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Design of Large Cylindrical Fish Screens for the USBR Lower Yellowstone Project

Darryl Hayes, P.E., *American Society of Civil Engineers, American Fisheries Society*

The Lower Yellowstone Irrigation District diverts up to 1400 cfs into its main canal system on the lower Yellowstone River in Northeastern Montana. In late 2010, as part of a pallid sturgeon recovery program, the USBR and USACE began construction of a new state-of-the-art screened canal headworks structure. After over 100 years of unscreened operations, the new fish screened facility was opened in spring 2012. The headworks will be integrated into a major river gradient fish passage facility being proposed for construction soon. When completed, the new passage and protection facilities will reduce fish entrainment and open an additional 165 miles of river habitat for the endangered and native fishes. The new headwork facility’s fish protection system consists of twelve, 6.5-foot diameter and 25 feet long cylindrical fish protection screens. Each screen is designed to seal over the intake’s submerged sluice gates spaced along the 350-foot long riverbank facility. An integrated and flush-mounted track system was built into the vertical concrete walls to raise the screens in the non-irrigation season for protection from the significant ice and flood flows common on the river. When the 71-mile long irrigation canal is operational, each screen is lowered into position and an automatic brush cleaning system is used to keep the 1.75 mm wedgewire slots from clogging. The new intake facility was physically modeled at the USBR Hydraulics Lab along with several river fish passage options. The on-river screen design keeps the fish and debris in the river as opposed to traditional off-river screen designs with fish bypass facilities. The cylindrical design also reduced the facility footprint and allows diversions to occur over the river’s wide-ranging water surface fluctuations. This presentation will focus on the design, construction, and hydraulics of the intake screen facility, as well as the initial season’s operational experiences.

Darryl Hayes has been working as the Engineering Manager at Intake Screens, Inc. in Sacramento, CA, for the past 7 years. He has been working on fish protection and passage systems for the past 20 years. He was previously a Senior consultant at CH2M HILL and the Fish Facility Chief at the California Department of Water Resources. Darryl is a Past President of the American Fisheries Society's Bioengineering Section.

Screening Large Irrigation Diversions, Lessons Learned From Screens That Have Worked And Not Worked As Planned

Brent Mefford, P.E., *US Bureau of Reeclamation*

Screening water diversions located on natural channels is and important link in sustaining a native fishery. Migratory species can be especially vulnerable to unscreened diversions as they often move long distances yearly exposing them to multiple diversions. National Marine Fisheries Service (NMFS) fish screen criteria has become the standard for screening both anadromous and non-anadromous fish in the western United States. Both designing and maintaining a large fish screen to meet hydraulic criteria can be challenging. This paper covers a number of case studies and research that highlight important lessons learned in the design, operation and maintenance of larger fish screens. Case studies will be used to illustrate many important design issues on screen layout, orientation to channel flow, achieving flow conditions that assist with debris management, dealing with biofouling and use of isolation gates. Post-construction corrective measures that can be implemented when screen flow conditions don’t quite turn out as planned are also presented. Screens located in California, Nevada and Colorado are discussed.

Brent Mefford is a hydraulic/fish passage engineer at the Bureau of Reclamation's Technical Service Center in Denver, Colorado.

He has 30+ yeas experience designing and researching fish passage and screening.

Predator Densities And Associated Salmonid Smolt Mortality Around Water Diversions

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State-of-the-art fish screens on large water diversions effectively prevent juvenile salmon from being entrained by the diversion, but the physical structure and their prey-concentrating effect may attract predators and create a local predation problem. We are assessing the impact of predation near two large diversions on juvenile Central Valley Chinook salmon (Oncorhynchus tshawytscha) using a combination of acoustic telemetry, a DIDSON camera, and tethering. We expect to answer these questions:

(1) Is predator density higher near water diversions relative to nearby areas?
(2) Do predators express site fidelity to the diversions?
(3) Is the relative smolt predation rate near the diversions higher than nearby areas? What about seasonal and diel predation rate dynamics?
(4) What proportion of the predators' diets consists of smolts near the diversions?
(5) All factors combined, does this result in higher than average smolt mortality rates near the diversions?

During a pilot season in 2011 on one diversion on the Sacramento River, we gained limited insight into these questions. Predator densities were lowest near the diversion, and highest near the riverbank. Striped bass (Morone saxatilis) did not seem to express site fidelity while Sacramento pikeminnow (Ptychocheilus grandis) did. Finally, relative predation rates around the diversion were near average, with the highest relative predation rates near the riverbank.

In the 2012 season, we added a second diversion representing a different design model, allowing the comparison of predator-prey dynamics between different commonly-used diversion designs. We will present data from this more intensive second season along with a preliminary look at data from the 2013 season. This project was conceived in response to the knowledge gap regarding how large water diversions influence predator-smolt dynamics; the majority of research on the impacts of diversions on salmonids concentrate on dewatering and lethal entrainment into pumps.

Refugia for Juvenile Salmonids at Fish Screens

Steven L. Thomas*, NOAA / NMFS*

Civil structures built on the banks of rivers may replace natural riparian habitat with vertical concrete or steel walls. Examples include fish screens which are designed to have smooth faces to allow fish and debris to move past the screen. Internal bypasses can limit the time exposure of fish to the screen, but only when there is sufficient head to drive the bypass. NOAA Fisheries Service and other agencies are developing concepts for providing refugia areas along fish screens to allow smaller fish to escape the hydraulic influence of the diversion and predators that may take advantage of the lack of habitat at fish screens to prey on passing fish. Steve Thomas will present some of the refugia concepts being considered for larger fish screens on the Sacramento River in California.

Steve Thomas has been a hydraulic engineer with the National Marine Fisheries Service based in Santa Rosa, California since 1997. His has worked primarily on fish screen projects for the Central Valley Project's Anadromous Fish Screen Program which provides assistance to water users needing fish screens or fish screen improvements on the Sacramento and San Joaquin Rivers and their tributaries. He monitors fish screen performance by inspecting screens using SCUBA and conducting hydraulic evaluations.

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A Comparison Of The NMFS And Section 316(B) Of The Clean Water Act Of Fish Screen Criteria

Nathaniel Olken, Jon Black, *Alden Research Laboratory, Inc.*

Both EPA and NMFS have authority to provide regulations and design criteria to protect fish at water withdrawals. The NMFS criteria were created to protect anadromous salmonids and apply to hydropower, irrigation, and other water withdrawals. The NMFS criteria is intended to expedite the permit renewal process for fish screens and bypass designs that are required by various state or federal regulations. EPA is authorized under the Clean Water Act to require compliance with its fish screening regulations. EPA's 316(b) Rule, which is expected to be finalized on June 27, 2013, will be applied on a national level and impact all existing facilities that withdraw 2 MGD or more water from Waters of the US and use at least 25% or more of that water exclusively for cooling, regardless of the species present. This presentation will highlight the differences and similarities between the NMFS and EPA fish protection strategies with an emphasis on the impact of 316(b) regulations in the northwest.

Mr. Olken is a Project Engineer at Alden Research Laboratory, Inc. where he has been involved a wide array of projects to reduce the human impacts on aquatic organisms. His work has focused primarily with Section 316(b) of the Clean Water Act. Mr. Olken has been the lead engineer on over one-hundred 316(b) evaluations for power companies across the country and is an expert in fish protection technologies for use at large water withdrawals. Mr. Olken currently works from Alden's branch office in Portland Oregon.

Red Bluff Fish Passage Project - Design & Construction Challenges For 2,500 CFS Fish Screen

Jeffrey P. Sutton*, Tehama Colusa Canal*, *Authority General Manager,* Robert Gatton, *CH2M HILL,* Peter Rude, *CH2M HILL*

The Red Bluff Fish Passage Improvement Project was a joint design and construction managment effort by the U.S.Bureau of Reclamation and CH2M HILL for the Tehama Colusa Canal Authority to allow up to 2,500 cfs of fish friendly water to be diverted from the Sacramento River to irrigate 150,000 acres of high value crops in three counties. Unique aspects of the fish screen structure included fish refuges and a sediment jetting sytem. The project recieved $114 million of stimulus funding and was operational by May 2012 to meet a Federal Court order.

Mr. Rude, P.E. has been with CH2M HILL for 23 years and has managed several fish screen design and construction efforts for irrigation districts on the Sacramento River over the last 15 years. B.S. in Agricultural Engineering from Colorado State University and M.S. in Agricultural Engineering from University of Arizona.

Fish Passage And Screening On Whychus Creek In Central Oregon

Les Perkins, *Farmers Conservation Alliance*

A three year collaborative design process involving USFS, NOAA/NMFS, ODFW, DEQ, USFWS, Three Sisters Irrigation District, Upper Deschutes Watershed Council, River Design Group, Anderson Perry and Associates, and Farmers Conservation Alliance created a project on Whychus Creek in central Oregon that includes in-stream fish passage, floodplain reconnection, and a low maintenance Farmers Screen. The project was fully operational for the 2011 irrigation season. Three Sisters Irrigation District (TSID) diverts up to 160 CFS from Whychus Creek, a tributary to the Deschutes River. TSID has historically diverted water using a stream spanning low head dam and did not have a fish screen in place. The diversion is located on US Forest Service land in the National Forest where a re-introduction of summer Steelhead is occurring. The project goals included in-stream fish passage at the dam, reconnection of the flood plain, and installation of a fish screen capable of protecting fish while reliably supplying irrigation water through a wide range of stream flows and diverted flows in a system with high levels of glacial silt. The 160 CFS maximum capacity fish screen is the largest Farmers Screen installed to date. The screen is a dual bay design which allows for a very wide range of diverted flows (30 to 160 CFS) while still meeting NMFS criteria. The TSID Farmers Screen has built in sediment management which allows continuous flushing of sediment from under the screen during the high sediment times of the year. The TSID Whychus Creek project is a great example of meeting the needs of both the agricultural community and the environment.

Les Perkins has been with FCA since its inception in early 2006. Les has a Bachelors degree in Biology from Lewis and Clark College and has been directly involved in 27 fish screening and passage projects in Oregon, Washington, Idaho, Montana, and Wyoming.

Practical Aspects Of The Hydraulic Evaluation Of Fish Screens

Peter Grant, PE, Justin Arnold, PE, and Joe Orlins, PE, PhD, D.WRE

Senior Engineer, Principal Engineer, and Director, Hydraulic Modeling & Consulting – Alden Research Laboratory

Significant improvements are being made in fish guidance systems used for downstream anadromous juvenile fish passage such as Floating Surface Collectors at Upper Baker Lake, Swift Reservoir, and Lower Baker Lake. These systems include converging vertical wedge-wire dewatering screens that pass flow pumped by submerged low-head axial pumps. The guidelines by which these systems are designed are set forth by the National Marine and Fisheries Service (NMFS), and require adherence to criteria such as transport velocity, screen approach velocity, and acceleration. As part of the final stage of commissioning, hydraulic balancing and operational evaluation are conducted using velocity and water level meters to adjust baffles for the purpose of distributing flow in accordance with their intended design flows, transport velocity, and screen approach velocity. This paper will discuss the guidelines for design, balancing, and evaluation of these facilities in the context of the practical field operations required to conduct the balancing and evaluation. An account of historical field operations and an analysis of the measurement uncertainties for the instrumentation used and deployment techniques will be provided. A descriptive comparative analysis of the dewatering process between these three projects and the documentation obtained in verifying NMFS criteria have been met will be provided. Lastly, discussion will be provided regarding the correlation between the criteria, how it is measured, and what the documentation validates in terms of fish protection.

Peter Grant has 9 years experience as a hydraulic / mechanical engineer and modeling consultant. He has performed field start-up, including hydraulic evaluation and balancing of fish screens for the Swift Reservoir Floating Surface Collector, White River Diversion screens, Lower and Upper Baker Dams' Floating Surface Collectors.

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Flood Channels: Developing Fish Resting Pools In A Concrete Channel Using Fish Energetics And Hydrodynamic Modeling

Michael Love, P.E., *Michael Love & Associates, Inc.*

Corte Madera Creek in Marin County, California flows through an urbanized corridor before entering San Francisco Bay. It historically supported runs of coho salmon and continues to maintain a run of ESA listed steelhead trout. The lower 6.2 km of Corte Madera Creek is contained within a flood control channel designed by the US Army Corps of Engineers. Most of the flood control channel is tidally influence and provides no impediments to migrating adult steelhead. However, the upper 730 m of channel is above mean lower-low tide, consists of concrete vertical walls and V-shaped floor, and designed for supercritical flow. Prior to floodway construction in 1972, the potential of creating a steelhead depth and exhaustion barrier was recognized. As mitigation, 28 rectangular pools spaced 19.5 m apart were included in the channel. Each pool is 1.2 m long, 4.0 m wide, and have a flat bottom placed 2.5 cm below the channel invert. The outside edges of the pools are 38 cm deep due to the V-shaped bottom. Examination of the flow patterns within the pools combined with observations of steelhead swimming within the channel suggests the existing pools are undersized and provide minimal resting habitat during typical migration flows. As part of a project lead by the Friends of Corte Madera, steelhead passage conditions within the present channel were assessed and conceptual designs were developed for providing fish passage over a wide range of stream flow through improved resting pools. The project team used several innovative approaches to address the problem, including (1) using volunteers to record observations of flow conditions and fish movement, (2) development of a 2-D hydrodynamic model to analyze existing hydraulic conditions and evaluate hydraulic performance of different resting pool alternatives, (3) development and application of a population-based fish routing and energetics model to evaluate passage conditions and determine preferred pool spacing, and (4) use of a 1-D HEC-RAS model to evaluate impacts of the preferred pool geometry and spacing on water levels during the capacity discharge of 153 cms. Project issues addressed include attempting to provide upstream passage at migration flows for an acceptable proportion of the steelhead population, minimizing pool sedimentation, minimizing flooding impacts, and ensuring proposed alternatives are constructible. This presentation will outline the alternatives development process and focus on how combining 2-D hydrodynamic modeling and population based fish passage modeling can provide valuable insight during the design process. The full report is available at the Friends of Corte Madera website: http://www.friendsofcortemaderacreek.org/.

The Utility Of Hydraulic Modeling In Reviewing Fish Passage Engineering Projects

David W. Crowder, *National Marine Fisheries Service, Southwest Region, Habitat Conservation Division*

The National Marine Fisheries Service (NMFS) and other resource agencies frequently review fish passage projects that may affect trust species. What type of hydraulic information is needed to evaluate a proposed project is an important question that project proponents and resource agencies often need to answer. Frequently, the hydraulic information used to design and evaluate a project is obtained through hydraulic modeling. However, selecting an appropriate model (e.g. a 1-D, 2-D, or 3-D numerical model or a physical model) is not always a straightforward decision, as each model has its own pros and cons. Currently, NMFS does not have formal guidelines for determining when a specific type of model is preferable. Experience suggests that every project has its own unique constraints and specific biological goals associated with it. The type of information needed to review the effects and/or suitability of a proposed project should reflect the project's specific constraints and biological goals. Examples of where NMFS has found certain types of hydraulic models to be particularly useful to address both common and unexpected fish passage situations are provided. Factors NMFS considers when evaluating fish passage projects and how this might help guide the selection of an appropriate hydraulic model is also discussed.

David Crowder obtained his B.S. M.S., and Ph.D. in Civil Enginering at Virgia Tech. He subsequently worked at the Illinois State Water Survey before joining the National Marine Fisheries Service 4.5 years ago. His areas of interest include hydraulic modeling, sediment sampling, and fish passage engineering. He has published/coauthored journal articles in the Canadian Journal of Fisheries and Aquatic Science, the Journal of Hydrology, Geomorphology, River Research and Applications, and the Journal of Hydraulic Engineering.

Multi-Dimensional Hydraulic Modeling And Preliminary Monitoring Results For The Mission Creek Flood Control Channel

Jonathon Mann, Mike Garello, *HDR Engineering, Inc., Fisheries Design Center*

A project to provide fish passage in the Mission Creek flood control channel of Santa Barbara, California, has been underway for many years. Flood flows are conveyed through two trapezoidal concrete–lined channel reaches with a combined length of over one mile and present passage barriers to migrating adult steelhead. These passage barriers may lead to complete extirpation of the steelhead populations in the watershed. Therefore, it is necessary to minimize the impact of the barriers on steelhead migration and provide the most favorable hydraulic conditions as practical. The City of Santa Barbara with support from others is planning to modify the two concrete-lined reaches and restore fish passage. Final designs have been completed and one reach of fish passage improvements has been constructed. In the course of detailed design development computational fluid dynamic modeling and other hydraulic analyses were used to optimize fish passage performance, neutralize impacts to flood control and balance sediment transport and associated maintenance requirements. The steps to evaluate and refine the detailed design are presented along with some preliminary monitoring results. This is part of longer term effort to evaluate project effectiveness and performance with the potential to apply similar designs for other flood control channels.

Jonathon Mann is a California Registered Professional Civil Engineer with extensive experience in hydraulic engineering and a special focus on fish passage and stream channel restoration. During the course of his career, Jon worked 9 years with the National Marine Fisheries Service on many fisheries projects throughout California. Jon's more recent experience in private practice includes 8 years of managing many diverse fisheries-related projects all over North America, including preparing conceptual and detailed project designs of complex fish passage systems.

Use Of Measured Data And Hydraulic Models For Evaluation Of Constructed Fish Passage Structures

Joey Howard, P.E., Brian Wardman, P.E., Brady McDaniel, *Northwest Hydraulic Consultants*

Channel wide fish passage structures have been installed throughout the Pacific Coast to allow movement of aquatic organisms, facilitate sediment transport, and provide debris conveyance. These structures are often designed using stream simulation or hydraulic design techniques. Very few of these projects are monitored to assess the post construction hydraulic characteristics and evaluate their performance relative to adjacent stream conditions or hydraulic design criteria. Monitoring is often difficult due to short flow durations and logistical constraints associated with personnel and equipment access. Comprehensive monitoring of hydraulic conditions requires multiple measurements throughout the range of fish passage design flows. These efforts are often costly and difficult to implement. This study investigates the use of episodic flow measurements combined with 2-dimensional modeling over a range flows to evaluate post project passage conditions.

Joey Howard is a river engineer that specializes in fish passage and screen projects in Southern Oregon and Northern California.

Some Aspects Of Fish Behaviour And Hydraulics Which May Affect Passage Effectiveness

Christos Katopodis, *Katopodis Ecohydraulics Ltd.*

Fish behaviour over space, time, life cycle needs and ecohydraulic conditions may affect the effectiveness of upstream and downstream passage systems. The spacial extent of migratory movements may depend on whether available and suitable habitat which meets the life cycle needs of specific species exists only below or only above a barrier, or in both locations. Highly effective passage systems have the following characteristics: a) their use is compelled by the migratory needs of specific species; b) are easy to locate by the migratory fish community as they offer topographical and flow conditions that species seek rather than avoid; and c) combine morphological features and hydrodynamic conditions which match their biomechanical capabilities and are suitable for efficient transport. These factors relate to species motivation (required versus tentative movements), attraction or guidance efficiency (probability that fish will locate the upstream fishway entrance or be actively guided downstream), and passage efficiency (probability fish will move through passage system), respectively. Any one of these factors or any combination of the three may limit overall system passage effectiveness. Field assessments for several species and many passage systems around the globe, supplemented by controlled laboratory studies, have demonstrated considerable variation in attraction or guidance efficiency, as well as passage efficiency. Not surprisingly, biological factors, such as migratory, morphological or ecological characteristics of different species, species abilities, salmonids vs non-salmonids, as well as passage system design features, such as dimensions, velocities, turbulence and appropriate flows, are important. Although available field assessments are based on limited and often non-standardized data, they provide evidence that attraction or guidance efficiency may depend more (but not exclusively) on biological factors. Field and laboratory studies indicate that passage efficiency may depend more (but not exclusively) on passage system design features, particularly when biological requirements and hydraulic conditions are well matched. Although frequently not well understood or quantified, species motivation and use of habitat below or above barriers may also affect attraction, guidance and passage efficiency, as fish may utilize fish passage systems for tentative rather than required movements. Innovative fish tracking techniques in field and laboratory studies are providing ways to quantify motivation, attraction/guidance, and passage factors. Ecohydraulic approaches, which integrate improved biological assessments with advanced hydraulics, enhance understanding of fish behaviour and the factors affecting passage effectiveness. Responses of downstream moving fish associated with spillway re-design, bypasses, and bar racks or upstream moving fish associated with habitat use, attraction efficiency to fishway entrances and passage efficiency through submerged orifices or surface weirs or different turbulence characteristics in pools are highlighted. Results of such ecohydraulic studies are invaluable in calibrating numerical simulations and enhancing biological ground-truthing of CFD modeling for 1, 2 or 3 dimensions. Such modeling may provide additional insights about turbulent flow and fish behaviour. Much more effort on ecohydraulic studies is needed in the field and in the laboratory to quantify responses of species with different migratory needs and biomechanical capabilities. This effort is needed to further improve knowledge, validate fish behaviour assumptions, ground-truth models and assist the development of more robust and effective fish passage systems.

Modeling Fish Passage for American Shad in a Steeppass Fishway using a Computational Fluid Dynamics (CFD) Model

Katey Plymesser, Joel Cahoon, *Montana State University*

The Alaska Steeppass is a type of chute fishway used extensively on coastal streams in the east and in remote locations of the U.S. Typically prefabricated out of ¼ aluminum plate into 27-inch-high, 18-inch-wide, 10-foot sections, these chutes are highly portable and relatively inexpensive. The Model A Steeppass, a derivative of the modified Denil No. 6 developed by McLeod and Nemenyi, is the most widely used variant because it reduces flow velocities to magnitudes negotiable by many salmonid and alosa species. The results of the CFD model will be briefly described and the focus of the presentation will be to demonstrate how the CFD model was used to estimate the probability of passage for American Shad in a steeppass fishway for a selection of swim paths. Passage efficiency can be estimated using optimal swim speeds for the target species (Castro-Santos 2005) allowing for variation in water velocity (Castro-Santos, 2006). The results will be compared to experimental results for passage efficiency published by researchers at the S.O. Conte Anadromous Fish Research Center (Haro, et al, 1999) to demonstrate that water velocity alone does not limit ascent of the fishway by American Shad.

Katey Plymesser received her undergraduate degree in Civil Engineering in 2001 from Case Western Reserve University in Cleveland, Ohio. After working as a consulting engineer in land development for six years, she decided to return to graduate school full-time. She is currently a PhD Candidate in the Civil Engineering Department (Water Resources) at Montana State University. Her research work combines three-dimensional computational fluid dynamics modeling and fish passage. She is currently funded by a Hydro Research Foundation fellowship which was designed to help outstanding early-career researchers facilitate research related to hydropower.