# waterscapes

HDR

A TECHNICAL PUBLICATION BY
HDR'S WATER PROGRAM

2022, ISSUE NO. 1

## Pushing Boundaries

**By merging cutting edge science with innovative fisheries engineering solutions, we're helping our clients clear obstacles and push the boundaries to what's possible, every day.**

*The new Pettit Lake Creek Weir marks a key point in the critical restoration of the Shoshone-Bannock Tribe and region's biological and cultural heritage. It won the American Council of Engineering Companies 2022 Engineering Excellence Grand Award.*

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2022, NO. 1

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**EDITING & DESIGN**
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Cover © AdobeStock.com
Inside Cover @ Pettit Lake Creek Sockeye Salmon Weir; Shoshone-Bannock Tribes Fish and Wildlife Department — Fort Hall, Idaho

# It all begins with passion, followed by accountability and innovative fisheries engineering solutions.

Most conversations about fish begin with a memory, a story, a tale about angling with friends and family — recounting every detail of the scenery and, most of all, the "big catch" that somehow grows bigger with each retelling.

While memories like these shine bright, the latest news reports are more grim. Our beloved waters are touched by declining fish populations, warming from climate change, ecosystem disruption and dwindling fresh water. Within this environment, we must also continue the progress of maintaining our cities, ensuring reliable municipal water, producing agricultural water for food and many more essential activities. Where do innovative solutions arise, and how do we strike an efficient balance between the natural and the man-made?

*"We do things right to make great things possible."*

It begins with passion. The HDR fisheries team lives and breathes what we do — with staff representing fisheries facilities (hatcheries), fish passage and ecohydraulics, aquatic biology and regulatory support. This passion is then focused into a client-first approach, where we align ourselves with each challenge experienced by our client leaders and their staff. In a practical sense, this means our fisheries staff listen first, push boundaries, provide creative solutions and always hold themselves accountable.

To meet the expectations of our team and our clients, fisheries staff are constantly learning and evolving. We apply the latest tools, utilize cutting-edge methodologies and maintain institutional knowledge and understanding through training, investigation and study.

In the following pages, you will find a selection of articles representing our passion for and dedication to fisheries, reflected in important projects and topics. The articles are authored by technical leaders across the U.S. who address many diverse fisheries challenges every day. Collectively, we hope that you enjoy this issue of Waterscapes and consider how HDR might be a part of solving your future challenges.

Matt Cochran
*Fisheries Director*

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# Knowledge is (Hydro)Power:

## Understanding Fish Issues in FERC Relicensing

*By Chuck Vertucci - Aquatic Sciences Lead, Sacramento, CA; Jim Gibson - National Relicensing Lead, Syracuse, NY; Misty Huddleston - Environmental Project Manager, Charlotte, NC*

*HDR's current and historic FERC relicensing efforts.*

Water is one of our most precious — and versatile — resources. Yet there are constant challenges and debate over how water is allocated for its many uses by humans and the environment. One important intersection of water's competing uses is the generation of electricity using hydropower. In the United States, there are an estimated 1,500 hydropower plants that generated approximately 291 billion megawatt-hours in 2020, or enough energy to power roughly 26.5 million homes for one year. Whereas hydropower provides the U.S. with an essential source of carbon-free renewable energy, its use of water can impact resources such as fish habitat and migratory fish. In the U.S., hydropower facilities under the jurisdiction of the Federal Energy Regulatory Commission are relicensed every 30 to 50 years using a robust public process that analyzes, evaluates and balances the developmental (energy generation and flood protection) and non-developmental (aquatic and terrestrial habitats) resources related to the hydropower plant. Our hydropower experts have supported the FERC relicensing of hundreds of hydropower plants and have helped the industry navigate the delicate balance between optimizing valuable hydropower resources and preserving natural environmental resources. At the forefront of these efforts is the need to support the balancing of hydropower with the rivers and aquatic habitats that are home to America's fisheries.

### The Relicensing Process

FERC regulates the hydropower industry, including the relicensing process, under authority from the Federal Power Act. In 1986, Congress amended the FPA through the Electric Consumers Protection Act. This landmark legislation requires FERC to give equal consideration to both power and non-power resources when issuing a new hydropower license. ECPA, in conjunction with subsequent court rulings, established the hydropower relicensing process we know today.

The formal relicensing process begins about five years prior to expiration of the existing license — when the licensee files a Notice of Intent and Pre-Application Document. The PAD provides agency personnel and interested stakeholders with existing, relevant and reasonably available information regarding the hydropower plant and the surrounding assets that include environmental, cultural and recreational resources. Although these filings are the first formal step of FERC's relicensing process, our teams begin working with our clients well in advance of this initial milestone. Essential to this process is developing clear goals and objectives for the relicensing and defining a successful outcome for the proceeding. There is no benefit to undertaking a multiyear relicensing process that, in turn, does not result in a viable project that logistically and fiscally supports an owner's long-term success.

The PAD also identifies data gaps that need to be addressed during the proceeding. This information is required to help define structural and operational modifications to the hydropower plant following issuance of the new license. These information needs are often addressed through resource-specific studies and by determining a nexus or connection between plant operations and effects on a resource. Performing resource studies in support of obtaining the new license is a critical phase of relicensing. The study plan design and implementation phase can account for 40 to 60 percent of the overall cost of relicensing and typically involves consultation with agencies (state fish and wildlife, federal land managers, etc.), Native American tribes and nongovernmental organizations (e.g., Trout Unlimited, American Rivers, American Whitewater). We develop aquatic studies in collaboration with agency staff while keeping an "owner's perspective" throughout the process.

After addressing the information needs and performing necessary studies, relicensing focuses on the development of the License Application, which by statute must be filed with FERC at least two years prior to expiration of the existing license. The License Application includes protection, mitigation and enhancement measures that the licensee proposes to implement over the term of the new license. In some relicensing cases, the licensee chooses to develop and negotiate these PM&Es with various stakeholders ahead of filing the License Application. We provide critical support during this phase by helping our clients negotiate reasonable PM&E measures — considering capital and operational costs, generation impacts and resource benefits. Given that negotiated PM&Es will be required for the term of the new license (30 to 50 years), negotiating reasonable measures is essential to a successful relicensing.

Once FERC and the resource agencies complete their respective environmental analyses (an environmental assessment or environmental impact statement for FERC) and the State issues a Section 401 Water Quality Certificate, FERC issues the new license. The license grants our clients the right to operate the hydropower plant consistent with the terms of the new license. Given the site-specific expertise developed over the course of a relicensing, we often continue supporting our clients with the implementation and compliance of the new license. This support is often in the form of regulatory, environmental and engineering services.

## Aquatic Habitat Evaluations

Most hydropower owners are required to release a minimum baseflow of water downstream of their facilities for environmental benefits. The relicensing process provides agencies and stakeholders the opportunity to reevaluate the quantity and timing of these downstream releases. To better understand the environmental effects of varied flow regimes downstream of a hydropower plant, our teams perform detailed aquatic habitat evaluations using site-specific field data and various models from new or preexisting data. These models incorporate habitat variables such as substrate, water depth, water velocity and water temperature, along with the preferences of these variables by species expected to be present in the downstream river reach. Often, the analysis is broken down further by life stage and life history. HDR's ability to develop and apply these robust models is due to the collaborative efforts of our fisheries, geomorphology and geospatial scientists and engineers.

*A team member getting ready to perform an aquatic habitat evaluation for the Merced Irrigation District's Merced River Project in the Central Valley of California.*

One suite of studies was completed for the Merced Irrigation District's Merced River Project in the Central Valley of California. The lower Merced River extends 52 miles from Merced ID's Crocker-Huffman Diversion Dam to the river's confluence with the San Joaquin River. Fall-run Chinook salmon are known to spawn mostly in the upper 20 miles of the lower Merced River, and the river contains potential habitat for Endangered Species Act-listed Central Valley steelhead.

To better understand how changes in flow and Merced ID's project operations impact habitat availability for the various species and life stages, our staff completed both one- and two-dimensional habitat models for the lower Merced River. In support of the 1-D model, we established and collected data along 65 transects representative of the various aquatic habitats associated with the river. The combination of the transect data and model allowed us to extrapolate and apply the observed river conditions to the larger river reach. To further understand habitat conditions in the lower Merced River, we developed a 2-D model that incorporated data from the entire 20-mile "spawning reach" where each individual habitat unit was surveyed and evaluated. In total, millions of topographic data points were collected using a combination of aerial LIDAR, boat-based bathymetry and hand-held surveying. To complete the model, we combined these data with hundreds of water depth and velocity measurements taken at three target flow rates. The model also incorporated substrate, vegetation and water temperature in order to evaluate habitat and flow suitability for species and life stages such as juvenile fall-run Chinook salmon.

The models gave Merced ID and the resource agencies a calibrated approach to evaluate base flow and operational scenarios in support of developing the License Application. In some instances, the models allowed Merced ID to demonstrate that higher seasonal flows were not always beneficial to the fish habitat of interest and paved the way for Merced ID to propose lower flows to better balance the flows in support of hydropower generation and environmental benefits. This was a critical success for Merced ID because any opportunity to conserve water or reallocate water for other beneficial uses such as agriculture or consumption, while still providing environmental benefits, is valuable and provides long-term sustainability to the aquatic system.

## Fish Populations

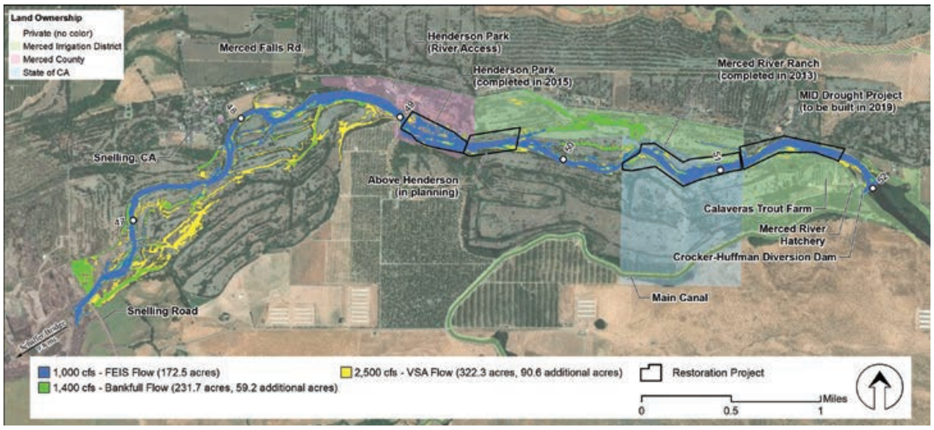
The aquatic communities and the fish species present in reservoirs formed by hydropower facilities, as well as the downstream river reaches, will dictate the scope of studies to be performed during a relicensing proceeding. Hydropower facilities with species listed under state or federal endangered species laws, or anadromous species, such as salmon, may require more robust evaluation. Our fisheries biologists perform species-specific and population-level fisheries studies throughout the United States and are well-versed with backpack and boat-based electrofishing, seining, gill netting and snorkeling to determine the presence of target species and the potential impact of hydropower operations on the species' life cycle. Given that no two hydropower plants are identical, every methodology is customized to meet the study objectives and to address the data gap of the specific relicensing proceeding.

An example where our fisheries team performed a large-scale fisheries study was the joint relicensing of Pacific Gas and Electric's Drum-Spaulding and Nevada Irrigation District's Yuba-Bear Projects, considered one of the country's most complicated relicensings due to the number of facilities, stream reaches and reservoirs. As part of the study, we sampled fish in 55 stream reaches and five reservoirs ranging in elevation from about 500 feet to almost 8,000 feet. Sampling consisted of electrofishing and snorkeling of stream reaches, and electrofishing and gill netting in reservoirs. Overall, approximately 4,500 individual fish were observed or captured from 15 species. Our staff performed field surveys, managed the field data and developed detailed analyses and reports. The results of this effort were essential to preparing the License Application and provided vital data and analysis used during negotiations of PM&E measures with resource agencies.

This large-scale study and corresponding data set was also used in conjunction with other studies related to water quality, water temperature, benthic macroinvertebrates and amphibians to better understand the overall aquatic community and help benefit the power and non-power resources through this robust relicensing proceeding.

## Fish Passage

The FERC relicensing process provides federal and state fishery management and resource agencies with the rare opportunity to require the installation of upstream and downstream fish passage at a hydropower facility. Although there may be opportunities during the term of the new license for an agency to pursue fish passage measures, the FPA and associated statutes and regulations provide the agencies with the defined process to require such measures during the course of the relicensing proceeding. Therefore, evaluating the need for fish passage, as well as the balancing of hydropower operations and fish passage, is a resource area of focus for many hydropower agencies.





*Model output of usable salmon habitat along the Merced River (top, left). HDR fisheries team members completing snorkel surveys in the Yuba River watershed (top, right). HDR employees completing boat-based electrofishing surveys (bottom, left). Brookfield Renewable's Hawks Nest Dam on the New River (bottom, right).*

Fish passage is very region specific. For example, our hydropower clients in the Northeast must consider upstream and downstream passage for American eel and alosines (e.g., shad and blueback herring) for all rivers that connect to the Atlantic Ocean and the St. Lawrence watershed. In addition, rivers in Maine are home to the ESA-listed Atlantic salmon, and various species of sturgeon and walleye are found in river systems throughout the country. Essential to a successful relicensing is the understanding of potential fish passage measures that may be required by the new license, as well as the costs to develop and operate the passage measures over the term of the new license. Our fisheries biologists and fishway design engineers routinely support hydropower agencies with developing the necessary information to understand the potential implications of fish passage to hydropower operations, and on the capital and operations and maintenance budgets related to implementing the new license.

Our fisheries biologists and fishway engineers are well versed in this design process, as well as the agency consultation that is required to develop an effective fish passage structure in a timely and efficient manner. Essential to a successful fish passage structure is the understanding and combining of fish biology and migratory movement, fishway hydraulics, structural design and the electrical and mechanical engineering required to integrate the fishway into the hydropower facility's internal operations.

*Nature-like fishway at Brookfield Renewable's Oswegatchie Project on the Oswegatchie River.*

Recent fishway designs that we developed following the issuance of a new FERC license include two nature-like fishways that are operational in New York. In addition, we are currently supporting multiple agencies with the design and subsequent effectiveness testing of additional fishways that resulted from the FERC relicensing process.

## Entrainment and Impingement

In addition to determining the composition, abundance and distribution of the fish community, and the need to provide passage for these species, relicensing agencies are often required to perform a field or desktop assessment of fish impingement or entrainment. Impingement occurs when a fish is held against or entrapped on the exterior intake structure screen or bar racks due to forces created by velocities at the intake. Entrainment occurs when the fish passes through the fish screens or bar racks and is withdrawn into the intake structure.

The potential for fish to become entrained or impinged at a hydroelectric facility is dependent on a variety of factors, such as fish life history, size and swimming ability, water quality, operating regimes, inflow, turbine configurations, intake structure dimensions and presence of a spillway or bypass channel. These factors are used to select comparable and representative studies from an existing entrainment database compiled by the Electric Power Research Institute (EPRI 1997).

The desktop entrainment study uses database entrainment results from studies performed at facilities comparable in design and operation to the current facility in order to estimate entrainment rates (monthly, seasonal, annual) for target species. Our experts estimate fish turbine entrainment or spillway passage mortality at hydroelectric dams using the U.S. Fish and Wildlife Service's Turbine Blade Strike Assessment Model, which was released in 2018.

Our fish entrainment experts also design and implement field-based assessments of entrainment and impingement at cooling water intake structures for electric utility agencies across the U.S., including Duke Energy, Dominion Energy and Muscatine Power and Water, to support compliance with requirements of the Clean Water Act Section 316(b) Final Rule (CWA 2014). Fish and ichthyoplankton collections are processed and identified taxonomically at our biological laboratory in Nanuet, New York.

## Summary

The FERC relicensing process is focused on balancing the power and non-power resources associated with a hydropower facility, as well as the interests of various stakeholders with the generation of carbon-free renewable energy. Our FERC regulatory specialists and fisheries staff collaborate with hydropower agencies to better define the aquatic communities and the potential impacts and benefits of hydropower operations on these resources. By developing and implementing site-specific and focused studies, we are able to help our hydropower clients successfully navigate the relicensing process by emphasizing the owner's goals, while also developing effective and streamlined PM&E measures to address environmental interests and enhance the resources associated with the hydropower plant. As water availability continues to be a major issue in the U.S. and beyond, the ability to thoughtfully balance competing needs through regulatory processes like FERC relicensing will be invaluable.

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# Two Centuries of Aquaculture:

## Challenges and Solutions, Then and Now

*By Matt Cochran - Director of Fisheries, Springfield, IL*

*Interior of Roxbury Fish Culture Station in Roxbury, Vermont.*

Would you believe me if I told you that we eat over a million blue whales annually across the globe? Well, figuratively speaking that is. The global consumption of fish and shellfish is a staggering 156 million tons per year, or the equivalent of one million blue whales. In North America alone, the average individual consumes between 18 and 19 pounds of fish and shellfish each year, for a total of 3.5 million tons. Worldwide, fish consumption represents 25% of protein intake, and that number jumps to over 50% of protein intake in developing countries. *Holy mackerel*, fish is an important part of our diets!

Not only do we consume fish and shellfish on a regular basis, but also we spend a staggering amount of money in pursuit of them. According to The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, Americans alone spend over $46.1 billion annually on fishing-related expenditures. More than 35.8 million people over the age of 16 fish annually; that's more than the number of people living in the entire state of Texas. While fishing is an economic catalyst — driving sales of gas, gear and hotel expenditures — it goes beyond that. Fishing-related activities represent time on the water, relaxing, with friends or family, and are considered healthy to participate in. Fishing is a big deal — bigger than Texas! But how often does the average individual stop to think about where the resources we consume and pursue actually come from and what tools are used to manage those resources?

As our communities, cities and states all advance in development, unintended impacts to the environment have led to dwindling fish populations and stressed environments. In addition, the overwhelming popularity of fish in restaurants and grocery stores has increased demand, in some cases beyond sustainable population numbers. In response to these conditions, an important tool was developed that has been utilized for portions of two centuries to help manage populations, mitigate environmental concerns, and produce fish for consumption: the fish hatchery. Known globally as "aquaculture," fish and shellfish production in hatcheries represents an important component of protecting populations from declining to dire levels, as well as a means of providing mitigative support from development projects. The balance leads to a biological insurance policy that protects against fish losses and works toward securing the future of our fisheries for generations to come.

From its humble beginnings in make-shift facilities alongside the backwaters of rivers to state-of-the-art, center-of-town buildings that control everything from the temperature of the water to the color of the light, fish hatcheries have a rich history of supporting a beloved tradition and an important food source. Behind the scenes of producing fish, the planning, design and construction of hatcheries has evolved over time, keeping pace with the changing demands to produce.

In short, from food to fishing to environmental conservations, North American hatcheries offer an immense public service, backed by an intriguing and challenging development history. Let's take a brief look at two centuries of fish and shellfish production and the design needs that have driven their success.

### Early History

In the early 1800s, westward migration and increasing populations across the U.S. and Canada brought on a range of challenges to native fish species.

*United States Bureau of Fisheries Hatchery at Baird, CA. The first fish-cultural station on the Pacific Coast.*

*By John Nathan Cobb - Cobb, John N. (1922) Pacific Salmon Fisheries, Report of the United States Commissioner of Fisheries for the Fiscal Year 1921, with Appendixes, Washington, DC: Government Printing Office, Public Domain, https://commons.wikimedia.org/w/index.php?curid=42384896*

Overfishing, habitat disruption, pollution and man-made waterway obstructions became increasingly commonplace, creating a clear need to artificially support natural fish resources.

As early as the 1850s, a decade before the American Civil War, wealthy individuals began artificially propagating trout near Cleveland, Ohio, and within New England. It marked the beginning of planning for, designing and constructing facilities. Only a few years later, several U.S. state legislatures commissioned studies of aquaculture as a means to reestablish struggling shad and salmon runs.[1] Finally, in 1871, Robert Roosevelt — uncle to President Theodore Roosevelt — originated the bill that would establish the U.S. Fish Commission (now known as the U.S. Fish and Wildlife Service and NOAA Fisheries) in 1872.[2]

Canadian aquaculture followed a parallel path. In 1857, the first Superintendent of Fisheries in Lower Canada (now Quebec) began studying the process of incubating and hatching eggs for Atlantic Salmon and Brook Trout.[3] Artificial propagation of oysters began not long after, in 1865, and later expanded to include Rainbow Trout and cod.

In the early days, hatcheries were established near natural spawning areas, which could take exhaustive scouting to locate. California represented an excellent location to mark the first U.S. national fish hatchery. California once held some of the largest runs of salmon and steelhead, but they were aggressively impacted not only by overharvest but also from dredging operations during gold mining that clogged waterways. These are still visible today, with mounds of cobble littered along the shorelines of major rivers.

The first national hatchery, pictured to the left, was established on the McCloud River near Redding, California, adjacent to then-untouched salmon spawning areas. It took months to identify the perfect location.[4] Once established, salmon eggs were harvested by hatchery employees to be shipped by wagon and train to stock waters across the country.[4,5] According to an 1872 account, this precious cargo was routinely packed between layers of live moss in thick wooden crates, each containing approximately 75,000 eggs, covered with a layer of ice.[6] A successful shipment, despite the transportation and temperature-control challenges of the day, would lose a mere 3% of eggs.

The actual construction of hatchery facilities came with its own set of challenges. The facility locations, justifiably, were driven by fish needs, not necessarily by the ease of construction or transportation of finished product. Remote sites, access to construction materials, the need for makeshift fish culture equipment, and general equipment to build the facilities were all early challenges faced by the industry.

*Spawntaking operations, Baird, CA. Chinook Salmon eggs being harvested by hatchery employees.*

*By John Wheelock Titcomb - Titcomb, John W. (1910) Fish-Cultural Practices in the United States Bureau of Fisheries, Bulletin of the Bureau of Fisheries, vol. 28, 1908, Part 2, Washington, DC: Government Printing Office, Public Domain, https://commons.wikimedia.org/w/index.php?curid=42501358*

While many challenges existed, the concept of a fish hatchery was born in this era. By the turn of the century and roaring into the 1920s and 1930s, hatcheries were springing up throughout North America. Some of the earliest facilities still in existence today got their start during this time in places like Washington (Spring Creek Hatchery – 1901), Wisconsin (Art Oehmcke Hatchery – 1901), Pennsylvania (Pleasant Gap Hatchery – 1903), Ohio (St. Mary's Hatchery – 1913), Iowa (Spirit Lake Hatchery – 1915), Arkansas (Joe Hogan Hatchery – 1928) and Maine (Dry Mills – 1933).

## Mid-Century

In the 20th century, the mission of aquaculture began to broaden from simply mitigating human influences on the natural environment for just a few species — such as dams and structures, pollution and overfishing — and expanded to include active preservation of fishery resources. This became particularly true as conservationist efforts entered the public consciousness in force in the 1970s, with legislation such as the Clean Water Act in 1972.

*A.E. Wood in Texas was constructed in 1989 and illustrates a mid-century, large-scale fish production facility.*

Many of North America's early hatchery facilities were significantly aging by the mid-century — some by then were as old as 100 years — and building new facilities had to be considered. This time frame also marked a transition toward producing more varieties of fish to meet angler and restoration demands. Larger and more sophisticated facilities were needed, as the science of aquaculture advanced techniques to successfully rear species that were traditionally not feasible.

These modern facilities centered on moving large volumes of water, producing mass quantities of fish and ushered in a new concept: visitor access. Small facilities once placed close to the spawning locations of fish, such as Baird Station on the McCloud River, were now being placed on expansive properties occupying hundreds of acres. Modern concrete raceways and lined ponds focused on production of warmwater species became common features of these facilities.

Designs in this era had to accommodate emerging technologies such as more sophisticated concrete harvest kettles that allowed for easier harvesting of fish, attempts at fish transfer systems to move fish throughout the facility and into stocking trucks, plastic liners in earthen ponds, pumping and discharging mass quantities of water, the use of well water with dissolved gases and indoor covered rearing facilities. Large design plan sets, biological reviews, fish growth modeling and modernized construction techniques were all part of the equation by mid-century.

HDR's history with updating, rehabilitating and designing fish hatcheries began in this transitional period. Since our start with studying, planning and designing hatcheries, our Fisheries Design Center has touched more than 300 state, province, federal and tribal facilities. The experience gained by this volume of work enables our team to remain at the forefront of hatchery renovations and the design of new facilities.

## Modern Era

The current fish hatchery environment has undergone a significant transition in a short time. While the transition from historical hatcheries to the mass-production facilities of the '70s, '80s and '90s took almost 100 years, movement to the current state of hatcheries occurred over less than two decades. Water supply shortages, aging infrastructure, effluent treatment and nutrient removal, genetics, species conservation, climate change, unregulated chemicals, visitor outreach and the growing need to operate resilient facilities all hastened this rapid transition to modernization.

Aging infrastructure is an ever-present challenge to hatchery infrastructure in North America. While transitions to

*Facilities such as the Nimbus Hatchery in California utilize recirculation technology to reduce water demand and improve biosecurity.*

mid-century technology, production and infrastructure investment have taken place, many facilities are still operating with 80-year-old infrastructure in place (some even as much as 100 years old). Today, a key challenge for the industry is obtaining funding for these facilities to modernize antiquated equipment and implement modern techniques.

A primary goal for governmental and private facilities is now producing fish and discharging wastewater that does not negatively impact the receiving water body. Releasing solids and nutrients into hatchery effluent streams is an increasing concern for both fish producers and regulatory agencies. With increasingly complex watersheds, the levels of nutrients outlined in permits have reached an all-time low, with limits shrinking to as little as 12 µg/L for phosphorus. These low limits present a technical challenge and an operational complexity unforeseen in early generation hatcheries.

Water use trends, availability, water rights, impacts of climate change and extreme weather events all play crucial roles in the operation of fish hatcheries. As water uncertainty and the drive to utilize less resources prevail, technologies that allow for water recirculation in the production of fish have grown. This has resulted in very sophisticated facilities that use only a fraction of water compared to traditional facilities but incorporate a lot of treatment technology to maintain fish health and discharge water suitable for the environment to receive it.

While the past included some mass production of species for stocking throughout North America, today we work with numerous regional and even watershed-specific species. These include subpopulations of Pacific salmon species in the Northwest, trout in the Northeast, Largemouth Bass and catfish in the South, cutthroat species through the Rockies and a host of similar species through North America. The facilities we design must be flexible and adaptable to raise these species in biosecure and isolated settings to preserve genetic integrity.

Future climate changes could pose significant risks to hatchery infrastructure, and thus increased climate resilience in hatchery designs has also become a focus of facility modernization. Subtle changes in extreme weather events, warming water, season shifts and water shortages have profound impacts on aquaculture. As a result, our future facility designs must be able to accommodate such shifts.

## Conclusion

North American hatcheries support food- and sport-related production, conservation efforts and research in fish disease, methodologies and more. Over the decades, these hatcheries have evolved from a few scattered, simple facilities producing one or two species to vast a network of more than 700 facilities producing hundreds of varieties of fish for restoration and food consumption.

HDR has been working alongside state and federal agencies, tribes and private hatcheries for much of this evolution to conserve and sustain fishery resources. Our staff have played a pivotal role in transforming historical facilities into modernized fish production campuses, complete with biosecurity, efficient equipment, worker safety and resilient features. Along the way, we've managed through design and construction challenges, enhanced our lessons learned and incorporated sensitivity to individual species' needs to produce state-of-the-art facilities capable of continuing the fish production mission started centuries ago. Many of the renovations today take place within the footprints of the original facility, thus incorporating history with modern features. Our Fisheries Design Center staff are dedicated to supporting and continuing the work of North American hatcheries for the next century of their history.

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*Adult holding facility at Tumwater Falls Fish Hatchery in Tumwater, Washington (left). Bio secure incubation room at Wells Dam Hatchery in Douglas County, Washington (top right). Fish feeding at Roxbury Fish Culture Station in Roxbury, Vermont (bottom right).*

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# Re-plumbing California:

## Preparing for Water Management under Future Climate Conditions in a Litigious State

*By John Spranza - Lakes and Reservoir Practice Lead, Sacramento, CA*

*The California Aqueduct system was developed in the 1960s to store water and distribute it to 29 urban and agricultural water suppliers in Northern, Central and Southern California.*

The California water capture, storage and delivery infrastructure system is quite possibly the most extensive in the world. It can capture rainfall at the northern border of the state, store it and then move it over 750 miles to the southernmost portion of the state along the Mexican border.

Drought and hydrologic variability is a way of life in California, as the state's climate and hydrology are unlike any other in the nation. With dry summers and wet winters, the state's climate is characterized by dramatic variability and uncertainty. Climatic conditions range from temperate rainforest conditions in the north to arid deserts in the south with precipitation varying from year to year, anywhere from extensive droughts in one year to damaging floods in the next. There simply is no such thing as an average water year in California hydrology, which makes managing water in this state particularly challenging.

Adding to this complexity is a water management system originally conceived in 1919 that centered on capturing snowmelt in the state's vast mountain ranges and slowly releasing that stored meltwater to provide a year-round supply of water to areas that would not otherwise receive significant rainfall from May to November.

### Stress on the Water System

With the growth of California's population from 5.7 million in 1930 to 39.5 million in 2020, the state's water infrastructure backbone has begun to show its age and design limitations. Further stressing the system are the myriad environmental laws that original designers did not have to consider. These include national regulations such as the federal Endangered Species Act, Clean Water Act and National Environmental Policy Act, as well as those unique to the state including the California Endangered Species Act, Porter-Cologne Water Quality Control Act and California Water Law. More recently, changing climate and rainfall patterns have become a challenge for water managers to address, plan for and incorporate into this already overly complex system.

At HDR, we are playing a major role in addressing all of these challenges by supporting the Sites Project Authority in the planning, design, construction and environmental permitting of the new, 1.5 million acre-foot Sites Reservoir — the first major Northern California reservoir to be built since 1978 and the first major new water right in over half a century. Our primary task is to recommend, establish and execute solutions that will allow the Authority to construct and operate this project within the anticipated time frame and estimated budget, with minimal risk and approval by all oversight agencies. Our new Lakes and Reservoirs national practice group maintains key roles on this effort, pulling from members' diverse expertise in water quality, limnology, reservoir management, environmental permitting and ecology to provide the Authority with advice and information as part of the daily decision-making activities in the development of the project.

### California's Plumbing

Out of more than 1,400 reservoirs in the state, 42 dams and reservoirs and 1,500+ miles of major canals, tunnels and related facilities make up the backbone of the system. This key infrastructure comprises the State Water Project, which is operated by the California Department of Water Resources, and the Central Valley Project, which is run by the U.S. Bureau of Reclamation. These two projects alone provide drinking water for more than 30 million people, support 5.75 million acres of farmland and sustain the sixth-largest economy in the world, all while maintaining vast native ecosystems including the largest freshwater tidal


**Figure 1:** *Major water project in California. Source: California Dept. of Water Resources.*

estuary in western North America and four runs of salmon (Figure 1).

## A Changing Climate and Water Management Paradigm

California's water infrastructure is designed to capture precipitation during the state's rainy season and store it for use throughout the year. Although 60 percent of the state's population lives in semi-arid Southern California, most of the precipitation falls in the north and east-central portion of the state from December through March (Figure 2). Up to one-third of this precipitation falls in the Sierra Nevada Mountains in the form of snow. By accumulating snow during the wet winters and releasing it slowly during the dry springs and summers, the snowpack acts like a giant reservoir that is essential in meeting the state's municipal, industrial, agricultural and ecological water demands.

Climate models predict more variable weather patterns throughout California. More variability can lead to longer and more severe droughts and floods, which present significant challenges to California's water supply. These models also predict more precipitation to fall as rain and not snow, breaking the current water management paradigm in the state. As a result of this change in the form of precipitation, the peak discharge from melt will be up to three months sooner, moving it from April into February. Perhaps the most challenging prediction is that rising sea levels will bring more saltwater into the Sacramento-San Joaquin Delta — the heart of the California water supply system and a key source of water for 25 million people and millions of acres of farmland. To keep the salt water out, more freshwater will need to be pushed through the Delta, decreasing the amount of water available for people who have historically relied on it (Figure 4). Add in increasing frequency of extreme and exceptional droughts, catastrophic wildfires, declining groundwater reserves, the continued decline of endangered salmon, a collapsing Delta ecosystem and continuing population growth, and it becomes clear that California is facing unprecedented challenges to a water management system that was designed for different conditions.

## A New 'Old' Project Emerges

Beginning in 1955, DWR and BOR initiated the evaluation of expanded surface water storage in the Sacramento and San Joaquin Valleys; Sites Reservoir was part of that evaluation. In 2010, a new entity, the Sites Project Authority was formed to pursue the development and construction of the Sites Reservoir Project, which since 1955 has been viewed as an ideal location for additional off-stream storage to provide direct and real benefits to instream flows, the Delta ecosystem and California water supply. Sites Reservoir would not rely on snowmelt, instead it would capture winter runoff below the existing reservoirs in the Sacramento Valley. Because of this, it's a new source of water that will inherently adapt to future climate conditions. It will be operated to improve water supply resilience to the predicted changes in weather. Much of the rainfall from extreme events — especially those that occur back-to-back when the ground is saturated — runs off before it can be captured by the State Water Project and Central Valley Project for maximum environmental, urban and agricultural benefit. By capturing a portion of these high-flow events from the Sacramento River and operating in conjunction with other CVP and SWP reservoirs, Sites Reservoir would increase the resiliency of water supplies by not relying on spring snowmelt for filling and instead capturing winter storm-related runoff that is not normally captured. Unlike most major reservoirs in the state, Sites Reservoir would not block a major stream or river. It would be located 17 miles west of the Sacramento River and, in critically dry water years, will on average provide an additional 250,000 to 300,000 acre-feet of water to improve water quality conditions, help critically endangered salmon and meet urban and agricultural demand.

## Playing Our Part to Support California's Water Future

Since 2018, we have been supporting the Authority by acting as staff support, program managers, project managers, scientists, engineers, water operations specialists and environmental permitting

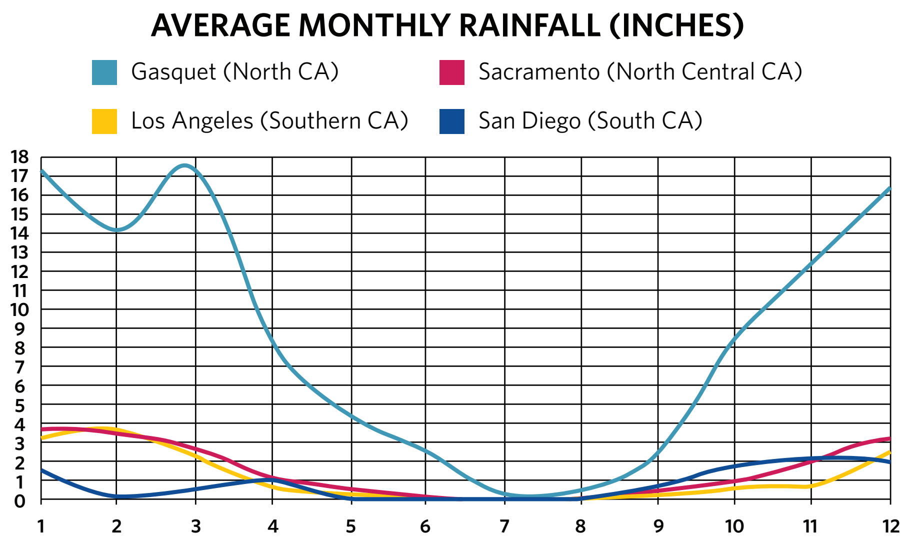


**Figure 2:** *Monthly average rainfall from the northern to southern California border.*


**Figure 3:** *The new Sites Reservoir would be an off-stream reservoir that would increase Northern California's water storage capacity by up to 15 percent and help address the effects of climate change by increasing the flexibility, reliability and resiliency of CVP and SWP.*

specialists. A key part of this effort has been supporting the Authority's environmental permitting and planning manager by managing the day-to-day activities of the extensive state and federal environmental permitting for the construction and operation of the new reservoir. With over 20 permits required, this is a challenging task in highly progressive California, where a single environmental permitting document commonly exceeds a thousand pages and litigation threat looms over even some of the most mundane projects. The state itself has grown to be a leader in environmental protection and regulation, pioneering some of the toughest state legislation to address environmental issues such as climate change, toxic waste disposal, water quality, pollution and loss of wildlife and habitat.

The Sites Reservoir project will inundate over 13,000 acres of grasslands, wetlands, streams, oak woodlands and farmland, much of which is suitable habitat for rare vegetation communities and threatened and endangered species. The project will also file for a water right to pump and store up to 1.5 million acre-feet (488.8 billion gallons) of water from the Sacramento River a year. The river is home to numerous threatened and endangered species and rare habitats and supports urban, municipal and industrial water demands, as well as large recreational and commercial salmon fishing. Given all of this, if you wanted an environmental permitting challenge in California, this project would be at the top of the list. Below are a few key components and lessons learned of this ongoing permitting program.

## California Environmental Quality Act and National Environmental Policy Act

The primary state and federal environmental permitting documents are those associated with the California Environmental Quality Act and the National Environmental Policy Act in that in that they are designed to provide the public with a disclosure of a project's environmental effects across over a dozen different categories, from cultural and tribal resources to water quality, climate change, environmental justice, fisheries, energy and agricultural resources.

Acting as staff to the Authority's environmental permitting and planning manager, our permitting and planning program managers and technical experts worked to oversee the preparation of the California Environmental Quality Act and the National Environmental Policy Act permitting documents by numerous consultants. This process transitioned through two state governors and three presidential administrations, each with differing environmental and water policy platforms to adapt to and address. Key to this process was to confirm that the Authority's EPP manager and executive director had the necessary information and support to brief the Authority's board of directors and numerous environmental committees and discuss the options, opportunities and risks of the CEQA/NEPA analysis and approach with them. All 23 member agencies or entities that make up and fund the Authority have concerns and objectives that are specific to their particular location within the state (north to south and east to west), constituency, rate payers or, in some cases, their own family farms. Addressing each of the member's questions and concerns while balancing the overall project objectives requires effort, organization and flexibility, which we provided to the Authority staff through the management of the 100+ person consultant team.

Working with the Authority's design, geotechnical, modeling and environmental consultants, we organized and led interagency meetings between state and federal permitting agencies. We also worked extensively with the project's federal partner, BOR, to mesh the complexities of different state CEQA and federal NEPA documentation and analysis requirements into a consolidated Environmental Impact Statement/ Environmental Impact Report for the project. The result of this effort was the successful release of the Draft EIR in November 2021 for public review and comment.

## Federal and State Endangered Species Act

Like the federal government, the State of California has its own Endangered Species Act statute. However, unlike the federal ESA, which only requires an applicant to minimize and mitigate the impacts of take of a listed species to the "maximum extent practicable," CESA requires that take must be "fully mitigated" (e.g., a minimum of one-for-one mitigation) and must not jeopardize the continued existence of the species, which is a quite higher standard when compared to federal regulations.

The Sites Reservoir project has the potential to affect 13 federally listed species and nine state-listed species, including both terrestrial species like the giant garter snake and Swainson's hawk and aquatic species such as Chinook salmon, green sturgeon and Delta smelt. Members from our Lakes and Reservoirs practice group acted as technical support staff to the Authority's EPP manager and directed the on-the ground daily activities of the state and federal ESA permitting of the project, providing the Authority's EPP manager the flexibility to choose which activities to take a lead role in while still maintaining the overall program and addressing the concerns of the Authority's board of directors and numerous environmental committees.

We worked with the Authority's environmental and modeling consultant teams to develop and refine terrestrial and aquatic habitat models for state and federally listed species and wetlands that were used to identify potentially suitable habitat for these species throughout the more than 20,000-acre project area. One of the strategies we employed was to negotiate with the California Department of Fish and Wildlife and U.S. Fish and Wildlife Service to allow effects, determinations and mitigation ratios in the ESA permits that were modifiable. Knowing that the project would initially grossly overestimate effects due to the lack of access to biological surveys of 99% of the project area, we confirmed that the project's mitigation requirements and financial assurances would be reduced as appropriate biological surveys were performed and effects to listed species and rare habitat were verified. If no species or habitat were found in previously unsurveyed areas, the mitigation and associated financial assurances would be reduced without the need for a lengthy permit amendment. This addressed some key concerns by the Authority and its members about over-mitigating for the effects of the project.

We also worked as part of the hydrological modeling and fisheries teams to assess the aquatic effects of the construction and operation of the project on listed aquatic species within the Sacramento, Feather and American Rivers, as well as the Delta. These effects ranged from near-field effects that would occur at the Sacramento River diversion pumps, to far-field effects seen over a week's water travel time and 150 miles downstream from the project's diversions. We then planned and moderated more than 60 workshops and technical meetings with state and federal scientists and regulators in a 24-month period to develop suitable aquatic effects models and water diversion criteria that would meet regulatory requirements while achieving the goals of a permittable and affordable project. Although this is a highly collaborative process, not all areas of concern are consistent across agencies and their respective management, staff and scientists. We worked to address this issue by supporting the Authority in preparing for and facilitating dialogue among state and federal agencies and between their staff and scientists and the Authority's subject area experts and technical consulting team. We employed new and developing science from local California river systems in our discussions that allowed the regulatory agencies to reduce their required Sacramento River bypass flow criteria from 13,000 cubic feet per second year-round to 10,700 cfs during the peak salmonid outmigration period. This results in a substantial increase in the amount of divertible flow for the project while simultaneously protecting listed salmon. ESA permit applications continue to be refined, with the first permit application being submitted in the Fall of 2023.

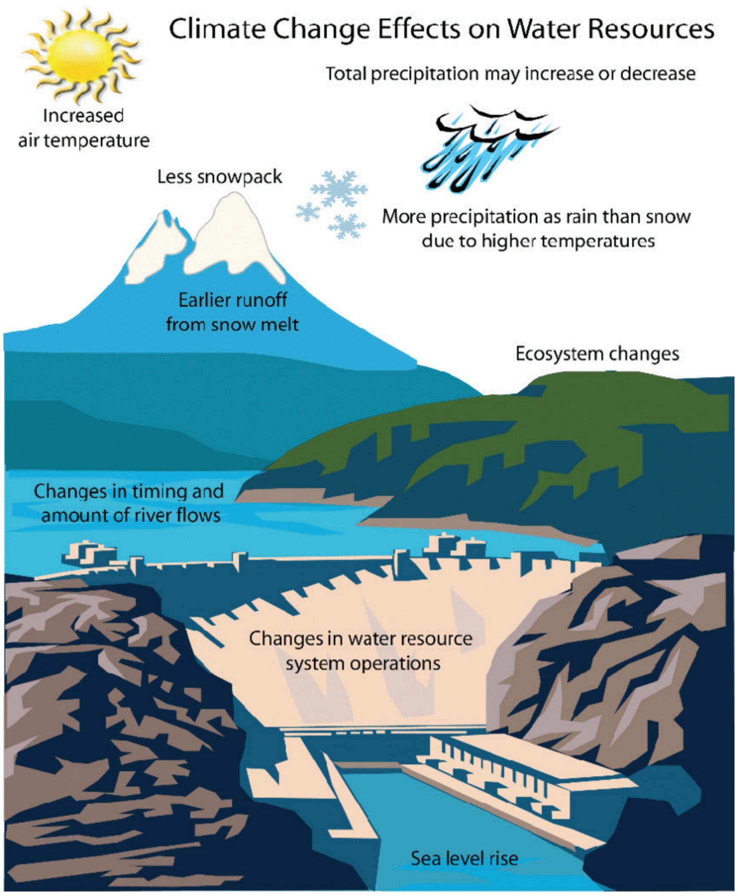


**Figure 4:** *Climate change effects on California water resources. Source: California Dept. of Water Resources.*

## The Work Continues

We continue to support the Authority in obtaining a water right and permits under the Clean Water Act, state and federal Endangered Species Acts, National Historic Preservation Act, Bald and Golden Eagle Protection Act, California Streambed Alteration Agreements, and the other dozen or so key permits that would allow construction and operation of the project. Our goal is simply to support the Authority and its consultants in achieving the goals and objectives of the $4 billion project. Our work extends beyond the several key insights and lessons learned described above as final CEQA/NEPA documents and permits need to be obtained and the terms and conditions implemented. The project also has a several-hundred-million-dollar mitigation and adaptive management program to implement, which we will support. To do so, we will continue to look for ways to expeditiously carry out the program oversight, technical review and daily support tasks that move the project from the current planning and permitting phase into construction and ultimately operation.

For more information, please see: [https://sitesproject.org](https://sitesproject.org)


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# Return of a Legend:

## Reimagining a New York Fishery

*By Dave Davis - Project Manager, Mahwah, NJ*

*Salmon in the Columbia River, Oregon.*

In Norman Maclean's novella, *A River Runs Through It*, the movement of water is a metaphor for the passage of time, and fishing represents a symbolic expression of one's eternal search for understanding. "Poets talk about the 'Spots of Time' but it is really fishermen who experience eternity compressed into a moment," writes Maclean. "No one can tell what a spot of time is until suddenly the whole world is a fish and the fish is gone."

In western New York state, the sinuous tributaries of Lake Ontario, fed also by flow from the historic Erie Canal, create a similarly mythic connection of waters and fish, representing home to a world-class salmon and trout fishery. Each fall and into winter, these streams abound with massive trout and salmon that surge upstream from Lake Ontario into streams small enough to cast a fishing line across. Just below the surface lies a diverse population of Chinook and coho salmon, Brown trout and rainbow trout, or "steelhead" driven upstream into narrow waters by their instinct to complete an epic life history and journey to their natal spawning grounds. Every fall, throngs of eager anglers await the arrival of these lake denizens into their favorite streams such as Oak Orchard, Sandy, Eighteen Mile and Johnson Creeks.

The movement of trout and salmon from Lake Ontario into tributary streams can be stimulated by high water events such as a rainstorm or regulated releases of water from the Erie Canal, which is hydraulically connected to several Lake Ontario tributaries. In addition to drawing fish into the tributaries, the scheduled higher flows also create more predictable angling opportunities, provide fish cover and opportunities for fish to disperse throughout the stream, and offer a more enjoyable angling experience. The "Reimagine the Canals" team at the New York Power Authority saw an opportunity to support and enhance the tributary fisheries by scheduling releases of water from the Erie Canal during the fall salmon and trout season.

In 2020, the New York Power Authority (with input from the New York State Department of Environmental Conservation), supported by HDR, developed a fisheries pilot program to determine if the use of canal infrastructure to mimic "natural" high-flow events would trigger fish to run upstream, thereby resulting in enhanced recreational fishing in Lake Ontario tributaries. From September to December 2020, water releases from canal waste gates were modified to enhance tributary fisheries. Data collection efforts included collecting discharge data from U.S. Geological Survey gauges, temperature and dissolved oxygen monitoring in the canal and the receiving tributaries, an angler survey to assess the impact of the water releases on the fishing experience along the tributaries, and interviews with stakeholders to provide feedback on the program. Pilot study streams in 2020 included Oak Orchard and Sandy Creek.

Our team was hired by the NYPA and New York State Canal Corporation to provide fisheries technical assistance to the program by evaluating water releases, overseeing a creel survey conducted by SUNY Brockport, conducting stakeholder interviews, preparing recommendations for future seasons, conducting a pilot acoustic study, and preparing a pilot study and final report for the program. The diverse skill sets of our team were used to support the technical and recreational fishing aspects of this unique project.

### Evaluation of Project Discharges

The summer and fall of 2020 were exceptionally dry, and prior to the infusion of the supplemental canal water, program streams were near historically low levels. Project stakeholders reported that low water levels negatively impact the fishing experience. Impacts are varied but can include fewer fish attracted to streams and crowding in smaller pools for those returning fish. Due to the resultant fish stress, individuals in pools experience increased angler pressure given the densely stacked fish and reduced catch. Following the release of water primarily from Lake Erie (which is less impacted from drought conditions) through the Erie Canal gates, downstream fishing areas were quickly lifted out of drought conditions and into water levels much better suited for fishing. The ability to release supplemental water from the Erie Canal into streams is a great insurance policy against dry seasons and provides predictable fishing conditions that enhance the angling experience. This water management approach consisted of creating periods of elevated base flow to the tributaries where a moderate amount of supplemental water from the canal was provided, as well as multiple high-flow events where a greater amount of water was provided to simulate a large rainstorm.

To monitor the pilot program releases and put them in the context of historical flows within each stream, available daily discharge data from USGS gauges was reviewed and processed to produce monthly flow exceedance curves and percentile tables for each program stream.

Our scientists used a custom-developed statistical script (or analytical automation) to gather, process, analyze and plot this discharge data. This tool makes analysis efficient and repeatable for future seasons or additional streams. Our team used summarized flow data and the USGS Stream Stats tool to develop informed recommendations for target canal release volumes in the future.

## Stakeholder Feedback Interviews

The Reimagine the Canals Fisheries Program was developed by NYPA staff in close coordination with NYSDEC fisheries biologists and an engaged fisheries stakeholder community. During the 2020 pilot season, our team conducted several interviews with a diverse group of stakeholders affiliated with the fishery and the canal. Stakeholders included fishing guides, a tackle shop owner, active anglers, a county tourism official, the Canal Corporation operations and maintenance lead and a group of NYSDEC fisheries biologists. The opportunity to directly interface with this group of stakeholders was an informative and fulfilling experience. These stakeholders provided constructive feedback on the pilot program releases, schedule and a wealth of information about the fishery. Their feedback was instrumental to the development of recommendations for future seasons.

## ARIS Pilot Study

The Reimagine the Canals Fisheries Program provides a unique opportunity to evaluate the movement patterns, timing and number of salmonids entering Lake Ontario tributaries. Direct measurement on the timing and number of salmonids entering tributaries would provide an independent measure of the influence of program flows on fish movements and could help inform future flow programs, as well as provide opportunities for citizen science and public engagement.

In 2020, we performed a pilot study to evaluate options to monitor the movement of fish into Oak Orchard Creek and other tributary streams. The gear selected for evaluation was an Adaptive Resolution Imaging Sonar by Sound Metrics. This acoustic camera uses sound to “see,” which provides a video-like image similar to an HD sonogram and can be used effectively in no-light and turbid environments. ARIS systems have been successfully employed to monitor runs of Pacific Salmon in the Pacific Northwest, and Dual Frequency Identification Sonar, a predecessor to ARIS, has been used to

*HDR’s employee conducting a pilot study to evaluate options to monitor the movement of fish into Oak Orchard Creek and other tributary streams.*

*Lake Ontario sunset.*

monitor the migration of Lake Sturgeon on the Winooski River in Vermont. ARIS imagery can provide a detailed view of underwater environments and has numerous underwater inspection applications (its original intent when first developed by the Navy). Remote sensing gear such as the ARIS does not require capturing, handling or tagging of fish, which is ideal given the recreational value of the study fish and the level of effort involved with tagging studies. The ARIS transducer generally can have an effective monitoring range of up to 30 meters (depending on camera model), which is sufficient to span the width of program tributaries.

The data collected by the ARIS unit provides an engaging, video-like format that may be of interest to members of the public and could promote engagement with the fishery. As an example, students and volunteers have reviewed underwater video of migrating river herring on Town Brook in Plymouth, Massachusetts.

In December 2020, we conducted a site visit and trial implementation of the ARIS system at Oak Orchard Creek. We surveyed Oak Orchard Creek from the Waterport dam downstream to the main lake for potential locations to install the ARIS system. Consideration was given to site security, intensity of angler use, electrical power, access, position within the watershed, channel width and morphology. We fabricated a custom metal mount system for the ARIS transducer, and the unit was deployed at multiple locations in Oak Orchard Creek. The ARIS unit was able to successfully record the movements of fish through the transducer beam at a variety of ranges. Fish were observed passing upstream and downstream. When deployed along the channel edge in Oak Orchard Creek, the 30 m beam from the ARIS unit could span the width of the river. It is possible to estimate the size of passing fish targets, but based on the resolution of the acoustic video imagery, it is generally not possible (or prudent) to speciate the fish with certainty. In instances where fish are uniquely shaped, species identification can be attempted, but in the current area, fish morphology (shape) was too similar. However, based on the review of size of swimming motion of passing targets, it is likely possible to identify targets as adult salmonids. Estimated lengths of passing fish were consistent with those of adult salmonids.

## Report and Recommendations

We prepared a comprehensive report documenting the 2020 pilot program activities and provided a number of technical and non-technical recommendations for NYPA to consider during potential future seasons of the Reimagine the Canals Fisheries Program. The recommendations also considered several points raised by the project stakeholders. These recommendations included suggestions for canal release schedules, volumes, flow monitoring, enhancements to public fishing access, continuation of a creel survey, public engagement programs and additional coordination with Environmental Conservation Law Enforcement.

The Reimagine the Canals Fisheries Pilot Program was implemented again during the 2021-22 winter season and incorporated a number of the recommendations in the 2020 report.

Overall, the project represents many important meanings to all those involved. Protecting natural resources by adapting existing infrastructure is a success story for the state and programmatic managers. Improving and protecting the fishery is an important cultural and emotional tie to anglers and those who simply love nature. Finally, for the HDR teams involved, the study represents creative methods, exciting interactions with interested parties and a sense of pride to be part of an excellent program offering so many benefits.

To learn more about the Reimagine the Canals Fisheries Program, visit the Canal Corporation website: **Canal Fall fishing** (*www.ny.gov/programs/reimagine-canals-initiative*).

*Contact Dave Davis at david.davis@hdrinc.com or at +1 (201) 335-9352 for more information.*

# Master Planning

## for Killer Whales

*By Chad Wiseman - Senior Environmental Scientist, Olympia, WA*
*and Becky Holloway - Senior Environmental Biologist, Gig Harbor, WA*

*A killer whale jumping out of the water.*

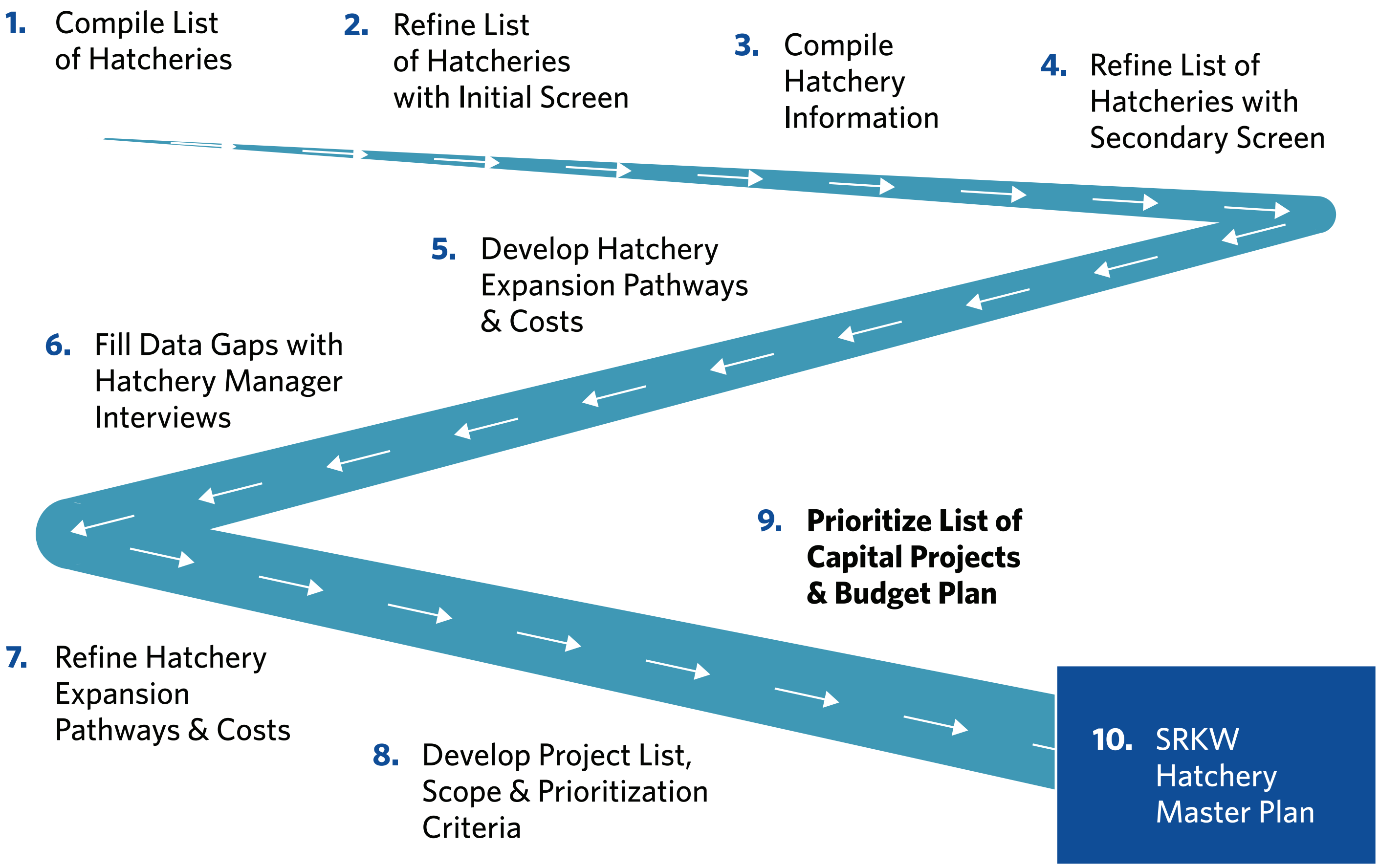
The Salish Sea is an integral feature of the Pacific Northwest that has been used for thousands of years for transportation, trade and sustenance. It's an "inland sea" composed of the Strait of Juan de Fuca, Puget Sound, Hood Canal, the San Juan Islands, the Gulf Islands and the Georgia Straits. This inland sea has many endearing attributes that make it part of the region's unique culture and identity. The most iconic representatives of the Salish Sea are the Southern Resident Killer Whales (SRKWs; Orcinus orca), which are native to the region and distinguished as a Distinct Population Segment by the National Marine Fisheries Service.

In the Pacific Ocean, killer whales exhibit several life histories including transients, offshores and residents. Transient and offshore killer whales forage primarily on marine mammals and sharks, respectively. However, resident killer whales like the SRKWs have evolved to forage on fish, with salmon as their preferred prey items in the Salish Sea and along the 1,000-mile stretch of the Pacific Coast. In fact, in the summer and spring when SRKWs occupy inland waters of the Salish Sea, they feed almost exclusively on Chinook salmon (Oncorhynchus tshawytscha), and for good reason. The Salish Sea and adjacent coastal waters are migratory corridors and foraging areas for historically large salmon runs emanating from Columbia River, Fraser River, coastal and Salish Sea rivers. Historically, the Salish Sea was an ideal habitat for killer whales, as there was very little pressure on the habitat and prey they had evolved to exploit.

Pressure has been brought to bear on SRKW habitat over time, and along with other limiting factors, SRKWs are now listed as an endangered species by the state and federal government. Despite these regulatory protections, the population continues to decline in both fitness and abundance and has recently dropped to only 73 individuals — the lowest level in over four decades. SRKWs face several complex threats: a severe reduction in salmon prey items (particularly Chinook salmon), disturbance from noise and vessel traffic, toxic contaminants and emerging effects of climate change. The current lack of Chinook salmon availability is believed to contribute to poor SRKW health and reproductive failure.

*A Chinook salmon.*

Increasing the availability of Chinook salmon for SRKW consumption is one of the many tools that could contribute to SRKW recovery. Increased Chinook salmon prey availability could be achieved in several ways, including increasing natural and hatchery production. Programs intended to increase natural production through restoring habitats, correcting fish passage barriers, improving survival through the hydropower systems and decreasing predation of juvenile salmon are state and federal priorities and the subjects of ongoing implementation. Increasing hatchery production at existing and proposed new state facilities may more immediately increase SRKW prey availability. Combined with habitat improvements to address pollutants (including contaminants and vessel noise) in SRKW marine waters, increasing natural and hatchery Chinook salmon production may provide the best chance to assist SRKW recovery.




*Schematic of the Southern Resident Killer Whales' hatchery master plan that HDR developed in partnership with the Washington Department of Fish and Wildlife.*

In 2018, Washington Governor Jay Inslee established Executive Order 18-02, directing a task force to recommend immediate and long-term actions to benefit SRKWs. Of these, one recommendation was to increase hatchery production by 50 million smolts (i.e., juvenile salmon). To meet this goal, since 2018, the Washington Department of Fish and Wildlife, as well as several tribes and one utility, have increased hatchery production at existing facilities through modified operations and maximized facility use. These efforts increased hatchery production by over 26 million anadromous salmon (of all species), including over 9 million Chinook salmon. In concert with these efforts, the Washington state legislature directed the WDFW to develop a SRKW Hatchery Master Plan that would define a roadmap to increase the production of hatchery Chinook salmon to benefit SRKWs in a manner consistent with existing state and federal policies.

To that end, the WDFW partnered with HDR in July 2020 to develop the master plan. We led the planning process with expertise in hatchery planning, design, cost estimation and an economic-based benefits risk analysis. WDFW worked very closely with our team to facilitate information exchange and leverage the critical knowledge of WDFW regional and hatchery managers. WDFW used information expressed in previous informal discussions with co-managers to, in turn, leverage their knowledge and expectations for stock management. Co-manager consultation is important and will continue consistent with WDFW policy for communication, coordination and consultation with tribal governments. Close coordination was important not only for information exchange but also because of the short project timeline and challenges from COVID-19 work restrictions. Because legislative funding was not available until the beginning of the fiscal year (July 1, 2020) and the master plan was due to the legislature by January 15, 2021, the planning process was compressed into a very aggressive schedule. COVID-19 work restrictions required all meetings to be held virtually with limited site visits.

## Facility Screening

To develop this master plan, the WDFW and HDR team implemented a screening and planning process. The screening evaluation helped the team target hatcheries for further evaluation and project development. An initial screening step removed from consideration most non-WDFW-owned hatcheries (with a few exceptions), state hatcheries that do not produce salmon, and hatcheries that may not produce additional Chinook salmon, pursuant to the Endangered Species Act and recovery plan production limits. For ESA constraints, a facility was only screened out from further consideration if successful re-initiation of ESA consultation (for increased production) was unlikely. The goal of ESA constraints is to protect the genetic integrity of native salmonid stocks in the watersheds where hatchery production is occurring.

Mixing of adult hatchery and native salmon of the same species in the same river may lead to genetic mixing, which, over several generations, may decrease the genetic integrity of the native stock that has evolved to specific conditions in that watershed. These constraints are documented in the recovery plans crafted by state, federal and tribal co-managers.

The second screening step characterized the refined list of hatcheries to better understand their capacity for expanded production. Additional facilities were removed from further evaluation based on site-specific factors, including land and water availability to support new development, or hatchery production constraints under existing state and federal policies including the ESA. This evaluation required a “deep dive” into facility details, such as water rights, water infrastructure, land availability, management objectives and constraints. These remaining hatcheries were further evaluated as projects.

Finally, two new WDFW hatcheries were proposed as part of this master plan: the Deschutes River Hatchery and the Cowlitz River Hatchery. These hatcheries were proposed because of their potential for large contributions to the goal of 50 million new salmon smolts and their consistency with regional recovery plans and tribal co-manager support.

## Project Definition and Cost Estimating

The next step in the master planning process was to define the improvement and expansion projects at each facility that passed through screening, and then prioritize these improvements based on specific criteria. For each facility, potential Chinook salmon production, new infrastructure requirements (e.g., incubation and rearing units, flow rates, additional water needs), and costs were developed. Proposed infrastructure improvements and costs were defined in the context of the WDFW’s existing 10-year capital plan for hatchery infrastructure. The CP targets infrastructure improvements necessary for the maintenance of the state's hatchery facilities, regardless of the SRKW prey enhancement directive. For example, if a CP project was occurring at a facility, those improvements may affect the nature or timing of a SRKW Hatchery Master Plan project.

Hatchery improvements incorporated Partially Recirculating Aquaculture System components, whenever feasible, to increase their hatchery system resiliency over time. PRAS reuses water with treatment and can produce a given quantity of salmon with less water than traditional “single-pass” methods. WDFW recognized that increasing pressure on Washington’s surface and groundwater resources, along with climate change, will make it harder to meet existing fish production goals. Incorporating PRAS whenever feasible can mitigate these current and future water resource limitations, while increasing capacity for production. By incorporating PRAS into the master plan, the WDFW is charting a new course for modernization of their hatchery system.

## Project Prioritization and Budgeting

Following the identification of potential expansion projects, WDFW and HDR bundled the facility improvements into pathways. In some cases, these pathways included more than one facility to expand Chinook salmon production; however, most pathways were contained within a single facility. Pathways also included acclimation and release at existing or new marine net pens. Each pathway was prioritized based on prey availability, co-manager consultation, consistency with ESA regulations, constructability and water availability, and cost-benefit ratio.

The prioritization scoring and capital costs were used to develop an implementation schedule and budget request for SRKW prey enhancement pathways proposed in this master plan for each fiscal biennium, through FY 45-47. Cost centers for each biennium included predesign, design and construction. In some cases, construction for one project exceeded one biennium. The implementation schedule was developed relative to an approximate biennial budget of $15 million, plus applied escalation.

### PRIORITIZATION CRITERIA

- SRKW Prey Availability
- Comanager Consultation
- Consistent with ESA
- Constructability and Water Availability
- Cost Effectiveness

## Conclusion

The master plan identified a Chinook salmon production increase of approximately 36.425 million fish from improvements at existing facilities and from two new state hatchery facilities (Deschutes River Hatchery and Cowlitz River State Salmon Hatchery) that would support SRKW prey production. When combining the master plan targets, WDFW's ongoing annual program of over 9.125 million Chinook salmon for SRKW prey enhancement, and 5.35 million Chinook salmon from tribal and utility production initiated in 2018, the total potential goal for Chinook salmon (approximately 51 million) now exceeds the EO 18-02 goal of 50 million Chinook salmon smolts.

During implementation over the next several biennia, projects must undergo co-manager consultation, consider the need for coordination with landowners for facility development, compliance with environmental regulations, compliance with dynamic hatchery programs and policies, coordination with public interest groups, and implementation of long-term monitoring plans to verify the programs are meeting established goals and objectives. WDFW will coordinate with co-managers and regulators on policies established under the ESA to confirm the long-term viability of proposed production pathways.

WDFW will continue to coordinate with other partners, including federally operated hatchery facilities, tribal hatcheries, upper


Columbia facilities and private facilities, to determine if additional SRKW prey enhancement is possible in concert with ongoing production and the production goals recommended herein. Consultation with the Oregon Department of Fish and Wildlife will also occur to determine if Columbia Basin hatcheries in Oregon have the capacity to participate in the effort to enhance salmonid prey for SRKW.

Implementation of the master plan and realization of its benefits to the SRKW will occur cumulatively over the next several biennia. Immediate production increases from available capacity (9.125 million from the WDFW and 5.35 million Chinook from tribal and utility production) will be followed by cumulative implementation of the SRKW Master Plan projects. The benefits of these production increases will need to be monitored in terms of actual prey availability to the SRKW, contributions from natural Chinook production, and in the context of other challenges to SRKW population viability, such as disturbance from noise and vessel traffic, toxic contaminants and the emerging impacts of climate change. As development in the Salish Sea watershed intensifies over time, careful management of our resources becomes increasingly important. Hatchery master planning, incorporation of technology such as PRAS and coordination with co-managers are vital to contributing to the future viability of the SRKW.

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# Hands Off!

## Assessing Aquatic Ecosystems with eDNA

*By Gabe Kopp - Fisheries Lead, Sacramento, CA*
*and Tom Thompson - Senior Fisheries Biologist, Raleigh, NC*

*DNA strand.*

Imagine a real-world tool that can detect the presence of a living being by filtering water it recently was exposed to. Sure, you might see a similar cutting-edge method on a late-night investigation show on TV, where a person in a tailored lab coat stares at a vial of liquid in a dimly lit laboratory. Interestingly, half of that primetime TV depiction is actually true — the incorrect component is a dimly lit lab (no genetic labs are ever that dark).

Researchers have developed a methodology to identify individuals of a species by filtering their shed environmental DNA, or eDNA. Essentially, as you move through the earth, you slough off bits of DNA that can be amplified and analyzed. So, the next time you go swimming in a pool, you can only imagine the slurry of eDNA floating around you. Nonetheless, the potential applications for this tool are incredible.

So how does eDNA work? A sample of DNA can be collected in water, soil, sediment or from a surface swab. The DNA is then extracted, purified and amplified for analyses. Analyses are completed through a quantitative polymerase chain reaction, or qPCR, by which a known signature for mitochondrial DNA, or mtDNA, is sought after and identified. Analyses can be used to look for a single species or more broadly identify which communities of species are found within each sample.

Factors affecting the persistence and transport of eDNA in a waterbody, like degradation and transport, can be addressed and evaluated by study design, such as more frequent sampling on temporal or spatial scales, as needed. Different species groups may shed eDNA at different rates. Fish and macroinvertebrates shed relatively large amounts of eDNA to the water column. Submerged aquatic vegetation typically sheds eDNA in detectable amounts during senescence in late summer and fall, indicating a need for seasonal-based sampling if aquatic macrophytes are of interest. The goals of the project and species of interest dictate the study design.

There are numerous advantages to using eDNA for species presence detection. Finding rare species can be very difficult. Using methods to visually hunt and identify cryptic or otherwise well-hidden individuals that are few in number can take countless hours. More aggressive sample approaches to capture and catalog species distribution are less palatable for populations with distressed population status. Also, detecting the presence of an invasive or undesired species as well as pathogens can be critical for natural environments or even commercial applications, such as rearing ponds for planting in public lakes. In addition, eDNA may be used to assess harmful algal blooms in public waters. Using eDNA allows for a rapid sample collection effort and detection without ever handling or observing the individual. Therefore, the approach is less impactive and time-saving.

The database of mitochondrial DNA signatures for species identification is large and growing. However, if you encounter a species that has not been analyzed, a reference sample of DNA is required to develop a species profile. Archival catalogs of both common and rare species are readily available, and even aged DNA can be analyzed to develop a profile in the matter of weeks.

The method just seems too good to be true, so it must be cost prohibitive, right? Surprisingly, no. Lab analyses for species identification for small- to moderate-sized projects often cost tens of thousands of dollars after the effort for field collection. In the end, the sample


*Netting a rainbow trout (left). Distribution map from the Camp Far West Project eDNA sampling results (right).*

collection, analyses and results can be completed in weeks for a relatively low fee, making eDNA a true paradigm shift in how we conduct fieldwork, locate species presence and map population distribution.

While the idea of eDNA may seem new or untested, the actual method has been around for over a decade and has undergone a wealth of examination. In recent years, eDNA has become an acceptable approach for scientific investigation in regulatory processes, such as a Federal Energy Regulatory Commission relicensing of a hydropower facility. HDR has implemented eDNA investigations on multiple different FERC projects with successful outcomes and results that passed regulatory scrutiny.

## South Sutter Water District – Bear River, Northern California

The South Sutter Water District recently needed to complete the regulatory process to relicense its hydropower operations as part of the Camp Far West Project and receive approval for another 30 to 50 years of license of operation by FERC. During investigation to understand the aquatic resources in the Bear River, a request was made to document the status (presence or absence) of rainbow trout, Chinook salmon, green sturgeon, and white sturgeon. All of these species can be difficult to monitor, and regulatory protections are provided for steelhead and green sturgeon, limiting more aggressive sampling approaches. Sturgeon in particular are a very difficult species to identify due to their preference for deep water and ability to rapidly avoid detection.

Our field biologists mobilized to collect 50 samples in spatial intervals along the entire length of the river. Staff adapted a customized backpack-mounted peristaltic pump system to actively filter water across a specialized filter. As water was filtered, genetic material was left behind. The filter samples were handled using best practices commonly applied for water quality sampling. The filters were kept cool in an ice chest that was readily provided to a local genetic lab for testing and reporting of results.

Overall, our field team was able to conduct the river sampling in a little over one week with only two staff. The crew rigorously sampled the entire river, which would have otherwise been a much longer and more labor-intensive effort using past standard practices. The results of the study confirmed the presence of salmonids and also provided insight into the absence of sturgeon during the survey (both green and white). Regulatory representatives suggested a likelihood that sturgeon were present, but the data reflected otherwise. Data provided direct support for focusing mitigative actions by the district to only address known species in the basin and limited the requirement for extra effort that was not necessary.

## California Department of Water Resources – Piru Creek, California

The California Department of Water Resources operates the South State Water Project, which includes a number of large facilities and complex interconnections for generation of power and distribution of water. Similar to the Camp Far West Project, CDWR was required to complete a FERC relicensing process to allow for future operation of its hydro facilities. During the environmental investigation into aquatic resources, it was determined that a survey was needed to document the presence and distribution of Santa Ana Sucker, arroyo chub and rainbow trout. Given the small number of sucker and chub potentially present, a non-invasive approach using eDNA was selected.

During technical study development, it was realized there was not a DNA barcode or genetic species voucher for the Santa Ana sucker or arroyo chub. By working with local resource agencies, we obtained a preserved DNA sample for each


*Filtering water for an eDNA sample (left) and field data collection (right).*

species. The sample was then processed by a genetic lab to allow for identification from eDNA samples. Uniquely, the study provided the first usage and development of genetic species identification using eDNA for both species.

Following development of species markers, our field biologists collected filtered water samples for eDNA. The area of survey interest was the Pyramid Reach of Piru Creek (tributary to the Santa Clara River), downstream of Pyramid Dam, with 60 samples and duplicates. Sites were spaced every 500 meters over 18.5 miles. Sampling was conducted twice in the spring of 2018. By employing a custom frame-mounted pump, the team was able to effectively mobilize into remote areas to conduct the sampling successfully.

## Navigating Piru Creek

The results of the study documented the presence of all target species and mapped their distribution. Interestingly, the study also found that hybridization was occurring between the Santa Ana sucker and the Owens sucker. The hybridization indicated that the Santa Ana sucker population was not a distinct genetic unit and helped to revise management needs for the future of project-required activity.

## Conclusion

Recent project successes during highly scrutinized regulatory processes have tested the efficacy of the technique and found the results to be sound. Further, the cost efficiency, reduced field effort and minimal permitting requirements all build upon the many benefits of the application. Our field team specializes in obtaining and interpreting eDNA studies and has partnered with prestigious labs to ensure the best overall project. We are excited about the future of using eDNA in a number of varied and diverse applications.

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# Fisheries Ecohydraulics:

## Solutions in a Changing Environment

We offer a nationally diverse team of experts focused on the integration of complex ecohydraulic principles involving ecology, biology, hydraulic design and surface water resource management. Our Fisheries Ecohydraulics Practice brings decades of experience to solve unique challenges facing our clients. Through collaborative problem-solving techniques, we offer solutions that deliver the delicate balance between owner infrastructure, regulatory requirements, public resources, economic investment and sustainability.

Our multi-disciplinary working environment is influenced by the complex needs of fisheries and aquatic systems of all types, with a strong emphasis on technical fish passage, water crossing design and stream restoration. Our Fisheries Ecohydraulics team has established a broad range of expertise and full suite of support services to provide the most advanced directive fish transport systems at high dams, geomorphic approaches to barrier removal or modification and natural channel/habitat designs for river restoration projects, among decades of additional successfully completed project examples. A few are showcased in the following pages.

### ALAMEDA CREEK DIVERSION DAM FISH PASSAGE AND SCREENINGS IMPROVEMENTS

San Francisco Public Utilities Commission, California

We developed fish passage and screening improvements at San Francisco Public Utilities Commission's 31-foot-tall Alameda Creek Diversion Dam. We conducted a feasibility study to develop and evaluate alternatives. The final design included a 550-foot-long fish ladder, which successfully excluded specific fish.

**QUIOTA CREEK FISH PASSAGE ENHANCEMENT**

Cachuma Operation And Maintenance Board, California

We prepared a Fish Passage Assessment and Enhancement Plan, provided modeling and design, and coordinated with state and federal fisheries agencies for the Cachuma Operation and Maintenance Board. The design team also provided grant writing support, assisted COMB in leveraging over $5 million in construction funds and has provided construction oversight for numerous crossings.

**MIDDLE FORK NOOKSACK RIVER FISH PASSAGE**

City of Bellingham, Washington

When completed, this project will achieve a major objective in the regional efforts to increase natural reproduction of Puget Sound Chinook salmon. We were selected to summarize alternative concepts, develop a selection methodology and carry the preferred alternative through construction plans and specifications and a cost estimate. We also managed a large team of subconsultants and coordinated with multiple federal, state and local agencies.

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## BIG BAR LANDSLIDE RESPONSE

Fisheries and Oceans Canada

We were retained to provide ecohydraulic services in response to the 2018 Big Bar Landslide. These services included emergency response assisted transport and permanent vertical slot fish ladder design.

For the emergency response assisted transport, we rapidly assessed 150 alternatives, recommended the top two, and provided preliminary design, final design and engineering services during construction under a severely constrained timeframe. We designed a temporary fish passage system to transport upstream migrating fish around the slide during the 2020 and 2021 migration seasons. In 2020, the selected temporary fish passage system included a block fishway, a holding gallery, incorporation of a 6-lane Whooshh fish transport portal, steel hangers mounted on a vertical rock wall and six transport lanes extending 300 meters upstream of the slide. In 2021, we created a revised fish transport design that relied on a trap and haul strategy using off-road rock trucks modified with fish transport vessels.

In addition to emergency assisted transport designs, we assisted Fisheries and Oceans Canada in preparing reference designs and implementing a design-build contract for a permanent technical fish ladder.

*Photos provided by Fisheries and Oceans Canada*

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