Mokelumme River Project

LOCATION:

Woodbridge, Calif, USA

SUBMITTING FIRM:

GHD

FIDIC MEMBER:

American Council of Engineering Companies (ACEC)

Introduction

Newspaper headlines read, "*Salmon season cancelled in Pacific Northwest rivers.*" This belated act of conservation was the result of a dwindling population of salmon migrating to Central and Northern California rivers. Coho salmon and steelhead had been placed on the Endangered Species Act list as "Threatened" in 1991 and as "Endangered" in 1994. Efforts to restore streambed habitat increased in the late 1990s including the commencement of projects to improve fish passage facilities on selected rivers and streams. A moratorium was placed on the construction of dams and serious discussion ensued on the removal of some existing dams to improve migration conditions. One of the few California dams approved for construction in recent years was built on the Mokelumne River and is the subject of this submittal.

In 1910 the Woodbridge Irrigation District (WID) constructed a concrete buttress and timber flashboard structure on the river for the diversion of a 414 cfs water right entitlement to irrigate 38,700 acres of rich delta farmland. Because the Mokelumne River was a well known salmon and steelhead migratory stream, a crude fish ladder was incorporated in the dam's construction. This original fish ladder was abandoned in 1947 and replaced with a new ladder. However, the ladder technology at Woodbridge soon became obsolete and the annual run of salmon and steelhead declined rapidly to where in 1995 no steelhead were counted at Woodbridge and the salmon run was nearly non-existent.

The WID needed to replace its aging and technically obsolete diversion structure and, recognizing the need to improve streambed conditions for migrating fish, embarked on a project that would take three years in planning and design and another two years to construct. The new structure incorporated a massive fish passage facility consisting of both high and low water level ladders for the upstream migration pattern and a pool-and-chute ladder to accommodate the safe return of smolt to the lower reaches of the river and ultimately to the sea. In 1991 less than 400 salmon were counted passing the old WID diversion structure. In 2006, the new facility's first year of operation, over 16,000 salmon were counted as passing through the new ladder facilities and 180 steelhead were returned to the upstream hatchery beds.

Role of Entrant's Firm

GHD was responsible for all structural, civil, mechanical, electrical and architectural designs for a new dam that was to be sensitive in all aspects of the migratory patterns of salmon and steelhead in the river. Designs included streambed restorations that would minimize the threat posed by predatory species, such as striped bass, to smolt returning to the lower reaches of the river. For reasons of economy and local foundation conditions, the new dam was to be built over the actual site of the existing dam and without interruption of annual diversion schedules during construction. This meant that half of the dam was to be built one year, while passing flows through half of the old dam, and half the next year with flows diverted to the new structure. The new structure incorporated ten state-of-the-art pneumatically operated stainless steel gates controlled by a fully automated system keyed to real-time river flows and diversion requirements.

GHD's Contribution

Original or Innovative Applications

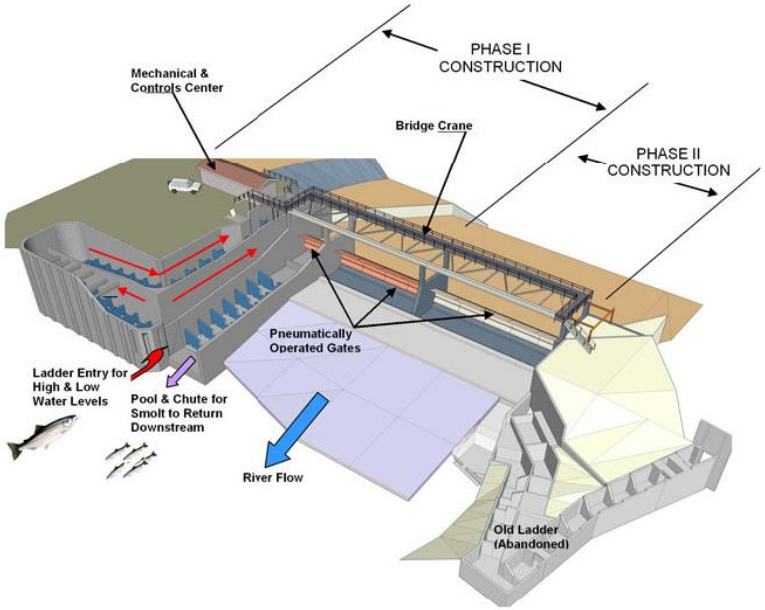
At least two elements of design identify this project as innovative: the construction of a new dam over the top of an existing dam and unique state-of-today's-art fish passage facilities. Locating the new structure at the existing site, not only provided construction efficiencies, but also allowed continued use of the best fish passage site on this winding streambed. The streambed just below the dam, however, needed significant improvement.

During periods of high flows, an area of as much as 12,000 SF would scour a hole up to 6 feet deep immediately below the dam. The existing fish ladder emptied directly into the scour hole, providing a resting area for smolt moving downstream. It also provided a focal point in the streambed for predatory fish, such as stripped bass, to feast on the fingerlings as they arrived. This was devastating to the new crop of smolt. The problem was corrected by filling the scour area with large rock and then graded riprap at the surface. A streambed providing nearly uniform flow bank to bank removed the focal point of predatory fish ambush.

The old dam was a concrete foundation and buttress structure with removable timber flashboards to control reservoir levels. Flashboards had to be added or removed to maintain desirable levels in the Lodi Lake recreation area and allow appropriate diversions into WID's irrigable land. The Mokelumne River carries large amounts of debris during the winter flood seasons. At the end of each irrigation season, all flashboards were removed to allow the river to flush debris through the site. The addition and removal of flashboards on this old structure was the fodder of nightmares for WID's maintenance people. A relatively new gate system was identified that had been installed at a Central Valley site in California. Still under development, the system required site-specific adaptation but appeared to be ideal for the Mokelumne River location. Pneumatically operated 15-foot-wide stainless steel gates in a new 167-foot structure replaced the timber flashboard dam. A network of PLCs (Programmable Logic Controllers) sensing water levels in the upstream recreation area, at the District's diversion canal, at the fish ladder, and downstream of the dam (tailwater) hold lake levels to within 0.02 of a foot of a programmed level. The dam impounds 2,464 acre-feet of water over 474 acres of pristine recreation area.

The trauma-inducing effects of ladder passage were dramatically reduced by limiting ascent increments within the ladders to one foot and providing resting pools at each weir.

More accurate methods of counting fish passing the dam were needed. GHD designed a vault adjacent to the high-level fish ladder with a viewing window into the ladder. A "squeeze box" was designed to force migrating fish into a narrower passageway next to the window and a video camera was set up in the vault to record activity in the ladder 24 hours a day. Remote controlled video cameras were also set up on the low-level ladder and the pool-and-chute for counting purposes there.

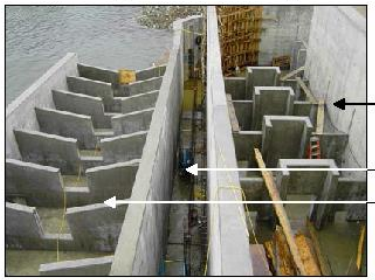


Future Value to Engineering Profession

The Woodbridge Irrigation District project provides guidelines for both streambed restoration procedures and dam structure replacement efficiencies.

Streambed Restoration – In streambed evaluations, it is important to identify all significant hazards to endangered species. Inland streams often provide ideal surroundings for predatory species whose primary food source are the juveniles of other species. A classic example of this type of hazard was a large 10-foot-deep scour hole below the existing fish ladder at Woodbridge. It provided the perfect ambush zone for stripped bass awaiting the arrival of smolt and fingerling steelhead migrating downstream. The template for correction of this hazard was to fill and armor the scour hole creating uniform flow characteristics from bank to bank and minimizing the focused advantage of the predatory bass.

Of even greater value to the engineering profession was a series of three ladders configured to provide the best possible passage facilities for salmon and steelhead. Internationally known fish biologists from federal, state and local resources contributed to these state-of-today's-art ladders. The ladder system provided for safe passage upstream at all levels of



Looking downstream at ladders under construction:

High water level ladder (Note 1' increment weirs and gated weir orifices).

Low water level ladder with weirs not yet poured.

Pool & Chute for smolt returning downstream.

flow in the river and for the return of smolt to the lower reaches of the Mokelumne River.

Dam Replacement Efficiencies – Two things guided the location of the 1910 structure on the Mokelumne River: irrigation diversion requirements and foundation conditions on the river. The latter dictated a site for the dam nearly 1,800 feet downstream from the diversion canal. Careful examination of the existing dam's foundation revealed significant salvageable elements of the structure that could be incorporated into the new dam providing cost-effective construction efficiencies. This included using the existing foundation, once the buttresses were cut off, for energy dissipation ahead of the downstream apron. The existing upstream tie-back grade beam was employed as part of the lateral force restraint system for the new dam. The replacement structure construction was scheduled for two flow seasons so that half of the existing structure could carry runoff while Phase I was being built.

Social, Economic and Sustainable Design Considerations

Once construction of the dam began, local shops and restaurants saw a dramatic increase in business and the community began a downtown facelift that transformed a very old main street to one filled with boutique shops, a widened main street with planted center divide, and a new bridge over the District's diversion canal on the south side of town.

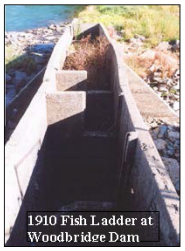
One of the most significant social and economic benefits, however, came from the agreement between the District and the City of Lodi. The City had historically drawn its potable water supply from wells, exacerbating an existing groundwater basin overdraft problem. With the new water resource provided by WID, the City has embarked on the construction of a new 10 MGD water treatment plant that will allow them to cease drawing from groundwater and provide enough additional supply for them to begin an aggressive groundwater replenishment program with treated water from the new plant. The $30 million water treatment plant will generate new jobs, provide improved water quality and accommodate the burgeoning growth of the area.

The Mokelumne River Project transformed a hostile streambed environment into a habitat that will embrace the migration of salmon and steelhead for decades to come and provided WID with a new diversion facility for under $9 million.

Complexity

The focus of this submittal is environmental but construction was affected by some formidable technical issues. They included building a replacement structure at the same location as the existing dam without curtailment of stream flows and site-specific designs for the new impounding gates and their operating and control systems. Foundation conditions in the area emphasized a need to incorporate portions of the existing structure's foundation in the new dam. This was accomplished by cutting the existing buttresses off and incorporating the existing concrete base, piling, and tieback grade beam into the new structure foundation.

The pneumatic gate system had been used previously at the Friant Dam in the Central Valley but with fully different operating and control systems. Also, each of the gates at Friant were operated with a large single pneumatic bladder, which the manufacturer now felt needed to have redundancy in the form of a second bladder at each gate. The Woodbridge dam had served as an impounding structure for one of the San Joaquin Valley's premier recreation areas, Lodi Lake. The recreational impoundment had to be maintained in the summer months while construction was ongoing. This meant a two-season construction period, one for each half of the dam, while flows continued to pass through the structure.


1910 Fish Ladder at Woodbridge Dam

The planning for new fish passage facilities at Woodbridge injected a whole new level of complexity to the project. Monthly progress

meetings were held during design to develop new configurations that would enhance migratory patterns. Required oversight involved detailed input from fish biologists from the Bureau of Reclamation, U.S. Fish & Wildlife, National Marine Fisheries, State Fish & Game, and East Bay Municipal Utility District. Witnessed by designs produced for the 1910 and 1947 structures, fish biology even today is more of an evolving art form than science and individual professional opinions on fish passage configurations vary dramatically.

Over the years, the District's irrigable land slowly gave way to industrial and residential development and the need for its full diversion entitlement diminished. Lodi, the diversion structure's closest neighbor, was growing rapidly and needed additional water for domestic use. The City's need for more water, plus a creative exchange agreement, provided WID with a long-term revenue stream sufficient to enable private bonding for a project that included modern fish passage and monitoring facilities.


1947 Fish Ladder at Woodbridge

Exceeding Owner / Client Needs

The Mokelumne River Project had many unique features and required a functional approach to alternatives evaluation and design. Examples include the phased building of a replacement dam and employing newly developed adjustable weir (gate) technology over an old structure while maintaining both local diversion and stream flow requirements. The design of this structure garnered ten competitive construction bids, the lowest of which was 22% below the engineer's estimate. The budgeted and final costs for the project design were identical at $12.5 million. There were no design-related change orders and substantial completion was obtained in December 2005. GHD's design team met and exceeded all technical and support needs of the District in procuring a functioning state-of-the-art system.

A Unique Project

The project provides today's most technically advanced fish passage facilities in the nation. It considers both high and low level flows in the river, minimizes predatory fish hazards to salmon and steelhead, reduces trauma to adult fish migrating upstream and smolt returning to the sea, and includes state-of-the-art migration monitoring equipment.