km). In contrast, the eastern basin of Island Park Reservoir consists of the Henrys Fork river canyon which is deep (max. depth = 22 m, mean depth = 14.7 m), and narrow (fetch = 4.4 km, average width = 1.5 km). Despite making up only 21% of the reservoir's surface area (6.6 km^2), the eastern basin contains 60% of

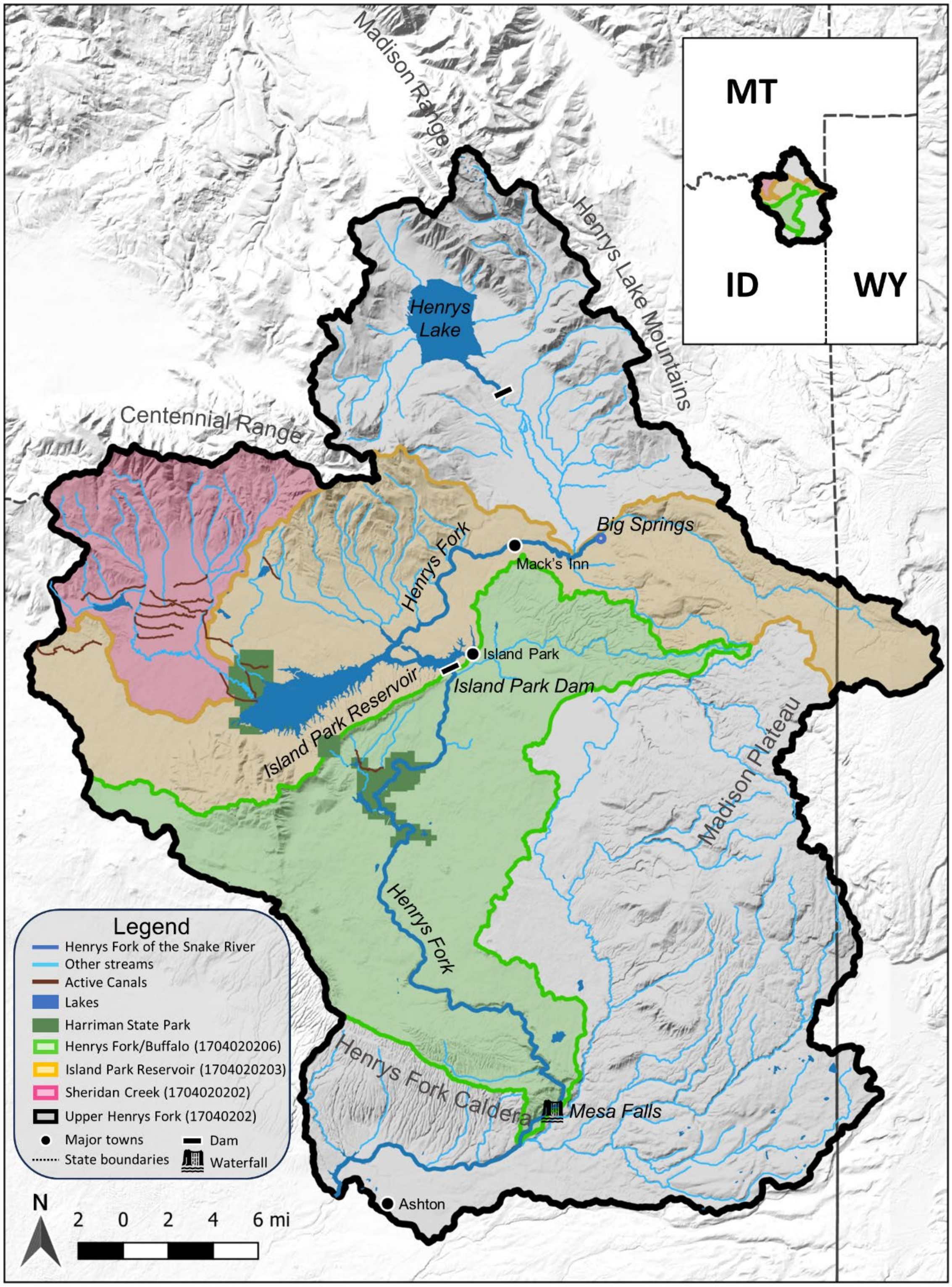

Figure 1: Map of the study area, referred to as the Henrys Fork Watershed upstream of Mesa Falls. The proposed planning and design study will focus on three HUC-10 watersheds within

this area: Henrys Fork/Buffalo, Island Park Reservoir, and Sheridan Creek. Flow direction on the Henrys Fork within the watershed is from north to south.

Table 1: Basic information about Reclamation facility Island Park Reservoir

Year built	1938	
Drainage area	482 sq. mi. (1250 sq. km)	
Dam type	Zoned earth and rock fill	
Dam height	91 ft. (27.7 m)	
Dam crest elevation	6309 ft. (1923.0 m)	
Maximum surface elevation	6303 ft. (1921.1 m)	
Dam Location	44.418894° N, 111.396462° W	
Purpose	Irrigation storage and supply (primary), hydroelectric power generation (secondary), recreation (secondary), flood control (secondary)	
Ecoregion	USEPA 17j – Middle Rockies West Yellowstone Plateau	
	Full pool	**Average annual minimum**
Surface Area	7800 ac. (3156 ha.)	4500 ac. (1821 ha.)
Volume	135,205 acre-feet ($1.67*10^8$ m^3)	61,000 acre-feet ($7.52*10^7 m^3$)
Average depth	17.3 ft (5.27 m)	13.5 ft. (4 m)
Maximum depth	73 ft (22 m)	63 ft (19 m)

the reservoir's total volume and 80% of its inflow by annual volume. The eastern basin has the dam and dual outlet works. Outflow #1, constructed in 1939, is through the right abutment at 23 m in depth at full pool (1899 m AMSL), the deepest point in Island Park Reservoir. Outflow #2, constructed in 1992, is routed via siphon up and over the left abutment with the intake located at 16 m in depth at full pool (1905 m AMSL).

In the western basin, frequent mixing, a large surface area, nutrient inputs from the landscape, and erosive bottom and shoreline sediments create high water temperatures, high productivity, and high levels of suspended organic and inorganic material during the growing season (Figure 2). In contrast, the eastern basin thermally stratifies. Water temperatures, dissolved oxygen concentrations, and productivity are higher in the epilimnion than in the hypolimnion during the summer. Compared to the western basin, the eastern basin has lower water temperatures, lower primary productivity, and higher water clarity (Figure 2).

Key tributaries to Island Park Reservoir include Sheridan Creek, Icehouse Creek, Hotel Creek, Mill Creek, and the Henrys Fork River, their tributaries, and dozens of intermittent streams and groundwater inputs. Tributaries to the Henrys Fork between Island Park Reservoir and Mesa Falls include the Buffalo River, Box Canyon Creek, Blue Springs Creek, Antelope Creek, Thurmon Creek, Fish Pond Creek, and Osborne Springs. The Henrys Fork also receives significant groundwater inflow in the Harriman State Park (HSP) reach. Many tributaries were historically diverted to irrigate pastureland for cattle grazing in the ranch that was donated to the state to form HSP, and most of the canal system still exists. However, most diverted water is no longer used for irrigation and instead returns to the Henrys Fork as an artificial surface tributary.

Sheridan creek is impounded in Sheridan Lake, a private reservoir. Thurmon Creek is impounded twice in Golden and Silver Lakes, and Fish Pond Creek is impounded in the Harriman Fish Pond, all within HSP.

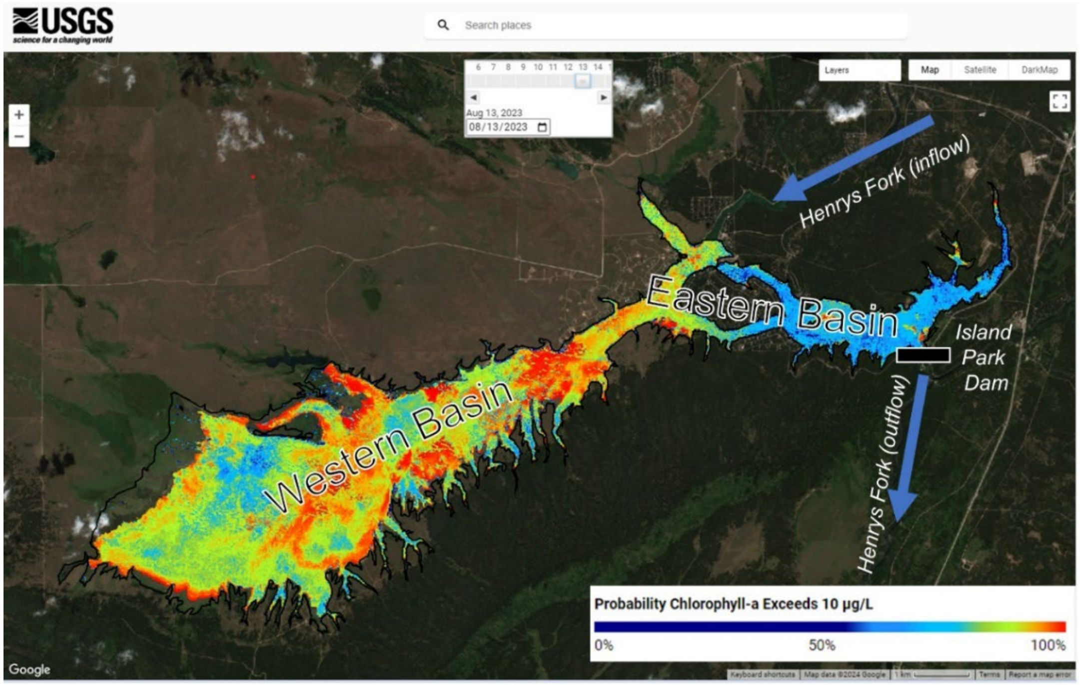

Figure 2: Map of Island Park Reservoir with false-color imagery showing the probability that chlorophyll-a concentrations exceed 10 µg/L, as determined by the [USGS REmote Aquatic Chlorophyll-a Tracker (REACT) tool](). Probabilities of high chlorophyll-a concentrations are much higher in the western basin of Island Park Reservoir than in the eastern basin, due in part to differences in morphology, limnology, and inputs to each basin.

Project Goal

Water quality degradation in the Henrys Fork watershed is responsible for declines in fish and wildlife resiliency, with consequences for regional recreational and economic quality. The project goal is to develop a water quality basin plan which will include data, models, and 60% design plans needed to implement evidence- and nature-based restoration, including updates to Island Park Reservoir infrastructure and tributary restoration in the project area. Collaborative, evidence- and nature-based solutions to be explored in a water quality basin plan have the potential to protect fish and wildlife resources in the upper Henrys Fork watershed, supporting the missions of IDFG and the HFF.

Developing a water quality basin plan requires collaboration with stakeholders within the Henrys Fork Watershed over three years to identify critical issues of concern, identify potential infrastructure or restoration actions, collect engineering and ecologic data to understand costs and benefits, and develop and evaluate design plans for implementation. A collaborative, evidence-based evaluation process will increase the likelihood of implementation and subsequent water quality, fisheries, ecological, and economic benefits. Design plans will:

1) **Address water quality problems caused by aging and inflexible physical and natural infrastructure at Island Park Reservoir** through projects such as variable-elevation withdrawal gates, hypolimnetic oxygenation, algaecides, water column nutrient management, sediment stabilization, sediment removal, and/or a watershed sediment and nutrient control plan.
2) **Restore degraded surface and groundwater inputs to Island Park Reservoir and the Henrys Fork with** nature-based stream, wetland, and shallow aquifer restoration projects implemented throughout the project watershed.

"Physical infrastructure" refers to the property, utilities, and equipment necessary for Island Park Reservoir to exist and function, including the dam, outflow works, and power generation facilities. "Natural infrastructure" refers to the existing natural area of Island Park Reservoir, including its bed, banks, and water, which are the source of ecological and recreational benefits. Research by the HFF has found inflexible and aging physical and natural infrastructure of Island Park Reservoir contributes to or causes elevated water temperatures, eutrophication leading to HABs and low dissolved oxygen, and organic and inorganic sediment deposition within the reservoir. These water quality problems then make their way into the outflowing Henrys Fork River when the reservoir is drawn down for irrigation.

Research by the HFF and our partners has found that degraded surface water inputs can increase temperature, fine sediment, and nutrient concentrations in receiving waterways, including Island Park Reservoir and the Henrys Fork River. The HFF has also found local groundwater inputs decrease water temperature. Drought, climate change, and reservoir management decisions may be suppressing groundwater inputs to Island Park Reservoir and the Henrys Fork. We seek to study potential methods to increase groundwater inputs and restore the quality of surface water inputs.

Filling data gaps

Developing a water quality basin plan requires closing important data gaps to 1) support stakeholder engagement, 2) address stakeholder concerns, and 3) obtain necessary data and information to produce accurate design plans. We propose to fill these data gaps through a combination of contracted activities with external consultants and in-house data collection and analysis.

Dynamic water quality model

First, we propose expanding current HFF water-quality monitoring of Island Park Reservoir and the Henrys Fork. In concert with consultants, we will use these data to develop a dynamic model of water, temperature, dissolved oxygen, sediment, and novel pollutants in Island Park Reservoir and the Henrys Fork in HSP. Developing this model for Island Park Reservoir will require high-resolution vertical profiles of water quality parameters and a clearer understanding of the inputs and sediment dynamics of Island Park Reservoir. To collect these data, we propose a comprehensive lake and river water quality testing procedure. This procedure will include studies by consultants on sediment oxygen demand and studies by the HFF on nutrient, sediment, and thermal load from surface and ground-water inputs. Similarly, development of river cross-sections and studies on water quality and constituent transport will be needed to understand the dynamics of outflow from Island Park Reservoir to the Henry's Fork downstream. To accomplish creation of a dynamic water quality model, especially for determining sediment and nutrient loads into and out of Island Park Reservoir, the HFF proposes expanding its in-house water quality testing capacity to include supplies for in-house measurement of suspended sediment concentrations. We also propose funding for additional water quality testing for emerging pollutants to address and potentially develop project alternatives for as-yet-undefined water quality problems.

A clear understanding of water quality throughout the reservoir is a critical piece of data infrastructure. A dynamic model will allow the HFF and its partners evaluate costs and water quality benefits of proposed actions to improve water quality in Island Park Reservoir. The proposed modeling and buoy infrastructure provide managers with real-time water quality data within Island Park Reservoir. These data are required for effective use of potential proposed future water quality improvement projects in Island Park Reservoir. For example, real-time water quality data will allow managers to understand when and where to inject hypolimnetic oxygen, what elevation to select in a variable-elevation outflow gate, and/or whether algae, nutrient, and turbidity-reduction projects around the western basin are effective.

Water quality monitoring buoy

We propose installing a permanent water quality sampling buoy on Island Park Reservoir at or near the dam to collect continuous vertical water quality profiles. The water quality buoy on Island Park Reservoir will serve multiple purposes. Water quality profiles will be used to calibrate a dynamic model of the reservoir. The buoy will be used in a joint HFF-USGS study to identify drivers of HABs and other sources of turbidity within the western basin, and the specifics of migration of water from the western basin to the eastern basin. The USGS Remote Aquatic Chlorophyll-a Tracker (REACT) tool estimates algal concentrations from satellite imagery and can identify water quality across the entire reservoir surface. We propose ground-truthing REACT imagery with the buoy and other water quality data collected at Island Park Reservoir.

Fish and fish habitat

Final data gaps revolve around clarifying what effect, if any, proposed water-quality improvement actions would have on fish habitat. The HFF has strong existing data regarding the fish habitat envelope for rainbow trout (*Oncorhyncus mykiss*), kokanee (*O. nerka*), native Yellowstone cutthroat trout (*O. clarkii bouveri*), and brook trout (*Salvelinus fontinalis*) in Island Park Reservoir and the Henrys Fork. Development of real-time dynamic water quality monitoring with a buoy and a dynamic water quality model will allow for unprecedented modeling of these fishes' habitat through time. Models of water temperature and dissolved oxygen throughout the watershed will provide the basis for studying fish habitat availability, growth potential, hooking mortality, and even populations through time given different scenarios and water-quality improvement actions.

Another species of native coldwater sportfish is the mountain whitefish (*Prosopium williamsoni*). Mountain whitefish declines in the Henrys Fork are anecdotal but backed by similar declines across their range. The habitat requirements and preferences for whitefish in the Henrys Fork are unclear. To understand the potential impact of climate change, drought, water management, and any potential water quality improvement projects developed through a water quality basin study, the HFF proposes a paired-differences snorkeling study. This study would provide first-of-its-kind observations of quantitative habitat preferences of this understudied native species, perhaps marking a significant step forward in species conservation.

The final set of data gaps involve the role of groundwater in Island Park Reservoir and HSP water quality. We propose a shallow groundwater study to evaluate the potential efficacy of incidental aquifer recharge via restoration of flood irrigation or process-based restoration in HSP for expanding fish habitat.

Stakeholder outreach

To complete a water quality basin plan, stakeholder outreach will be paramount. Stakeholder outreach and collaboration will drive development of infrastructure and restoration alternatives, analysis of costs and benefits, and final project rankings and evaluation for implementation. At the highest level, stakeholders fall into two general categories: 1) agencies and engineering/natural resource professionals and 2) community members.

Identify community priorities.

Assessing community priorities, identifying projects to develop, and testing early community support for proposed alternatives is important for eventual implementation. In the first months of the grant, we will facilitate meetings with a variety of water managers and users, state and federal agencies, university researchers, and nongovernmental organizations (NGOs), with a goal of identifying technical and scientific issues and needs for inter-agency coordination. Separately, we propose to identify community and recreationist priorities through listening sessions in the first year of this project.

Develop design plans, present findings

In the second year of stakeholder outreach, we will emphasize data sharing and science communication. As potential water-quality improvement actions and models are developed, we will elicit feedback from both professionals and community members. We will present a dynamic model overview and workshop to the Henry's Fork Watershed Council (HFWC) to gather feedback from professionals on the model and the best way to share results.

Presenting findings from engineering and ecological studies to community members will allow for continued evaluation of their priorities. Once data gaps begin to close, an assessment of project costs— financial, material, and political—can begin. Project designs will be assessed based on a cost per unit water quality improvement (e.g., cost per °C, cost per mg/L PO_4, or cost per 1 Nephelometric Turbidity Unit [NTU] reduction). Input from and discussions with all stakeholders will result in a list of preferred projects, and those with the highest feasibility and social acceptability will be advanced to the 60% design phase.

Throughout the project, the HFF communications teams will share updates on river conditions and project development with community members and recreationists on the Henry's Fork through social media, email, and blog posts. The goal of these communications is to increase public understanding of scientific and technical information relevant to the ultimate goal of improving water quality. The communications team will also facilitate regular HFWC meetings to keep agencies informed of progress and identify needed agency coordination.

Produce final water quality basin plan

Final engagement with both professionals and community members will focus on presenting completed designs, allowing for completion of project evaluation and prioritization for implementation. A final report with each project, design plans, and stakeholder priorities will thereby produce a final list of projects ready for implementation. The water quality basin plan will then be used to obtain implementation funding.

More Information

Project Benefits

General Project Benefits:

HFF monitoring has found water quality impairment in Island Park Reservoir and the Henrys Fork downstream of the reservoir, including high water temperatures in the summer, increased suspended fine sediment and turbidity, low dissolved oxygen concentrations, and HABs. In the 2022 Integrated Report to the USEPA, IDEQ listed the Henrys Fork within HSP, Sheridan Creek upstream from its confluence with Willow Creek, and the Buffalo River downstream of Elk Creek as "impaired waterways" under the Clean Water Act (CWA) due to water temperatures exceeding state standards for salmonid spawning and cold-water aquatic life. Sheridan Creek is also impaired due to sedimentation. Increased turbidity and water temperatures can also hinder fishing success. Anglers have noticed water quality declines and changes in aquatic macroinvertebrate communities and declines in fish populations.

Drought, climate change, and land use combine with the following two critical issues to produce water quality impairments in the Henrys Fork watershed:

1. **Aging and inflexible natural and physical infrastructure in Island Park Reservoir**. This infrastructure issue contributes to increasing water temperatures, excessive nutrients leading to HABs, fine sediment erosion and transport, and decreases in dissolved oxygen within Island Park Reservoir and in its outflow, the Henrys Fork.
2. **Degraded tributaries to Island Park Reservoir and the Henrys Fork.** Anthropogenic land uses, including cattle grazing, irrigation, damming, and residential development all increase fine sediment erosion, water temperatures, and nutrient load in tributary streams. Simultaneously, drought and changing land uses may be endangering beneficial cool, clean groundwater inputs to the Henrys Fork and Island Park Reservoir

We propose a planning process to produce a water quality basin plan, defined as a prioritized list of alternatives with quantified costs and benefits through engineering and ecological studies. We anticipate that the most feasible and accepted of the alternatives will be advanced to 60% design status by the end of the project. A water quality basin plan will be created in collaboration with diverse stakeholders and partners. The water quality basin plan will prepare these alternatives for implementation funding. Once implemented, benefits will include:

1. Reduced turbidity in Island Park Reservoir, including reduced HAB frequency,
2. Reduced fine sediment export from Island Park Reservoir into the Henrys Fork,
3. Increased cold, oxygenated refugia in Island Park Reservoir and the Henrys Fork, as well as reduced summertime maximum temperatures throughout the watershed,
4. Reduced year-to-year variability in reservoir and outflow water quality by buffering water quality from fluctuations in climate and water supply.

Improved water quality in combination with riparian restoration is anticipated to increase fish and wildlife habitat and encourage healthy ecosystem function and resiliency (Figure 3).

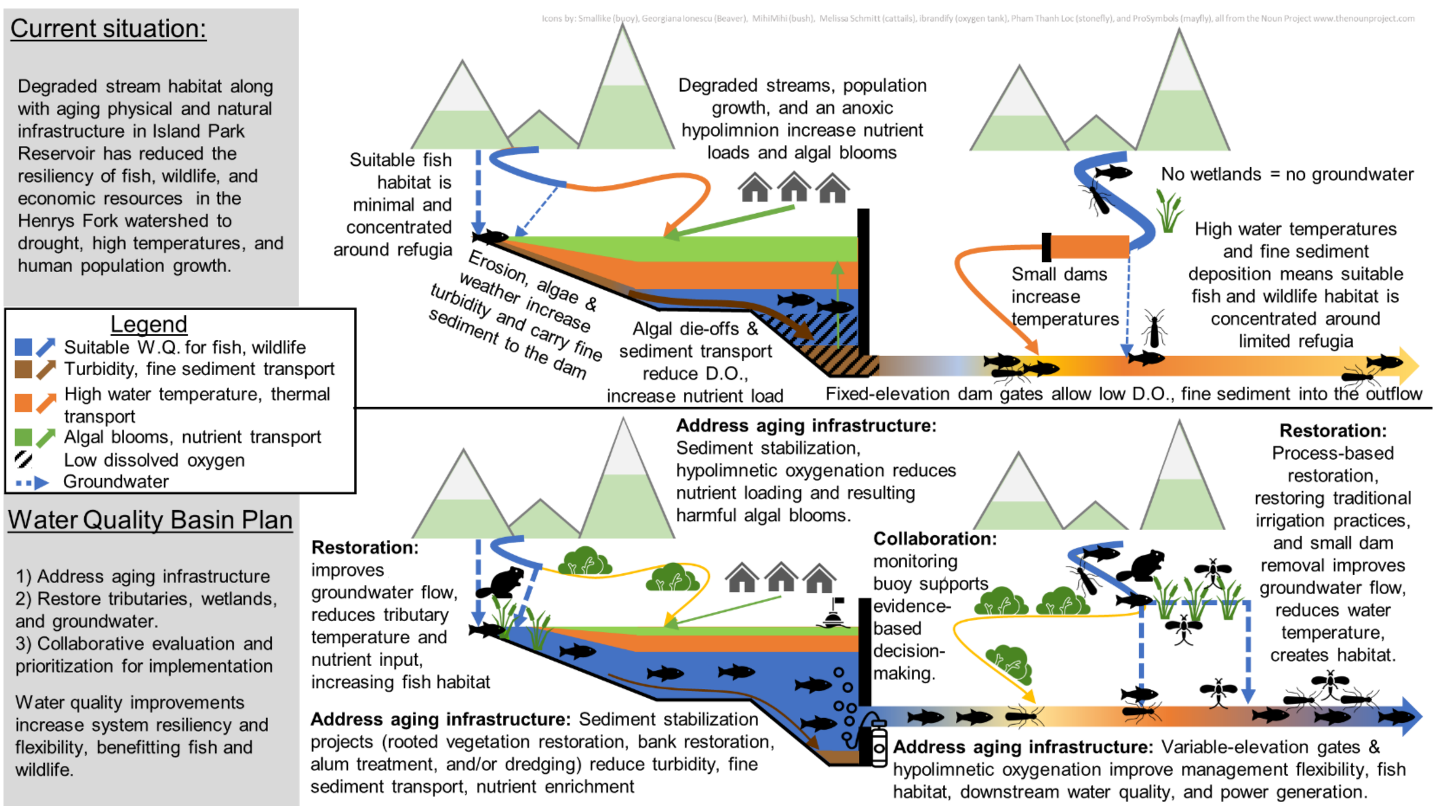

Figure 3: Conceptual diagram of the current impaired state of Island Park Reservoir, its tributaries, and the Henrys Fork River outflow (top panel), and goals of the water quality basin plan (bottom panel), including potential projects to be explored and their potential benefits.

Quantification of Specific Project Benefits

Water quality impairment in Island Park Reservoir and the Henrys Fork degrades fish and wildlife health and habitat conditions. Habitat issues of concern are:

1. High turbidity in Island Park Reservoir, including increased HAB frequency,
2. Increasing fine sediment export from Island Park Reservoir into the Henrys Fork,
3. A lack of cold, oxygenated refugia in Island Park Reservoir and the Henrys Fork to protect against increasing summer maximum temperatures, and
4. High year-to-year variability in reservoir and outflow water quality due to fluctuations in climate and water supply.

In 2023, wild rainbow trout population estimates on the Henrys Fork downstream of Island Park Reservoir, including HSP, set period-of-record (1994-2023) lows. Kokanee populations in Island Park Reservoir have declined since the early 2000s due to high water temperatures and low dissolved oxygen within Island Park Reservoir. Higher outflow of fine sediment and warmer water temperatures from Island Park Reservoir has also changed macroinvertebrate community quality, and may impact biodiversity and populations.

Aging and inflexible natural and physical infrastructure along with degraded tributaries contributes to turbidity and HABs in Island Park Reservoir. The western basin of Island Park Reservoir is a eutrophic system due to inflows from septic tanks and tributary streams flowing through erosive soils, pastureland, impoundments, and diversions, such as Sheridan Creek. Cattle grazing prevents growth of sediment-stabilizing vegetation. Eroded fine sediment contains phosphate given the erosive Cretaceous-Cambrian (70-540 Ma) phosphorite sedimentary rocks common in the Henrys Fork watershed. Excessive phosphorus causes harmful and benign algal blooms. These blooms block sunlight from reaching littoral sediments, preventing growth of rooted aquatic vegetation. Without rooted aquatic vegetation, unstable bottom sediments are easily resuspended by wave energy from weather and recreational boating. Algal blooms and resuspended sediment perpetuate a state of high organic and inorganic turbidity. Density currents then deliver fine organic and inorganic sediment from the western basin along the bottom of the reservoir directly to the two hypolimnetic outflow structures at the dam. Inflexibility in outflow elevation means these density currents are passed into the outflow, increasing turbidity from a background level of 2.5 NTU to 10-15 NTU.

Aging natural infrastructure in Island Park Reservoir contributes to the loss of cool hypolimnion fish habitat refugia through oxygen depletion. Epilimnion temperatures in Island Park Reservoir reach a maximum of 23 °C, exceeding optimal water temperature limits for coldwater salmonids. The cold hypolimnion near the bottom of the reservoir provides refuge habitat for valuable coldwater fish. However, algal blooms decay and consume oxygen to 0 mg/L within the hypolimnion about four weeks after the onset of thermal stratification, eliminating fish habitat. Low oxygen in the hypolimnion also releases natural phosphate bound to the loess and alluvial sediments that underlie the western basin in a chemical process called internal nutrient loading. The released phosphate encourages more algal blooms, which then decay and continue the cycle.

Inflexible physical infrastructure contributes to the loss of thermal refugia within and downstream of Island Park Reservoir. When Island Park Reservoir first stratifies in the spring, the average epilimnion depth is ~6 m, meaning ~40% of the reservoir's volume is in the hypolimnion. Both reservoir outflow points (at 23 m and 16 m depth, respectively) are limited to drawing from the cold hypolimnion. Island Park Reservoir is drawn down by an average of 60% (40% of full volume remaining) by the end of the irrigation season. As a result, this valuable cold hypolimnetic water is evacuated downstream faster than can be replaced by cold-water inflows from groundwater inflow and tributaries. This reduces water temperatures in the Henrys Fork outflow temporarily during early summer. However, without the flexibility to change outflow elevation throughout the year, drought and higher drawdown eventually result in high maximum water temperatures in the Henrys Fork outflow and high overall temperatures within Island Park Reservoir.

Degraded tributaries also affect thermal refugia in the Henrys Fork watershed. When tributaries are degraded through anthropogenic land use, the stream bed and banks erode, widening and downcutting the stream channel. A wider, unshaded stream absorbs more thermal energy. Streams with impoundments also absorb more thermal energy. Within our project area, streams with unmitigated damage from cattle grazing or impoundments include Sheridan Creek, Antelope Creek, Thurmon Creek, Fish Pond Creek, and water returning to the Henrys Fork through the Harriman canal system. The HFF's and IDEQ's monitoring on Sheridan Creek, Blue Springs Creek, Antelope Creek, Thurmon Creek, Fish Pond Creek, the Buffalo River, and in HSP canal return flow all show average and daily maximum water temperatures exceeding that of the Henrys Fork and Island Park Reservoir, sometimes by up to 3 °C. These tributaries are disconnected from their floodplain—either due to riparian damage and downcutting or a reduction in use for traditional flood irrigation practices—reducing interaction with groundwater and potentially lowering the water table. A lowered water table could reduce cool groundwater input to the Henrys Fork River. HFF monitoring indicates water temperatures in HSP are moderated by up to 1°C by discrete groundwater inputs like Osborne Springs and diffuse seeps throughout the river. Island Park Reservoir also benefits from groundwater inputs. Groundwater inputs form approximately 1000 acre-feet of the only suitable habitats for coldwater aquatic salmonids in Island Park Reservoir.

Inflexibility in outflow elevations and inadequate aeration infrastructure contribute to low dissolved oxygen concentrations and high fine sediment export in Island Park Reservoir and its outflow, affecting fish and macroinvertebrate habitat. Organic material, either drifting down from algal blooms in the epilimnion or transported via density currents from the western basin, decay and use oxygen. Oxygen depletion in concert with increasing temperatures due to drawdown threatens fish habitat in Island Park Reservoir, but also threatens dissolved oxygen standards and fish habitat in the Henrys Fork outflow. Initially, cold temperatures in the hypolimnion ensure easy reoxygenation by current aeration infrastructure in both outflows. For example, at 10°C, 100% oxygen saturation at 6300 feet in elevation is approximately 9 mg/L; aeration facilities need not be 100% efficient to meet the 6 mg/L standard in the Henrys Fork outflow. As the summer progresses, the hypolimnion is eventually entrained into the outflow and replaced by warm water rich in organic material. The inability to influence outflow water quality allows this warm water rich in decaying organic material to be entrained, making reaeration difficult. At 23 °C, 100% oxygen saturation at 6300 feet is 6.5 mg/L, necessitating very high efficiency oxygenation facilities.

Strategies to benefit fish habitat will be identified via the stakeholder outreach process, and will focus on producing three of the benefits defined above:

1. Reduced turbidity in Island Park Reservoir, including reduced HAB frequency,
2. Reduced fine sediment export from Island Park Reservoir into the Henrys Fork,
3. Increased cold, oxygenated refugia in Island Park Reservoir and the Henrys Fork, as well as reduced summertime maximum temperatures throughout the watershed,

The HFF has already identified numerous projects intended to address water quality and fish habitat problems. Potential infrastructure updates include variable-elevation outflow gates, hypolimnetic oxygenation, and sediment stabilization. Potential degraded tributary restoration will focus on process-based restoration, incidental recharge, and small dam removal or retrofits in Shotgun Valley and HSP to increase shading and groundwater interface while also decreasing erosion and associated sediment and nutrient transport.

Breaking the eutrophication feedback loop is central to addressing the sources of turbidity, fine sediment, and low dissolved oxygen in Island Park Reservoir—particularly within the western basin—and by extension the Henrys Fork watershed. First, sources of nutrients from the watershed must be controlled. In the Henrys Fork, removing sources of water quality degradation will focus on working with landowners and agencies to address landscape-scale land-use issues such as cattle grazing practices, septic tanks, and stream restoration. The water quality basin plan will identify and design multiple strategies focused on best management practices to reduce stream channel degradation and resulting water quality impairment. Such goals could be accomplished by working with landowners to change cattle grazing practices and strategies like fencing or rotational grazing, or working with homeowners and Fremont County to reduce septic tank inputs to Island Park Reservoir. Removing cattle from the riparian area will reduce erosion and allow riparian vegetation to regrow, starting the process of watershed restoration. Changing cattle grazing practices could reduce direct and indirect nutrient input by reducing erosion and manure runoff, and encouraging healthy, nutrient-absorbing vegetation growth. After land use is managed, the water quality basin plan can include additional strategies to create long-term, large-scale, process-based restoration. Beaver reintroduction, beaver-dam analogs, post-assisted log structures, and other process-based solutions could help restore the stream channel to a state that reduces sediment transport and nutrient enrichment. No matter what strategy is ultimately chosen, the water quality basin plan will focus on large-scale action that makes a watershed-scale difference in water quality.

Once nutrient inputs are better controlled, projects within Island Park Reservoir become the priority. Nutrient flocculation is one potential solution to break the eutrophication cycle. Applying alum, bentonite clay, zeolite, or other flocculants across the western basin of Island Park Reservoir would bind and flocculate free phosphorus in the water column, removing the fuel needed for algal growth and storing it in sediments where it is available for rooted vegetation. Alum, bentonite, and zeolite can cap sediments, sealing the sediment-water interface and preventing the release of stored phosphate into the water column if dissolved oxygen is depleted. With adequate application, capped sediments may also be less likely to resuspend during wind-wave events or heavy recreational boating activity, reducing inorganic sediment transport within Island Park Reservoir. The effect of these applications is temporary (1–5 year lifespan), but the temporarily clarified water can help reestablish rooted aquatic vegetation growth, further stabilizing sediments and breaking the eutrophication cycle in the long term.

Cyanobacteria can also be directly controlled through application of algaecides or cyanobacteria-specific algaecides. In particular, sodium percarbonate dissolves cyanobacteria, preventing heavy organic sediment deposition from intact dead cells. Sodium percarbonate also temporarily increases dissolved oxygen concentrations and reduces turbidity. These applications can be a cost-effective temporary solution for reducing toxins and harmful algal blooms, as well as having a potential application for improving water clarity to establish rooted aquatic plants. In addition, sodium percarbonate could temporarily prevent phosphate release from sediments by temporarily increasing dissolved oxygen in the water column.

Sediment stabilization projects would reduce inorganic sediment resuspension, reducing fine sediment transport into the outflow in density currents and would increase overall water clarity. Increased water clarity increases the area of the reservoir in which rooted aquatic vegetation can establish, further improving clarity and reversing eutrophication. Rooted aquatic plants are the most effective solution for stabilizing sediments in a large area across large areas such as Island Park Reservoir. Assisting rooted aquatic plant establishment with seeds or plugs may be one strategy once turbidity is reduced with other strategies. Outside of capping sediments with alum, bentonite, or zeolite applications, sediment stabilization and subsequent turbidity reduction can be accomplished through a number of common reservoir management projects. Dredging could stabilize sediments by removing layers of unstable fine loess and organic deposits. Hydroseeding exposed mudflats when Island Park Reservoir is drawn down could establish root networks to hold sediments in place. Bank stabilization projects—gabbions, rip-rap, willow planting, re-grading—could reduce fine sediment suspended due to wave action along shorelines. Finally, check dams, coffer dams, or dikes built in the reservoir could reduce density current movement from the western basin to the eastern basin, compartmentalizing water quality problems away from the eastern basin and the Henrys Fork outflow.

Next, actions could be designed to increase oxythermal refugia in Island Park Reservoir and the Henrys Fork. Variable-elevation outflow systems work by allowing managers to strategically select which layer of water within Island Park Reservoir is withdrawn into the Henrys Fork outflow. Variable-elevation outflow structures would grant managers unprecedented flexibility to adapt to current conditions and evaluate trade-offs to ensure a best-possible scenario for in-reservoir and downstream water quality. To manage water temperatures, managers could draw epilimnetic water from higher elevations within the reservoir during the cool springtime period. This would increase springtime temperatures in the outflow—when high water temperatures are not a concern—but preserve a larger-volume cold hypolimnion within the reservoir. This larger pool of cool water could then be used strategically to cool the Henrys Fork outflow during high water temperature periods later in the summer. Variable-outflow elevation systems could also mitigate dissolved oxygen problems by allowing managers to prioritize water primed for reaeration: cool, low in organic material, and high in dissolved oxygen. An additional benefit is the ability to manage fine sediment export; managers could raise outflow elevation to react to density currents.

Altering impoundments such as Golden or Silver Lakes on HSP is another option to reduce sources of temperature impairment. Golden and Silver Lakes inputs are cold, spring-fed creeks, but water impounded in these small lakes is warmed substantially by solar radiation. The outflows from each lake are from this warm surface water, so these tributaries are artificially warm. One potential solution is to retrofit the dams to release cooler hypolimnetic water. Another option to explore is routing the inflow around the lakes, thereby replacing an artificially warm outflow with a more natural water temperature pattern. Removing the lakes entirely and restoring the former lakebed to a more natural riparian area is another option to explore to reduce tributary water temperature.

Another set of potential strategies to centers on restoring local shallow aquifers to improve groundwater inflows to the Henrys Fork and Island Park Reservoir. Aquifer recharge is especially attractive given the state of existing infrastructure in the Henrys Fork basin, especially in HSP and Shotgun Valley, and can be accomplished with existing water rights and supply via restoration or expansion of traditional flood irrigation practices. An effective strategy could be to divert some tributaries into existing canal infrastructure for the purposes of recharging local groundwater, rather than allowing the degraded water quality to reach the Henrys Fork. In HSP, Thurmon Creek, Fish Pond Creek, and the Henrys Fork were traditionally diverted to flood-irrigate pastureland. Flood irrigation canals and ditch networks still exist but are unused. Currently, diversions on HSP are either inactive or diverted water is returned to the Henrys Fork as de facto surface streams. Restoring traditional flood irrigation practices to HSP could simultaneously prevent high sediment, temperature, and nutrient input to the Henrys Fork and instead increase cold groundwater-fed refugia. Process-based restoration of stream channels also significantly increases stream interaction with groundwater. Back-of-the-envelope calculations using parameters developed for the Henrys Fork suggest a 50% increase in groundwater flow (16 to 24 cfs) to the Henrys Fork is possible through the restoration of flood irrigation practices or similar process-based projects aimed at reconnecting streams with their floodplain.

An updated oxygenation system could increase hypolimnion and outflow dissolved oxygen concentrations, improving fish habitat and helping prevent internal nutrient loading. A point-of-discharge upgrade to FRREC facilities could increase aeration efficiency, potentially increasing water quality compliance and downstream water quality. In contrast, an in-reservoir system would use hoses or a Speece cone to efficiently mix pure oxygen into the hypolimnion of Island Park Reservoir with minimal atmospheric loss. In 2021, our data suggests a hypolimnetic oxygenation system would have increased total habitat for kokanee salmon in Island Park Reservoir from <1,000 acre feet to ~3,500 acre-feet, an increase of 350%. Absolute habitat savings will be even larger in years where Island Park Reservoir drawdown is lower—preliminary data from Henry's Fork Foundation monitoring indicates up to 20,000 acre-feet in habitat improvement is possible in years with lower drawdown. This oxygen would also prevent internal nutrient loading from sediments, helping mitigate internal nutrient loading and associated algal blooms in Island Park Reservoir. When used in concert with a variable-elevation outflow system, hypolimnetic oxygenation could create a large pool of high-oxygen, low-nutrient water in the hypolimnion that could be used strategically throughout the growing season to balance in-reservoir fish habitat and downstream water quality, among other potential benefits.

Watershed Benefits.

Frequent and variable drawdowns along with a warming climate, aging infrastructure, and degraded tributaries are producing degraded water quality, reduced ecological function, and most importantly, reduced ecological resiliency. Excessive annual drawdowns negatively affect water quality and fish habitat resiliency in Island Park Reservoir and the Henrys Fork. Drawdowns are becoming more frequent and variable as water supply declines and managers struggle to balance statutory water rights with ecological and economic resources. HFF monitoring has found Island Park Reservoir drawdown increases water temperatures, fine sediment transport, eutrophication in Island Park Reservoir, and decreases dissolved oxygen concentrations throughout Island Park Reservoir and the Henrys Fork. Macroinvertebrate communities in the Island Park Reservoir outflow are more variable than anywhere else in the watershed. These variable conditions threaten the “hatches” of aquatic insects critical for trout growth and for the fishing experience.

A water quality basin plan is intended to buffer water quality changes from fluctuations in climate and water supply by focusing on how changes to infrastructure and landscapes could produce water quality, fish habitat, and macroinvertebrate community improvements despite a warming, drying world. This complements ongoing HFF work to improve water quality by reducing drawdown. HFF reductions in drawdown have saved about 26,000 acre-feet in Island Park Reservoir annually, good for an observed 150% increase in kokanee numbers in Island Park Reservoir over expected values. However, a 150% increase in kokanee numbers still was not enough to increase total populations back to levels seen 20+ years ago (~500 kokanee/mile observed spawning in 2020s vs. 1,000+ kokanee/mile observed spawning in 1990s).

A water quality basin study intends to take the next logical step to buffer water quality and subsequent fish and macroinvertebrate habitat from climate change and drought by identifying, designing, and evaluating for implementation a wide variety of water quality improvement projects aimed at aging and inflexible physical and natural infrastructure in Island Park Reservoir and degraded tributaries throughout the watershed. This will produce projects like a hypolimnetic oxygenation system, which could increase fish habitat in Island Park Reservoir by 350% and permanently increase deep, cold-water refugia despite climate-driven uncertainty.

Water supply in the project area was 18% lower in water years 2001–2023 than in 1965–2000, and droughts have become more frequent and more severe. The proposed project will build resilience to drought by increasing the water-quality benefits that can be attained per unit of water conservation by a factor of around 1.5, thereby improving water quality roughly to early 1990s levels and providing a 30-year buffer to current climate trends. Statistical relationships indicate that for each 100 cfs reduction in summertime reservoir outflow, turbidity decreases by around 1 NTU and suspended sediment load decreases by around 325 tons. Water conservation efforts first implemented by the applicant and its partners in 2018 have increased carryover in Island Park Reservoir by an average of 26,000 acre-feet/year relative to water supply, equivalent to a 160 cfs decrease in mean summertime discharge. Thus, over the past six years, water conservation has lowered turbidity by 1.6 NTU and suspended load by 520 tons relative to what they would have been with the given water supply. In addition, outflow temperature decreases by around 0.3 °F per 10,000 acre-feet of increase in reservoir carryover, so water conservation efforts to date have reduced outflow temperature by around 0.75 °F, offsetting roughly 25 years of temperature increase.

Our hydrologic modeling suggests that additional improvements in water conservation will just keep pace with decreased water supply in the future, so that any additional improvements in water quality will come from the specific actions developed through this project. Based on analysis of Island Park Reservoir water quality and reservoir dynamics to date, we estimate that infrastructure improvements to the dam and reservoir could increase the turbidity benefit of water conservation to 1.5 NTU and 450 tons of sediment per 100 cfs reduction in summertime outflow. Thus, when coupled with existing water conservation relative to supply, our analysis shows that these infrastructure improvements will reduce turbidity by around 2.5 NTU relative to the current summertime average of 5 NTU, which is roughly the visual threshold above which anglers report degraded fishing conditions. This improvement will roughly set turbidity and sediment load conditions back to what they were in the early 1990s, thereby providing around a 30-year buffer before the worst water-quality experienced over the past 10 years will become the norm. While we do not expect much additional improvement in reservoir outflow temperatures as a result of reservoir infrastructure, we estimate that groundwater recharge and nature-based restoration downstream of the dam have the potential to increase the input of cool groundwater by around 50% (from around 16 cfs to 24 cfs) and decrease mid-summer temperatures of currently unshaded tributaries by 2-3 °F. Based on mass balance, this will cool the mean temperature of the main river by around 0.25 °F but more importantly increase the areal extent and quality of cold-water refugia. When combined with the current improvement in reservoir outflow of 0.75 °F, the temperature improvements also equate to ~30 years of climate buffer.

Water Supply Benefits

As mentioned above, annual natural streamflow ("water supply") in the upper Henrys Fork subwatershed has averaged 18% (~215,000 acre-feet) lower since 2001 than between 1965 and 2000. From purely a water-supply standpoint, the two most direct effects of lower water supply on aquatic ecosystems in the project area are 1) annual draft of Island Park Reservoir and resulting loss of reservoir fish habitat and 2) decreased outflow from the reservoir into the river downstream during winter fill operations. Decreased water supply across the whole watershed drives the need for increased reservoir draft to meet irrigation demand, resulting in reductions to populations of reservoir fish and the numbers of these fish that migrate upstream into the Henrys Fork. Decreased winter outflow is well documented as the single biggest factor affecting recruitment of wild rainbow trout in the river reach downstream of the dam. Lower winter flows result in lower survival of juvenile trout, resulting in lower recruitment two years hence.

Even if reservoir drawdown is reduced through water conservation actions, as has been done for the past six years, low winter inflow during periods of drought results in low winter outflow to attain required reservoir fill rates. For example, going into the winter of 2022-2023, water conservation efforts by HFF, FMID, Reclamation and others increased reservoir carryover by over 44,000 acre-feet (nearly a factor of 3) over what was expected based on water supply, thereby reducing need for winter (October to reservoir ice-off in April) fill from an expected 109,455 acre-feet to 65,208 acre-feet. However, winter inflow to the reservoir was the lowest in the modern 1978–2023 period of record, resulting in winter outflow of 212 cfs, compared with an average of 356 cfs, despite unprecedented water conservation successes.

Modeling and analysis by HFF shows that reservoir carryover of at least 60,000 acre-feet (44% full) and winter outflow of at least 400 cfs is necessary in at least two years out of three to consistently maintain fish populations at desirable levels. Since the start of the current long-term and widespread drought in the western U.S. in 2001, the reservoir carryover objective has been met in only 10 out of 23 (43%) years, five of which have occurred in the last six years since implementation of collaborative water conservation and management efforts. By comparison, the carryover objective was met in 22 of the preceding 36 years (61%). The winter flow objective has been met in only four years (17%) since 2001, three of which have occurred in the last six. By comparison, the winter flow objective was met in 18 of the previous 36 years (50%). Thus, despite substantial improvements in these two key water-supply metrics over the past few years because of water conservation, water supply remains lower than desired to meet fisheries objectives, which were met much more frequently—and incidental to customary management—between 1965–2000, when expectations for the quality of fisheries in the project area were set.

The proposed project is not designed specifically to address water supply. However, the project will increase reservoir carryover and hence winter flow very modestly through three mechanisms. First, any upgrades to outlet infrastructure will be built with increased precision so that finer adjustments to reservoir outflow can be made than currently possible. These will likely be small—on the order of 10 cfs—relative to the average outflow adjustments of 50–200 cfs that are currently made. Half of the improvement in precision will be realized as irrigation-season benefits to irrigators and streamflow well downstream of the project area, which will occur when outflow is being increased as demand increases in early summer. The other half of the improvement will be in retaining water in the reservoir during the late summer when demand is being reduced. This is about a six-week period, over which a 10-cfs savings would increase carryover by around 800 acre-feet. That would result in an increase in winter flow of around 3.5 cfs. These are improvements of around 1%.

Second, aquifer recharge via restoration of flood irrigation in HSP is expected to increase groundwater returns by around 8 cfs. Over the typical period of reservoir draft, this is an increase in streamflow gains of ~1,000 acre-feet. Most flood irrigation will occur before reservoir draft is needed, thereby using the shallow aquifer as a storage reservoir to replace 1,000 acre-feet of Island Park draft, another roughly 1% improvement in each of carryover and winter flow.

The third mechanism by which the project will address water supply is via implementation of supply-independent mechanisms for improving water quality. For example, one of the few strategies currently available to minimize the negative effects of fine sediment deposition in the Island Park to Riverside reach is delivery of a managed peak-flow freshet from Island Park Reservoir during April or May. This operation results in temporary draft of the reservoir, potentially jeopardizing fill prior to irrigation need, and can thus be done only in years of above average water supply. These conditions have existed in only about one-third of years since 2001. Reducing sediment deposition via measures explored in the proposed project could reduce the need for a managed freshet, potentially freeing up that water for other uses such as higher winter flow or managed aquifer recharge.

Other Quantifiable Benefits

Hydroelectric power generation is threatened by low dissolved oxygen from eutrophication and increased water temperatures. The FRREC holds a 50-year Federal Energy Regulatory Commission (FERC) permit to generate hydropower through outflow #2. The power plant operates as a run-of-reservoir between 200 cfs and 960 cfs. Any flow more than 960 cfs is passed to the original dam outflow gates. As a condition of operation, FRREC is required to meet dissolved oxygen concentration standards in their outflow of Island Park Reservoir into the Henrys Fork. During salmonid spawning (March through June), instantaneous dissolved oxygen concentrations must be at least 8 mg/L. Outside of the salmonid spawning period, instantaneous dissolved oxygen concentrations must be no less than 6 mg/L. As such, power generation facilities include two forced air "blowers" to aerate outflow. Low dissolved oxygen concentrations in the hypolimnion outstrips FRREC's original aeration infrastructure, forcing FRREC to reduce or cease hydropower generation. Addressing this aeration infrastructure could benefit FRREC operations as well as fish and macroinvertebrate habitat.

Reduced fish habitat in Island Park Reservoir negatively impacts statewide economic benefits. Island Park Reservoir's fishery has declined since the 1980s, when it was once a "fishery of significant state interest". Low kokanee numbers result in reduced angler effort and loss of an egg collection source by IDFG for statewide hatchery operations. Variability in aquatic macroinvertebrate communities in the Henry's Fork downstream damages a world-famous dry-fly fishing experience that drives a local fishing-based economy worth $30 million annually.

Recreational safety on Island Park Reservoir is threatened by HABs. Our proposed study to ground-truth USGS REACT imagery with data from the buoy and a 3D reservoir model will give managers a clear picture of water quality across the reservoir in nearly real time. This information can be used to predict HABs, density currents, and other water quality issues to improve safety and reservoir management. This information can be passed along to recreators and managers.

Prior Restoration Planning and Stakeholder Involvement and Support

Table 2: Planning efforts that support the proposed project.

Plan	Organizational authority	Year	Process and collaboration
Henrys Fork Basin Plan	Idaho Water Resource Board	1992	Stakeholder input via local advisory group
Henry's Fork Drought Management Plan	Six signatories, including U.S. Bureau of Reclamation	2005, 2018	Stakeholder input via HF Watershed Council
Henrys Fork Basin Study	Idaho Water Resource Board U.S. Bureau of Reclamation	2015	Stakeholder input via HF Watershed Council
State Fisheries Management Plan	Idaho Department of Fish and Game	2019	Internal process with solicited stakeholder input
Strategic Plan	Henry's Fork Foundation	2022	Internal process with solicited stakeholder input

Henrys Fork Basin Plan

The Henrys Fork Basin Plan is one of 10 basin-specific components of the Idaho State Water Plan, which was initially developed on an interim basis by the Idaho Water Resource Board in 1972 and has been regularly updated and confirmed by the Idaho State Legislature since then. The Henrys Fork Basin planning process commenced in 1988 with interim protection for the Henrys Fork from Henrys Lake to Ashton Reservoir passed by the Idaho Legislature in Idaho Code §42-1734H and direction therein given to the Board to prepare a comprehensive plan for the basin. A public meeting held in the watershed on January 31, 1989 formally announced the start of the planning effort and called for nominations for a committee of local citizens to provide input to the process. The Board appointed a 13-member advisory committee including representatives of fisheries, irrigation, hydroelectric power, tourism, and timber interests, as well as commissioners from the three counties in the watershed—Fremont, Madison, and Teton. The HFF was represented on the advisory board. The Plan was adopted in 1992.

While applied to the entire 3,200-acre watershed, the planning process divided the watershed into stream reaches for the purposes of identifying and designating appropriate levels of protection and allowable future development. Two river reaches within the proposed project area were designated as "recreational"—the Henrys Fork from Island Park Dam to Riverside Campground, and the Thurmon Creek drainage from Golden Lake to the Henrys Fork confluence, including Golden and Silver lakes. The Basin Plan noted that the Island Park to Riverside reach supports a nationally and internationally recognized trophy trout fishery, and that Golden and Silver lakes support Trumpeter Swan nesting and have high aesthetic value. With respect to the latter, the Plan states that "close coordination with the Idaho Department of Parks and Recreation will be necessary to ensure that their management of the lakes and creeks complements this designation." The "recreational" designation in the Basin Plan limits alterations of the streambed in these reaches to only those necessary to maintain existing utilities, roadways, diversion works, and public access. New diversions, dams, hydroelectric projects, dredge or placer mining, and sand or gravel extraction are prohibited, and any new fishery enhancement or access facilities are limited to those implemented by public agencies.

Although over 30 years old, the Henrys Fork Basin Plan continues to protect the outstanding fishery, aesthetic, and recreational resources of the two stream reaches in the project area and provide guidance to state agencies in managing the water resources of the whole basin. The basin-wide perspective is critical because management of irrigation in the lower basin has a direct impact on the Island Park to Riverside reach via management of Island Park Reservoir. While the vision, protection, and guidance of the 1992 Plan are still relevant, the authors could not have anticipated the effects of drought, climate change and aging infrastructure on the outstanding resources of these two water bodies. The proposed project is necessary to maintain and enhance these resources into the future, thus ensuring the intent of the citizen's advisory group and the Water Resource Board at the time. Further, the proposed project will adhere to protections afforded by the 1992 Plan by using nature-based methods on water bodies in and adjacent to HSP and by facilitating coordination of all relevant agencies.

Henry's Fork Drought Management Plan

In part because of conflict that arose among different interest groups during development of the Basin Plan and in part because of lack of agency coordination made apparent by two separate river sedimentation events that occurred in 1992, the Henry's Fork Watershed Council was established during a year-long series of meetings held in 1993. The Council was chartered by the Idaho legislature in 1994 as a "grassroots community forum which uses a nonadversarial, consensus-based approach" to address natural resource management issues in the Henrys Fork watershed. The Council is co-facilitated by FMID and HFF and has served as a model of collaborative watershed management for three decades. In the early 2000s, the HFWC assessed potential social, economic, and environmental effects of proposed transfer of title of Reclamation infrastructure in the watershed to FMID. After several years of deliberation, the HFWC reached consensus that title transfer of a diversion dam, canal, and groundwater wells in the lower watershed would serve the interests of watershed stakeholders, while transfer of the two Reclamation storage reservoirs in the watershed—including Island Park Reservoir—would not. Upon the HFWC's recommendation, the Fremont-Madison Conveyance Act, passed by the U.S. Congress in 2003 to transfer the infrastructure, included a requirement that a drought management planning committee be established for the purposes of collaborative management of the watershed's water resources to benefit multiple stakeholders.

In 2005, the Henry's Fork Drought Management Plan (DMP) was completed and signed by six signatories: FMID, HFF, North Fork Reservoir Company, Trout Unlimited, The Nature Conservancy, and Reclamation. The DMP was last revised in 2018, with a goal to "maintain or enhance watershed health and ecology, even in years of below-average precipitation, in balance with agricultural needs through flexible and adaptive water management within the context of Idaho water law." Although only these six entities signed the DMP, its scheduled quarterly and other ad hoc meetings are open to the public. Regular non-signatory participants include IDFG and FRREC, key partners in the proposed project. The full HFWC is briefed at least twice each year on implementation of the DMP.

Because of the long-established dependence of trout recruitment downstream of Island Park Dam on streamflow during the winter, the DMP initially focused on winter flow management.

The primary strategy used to maximize winter outflow while filling the reservoir to meet storage water rights was to lower outflow during October and November, when reservoir draft is not needed to meet irrigation demand but prior to onset of winter conditions in the aquatic ecosystem. This earlier storage allowed higher outflow during the December-February period critical for trout survival. However, after the four-year drought of 2013–2016, it became apparent that this strategy alone had only a relatively small (~10%) effect on winter flow, given that the single biggest factor affecting winter outflow was reservoir content at the end of the irrigation season. Further, research and monitoring done during and since that drought showed that high reservoir draft negatively affected fish populations in and upstream of the reservoir as well as water quality and fishing experience downstream. The 2018 revision of the DMP reflected this new understanding and included consideration of other water management actions such as managed aquifer recharge, demand reduction incentives, and lower-watershed streamflow targets that could limit the amount of reservoir drawdown during irrigation season, thereby reducing the amount of storage needed to fill the reservoir. Earlier sections of this application documented the improvements in physical reservoir carryover (50%) and winter flow (43%) since 2018 thanks to a suite of collaborative conservation measures including water management strategies, irrigation infrastructure, demand-reduction programs, expanded stream and canal gaging, and new predictive hydrologic models. Many of these conservation efforts have been funded by previous Reclamation WaterSMART grants. In addition to physical water savings these efforts have increased administrative carryover by around 24%, saving irrigators storage-use costs and providing them with more certainty going into the subsequent year.

While decreased reservoir draft has had measurable positive effects on turbidity, water temperature, and sediment loads downstream, these effects are relatively small and not sufficient to outweigh the effects of climate change. Our proposed project is the next logical step in addressing water quality issues to a larger degree than can be accomplished by water management actions via the DMP alone. By improving water quality through measures independent of water management, our proposed project will provide more resilience to aquatic ecosystems while also allowing more flexibility in water management to accommodate future water supply challenges. As an example, updating infrastructure at Island Park Reservoir will help meet the DMP's objective of "manag[ing] water out of Island Park Reservoir to optimize…fish and wildlife populations [and] aquatic processes…". Currently, at least some outflow must be transferred to the bottom-withdrawal gates late in the summer when the power plant is unable to meet its dissolved oxygen criteria, resulting in higher turbidity and sediment export at a desired total outflow. In other cases, outflow is set either higher or lower than intended to meet water-management objectives because of outflow or reservoir-level constraints imposed by current infrastructure (e.g., ice encroachment on 30-year old spillway infrastructure). Thus, infrastructure upgrades can both improve water quality and water management precision.

Henrys Fork Basin Study

The Reclamation Basin Study program "supports collaborative planning to help Reclamation and its partners assess risks to water supplies from competing demands and to identify strategies to meet those demands." To date, 21 basin studies have been completed, including the Henrys Fork Basin Study in 2015, conducted jointly by the Idaho Water Resource Board and Reclamation. The HFWC served as the stakeholder workgroup for the Henrys Fork Basin Study and spent three years working on all aspects of the study, from hydrologic modeling, to alternatives assessment, to identification of potential sources of funding to implement study recommendations. As both of the previously described planning processes did, the Basin Study emphasized the high ecological value of fisheries and other aquatic resources in the Henrys Fork watershed and the need to maintain these resources while also meeting demand for irrigation and other uses. Further, the Basin Study modeled effects of climate change on water resources, finding that natural flow would become more concentrated in a shorter-duration, earlier runoff period in the spring, ultimately resulting in greater reliance on reservoir draft to meet irrigation demand late in the summer and on lower reservoir levels and natural streamflow at the end of the season. These projected climate changes and effects are those that have subsequently been shown to reduce water quality in and downstream of Island Park Reservoir.

The Basin Study identified five categories of conservation and management actions that could increase reliability of water supply in the basin: 1) increased surface water storage, 2) replacement of specific canals with pipelines, 3) on-farm irrigation demand reduction, 4) expanded managed aquifer recharge capacity, and 5) automation of canal infrastructure. The alternatives for increased surface storage had relatively high economic and environmental costs, and none have been seriously pursued in recent years. However, the other categories of water-conservation measures have been pursued aggressively through collaborations involving irrigation entities, Reclamation, the Idaho Water Resource Board, and non-governmental organizations. Funding has come from a variety of state, federal and private sources, including Reclamation WaterSMART. Watershed-wide coordination and implementation of improved water-management strategies has been implemented through the DMP participants, led by HFF, FMID, and Reclamation. These actions have improved physical reservoir carryover, administrative reservoir carryover, fish populations, and water quality.

However, as mentioned above, the water-quality improvements realized through water-quantity improvements fall short of those needed to align ecological resilience with water-supply resilience. The proposed project is designed to complement already successful water conservation actions, both taking advantage of the ecological benefits of improved water management while also potentially increasing water-management flexibility.

Idaho Department of Fish and Game State Fisheries Management Plan

The 2019–2024 IDFG State Fisheries Management Plan is the "guiding policy document for fisheries activities" within the agency. While largely an internal document, it "reflect[s] the desires of anglers and other interested stakeholders regarding conservation and management of Idaho's aquatic resources to benefit the public." Statewide guiding principles include emphasis on maintenance of self-sustaining wild fish populations, the belief that "productive habitats and healthy ecosystems are essential in sustaining diverse fish and wildlife and Idaho's communities and economies", and active support for state and federal agencies, Tribes, and private entities on projects that protect or enhance water quality, in-stream flows and fish habitat. Specific IDFG management objectives for waters in the project area are to 1) "manage the Henrys Fork above Island Park Reservoir for satisfactory and diverse angling opportunity", 2) "sustain a satisfactory fishing experience in the Henrys Fork on the catch-and-release section from Riverside Campground upstream to Island Park Dam", and 3) "produce and maintain a quality, consumptive salmonid fishery in Island Park Reservoir". The fisheries management plan also incorporates relevant goals and objectives from other plans such as the State Wildlife Action Plan and the Management Plan for Conservation of Yellowstone Cutthroat Trout in Idaho.

Our proposed water quality basin plan will help IDFG accomplish its objective of emphasizing wild, naturally reproducing trout populations in the Henrys Fork and is consistent with IDFG's statewide emphasis on maintaining productive habitats and ecosystems. Furthermore, the evidence- and collaboration-based process we propose to evaluate and prioritize alternatives matches with IDFG core values that "scientifically-developed knowledge and information are the foundation of fish and wildlife management" and that its "management responsibility is to foster solutions to fish and wildlife issues that are ecologically viable, economically feasible, and socially acceptable." More specifically, the key objective of the water quality basin plan is to restore water quality in the Henrys Fork downstream of Island Park Reservoir to improve fish and macroinvertebrate habitat and ecological function to support the fishing experience. By improving water quality in Island Park Reservoir, alternatives developed through the proposed water quality basin plan could increase the amount of trout habitat in the reservoir, which has been shown to improve quality and trophy fish numbers available for anglers both within Island Park Reservoir and in the family fishery in the Henrys Fork upstream. Strategies outlined in the IDFG Fisheries Management Plan will be developed into specific projects with design plans for implementation. These strategies include creating "biologically meaningful habitat, water quality and stream flow protection and enhancement" in the Henrys Fork downstream of Island Park Dam, "reservoir tributary habitat and stream flow protection and enhancement", "managing Island Park Reservoir for optimum trout production goals to ensure strong escapements of spawning Rainbow Trout and kokanee upstream through the upper Henrys Fork to Moose Creek, Big Springs, and Henrys Lake Outlet", and "addressing limiting factors on kokanee salmon to create quality kokanee fishery".

Restoring tributaries to Island Park Reservoir could also create new habitat for Yellowstone cutthroat trout, a state species of special concern. Improved habitat complexity in tributaries not only benefits downstream water supply and water quality, but can also improve cutthroat trout habitat, supporting IDFG goals to ensure the persistence of Yellowstone cutthroat trout in the Henrys Fork Watershed. Restoring tributaries to the Henrys Fork and Island Park Reservoir also produces practical opportunities to restore Yellowstone cutthroat trout to its native range within the Henrys Fork watershed. Candidate streams for restoration to improve water quality in the Island Park Reservoir watershed are West Dry, Icehouse, Taylor, and Schneider creeks (tributaries of Sheridan Creek), which are also identified by IDFG as candidates for Yellowstone Cutthroat Trout restoration.

Henry's Fork Foundation Strategic Plan

The HFF is governed by a Board of Directors, which conducts strategic planning every 5–10 years to assess organizational effectiveness relative to challenges and threats and to prioritize programs and projects. The HFF strategic plan was last updated in 2022 and included substantial changes to organizational structure of HFF's Science and Technology Department and addition of quantitative water-quality objectives, reflecting extensive advancement in HFF's scientific understanding of water quality and aquatic ecosystem function since the previous plan revision in 2014. The proposed project has grown out of the process of routinely evaluating the effectiveness of 40 years of aquatic conservation work in the Henry's Fork watershed and of incorporating the latest scientific information as it is produced and published, including 13 relevant peer-reviewed publications by HFF staff and affiliated students since 2014.

Like IDFG's fisheries management planning process, HFF's strategic planning process is internally driven but incorporates input from stakeholders. During the most recent plan revision, HFF hired a consultant to conduct structured interviews with a variety of watershed stakeholders, ranging from agricultural producers to fishing guides and outfitters. In addition, HFF frequently receives unsolicited input from stakeholders, primarily anglers and fishing guides/outfitters. Over the past decade, anglers and fishing guides/outfitters have expressed increasing concern over water quality—primarily high water temperatures and high turbidity—and potential negative effects on aquatic invertebrates and the related dry-fly fishing experience for which the river is known. These concerns motivated HFF to establish the first systematic and comprehensive water quality monitoring program in its history in 2013, starting with collection of turbidity, suspended sediment and nutrient samples immediately downstream of Island Park Dam. The following summer, HFF installed the first five of what in 2016 would become a network of 11 continuously recording water-quality sondes and expanded the sediment and nutrient sampling program to match the sonde locations. Currently, 10 of the 11 sondes remotely transmit water-quality data to a website in near real-time. In 2015, HFF added annual, replicated sampling of aquatic macroinvertebrates at five key locations in the river, including two in the project reach, and began regularly measuring water quality in Island Park Reservoir, in collaboration with IDEQ.

Whereas the 2014 version of HFF's strategic plan emphasized monitoring and assessment, the 2022 version emphasizes outcomes, including quantitative objectives for water quality and water quantity. Through its participation in the collaborative water conservation and management projects described above, HFF has largely met its water quantity objectives over the past few years. However, its water-quality objectives for temperature and turbidity in the project area have not been met during years of below-average water supply, which have occurred more frequently in recent years, as documented above. With a 10th season of HFF's water-quality data now in hand, it is apparent that the two most important factors affecting water quality in Island Park Reservoir are natural flow (lower flow = worse water quality) and spring/summer air temperatures (increasing trend; warmer temperatures = worse water quality).

The proposed project is not only necessary to address these issues but is also the logical next step in HFF's 40-year conservation history. The organization's early efforts focused on immediate threats to numerous river reaches from proposed hydroelectric development and on more localized but obvious impacts from livestock grazing along the river in the project reach. After those issues were largely addressed, the organization focused on improving fish passage, conserving native trout in headwater areas, and ensuring river access. Through the development and implementation of the DMP, HFF addressed water-quantity issues although not at the current scale until after the 2013–2016 drought, when it became apparent that the larger water conservation strategies included in the 2015 Basin Study would be necessary to achieve meaningful results. HFF's current strategic plan explicitly includes programs and staff to pursue large-scale water conservation that were not present in the previous plan, in response to quantitative assessments that showed that "traditional" conservation projects such as fish passage, riparian protection, and headwater restoration were not maintaining the main-river fishing experience stakeholders desired. The current plan also combined what were previously separate Research and Restoration and Stewardship programs into a single Science and Technology department, directed by a Ph.D. scientist and currently staffed by five other permanent staff members and contractors, including two other Ph.D. scientists. Undergraduate interns and graduate students also contribute to HFF's science and technology work. The reorganization of HFF's departments not only fully integrates on-the-ground conservation activities with water-quality monitoring but also facilitates rapid translation of science and data into conservation actions. Further, the current plan identifies a critical need for external communications and stakeholder engagement to build the understanding and support needed to address large-scale issues associated with climate change and aging infrastructure with equally large-scale restoration projects. To help meet this need, HFF recently received a large grant from a private foundation to establish a new Climate Adaptation Program, managed by a Ph.D. scientist as of January 1, 2024.

The proposed project will set the stage for implementation of the large-scale projects needed to meet HFF's water-quality and aquatic habitat objectives, and ultimately its stakeholder-driven mission. The current HFF strategic plan not only led to this project but also supports it via long-term organizational commitment to a stable staff of highly trained aquatic resource professionals, state-of-the-art monitoring technology, and science-based collaboration.

Stakeholder Involvement and Support

Table 3: Stakeholder engagement objectives and activities by project year.

	Objectives	Activities
Year 1	1. Gather stakeholder concerns related to water quality, fisheries, and habitat 2. Coordinate with and report to agencies/municipalities/NGOs	1. Open-ended listening sessions and surveys prefaced with little background information and no specific infrastructure/restoration actions 2. Two meetings per year of the Henry's Fork Watershed Council
Year 2	1. Summarize and respond to concerns, present new data,	1. Formal presentations followed by question/answer, break outs, and large group discussion

	introduce potential infrastructure/restoration actions 2. Coordinate with and report to agencies/municipalities/NGOs	2. Two meetings per year of the Henry's Fork Watershed Council
Year 3	1. Vet specific infrastructure upgrades and restoration actions for feasibility and stakeholder acceptance 2. Coordinate with and report to agencies/municipalities/NGOs 3. Visit sites of potential restoration actions	1. Formal presentation of specific actions, followed by Q/A and discussion over multiple sessions 2. Two meetings per year of the Henry's Fork Watershed Council 3. Henry's Fork Watershed Council annual field trip

Project Implementation and Readiness to Proceed

In addition to ongoing water-quality, invertebrate, habitat, and fisheries monitoring and assessments conducted by HFF, IDFG, and IDEQ, the HFF will conduct several project-specific assessments to fill known data gaps. These include one-hour-frequency reservoir water-quality profiles near the dam from a buoy-mounted water-quality sonde, field measurements of streamflow and sediment concentrations in Island Park Reservoir tributaries, whitefish habitat assessment, Island Park Reservoir boater use estimate, and groundwater flow assessment in the area that could potentially be used for managed aquifer recharge. These studies will be planned and provisioned during the first six months of the project so they can be implemented during the 2025 field season. The boater use and whitefish assessment will be conducted solely during that field season. The other activities will continue at least through the second field season of the project.

Development of technical and engineering aspects of in-reservoir treatments, infrastructure improvements, and nature-based restoration will be done by consulting firms with expertise in these areas. In addition, assessments such as sediment composition and provenance that are beyond the technical capabilities of HFF will be done by consulting firms. Project staff at HFF and their agency partners will develop Requests for Proposals (RFPs) for this work as soon as grant agreement is finalized so that bids and contracts can be awarded in time to begin work by the end of the first field season of the project (Table 4). Contractor(s) will be required to provide initial development and assessment of alternatives by August of the second summer, so that these initial alternatives can be presented by the end of that summer to stakeholders who visit or reside in the study area only seasonally. After stakeholder review and input, consultants will provide more refined analysis for the alternatives that have the highest potential to meet water-quality and habitat objectives and receive stakeholder support for implementation. These alternatives will be advanced to stakeholder-informed cost-benefit analysis during the spring and summer of Year 3.

Table 4: Project timeline and milestones

Tasks	FY 2025		FY 2026		FY 2027		Completion (end of month)
	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	Apr-Sep	
Address water quality problems caused by aging infrastructure at Island Park Reservoir. Restore degraded surface and groundwater inputs to Island Park Reservoir and Henrys Fork.							
RFPs for contractors advertised	■						Dec 2024
Bids prepared and submitted	■	■					Apr 2025
Evaluate bids, award contract(s)		■					Aug 2025
Develop solutions/upgrades/projects		■	■	■			Aug 2026
Stakeholder review and input				■	■		Nov 2026
Refine solutions/upgrades/projects					■		Mar 2027
Stakeholder-informed cost/benefit						■	Jun 2027
60% design for feasible alternatives						■	Sep 2027
Stakeholder engagement							
RFPs for contractors advertised	■						Nov 2024
Bids prepared and submitted	■	■					Feb 2025
Evaluate bids, award contract(s)		■					May 2025
Stakeholder listening sessions		■					Sep 2025
Analysis of listening session input			■				Mar 2026
Stakeholder review: alternatives/data				■	■		Nov 2026
Cost/benefit and feasibility review						■	Jun 2027
Watershed Council meetings	■	■	■	■	■	■	2 per year
Community interactions	■	■	■	■	■	■	Ongoing
Fill data gaps							
HF water quality/invert. monitoring	■	■	■	■	■	■	Ongoing
Plan, purchase supplies/equipment	■						Mar 2025
Whitefish habitat use assessment		■	■				Oct 2025
IP Reservoir boater use estimate		■	■				Nov 2025
Groundwater flow assessment		■	■	■	■		Oct 2026
IP Reservoir and tributary monitoring		■	■	■	■	■	Ongoing

All of the potential types of reservoir treatments, infrastructure upgrades, nature-based restoration, and aquifer recharge activities mentioned in this application and considered by the

HFF to date have been successfully applied in other locations. Although we have not pursued design of any of these activities in the project area, designs for similar activities exist, and familiarity with such activities will be a key criterion for selection of consultants to conduct design components of this project. Thus, we anticipate that alternatives advanced to cost-benefit analysis during the second half of Year 3 will be partway through the design process at that point. Relatively simple alternatives with strong stakeholder buy-in could be advanced to 60% design by the end of the project. We realize that some of the more complex and expensive alternatives may require additional planning beyond this grant to attain 60% design status, but the water quality basin plan produced by this project will provide a mid-way point for the remaining analysis, assessment, and stakeholder engagement necessary to advance those alternatives to 60% design and stakeholder acceptance.