State of California
The Resources Agency
Department of Water Resources

FINAL REPORT
EVALUATION OF METHODS AND DEVICES USED IN THE CAPTURE, SORTING, HOLDING TRANSPORT, AND RELEASE OF FISH
SP-F15, Task 3

Oroville Facilities Relicensing
FERC Project No. 2100

JUNE 2004

ARNOLD SCHWARZENEGGER
Governor
State of California

MIKE CHRISMAN
Secretary for Resources
The Resources Agency

LESTER A. SNOW
Director
Department of Water Resources

State of California
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This report was prepared under the direction of

Terry J. Mills ..... Environmental Program Manager I, DWR

by

Paul M. Bratovich .....Principal/Fisheries Technical Lead, SWRI
David Olson..... Senior Environmental Scientist/Project Manager, SWRI
Erin Gibson ..... Environmental Planner/Author, SWRI
Adrian E. Pitts .....Associate Environmental Scientist/Author, SWRI
John Cornell .....Associate Environmental Scientist/Author, SWRI
Amanda O'Connell ..... Environmental Planner/Author, SWRI

Assisted by

Becky Fredlund ..... Graphics/GIS Technician/Graphical Support, SWRI

REPORT SUMMARY

The objective of Task 3 of SP-F15 was to evaluate the proposed Resource Action to examine the feasibility of moving anadromous salmonids and other targeted migratory fish species, specifically green sturgeon, past the Oroville Facilities. In order to accomplish this task, a literature review was conducted to determine the devices and methods that could potentially be employed in a fish passage program. Although sturgeon and steelhead information is included in the report when available, the preponderance of information available was only directly applicable to evaluating the feasibility of a fish passage program for Chinook salmon. Chinook salmon are the most likely of the potential fish species evaluated to be feasible for use in a potential fish passage program. Therefore, the majority of the report focuses on the evaluation of Chinook salmon passage.

The adult fish passage phase elements include: capture, sorting and tag reading, holding, transport, and release. The juvenile fish passage phase elements include: capture, sorting and tagging, holding, transport, and release. The adult and juvenile phases and individual elements of the fish passage program, their alternatives, interactions, interdependencies, functional requirements, logistics, and characteristics are described and evaluated in the report. The advantages and disadvantages of each program and device alternative are evaluated against their ability to successfully accomplish the potential fish passage program goals.

Program and device alternatives are recommended based on their favorable characteristics compared to the other alternatives to fulfill the program functions, and for their compatibility with the potential fish passage program goals. Selection of program and device alternatives, in some cases, depends on the goal of the program.

Because the study plan F-15 was designed to evaluate the feasibility of a potential Resource Action, it is appropriate to identify that some of the potential goals of a fish passage program could be accomplished through alternative resource actions. Those alternative methods to achieve the same resource goals could potentially be accomplished at lower risk, cost, and conflict with other resource management goals. Potential fish passage program goals include to: protect, enhance, or restore the genetic integrity of a fish stock, to increase total salmonid production, or to provide access to habitat conditions more closely resembling historical conditions. Protection, enhancement, or restoration of the genetic integrity of a fish stock could alternatively also potentially be accomplished without a fish passage program through the segregation of a fish population in the lower Feather River with the use of fish barrier weirs. An increase in total salmonid production also could potentially alternatively be accomplished without a fish passage program through existing habitat enhancements and new habitat creation in the lower Feather River. Both of these alternative methods to accomplish these specific potential fish passage program goals could potentially be accomplished at lower cost, with lower levels of uncertainty of success, and at lower levels of risk of failure than a fish passage program. Only the potential fish passage

goal of providing access to conditions more closely approximating historical conditions could not be accomplished through alternative Resource Actions.

Overall, the results of the feasibility analysis indicate that fish passage could potentially be physically feasible, but it is likely that the goals of a fish passage program could potentially be accomplished by other Resource Actions at lower costs, risks, and resource conflicts. Additionally, the likelihood of success of a potential fish passage program accomplishing those goals is unclear because existing fish passage programs do not address the same physical, social, and economic issues associated with fish passage past the Oroville Facilities.

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1.0 INTRODUCTION

Anadromous salmonids historically present in the Feather River watershed were reportedly able to migrate to spawning grounds substantially further upstream than the present-day location of the Oroville Facilities (Yoshiyama et al. 1998; Yoshiyama et al. 2001). Little information exists on historic spawning areas utilized by non-salmonid anadromous species. Currently, anadromous fishes in the lower Feather River are unable to migrate above the Fish Barrier Dam located approximately at river mile (RM) 67. The Fish Barrier Dam is located a short distance downstream from the Oroville Dam. Although the Fish Barrier Dam is the first migration barrier to upstream migrating anadromous fishes the Oroville Dam, at 770 feet tall is also a barrier to anadromous upstream migrating adult fishes. Figure 1.2-1 shows the relative locations of the Fish Barrier Dam and Oroville Dam to each other. Use of existing facilities or construction of new facilities along with implantation of a fish passage program to pass anadromous fishes above Oroville Dam would potentially allow anadromous fishes access to the portion of their historic spawning grounds below the next upstream fish passage barriers.

1.1 BACKGROUND INFORMATION

Ongoing operation of the Oroville Facilities continues to halt the upstream migration of anadromous fishes including Chinook salmon, steelhead, green sturgeon, white sturgeon, river lamprey, and Pacific lamprey at the Fish Barrier Dam, preventing these species access to the upper reaches of the Feather River. As a component of study plan (SP)-F15, *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams,* Task 3 of SP-15 evaluates methods and devices used in the capture, sorting, holding, transport, and release of fish. Upstream passage of adult anadromous salmonids and green sturgeon as well as downstream passage of juvenile anadromous salmonids and green sturgeon and repeatedly spawning adult steelhead and green sturgeon is included in the evaluation of potential methods and devices considered for use in a fish passage program to the extent that supporting literature was available.

1.1.1 Statutory/Regulatory Requirements

The purpose of SP-F15 Task 3 is to evaluate the methods and devices that potentially could be used in passing anadromous fish above Oroville facility dams. Salmonids present in the lower Feather River include spring-run Chinook salmon (*Oncorhynchus tshawytscha*), fall-run Chinook salmon (*O. tshawytscha*), and steelhead (*O. mykiss*). On September 16, 1999, naturally-spawned Central Valley spring-run Chinook salmon were listed as threatened under the federal Endangered Species Act (ESA) by the Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) (NOAA Fisheries 1999). The Central Valley spring-run Chinook salmon Evolutionarily Significant Unit (ESU) includes all naturally-

spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries, which includes naturally-spawned spring-run Chinook salmon in the lower Feather River (NOAA Fisheries 1999). On March 19, 1998, naturally-spawned Central Valley steelhead were listed as threatened under the federal ESA by NOAA Fisheries (NOAA Fisheries 1998b). The Central Valley steelhead ESU includes all naturally-spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries, which includes naturally-spawned steelhead in the lower Feather River (NOAA Fisheries 1998b).

The results and recommendations from this study fulfill, in part, statutory and regulatory requirements mandated by the ESA as it pertains to Central Valley spring-run and fall-run Chinook salmon. In addition to the ESA and California Species of Special Concern, Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (FERC 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operations. Consideration for potential feasibility of fish passage is required by section 17 of the Federal ‘Power Act. As a subtask of SP-F15, Task 3 fulfills a portion of the FERC application requirements by detailing the methods and devices that could potentially be utilized in a fish passage program. In addition to fulfilling these requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

1.1.2 Study Area

The study area for SP-F15 Task 3 encompasses the Feather River upstream and downstream of the Fish Barrier Dam, including FERC project waters comprised of Lake Oroville, its upstream tributaries to the first impassable fish barrier, the Thermalito Complex, the Fish Barrier Pool, and the Diversion Pool. The upstream tributaries of Lake Oroville consist of four major tributaries: the North Fork Feather River, the West Branch of the North Fork Feather River, the Middle Fork Feather River and the South Fork Feather River. The upstream extent of the study area for SP-F15 Task 3 extends to the first stream channel obstructions in each of the four major upstream tributaries of the Feather River that would completely block upstream migration of anadromous salmonids. The upstream migration barriers on the tributaries have been definitively identified in Task 1A of SP-F3.1.

1.1.2.1 Description

The four main tributaries to Lake Oroville include the North Fork Feather River, West Branch of the North Fork Feather River, Middle Fork Feather River, and South Fork Feather River. Additionally, there are a number of smaller tributaries (tributaries that are second order or larger) evaluated in this task including Berry Creek, Canyon Creek,

Chino Creek, Concow Creek, Fall River, French Creek, Frey Creek, Sucker Run Creek, McCabe Creek and Stony Creek. In general, the upstream tributaries can be classified into two types: those above Lake Oroville's high water mark, and those within the fluctuation zone of Lake Oroville below the high water mark. Below Lake Oroville's high water mark are tributaries that lie within the lakebed. Because these tributaries are within the fluctuation zone of Lake Oroville, the extent of the tributaries falling into this category is dependent upon the water surface elevation of Lake Oroville. When Lake Oroville is at full pool, the tributaries are inundated to the high water mark and are part of Lake Oroville. Under these conditions, the fully inundated reaches of the tributaries lose their riverine characteristics, become lentic in character and are not suitable for potential salmonid spawning or rearing habitat. When Lake Oroville is not at full pool, tributaries run as streams until they reach the surface of Lake Oroville, and the tributaries within Lake Oroville's fluctuation zone are exposed. Additionally, this section of the upstream tributaries receives sediment deposits during flood events, which could potentially act as migration barriers to upstream migrating fish during some water years. Near the interface of Lake Oroville and its upstream tributaries and in the tributary reaches that are within the fluctuation zone, the fish assemblages are similar to those in Lake Oroville (see Task 2 of SP-F3.1) (DWR 2002b).

The tributaries above Lake Oroville's high water mark are different from those within the fluctuation zone of Lake Oroville because, as described above, they are not seasonally inundated as are the tributaries within the fluctuation zone of Lake Oroville. Habitat in these reaches of the upstream tributaries includes habitat that has the potential to support the majority of anadromous salmonid spawning and rearing. Generally, the upstream tributaries are managed for coldwater fish species, although flow and water temperature components of the habitat are not controlled by the Oroville Project. Upstream of the high water mark of Lake Oroville, the tributaries support a typical California foothill stream-dwelling fish assemblage, which includes rainbow trout, brown trout, several black bass species such as smallmouth bass, spotted bass, largemouth bass, and redeye bass, hardhead, pikeminnow, and Sacramento sucker.

1.1.2.2 History

Prior to the construction of Oroville Dam, the upstream extent of fish passage was limited by natural fish barriers and previously constructed hydroelectric projects. Existing natural and manmade fish barriers were documented in California Department of Water Resources reports (DWR 1993), CDFG fish survey and escapement reports and bulletins (DFG 1952), studies on historical spawning distribution (Yoshiyama et al. 1998), newspaper articles and through local project knowledge of upstream conditions and features (pers. com. E. See, 2001). Additionally, SP-F3.1 Task 1A, reported potential fish barriers above Lake Oroville's high water mark.

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations,

and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate an average of 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

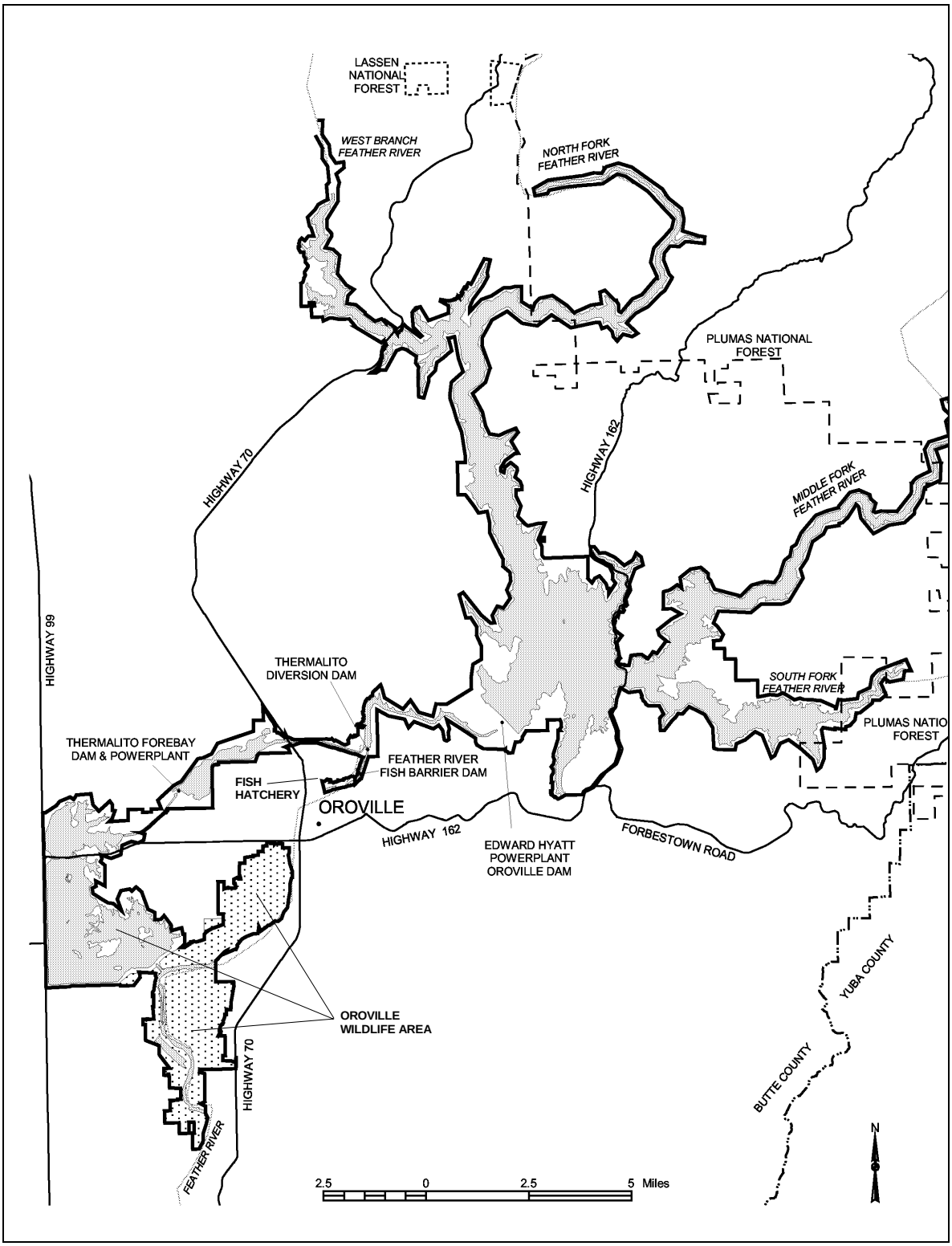

Figure 1.2-1. Oroville Facilities FERC Project Boundary.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, “Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife,” sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the

Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Water Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice

water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the

watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

Task 3 is a subtask of SP-F15, *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams*. Task 3 fulfills a portion of the FERC application requirements by evaluating the methods and devices that could potentially be used in the capture, sorting, holding, transport, and release of fish in a potential fish passage program. In addition to fulfilling statutory requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

This study is necessary, in part, because operation of the Oroville Facilities block upstream passage of migrating anadromous fish to the upstream reaches of the Feather River. Assessment of the methods and devices that could potentially be used to pass upstream migrating anadromous fish above the Oroville Dam and returning downstream migrating anadromous fish to the lower Feather River could allow decisions to be made regarding the feasibility of a fish passage program.

SP-F15 is titled *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams*. Task 3, herein, evaluates the methods and devices that could potentially be utilized in a fish passage program. Task 1 provides life history characteristics and habitat requirements for anadromous salmonids and other species targeted for passage above Oroville Dam, Task 2 provides an inventory of available habitat for juvenile and adult fish upstream of Lake Oroville, and Task 4 provides a fish passage model for a decision support tool to aid in decision making regarding the feasibility of a fish passage program. For further description of Tasks 1, 2, and 4, see SP-F15.

3.0 STUDY OBJECTIVE(S)

The objective of SP-F15 Task 3 is to develop information regarding the requirements and feasibility to move anadromous salmonids and other targeted migratory fish, specifically green sturgeon, past the Oroville Facilities by evaluating the methods and devices that could potentially be used to capture, hold, sort, transport, and release fish in a fish passage program.

3.1 APPLICATION OF STUDY INFORMATION

The SP-F15 Task 3 report evaluates the methods and devices used in the elements of a fish passage program including those that could potentially be used to capture, hold, sort, transport, and release fish. Information obtained in this study is associated with the other SP-F15 deliverables to evaluate the feasibility of a fish passage program and to identify the combination of methods and alternatives to potentially phase and implement a fish passage program at the Oroville facilities.

3.1.1 Department of Water Resources/Stakeholders

The information from this analysis will be used by DWR and the Environmental Work Group (EWG) to evaluate a potential fish passage program by evaluating the methods and devices used in the main elements of a fish passage program. Additionally, information collected in this task serves as a foundation for future evaluation and development of potential Resource Actions.

3.1.2 Other Studies

As a subtask of study plan SP-F15, *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams,* Task 3 evaluates the methods and devices that could potentially be utilized in a fish passage program. Task 1 provides life history characteristics and habitat requirements for anadromous salmonids and other species targeted for passage above Oroville Dam, Task 2 provides an inventory of available habitat for juvenile and adult fish upstream of Lake Oroville, and Task 4 provides a fish passage model for a decision support tool to aid in decision making regarding the feasibility of a fish passage program. For further description of Tasks 1, 2, and 4, see SP-F15.

3.1.3 Engineering Exhibits

No modeling results from DWR's Engineering and Operations Group were necessary to complete this study plan report because the focus of SP-F15 Task 3, evaluation of the methods and devices used in the capture, holding, sorting, transport, and release of fish, is to evaluate a potential fish passage program regardless of facility operations.

3.1.4 Environmental Documentation

In addition to Section 4.51(f)(3) of 18 CFR, which requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects (FERC 2001), it may be necessary to satisfy the requirements of the National Environmental Policy Act (NEPA) as well as the Endangered Species Act (ESA). Because FERC has the authority to grant an operating license to DWR for continued operation of the Oroville Facilities, discussion is required to identify the potential impacts of the project on many types of resources, including fish, wildlife, and botanical resources. In addition, NEPA requires discussion of any anticipated continuing impact from on-going and future operations. To satisfy NEPA and ESA, DWR is preparing a Preliminary Draft Environmental Assessment (PDEA) to attach to the FERC license application, which shall include information provided by this study plan report.

3.1.5 Settlement Agreement

In addition to statutory and regulatory requirements, SP-F15 Task 3 provides information which may be useful in the development of potential Resource Actions to be negotiated during the collaborative process.

4.0 METHODOLOGY

4.1 STUDY DESIGN

The objective of Task 3 of SP-F15 was to develop information regarding the ability to move anadromous salmonids and other targeted migratory fish species, specifically green sturgeon, past the Oroville Facilities. In order to accomplish this task, a literature review was conducted to determine the devices and methods that could potentially be used to capture, sort, hold, transport, and release fish within the context of a fish passage program. Although sturgeon and steelhead information is included in the report when available, the preponderance of information available was only directly applicable to evaluating the feasibility of a fish passage program for Chinook salmon. Chinook salmon are the most likely of these fish species to be feasible for a potential fish passage program, so the majority of the report focuses on the evaluation of Chinook salmon passage.

Upon completion of the literature review, each passage element was analyzed and presented separately for as many devices, methods, and considerations for which literature was available.

4.2 HOW AND WHERE THE STUDIES WERE CONDUCTED

Because it is essential to understand the practicalities (e.g. mechanical capabilities, physical habitat requirements, estimated costs associated with implementation, operation and maintenance, etc.) associated with each device alternative evaluated, multiple strategies were employed during the literature review.

A review of literature available on the devices and methods utilized at other dams that have attempted to implement fish passage programs, or that currently have fish passage programs in place was one strategy employed during the literature review process. Additionally, literature on fish physiological responses to handling, anadromous salmonid reproductive success, anadromous salmonid life history characteristics, anadromous salmonid spawning and rearing habitat availability above Lake Oroville, salmonid hatchery practices, and general fish passage concepts was also reviewed.

Each portion of a potential fish passage program was evaluated separately. Overall, ten separate elements of fish passage were evaluated for appropriateness, efficiency, including capital cost, operation and maintenance cost, potential negative effects on individual fish, device capabilities, agency requirements, and device lifespan for the available information. Five elements each were evaluated for upstream immigrating adults and for downstream emigrating juveniles. The mechanisms evaluated for both juvenile and adult phases of the fish passage program were:

- Capture of migrating fish
- Sorting (and tagging) captured fish by age/size class and by species
- Holding captured and sorted fish
- Transporting fish to a release location upstream (adults) or downstream (juveniles) of the Oroville Dam.
- Release of fish

Additionally, a description of the applicability of each device at each stage during the fish passage to the Oroville Facilities and the Feather River is provided.

5.0 STUDY RESULTS

5.1 POTENTIAL ADULT FISH PASSAGE PROGRAM ELEMENTS

Figure 5.1-1 Potential Adult Fish Passage Program Elements illustrates the general sequence and relationships of the fish passage elements for the adult phase of a potential fish passage program. The figure also identifies the geographic alternatives associated with each of the potential upstream adult fish passage program elements.

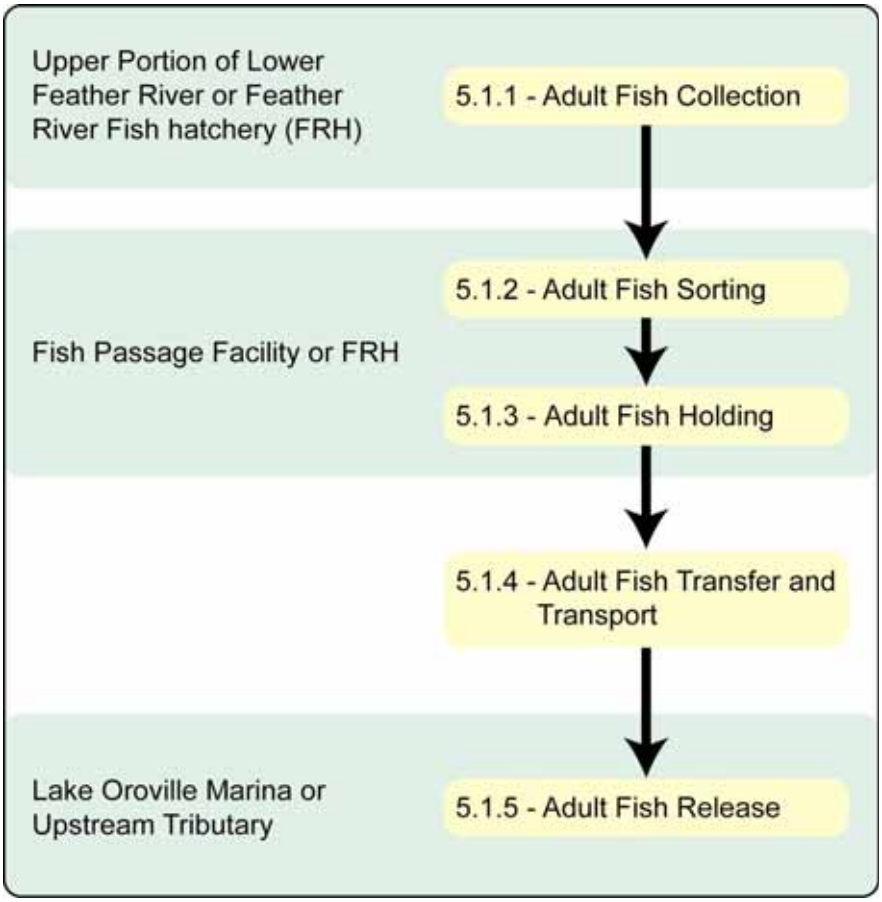

Figure 5.1-1 Potential Adult Fish Passage Program Elements

5.1.1 Adult Fish Collection

The first step in a potential fish passage program is to collect adult fish for inclusion in the program. The goal of this particular phase is to capture upstream migrating adult Chinook salmon while minimizing mortality due to stress associated with handling while maximizing target capture opportunities.

5.1.1.1 Location

Adult fish collection would be conducted in the upper portions of the lower Feather River, above Honcut Creek. Because it is possible that anadromous salmonids collected downstream from Honcut Creek are homing to tributaries of the lower Feather River including the Bear River, the Yuba River, and Honcut Creek, those individuals would not be candidates for passage above Oroville Dam. Therefore, collection would likely occur upstream from Honcut Creek, which is the most upstream tributary on the Feather River below the Fish Barrier Dam. The Fish Barrier Dam is the upstream-most point that adult fish capture could occur on the Lower Feather River. See Figure 5.1-2 Orthophoto of Fish Barrier Dam and Feather River Fish Hatchery for the general area in which adult fish capture likely would be conducted. If potential collection sites were located closer to the Fish Barrier Dam, adult fish transport distances would be decreased.

The upper portion of the Lower Feather River is characterized by a sequence of shallow riffles, 2 to 5 meter deep pools and island bar complexes. It also has riparian vegetation to the water line, instream woody debris and varies in width from 20 to 30 meters. Although several instream adult fish capture device alternatives were investigated, due to the limitations of the applicability of these devices given the site conditions as well as the comparative problems with non-volitional capture devices in comparison to the fish ladder alternative, these devices were eliminated from further consideration. The fish ladder adult fish collection alternative was the main focus of the following evaluations because it has the advantages of a low operational cost, a high capture efficiency, provides for volitional passage, and reduces the number of non-target species captured for the fish passage program.

5.1.1.2 Alternatives

Several devices have been developed and used for the capture and collection of adult fish for the purpose of aiding upstream passage beyond migration barriers. Two types of fish collection devices were evaluated for use at the Fish Barrier Dam: mechanical lifting devices and fish ladders.

A review of available literature indicates that there are three basic types of mechanical lifts typically used for fish passage: fish elevators/lifts, fish locks, and navigation locks. Navigation locks were eliminated from consideration as a potential fish passage device in this analysis, because the location within the Feather River under consideration for potential fish capture (upstream from Honcut Creek) would not physically accommodate a navigation lock.

Figure 5.1-2 Orthophoto of Fish Barrier Dam and Feather River Fish Hatchery.

Clay (1995), reported that fish lifts and fish locks are both capable of lifting fish over dams of up to 200 feet (61 m) in height. However, although the Fish Barrier Dam is substantially less than 200 feet (61 m) high, the use of fish lifts or fish locks would

require lifting fish over the Fish Barrier Dam and releasing them either into the Fish Barrier Pool for holding or into tank trucks for upstream transport. Both of these options likely would result in higher levels of capture-related stress on adult fish compared to the use of a fish ladder. Additional stress could occur due to an increased number of steps in the process of collecting adults for transport above the dam. For example, fish lifted and released directly into the Fish Barrier Pool would potentially undergo up to three handling events: (1) prior to elevation/lift over the dam; (2) prior to sorting; and (3) transfer to tank trucks for upstream transport. Each of these handling events could result in injury or stress leading to direct and indirect sources of mortality. Therefore, lifting and subsequent holding of fish in the Fish Barrier Pool was eliminated from further analysis. Similarly, lifting fish and releasing them directly into tank trucks would result in several handling events. Because there is no direct truck access to the Fish Barrier Dam, the fish would be collected, lifted, and conveyed for loading into the tank trucks, also resulting in higher levels of handling stress than could potentially occur with the use of a fish ladder. The mechanical lift devices have the potential to increase capture-related stress, relative to the use of a fish ladder, and therefore, were eliminated from further analysis.

Fish ladder

Operation of a fish ladder for the upstream passage of adult Chinook salmon, steelhead, and green sturgeon could involve: (1) use of the existing FRFH fish ladder; (2) design, construction, and operation of a separate fish ladder at the Fish Barrier Dam; or (3) use of the existing facility and construction and operation of new structure(s). Use of the existing fish ladder at the hatchery would reduce the capital costs associated with a potential fish passage program. Design and construction of new structure(s) would allow for the physical separation of the current hatchery program from the fish passage program. Physical separation may or may not be desirable based on program requirements.

Description

A fish ladder is a water passage structure used to facilitate passage of fish over an obstacle, typically, a dam or other migration barrier. Specifically, as defined by NOAA Fisheries, the fish ladder is the component of a fish passage facility that dissipates the potential energy into discrete pools or into a baffled chute to provide passage for upstream migrants (NOAA Fisheries 2003). Fish ladders are the most commonly used method for allowing the migration of fish upstream past in-stream barriers.

There are a variety of fish ladder designs, although all are based on the same basic design concepts. The height and length of individual ladders will vary depending upon the height of the obstacle, the hydrology of the river system, and the fish species utilizing the facility. According to USACE, the recommended practical minimum width

for a fish ladder is six feet, although the hydrology of the river system also must be considered.

Typically, fish ladders consist of a series of ascending pools that must be “climbed” or jumped by the fish. A series of pools contained within the water passage acts to incrementally divide up the height of the passage dissipating the energy in the water and gradually decreasing the upward climb required to pass over the obstacle. The number of pools contained within the fish ladder depends on the climb required to pass over the obstacle. Although the incremental drop between pools may vary depending on the leaping capabilities of the species that need to pass through the ladder, the most frequently utilized drop is one foot (0.3 m). Fish move up the ladder by leaping from one pool to the next in an upstream direction. Upon ascending the ladder individuals can be collected in confined pools or tanks at the top of the ladder (Larinier, M. 2000; USACE 1996).

To design a fish ladder that will be most effective for target fish in a fish passage program, species-specific criteria must be taken into consideration. In *Design of Fishways and Other Fish Facilities*, Clay (1995) reported essential design criteria for salmonid fish ladder design. According to Clay (1995), the most appropriate entrance velocity for a fish ladder designed for Pacific salmon is 4 feet per second, with the acceptable entrance velocity falling between 4 and 8 feet per second. The preferred depth of the entrance reportedly is at least 4 feet but can differ depending on site conditions (Clay 1995). Reportedly, Pacific salmon are able to handle velocities (in slots over weirs) of up to 8 feet per second with preferred head difference between pools of 1 foot. Another important consideration, reported by Clay (1995), is that a minimum space per fish is required. In the case of salmonids approximately 0.2 ft^3/lb per fish is needed (Clay 1995).

An important aspect of fish ladder use is the ability to draw fish into the ladder once they reach the general area below the entrance (Coutant 2001b). One method for increasing the likelihood that fish will enter the ladder is to use auxiliary water to make the flow out of the fish ladder as noticeable as possible at the greatest distance without obtaining velocities that prevent fish from entering. The creation of flow to draw fish into the fish ladder is referred to as attraction flow because the increased water velocities through the ladder stimulate fish to progress upstream against these velocities (Clay 1995). Clay (1995) indicates that a velocity of approximately 4 feet per second is generally an accepted standard for creating an attraction flow for salmonid species. However, the turbulence of the river system should be considered during the design of the ladder when determining the magnitude of attraction flows. High turbulence tends to reduce the effectiveness of attraction flow, but it is suspected that even the strongest fish cannot safely maneuver through a ladder at velocities approaching 8 feet per second for an extended period of time (Clay 1995).

The following sections describe five fish ladder design variations: (1) pool and weir; (2) pool and orifice; (3) denil; (4) vertical slot; and (5) rock ramp.

Type 1-Pool and weir fish ladder - The pool and weir fish ladder is oldest and most widely used fish ladder design (DNR Website 2004), and is the type used for adult Chinook salmon and steelhead collection at the FRFH. The design consists of a series of rectangular pools that are separated by walls or baffles that act as weirs (Figure 5.1-3). Depending on the swimming capabilities and behavior of the target species, as well as hydraulic modeling data and field experience, the drop between pools typically varies from 4 to 18 inches (0.10 to 0.45 meters), although is frequently around 12 inches (0.3 meters). The hydraulic behavior of this type of fish ladder is determined by pool dimensions and the weirs separating pools (Larinier, M. 2000; USACE 1996).

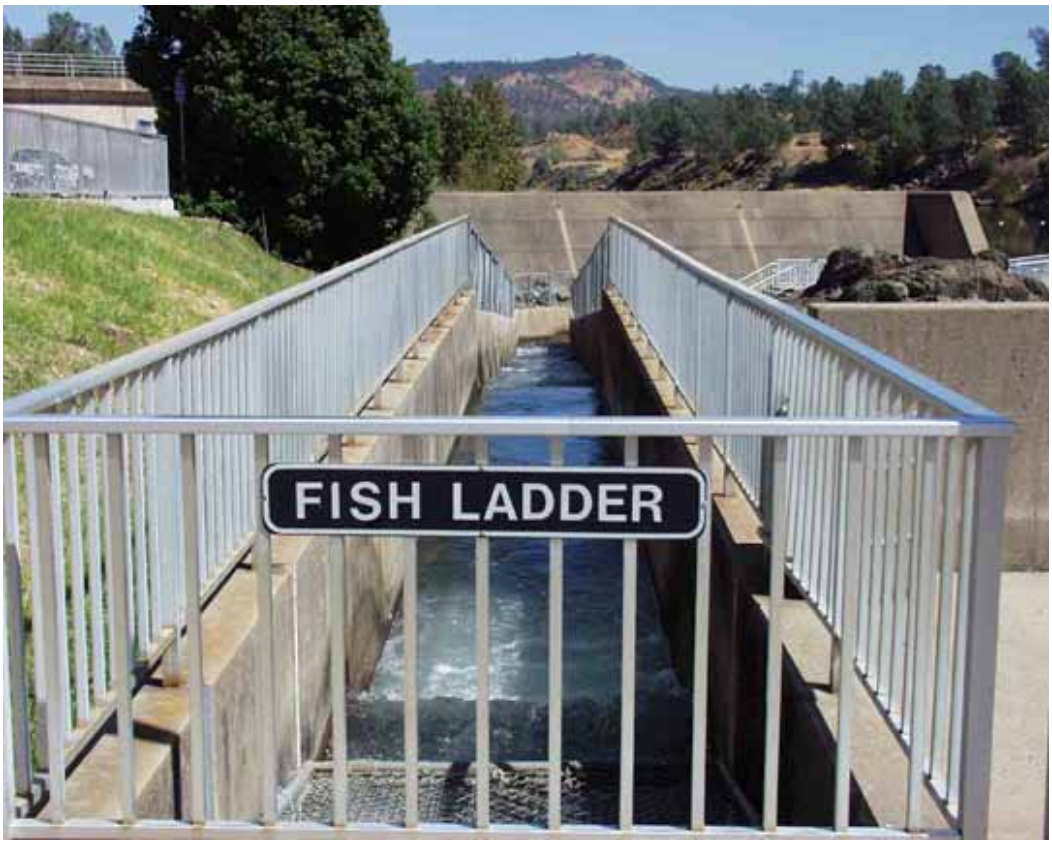

Figure 5.1-3. Feather River Fish Hatchery Ladder.

The weirs separating the ladder pools control the water level in each pool. Flow through the ladder happens by way of surface overflow as water spills from one pool to the next lower pool. Fish gradually ascend the fish ladder by leaping over the pool wall, or baffle. The pools offer resting areas for the fish as well as ensure adequate energy dissipation of the water to allow for safe passage. Depending on the swimming ability of the target species, pool and weir ladders can be designed to allow flow to move through

one or more notches or slots throughout the fish ladder or the design can allow for flow to move over the entire baffle (Larinier, M. 2000; USACE 1996).

Type 2-Weir and orifice fish ladder - The weir and orifice fish ladder is a variation of the pool and weir design with submerged orifices incorporated into the pool baffles. A primary difference between the two designs is the location of the transition area between successive pools, which, with the orifices, is located at or near the bottom of the baffle rather than near the top at a weir (USACE 1996).

The orifices are sized according to the target fish species and are either aligned to keep fish moving with the least interference or offset to reduce flow through the facility (Clay 1995; USACE 1996). According to Clay (1995), typical pool dimensions for this type of fish ladder would be a length of six times the orifice diameter and a width of four times the orifice diameter with a recommended drop between pools of 18 inches (0.46 m).

The design of this type of fish ladder allows water to flow over the weirs as well as through the orifices. Therefore, fish are able to ascend this type of ladder by moving over the pool walls, as they would in the pool and weir design, or through the orifices in the baffles. Therefore, the size and shape of the orifices should be appropriate for the target species but an additional factor to consider is that orifice size should also be determined by restrictions on discharge and velocity set by the system. Weir and orifice fish ladders reportedly better accommodate benthic species that are less likely to jump over obstacles (Clay 1995; USACE 1996).

Type 3- Denil fish ladder - The Denil fish ladder is a steep flume or water passage that contains vanes on the sides and bottom of the flume for the purpose of altering the flow of the water (Figure 5.1-4). These types of ladders typically are used with a vertical elevation change of less than three feet (0.9 m), a length of approximately 25 feet (7.6 m), and a slope of between 10 and 15 percent (USACE 1996).

Individuals generally ascend up a typical pool and weir or pool and orifice fish ladder by leaping from pool to pool in an upstream direction while resting in some pools to avoid exhaustion, particularly at ladders used at obstacles over 12 feet (3.7 m) in height (USACE 1996). Fish ascend up the Denil ladder in much the same way as they would in a pool and weir ladder except that the vanes installed along the sides and bottom of the flume, cause the water flow in the flume to turn back on itself creating velocity refuges (Clay 1995).

The Denil ladder design generally is considered a variant of the basic pool and weir ladder and is similar to the vertical slot ladder but has inclined, rather than vertical, baffles (USACE 1996). According to USACE (1996), the Denil ladder is able to pass large volumes of water, compared to other ladder designs of comparable size, which allows for generation of greater attraction flows.

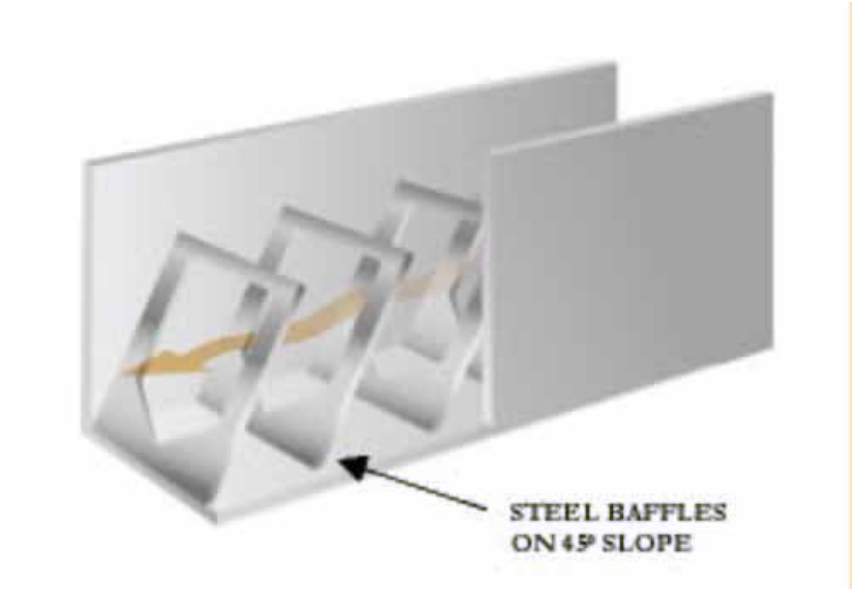

Figure 5.1-4. Denil fish ladder.

Type 4- Vertical slot fish ladder - The vertical slot fish ladder, also referred to as "Hells Gate" fish ladder, which is a type of "pool & jet" fish ladder, has the basic design of the weir and orifice fish ladder except that the orifices extend over the full height of the pool wall and the slope of these fish ladders typically is set at ten percent (Clay 1995; USACE 1996).

Vertical slot fish ladders consist of baffles between the walls of the flume that act to turn the flow back in an upstream direction in order to obtain efficient energy dissipation (Figure 5.1-5). Vertical slot ladders allow fish to move through the baffles rather than over them, allowing fish that are less likely to be able to leap over the baffles of a ladder to use them. An additional characteristic of this type of ladder is that the slot in the pool wall is typically 18 inches (0.46 m) in diameter and can accommodate passage by larger species.

The vertical slot fish ladder design is a variation on the pool and weir design that does not have flow over the baffles, which also is similar to the weir and orifice design except with the orifices reaching the full height of the baffle (Clay 1995; USACE 1996). According to Clay (1995), the vertical slot ladder incorporates the principles used in the Denil and can be considered a combination of all fish ladder types.

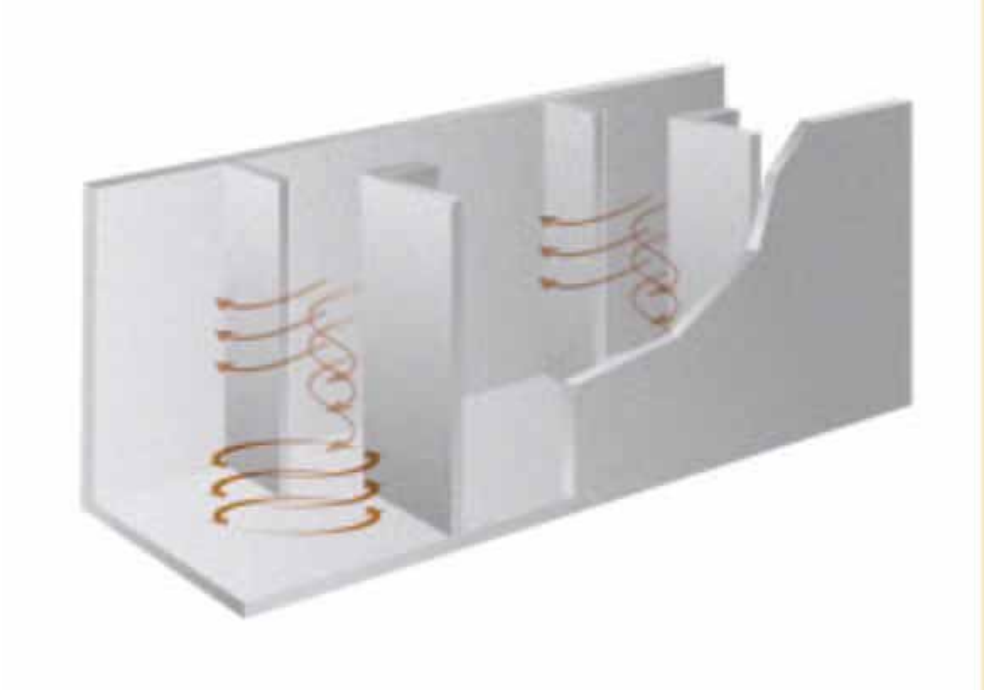

Figure 5.1-5. Vertical slot fish ladder.

Type 5-Rock-ramp fish ladder - Rock-ramp fish ladders are constructed by placing rocks in a semi-random pattern to simulate a riffle bed and create a shallow rock-ramp around barriers (Odeh and Haro 2000) (Figure 5.1-6). Typically, rock-ramp fish ladders are built with slopes of 1:18 but have been reported to have slopes of 1:20 in New South Wales (Thorncraft and Harris 1997, Harris et al. 1996 *in* Odeh and Haro (2000) and most recently have been built on a slope of 1:30 (Odeh and Haro 2000).

Figure 5.1-6. Rock-ramp fish ladder

The shallow depths of the rock-ramps allow small migratory fish, 4 to 25 cm in length (1.6 to 9.8 in) to pass but may exclude larger migratory fish from 25 to 40 cm in length (9.8 to 15.7 in). According to Odeh and Haro (2000), building fish ladders on a slope of

1:30 increases the depth of the ladder allowing the passage of larger fish. In addition, a benefit to having a slope of 1:30 is that the hydraulics associated with the ladder would be maintained if rocks were moved during floods.

Characteristics

Fish ladders of various types have been successfully designed and implemented to aid the passage of fish upstream around dams or other artificial structures that block historic migration routes as well as within rivers that may have naturally occurring barriers to upstream migration or features that reduce upstream migration success. Fish ladders reportedly are used for the collection of adult fish in combination with fish holding and sorting areas at fish hatcheries and with holding and sorting, and transport and release elements of fish passage programs.

The DNR Website (2004) reported that pool and weir ladders commonly are used at artificial structures. Clay (1995) reported that weir and orifice fish ladders have a long history of use at dams on the Pacific Coast of North America, mostly on the Columbia River in the Pacific Northwest. Additionally, the weir and orifice ladders have successfully been used to pass all five species of Pacific salmon, steelhead, and sturgeon. The vertical slot fish ladder also is commonly used at Columbia River dams for passing all five species of Pacific salmon and steelhead, however, it reportedly is less successful at passing sturgeon (Clay 1995).

USACE (2000) proposed the installation of a vertical slot fish ladder for the collection of upstream migrating adult Chinook salmon and steelhead at the Cougar Lake Project, Washington. In the feasibility analysis conducted for the project, it was suggested that the anticipated design life of the structure would be approximately 60 years, which was similar to the estimated design life of existing structures at the facility (USACE 2000).

At the John Day Dam on the Columbia River, Oregon, USACE conducted a study to develop a multi-species pool and weir fish ladder that would improve the passage of American shad while maintaining high passage rates for steelhead, Chinook salmon, and sockeye salmon. The study evaluated the passage efficiency of different fish ladder weir configurations using a full-scale laboratory model. Based on the results of the laboratory testing, USACE developed two pool and weir fish ladder designs. The weirs of Plan A each had a vertical slot near the center and an orifice on the right side (looking upstream). The Plan B design had slot type weirs along the centerline of the ladder, but had no orifices. Passage of all four fish species (American shad, steelhead, Chinook salmon, and sockeye salmon) was evaluated for both designs. Although the results indicated that Chinook salmon passage results were slightly better with the Plan A design (98 to 100 percent passage) compared to the Plan B design (97 to 99 percent passage), the overall program goals were better met by the Plan B design. A follow-up evaluation of the performance of the Plan B design fish ladder at the John Day Dam indicated that the fish ladder provided an average of 94 percent passage effectiveness

for Chinook salmon, sockeye salmon, coho salmon, and steelhead combined (Monk et al. 1989).

Clay (1995) reported that the Canadian Department of Fisheries and the International Pacific Salmon Fisheries Commission were able to determine fish ladder capacity for the best known facilities on the Fraser River in British Columbia using the fish ladder space criterion of 4 ft^3 per adult sockeye salmon and the maximum rate of ascent calculated by obtaining counts of fish entering a fish ladder as well as simultaneous counts at various intervals along the fish ladder for a distance of 35 pools from the fish ladder entrance. By applying these design criteria to proposed dams on the Fraser River, the Canadian Department of Fisheries and the International Pacific Salmon Fisheries Commission calculated that a fish ladder that would accommodate a maximum daily run of 750,000 adult sockeye salmon and would pass 675,000 fish, taking into account a 90 percent fish ladder efficiency. Based on their calculation that 35 pools would accommodate 25.4 percent of the maximum percentage of the maximum daily run, 35 pools would be required to accommodate 171,450 adult sockeye salmon with one pool required to hold approximately 4,900 fish. Therefore, based on these calculations each pool would have to be 19,600 ft^3 with dimensions of 10 feet deep by 16 feet long by 123 feet wide (Clay 1995). Clay suggested that using the experimental work on the Columbia River at the Bonneville Dam fish ladder, which indicated that 14 percent of the maximum daily run entered the ladder in one hour, the Fraser River would have a maximum hourly run of 105,000 fish. Using the maximum hourly run size and dividing it by the number of fish per pool multiplied by the number of pools, it was calculated that the ascent rate would be 3.57 minutes per pool (Clay 1995).

According to Clay (1995), the following formula can be used to determine fishway capacity: $C = V / v (60r)$

Where:

C = fish ladder capacity, in numbers of fish per hour
V = pool volume, in cubic feet
v = volume required per fish, in cubic feet
r = rate of ascent, in numbers of pools per minute

Additionally, Clay (1995) reported that fish crowding within the fish ladder may be a source of fish ladder failure. Although fish ladders may have the potential to accommodate a specified maximum number of fish, Clay (1995) literature suggests that crowding within fish ladders hinders movement. Therefore there may be a risk that crowding could cause fish ladders capacity to be substantially less than calculated (Clay 1995).

According to USACE (1996), a pool and weir ladder with dimensions of four feet wide by eight feet long by 6 feet deep, comparable to the ladder used at the Bonneville Dam hydraulics laboratory, would have a theoretical capacity of 800 fish per hour.

At the Stornorrfors Power Station fish passage project on the Umealven, Umeå, Sweden, the Norrfors Dam uses a 280 meter pool and weir fish ladder, with 75 weirs and 7 resting pools space throughout, to pass Atlantic salmon. Total elevation gain of the ladder design is 26.5 m with a 1:10 slope. According to the *Reccommendations for Improving Fish Passage at the Stornorrfors Power Station,* the maximum number of adult Atlantic salmon expected to pass the ladder in one day was 1,250 fish (Hans Lundqvist, SLU, Pers. Comm. February 2002 *in* Ferguson et al. (2002)). It also was estimated that the maximum total biomass on a peak day of passage would be 3,750 kg although the maximum facility holding capacity was unknown (Ferguson, et al. 2002).

Two critical design considerations for fish passage facilities (i.e., fish ladders) include appropriate attraction flows and the ability of the facilities to pass adult salmonids upstream once they enter the passage facility. One source of fish ladder failure that is extensively discussed in the literature, is inappropriate attraction flow (Bjornn, T. C., et al. 1999; Clay 1995; Ferguson, J. W., et al. 2002). Appropriate attraction flow reportedly is essential in attracting fish into the fish ladder entrance and encourages fish within the transportation channel of the ladder to keep moving upstream (Clay 1995).

At McNary Dam on the Columbia River on the Oregon – Washington border, attraction flow is used to draw fish into the fish ladder. The auxiliary water used for the creation of attraction flow is taken from the forebay through a closed system and then a vertical expansion well in the wall of the fish ladder is used to dissipate energy to achieve the desired head (Clay 1995). In addition, at the auxiliary water supply facilities, it was decided, “that potential injuries in the high-pressure system from the forebay were sufficient to justify screening the auxiliary water intakes with traveling mechanical screens (Clay 1995).”

The John Day Dam on the Columbia River incorporates two fish ladders that facilitate adult salmonid upstream passage. The outflow from a powerhouse is near the south shore and most fish are attracted to that location. Bjornn et al. (Bjornn, T. C., et al. 1999) reported that during periods of low flow, passage would be improved if fish could be attracted to the north shore ladder. They found that during periods of no spill, 16 percent of the steelhead approached the north shore ladder. When spill on the north side was increased to 1.1 percent of the total river flow, 19 percent of steelhead approached the north shore ladder. Ferguson et al. (Ferguson, et al. 2002) suggest that fish ladder location in relation to river flow is critical in improving upstream fish migration and recommend a fish passage facility attraction flow of three to five percent of total river discharge. The three to five percent criterion provides attraction to fish ladder entrances in order to minimize adult upmigrant delays at dams (preferably less than 24 hours) and is recommended for situations where the attraction flow has to compete with

a large volume of powerhouse discharge spread across a wide area (Ferguson, J. W., et al. 2002).

Another source of fish ladder failure, also associated with creating attraction flow, is the introduction of highly aerated or turbulent water into the ladder, which could damage the structural components of the ladder, discourage fish from entering the fish ladder, and could result in fish passage delays and fish damage. It is suggested that furnishing water from a low-pressure system and preventing air from entering the system can ensure that the attraction water is not excessively aerated or turbulent (Clay 1995).

In addition to ladder failures associated with auxiliary water, Clay (1995) reports that there also could be difficulties associated with prevention of small downstream migrating fish from entering the auxiliary water supply system. To prevent harm to downstream migrating fish that could potentially be drawn into the facility, it is suggested screening auxiliary water supplies should be considered (Clay 1995)."

A study investigating salmonid passage at the fish ladders bypassing four Columbia River dams over a three-year period, reported that both Bonneville and McNary dams had passage efficiencies of 95 percent during all three years. Fish passage efficiencies at the Dalles Dam reportedly ranged from 93 to 95 percent, and at the John Day Dam passage efficiency reportedly ranged from 88 to 95 percent over the three-year period (Burke et al. 2001). Ferguson et al. (Ferguson, J. W., et al. 2002) indicated that upstream fish passage facilities should allow for greater than 95 percent efficiency.

The widespread use of fish ladders for passage of salmonids past obstacles and their reported high passage efficiency suggests that mortality associated with these devices is low (Larinier, M. 2000; Monk et al. 1989). However, available literature did not provide a precise measure of survival rates associated with fish ladder use by salmonids. An assumption regarding the survival of fish ascending ladders that can be derived from the literature is that, because fish ladders traditionally have been designed for use by jumping species such as salmonids, and have been reported to allow salmonids to safely ascend fish ladders and bypass some migration barriers, mortality related to fish ladder use is likely to be low (Peake et al. 1997; USACE 1996). In addition, it is assumed that survival associated with the different types of fish ladders would be comparable.

Limited information regarding capital and operation and maintenance costs for fish ladders was found in available literature. Clay (1995) reported that construction of large fish ladder structures, (reinforced concrete floor slabs and pool walls) on the Columbia River cost approximately 37 dollars per square foot (1987 price base). Based on operation and maintenance cost records, it was reported that the operation and maintenance cost estimates for large fish ladders are approximately 1 to 2 percent of the capitol cost (Clay 1995). The DNR Website (2004) reported construction costs for three separate pool and weir fish ladders in Michigan: (1) at Berrien Springs,

constructed in 1975 cost 692,500 dollars; (2) at Buchanen, constructed in 1990 cost 3 million dollars, and (3) the Niles, constructed in 1991 cost 2.5 million dollars (DNR Website 2004).

The wide use of fish ladders for both artificial and natural barriers suggests that fish ladders are appropriate for a variety of obstructions, but according to Clay (1995), because fish ladders at dams above 50 feet may become excessively expensive, if possible, other fish passage options should be considered for high elevation dams.

Traditionally, salmonids reportedly have been the primary target species in fish passage programs because of their economic value (Peake et al. 1997) and more recently because of their declining populations. However, recent concern over diminishing sturgeon populations also has created a need to design passage systems suitable for sturgeon (Kynard 1998; Peake et al. 1997; Warren and Beckman 1992). Available literature regarding passage of sturgeon past dams revealed that, among sturgeon passage studies, there is agreement that, although it is possible to develop a suitable sturgeon passage system it is problematic to create a passage system that will also accommodate salmonids. The primary multi-species fish ladder design concern is that fish ladders conventionally have been designed for species that are able to jump. With the recent interest in the passage of nonjumping species, such as sturgeon, all species-specific needs and limitations must to be assessed in order to allow safe passage for all species under consideration (Peake et al. 1997).

The main difficulty in designing a multi-species passage system for sturgeon and salmonids is attributed to the fact that sturgeon have morphological characteristics such as flat bodies, heterocercal tails, and large adult size, which prevent them from negotiating barriers and waterfalls. Salmonids have symmetrical tails that produce more thrust than the sturgeon tail, have streamlined body shape that reduces drag, and together these characteristics allow for more efficient swimming abilities and greater ability to negotiate barriers such as the weirs presents in most fish ladders (Peake et al. 1997).

Little literature regarding passage studies specifically focused on white and green sturgeon was available. Therefore, for the purposes of this study, a review of sturgeon passage studies, regardless of species, was conducted. It is assumed that these resources provided appropriate general information for the purpose of analyzing potential passage of white and green sturgeon because all sturgeon species have similar morphological characteristics including those that affect swimming performance such as flat bodies and heterocercal tails. In addition, it was assumed that sturgeon species of comparable size have roughly the same swimming and navigational capabilities.

In a study conducted with lake sturgeon from Moose River basin in Northern Ontario, researchers related swimming endurance of lake sturgeon to length and flow

characteristics of fish ladders and compared lake sturgeon swimming performance to that of salmonids. The study revealed that sturgeon fatigue curves are similar to salmonid fatigue curves except that sturgeon burst swimming does not occur with the frequency that it does in salmonids. In addition, although swimming speed and endurance increased with fish length, small, intermediate and large sturgeon were unable to swim at speeds greater than 50, 90, and 180 cm/s respectively. Small fish were defined as less than 55 cm, intermediate fish as 56 to106 cm and large fish were 106 to 132 cm in length. According to Peake et al. (1997), if fish ladders are to be successful, individuals should be capable of ascending them quickly. The ability to ascend a ladder is determined, in part, by measurement of prolonged and burst swimming capabilities. Therefore, although sturgeon fatigue curves are similar to salmonid fatigue curves to allow for prolonged swimming, sturgeon burst swimming capabilities may not be sufficient to allow them to be passed safely or efficiently. In addition, poor swimming performance of sturgeon compared to salmonids is not limited to burst swimming capabilities but occurs in all categories of swimming. Peake et al. (Peake et al. 1997) suggest that, in order to develop a fish ladder for use by salmonids and sturgeon, water velocities must be maintained within the swimming performance of the weaker swimmer because, in order to ascend a ladder or culvert, fish must swim faster than the water velocity in the fish ladder. In the case of sturgeon, their larger size would force them to expend more energy to attain the speeds that salmonids use to ascend ladders. Peake et al. (1997) also proposed that fish ladder designers take into account the amount of space within the ladder that is required per fish, which, because of the larger size of sturgeon, likely will differ between the two species. A further complication in designing a fishway for combined salmonid and sturgeon use is that fish ladders requiring fish to jump from step to step, as sometimes required in fish ladder ascent, generally are not conducive to the passage of sturgeon (Peake et al. 1997).

A USACE study that examined fish ladder use by white sturgeon on the Columbia River revealed that, although it was assumed that salmon and steelhead jumped from pool to pool in order to successfully negotiate the Bonneville Dam fish ladders, researchers reported that the white sturgeon preferred to stay under water while moving upstream through the orifices in the ladder weirs. Due to the benthic nature of sturgeon, the orifices were determined to be the essential component that allowed white sturgeon to use the fish ladders. Although the discovery of the ability of sturgeon to move through weir orifices allowed for greater passage efficiency, there have been reports of high variability in passage efficiency between ladders at different locations on the Columbia River. Studies monitoring the passage of white sturgeon from 1986 to 1991 found that whereas the Dalles Dam reportedly passed between 187 and 791 white sturgeon per year, the John Day Dam passed less than 100 fish over the entire 5-year period (Warren and Beckman 1992).

USBR reportedly conducted studies at the Water Resources Research laboratory in Denver, Colorado, to examine the use of three fish ladder designs for use by Yellowstone River sturgeon. The fish ladders tested included: a standard vertical slot

fish ladder, duel slot fish ladder, and a rock fish ladder. For each fish ladder test, individuals were released at the bottom of the ladder and then fish behavior was recorded as fish attempted to ascend. In all four tests conducted using a standard vertical slot fish ladder, only two of eight fish successfully passed all four slots. Velocities of passage ranged from 2.99 feet per second with a 0.26 foot differential water surface between pools to 3.8 feet per second with a 0.31 foot differential water surface between pools. In all five tests conducted using a dual slot fish ladder, it was reported that the fish moved with greater motivation than they had in the standard vertical slot fish ladder but only two out of ten sturgeon successfully passed the four sets of dual slots. The passage time of fish using the dual slot fish ladder ranged from 16 minutes to 53 minutes. In comparison to the other fish ladder tests, passage success of the rock fish ladder far surpassed that of the vertical slot or dual slot fish ladders. A total of twelve rock fish ladder tests were conducted and it was reported that 15 out of 24 fish were successfully passed (62.5 percent) with passage time ranging from 14 to 83 minutes (White and Mefford 2002).

Peake et al. (1997) reported that fish ladder designs requiring fish to make their ascent by jumping from pool to pool generally do not allow for the safe passage of sturgeon. The modification of fish ladders by incorporating orifices into the traditional pool and weir design has been reported to improve the safety and efficiency of fish ladders for use by larger species, such as sturgeon, by allowing them to move along the bottom of the ladder rather than over each pool wall (USACE 1996). There was no estimate of sturgeon survival, as related to fish ladder use, reported in the literature, but in order to improve safety of fish ladders for use by sturgeon, and thus, survival rates, Peake et al. (1997) suggest that fish ladders must be compatible with the swimming capabilities of sturgeon.

Considerations

NOAA Fisheries' *Anadromous Salmonid Passage Facility Guidelines and Criteria,* included criteria and guidance for the design of fish ladders for adult fish passage (NOAA Fisheries 2003). Design guidelines are presented for the ladder entry, the pool dimensions and flows, and the exit of the fish ladder passage system. NOAA Fisheries' guidelines suggest that the attraction flow from a fish ladder entrance should be between 5 and 10 percent of high design passage flows for streams with mean annual discharges exceeding 1,000 cfs. Fish ladder entrance heads are to be maintained between 1 to 1.5 feet. The shape of fish ladder entrances is dependent upon attraction flow requirements. However, the entrance should be at least six feet deep and four feet wide. Entrances should have downward closing slide gates, unless prior approval has been given by NOAA Fisheries. Staff gates also should be included in the design of the fish ladder entrance for determination of whether entrance head criterion is being met (NOAA Fisheries 2003).

NOAA Fisheries (2003) also provided entrance pool criteria indicating that transport velocity between the fish ladder entrance and the first weir, as well as over submerged weirs, must be a minimum of 1.5 feet per second. Other fish ladder design criteria include a maximum hydraulic drop of 12 inches per pool and a minimum depth of 12 inches over ladder overflow weirs. Pool dimensions also must be a minimum of 8 feet long by 6 feet wide and be a minimum depth of 5 feet. Additionally, NOAA Fisheries' suggests that the fish ladder pool volume be a minimum of:

$$V \geq \frac{\gamma \mathrm{QH}}{4\mathrm{ft\text{-}lbs/s}}$$

Where:

V= pool volume, in ft^3
γ= unit weight of water, 62.4 pounds (lb) per ft^3
Q= fish ladder flow, in ft^3/s
H= energy head of pool-to-pool flow, in feet

Fish ladder pools must be at least double in length if they are a turning pool, located at position in the fish ladder where a bend of 90 degrees occurs. Orifices also should be at least 15 inches high and 12 inches wide, and the freeboard of the ladder pools shall be at least 5 feet high (NOAA Fisheries 2003).

NOAA Fisheries (2003) also sets forth specific design criteria for the exit of a fish ladder, although some aspects depend upon the type of ladder design. The hydraulic drop in the exit control section of the fish ladder shall range from 0.5 to 1.0 foot per pool. The exit channel upstream from the exit control section also must be a minimum of two standard ladder pool lengths. The ladder exit also should be located in a low velocity zone of less than 4 feet per second, preferably along a shoreline (NOAA Fisheries 2003).

NOAA Fisheries provided performance criteria for adult fish ladder collection associated with the Klamath Hydroelectric Project, which indicated that for adult fish passage through both the fish ladder and the trap and haul stages of the program, the combined fish survival should be 98 percent or greater. In addition, passage and survival through the Klamath Reservoir should be 80 percent or better, and overall passage survival through the fish ladder, trap and haul, and reservoir elements of the program should be at least 75 percent (White and Mefford 2002).

5.1.1.3 Conclusions

Because the general vicinity of Fish Barrier Dam is the preferred geographic location for the adult fish collection facility, the existing fish ladder located at the FRFH could be used as a part of a potential fish passage program. Modifications to the existing facility

potentially would be required to accommodate potential fish passage program individuals. Another option for the use of a fish ladder to collect adult fish would be to construct an additional fish ladder at the Fish Barrier Dam. Construction of a new fish ladder would be required to accommodate the expected number of fish while minimizing crowding. Both options for the use of a fish ladder are considered to be compatible with a potential fish passage program at Lake Oroville.

5.1.2 Adult Fish Sorting

The second element of a potential fish passage program is adult fish sorting, which would remove any fish collected that are not to be included in the fish passage program, either because they are not a target species, or do not meet the fish passage program operating criteria (incorrect timing, size, inappropriate sex ratio, etc.). Adult fish sorting occurs before adult fish holding to avoid holding non-target fish. Sorting can either be conducted manually or with the use of tag readers depending on the level of sophistication appropriate for the goals of a potential fish passage program. If the goal of restoring or protecting genetic integrity among Chinook salmon runs is important to a potential fish passage program, the sorting and tag reading element of the program becomes a crucial part of the program.

5.1.2.1 Location

Adult fish sorting would occur either in the current FRFH or in a new fish passage program facility. Adult fish collected would need to be sorted on a daily basis before being transferred to the holding facilities. At times of peak adult immigration, this part of the program could potentially be a continuous operation.

Because minimization of stress associated with transport would be a major goal of a potential fish passage program, the sorting devices would be required to be located immediately adjacent to or directly associated with the adult collection devices.

5.1.2.2 Alternatives

Adult fish sorting as part of a fish passage program at the Oroville Facilities could be accomplished either by manual (hand) or automated sorting procedures.

Fish Sorting by Hand

Description

Hand-sorting requires trained personnel to handle and visually inspect each individual fish and separate them into specific groups. The adult fish sorting process involves moving fish from the collection area into a tranquilizing tank, then to a sorting area, table or other platform where trained personnel can easily access the fish to visually inspect

and sort the fish by species, sex, and by origin (hatchery, wild lower Feather River, wild upper Feather River). Hand-held fish tag scanners can be used to assist in detection of coded wire tags (CWTs) and/or passive integrated transponder (PIT) tags. Following sorting, tranquilized fish would be placed in a recovery area.

Characteristics

Sorting fish by hand is a method commonly used in both fish passage programs and hatchery programs. The Stornorrfors Power Station Fish Passage Program, Sweden employs hand-sorting methods. Adult Atlantic salmon are collected in the upper most pool of a pool and weir fish ladder, removed using hand-nets, weighed, and then hand sorted to distinguish hatchery fish from passage program fish (wild fish) (Ferguson, J. W, et al. 2002). The program conducts the hand sorting without the use of anesthesia or water-to-water transfer, which reportedly could induce stress (Ferguson, J. W.,et al. 2002) or affect pre-spawning adult or in-vivo egg mortality.

The FRFH reportedly successfully employs hand sorting procedures to separate adult Chinook salmon and steelhead that are ready to spawn from those that are not (DFG Website 2003). At the FRFH, handling procedures are similar to those described by NOAA Fisheries (2003), except that carbon dioxide is used as the anesthetizing agent (DFG Website 2003). NOAA Fisheries reportedly does not permit the use of carbon dioxide at this time for passage program fish (NOAA Fisheries 2003).

One of the primary risks associated with hand sorting adult fish is handling induced stress. Although no published information on mortality of adult salmonids specifically related to the sorting element of a fish passage program was found in available literature, Bernard et al. (1999) reported a mortality of 0.9 percent due to handling stress when fitting adult Chinook salmon with radio transmitters. Because sorting would involve the handling fish in a manner similar to that of fitting with radio transmitters, although less intrusive, a less than one percent mortality rate could be anticipated during this element of a potential fish passage program.

Another potential risk of hand-sorting adult fish involves incorrect identification of fish species due to human error. However, depending upon the species involved, this risk is relatively minimal. Adult Chinook salmon characteristics, including their black mouth and gums, large black spots on the back and both lobes of the caudal fin (DFG 2002) are readily identifiable during external examination. Distinguishing characteristics of adult steelhead include white mouth and gums, small dark spots on the back and both lobes of the caudal fin, and dark spots on the caudal fin arranged in uniform rows (DFG 2002). Trained personnel also can easily identify sturgeon because of their unique morphological characteristics, including heterocercal tails, flat bodies, and bony scutes. Separation of spring-run Chinook salmon from fall-run Chinook salmon would be determined by calendar date of capture. Current FRFH practices define spring-run Chinook salmon as those fish ascending the fish ladder from September 1 through

September 15 of each year. Chinook salmon captured subsequent to September 15 are defined as fall-run Chinook salmon (Kastner, A. 2003). Based upon fish species characteristics and the determination of Chinook salmon runs by specific calendar dates, sorting errors likely would be uncommon with the most likely consequence of an error being placement of Chinook salmon or steelhead in the wrong temporary holding pool causing some stress to the fish placed in a holding pool comprised mostly of fish of another species.

Physical site requirements for adult fish sorting as part of a potential fish passage program include adequate space for tranquilizing tanks, sorting tables or platforms, and recovery tanks. Other requirements include personnel trained to identify appropriate fish species, and handling procedures to minimize stress and mortality of fish during the sorting process.

Considerations

NOAA Fisheries (2003) describes fish handling criteria and guidelines that would be applicable to a potential Oroville Facilities fish passage program. The handling guidelines indicate that fish (salmonids) should not be handled prior to anesthetization and that anesthetization should only occur by diverting fish into an anesthetic tank via water-to-water transfer or through a wetted distribution flume with no sudden bends. Additionally, carbon dioxide should not to be used an anesthetic, and the chosen anesthesia shall be adjusted as necessary to keep the water temperature within 2°F of ambient water temperatures, and handling shall not be permitted in ambient water temperatures greater than 68°F (20oC) (NOAA Fisheries 2003)

Use of hand-sorting methods for adult fish sorting would be compatible with other elements of an Oroville Facilities fish passage program. The structures and procedures that would be required for hand-sorting adult fish in a potential passage program generally are compatible with the existing practices at the FRFH (with the exception of the anesthetizing agent). The structures required to facilitate adult fish sorting could be developed through modification of existing FRFH facilities or through the construction of new facilities at the hatchery or at a new fish collection and handling location.

Automated Fish Sorting

Description

Automated fish sorting would be performed through use of an electronic detection device that triggered the opening of a gate to direct fish meeting sorting criteria into holding pools or another area away from non-target fish. Use of an automated system would require that the target individuals have either a CWT or PIT tag implanted. Automatic fish sorting minimizes the amount of fish handling and therefore is consistent with overall passage program goals of reducing stress and mortality of the fish.

Basic components of an automated fish sorting facility include a flume or pipe fitted with an electronic tag detection device, a mechanized gate wired to the detection device, and holding pools or other areas designated for the sorted target and non-target fish. This system can be situated at the end of a fish ladder.

Characteristics

Automated sorting facilities can be used as part of hatchery operations and/or fish passage programs to minimize fish handling. Ferguson, et al. (2002) suggested use of an automated sorting system for the detection and separation of hatchery fish (with a detectable CWT) from wild fish (no detectable CWT, passage program fish) at the Norrfors Dam, Sweden pool and weir fish ladder. As part of the automated sorting system suggested by Ferguson, et al. (2002), fish would leap over a false weir, enter a flume or pipe, and then pass through a CWT detector. The CWT detector would trigger a mechanism that would open a gate diverting coded-wire tagged (hatchery) fish to separate pools where they would be held prior to the next step in the hatchery process, while wild fish would be allowed to pass through the facility Ferguson et al. (2002). All adult fish passage recommendations reported by Ferguson et al. (2002) were based on Pacific salmon criteria and then assumed to apply to Atlantic salmon (Ferguson et al. 2002).

At Lower Granite Dam and Little Goose Dam, on the Columbia River, a similar automated fish sorting system was designed for use with PIT tagged fish. The system consisted of an automated PIT tag detector, which triggered a “slide gate” used to divert juvenile salmonids back to the river (Skalski et al. 1998). It is assumed that a similar system could be developed for use with a potential adult fish passage monitoring program.

Mortality rates associated with the use of automated sorting devices were not reported in the literature, however, because automated fish sorting would reduce the stress associated with fish handling, it is likely that mortality rates would be less than for a manual or hand sorting system. Additionally, although there was no information available on automated sorting of sturgeon, it also is likely that automated sorting would reduce stress and mortality during the sorting process.

One of the risks associated with using an automated device for identifying tagged fish is that some tags could potentially be missed because of either detector or tag failure.

Considerations

Review of available literature did not specifically elucidate regulatory agency criteria for design and implementation of an automated sorting facility. It is likely, however, that automated sorting would be accepted by NOAA Fisheries as a method of sorting adults

because Ferguson et al. (2002) reported that NOAA Fisheries had approved automated sorting at one facility in 2002. It is unclear whether regulatory restrictions would be placed on the use of automated sorters for sturgeon sorting, however.

Incorporation of an automated adult fish sorting facility would be compatible with and aid in the achievement of overall goals of a potential fish passage program at the Oroville Facilities. The devices and facilities required to facilitate adult fish sorting could be developed through modification of existing FRFH facilities or by the construction of new facilities either at the existing hatchery or at a new fish collection location. Use of an automated fish sorting method is compatible with fish ladder collection methods, including pool and weir fish ladders like the one at the FRFH.

5.1.2.3 Conclusions

Both manual and automated adult salmonid sorting techniques currently are employed at fish passage program facilities. The adult sorting methodology implemented in a potential fish passage program is dependant on the goals of the program. Sorting of adult salmonids by species, sex, and run timing could be accomplished effectively using manual techniques. However, if the goal of the program is to maintain the genetic integrity of potential passage program fish, more sophisticated techniques would be required, potentially utilizing automated systems to detect CWT's or PIT tags to identify program fish.

5.1.3 Adult Fish Holding

One of the operating principles of the fish passage program is to minimize stress on passage program fish by minimizing the number of times a fish is handled and to minimize the duration of exposure of fish to passage program stresses. Those fish identified in the sorting process as candidates for a potential passage program would be held for the minimum amount of time that is operationally feasible. It is likely that the minimum amount of time that adult fish would be held prior to transport would be 24 hours to 48 hours depending on the number of upmigrant adults arriving and the capacity of the holding facilities.

5.1.3.1 Location

Adult holding facilities would be located adjacent to the fish sorting facility, which also would be in the FRFH or in a new facility constructed specifically for a potential fish passage program. The Fish Barrier Dam Pool was evaluated as a potential adult fish holding alternative, but was eliminated from further consideration as the operation of the pool as a holding facility would require capture and recapture of the fish, and would increase the duration of exposure of individuals to fish passage program stresses.

5.1.3.2 Alternatives

Holding tanks, also referred to as holding pools or holding ponds, would be the preferred method of holding adult upmigrant fish prior to transport as part of a potential fish passage program.

Holding Tanks, Pools and Ponds

Description

Holding tanks, also called holding pools and holding ponds, are enclosures commonly utilized by fish hatchery and fish passage programs to provide temporary holding habitat for adult fish. Holding tanks typically are constructed from concrete (DFG Website 2003), however, some Pacific Northwest hatcheries reportedly use fiberglass tanks (pers. com. R. Rhoads, 2003). It also is reported to be a common practice to use the upper-most pool of a fish ladder as a holding area prior to fish sorting (DFG Website 2004). Holding tank size and design parameters would vary according to the individual program needs (i.e., fish species, maximum number of fish to be held over the maximum holding period, etc.).

Operation of adult fish holding tanks would require maintenance of an appropriate physiochemical environment in the tank (including, but not limited to, suitable water temperature and dissolved oxygen concentration) to ensure safe and effective use of the tank. At most fish facilities these water quality parameters are kept at appropriate levels by maintaining a constant flow of water through the tank. Additionally, some facilities use pumps to aerate the water to increase the oxygen concentration or coolers to ensure maintenance of desired water temperatures.

Characteristics

Adult fish holding facilities commonly are used for fish hatchery and fish passage programs. Available literature generally described holding facilities for anadromous salmonids (Chinook salmon and steelhead) and little information was available regarding green sturgeon holding facilities.

The FRFH holding facility is representative of a typical hatchery holding facility design (DFG Website 2003). The FRFH maintains a half-mile long fish ladder that allows adult anadromous salmonids (Chinook salmon and steelhead) to swim from the pool at the base of the Fish Barrier Dam to the hatchery. A gathering tank, an enlarged pool at the upstream terminus of the fish ladder, serves as a trap for those individuals that have ascended the ladder. A mechanical sweep gathers trapped individuals and deposits them into a tranquilizing tank where they are sorted by species and sex. Those fish not ready to spawn are diverted into one of four circular holding pools until they are ready to spawn (Figure 5.1-7) (DWR 2001). The four circular holding pools, each approximately

sized 42 feet (12.65 m) in diameter and 4 feet (1.22 m) in depth (DFG Website 2003; DWR 2001), are interconnected with the main hatchery building by a network of concrete flumes. The hatchery uses a system of control gates to change the flow of water through the tanks and flumes to facilitate fish movement from the gathering tank to a particular holding tank (DFG Website 2003).

Figure 5.1-7. Fish holding pool at Feather River Fish Hatchery.

The DFG Nimbus Fish Hatchery on the American River, Sacramento, California, holds adult steelhead in a pool located at the end of the fish ladder for broodstock collection (DFG Website 2004). The Leavenworth Hatchery on the Wenatchee River near Leavenworth, Washington, reportedly holds adult Chinook salmon and steelhead in two concrete holding ponds that are both 7,800 ft^3 in size (Sampson, D. 1998).

Ferguson et al. (2002) describe a capture and holding system that involves a pool and weir fish ladder connected directly to the entrance of a holding pool that has a v-picketed lead designed to prevent fish from backing out of the pool once they have entered. The design provides for 100 percent capture efficiency of fish that ascend the ladder. The holding pool is described to be 2.4 m deep by 2.6 m wide by 9.1 m long. The design assumptions were based upon Pacific salmon criteria to be applied to Atlantic salmon. The capacity of the pool was determined based upon a holding volume of 0.23 m^3 of water for adult Pacific salmon and 0.07 m^3 of water for adult steelhead. The maximum holding capacity of the pool was calculated to be approximately 1,440 for smaller fish or 450 adult Chinook salmon. The design criteria were based on a maximum daily run size of approximately 1,250 fish. It also was assumed that the pool would be emptied of fish on a daily basis (Ferguson et al. 2002). A crowder is used to force fish to move from the holding pool to the braille pool where fish sorting is conducted (Ferguson et al. 2002).

The Quinault Indian Nation's Salmon River Fish Culture Facility, Washington has been using a semi-natural pool approximately 25 meters long by three meters wide and one meter deep for holding adult Chinook salmon in since 1993 (pers. com. R. Rhodes, 2003). Adult Chinook salmon held in the holding pool for one and three weeks, typically exhibited survival rates of 100 and 90 percent, respectively. During the same holding time period, coho salmon were held in fiberglass tanks. In general, survival in holding tanks is good (near 100 percent) for periods of up to one week, and survival of 75 percent for periods longer than two weeks is fairly common. Fish held in the Quinault Indian Nations' facility generally are handled once a week to determine readiness for spawning (pers. com. R. Rhodes, 2003).

A holding facility similar to the FRFH design would be considered suitable for use at a potential fish passage project. At facilities where the holding pool exists at the terminus of a fish ladder, because there is no exit from the holding pool, capture efficiency is 100 percent for those fish successfully ascending the ladder.

Considerations

NOAA Fisheries (2003) describes criteria for holding pools/fish trapping systems that would be applicable to a potential Oroville Facilities fish passage program. The NOAA Fisheries handling guidelines indicate specific requirements for holding pool conditions, including a maximum holding pool volume of 5 ft^3 per fish. The criteria indicate that water must be supplied to the holding pools at a rate of 2 gallons per minute per adult fish. Additionally, methods to be employed to minimize stress upon fish associated with human activity in the vicinity include providing water spray across the entire pool surface or use of a pool cover to prevent fish agitation from nearby human activities. NOAA Fisheries (2003) also recommends that water surface elevation in the holding pools be controlled through the use of an exit overflow weir, and holding pools should have separate water supply and drain systems incorporated into their designs. Due to the likelihood of fish jumping within the holding pools, soft netting or darkening of the area over the pool should be provided to minimize fish injury. Holding tanks also should rise above the water surface of the holding pool (NOAA Fisheries 2003).

USACE (2000), based on Bell (1991) suggested that fish collection facilities supply 1.5 ft^3 of water per five pounds of fish. In addition, USACE (2000) also recommends dissolved oxygen saturation of 80 percent or higher be maintained through sufficient flow through the holding area and that dissolved oxygen levels should never be below a minimum of 5 mg/l (USACE 2000).

5.1.3.3 Conclusions

Holding tanks reportedly have been used to hold adult salmonids for both hatchery and wild fish passage programs successfully (DFG Website 2003; DFG Website 2004; Ferguson et al. 2002). Therefore, it would be expected that the use of dedicated adult

salmonid holding tanks would be compatible with a potential Oroville Facilities fish passage program at. The facilities and procedures required for temporary holding of adult fish in a potential passage program could be developed through modification of existing FRFH facilities or through the construction of new facilities at the hatchery, or at a new fish collection and handling location.

5.1.4 Adult Fish Transfer and Transport

Several alternatives exist for transferring fish from holding facilities to transport vehicles. The fish transfer facilities would be located at the capture and holding facilities, which would either be located at the existing FRFH facilities, or in a new, dedicated fish passage program facility. Additionally, several alternatives for the mode of fish transport were considered, but due to the costs, logistical constraints and speed and reliability of conveyance, only truck transport was evaluated in detail.

5.1.4.1 Location

After fish are transferred to a tank truck, they could be transported to a number of different potential adult release locations, including boat ramp or marina locations within the reservoir, or into selected locations in one of the upstream tributaries.

5.1.4.2 Alternatives

The adult fish transport methods considered in a preliminary feasibility analysis included tank trucks, barges, helicopters, and trains. The use of barges, helicopters, and trains were eliminated from further analysis because the use of these vehicles would not meet program goals as effectively as use of tank trucks.

Potential barge transport of adult fish upstream from Lake Oroville was eliminated from detailed analysis because the use of this method would not be consistent with a potential passage project's goals. Transporting fish by barge would require that fish first be transported by truck to a location upstream from the Oroville Dam and then transferred to a barge for transport to upstream spawning habitat. The implementation of a trap and barge program would increase the number of times that individuals would be handled. As a result, there would be a greater risk of increasing transport related stress and mortality. Therefore, the transportation of fish by barge is inconsistent with the goals of a potential fish passage program, which specify that opportunities to induce stress shall be minimized.

Helicopter transport of adult fish upstream from Lake Oroville was eliminated from detailed analysis because the cost per fish would be substantially higher than the cost associated with trucking fish while the benefit gained, in terms of fish survival, would not be a substantial improvement over that which can be achieved with tank trucks. Therefore, the substantial increase in the cost per fish associated with helicopter

transport renders this method of fish transport impractical for use in a potential Oroville Facilities fish passage program.

The use of rail transport would be somewhat comparable to truck transport in terms of fish survival rates as well as operation and maintenance costs involved but, the capitol costs associated with rail transport would likely exceed those of truck transport. The capitol costs associated with construction of railway spurs and associated facilities, rail transport would substantially increase the cost per fish, compared to the cost per fish associated with truck transport, rendering this method impractical for use in a potential Oroville Facilities fish passage program. Additionally, rail transport would not be as flexible as truck transport for potential changes if future potential passage program adult fish release locations.

Tank Trucks

Description

Adult fish transport from the holding facilities below the Oroville Dam to Lake Oroville or the tributaries to Lake Oroville would likely occur with the use of tank trucks. Because there is little information regarding adult trap and haul projects, it is assumed that if tank trucks were used to haul adult fish to upstream release sites, the trucks would be similar to trucks currently used to transport juveniles. Modifications such as attachment of automatic quick release gates could potentially be necessary to accommodate the transport and subsequent release of adult fish.

A survey of fish transportation equipment and techniques used by hatcheries, private producers, Indian reservations, and research laboratories conducted by Carmichael and Tomasso (1988), revealed that among survey respondents, truck-mounted tanks were more common than trailer-mounted tanks and a majority of transport vehicles carried only one tank. More than half of the loading volumes were reported to be between 60 and 500 gallons of water with between 501 and 1000 gallons of water being the second most common loading volume class reported. The survey also revealed that fiberglass tanks were the most common type of tank used among respondents and that tanks typically contained some type of insulation. Ice was most commonly used for water temperature maintenance rather than refrigeration units, and 47 percent of respondents reported using some form of air vent ventilation method. Infusion of bottled oxygen directly into the water in the tanks was the most common mechanism of tank ventilation (Carmichael and Tomasso 1988). Respondents to the survey reported using tank trucks for transporting a number of salmonid species including rainbow trout, brown trout, brook trout, coho salmon, and Chinook salmon.

Fish tank trucks used for Snake and Columbia river fish passage programs were reported to have water volume capacities of 3,500 gallons per tanker (Koski, C. H., Pettit, S. W., and McKern, J. L. 1990). Tank trucks are used to transport juvenile

salmonids from three different dams on the Columbia-Snake River system to just below the Bonneville Dam on the Columbia River. Driving times range from 3.5 to 8.0 (Koski, C. H., Pettit, S. W., and McKern, J. L. 1990).

A common practice in the Pacific Northwest is to load each individual fish into a transport tube. Individual fish transport tubes are made of polyvinyl chloride (PVC) pipe, typically sized three feet (0.9 m) in length with a 12-inch (0.3 m) diameter so that they are large enough to contain a large adult salmonid. The transport tubes have flapper doors on both ends of the tube to allow water to flow through the tube, and are equipped with handles for loading and unloading the fish from tank trucks (Simpson Resource Company 2002). In addition, the fish transport tubes generally are carried via tank trucks from the sorting and holding area to the unloading destination (i.e., another holding area or release site). Tubes may be stacked horizontally within the water tank. Use of the individual fish transport tubes nearly eliminates direct handling of the fish, but their use is limited when water-to-water transfer is required. In addition to reducing fish handling, thereby reducing the risk of causing handling related stress, use of the individual transport tubes reportedly reduces transportation-related stress that can occur when fish are crowded in a tank (Simpson Resource Company 2002). Transport tube use also is common to tribal hatcheries in the Pacific Northwest for the transport of steelhead, sockeye salmon, coho salmon, and Chinook salmon (pers. com. R. Rhodes, 2003). In addition, Simpson Resource Company (Simpson Resource Company 2002) identified the transport of adult coho salmon spawners as a potential cause of direct mortality as well as post release adult pre-spawn mortality and suggested that the use of individual fish transport tubes could be used to decrease mortality associated with transport.

Characteristics

The use of tank trucks to transport adult salmonids reportedly is a common practice at hatcheries. The FRFH uses transport trucks of either a 500-gallon or a 2,000-gallon capacity, depending upon the number of juveniles to be transported. The transport tanks are internally baffled to minimize physical damage to fish and are fully oxygenated. It also is common for ice and salt to be added for the purpose of reducing transport stress (DWR 2001). At the Salmon River Fish Culture Facility, a tribal hatchery in Queets, Washington, adult Chinook salmon and coho salmon are trapped in the Queets and Clearwater rivers and then transported by tank truck to the hatchery spawning facilities (pers. com. R. Rhoads, 2003).

Salmonid fish passage programs also employ tank trucks for the adult “trap and haul” stages of the program. The Baker River Hydroelectric Project in northwestern Washington includes a trap and haul element as part of the fish passage operations. The facilities include the Upper Baker Development, which consists of the Upper Baker Dam, a powerhouse, Baker Lake and associated fish collection facilities, and the Lower Baker Development which consists of the Baker River Fish Barrier Dam (Lower Baker

Dam), a powerhouse, Lake Shannon and associated fish facilities. Upon approaching Lower Baker Dam, migrating adult coho salmon and sockeye salmon are guided by attraction flow into a trapping facility similar to a fish ladder and then counted, measured and loaded into a truck by hand for transport to the Upper Baker facilities. The duration of fish transport was reported to be approximately twenty to twenty-five minutes. The tank trucks are equipped with aeration and oxygen diffusers. Adult sockeye salmon are released in the artificial spawning beaches located at the upstream end of Baker Lake while adult coho salmon are released in Baker Lake and Lake Shannon (Puget Sound Energy 2002). Lower Baker Dam fish facility operations also include upstream transport of adult Chinook salmon and steelhead using tank trucks (Puget Sound Energy 2002).

One risk associated with transporting adult fish by tank truck is handling related stress, which can increase the incidence of fish mortality (NOAA Fisheries 1998a; Pacific Fishery Management Council 2003). It was reported that no more than one to three adult coho salmon were injured or killed annually as a result of transfer to a transport truck at the Elk Creek Dam on the Rogue River, Oregon (NOAA Fisheries 1998a; Puget Sound Energy 2002). Between 38 and 1,053 adults were transported annually at Elk Creek Dam and the survival rates associated with the passage program were estimated to range from approximately 92.1 percent (35 out of 38 adults survive) to 99.9 percent (1,052 out of 1,053 adults survive). It was estimated that the time each individual spent in the transport truck was approximately 45 minutes. No mortality directly associated with the actual trucking and release process was reported.

It is assumed that there could potentially be a higher risk of fish mortality during transport if there is an extended duration of transport. The main concerns associated with the duration of transport are maintenance of suitable holding water temperatures and adequate oxygenation of the water because extreme change in these physiochemical parameters could drastically effect the survival of the fish.

During the October 1995 through September 1996 period, 2,196 adult spring-run Chinook salmon were transported via truck in the lower Umatilla River, Oregon for the Umatilla River Trap and Haul Program. A total of 8 adult spring-run Chinook salmon died during trucking, resulting in a trucking survival rate of approximately 99.6 percent (Zimmerman, B. C. and Duke, B. B. 1996). The length of time required for transport was not reported, but was assumed to be less than one hour because the total distance travelled was approximately 30 miles.

Limited information was reported in available literature regarding the cost of tank trucks for use in adult fish transport. Clay (1995) provided cost estimate values (1987 US Dollars) reported from fish passage facilities worldwide, in which fish transport tanks, including piping, valves, and two circulating pumps, cost between $17,000 for a 300-gallon tank and $28,000 dollars for a 1000-gallon tank. The cost of truck chasses also was dependent on tank size and ranged from $20,000 to $50,000 for tanks from 300-

gallons to 1,000-gallons. Additionally, annual truck operating and replacement costs were estimated to be up to $5,000 per truck (Clay 1995).

USACE (2000) reported estimated transport truck operating costs of approximately $1,000 per month during the migration season (April through September) at the proposed Cougar Lake Fish Passage Project, Washington. A more recent estimate of the costs of fish tank trucks was reported by the (Commercial Salmon Trollers Advisory Committee Website 2004), which purchased a total of five tank truck trailers for $30,000 each as part of the Commercial Salmon Stamp Project. The size of the tanks purchased and other related costs were not reported (Commercial Salmon Trollers Advisory Committee Website 2004).

Considerations

Performance criteria for adult fish transportation (trap and haul operation) associated with the Klamath Hydroelectric Project was provided by (pers. com. D. White, 2003), in which NOAA Fisheries indicated that for adult fish passage through both the fish ladder and the trap and haul stages of the program, the combined adult survival should be 98 percent or greater. Additionally, passage and survival through the Klamath Reservoir should be 80 percent or better, and overall passage survival through the fish ladder, trap and haul, and reservoir elements of the program should be at least 75 percent (White and Mefford 2002).

USACE (2000) used criteria reported by Bell (1991) that indicated the transportation criteria for adult fish was 1.5 cubic feet of water for each 5 pounds of fish. Additionally, USACE (2000) cited Baxter (1996) as reporting that truck water tank temperatures should be held within 3 degrees of ambient water temperatures at the release site.

5.1.4.3 Conclusions

Utilization of tank trucks as part of a potential Oroville Facilities fish program would be compatible with other elements of the adult phase of a potential passage program because the preferred location for collection and holding of adult upmigrants would be the FRFH, which currently is accessed by existing roads. Use of the FRFH, which already can accommodate tank trucks, provides an opportunity to minimize the amount of fish handling required moving fish from the collection/holding facility into transport trucks. It also is assumed that the adult fish release location(s) (Lake Oroville or one or more of the upstream tributaries to Lake Oroville) could be designed/modified to accommodate the use of fish tank trucks. Potential road improvements could include basic maintenance, increase of bearing capacity of culverts or bridges to support truck capacities, and alteration of road turnarounds to accommodate minimum turning radius of the transport trucks. Potential access location improvements could include creation of ramps, chutes, or flumes to ensure adequate access to adult release locations. Detailed engineering requirements for potential road or access site modifications are not

included in the scope of this report. Overall, the use of tank trucks to transport adult salmonids would be considered consistent with Oroville Facilities fish passage program goals and compatible with other elements of the upstream adult fish passage phase.

5.1.5 Adult Fish Release

There are several different potential release locations that could be utilized in a potential fish passage program. The potential locations could be divided into two major groups, each with their own set of factors that should be considered: a release directly to Lake Oroville, or a release into selected locations in the upstream tributaries. Adult release from trucks requires very little infrastructure to support other than direct access to the waters edge, therefore few, if any, facilities would be required at potential release locations.

5.1.5.1 Lake Oroville Release

Potential Lake Oroville adult release locations include, but are not limited to areas in the West Branch arm, the South Fork arm, and the main body of the lake. Potential release locations on the West Branch and South Fork arms include the Lime Saddle Marina and the Enterprise Area Marina. Potential adult release locations in the main reservoir body include Spillway Boat Ramp, Bidwell Canyon Boat Ramp, and Loafer Creek Boat Launch. Figure 5.1-8 shows the potential adult release locations on Lake Oroville. The reservoir tends to be at relatively high stage elevations during the early upmigrant Chinook salmon and steelhead immigration periods, so all of the potential boat ramps would be accessible and watered. Reservoir stage elevations tend to be lower during the late upmigrant Chinook salmon immigration period and could potentially present access limitations because some boat ramps could potentially be dewatered in some years.

Factors that should be considered when releasing adults into Lake Oroville include; potential for disease transmission, exposure to elevated surface water temperatures in during transfer, straying to unrecoverable tributaries, residualization, potential thermal barriers to immigration in tributary arms of the reservoir, ability of migrating adults to pass sediment wedges in reservoir tributary arms, likely required changes to Lake Oroville fishing regulations, and the potential reduction in management flexibility of the stocked coldwater fishery.

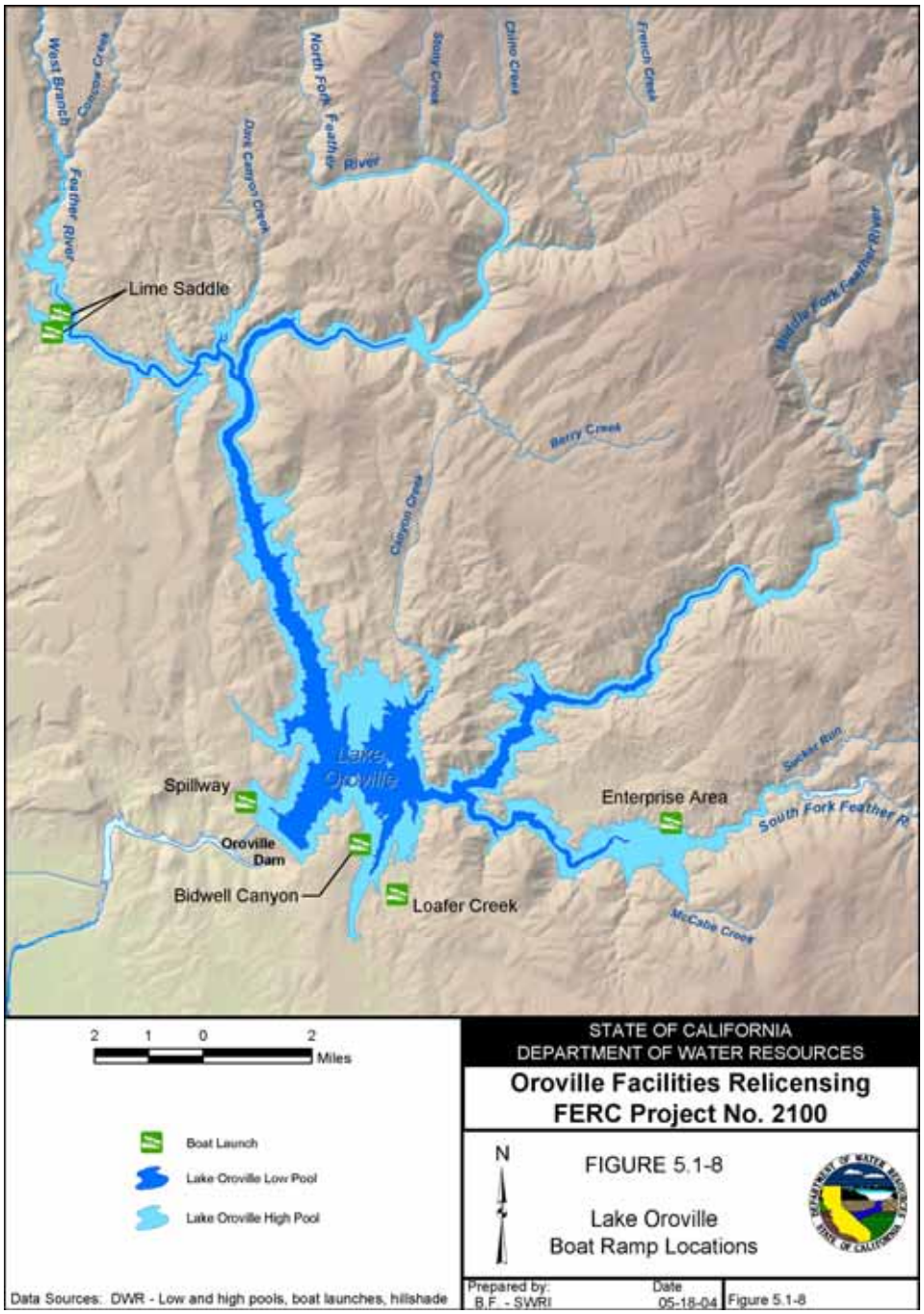

Figure 5.1-8 Lake Oroville with Marinas and Boat Ramp Locations.

Providing anadromous salmonids passage to upstream areas from the fish barrier dam creates a risk of infecting the FRFH water supply with the Infectious Hematopoietic Necrosis Virus (IHNV). In California, IHNV has been eliminated from most of its historic range by dam construction and the blocking of inland waters from the spawning and juvenile rearing of anadromous salmonids. Historically, IHNV was endemic to the entire Sacramento, American, Merced and Feather River drainages. Currently, only those

portions of these watersheds below dams blocking anadromous salmonids contain IHNV (pers. com. W. T. Cox, 2003).

If anadromous salmonid passage were established above the Oroville Dam, there would be an associated risk of potentially contaminating the FRFH water supply with IHNV. Eliminating the risk of infected water entering the FRFH would require either an alternative water source, or a method to disinfect the incoming water supply. Without an alternative or disinfected water source there would be an increased risk of disease outbreak and associated mortality at the hatchery. The risk associated with potential losses of fish would have to be weighed against the cost of obtaining alternate water sources for the hatchery.

The transmission of IHNV infection from transported fish to native species in the upper Feather River watershed may not be likely. Steward and Bjornn (1990) *in* Campton (1995) found that, "in spite of the comparatively high incidence of disease among some hatchery fish stocks, there is little evidence to suggest that diseases or parasites are routinely transmitted from hatchery fish to wild fish." Additionally, Foott, J. et al. (2000) were unable to induce IHNV infection of healthy Chinook salmon by placing them in close proximity to infected fish. They concluded that the low virulence of the Sacramento River strain of IHNV reduces the likelihood of initial infection progressing to a disease state in juvenile Chinook salmon and that the releases of infected hatchery fish to the Sacramento River presents a low ecological risk to natural populations. However release of adult Chinook salmon in Lake Oroville or the upstream tributaries could potentially be associated with a cumulative effect of increased pathogen pressures in Lake Oroville and the lower Feather River associated with transporting infected fish upstream from Lake Oroville. Even if water were disinfected for hatchery purposes, the potential for virus entering the Thermalito Forebay, Thermalito Afterbay, and LFC directly from Lake Oroville still would exist. Although transmission of the disease to salmonids in these areas is not likely, the potential should be considered in any risk analysis associated with allowing upstream passage of anadromous salmonids.

During the period when adult upmigrant Chinook salmon would be released into Lake Oroville as part of a potential passage program, surface water temperatures generally range from 20°C to 27°C (68 to 80°F). Although released fish would probably seek coldwater refuges in the lake, the initial stress associated with warm water transit will be unavoidable. Methods attempting to avoid initial exposure to elevated surface water temperatures during release of adult salmonids reportedly have not been successful (pers. com. D. P. Lee, 2004). Additionally, it is unknown if the adults released will hold in the reservoir or if they will continue upstream migration to lake tributaries.

Study plan report SP-F3.1 Task 2B, *Evaluation of the Ability of Lake Oroville's Coldwater Pool to Support Salmonid Stocking Recommendations*, examined usable coldwater habitat in Lake Oroville. For the purpose of this analysis, the usable coldwater habitat was defined as any zone in Lake Oroville in which the water

temperature criteria of less than 18°C (64.4^{o}F) and the dissolved oxygen criteria of greater than or equal to 6.5 mg/l were met. Water temperature and dissolved oxygen profiles collected over 51 months at as many as 8 different sampling locations in Lake Oroville were analyzed and for each month of the period of record the volume of useable coldwater habitat at each location for which data were available was calculated. Because of the variability in the volume of usable coldwater habitat between locations, the average volume of usable coldwater habitat was calculated for each month and year of the period of record. Results suggest that even in the months and years with the lowest calculated average volume of usable coldwater habitat in Lake Oroville, the volume of usable coldwater habitat available per fish would exceed the volume of water provided for fish in settings such as hatcheries, and experimental and commercial net-pen operations. The assumptions associated with calculating usable coldwater habitat were highly conservative, almost certainly resulting in an underestimation of the actual volume of usable coldwater habitat in Lake Oroville. Therefore, continued operation of the Oroville facilities in a manner consistent with current operations would be expected to result in sufficient coldwater habitat in the reservoir to support potential fish passage program release locations in Lake Oroville. It is unclear, however, whether released adult Chinook salmon and steelhead would be capable of finding and utilizing available coldwater habitat. It also should be noted that the investigation of the coldwater pool availability did confirm that there was coldwater pool habitat available at all times evaluated, but coldwater pool was not always available in all sample locations. Adult release into reservoir tributaries at locations and times without available coldwater pool may result in increased adult pre-spawn mortality and in-vivo egg mortality. Monitoring of coldwater availability at times of adult release may be required for adaptive management of a potential fish passage program. Additionally, future changes to Oroville operations to more fully utilize the reservoir coldwater pool for lower Feather River water temperature management could potentially affect the volume, availability, timing, distribution, and suitability of the coldwater pool habitat in the reservoir.

Successful spawning of adult Chinook salmon released into Lake Oroville would require continued migration through the reservoir into suitable tributary spawning habitat, and would require appropriate tributary inflows, water temperatures, and reservoir surface elevations.

The amount of attraction flow to any particular tributary is dynamic and dependent on tributary flows (runoff and upstream reservoir operations), reservoir stage elevation, and location relative to other tributary arms and the main body of the reservoir. Lake Oroville is a multi-armed tributary reservoir that has very different hydrologic characteristics than a “run-of-the-river” type reservoir (i.e. Columbia River reservoirs) with organized mass flow that acts to attraction anadromous fishes. Tributary arms of the reservoir with low proportional flow contribution during reservoir filling may have low or even negative velocities at times, which may contribute to reduced homing cues, immigration delays, or potentially increased straying to other tributaries.

Transported adults migrating to, and spawning in tributaries without associated capture facilities would result in the loss of the offspring from those adults to a passage program. Therefore, adult migration to tributaries without associated juvenile capture facilities would result in effects as detrimental to potential passage program productivity as adult pre-spawn mortality. There are four major tributaries and ten 2nd order or higher streams feeding into Lake Oroville. Most of these tributaries have impassable fish barriers at the confluence with the reservoir high pool, but some may have the potential to attract adult salmonids to stray into them. If a potential fish passage program was associated with in-reservoir release of adults, and juvenile collection facilities were not constructed at all major tributaries or in 2nd order tributaries that may attract salmonid spawning, there would be losses in program productivity (i.e. juvenile losses) proportional to the straying to those tributaries.

The release location of program fish could have effects on homing cues and straying. For example, both the West Branch of the North Fork Feather River (West Branch) and the North Fork Feather River (North Fork) could potentially provide suitable spawning habitat for Chinook salmon. If release occurred at the Lime Saddle Marina, the West Branch would likely provide suitable attraction flow. However, individuals would need to migrate downstream without direct attraction and navigation cues for approximately 4.2 miles within the West Branch arm of Lake Oroville to reach the confluence of the North Fork and West Branch arms. A review of available fisheries literature did not provide insight to the likelihood of such migrations occurring. In contrast, potential main reservoir release locations, including Spillway Boat Ramp, Bidwell Canyon, and Loafer Creek Boat Launch would provide direct access to homing cues from all tributaries. However, only small proportional volumes of flow for potential attraction would likely influence the released individuals.

Water temperature is one of the most important environmental parameters affecting the distribution, growth, and survival of fish populations. Lethal water temperatures influence fish populations by directly reducing population size, while elevated sub-lethal water temperatures can influence fish populations through indirect effects on the physiology of individuals during different life stages.

Water temperatures in Lake Oroville tributaries may present thermal barriers to adult Chinook salmon immigration, thus precluding them from spawning without directly causing mortality. Similarly, warm epilimnetic water in Lake Oroville during late spring, summer, and fall also may present thermal barriers to migration, restricting adult Chinook salmon to cooler hypolimnetic waters, potentially eliminating them from the spawning population. Adult Chinook salmon planted in Lake Oroville may cease normal immigration and spawning behavior, a process known as residualization, and take up residence in the reservoir. Although documentation of residualization of immigrating adult Chinook salmon was not located, residualization of juvenile salmonids is well documented (e.g., (Muir et al. 2001; Viola and Schuck 1995) and adult residualization remains a possibility.

Based on an extensive review and evaluation of available literature, a set of water temperature index values for adult Chinook salmon immigration and holding was developed. Water temperature index evaluation criteria for adult immigration and holding were established for all Chinook salmon run-types to reflect a water temperature range reported in the literature to provide optimal, suitable, sublethal, or lethal water temperature conditions during the upstream immigration and holding period. The water temperature index values selected to evaluate the Chinook salmon and adult immigration life stage are 60°F, 64°F, and 68°F (Table 5.1-1). Although 56°F is referenced in the literature frequently as the upper water temperature limit required for upstream migration and holding, the references are not foundational studies, and often are inappropriate citations. For example, many of the references to 56°F are based on Hinze, (1959), which is a study examining the effects of water temperature on incubating Chinook salmon eggs. Boles et al. (1988), Marine (1992), and (NOAA Fisheries (1997b) all cite Hinze, (1959) in support of recommendations for a water temperature of 56°F for Chinook salmon immigration. Because 56°F is not strongly supported in the foundational literature, it was not selected as an index value. The lowest water temperature index value selected was 60°F, because in the NOAA Fisheries biological opinion for the proposed operation of the Central Valley Project and State Water Project, 59°F to 60°F is reported as, “The upper limit of the optimal temperature range for adults holding while eggs are maturing” (NOAA Fisheries 2000a). NOAA Fisheries (1997b) states, “Generally, the maximum temperature of adults holding, while eggs are maturing, is about 59°F to 60°F" and that the, “Acceptable range for adults migrating upstream range from 57°F to 67°F. ODEQ (1995), reports that, “…many of the diseases that commonly affect Chinook salmon become highly infectious and virulent above 60°F.” In addition, 64°F was chosen as an index value, because Berman (1990) suggests that effects of thermal stress to pre-spawning adult Chinook salmon are evident at water temperatures near 64°F and also because 64°F represents a mid-point value between the water temperature index values of 60°F and 68°F. Berman (1990) conducted a laboratory study to determine if pre-spawning water temperatures experienced by adult Chinook salmon influenced reproductive success, and found evidence suggesting latent embryonic abnormalities associated with water temperature exposure to pre-spawning adults occurs at 63.5°F to 66.2°F. Finally, 68°F was selected as an index value, because the literature suggests that thermal stress at water temperatures greater than or equal to 68°F is pronounced and severe adverse effects to immigrating and holding pre-spawning adults, including mortality can be expected (Berman 1990; Marine 1992; NOAA Fisheries 1997b). Because significant impacts to immigrating and holding adult Chinook salmon reportedly occur at water temperatures greater than or equal to 68°F, it was not necessary to select index values higher than 68°F.

Table 5.1-1. Chinook Salmon Adult Immigration and Holding Water Temperature Index Values and the Literature Supporting Each Value.

Index Value	Supporting Literature
60°F (15.6°C)	Maximum water temperature for adults holding, while eggs are maturing, is approximately 59ºF to 60ºF (NOAA Fisheries 1997b); Acceptable water temperatures for adults migrating upstream range from 57ºF to 67ºF (NOAA Fisheries 1997b); Upper limit of the optimal water temperature range for adults holding while eggs are maturing is 59°F to 60°F (NOAA Fisheries 2000a); Many of the diseases that commonly affect Chinook salmon become highly infectious and virulent above 60ºF (ODEQ 1995); Mature females subjected to prolonged exposure to water temperatures above 60°F have poor survival rates and produce less viable eggs than females exposed to lower water temperatures (USFWS 1995)
64°F (17.8°C)	Acceptable range for adults migrating upstream is from 57ºF to 67ºF (NOAA Fisheries 1997b); Disease risk becomes high at water temperatures above 64.4°F (EPA 2003); Latent embryonic mortalities and abnormalities associated with water temperature exposure to pre-spawning adults occur at 63.5ºF to 66.2°F (Berman 1990)
68°F (20°C)	Acceptable range for adults migrating upstream range from 57ºF to 67ºF (NOAA Fisheries 1997b); For chronic exposures, an incipient upper lethal water temperature limit for pre-spawning adult salmon probably falls within the range of 62.6°F to 68.0°F (Marine, K. R. 1992); Spring-run chinook salmon embryos from adults held at 63.5ºF to 66.2°F had greater numbers of pre-hatch mortalities and developmental abnormalities than embryos from adults held at 57.2ºF to 59.9°F (Berman 1990); Water temperatures of 68°F resulted in nearly 100 percent mortality of Chinook salmon during columnaris outbreaks (Ordal and Pacha 1963)

A recent study completed by Peery et al. (2003) examined water temperatures and passage of adult Chinook salmon in the lower Snake River, Idaho. Radio telemetry was used to monitor up-stream migrations of adult Chinook salmon and steelhead. The analyses showed a high correlation between travel times between dams and water temperature. Additionally, Peery et al. (2003) reported that salmon stopped up-stream migration when water temperatures at fish ladders approached 20°C (68°F). Water temperatures at a depth of one meter in Lake Oroville and the study area on the Snake River are compared to the water temperature index values for Chinook salmon holding and immigration in Figure 5.1-9.

Based on data used to create Figure 5.1-9, it would appear that a thermal barrier to migration into the upper tributaries of Lake Oroville would be in place until mid-October and perhaps into November. It also should be noted that the timing of the thermal barrier dissolution corresponds to low inflow from upstream tributaries and low reservoir storage levels that could potentially coincide with sediment wedge exposure periods and reduced attraction flows.

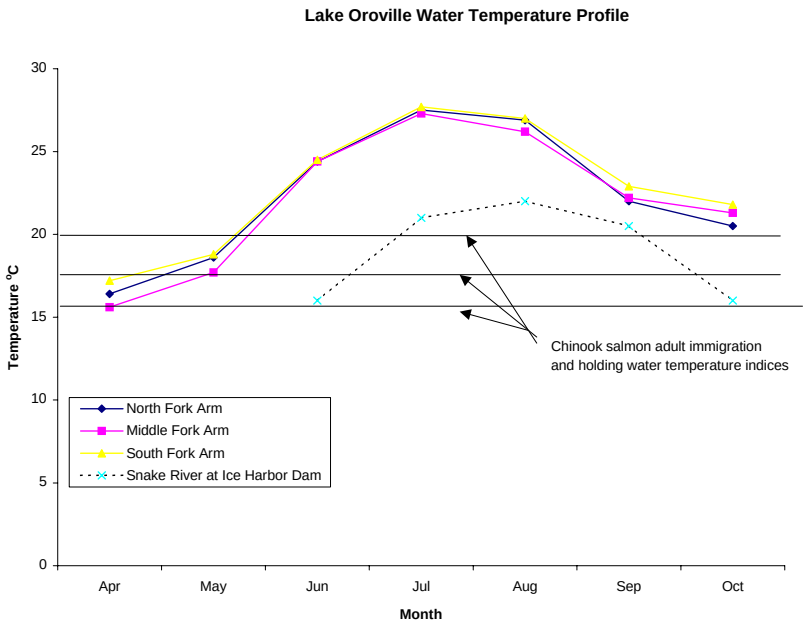

Figure 5.1-9. Lake Oroville water temperatures at a depth of one meter in the North, Middle, and South Fork arms compared to Snake River water temperatures at Ice Harbor Dam. Horizontal black lines indicate Chinook salmon immigration and holding water temperature index values.

If transported adults released into Lake Oroville do not hold in the coldwater pool and continue their upstream migration, there could be a temporal overlap between adults immigrating into the upstream tributaries to spawn and juveniles emigrating out of the tributaries. If a surface flow collection system (gulper system) is used for juvenile fish capture in the tributary arms of Lake Oroville, the associated guide nets could potentially effectively block the immigrating adults from reaching the upstream tributary spawning areas. The gulper and guide nets would be anticipated to be in place beginning in mid-November through May of each year and the early upmigrant Chinook salmon transport period would occur from March through June. The overlap in timing between juvenile emigration and adult immigration could potentially result in a block or delay in adult immigration that may contribute to potential residualization, increased exposure to unsuitable water temperatures, increased straying rates to non-target fish passage program tributaries, increased adult prespawn mortality, and increased in-vivo egg mortality.

Another potential source of effective mortality (i.e. adult Chinook salmon not reaching spawning habitat) could be the presence of sediment wedges that occurred at 700 ft to 720 ft msl in Lake Oroville during DWR site visits. The sediment wedges could potentially block upstream migrating adult Chinook salmon from entering the upstream tributaries after adult passage and release in Lake Oroville if the sediment wedges are not inundated by the reservoir stage elevation during the immigration period. According to analysis performed for SP-F3.1 Task 1A, upstream migration of adult Chinook salmon would only infrequently potentially be hindered by sediment wedges located at

approximately 700 ft msl. It should be noted that sediment wedges are formed after tributary high flow events and will likely at times form sediment wedges at higher reservoir stage elevations, which would more frequently present a potential salmonid immigration barrier. For detailed analysis of sediment wedge inundation frequencies see SP-F3.1 Task 1A Final Report.

In addition to sediment wedges potentially limiting access to upstream tributaries for fish immigrating from Lake Oroville, other potential barriers to fish immigration exist on some tributaries. In the West Branch, both Salmon Falls and Miocene Dam represent potential effective fish barriers to upstream migration. Salmon Falls is located on the West Branch 2.2 miles upstream from and approximately 250 vertical feet above the Lake Oroville high pool at an elevation of 1148 feet. Miocene Dam is 4.0 miles upstream from Salmon Falls. Evidence at both sites indicates that these features may be passable by fish at some flows higher than the flows observed during a fish passage assessment conducted by DWR. The passability of these potential fish passage barriers would be dependent upon the timing, magnitude and frequency of high flow events sufficient to provide for fish passage during the salmonid immigration period. The comparison of fish migration timing to the frequency of high flow events in the West Branch Feather River reveals that twenty-seven high flow events during the 18-year period of record examined occurred during the spring-run Chinook salmon upstream migration period and eighteen high flow events occurred during the fall-run Chinook salmon upstream migration period. Actual flow levels required to create conditions that would make these potential fish barriers on the West Branch passable to adult Chinook salmon, steelhead and green sturgeon is unknown. For detailed analysis of the West Branch high flow event frequency during salmonid immigration periods, see SP-F3.1 Task 1A Final Report.

Big Bend Dam is another potential fish passage barrier to fish immigrating from Lake Oroville up the North Fork. Big Bend Dam is located on the North Fork within the Lake Oroville high pool and is 1.0 mile downstream from the Poe Powerhouse. The dam is currently only passable when the Lake Oroville stage elevation is near maximum pool during the salmonid immigration period. The comparison of the timing of the high pool events to the salmonid upstream migration timing indicates that the only significant overlap in timing is with spring-run Chinook salmon, for which 25 out of 26 high pool events examined recorded over the 34 year period fell within their migration timing range. Steelhead immigration timing has significantly less overlap relative to the spring-run Chinook salmon immigration period, and corresponds to only 1-recorded high pool event over the entire 34-year period. In the case of fall-run Chinook salmon, immigration timing does not overlap with any of the recorded high pool events. Analysis of these results indicate that passage of steelhead and fall-run Chinook salmon may not be possible if the timing of high pool events recorded from 1967 through 2001 is indicative of future conditions. For a detailed analysis of the frequency of Lake Oroville high pool events for Big Bend Dam fish passage during the salmonid immigration period, see SP-F3.1 Task 1A Final Report.

One other factor that should be considered in a potential Lake Oroville release of passage program fish is the possible exposure to gas bubble disease (GBD). Dissolved gasses in water cause GBD when the sum of the partial pressures of all dissolved gasses exceeds atmospheric pressure. One of the main causes of dissolved gas supersaturation reportedly occurs when water is released over dam sluiceways. Within these structures air is entrained in falling water, which plunges to depth in pools at the base of the dam. Under elevated hydrostatic pressure, air bubbles are forced into solution (Fidler and Miller 1994). When this occurs in water that enters the respiratory system of fish, gases can come out of solution as fish decrease their depth, which can form emboli in the blood vessels of many organs (Noga 1996). Direct effects of GBD on fish include bubble formation in the cardiovascular system, over inflation and possible rupture of the swim bladder in juveniles, extracorporeal bubble formation in gill lamella or in the buccal cavity, subdermal emphysema on body surfaces and in the lining of the mouth, and exopthalmia and ocular lesions (Bouck 1980; Fidler and Miller 1994; Weitkamp and Katz 1980). Indirect effects of GBD include increased susceptibility to bacterial, fungal or viral infections, and increased susceptibility to predation (Fidler and Miller 1994; Weitkamp and Katz 1980). Mortality can occur from either direct or indirect effects or a combination of both. In general, levels of about 110 percent saturation are considered dangerous to fish, however effects vary with species. For example, adult salmonids often tolerate saturations above 125 percent (Noga 1996). Current EPA guidelines recommend that total dissolved gas pressure remain below a maximum of 110 percent of ambient atmospheric pressure (EPA 1986).

Cochnauer and Davis (1998) evaluated the effect of gas supersaturation on adult salmonids in the Clearwater River below the Dworshak Dam, Idaho. They encountered gas saturation levels of up to 122.96 percent and concluded that there were no detrimental effects to adult salmonids captured in the immediate area. During construction of the John Day Dam on the Columbia River, Backman and Evans (2002) reported 20,000 adult Chinook salmon were killed when saturation levels neared 140 percent. Additionally, Chinook salmon reportedly appear to be more tolerant of gas supersaturation than other salmonid species based on a less than one percent mortality rate for adult Chinook salmon when levels are below 126 percent (Backman and Evans 2002). It also was reported by Gale et al. (2001) that fish surviving supersaturation exposure suffer no decrease in reproductive success.

Structures, both artificial and natural, in the project area that could potentially create conditions promoting gas supersaturation include; Salmon Falls, Miocene Dam and Big Bend Dam.

Salmon Falls, located on the West Branch creates a vertical drop of 15 to 18 feet during high flow events. The depth of the pool at the base of the falls was not measured for safety reasons. Miocene Dam, also located on the West Branch presents a vertical drop of 7.9 feet during high flows and 10.1 feet during low flows. The pool at the base

of the dam was measured to a depth of 15 feet during a low flow period. Big Bend Dam presents a vertical drop of 30 feet during low flows (see Figure 5.1-10) and is completely inundated during high flow events.

Figure 5.1-10 Oblique aerial photograph of Big Bend Dam and plunge pool.

Several factors interact to determine the level of gas saturation in falling waters including height of fall, water temperature, flow, and geologic conditions at the base of the fall. The depth of the pool at the base of the falls can determine saturation levels. Weitkamp, D. E. (2000) reported that the level of saturation decreases approximately 10 percent per meter of depth. For example, if gas saturation were measured at 130 percent at the water surface, saturation would be 110 percent at a depth of two meters.

Gas saturation levels have been measured continuously at several Columbia River dams by the USGS. Peak levels of saturation recorded since 1998 are 127 percent at the John Day Dam with a vertical height of 219 feet and 130 percent at Bonneville Dam with a vertical height of 197 feet (USGS Website). It is unknown if any of the features that could be associated with a potential Oroville Facilities fish passage program would result in nitrogen supersaturation, but because the facilities at which supersaturation detrimental to salmonids reportedly occurs, have substantially larger vertical drops than the identified features upstream from Oroville Dam, it is unlikely that supersaturation would occur at levels detrimental to a potential fish passage program.

5.1.5.2 Upstream Tributary Release

Adult salmonids transported as part of a potential fish passage program could alternatively be released into selected locations in the upper Feather River tributaries. Release into the upstream tributaries requires physical access similar to those described for the reservoir adult release. Tubes or chutes could potentially be constructed to extend access from the transport truck into the selected tributary location to eliminate the need for access to a boat ramp. Road access to the upstream tributaries is limited by steep terrain and limited development and land use intensity. In addition to road access constraints, the proximity of holding habitat to spawning areas, holding and spawning habitat availability and suitability, and the potential locations available for juvenile collection would affect the selection of adult release locations. Evaluation of the upstream tributary habitat and its suitability for anadromous salmonids is discussed in Final Report prepared for SP-F15 Task 2. Potential release locations could include areas on the West Branch, North Fork, Middle Fork Feather River (Middle Fork) and South Fork Feather River (South Fork).

Steep terrain and a deep river canyon limit access to the West Branch. Although several roads parallel the canyon on both the east and west sides of the canyon rim, the only direct access points currently identified as potential locations for adult release in the West Branch are the Miocene Dam access road and the bridge on Jordan Hills Road. Both roads currently are serviceable for adult fish transport (Figure 5.1-11).

The land immediately adjacent to the Miocene Dam is federally owned (see Figure 5.1-14). Access to the tributary from the truck to areas upstream or downstream from the facility could likely be achieved through a tube or chute that would run from the transport truck to the tributary. Adults released downstream from Miocene Dam would have access to approximately 6.2 river miles containing potential spawning habitat, see SP-F15 Task 2 report and Figure 5.1-11. Because there are currently no identified access points downstream from this location, progeny of adults released below Miocene Dam would likely be required to be captured using a gulper in the Oroville reservoir rather than an instream or off channel screening facility (see Section 5.2.1). Adults released above Miocene Dam would have access to approximately 7.3 river miles of habitat upstream to the falls below Big Kimshew Creek, which has been defined as a provisional impassable fish barrier in the Final Study Plan Report for SP-F3.1 Task 1A.

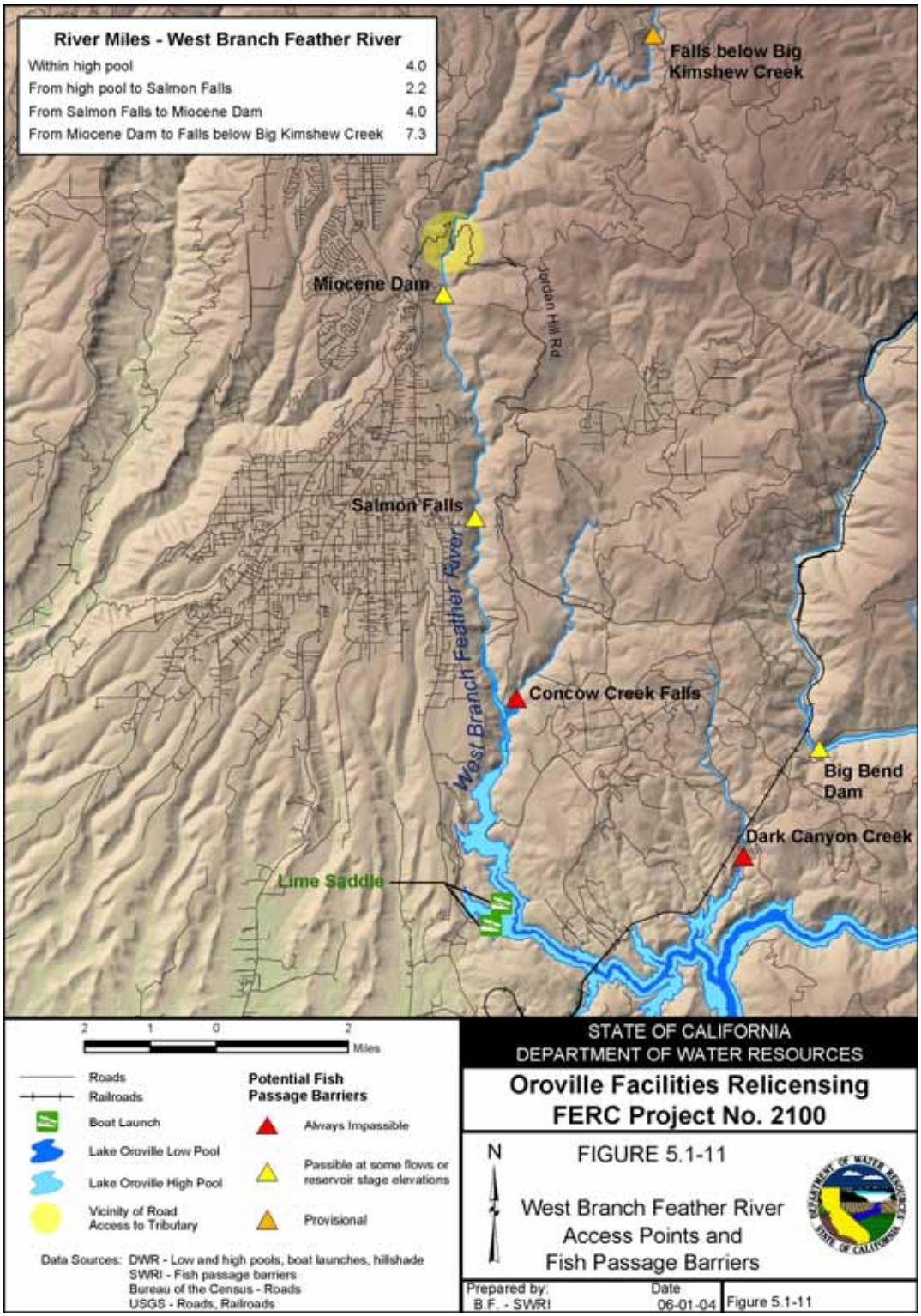

Figure 5.1-11 West Branch Feather River Access Points and Fish Passage Barriers

The bridge at the Jordan Hills Road could also potentially provide access for adult fish release, but the site conditions and potential adult release alternatives have not been evaluated. The land surrounding the bridge access point is privately owned (see Figure 5.1-14). Adult fish released at the bridge would have access to the same habitat as those adults released above Miocene Dam.

Access to the North Fork Feather River is somewhat limited by steep terrain and a deep river canyon. However, several roads intersect the tributary between Big Bend Dam and Poe Dam. Figure 5.1-12 shows a map of the North Fork area with access road names and access points on the river highlighted in yellow.

The Big Bend Dam access road is washed out in several locations and would require substantial re-engineering to support adult transport trucks. Site conditions on the West side of Big Bend Dam at the terminus of the access road do not appear adequate to accommodate truck turnaround space requirements. The area adjacent to Big Bend Dam on the access road from the South is owned by the state.

The next upstream access point for the North Fork is via several different logging roads that intersect the railroad tracks that parallel the river on the east side. The best access to the railroad tracks is via the Poe Powerhouse access road. The Western Pacific Railroad owns the railroad and any access to their right of way would need to be negotiated.

Based on access to available habitat and appropriateness for adult fish transport trucks, the most suitable access to the North Fork is via the access road to the Poe Powerhouse. The Poe facility and adjacent lands are owned by PG&E. Adults released downstream of the Poe Powerhouse would have access to 1.0 river miles of potential habitat. Some of this reach is known to be pool mesohabitat resulting from Big Bend Dam and Lake Oroville high pool, and could provide potential salmonid holding habitat with the combination of increased flows and cooler water temperatures resulting from the Poe Powerhouse releases. Adults released upstream of Poe Powerhouse would have access to approximately 7.7 river miles of potential holding, spawning, and rearing habitat upstream to the Poe Dam, see SP-F15 Task 2 report and Figure 5.1-12.

There currently are no identified access opportunities for the Middle Fork between the Oroville reservoir high pool and the first impassable fish barrier. Figure 5.1-13 shows the Middle Fork and South Fork. Adult release in the Middle Fork would need to be accomplished either by construction of a new access through some very steep terrain or by helicopter drop. The first impassable fish barrier in the South Fork is the Ponderosa Dam at the high pool of Lake Oroville, so there is no spawning habitat currently accessible above the inundation zone of the reservoir. Based on habitat availability in each of the four major tributaries entering Lake Oroville (reported in the Final Report for SP-F15 Task 2), the South Fork was determined to be the least appropriate for Chinook salmon.

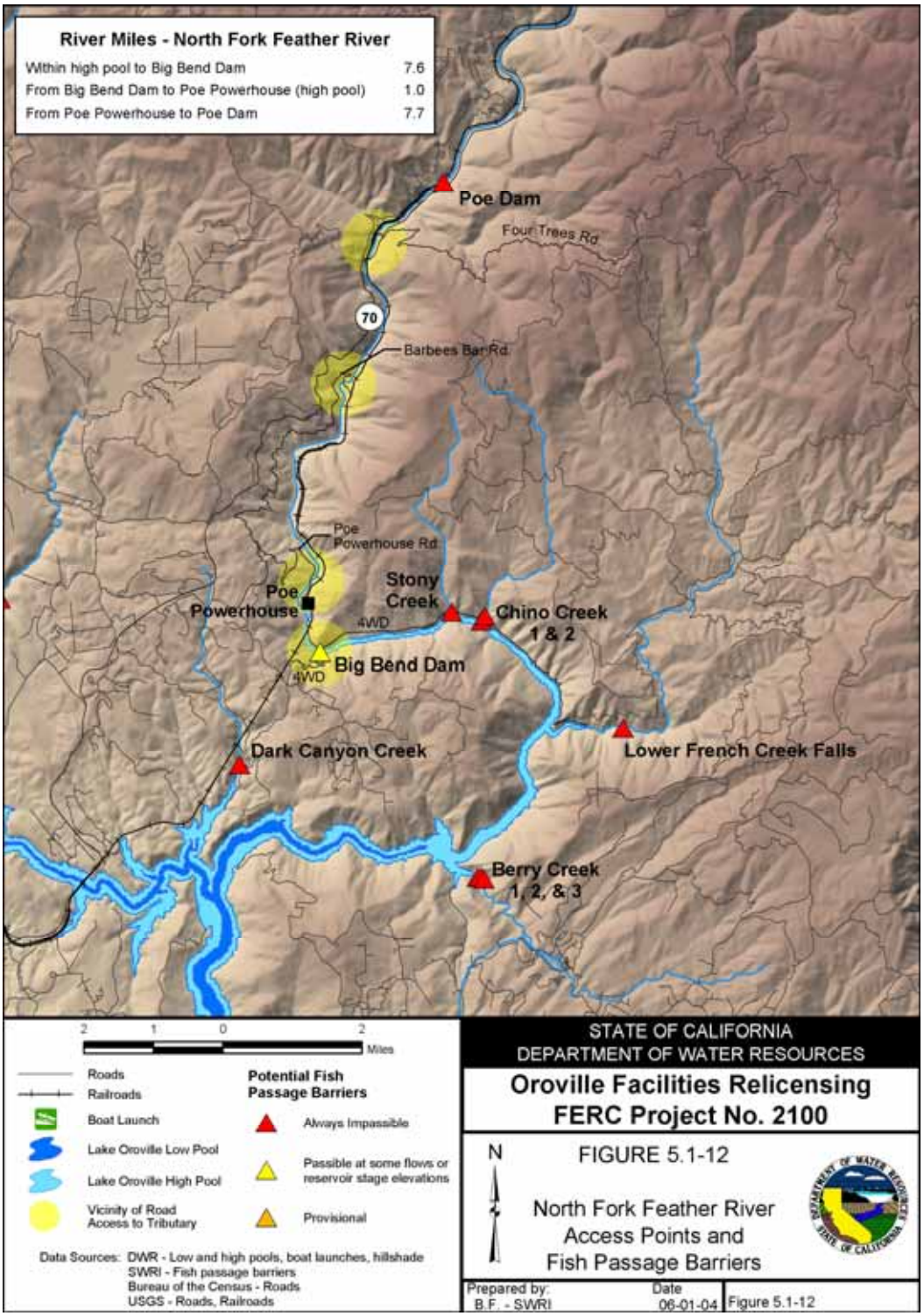

Figure 5.1-12. North Fork Feather River Access Points and Fish Passage Barriers.

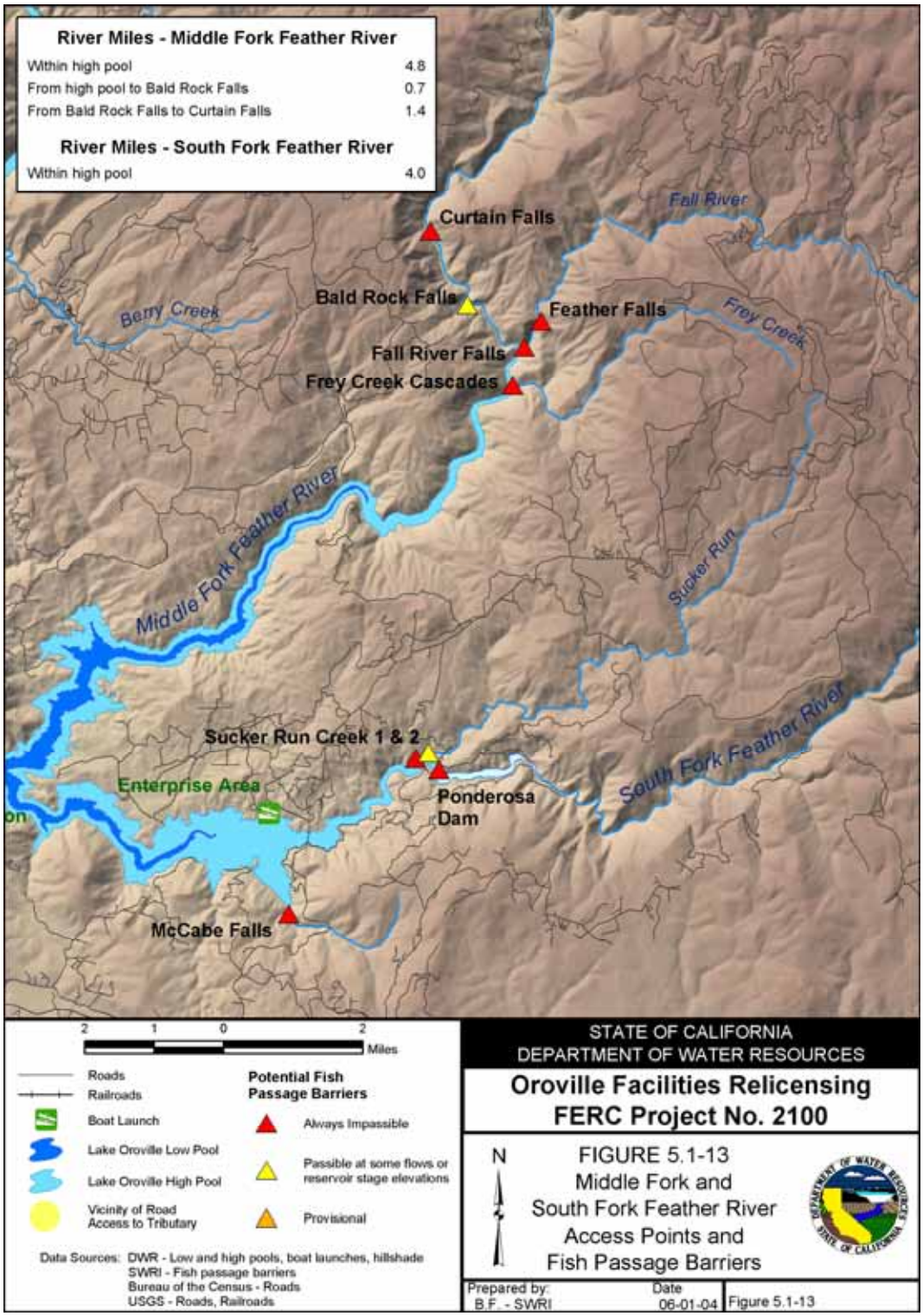

Figure 5.1-13. Middle Fork and South Branch Feather River Access Points and Fish Passage Barriers.

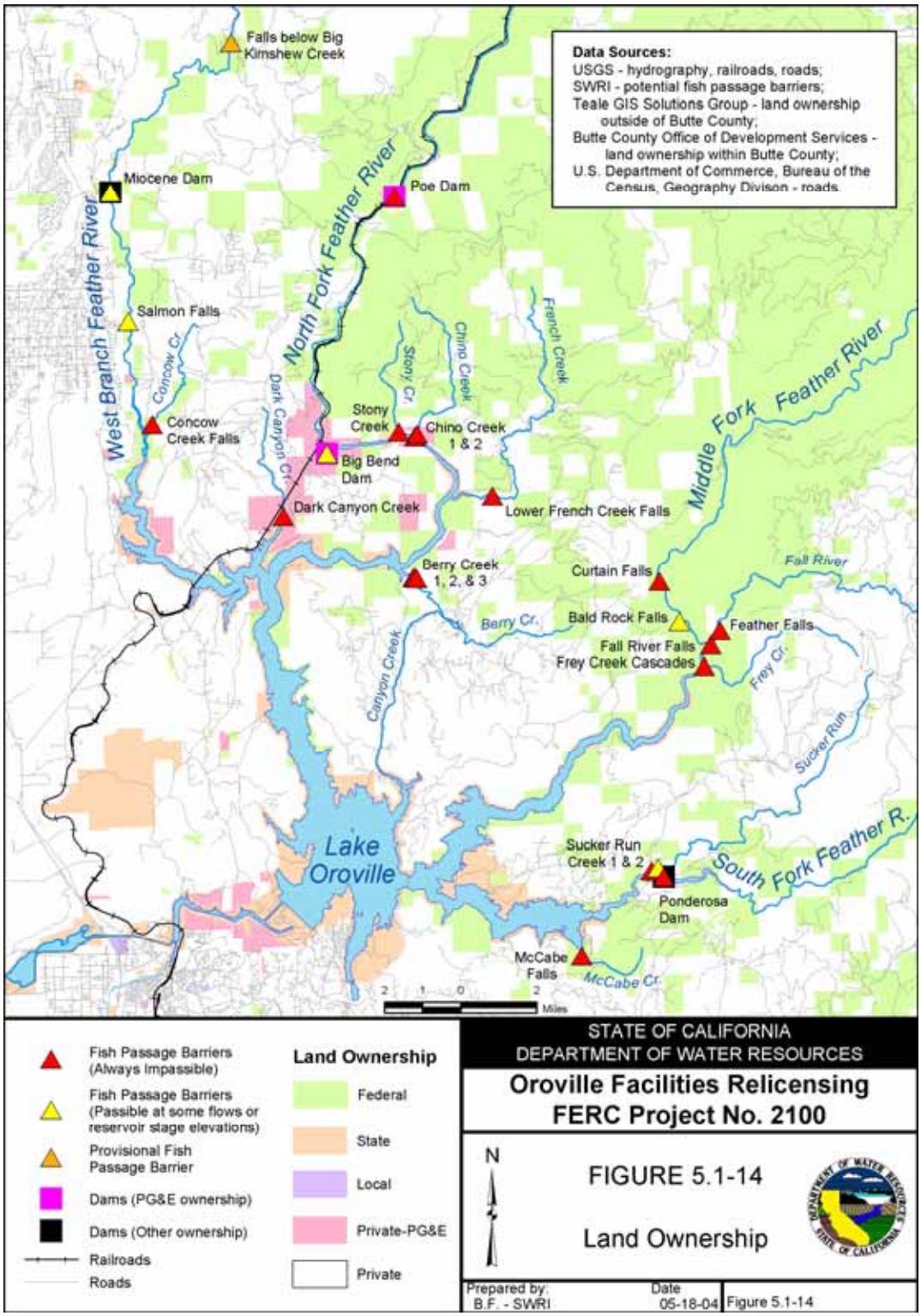

Figure 5.1-14. Land Ownership in the Upstream Tributaries of Lake Oroville.

5.1.5.3 Alternatives

Removal and release of the adult fish from the transport vehicle(s) to the receiving waters can be accomplished by unloading each individual fish or by unloading all transported fish at one time. The use of transport tubes would be the preferred method of transporting fish when they would be released individually at the release site. Unloading individual adult fish contained in transport tubes would involve lifting each tube from within the tank truck and releasing the fish from the tube into the receiving water. Unloading all transported fish at one time would involve use of a tank truck with a quick-acting release gate. Either the use of individual fish transport tubes (see Section 5.1.4.), or quick-release from a tank truck would result in less handling than attempting to net individual free-swimming fish to unload them from tanks prior to release into the receiving water body. However, determination of the appropriate release method for a potential fish passage program requires consideration of the preferred transportation method/vehicles as well as the on-site conditions (i.e., access, maneuverability, potential fish stress associated with method, etc.) at the preferred release location.

Individual removal and release of fish

Description

Removal and release of individual adult fish could potentially be accomplished by use of nets or fish transport tubes. Individual fish release through use of nets involves capture of free-swimming adult fish transported in tank trucks using a net, unloading them from the tank, and carrying and releasing the fish into the receiving water (or other destination). Rice (1960), reporting on the manual capture and release of fish at the DFG Nimbus Fish Hatchery on the American River, Sacramento, California, reported that the capture, unloading, and release of individual, free swimming adult salmonids from tank trucks is time consuming and requires considerable effort.

Fish transport tubes, described Section 5.1.4. Adult Transport and Transfer, are used to contain adult fish within transport tanks and to facilitate the process of unloading and releasing fish individually into receiving waters (pers. com. R. Rhodes, 2003; Simpson Resource Company 2002). The transport tubes typically are manually loaded and unloaded through trap doors at the top of the tanks. Compared to use of nets this form of transport and release minimizes direct human contact with the adult fish, thereby reducing associated stress. Adult fish can be released from the individual transport tubes immediately upon unloading from the tank by opening one end of the tube and allowing the fish to volitionally move into the receiving water. Alternatively, the transport tubes still containing the fish can be tethered to a stationary object and then placed in the receiving waters for fifteen to twenty minutes allowing the fish to acclimate to the receiving water prior to release from the transport tube.

Characteristics

According to R. Rhodes (pers. com. 2003), Pacific Northwest tribal hatcheries reportedly place transport tubes containing either steelhead, sockeye salmon, coho salmon, or Chinook salmon in the receiving waters for a period of time to allow individuals to acclimate prior to release. Additionally, an impact analysis of the use of transport tubes indicated that it would be anticipated that acclimation using transport tubes minimizes stress and reduces the risk of adult pre-spawn mortality associated with fish release (Simpson Resource Company 2002).

Considerations

Based on available reports, the use of individual release methods may be appropriate for release of adult Chinook salmon and steelhead into receiving waters as part of a potential fish passage program.

Quick-acting release gate

Description

According to Clay (1995), the use of a tank truck equipped with a quick-acting release gate is considered to be the best method to quickly and safely release adult fish directly into receiving waters. As described in (Clay 1995), "the release mechanism is tripped by means of the lever on the left side of the truck, which disengages the cam rollers from the cams on each side of the gate, allowing the two heavy-duty springs to pull the gate fully open very quickly." Typically, a truck of this type has a clear gate opening of a little less than two feet by two feet.

In a location where there is no truck access at the waters edge or if the water is shallow and there is the possible risk of injury to the fish, this system can be modified with the addition of a steep wooden or metal chute to transfer fish from the tank truck to the receiving water. It is recommended that if a chute is used that it be set at such a slope that fish passing down the chute are surrounded by water from the tank (Clay 1995).

Characteristics

Because Clay (1995) did not discuss mortality rates associated with the use of a quick-acting release gate it is unclear how release through the gates affects stress, injury, and adult pre-spawn mortality rates.

Hager and Costello (1999) proposed the use of a quick-acting release gate for releasing fish as part of the Upper Yakima River Spring-run Chinook Salmon Supplementation Project in Washington. The release strategy described by Hager and Costello (1999) involved discharge of the transport tank contents through a spring-loaded gate located

at the rear of the tank and included use of a flume to direct the released fish into the receiving waters.

Considerations

Based on available literature, the use of tank trucks equipped with quick-acting release gates may be an appropriate application for release of adult Chinook salmon and steelhead into receiving waters at potential release locations above Oroville Dam. Depending upon the access conditions at the location(s) selected for release, the method may include the use of a flume or chute.

5.1.5.4 Conclusions

The method of adult fish release could potentially vary depending on the selection of release locations and access to the sites. In some cases it may be necessary to release fish individually by manually carrying them to the receiving water in transport tubes. In other locations, quick release methods that transfer fish directly from the truck into the receiving water may be employed. Once specific release sites are identified, specific methods may be identified for use in specific locations.

Two different release location scenarios are under consideration. The first, and least costly would be releasing adult spring-run Chinook salmon directly into Lake Oroville. However, it is unknown what the behavior of the transported adults would be if released directly into the reservoir. It is possible that they would continue upstream migration to the tributaries or, because the release of spring-run Chinook salmon coincides with warm surface water temperatures (68 to 80°F), they may seek coldwater refuges in the in the hypolimnion of the reservoir. If the fish remain in the reservoir until dissolution of thermal barriers to upstream migration occurs, other obstacles may be encountered (i.e. low attraction flows, low flows over potential fish passage barriers, sediment wedges, blockage to upstream tributaries by gulpers required for juvenile collection).

Transported adults also could be released directly into the upstream tributaries to Lake Oroville. Tributary release could potentially eliminate the potential for thermal barriers, low tributary inflow, sediment wedge exposure, and gulper guide net interference, to inhibit further upstream migration of transported adults. However, success likely would be dependent on the ability of the fish to find coldwater refuge appropriate for holding in the tributaries.

5.2 POTENTIAL JUVENILE FISH PASSAGE ELEMENTS

Figure 5.2-1 Potential Juvenile Fish Passage Elements illustrates the general sequence and relationships of fish passage elements for the juvenile phase of a potential fish passage program. The figure also identifies the relevant geographic locations and alternatives for each potential fish passage program element. The juvenile phase of a potential fish passage program is anticipated to run from mid-November through June

during the juvenile Chinook salmon emigration period. Upstream tributary habitat conditions and suitability for juvenile rearing and emigration salmonid life stage periods are evaluated in the Final Report for SP-F15 Task 2.

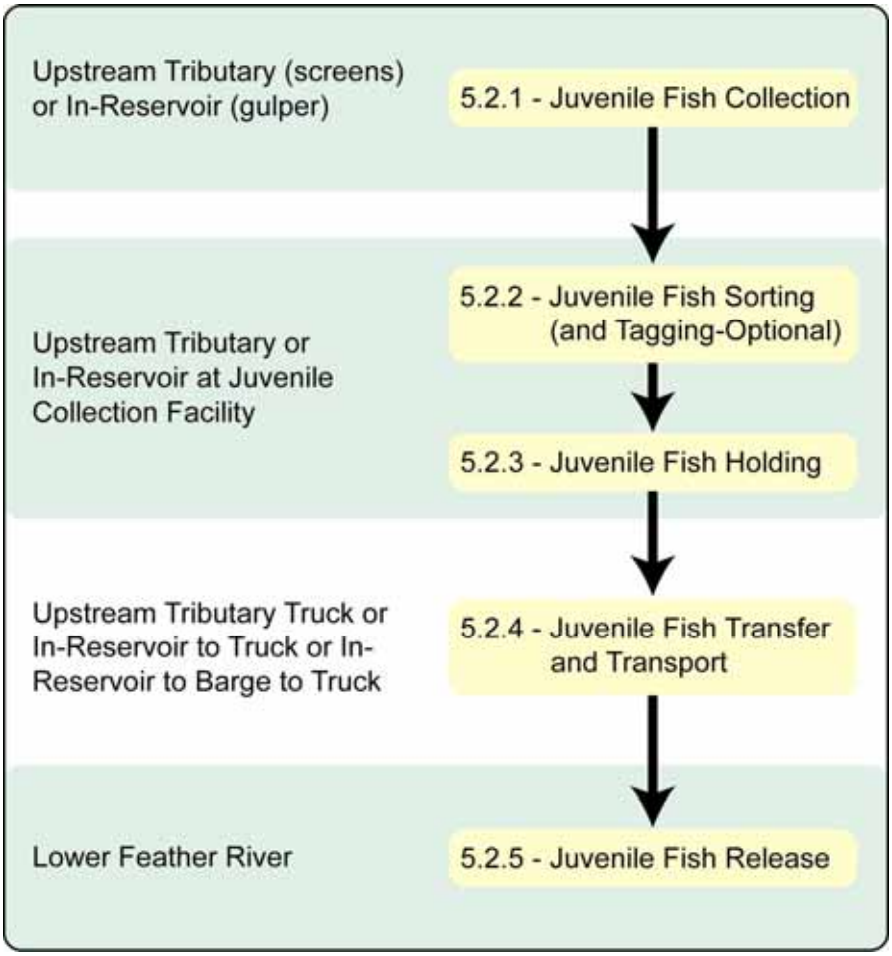

Figure 5.2-1 Potential Juvenile Fish Passage Program Elements.

5.2.1 Juvenile Fish Collection

The first element in the juvenile phase of a potential fish passage program is to collect individual juveniles for possible inclusion in the program. Juvenile fish collection occurs when the juvenile salmonids begin emigration from the upstream tributaries shortly after emergence or after a period of rearing. Juvenile downstream movement could occur within a short period of time after fry emergence if the fish are exhibiting ocean-type (fall-run) life history behavior or it could occur later after the fish have reared in the upstream tributary for a period of time and are exhibiting stream-type (spring-run) life history behavior.

The juvenile capture phase of a potential fish passage program is designed to minimize juvenile fish mortality due to stress from handling while maximizing target species

capture opportunities. Another fundamental premise of this element of a potential fish passage program is to minimize the disruption of resident fish either through capture and release downstream from Oroville Dam (inclusion of the fish in the passage program), capture and release of resident fish at the point of capture (in the upstream tributaries or reservoir) or by inhibition of the movement of resident fish in the upstream tributaries or reservoir.

5.2.1.1 Location

Juvenile fish collection could be conducted with two different types of juvenile collection devices in two different types of locations. Juvenile collection could be accomplished in the upstream tributaries with a fish screen or with a surface collector in the tributary arms in Lake Oroville. Capture in the upstream tributaries would be desirable for a potential fish passage program because the fish screens would likely have a higher capture efficiency than the gulper and the fish captured in the upstream tributaries would not be subjected to the potential losses associated with transit through the reservoir prior to capture by the gulper.

<u>Upstream Tributary Juvenile Collection</u>

Juvenile salmonid collection with a fish screen in the upstream tributaries could be accomplished with two different types of screen designs with different resulting costs and functionality. The first fish screen alternative is an inexpensive removable fish screen that is placed in the stream channel, but for purposes of this analysis only functions for flows below approximately 1200 cfs. Table 5.2-1 presents flow data for the West Branch, North Fork, and Middle Fork. Based on analysis of data presented in Table 5.2-1, this alternative may not be viable in the major upstream tributaries. The second fish screen alternative is a full-flow diversion to an off channel fish screen facility, which is more expensive than the removable screens, but can be designed to meet the range of flows in the specific tributaries during the juvenile salmonid emigration period. Both screen types require daily maintenance for removal of debris that may affect screen capture efficiency.

Table 5.2-1. Upstream Tributary Flow Data During Juvenile Chinook Emigration.

Tributary	% Flow Below 1220 (cfs)	Mean Flow (cfs)	95 Percentile Flow (cfs)
West Branch Feather River[A]	92.1	53	171
North Fork Feather River[B]	12.1	401	946
Middle Fork Feather River[C]	54.4	189	587

Source [A] USGS 11406500 West Branch Feather River Nr Yankee Hill Road (1931-1962)
[B] USGS 11404901 North Fork Feather River Pulga + Poe (1968-1983)
[C] CDEC Middle Fork Feather river at Merrimac (1987-2002)

Site selection criteria for an upstream tributary fish screen include:

- Accretions and depletions of flow affect the proportion of juvenile capture that could be accomplished with removable screens and/or the design specifications of off channel screens as well as the fish screen alternative overall suitability to the tributary
- Lower flows increase the proportion of juvenile capture for the in-channel fish screens and may reduce the cost of the off-channel fish screens
- Off channel physical space is required for a full flow diversion fish screen
- Road access for truck transport of collected juvenile fish
- The lower down the drainage the facility, the more potential rearing habitat is available and the farther upstream a facility, the less potential rearing habitat is available

The variation in life history strategies exhibited between spring- and fall-run Chinook salmon results in differences in the temporal distribution of juvenile emigration (Healey 1991; Moyle 2002). According to Moyle (2002), fall-run Chinook salmon emigration peaks during spring (March and April), and spring-run Chinook salmon emigration peaks during winter (January to February) and then again in spring (April).

Juvenile Chinook salmon downstream migrant trapping data from Butte Creek (Ward and McReynolds 2001) and the lower Feather River (DWR 2002a) were reviewed to estimate the proportion of fish that emigrated during “high flow” and “low flow” months. The lower Feather River data reported emigration timing for spring- and fall-run Chinook salmon based on juvenile outmigrant length-at-date from the Sacramento River Daily Length Table (Green 1992 *in* DWR 2002a). Ward and McReynolds (2001) reported spring-run juvenile Chinook salmon emigration timing for Butte Creek, which was utilized for comparison to spring-run Chinook salmon emigration timing in the lower Feather River. Juvenile Chinook salmon emigration patterns in the lower Feather River are assumed to be representative of potential emigration patterns in the upper tributaries (i.e., there is no difference in emigration timing between upstream tributaries and the lower Feather River).

Flow records obtained from the California Data Exchange Center Website (2003) were examined to characterize the "low flow" period of the year for tributaries to Lake Oroville. Data were available for North Fork Feather River at Pulga, Middle Fork Feather River at Merimac, and West Branch Feather River at Miocene Canal (Figure 5.2-2). Data were available from 1996 through 2001 for the North Fork, from 1998 through 2002 for the Middle Fork, and from1986 through 2002 for the West Branch. July through November was considered to represent the low flow period in all upper Feather River tributaries.

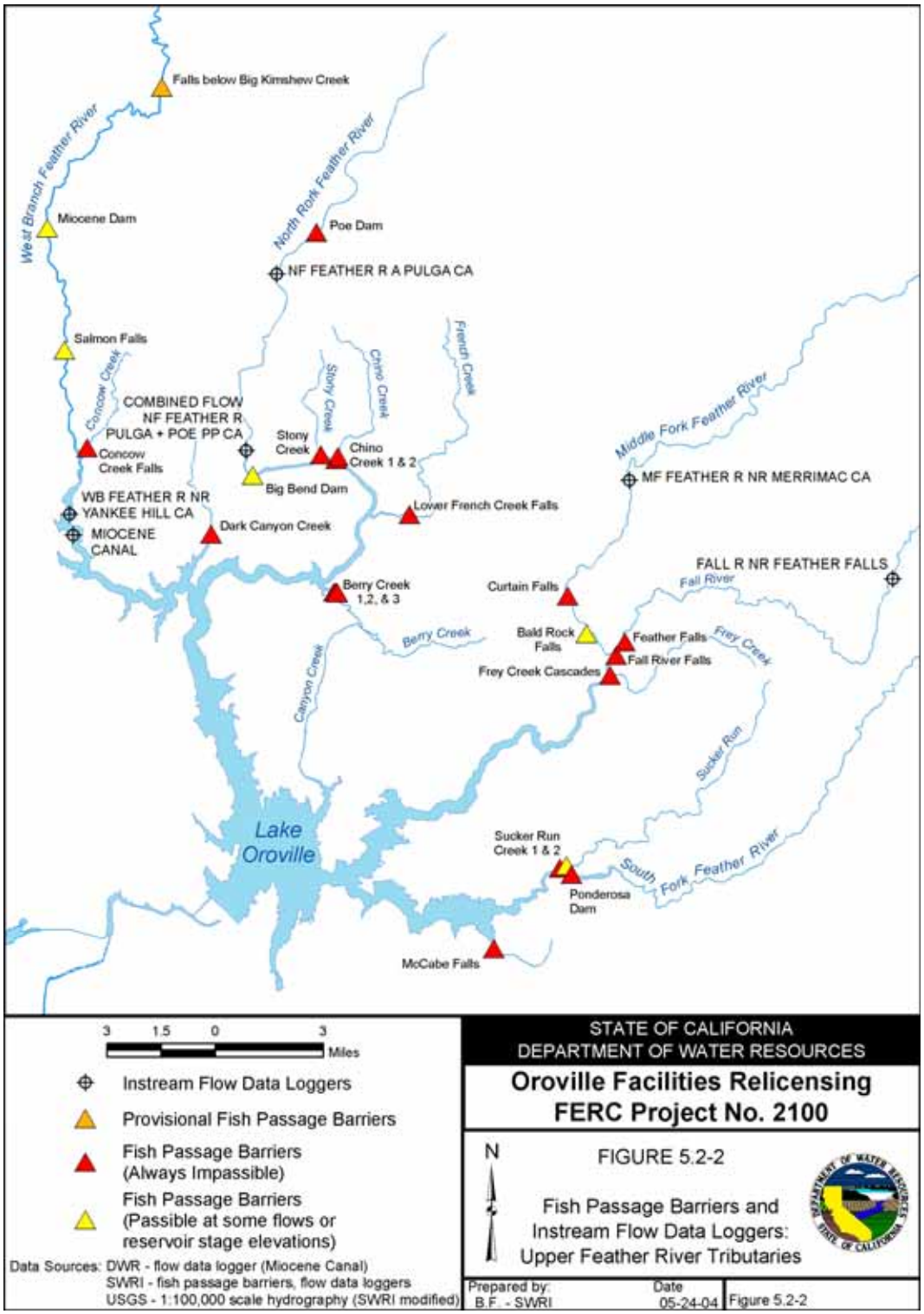

Figure 5.2-2. Gage stations and potential fish passage barriers in the upper Feather River tributaries to Lake Oroville.

Examination of the data revealed that flow in the West Branch was significantly lower than flow in either the Middle Fork or the North Fork. Examination of flow records in the Middle Fork and North Fork revealed that flows exhibited similar trends in monthly flow distribution. Specifically, flow decreases rapidly during spring, from May to July and is more pronounced in the Middle Fork. Flows of only 1/3 of the average monthly June flow remain throughout summer, gradually increasing during fall. Average monthly flows during November are about 2/3 of the flows that occur during June, and slightly more than ½ of those occurring during December.

An estimate of the proportion of juvenile spring- and fall-run Chinook salmon that typically emigrate from July through November was obtained by evaluating the juvenile Chinook salmon downstream migrant trapping data from Butte Creek and the lower Feather River (DWR 2002a; Ward and McReynolds 2001). During the analysis it was assumed that rotary screw trap data is not size-biased, and reflects true migration patterns of emigrating juvenile salmonids.

To assess the run migration timing of Butte Creek spring-run Chinook salmon, a combination of biweekly screen trap and screw trap catch data from Parrott-Phelan Diversion Dam from 1998 through 2000 was examined. Based on these data, the percentage of juvenile spring-run Chinook salmon in Butte creek that emigrated during the July through November period was determined to be approximately 0.32 percent over the two-year period.

Feather River Thermalito rotary screw trap catch distribution data collected from 1999 through 2001 was utilized to estimate the proportion of spring- and fall-run juvenile Chinook salmon emigrating from July through November. (DWR 2002a) assigned a race to all juvenile Chinook salmon captured using the length/date criterion set forth in the Sacramento River Daily Length Table (Green 1992 *in* (DWR 2002a)). Using the catch distribution data, the percentage of spring- and fall-run juvenile Chinook salmon in the lower Feather River that emigrated from July through November was calculated to be approximately 1.4 and 0.0 percent, respectively, over the three-year period. Although an indeterminate level of error is associated with the length-at-date size classification criteria used to identify juvenile Chinook salmon races in (DWR 2002a), the identification error was assumed to be negligible.

Because most fall-run Chinook salmon reportedly do not emigrate during the low-flow period (DWR 2002a) it is assumed that juvenile Chinook salmon captured during low flows (July through November) represent only emigrating juvenile spring-run Chinook salmon and represents less than 2.0 percent of the emigrating population.

Road access locations for the West Branch include, Miocene Dam Road and Jordan Road, see Figure 5.1-11. The site conditions at Miocene Dam appear to support the physical space requirements for an off channel screen. Miocene Dam is the most

downstream access point currently known in the drainage. The physical access characteristics and potential suitability at Jordan Road have not been evaluated.

Road access locations for the North Fork include, from most downstream to most upstream, Big Bend Dam access road, Poe Powerhouse Road, Barbees Bar Road, and Four Trees Road, which are shown on Figure 5.1-12.

The Big Bend Dam access road is washed out in several locations and would require substantial re-engineering to support juvenile fish transport activities. Site conditions on the west side of Big Bend Dam at the terminus of the access road do not appear adequate to be able to accommodate truck turnaround requirements.

The next upstream access point for the North Fork is via several different logging roads that intersect the railroad tracks that parallel the tributary on the east side. The best access to the railroad tracks is via the Poe Powerhouse access road. The Western Pacific Railroad owns the railroad and any access to their right of way would need to be negotiated.

The access to the North Fork that currently is the best based on ease of access and general condition of the access road is the access road to the Poe Powerhouse. Juveniles collected at the Poe Powerhouse location would have had access to approximately 7.7 river miles of potential rearing habitat upstream from the powerhouse to Poe Dam (Figure 5.1-12). For detailed analysis of available habitat see the Final Report of SP-F15 Task 2.

There currently are no identified access opportunities for the Middle Fork between the Lake Oroville high pool and the first impassable fish barrier (Figure 5.1-13). The relatively high flows in the Middle Fork make the removable instream screen applicable during the juvenile salmonid emigration period an average of only 54.4% of the time (Table 5.2-1). The steep canyon conditions, lack of available access, and lack of readily identifiable physical site opportunities for an off-channel fish screening facility make this upstream juvenile collection alternative appear impractical. Because the site conditions and flows in the Middle Fork appear to limit tributary juvenile capture opportunities, juvenile salmonid capture using a surface collection system in the reservoir appears to be the most feasible of the two juvenile fish capture alternatives.

The first impassable fish barrier in the South Fork is Ponderosa Dam at the high pool of Lake Oroville, so there is no rearing habitat currently accessible above the inundation zone of the reservoir. All potential rearing habitat on the South Fork is within the inundation zone of the reservoir and the habitat quantity potentially available within the fluctuation zone is subject to the reservoir inundation during the juvenile rearing period. Because juvenile collection would need to be conducted within the reservoir fluctuation zone on the West Branch, there are no physical space opportunities for off channel screen collection. The removable in-channel fish screen could potentially be used in

upstream juvenile collection, but with flows in the South Branch falling to 0 cfs during some times, the amount and quantity of potential rearing habitat would be seasonal and could be limited. Of the four major tributaries entering Lake Oroville, the South Fork was determined to be the least appropriate for Chinook salmon in the Final Report for SP-F15 Task 2.

In-Reservoir Juvenile Collection

The alternative method for juvenile salmonid capture is with a combination of a guide net and surface collector in the tributary arms of Lake Oroville. Operation of the surface collector in the reservoir tributary arms is desirable as a strategy to limit the amount of juvenile fish losses in the reservoir as well as to allow potentially distinct populations of fish to be genetically isolated by tributary.

The potential anchoring locations for surface collector operation are determined by the range of stage elevations of the reservoir and tributary inflows during the juvenile emigration period to provide appropriate average water column velocities for operation of guide nets. All surface collectors currently known to be in operation are operated at fixed locations attached to a dam while none are known to be moved to various operating locations. Surface collectors potentially located farther downstream in the reservoir tributary arm would be more likely to conflict with boating, fishing, and other forms of recreation on the lake. Nets reportedly can be designed for boat passage, but would likely reduce guiding efficiency (pers. com. D. Dorratcague, 2004).

Changes in reservoir stage elevation affect the operation and maintenance of the guide nets both by potential snagging of the nets from reservoir stage elevation increases as well as billowing of the nets and reduced guide net efficiency from reductions in reservoir stage elevations. Changes in reservoir stage elevations alter the water surface distance from shore to shore, requiring the net length to change with changes in reservoir elevation. Site conditions and net configuration engineering would determine the practical operating tolerance of the guide nets to reservoir stage elevation changes. The number of surface collector operating stations required for each tributary would be determined by net operating tolerance ranges and tributary arm water column velocities.

Acoustic devices designed to modify fish behavior were investigated as a potential alternative to guide nets to avoid the operational costs and constraints associated with guide nets, but were found not to provide high enough efficiency for further consideration for inclusion as an alternative. Section 5.2.1.3 provides the rationale for exclusion of behavioral guidance devices as potential alternatives to guide net use.

Juvenile salmonids emigrating from the upstream tributaries may be exposed to GBD. Dissolved gasses in water cause GBD when the sum of the partial pressures of all dissolved gasses exceeds atmospheric pressure. One of the main causes of dissolved gas supersaturation reportedly occurs when water is released over dam sluiceways.

Within these structures air is entrained in falling water, which plunges to depth in pools at the base of the dam. Under elevated hydrostatic pressure, air bubbles are forced into solution (Fidler and Miller 1994). When this occurs in water that enters the respiratory system of fish, gases can come out of solution as fish decrease their depth, which can form emboli in the blood vessels of many organs (Noga 1996). Direct effects of GBD on fish include bubble formation in the cardiovascular system, over inflation and possible rupture of the swim bladder in juveniles, extracorporeal bubble formation in gill lamella or in the buccal cavity, subdermal emphysema on body surfaces and in the lining of the mouth, and exopthalmia and ocular lesions (Bouck 1980; Fidler and Miller 1994; Weitkamp and Katz 1980). Indirect effects of GBD include increased susceptibility to bacterial, fungal or viral infections, and increased susceptibility to predation (Fidler and Miller 1994; Weitkamp and Katz 1980). Mortality can occur from either direct or indirect effects or a combination of both. In general, levels of about 110 percent saturation are considered dangerous to fish, however effects vary with species. Current EPA guidelines recommend that total dissolved gas pressure remain below a maximum of 110 percent of ambient atmospheric pressure (EPA 1986). Structures, both artificial and natural, in the project area that could potentially create conditions promoting gas supersaturation include Salmon Falls and Miocene Dam on the West Branch, and Big Bend Dam on the North Fork.

Upstream immigration timing of adult salmonids released into Lake Oroville as an option for the adult release location (see section 5.1.5.1) is not known. Adult fish would be released in the reservoir from April through June, which would occur concurrently with the operation of the surface collectors and their associated guide nets from mid-November through June. Effective blockage of the tributary arms of the reservoir by gulper guide nets could result in delays in adult fish upstream migration for those fish released in the reservoir (see section 5.1.5.1).

Surface collectors require substantial amounts of energy to operate (pers. com. D. Dorratcague, 2004). All surface collectors currently known to be in operation utilize electrical power sources at their station locations. No readily available existing accesses to power sources have been identified for any of the target tributaries for potential surface collector application. Some power transmission lines do cross the lower West Branch and Upper North Fork Feather River, but would require substantial investments for additional lines to access these potential power sources. The cost and feasibility of engineering these potential power supply projects is not within the scope of this report.

An alternative power supply to high voltage electrical access is to utilize diesel power generators. In surface collector station locations without road access, the generators would need to be included on the surface collection barge or companion barge and would require service and support by boat. This boat or barge support substantially adds to the costs and logistical complexities of surface collector operations. Vibration caused by diesel generators may also potentially affect surface collector efficiencies if

not adequately dampened. If road access is available at the surface collector station location, the generators could alternatively be stationed on land, reducing some of the logistical support challenges for fueling and maintenance. Regardless of the location of the diesel generators, a spill contingency plan, staff, and equipment would be required in addition to the requisite associated environmental permitting.

The surface collector requires shear log booms both upstream and downstream of the anchoring locations to protect the guide nets from disruption or destruction by debris. Road access upstream from the surface collector near the shear log boom is required for debris removal unless surface collector guide nets are designed to be lowered for passing debris rafts past the surface collector. Lowering the guide nets during surface collector operation may reduce capture efficiency during these operations.

Road access at a surface collector station location would reduce support logistics and costs, but is not considered mandatory for surface collector station location selection because it is anticipated that a surface collector could potentially be supported solely by boat and barge. None of the surface collector currently known to be in operation are supported by boat or barge, however. Support by boat and barge is anticipated as requisite for the surface collector as a juvenile capture alternative due to the limited number of road access locations in the reservoir tributary arms.

Site selection criteria for surface collector stations include:

- Average water column velocity of less than 0.1 - 0.2 fps for proper function of guide nets
- Range of tributary flows during juvenile emigration combined with the reservoir stage elevation and the resulting channel cross section determine the average water column velocity.
- Locations farther upstream in the tributary arms result in reduced exposure of emigrating juveniles to potential in-reservoir losses
- Road access for log boom debris removal and access to surface collector station location for service and juvenile truck transport (both optional)

Lake Oroville stage elevation averages approximately 815 feet during the juvenile emigration period with 5th percentile elevations of 704 feet and 95th percentile stage elevations of 894 feet during the 20-year period of record examined for Lake Oroville stage elevations from 1983 through 2003. The range of reservoir stage elevations that occur during the juvenile salmonid emigration period establishes the range of reservoir cross-section conditions in the tributary arms used to calculate of average water column velocities given specific flows.

The maximum stage elevation changes during the juvenile salmonid emigration period average 133 feet with 5th percentile changes of 89 feet and 95th percentile changes of 191 feet in the 20-year period of record examined for stage elevation changes during

the salmonid emigration period. The amount of reservoir stage elevation change within a juvenile salmonid emigration period evaluated against the stage elevation change operating tolerances of the guide net and surface collector station location would indicate how many times a gulper could potentially need to be moved per year.

A rough estimate of potential surface collector station location ranges by tributary can be made by evaluating the average and worst case flows by tributary, divided by the average water column velocity constraints of the surface collector guide net to determine the cross section required to achieve the appropriate guide net operating water column velocities. In general, guide nets reportedly require water column velocities of 0.1 to a maximum of approximately 0.2 fps (pers. com. D. Dorratcague, 2004). The required cross section for average and worst case flows can be compared to the resulting cross section areas from average and worst case reservoir stage elevations for each SP-G1 cross section (see Final Report for SP-G1, Plate 6.1-1) to establish an approximate range of potential surface collector station locations. Each estimation calculation does not take into account the proportion of flow from the tributary that is effectively being converted into and out of storage above the cross section location during increases or decreases in reservoir stage elevation. Additionally, this evaluation is not intended to be definitive of the engineering requirements for the surface collector station locations, but is intended to be used as an indicator of the range of potential station locations so that the implications of the potential surface collector fish screen station locations can be identified.

There are 4 river miles between low pool and high pool on the West Branch. In this reach there are 6 potential access locations upstream from the WB-3 reservoir cross section including: Lime Saddle Marina, at the furthest downstream point, Nelson Bar Road, Pioneer Trail, Granite Bridge Road, Los Amigos Lane, and Ro-Ann Way at the farthest upstream point (Figure 5.2-3). Additionally there are 6 potential access locations from the Lime Saddle Marina downstream to the confluence of the West Branch and North Fork including, in a downstream direction, Trevor Road, Truex Road, Deer Ridge Lane, Vinton Gulch, Rocky Top Toad, and Red Eye Road.

West Branch flows during the juvenile salmonid emigration period average 537 cfs with 5th percentile flows of 8.4 cfs and 95th percentile flows of 1,717 cfs during the 31 year period (from 1931 to 1962) of record examined for the West Branch Feather River near Yankee Hill gage station.

Based on average flow conditions and a 0.1 fps guide net water velocity criterion, the West Branch flows would require an effective cross section of approximately 5,370 square feet. With average reservoir stage elevations of approximately 815 feet, given the resulting reservoir cross section, the surface collector station location would be somewhere between SP-G1 cross section WB-3 and WB-4 (Figure 5.2-3).

Based on high tributary flow conditions and a 0.2 fps maximum recommended guide net water velocity criterion, the West Branch flows would require an effective cross section of approximately 8,585 square feet. With low reservoir stage elevations of approximately 704 feet, given the resulting reservoir cross section, the surface collector station location would be near SP-G1 cross section WB-1 above the confluence of the West Branch and North Fork Feather River (Figure 5.2-3). The confluence is 8.8 river miles from the reservoir high pool and is below the Lime Saddle Marina, which could potentially cause recreational use conflicts and boater safety issues.

The North Fork has 8.6 river miles between the reservoir low pool and high pool (Figure 5.2-3). In this reach there are several access locations including from Poe Powerhouse down the old railroad bed on the east side of the tributary, two off highway vehicle (OHV) trails at French Creek, and an access road at Berry Creek. Additionally there is another OHV trail access near the confluence of the North Fork and West Branch on the east side of the tributary.

North Fork flows below the Poe powerhouse during the juvenile salmonid emigration period average approximately 4,017 cfs with 5th percentile flows of 648 cfs and 95th percentile flows of 9,460 cfs during the 14 year period of record for the Pulga + Poe gage station from 1968 through 1982. The North Fork flows obtained from the Pulga + Poe gage station do not reflect flow contributions farther downstream in the tributary from Stony Creek, Chino Creek, French Creek, or Berry Creek.

Based on average flow conditions and a 0.1 fps guide net water velocity criterion, the North Fork Feather River flows would require an effective cross section of more than 40,170 square feet. Average reservoir stage elevations of approximately 815 feet during the juvenile salmonid emigration period result in the SP-G1 cross section NF-5 above the confluence of the West Branch and North Fork Feather River (Figure 5.2-3) having a 25,500 square foot cross section, which is 35% too small to theoretically dissipate flow velocities adequately to achieve the target water velocity. Based on high flows of 9,460 cfs, a 0.2 fps maximum recommended guide net water velocity criterion, and a low reservoir stage elevation of 704 feet, the NF-5 cross section would be approximately 70% too small. Assuming that the gulper station location would likely need to be below the confluence of the North Fork and the West Branch Feather River for both the average and high flow conditions, the flow and cross section requirements of the West Branch would need to be added to the North Fork cross section requirements in order to estimate the potential gulper station locations.

No cross sections further downstream on the North Fork Feather River were evaluated because of the compounding inaccuracies in the estimation procedure with additional flow from the West Branch and other tributaries, and the proportionally greater effect of effective reservoir storage volumes upstream from downstream cross sections. Wide portions of the channel upstream from the SP-G1 cross section NF-3 may provide enough cross sectional area to dissipate the average velocities to within the operational

ranges of the gulper guide nets. The channel is approximately 0.9 miles wide in this area and may have enough cross section to dissipate the average water column velocities into the guide net operational range. In the area of SP-G1 cross section NF-3, it also is possible that there may be negative water velocities and higher than operating tolerance water velocities in the thalweg of the channel. Guide nets installed in a channel the size and width of the North Fork in the vicinity of SP-G1 cross section NF-3 could potentially present an engineering challenge as well as a potential land use conflict with reservoir recreational boating use. The location of cross section NF 3 is approximately 12 river miles (or reservoir miles) from the North Fork high pool. If the distance of the surface collector station location from the reservoir-tributary interface increased, an increase in in-reservoir predation and mortality also would be expected. Surface collector station locations below the confluence of the West Branch and the North Fork could potentially confound the ability to establish and protect distinct genetic populations between these two tributaries.

The Middle Fork Feather River has 4.8 river miles between the reservoir low pool and high pool (see Figure 5.2-3). In this reach there are no identified access locations for gulper support or debris removal. Flows during the juvenile salmonid emigration period average approximately 1,897 cfs with 5th percentile flows of 223 cfs and 95th percentile flows of 5,874 cfs based on the combined flows from the Merrimac and Fall River near Feather River Falls gage stations. These combined flows do not reflect flow contributions from Frey Creek.

The Middle Fork Feather River is designated a Natural Heritage Trout Stream by CDFG, which may present additional challenges to a juvenile steelhead collection program if it were implemented on the Middle Fork Feather River (see section 6.2.2.1).

Based on average flow conditions and a 0.1 fps guide net water velocity criterion, the Middle Fork flows would require an effective cross section of approximately 18,740 square feet. With average reservoir stage elevations of approximately 815 feet and the resulting reservoir cross section, the surface collector station location would be somewhere between SP-G1 cross section MF-4 and MF-5 (Figure 5.2-3).

Based on high flow conditions and a 0.2 fps maximum recommended guide net water velocity criterion, the Middle Fork flows would require an effective cross section of approximately 29,370 square feet. With low reservoir stage elevations of approximately 704 feet and the resulting reservoir cross section, the surface collector station location would likely be somewhere between SP-G1 cross section MF-3 and MF-4 (Figure 5.2-3).

The South Fork Feather River has 4.0 river miles in the reservoir fluctuation zone (Figure 5.1-7). There are several access points in this reach including: Ponderosa Dam, Sucker Run Creek, Miners Ranch Canal, Enterprise Bridge, Enterprise Marina, and Ponderosa Way. South Branch flows below Ponderosa Dam can drop to 0 cfs,

which would result in no flow and isolated and limited amount of habitat above the confluence with Sucker Run Creek. Analysis of the limited flows and limited amount of habitat appear to indicate that adult release and juvenile capture on this tributary would not be consistent with program goals.

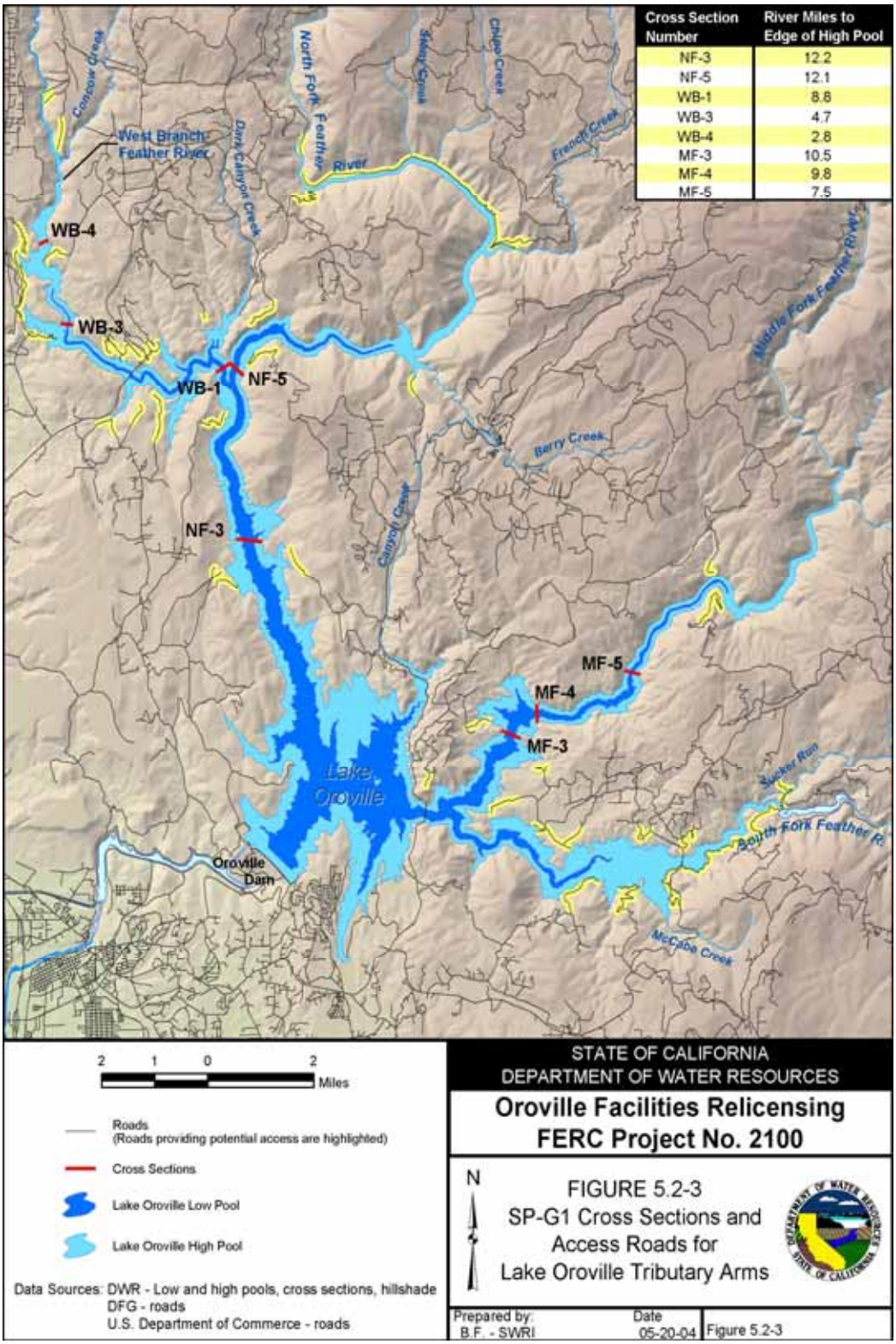

Figure 5.2-3 SP-G1 cross section and access road locations for Lake Oroville tributary arms.

5.2.1.2 Alternatives

Review of available literature indicated that a variety of methods existed to facilitate juvenile fish collection. However, only those devices and methods considered synergistic with program goals were fully analyzed. Juvenile surface collection devices (gulpers) used in conjunction with physical or behavioral guidance devices, and both low velocity instream screens (fixed or flat plate screens) and off channel screens were considered as potential capture devices in the feasibility analysis because the design and operation of these devices is assumed to be consistent with the goals of a potential fish passage program.

Because some methods and devices associated with fish capture were not consistent with program goals, they were eliminated from consideration for use in a potential fish passage program. The methods and devices eliminated from consideration include the use of fish traps without associated guidance devices, and the use of electric screens as a method for creating a behavioral barrier in the arms of Lake Oroville.

Commonly used smolt traps or inclined plane traps typically are used in medium to large rivers in Alaska to capture salmonid smolts. Trap evaluations were conducted on the Kasilof River, Crescent River, and Quartz Creek, Alaska using mark and recapture methods. During these studies the highest reported efficiency was 12.5 percent on the Kasilof River in 1991, while the lowest reported efficiency was 7.2 percent on the Kasilof River in 1993 and on Quartz Creek in 1983 (Todd 1994). Because efficiencies as high as 70 percent and 100 percent have been reported for alternative devices (pers. com. R. Rhodes, 2003; pers. com. D. White, 2003), and because the goals of a potential fish passage program include capturing a majority of emigrating juveniles, inclined plane traps were excluded from further analysis. In addition, operation of inclined plane traps would increase the amount of juvenile fish handling as well as stress associated with handling, when compared to alternative capture devices.

Behavioral modification devices were analyzed as part of a fish capture system, but the use of individual sources of stimuli to create a behavioral barrier was precluded from analysis because guidance efficiencies for single element deterrents generally have been reported to produce inconsistent results. Alternatively, dual element deterrents reportedly have proven to be more predictable and efficient (Coutant 2001a; Patrick et al. 1985; Popper and Carlson 1998; Welton et al. 2002). In addition, although reportedly less commonly utilized, electric screens have been used as behavioral guidance devices for downstream migrating juvenile salmonids. Use of electricity as a guidance device was excluded from analysis for use in a potential fish passage program because electric screens reportedly can be dangerous to target migratory species as well as other resident species (Ruggles 1991 *in* Popper and Carlson (1998). In addition, the use of electricity is inappropriate for many applications including the upper Feather River and Lake Oroville because it reportedly is most effective in shallow,

narrow areas (Ruggles 1991 *in* Office of Technology Assessment 1995; Popper and Carlson 1998)).

Device 1 – Instream Screen

Although gulper systems could be utilized as juvenile capture devices, their use is limited to very low velocity (< 0.1 fps) areas. An alternative juvenile capture system could potentially be installed in the tributaries to capture downstream migrants shortly after downstream movement has begun. Instream screens could be installed relatively near available spawning habitat limiting in-river transit times and eliminating in-reservoir transit times for downstream moving individuals. Limited in-river transit times limit juvenile exposure to in-river resident predators. Likewise, eliminating the need for in-reservoir transit eliminates juvenile migrant exposure to the suite of predators known to inhabit Lake Oroville. Additionally, juveniles would not be exposed to other potentially adverse conditions in Lake Oroville such as increased water temperatures.

Description

Instream screens that could potentially be used as juvenile capture devices in the tributaries upstream from Lake Oroville are vertical or nearly vertical screens composed of a wall of mesh panels. Vertical screens sometimes are installed in the "V" configuration with the opening of the "V" upstream and the junction of the arms of the "V" at the most downstream end of the screening unit. The "V" shape of the screening unit limits impingement of individuals by altering the angle at which juveniles approach the screens. Screens utilizing this general design are commonly referred to as stationary panel fixed screens, vertical fixed plate screens, and when associated with a pipe and holding box, the general term "smolt traps" often is used (WDFW 2000); Bates, personal communication 1995 *in* Office of Technology Assessment 1995); (Murphy Unpublished Work; USACE 2000). Vertical fixed plate screens installed in the "V" configuration are commonly referred to as "v-screens" (Murphy Unpublished Work). The use of instream screens at the Oroville project site would require the use of a transfer pipe and live trap, to facilitate the goals of a potential fish passage project of maximum capture efficiency and maximum survival of captured individuals.

A typical "v-screen" consists of v-shaped fence panels, lined with galvanized mesh, stretching the width of the stream. A PVC pipe is built into the apex of the fence to transport the fish to a live box for temporary holding. The live box generally would contain a sectioned compartment galvanized mesh that is sized to allow juveniles (fry and parr sized) to pass through if larger predators become trapped in the holding box (Murphy Unpublished Work).

USACE (2000) described a more complex instream low velocity screening system proposed for the Cougar Lake Fish Passage Project, Oregon. The proposed system consisted of primary and secondary screens built into a v-pattern on a concrete base

that raised the screens two feet above the existing riverbed. The primary and secondary screens lengths were 150 feet and 12 feet, respectively. Additionally, trash racks upstream from the primary screens were included as part of the design to keep large debris from damaging or limiting the screens' effectiveness. Traveling brush devices were designed to keep smaller debris off the primary screens while a backwash system was designed to keep smaller debris off the secondary screens. Flows into the screens would be controlled by an inflatable rubber dam in the main river channel (USACE 2000).

Typical "v-screens" with fish trap mechanisms allow the entire flow of water to move through the screen while diverting the fish toward and through the pipe at the junction of the arms of the "V" that leads to the live box. "V-screens" often are utilized because the design allows increased sweeping velocities along the face of the screen, minimizing impingement. Impingement also would be minimized by use of stream-specific angles and mesh sizes within the screening unit. Individual fish pass through the transfer pipe and into the holding box from where they can be transferred to appropriate transport vehicles. The maximum holding time would be based on the capacity of the box and the number of migrating juveniles as well as NOAA Fisheries standards for maximum fish holding times (Murphy Unpublished Work).

The system proposed for construction at the Cougar Lake Project, Oregon is more complex than that of typical "v-screen" systems because an inflatable rubber dam would be installed in the main channel to direct individuals through the "v-screen" system while a concrete ogee spillway would be located at the end of the system to maintain the water level through the screen area. Additionally, the more complex instream screen system described by USACE (2000) would involve screening a subsequently diminishing flow as it passes through the primary and secondary screening areas. The remaining flow would be passed through a reduced cross section between the two screening areas. After all instream flow has been screened, a reduced volume of water containing any screened juveniles would flow directly into holding raceways. Individuals pass from the primary screening area to the secondary screening area, over an adjustable weir, down a series of flumes and pipes to the holding raceways (USACE 2000).

<u>Characteristics</u>

Typical "v-screens" reportedly are used extensively in the Pacific Northwest in tribal fishery management programs for the capture of out-migrating juvenile salmonids on the Queets and Clearwater rivers in Washington (Murphy Unpublished Work; pers. com. R. Rhoads, 2003). In addition, similar screening systems were described for use at the Cougar Lake Fish Passage Project, Oregon to collect juvenile salmonids in the South Fork McKenzie River just above the maximum pool level of Cougar Reservoir (USACE 2000) and at the Upper North Fork of Newaukum Creek, Washington to collect juvenile salmonids including coho salmon, cutthroat trout, and steelhead as a part of the Mid-

Sound Fisheries Enhancement Group smolt migration study (Murphy Unpublished Work).

At the Upper North Fork of Newaukum Creek, a smolt trap that consisted of ”v-screens” with a transfer pipe and live box was installed to determine the number of anadromous fishes, particularly coho salmon, cutthroat trout, and steelhead that overwinter in the reaches upstream of a particular culvert. Smolts collected by the trap were held for a short period until data could be collected, and then were immediately released downstream from the trap. According to Murphy (Unpublished Work) the trap was checked twice daily but was checked more frequently during inclement weather when downstream fish and debris movement was high.

Although no information was obtained on the effectiveness of the instream screening system for use at the Cougar Lake Project, Oregon, the proposed system was designed to capture emigrating juveniles above the maximum pool level of Cougar Lake on the South Fork McKenzie River.

Screen removal during high flow events as well as damage to screens can cause lower than expected juvenile capture rates. Murphy (Unpublished Work) reported that in all three sampling years (2000 through 2002) the sampling period lasted from the beginning of April to the beginning of June, and in all three years, there were high water events during which the screens had to be removed. It also was reported that there were instances when damage to the trap allowed individuals to avoid capture (Murphy Unpublished Work).

Although screens are utilized in anadromous salmonid passage programs at various facilities, little information exists in available literature regarding the capture efficiency of vertical screen trapping systems. Bates (1995) *in* Office of Technology Assessment (1995) reported the use of fixed screens to exclude juveniles at sites in the Columbia River Basin has demonstrated greater than 95 percent overall efficiency and survival. According to draft criteria for anadromous salmonid passage published by (NOAA Fisheries 2003), juvenile survival rates through fish screens should be at least 95 percent. Although the literature reviewed did not indicate the capture efficiency associated with a fixed vertical screen and trap system it is likely that these types of screens are associated with high efficiency and survival.

Survival of juvenile salmonids captured by instream screen systems reportedly is very high (near 100 percent) if the live boxes associated with the systems are emptied on a daily basis (or as frequently as needed during peak out-migration) and the live boxes have sufficient water depth and flow to support a minimum of 1,000 fish (pers. com. R. Rhoads, 2003)

A study conducted by Danley et al. (2002) examined the effects of fish screen exposure on Sacramento splittail. Experimental fish were exposed to a screen while information

on swimming performance such as, screen contacts, equilibrium loss, the number of fish entering the bypass, and survival was recorded. An evaluation of swimming performance revealed that the number of screen contacts (tail and body) was minimal and did not differ significantly among treatments. In addition, splittail exposed to a screen did not show distinct velocity-dependent stress. No significant stress appeared to be associated with screen exposure but, as is commonly reported in evaluations of stress related to fish passage, the capture and handling of the fish at the end of the study did elicit stress responses (Danley et al. 2002).

Because instream screen placement would be site specific it is assumed that screens would be designed specifically for use at designated sites within the upper Feather River. Therefore, it is likely that screens would be designed to accommodate the range of flows and conditions likely to be encountered at each site.

Considerations

In 1994, NOAA published a report on experimental fish guidance devices that stated that well-designed facilities should result in guidance efficiencies of over 95 percent on a consistent basis (NOAA Fisheries 1994). NOAA Fisheries (1997b) reported fish screening criteria and guidelines applicable to downstream migrant fish passage facilities at hydroelectric, irrigation, and other water withdrawal projects, in which absolute criteria for juvenile capture were not published. However, it was stated that screens that afford the highest degree of protection to screened individuals given site conditions would be chosen (NOAA Fisheries 1997b).

The fish screening guidelines and criteria provided by NOAA Fisheries (1997b) are general and can vary from project-to-project based on site conditions provided that all juvenile passage facilities are, “designed to function properly through the full range of hydraulic conditions expected during fish migration periods.” NOAA Fisheries (1997b) also suggests that approach velocity, the water velocity vector component perpendicular to the screen surface, measured approximately three inches in front of the screen surface, shall not exceed 0.33 feet per second when fry are present. The total submerged screen area required can be calculated by dividing the maximum diverted flow by the allowable approach velocity. The water velocity vector component parallel and adjacent to the screen face is the sweeping velocity, which shall be greater than the approach velocity. Additionally, flow should be uniformly distributed across the surface of the screen (NOAA Fisheries 1997b).

NOAA Fisheries (1997b) also prescribed general criteria for screen face material based on screen use and screen type. Screens utilizing perforated plates should not have screen openings exceeding 2.38 mm in diameter. Screens utilizing profile bars should not have openings exceeding 1.75 mm in width. Woven wire screen openings should not exceed 2.38 mm when measured diagonally. The screen material also must

maintain at least 27 percent open area, as well as be corrosion resistant while maintaining a smooth surface after long-term use (NOAA Fisheries 1997b).

Modified criteria for small screens diverting flows less than 40 cfs also were provided by NOAA Fisheries (1997b). Although NOAA Fisheries requires screen angles to be less than 45 degrees with respect to flow, screens six feet or less in length may be oriented perpendicular to the instream flow. Other prescribed criteria remain the same for small or large screens (NOAA Fisheries 1997b).

Additionally NOAA Fisheries described performance criteria for screens proposed for use at the Klamath Hydroelectric Project, in which survival of juveniles through tributary collection was recommended to be at least 95 percent or greater (pers. com. D. White, 2003). It is assumed that the fish passage program proposed at the Klamath Hydroelectric Project would be similar to the program proposed at Lake Oroville. Therefore, it is likely that similar recommendations and requirements would be made for a potential fish passage program at Lake Oroville.

Information obtained from available literature indicates that instream screens are utilized most frequently under low flow conditions. However, water velocity at the screen face is the factor that determines the range of flows at which a screen is usable. Because water velocity varies between sites experiencing the same flow it is assumed that screens would be designed to meet NOAA Fisheries' recommended performance criteria and the range of water velocities that could occur at sites upstream from Lake Oroville.

Generally, the risks associated with the use of fish screens include fish impingement, which could result in a range of negative effects on individual condition including mortality, debris accumulation, which could cause damage to the screen, and the failure of screen seals which would result in fish passage past the screen. Because the goals of a potential fish passage program are consistent with minimizing the risks associated with instream screens, it is assumed that screens would be designed and operated to minimize impingement, debris accumulation, and catastrophic screen failure.

Device-2 Off-Channel Diversion Screens

Description

Although instream screens were analyzed as a juvenile capture device, the relatively high flows in the upper Feather River tributaries to Lake Oroville may limit their use during the juvenile downstream migration period. High flows coupled with high gradients and relatively narrow stream channels could create prohibitively high water velocities for instream screen use.

An off-channel fish screening facility would operate using the same basic principles as instream screens without the limitation of requiring relatively low velocities. Off-channel facility descriptions were unavailable in reviewed literature. However, an off-channel facility could comprise of a mechanism by which to divert all flows, lower the velocity of the full flow, and a screening device.

Tributary flow could be diverted into an off channel facility that allowed flow to lose velocity with a permanent or temporary inflatable weir or dam. Once velocity has decreased sufficiently flow could be screened using devices similar to those described for instream screens.

When tributary flow would be diverted, it would begin traveling within a canal with an appropriate width and gradient to allow water velocity to decrease sufficiently to be screened, but not substantially enough to create a backwater effect in the main tributary channel. After screening, all flow not being used to maintain the captured juveniles within the holding tanks would be diverted back into the tributary channel. An off-channel screening system could be designed in a variety of configurations depending on the hydrology and geomorphology of the tributary canyon. Therefore, it is inappropriate to suggest a detailed description of an off channel screening system.

Characteristics

Available literature was unable to provide examples of off channel screening facilities. However, Coanda-Effect screens were indicated for use in some applications to provide full flow screening. Coanda-Effect screens are capable of reducing flow within a channel, and have been used at a number of field sites for the removal of debris upstream from hydropower projects (Strong and Ott 1988 *in* USBR 2003) as well as for the exclusion of unwanted fish (Strong 1989 *in* USBR 2003). Additionally Coanda-Effect screens have been utilized in project areas where one of the main objectives of fish removal is maintaining high fish survival rates, suggesting that these systems could be designed to screen out endangered fish species as a part of fish passage programs.

The capture efficiency of an off-channel screening system would be a function of the efficiency with which the fish are diverted away from the tributary channel and the efficiency of the fish screens at capturing individual fish. Because 100 percent of flow is diverted and screened, and because the facility would be designed to divert the highest possible flows within each tributary, it is assumed that an off-channel screening facility would operate at 100 percent capture efficiency.

Mortality associated with an off channel screening system would be dependent on the reduction of water velocity to a velocity that would allow for the safe collection of fish. The use of fish screens with excessive flow could cause screen damage as well as fish impingement, both of which are potential causes of mortality.

Considerations

Because off-channel screening facilities were not described in available literature no regulatory criteria were defined for operation of off-channel screening facilities. However, NOAA Fisheries suggests that juvenile capture facilities should operate in a manner that allows for 95 percent survival of all captured juvenile salmonids (pers. com. D. White, 2003).

The risks associated with an off channel screening system are similar to the general risks associated with all fish screens. Generally, the main risk associated with fish screens is fish impingement, which could result in scale damage and/or mortality. Additionally, debris accumulation, which could cause damage to the screen and the failure of screen seals, could result in fish movement past the screens. Because the goals of a potential fish passage program are consistent with minimizing the risks associated with fish screens, it is assumed that screens would be designed and operated to minimize impingement, debris accumulation, and catastrophic screen failure.

Device – 3 Surface Flow Collector (Gulper)

Description

A surface flow collector, also called a surface flow bypass device or gulper, is a floating barge that utilizes an attraction flow to guide fish towards the device, and often is associated with an additional guidance device such as a physical or behavioral barrier to lure emigrating juveniles into a trap located within the barge. The mechanism by which surface flow collectors are able to function utilizes the natural surface orientation of emigrating juvenile salmonids. Because emigrating juvenile salmonids tend to remain near the surface, surface flow collectors are able to capture a large proportion of the population while remaining in one location within the water column. The most well documented use of a gulper as the primary method of juvenile salmonid collection is the Baker River Fish Passage Project, Washington (Puget Sound Energy Unpublished Work; Wayne Jr. 1961; Whitney et al. 1997). Because it is possible to separate the guidance devices from the collection barge (gulper), when discussed together, a gulper and guidance device will be called a gulper system.

The Baker River Fish Passage project utilizes two gulper systems (one in Baker Lake at the Upper Baker River Facilities and one in Lake Shannon at the lower Baker River Facilities) that were assumed to be representative of a typical fish gulper system that could be constructed for use in the potential fish passage project at Lake Oroville. Both gulper systems use similar gulpers and guidance devices (Puget Sound Energy 2002). Figure 5.2-4 shows a picture of the gulper system used in the Baker River Fish Passage Project.

Figure 5.2-4 Gulper system in use at the Baker River Fish Passage Project.

The surface collection barge in use at Baker Lake is a rectangular barge measuring 36 feet by 70 feet attached to steel floatation tanks that allow for adjustable buoyancy. The entrance channel to the collection barge is 12 feet wide by 35 feet long and attached to the steel trusses of the barge. The channel contains a sloping timber louver and two pumps that draw water through the louver. Immediately past the louver is a smaller flume that that leads to a gravity flow pipe connected to a fish trap. The trap measures 62 feet by 54 feet and is constructed of concrete floatation modules and a submersible steel box, which has a ballast that is compartmentalized into four raceway channels for holding and sorting fish (Puget Sound Energy 2002).

Although it can be used independently, a gulper is typically used in association with a physical or behavioral guidance device. The gulper systems utilized in the Baker River Fish Passage Project consist of gulpers and guide nets attached to each side of the gulpers. The nets are surface-to-bottom nets (extending to a depth of 285 feet in Baker Lake and 236 feet in Lake Shannon) that span the width of each reservoir. The mesh size of the nets is ¼ inch. Each net has a four-inch inflatable hose spanning the length of the top of the net with cork floats at a depth of fifty feet. A series of one-pound weights are sewn into the bottom of the net to keep the bottom of the net in place. The design allows the net to remain in the reservoir throughout the year because it

accommodates surface water fluctuations during spill events, avoiding damage to the guide net and the spill gate facilities. Additionally, the double-segment design of the guide net allows the fifty-feet of net closest to the surface of the reservoir to billow during normal surface elevation fluctuations while the bottom portion of the net remains taut avoiding snagging on objects on the reservoir bottom (pers. com. D. Dorratcague, 2004). To further maximize operational efficiency, a log boom located in forebay of Baker Lake protects the gulper system from damage that could occur from downstream transport of debris during high flow events (Puget Sound Energy Unpublished Work).

The surface collection barge at Baker Lake draws water from immediately below the reservoir surface and generates a flow designed to aid attraction of emigrating juveniles into the barge entrance channel. The attraction flow through the entrance channel reportedly acts to facilitate the movement of fish toward the timber louver and into a smaller flume and subsequent trap (Puget Sound Energy Unpublished Work; Puget Sound Energy 2002). The louver was designed to funnel fish into the flume, while the reduction in size from the louver to the flume was designed to create velocities that prohibit juveniles from swimming against the current, thus avoiding the trap and re-entering the reservoir (pers. com. D. Dorratcague, 2004). The guide net, which spans across the forebay, acts to form a complete migration barrier preventing fish from moving further into the reservoir while directing them toward the surface collector (Puget Sound Energy Unpublished Work; Puget Sound Energy 2002).

Although guide nets typically are used in association with gulpers to increase collection success, alternative methods such as behavioral guidance devices could potentially be used instead of physical barriers. A behavioral guidance device that reportedly has been successful in guiding juvenile Atlantic salmon is an acoustic bubble curtain (Welton et al. 2002). In addition to the use of acoustic bubble curtains as guidance devices, the use of other stimuli such as light and sound also have been investigated (Goetz et al. 2001; Johnson et al. 2001; Knudsen et al. 1994; Mueller et al. 2001; Sand et al. 2000; Sand et al. 2001). Additionally, evidence exists that the use of multiple stimuli may be more effective at guiding juvenile salmonids than either bubbles or light alone (Patrick et al. 1985 *in* Popper and Carlson 1998)).

Devices that operate using similar mechanisms to gulpers are surface bypass collectors, which are used in the Columbia River basin to guide juvenile salmonids away from turbines and provide safe passage past dams. Although the design of surface bypass devices at Columbia River dams is different to the gulpers utilized in the Baker River Fish Passage Project, the use of attraction flows near the surface of the water to take advantage of the natural behavior of migrating juveniles is similar. Surface collectors used at Columbia and Snake River projects utilize surface flow to attract juveniles into bypass routes , such as through spillway gates, or collection devices (Nordlund and Rainey 2000).

The Wells Dam hydrocombine hydroelectric facility was reported to have the first successful surface collector system on the Columbia River, and thus has served as a model for surface collector design at other dams along the Lower Columbia and Snake rivers including Bonneville Dam, The Dalles Dam, John Day Dam, Ice Harbor Dam, Lower Granite Dam, Wanapum Dam, Rock Island Dam, and Rocky Reach Dam. The current design of the Wells Dam surface collector system uses surface flow to guide juvenile salmonids away from turbines and into a bypass collection system. Due to the synergy between the hydroelectric facility and the surface collector designs, fish passage rates ranging from approximately 84.3 to 95.0 percent for spring migrants and 76.5 to 89.0 percent for summer migrants are reported for the Wells Dam collection facility, which reportedly were the highest passage rates of any juvenile bypass system on the Columbia and Snake Rivers (Skalski 1996 *in* Nordlund and Rainey 2000).

Characteristics

Gulper systems typically are used to collect juvenile fish in lacustrine environments where water velocities are too low to stimulate fish movement toward a collection device (Puget Sound Energy 2002). Gulper systems have been used to capture juvenile salmonids as part of the Baker River Fish Passage Project (Puget Sound Energy 2002) and have been proposed for use in other fish passage projects including the Cougar Lake Project, Oregon (USACE 2000) and the Klamath Project in California and Oregon (pers. com. B. Gatton, 2003).

At the Brownlee Dam on the Columbia River, it was observed that during the 1950's and 1960's in years when high inflow led to increased reservoir surface elevations, juvenile salmonids were not passing through the dam turbines during their downstream migration. It was hypothesized that the depth of the turbines and the surface orientation of emigrating juveniles was the reason for the lower numbers of emigrating salmon being observed downstream from the dam. In order to facilitate passage of juveniles below the dam, the use of inclined-plane fish traps was implemented. Downstream migrating juveniles were trapped shortly after they entered the reservoir. The trapping system, consisted of a barrier net stretched across the river in conjunction with inclined-plane fish traps floating on the surface of the water along the length of the net and pumps that provided appropriate attraction flow. The barrier net was placed across the reservoir approximately 4800 feet upstream of the dam and extended to a depth of 120 feet (Mighetto and Ebel 1995 *in* Whitney et al. 1997)). According to Mighetto and Ebel (1995) *in* Whitney et al. (1997), difficulty keeping the equipment in place because of adverse weather conditions and accumulation of debris as well as the reported low efficiency of the barrier net, led to the cessation of the passage program.

As part of the Baker River Fish Passage Project, gulper systems currently are used at both the upper and lower Baker River fish passage facilities (Baker Lake and Lake Shannon, respectively) to collect juvenile coho and sockeye salmon. Both gulpers are

used in conjunction with a barrier net to increase the likelihood of successful juvenile collection.

Beginning in 1986, studies were conducted at the Baker Lake facilities to determine methods to improve juvenile anadromous salmonid passage below the dams. Various net configurations were tested to maximize guidance efficiency into the bypasses (smolt collection barges), and a trap and haul system was installed and tested. After 1987, the passive guide nets were replaced with “exclusionary netting” that utilized a smaller mesh size. Additionally, the net configuration was altered. Net depth was increased from 100 feet to 200 feet and the nets were stretched from the shoreline to the barge entrance. Smaller mesh sizes minimized fish passage through the nets and the increased net depth minimized the potential for net avoidance. The most recent improvements to the guide nets at the Baker Lake facility involved installing a surface to bottom guidenet that could remain in position year-round (FERC 1993).

FERC (1993) reported that during an evaluation of the newest surface to bottom guide net design in Baker Lake, in comparison to the 200 foot deep net, the number of captured juvenile sockeye and coho salmon increased significantly with no negative effects to project operations. Using fixed location hydroacoustics to measure fish movement, guidance effectiveness was determined for the period from 1988 to1991. The proportion of migrating fish that were successfully guided into the trap and haul bypass reportedly ranged from 67 percent in 1991 to 79 percent in 1989 (FERC 1993).

Prior to 1989, the lower Baker River facilities (Lake Shannon) consisted of a guide net similar to the Baker Lake guide net, an attraction barge, and turbine intakes used to pass fish. Hydroaccoustic studies similar to those conducted in Baker Lake at the upper Baker River facilities were conducted in Lake Shannon at the Lower Baker River facilities from 1988 through 1990. FERC (1993) reported that facilities improvements in Lake Shannon were not as successful as the improvements to the Baker Lake facilities. The studies revealed that between one and six percent of migrants used the attraction barge from 1989 to 1990. In order to improve success of juvenile salmonid passage below the dam, a trap similar to the Baker Lake trap was installed in Lake Shannon in 1989. In addition to trap improvements, an alternative transport mechanism was implemented. A pipe was constructed that allowed juveniles to be passed from the trap in the lake directly into the tailrace below the dam. The pipeline was approved for transport of downstream migrating smolts for the 1992 and 1993 seasons (FERC 1993).

Recent studies have been conducted by Puget Sound Energy (Unpublished Work) at the Baker Lake fish passage facilities to evaluate the success of the fish gulper using PIT tagged individuals. The *Upper Baker PIT Tagging Study* was conducted to determine and compare the success rate and travel time of coho and sockeye salmon smolts through the reservoir under various project operating conditions. The success rate of the Baker Lake gulper when individuals were tagged and released at sites considered far from the gulper (upstream from the reservoir), under low and high power

generating conditions was 67 percent and 5 percent, respectively for sockeye salmon, and 19 and 29 percent, respectively for coho salmon. When tagged individuals were released from sites considered near the gulper (within the reservoir), no patterns were reported. Consequently, only total success rates for each species were reported. Trap success rates for sockeye salmon were reported to range from 3 to 86 percent while trap success rates for coho salmon were reported to range from 31 to 74 percent. When smolts were released in the collection barge under various operating conditions, trap success rates reportedly were not statistically significantly different between species and among operating conditions. Analysis of all study results indicates that although trap success was high once fish were at the entrance of the collection barge, trap success was substantially lower for individuals that traveled from near and far sites within and upstream from Baker Lake. Based on visual observation during portions of the study there apparently were periods when the net was submerged in several areas due to the accumulation of debris. It was suggested that periods of net submersal could have affected gulper success rates but the reduction in success was not reported (Puget Sound Energy Unpublished Work).

Gulper capture efficiency is defined as the proportion of emigrating juvenile Chinook salmon captured and passed to an adjacent sorting mechanism. Gulper capture efficiency includes, but is not limited to, the proportion of emigrating juveniles captured by the gulper, and the proportion of juveniles surviving capture. It is assumed that all emigrating juvenile Chinook salmon not collected prior to reservoir entrance and not subjected to in-river and in-reservoir mortality would be available to be captured by the gulper system.

During a study conducted at the Upper Baker lake fish gulper in 2002, acoustic tags were used to track the behavior of coho and sockeye salmon as they moved through the reservoir toward the gulper. Puget Sound Energy (Unpublished Work) reported that no consistent pattern suggesting that changes in surface water elevation and project operations affected the smolt route selection. Analysis of the results revealed, however, that large numbers of individuals reportedly swam across the mouth of the surface collector mechanism of the gulper, but did not enter the actual collection barge. The proportion of tagged fish that crossed the surface collector mechanism at least once was reported to be 64 to 100 percent whereas the proportion of fish that actually moved into the fish trap was reported to be 21 percent Puget Sound Energy (Unpublished Work). Earlier studies conducted at the Baker Lake gulper from 1988 to 1992, used fixed location hydroacoustics to determine guidance effectiveness (FERC 1993). FERC (1993) reported that guidance efficiencies over the test period ranged from 67 percent to 79 percent. Survival rates associated with fish gulpers are assumed to be high but limited information is available regarding injury and mortality related to the use of gulper systems.

Although little information was obtained relating to injury and mortality associated with the use of gulper systems to guide and capture emigrating juvenile salmonids, survival

of juvenile salmonids captured by gulper systems is assumed to be high. It is likely that, if the live boxes within the trap facility are emptied on a daily basis (or as frequently as needed during peak out-migration), and the live boxes have sufficient water volume to support the estimated number of fish to be captured between emptying events, survival would be high.

Although few gulper systems are in service and little information is available regarding the costs associated with construction and operation of gulper systems, it is estimated that construction of a gulper system in Lake Oroville would cost between eight and 15 million dollars (pers. com. D. Dorratcague, 2004). It is difficult to predict the costs associated with operation and maintenance of a gulper in Lake Oroville because these costs would be dependent on the type of fish passage program that would be implemented. For example, a program designed to transport large numbers of fish could potentially require more staff and equipment than a program designed to transport limited numbers of emigrating juveniles. Additionally the lifespan of the device is uncertain. Therefore, overall costs associated with operation and maintenance for the lifespan of the device also are uncertain.

The potential sites available for use as juvenile capture locations with gulpers are limited, in part, by appropriate water velocities. Because gulpers utilize attraction flows to guide individual fish to the collection component of the system they can only be used in areas with low water velocities. In addition, if nets are to be used in association with a fish gulper, water velocities equal to or less than 0.10 fps are required for them to function properly (pers. com. D. Dorratcague, 2004).

Another limiting factor to gulper placement in Lake Oroville is physical site access because debris removal, fish transfer, and fuel storage capabilities all are dependent on the accessibility of the site to transport vehicles. Currently, the North Fork Feather River and West Branch Feather River have been identified as having site access points.

In addition to site access, it is important to consider channel morphology when selecting the gulper-mooring site. Apart from channel morphology influencing potential water velocities, the ability of the system to remain anchored during high wind conditions is important. Finally, because the collection barge must be built to accommodate the minimum number of fish expected to utilize the trap over a specified collection period, the location must meet a minimum size requirement.

It is assumed that gulper systems would be placed in locations where velocities would not exceed 0.10 fps, where access is appropriate, and where anchoring the system is feasible, which depending on the tributary inflows and the reservoir pool level, could be as far upstream as the tributary-reservoir interface, or substantially further downstream (i.e. the confluence of the West Branch and North Fork Feather River).

Considerations

A literature search was conducted to determine regulatory criteria, guidelines, or recommendations for gulper capture efficiency rates. Because the use of gulper systems is relatively limited, NOAA Fisheries and DFG do not have published criteria for gulper efficiency. However, NOAA Fisheries' goals for juvenile fish capture in the Pacific Northwest reportedly state that projects should capture at least 98 percent of emigrating juvenile salmonids (pers. com. E. Theiss, 2004). Additionally, NOAA Fisheries provided performance criteria for the Klamath Hydroelectric Project where installation of a surface collector similar to the gulper system under consideration for juvenile collection in Lake Oroville was proposed. The performance criteria provided by NOAA Fisheries indicate that, for the Klamath Hydroelectric Project, juvenile survival through the collection facilities should meet or exceed 95 percent (pers. com. D. White, 2003).

Currently, the gulper system used in the Baker River Fish Passage Project is one of the few operational gulper systems (Puget Sound Energy 2002). Based on the success reported for the Baker Lake gulper system, gulpers have been proposed as collection devices at the Cougar Lake Project, Oregon and the Klamath Project in California and Oregon (Gatton 2003; USACE 2000). Because few gulper systems are in use, little information was obtained regarding the ability of the systems to successfully and efficiently capture fish other than emigrating juvenile salmonids. It is unclear whether adult steelhead, sturgeon, or other resident fish species would be captured by the gulper systems. In addition, if nets are used as guidance devices, net mesh size would be required to be fine enough to prevent the passage of small juvenile Chinook salmon and steelhead beyond the nets. Downstream migrating Chinook salmon fry may require mesh smaller than the ¼ inch mesh typically used to capture juvenile salmonids. The use of finer mesh nets is assumed to be feasible for fry capture, but may require additional efforts to remove increased sediment accumulation and algae growth associated with the use of fine-mesh nets (pers. com. D. Dorratcague, 2004). Sediment wedge erosion in the tributary arms of Lake Oroville also could contribute to increased maintenance requirements to guidance nets.

Because it is likely that guidance nets would be utilized in association with gulpers, it is likely that the nets in Lake Oroville would be required to extend from the surface to the bottom of the reservoir to prevent emigrating individuals from passing under the nets, thus avoiding collection. Additionally, because boat traffic and debris loading within Lake Oroville are extensive, boat passage over or around nets likely would be required, and robust log booms facilitating debris removal likely would be required to avoid potential damage to guidance device components.

Device 4 – Alternative Behavior Guidance Devices

Description

Behavioral modification devices use sensory stimuli to alter fish behavior, and can be used to deter, attract, or direct movement of individuals (Coutant 2001a). Within the context of a fish passage program, sensory stimuli such as light, sound, bubbles, altered flow within a water body, or combinations of these stimuli would be used to guide migrating individuals toward capture devices. Because response behaviors differ among species, the type and intensity of a sensory stimulus should be tailored for use with the target species. Additionally, stimuli should be chosen based on the likelihood of success within the range of environmental conditions likely to be encountered within the geographic area.

According to Coutant (2001a), behavioral guidance mechanisms fall into two categories, those that attract fish and those that repel fish. Attraction is most often used to guide fish in a desired direction, such as through a bypass, whereas the repulsion techniques keep fish away from potentially dangerous areas, such as construction activities. Both types of behavioral guidance mechanisms reportedly could be used to improve the use of fish passage devices at physical barriers (Coutant 2001a).

The use of behavioral modification devices in the Oroville program would involve the repulsion of fish in the reservoir arms to prevent the passage of juveniles into the Oroville reservoir as well as utilization of differential flow as an attraction stimulus to direct individuals to the gulper. Stimuli used to repel fish can be in the form of continuous stimuli that elicit a continuous reaction, such as swimming in the opposite direction of an acoustic stimulus until the stimulus is no longer in range, or “startle stimuli” which elicit brief reactions. According to Ruggles 1993 *in* Office of Technology Assessment (1995), it is important that “startle stimuli” include a directional component to avoid causing fish to move in a random direction away from the stimulus.

One behavioral modification device that could be appropriate for use in a proposed fish passage program at Lake Oroville is an acoustic bubble screen that uses sound and compressed air in the form of bubbles to elicit fish avoidance behavior.

Characteristics

Acoustic bubble screens generally have been used at hydroelectric project intakes to protect juvenile entrainment in turbines (Welton et al. 2002). Recent research suggests, however, that acoustic bubble screens could be used in channels with fairly stable flow to deflect juvenile salmonids from dangerous migration routes (Welton et al. 2002).

Because the use of behavioral barriers is considered by many regulatory agencies to be experimental, there were few examples in the available literature profiling fish passage programs using these methods and devices. However, where information was available, results reportedly have been varied, and oftentimes, contradictory (Kuznetson

1971 *in* Hocutt 1980; Welton et al. 2002). Alternatively, Solomon (1992) concluded that bubble screens could potentially be viable methods of exclusion despite conflicting results reported in other studies (Solomon 1992 *in* Welton et al. 2002).

Hocutt (1980) published a review of available literature that reported bubble curtain use at projects in Indian Point, NY (Anonymous 1970 *in* Hocutt 1980)), Quadracities, IL (Latvaitis et al. 1976 *in* Hocutt 1980), and Praries Island, MN (Grotbeck 1975 *in* Hocutt 1980). It also was indicated that, following reports detailing device inadequacies and ineffectiveness, the bubble curtains were removed from each of the projects.

Generally, the success of behavioral barriers has been shown to vary depending on the specific application. Specifically, the literature reviewed indicated that acoustic bubble screens are not always consistent in their effectiveness because of their dependence on species, life stage, motivational state, hydrology and light (Bates and Vanderwalken 1964, Smith 1961 *in* Hocutt 1980;Patrick et al. 1985; Welton et al. 2002). Additionally, Popper and Carlson (1998) cited Ruggles (1991), who suggested that air bubbles are effective in some saltwater applications, and potentially in some freshwater applications in streams, but may not be effective in rivers.

Two bubble curtain guidance efficiencies were reported in available literature. In the most recent study, Welton et al. (2002) reported the effectiveness of a bioaccoustic fish fence (BAFF) at guiding Atlantic salmon smolts in two channels of the Frome River, United Kingdom. Average deflection efficiencies of 20.3 and 43.8 percent were reported for each of the BAFFs during daylight while efficiencies of 72.9 and 73.8 percent were reported during darkness. All deflection efficiency estimates were reported to be greater than 60 percent during darkness. Statistical analysis indicated that, during all treatments, Atlantic salmon smolt use of the screened channel was significantly less than use of the unscreened channel (P ranging from < 0.05 to < 0.001). Deflection efficiencies during darkness conditions were found to be significantly higher than those under lit conditions. Results were similar in both channels in which a BAFF was installed. Welton et al. (2002) concluded that the installation of a BAFF system in a chalk stream could deflect greater than 70 percent of Atlantic salmon smolts away from hazardous areas, especially if light levels were reduced by overhanging cover Welton et al. (2002).

In the potential fish passage program at Lake Oroville, fish that escape collection and enter the reservoir would be assumed to be lost from the program. Based on the results of Welton et al. (2002), as many as 30 percent of outmigrating smolts could be lost from the program. Based on NOAA Fisheries performance criteria, which recommends that juvenile survival through fish collection facilities meet or exceed 95 percent (pers. com. D. White, 2003), a device that allows 30 percent of fish to escape collection would be inappropriate for use as part of a juvenile collection system.

In an earlier study conducted by Bates and Vanderwalken (1964), a bubble screen installed at a hydroelectric power plant intake was reported to be effective at attracting juvenile salmonids and was able to obtain a 90 percent guiding efficiency during daylight periods when intake velocity did not exceed 0.58 m/s (1.9 feet/sec). Alternatively, under night or turbid conditions the bubble screen reportedly was not effective (Bates and VanDerwalken 1964 *in* Hocutt 1980). Because this study tested the feasibility of bubble screens to guide fish by way of attraction, the guiding efficiency results would not necessarily be indicative of the feasibility of bubble screens to deter fish.

Although available literature reports varied efficiencies, it is likely that bubble curtains would be less expensive to install and operate than conventional physical screens. The (Office of Technology Assessment 1995) reports that behavior-based technologies generally are considered to be less expensive than physical screening methods.

Considerations

Review of available literature yielded no information regarding performance criteria specified by NOAA Fisheries or DFG for behavioral guidance devices. NOAA Fisheries, however, indicates that the use of behavioral modification devices in downstream migratory juvenile fish collection are only acceptable when used as “an adjunct to passage schemes employing physical barriers” (pers. com. D. White, 2003). Although performance criteria specified by the regulatory agencies for behavioral guidance devices was not presented in the literature, it is assumed that behavioral modification devices should have a minimum effectiveness of 95 percent because, according to NOAA Fisheries’ performance criteria for juvenile collection facilities, survival rates through juvenile collection facilities should meet or exceed 95 percent (pers. com. D. White, 2003). Therefore, it is assumed that if any component of a collection facility exhibits less than 95 percent efficiency, overall collection efficiency would be lower than 95 percent.

Additionally, the effectiveness of a bubble curtain at guiding emigrating juvenile Chinook salmon, steelhead, and green sturgeon is unclear. Bubble curtains reportedly have been successful at deterring Atlantic salmon smolt, which could potentially indicate that Chinook salmon smolts may respond similarly. However, Welton et al. (2002) reported that over 70 percent of Atlantic salmon could be deflected while NOAA Fisheries suggested that behavioral guidance devices should meet or exceed 95 percent effectiveness (pers. com. D. White, 2003). Literature describing the effectiveness of bubble curtains on altering the behavior of green sturgeon and steelhead were unavailable or inconclusive.

Based on current site conditions in the arms of Lake Oroville and on available literature, it is likely that installation and operation of a bubble curtain in association with a gulper system would be feasible. However, based on the low number and varied results of

studies conducted on behavioral guidance devices associated with fish passage for Chinook salmon and steelhead, the use of behavioral guidance devices alone likely would be inappropriate. The use of behavioral guidance devices with a guide net, could potentially increase the guidance efficiency of the system, and likely would be appropriate in a potential fish passage program at Lake Oroville.

5.2.1.2 Conclusions

Based on the low efficiency and high costs associated with gulper operation it is likely that instream or off channel screens would be employed as sole capture devices or in conjunction with gulper systems. It is unlikely, however, that gulper systems would be deemed appropriate for use without additional collection facilities in the tributaries. Instream screen devices may be only of limited use because main tributary flows upstream from Lake Oroville typically exceed 1,200 cfs, considered for purposes of this analysis to be near the upper limit of instream screen device effectiveness. Based on these higher flows, off-channel screening facilities could be more appropriate for juvenile capture in the tributaries.

Because access is limited in the Middle Fork and because gulper systems would not be recommended for use without in-tributary capture facilities, the Middle Fork would not be recommended as a potential receiving tributary for transported adults. Additionally, the Middle Fork Feather River is designated a Wild and Scenic River and a Natural Heritage Trout Stream, which may prohibit flow diversions required for an off-channel capture device and may present challenges collecting juvenile Chinook salmon and steelhead.

Behavioral modification devices such as bubble screens could potentially be applicable in some areas. However, a review of available literature on these devices indicates that efficiencies may not be high enough to meet objectives of a potential fish passage program for Lake Oroville alone, but could be useful if employed in conjunction with a guide net or other physical guidance device.

5.2.2 Juvenile Fish Sorting and Tagging (optional)

In a potential fish passage program, captured juvenile fish would need to be sorted, and potentially tagged prior to transport downstream below Oroville Dam. Juvenile fish sorting would eliminate any fish collected that would not to be included in a potential fish passage program, either because they are not the target species or do not meet a potential fish passage program operating criteria (incorrect timing, size, etc.). Juvenile fish sorting would occur before juvenile fish tagging or holding to avoid tagging or holding non-target fish. Sorting could be conducted manually or with the use of automated tagging machines depending on the level of sophistication required to meet the goals of a potential fish passage program.

Tagging is an important option for a potential fish passage program for monitoring and improving fish passage program performance and is an essential option for a potential fish passage program if a goal of the program is to protect, enhance, or restore fish genetic stocks. If the goal of restoring or protecting fish genetic integrity is important to a potential fish passage program, then the efficiency and accuracy of sorting and tagging also is important.

Coded Wire Tags (CWTs) are relatively inexpensive and can be used to tag fish for monitoring the juvenile survival and adult return rates of a potential fish passage program. However, CWT tagged fish must be sacrificed to read the tags. The presence of a CWT can be used to monitor instream survival rates, and reservoir capture device efficiency if individuals are captured in a tributary and CWT tagged, then are recaptured in the reservoir during downstream migration. Additional salmonid CWT tagging programs in the upstream tributaries would confound the results of these investigations, however. CWT tags also can be read on returning adults, either through a sample and sacrifice program prior to transport, or recovered in a carcass survey in the upstream tributaries to measure fish passage program performance (i.e return rates). Because CWT tags require sacrifice of the fish to be read, it is not a viable tagging alternative for a potential fish passage program goal of protecting or enhancing genetic stocks. Limited numbers of fish could be manually CWT tagged, but due to the potentially large numbers of juveniles emigrating in short periods of time from the upstream tributaries, automated tagging facilities would be recommended if significant percentages of the juvenile fish would be CWT tagged. It should be considered, that automated tagging trailers require stable power supplies and suitable level setup space.

Another tagging alternative would be the use of passive integrated transponder (PIT) tags, which are much more expensive per tag than CWT's and are limited to tagging fish approximately 60 mm or longer. Only a portion of the emigrating juvenile salmonids exhibiting extended in-river rearing behavior (stream type life history) are expected to reach lengths greater than 60 mm prior to juvenile capture. Early juvenile emigration behavior (ocean-type life history) is expected to produce no fish of 60 mm or greater, so the applicability of this tagging option may be limited depending on the rearing behavior of the juvenile salmonids present in the tributaries. PIT tags can be read without sacrificing the fish, which makes them a potential alternative to definitively identify returning adults that are progeny of a potential fish passage program, which is an essential function of accomplishing the potential fish passage program goal to protect or enhance genetic stocks.

5.2.2.1 Location

Juvenile fish sorting and tagging would occur at the juvenile fish capture facilities, both at the upstream tributary fish screen facilities, and at the in-reservoir gulpers for each tributary selected in a potential fish passage program. Juvenile fish collected would need to be sorted on a daily basis before being tagged and transferred to the holding

facilities. At times of peak juvenile emigration sorting and tagging could be a continuous operation.

5.2.2.2 Sorting Alternatives

Review of available literature revealed that a limited number of devices existed to facilitate juvenile fish sorting. Of the devices indicated in available literature as appropriate for juvenile fish sorting, all were compatible with program goals. Therefore, mesh separators and bar separators were analyzed for feasibility of use in a potential fish passage program at Lake Oroville.

Although passive mechanical sorting using mesh or bar sorters separates adults and other larger fish from target species juveniles, additional hand sorting may be required. Resident juvenile fishes including rainbow trout could potentially be migrating downstream during the period when collection facilities are operating. Because program goals would include minimizing impacts to resident species, captured resident species would be separated from passage program species by trained technicians able to distinguish between salmonid species and released near the capture site.

Device 1 – Mesh Sorters

Description

A removable mesh separator can be placed in each holding raceway to separate adults or larger fish from juveniles of the target species. A mesh separator is similar to an instream screen, but is placed in the holding area. The mesh, which is attached to a supporting frame, separates individuals passively by size based on the size of the openings within the mesh screen.

The mesh separators proposed for use in the Cougar Lake Fish Passage Project consist of 1.5-inch mesh that allows juveniles to pass through the screens and into the raceways but prevents adults and other larger fish from moving into the raceways. According to USACE (2000), additional separators could be added to the raceways to allow for more separation by size.

Characteristics

Mesh separators generally are used in association with juvenile salmon collection systems that involve the direct transfer of fish from a capture device to a holding tank. A mesh separator typically is placed in the holding tank creating a compartment accessible only to smaller individuals. The mesh separator would allow juveniles to remain separate from larger fish that could potentially enter the collection system (Murphy Unpublished Work).

In the Upper North Fork of Newaukum Creek, Washington coho salmon, cutthroat trout, and steelhead smolts were captured as a part of the Mid-Sound Fisheries Enhancement Group smolt migration study. During the study, smolts were captured using instream screens and subsequently transferred to a live box. The live box contained a compartment sectioned with ¼ inch galvanized mesh sized to allow juveniles (fry and parr sized) to pass through if larger predators became trapped in the holding box (Murphy Unpublished Work).

Similarly, a proposed method of juvenile collection at the Cougar Lake Fish Passage Project in Oregon would utilize an instream screen system in which fish would be transferred from the screens to holding raceways. The raceways would contain removable mesh separators that would allow juvenile fish to pass through the mesh while excluding any larger individuals including adults (USACE 2000).

The mesh size in a mesh separator could be specifically designed for target species of a specific age class, which would allow for high survival rates and a high degree of efficiency.

During sorting, mortality associated with handling induced stress could potentially occur. Because sorting methods that use devices such as mesh sorters rely on volitional movement of individuals through the mesh, mortality related to the sorting likely is low. However, review of available literature revealed little information related to sorting induced mortality. According to a literature review conducted by Ward et al. (1997), estimates of 10 percent, 15 percent, and 20 percent mortality related to collection, handling, and transport of juvenile fish is consistent with a variety of literature sources. Based on the range of mortality estimates reported by Ward et al. (1997), an average of 15 percent mortality related to capture, sorting, and transport of individuals was assumed to occur. Additionally, because sorting mortality was not reported separately, it was assumed that collection, handling, and sorting each contributed equally to mortality in the studies reviewed. Therefore, it was assumed that mortality related to sorting would be approximately 5 percent.

Considerations

Review of available literature produced no information elucidating regulatory criteria for sorting device design or performance. However, based on performance criteria for juvenile collection facilities provided for the Klamath Hydroelectric Project in California and Oregon that suggested survival rates through juvenile collection facilities should meet or exceed 95 percent, NOAA Fisheries could potentially recommend that survival rates for juvenile sorting be at least 95 percent.

A mesh separator was used to separate juvenile salmonids from adults or other larger fish that could be potential predators at the Upper North Fork of Newaukum Creek, Washington as a part of a smolt migration study (Murphy Unpublished Work). In

addition, at the Cougar Lake Fish Passage project a mesh separator was proposed for the separation of juvenile Chinook salmon and bull trout from adult steelhead in the holding raceways of the collection system (USACE 2000). A potential fish passage program at Lake Oroville would require sorters at the juvenile collection facilities to separate juvenile Chinook salmon from potential predators including adult resident rainbow trout and black bass. Because installation of mesh sorters would allow fish to be sorted with a minimal amount of handling stress, mortality associated with sorting would be minimized. Therefore, mesh sorting would likely be compatible with the goals of a potential fish passage program at Lake Oroville.

The main risk associated with using mesh sorters placed in holding tanks is that, although juveniles would be provided with a compartment that would allow them to escape predation by larger fish, juvenile stress could potentially be high if a large fish became trapped in the holding tank. Regular inspection of the holding tanks for entrained predators would minimize the risks of predator exacerbated stress to captured juveniles.

Device 2 – Bar Sorters

Description

Bar sorters, like mesh sorters allow fish of a specific maximum size to pass through the device while excluding others. Sorting occurs passively by allowing individuals to volitionally move through the device. Bar sorters generally are a series of bars mounted within a flume.

A bar sorter described by Seelbach et al. (1985) used PVC pipes 0.5 inches in diameter that were placed parallel to each other and spaced two inches apart. Typical bar sorters can be constructed from a variety of materials depending on the conditions under which the devices would be operated. The bars generally are arranged so that they allow small, smolt-sized fish to swim or fall through the slots between the bars, but exclude larger fish. Larger fish could be collected separately for relocation or release downstream from the capture device in which the sorter is used.

Characteristics

Although little information regarding the use of bar sorters was available, most documentation of bar sorter use that appeared in the literature were at fish passage projects at which migrating juvenile salmonids were the target species. In most cases, bars were mounted over the entrances to the smolt traps to prevent larger fish from being collected along with the juveniles.

Bar sorters were described by Seelbach et al. (1985) who examined a modified inclined screen trap in the Little Manistee River, Michigan. The trap made use of a floating catch

barge that was designed for capturing salmonid smolts in large rivers. The fish sorter was placed directly over the trap to facilitate collection of smolts rather than larger fish (Seelbach et al. 1985).

At the Baker Lake Fish Passage Project bar sorters (sometimes referred to as louvers) are used in the fish gulper channel to prevent adult steelhead from entering the trap. (Puget Sound Energy Unpublished Work) did not provide information regarding the success of the bar sorter used at the Baker Lake project, however it has been reported that adult steelhead generally are not found in the holding tanks of the Baker Lake gulper (pers. com. D. Dorratcague, 2004).

On the Snake and Columbia Rivers, two-stage submerged-bar separators are used at Little Goose Dam, Lower Monumental Dam, and McNary Dam collection facilities. The fish separator at the McNary Dam facility is located in a 5,800 L (1,530 gallon) stainless steel tank approximately four cm below the water surface and is composed of a series of 7.6-cm (3 inch) diameter plastic pipes. The separator is designed to allow only juvenile salmonids passage between the pipes and into the tank (Maule et al. 1988). According to USACE *in* Kelsey et al. (2002), approximately 32 percent of yearling Chinook salmon entered the “small fish” side of the separator in 1994 and the remainder entered the “large fish” side of the separator along with juvenile steelhead. It is unclear, however, whether the percentages of juveniles on each side of the sorter reported by Kelsey et al. (2002) are representative of all years or simply indicative of conditions during one sampling event.

The separation of adults from smolts using a bar sorter device on the Little Manistee River, Michigan was described by Seelbach et al. (1985). Although the actual efficiency of the trap was not tested it was reported that, based on observation, it was believed to be 90 to 100 percent efficient. However, because sorting occurred prior to collection, some smolts reportedly avoided collection by sliding off the sorter pipes (Seelbach et al. 1985). Because smolts in this study encountered the sorter prior to capture, it is likely that some individuals avoided the sorter. No information was included in the report on the amount or likelihood of sorter avoidance, however. Therefore, it is likely that sorter efficiency within a holding tank would have been as high or higher than the observations described by (Seelbach et al. 1985).

Bar sorters typically are associated with holding tanks or, in some cases, trap devices. The main requirement for the use of a bar sorter is a physical enclosure such as a flume or a trap on which a series of bars can be mounted. In addition, flow should be low enough to allow juveniles to navigate through the slots in the sorter without getting involuntarily thrust against the bars.

Like mesh sorters, mortality associated with handling induced stress could potentially occur. Because sorting methods that use devices such as mesh and bar sorters rely on volitional movement of individuals through the mesh screen or between the bars,

mortality related to the sorting likely is low. However, review of available literature revealed little information related to sorting induced mortality. Based on the similarity of bar sorters to mesh sorters it is likely that mortality rates associated with bar sorters also are similar to mesh sorters. According to a literature review conducted by Ward et al. (1997), estimates of 10 percent, 15 percent, and 20 percent mortality related to collection, handling, and transport of juvenile fish is consistent with a variety of literature sources. Based on the range of mortality estimates reported by Ward et al. (1997), an average of 15 percent mortality related to capture, sorting, and transport of individuals was assumed to occur. Additionally, because sorting mortality was not reported separately, it was assumed that collection, handling, and sorting each contributed equally to mortality in the studies reviewed. Therefore, it was assumed that mortality related to sorting would be approximately 5 percent.

Considerations

Review of available literature revealed little information on regulatory guidelines or criteria associated with the design, construction, or use of bar sorters in juvenile collection facilities. It is likely, however, that because NOAA Fisheries recommends a minimum of 95 percent survival at juvenile collection facilities associated with the Klamath Hydroelectric Project in California and Oregon, that similar guidelines would apply to sorters associated with collection facilities in a potential fish passage project at Lake Oroville.

The bar sorter used with the modified inclined screen trap on the Little Manistee River, Michigan was used to separate Chinook salmon and steelhead smolts from adult steelhead kelts (Seelbach et al. 1985). Because the potential fish passage program at Lake Oroville would require separation of downstream migrating Chinook salmon from larger predators, and because spacing between the bars of a bar sorter can be modified to accommodate the size of juvenile outmigrants expected to be captured, it is assumed that bar sorters would be appropriate for use at juvenile collection facilities. In addition, bar sorters can be placed over the top of most flumes or traps so that larger fish will be excluded from the juvenile collection system.

Although appropriate for use with a potential fish passage program at Lake Oroville, bar sorters do have risks associated with their use. The main risk associated with bar sorters is that juveniles could potentially slide off the sorter bars along with any larger fish. If these types of events occurred frequently, sorter efficiency could be diminished, and overall juvenile survival through collection facilities could be reduced.

5.2.2.3 Tagging Alternatives

Review of available literature revealed that a limited number of alternatives existed to facilitate meeting program goals and to measure the overall success of a potential fish passage program. One program goal could potentially be to maximize the number of

adult Chinook salmon returning to the Feather River (i.e. maximize production). To determine the success of the program goal of maximizing production, the ability to determine the number of adult Chinook salmon returning to the Feather River that were naturally spawned above Lake Oroville would be required. The most commonly used method of tracking hatchery-produced individuals is placement of a unique coded wire tag (CWT) in each captured juvenile that indicates the origin and brood year of the tagged individual. After subsequent spawning seasons, tags are collected from recovered carcasses (or from hatchery spawned adults) and "read" to obtain information about the origin of those individuals. A benefit of a CWT program associated with a potential fish passage program is that it would be relatively inexpensive. However, CWT's cannot be read while individuals are alive, and cannot be used to identify returning fish passage program adults prior to spawning. A second potential goal of a fish passage program could be to maintain genetic separation between runs that historically were separated temporally and spatially (i.e. allow spring-run Chinook salmon to spawn above Lake Oroville). In order to maintain genetic separation between those individuals spawned in the upper Feather River and those spawned elsewhere, transport above Lake Oroville would be restricted to those individuals that were collected in the upstream tributaries. One method utilized to identify specific individual fish while alive is the use of passive integrated transponder (PIT) tags. Returning adults could be scanned for the presence of PIT tags and could be transported to their natal tributary. Additionally, both PIT tags and CWT's could be used as a method of maintaining redundancy and measuring different aspects of program performance.

Because some individual marking methods were not consistent with program goals, they were eliminated from consideration for use in the potential fish passage program. The methods eliminated from consideration include the use of fin clipping techniques, and elastomer marking.

Adipose fin clipping often is used to identify individuals of hatchery origin. Although a reliable indicator of hatchery origin, it is unclear form which hatchery a fin-clipped individual came. Additionally, it is generally thought that it is possible for adipose fins to regenerate. Because hatcheries throughout the Sacramento River system utilize adipose fin clipping as a means to identify individuals of hatchery origin, it is unlikely that adipose fin clipping could be used to identify Chinook salmon or steelhead spawned in the upper Feather River. Removing a small portion of another fin, such as the pelvic or anal fin, also could potentially differentiate fish associated with the fish passage program from other naturally or hatchery spawned individuals. However, it is likely that removal of a portion of a fin used in maintaining balance or locomotion would be detrimental to the survivability of juvenile fish, and therefore, is inconsistent with program goals.

Elastomer marking is a practice that utilizes colored elastomer paint to place an identifying mark immediately beneath the surface of the skin of individual fish. Although appropriate for batch identification, elastomer marking generally is not considered

appropriate for individual marking, particularly for small individuals. Additionally, elastomer paints generally do not maintain their integrity for long periods of time, such as those associated with the ocean phase of an anadromous salmonid life cycle. Thus, elastomer marking techniques were inconsistent with program goals.

Device 1 – PIT Tagging

Description

PIT tags are small externally mounted or implanted radio frequency identification tags used to individually identify animals. PIT tagging is a common method of individual fish identification and monitoring frequently used to study growth, survival, and movement juvenile salmonids (Biomark Website 2004). The tags are valuable tools for use in fish passage projects because they allow fish to be identified individually or in batches without sacrificing tagged fish. Additionally, PIT tags have high retention rates and a long useful lifespan.

PIT tags consist of an antenna coil bonded and an integrated circuit chip (Roussel et al. 2000). The tags can be equipped for external mounting on an animal or be encapsulated in glass to allow them to be implanted under the skin or within the body cavity of the animal (Biomark Website 2004). PIT tags appropriate for monitoring small juvenile salmonids generally are between 11 and 32 mm in size (Roussel et al. 2000). Figure 5.2-5 shows a typical PIT tag suitable for juvenile salmonids.

Figure 5.2-5 Pit tag suitable for juvenile salmonids.

PIT tags are read-only tags that are programmed to transmit a unique code when activated. The tags are activated by handheld or fixed transceivers/readers (also referred to as interrogators) that generate electromagnetic signals that momentarily activate the tags. Both handheld and fixed interrogators are capable of reading and storing information obtained from individual PIT tags (Biomark Website 2004).

Characteristics

Available literature indicated that PIT tagging is a common juvenile salmon monitoring practice throughout the Northwest. PIT tagging is used to monitor both hatchery and wild fish populations but the most frequent use reported in the literature was to monitor the passage of wild juvenile salmon populations, including Chinook salmon and steelhead, past dams or other migration barriers (Achord et al. 1996; Biomark Website 2004; Prentice et al. 1990b).

In the Snake River system, monitoring programs have made use of PIT tagging technology to monitor Chinook salmon smolt migration timing and behavior. Specifically, Achord et al. (1996) conducted a study to determine the migration timing of Snake River Chinook salmon smolts looking at both wild and hatchery spawned individuals. A total of 45,158 wild Chinook salmon smolts and 55,348 hatchery-reared Chinook salmon smolts were collected, tagged and released in specified reaches upstream from Lower Granite Dam on the Snake River. According to Achord et al. (1996), over the three-year study period, 5.6 percent of wild fish and 15.1 of hatchery fish were detected at the Lower Granite Dam juvenile bypass. Delayed mortality and tag loss reportedly was low in a proportion of fish held for a twenty-four hour observation period after tagging.

At Faraday Hydro-electric Facility located near Estacada, Oregon, Marmot Dam on the Sandy River, and Sulivan Dam on the Willamette River near Oregon City, PIT tag monitors have been installed to aid in the determination of the number of migrating juvenile salmon and steelhead achieving dam passage. Although the design of the monitoring study design was not reported, the monitoring stations reportedly have reading efficiencies between 95 percent and 98 percent depending on the configuration of the systems (Biomark Website 2004).

In 1998 a pilot study was conducted on the Columbia River to determine the survival of Chinook salmon smolts passing through Wells Dam. Twenty-six thousand Chinook salmon smolts were PIT tagged along the Methow River near Pateros, Washington and released upstream from Wells Dam. PIT tag detection data collected indicated that spring-run Chinook salmon survival after passage through Wells Dam was estimated to be 95.7 percent. PIT tag data also revealed behavioral differences between Methow River fish and Wells Hatchery fish with respect to migration timing. Because the monitoring study performed appropriately, monitoring of steelhead has been implemented using PIT tagged individuals (Biomark Website 2004).

According to the Biomark Inc. website (2004), new monitor designs have improved tag detection capabilities allowing reading efficiencies ranging from of 95 percent to 98 percent. Prentice et al. (1990b) reported that in both hatchery and field trials tag detection efficiency was 93 percent or higher and tag- reading accuracy was at least 99 percent or higher.

Estimates of juvenile salmonid survival following PIT tagging vary based on species and size of fish tagged. Venditti et al. (2000) reported that in the three years that they tagged naturally produced Chinook salmon of at least 115 mm fork length (FL) in the Lower Snake River, Idaho tagging associated mortalities were 3.2, 1.5, and 2.5 percent. Prentice et al. (1990a) conducted a study to determine the minimum size at which a juvenile Chinook salmon could be PIT tagged, and the relationship between fork length and survival. Tagged juvenile Chinook salmon ranged in size from 56 mm to 120 mm FL. Although individuals as small as 56 mm FL were tagged, the smallest mean experimental treatment group size was 66 mm FL. Survival of experimental treatment groups ranged from 95 percent to 100 percent. Control group survival was 99 percent to 100 percent. No association was found between survival and fish size. A similar study conducted using sockeye salmon juveniles and smolts (55 to 107 mm FL) found survival of PIT tagged juvenile sockeye salmon exceeded 96.5 percent in each experimental group. The mean fork lengths for each experimental treatment group were 68 mm, 82 mm, and 99 mm. Control group survival exceeded 97 percent in each of the three control groups (Prentice et al. 1990a). In a study comparing survival among three different tagging methods at Columbia River dams, Prentice et al. (1990a) found that PIT tagged juvenile salmonid survival at 14-days post-tagging was not measurably different from control groups. Several other field studies using PIT tagging to monitor individual juvenile salmonids reportedly tagged only juvenile fish exceeding 60 mm FL (e.g., (Connor et al. 1998; Gries and Letcher 2002; Hockersmith et al. 2000; Roussel et al. 2000). Furthermore, Brakensiek (2002) reported substantially lower survival rates for smaller tagged fish.

Although literature reviewed did not indicate the minimum size at which juvenile salmonids could be effectively tagged while maintaining low mortality rates, mean fork lengths for each of the experimental treatment groups in the studies examined always were greater than 60 mm. It was assumed that the 60 mm FL size threshold was due to unacceptably high levels of tagging mortality or an inability to effectively tag fish smaller than 60 mm FL.

Because PIT tagged juvenile salmonids would spend between one and five years in the ocean before returning to the lower Feather River prior to passage above Oroville Dam, tag effective lifespan would be an important factor to consider when selecting a tagging method for use in a potential fish passage program. The effective lifespan of a tag is the length of time after which a tag would remain readable by an interrogator. According to Prentice et al. (1990a), PIT tag effective lifespan is estimated at ten or more years. Alternatively, the Biomark Inc. website (2004) reported that PIT tags are expected to be readable after one hundred years or more. Thus, the effective lifespan of PIT tags would likely not limit their use in a potential fish passage program.

Overall capital and operating costs associated with a PIT tag program are dependent on multiple variables including tag size, types of implantation devices, types of interrogators, and program size (i.e. how many tagging technicians, tags, implanters,

and interrogators). Preliminary investigation of costs revealed that PIT tags from Biomark Inc. start at six dollars per tag. Tagging kits, including an implanter and tag reader start at approximately $800 per kit (Biomark Website 2004). Because it is unclear how many and at what size emigrating juveniles would be tagged, it is unclear what type of tags, implanters, and readers would be required. Therefore, the range of capital and operating costs associated with PIT-tagging as a part of a passage program also is unclear. It is clear, however, that PIT-tagging associated with a fish passage program would be somewhat more costly than other performance measures such as CWT-tagging.

PIT tag monitors can be set up at most fish passage projects but the fish must come within 18 cm of the monitors in order to be detected (Prentice et al. 1990a). Therefore, the monitors would be required to be located in areas of the passage system (typically the bypass or trap) where fish are likely to be come within the required distance from the monitors. Additionally, because the use of PIT tags could be associated with sorting adults to be passed above Oroville Dam, from those that would be spawned at the FRFH or returned to the lower Feather River to spawn, it is likely that PIT tag interrogators would be associated with sorting devices in a potential fish passage project.

Considerations

Because most fish passage programs described in available literature are associated with run-of-river dams such as those in the Columbia and Snake River system where monitoring individual live fish is unnecessary, little information is available regarding regulatory agency guidelines or performance criteria for PIT tag use in a fish passage program.

Available literature identified various examples of PIT tag use for monitoring juvenile Chinook salmon and steelhead (Achord et al. 1996; Biomark Website 2004; Prentice et al. 1990a). In addition, recent projects have supported the use of PIT tag technology to monitor various species of sturgeon (Biomark Website 2004; WDNR Website 2004). It is unclear, however, whether the results from most monitoring programs utilizing PIT tags could be applied to a potential fish passage program at Lake Oroville. Because the lower Feather River supports a relatively large Chinook salmon spawning population, and because most monitoring programs using PIT tag technology are relatively small, it is unclear how these studies relate to a potential fish passage program.

Device 2 – Coded Wire Tagging

Description

Coded wire tagging has been used as a major salmonid stock identification tool by many fisheries agencies, and was developed over 30 years ago for large-scale studies

on migratory salmonids. Each year reportedly over 40 million CWTs are put into Pacific salmon and approximately 300,000 tags are recovered (Johnson et al 1990 *in* Solomon 2003). CWT tagging involves the implantation of a small wire tag into suitable tissue, generally the snout or dorsal muscle tissue of individuals. Standard CWTs typically are a small length of stainless steel wire approximately 1.1 mm in length and 0.25 mm in diameter. Half-length CWTs (approximately 0.5 mm long) are effectively implanted into fish as small as salmonid fry (Solomon 2003). Figure 5.2-6 shows a coded wire tag.

CWT tagging involves injecting a coded wire tag into the area of muscle, connective tissue, and cartilage in the snout of an anesthetized individual. Tag injection can be performed by hand or using automated tag injectors. Each tag usually is etched with a binary code that identifies its release group, but also can be etched with a unique identifying code. Returning CWT tagged fish are detected using sensitive metal detectors, but identification of the specific tag code requires fish to be sacrificed so that the tag can be removed and read.

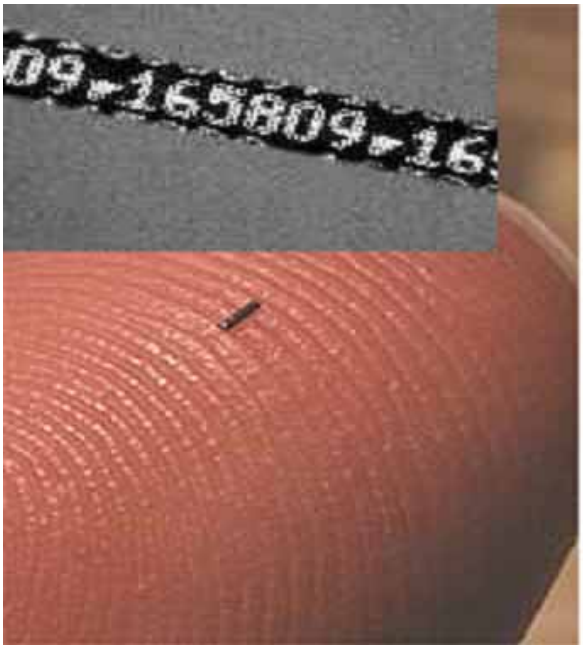

Figure 5.2-6 Coded Wire Tag (inset is magnification).

Characteristics

Coded wire tagging typically has been used as a salmonid stock identification tool by many fisheries resource agencies. Coded wire tags generally are used to monitor hatchery-produced fish return rates, but they also could be used to monitor wild passage program fish (USACE, Northwest Division: Pacific Salmon Coordination Office Website 2004).

The CWT Tagging survival rate is the percentage of juvenile fish that survive the CWT tagging procedure. Estimates of survival of the CWT tagging procedure for juvenile salmonids vary among species and size of fish tagged. Jonasson and Lindsay (1988) *in* Brun (2003) reported that from 1978 through 1980, the Oregon Department of Fish and Wildlife (ODFW) CWT tagged a total of 123,000 juvenile fall-run Chinook salmon from the Deschutes River, Oregon. Analysis of mortality rates showed that CWT-associated mortality reportedly ranged from 1.1 percent to 4.2 percent (Brun 2003). In the spring of 2002, the ODFW captured over 12,000 juvenile Chinook salmon below and above Sherar's falls on the Deschutes River for tagging with CWTs. The fork lengths of the juvenile Chinook salmon tagged ranged from 45 mm to 80 mm. Mortality for the CWT tagged fish reportedly was approximately 1.1 percent below Sherar's falls and 0.85% above Sherar's falls (Brun 2003).

CWTs also were used to estimate survival of juvenile Chinook salmon emigrating through the San Joaquin River system as part of the Vernalis Adaptive Management Plan (VAMP) 2002 test period. Three groups of approximately 25,000 juvenile Chinook salmon were tagged with CWTs. The associated tagging mortality rates reportedly were 0.48, 0.92 and 1.0 percent for the three groups (San Joaquin River Group Authority 2002). Over 80,000 juvenile Chinook salmon ranging in size from 36 mm to 95 mm FL were tagged using CWTs in the Trinity River in 1991. An estimated 5,330 juvenile Chinook salmon (6.7 percent) reportedly died as a result of the tagging process (Zuspan 1992).

CWT tagging is a useful procedure because large numbers of small individuals can be tagged with a relatively high survival rate for relatively low cost. CWT tagging reportedly is an acceptable technique for tagging juvenile salmonids as small as approximately 22 mm TL. Additionally, CWTs reportedly have high retention rates and do not degenerate over the lifespan of the individual in which the tag is implanted. Although CWTs reportedly can be relatively inexpensive, ranging from 3 cents per tag to 14 cents per tag depending on the information coded into the tag, tagging equipment can be relatively expensive. Tag injectors range from $105 for a handheld single injector to approximately $30,000 for an automatic tagging kit. Tag detectors range from approximately $6,000 to approximately $21, 000 (NMT Website 2004).

Considerations

Because CWTs have been in use for over 30 years, there are relatively few unknowns regarding the procedure. It has been reported that CWTs are relatively inexpensive, can be used on large numbers of small individuals, and have high retention rates. However, individuals are required to be sacrificed in order for information to be obtained from the tag. Because the uses and limitations of the tags are widely known, it is likely that CWTs would be useful to a potential fish passage program.

Device 3- Combined PIT tagging and CWT tagging

Because PIT tags and CWTs each have different strengths and weaknesses, the two types of tags could potentially be used together as part of a comprehensive fish passage monitoring program. Using both types of tags could potentially provide the benefit of having all emigrating juveniles identifiable by brood year, while allowing a portion of the population to be individually identifiable while still alive. Additionally, the use of the two types of tags would allow differential tagging based on the specific goals of a monitoring program.

5.2.2.4 Conclusions

Both mesh sorters and bar sorters have been used successfully in programs requiring the separation of juvenile salmonids based on size criteria. It should be noted, however, that these devices are not capable of sorting fish by species. Depending on the level of juvenile fish by-catch in the capture process, an additional manual sorting process may be required to meet program objectives.

Of the two tagging alternatives, CWT or PIT, CWT's are probably more applicable to a potential Oroville fish passage program. Although PIT tags allow identification of individual fish, their application to fish less than 60 mm in length could be problematic. The reading and decoding of CWT's requires sacrifice of fish, however the presence of a tag can be detected without harming the fish. Because hatchery fish also use CWT's it would not be possible to distinguish hatchery fish from passage program fish unless the hatchery stock were to receive an additional external mark. For example, hatchery fish may receive a CWT and an adipose fin-clip allowing for distinction between the hatchery stock and passage program fish. Therefore, returning adults without an adipose fin clip in which a CWT was detected could be assumed to be a part of a potential fish passage program and would be transported to the upstream tributaries. However, because reading CWT's requires sacrificing fish, potential challenges exist with their use. Specifically, it would not be possible to determine the natal tributary of returning individual adults. Therefore, genetic isolation of populations within each of the upstream tributaries would only occur if adults were released in Lake Oroville and volitionally returned to their natal tributaries. Uncertainties associated with release into Lake Oroville are discussed in Section 5.1.5.

5.2.3 Juvenile Fish Holding

One of the operating principles of a potential fish passage program is to minimize the stress to the fish by minimizing the number of times an individual fish is handled and to minimize the duration of the exposure of fish to passage program stresses. Those individuals identified in the sorting process as targets for a potential fish passage program will be held for as short a time as is operationally feasible, 24 hours to 48 hours depending on the number of juveniles arriving and the capacities of the holding facilities.

5.2.3.1 Location

Juvenile fish holding facilities would be adjacent to the fish sorting facility at the juvenile fish capture facilities, both at the upstream tributary screen facilities and at the in-reservoir gulper system for each tributary selected in a potential fish passage program.

5.2.3.2 Alternatives

The devices considered for detailed feasibility analyses were raceways (or other holding tanks) and net pens. Additional variations of these devices were not considered because the design of individual raceways or net pens, such as variations in raceway shape or wall color, would be determined by the best available science and technology at the time of design.

Device 1 - Raceways

Description

Raceways generally are considered rearing facilities in hatchery settings. Although somewhat similar in design and function, holding raceways associated with a potential fish passage program differ in several important aspects of form and function. In general, the term raceway is used because it refers to the rectangular shape that allows large numbers of individuals to be held for long periods of time. As part of a juvenile collection facility, a holding raceway would be utilized for short-term holding (no longer than 48 hours) of juveniles prior to downstream transport. Additionally, holding raceways associated with a potential fish passage program are not necessarily required to be rectangular. Specific holding tank shape would be determined based on specific site conditions and program goals. However, it is assumed, for purposes of this feasibility analysis, that holding raceways would be similar in shape and size to raceways described in available literature, including hatchery-rearing raceways.

Holding raceways generally are long, narrow, permanent concrete, or transient floating steel structures adjacent to collection devices in which juveniles would be held for up to three days. Raceways generally are designed as rectangular structures to maximize the number of individuals that can be held while minimizing the effort required maintain fish in a hatchery setting while maximizing water flow through the tank. Holding tanks associated with a potential fish passage program would be designed to maximize survival and minimize stress, and would be designed based on the best available science at the time of design. Because raceways currently are in use at most hatcheries and because limited information was available describing the performance of alternative raceway designs, the analysis conducted to determine the feasibility of raceway use was conducted on the type of raceway for which the most information was

available. In general the majority of information available describing raceways existed for rectangular concrete raceways used in hatchery settings.

The holding raceways proposed for use at the Cougar Lake Project, Oregon are representative of typical holding raceways. The raceways proposed for use at the Cougar Lake Project are primarily cast-in-place reinforced concrete that would be located on land adjacent to the collection devices. Raceways were proposed for construction at both the instream screening facility and the gulper facility. The raceways were proposed to be constructed five feet wide by four feet deep by sixty feet long and five feet wide by four feet deep by forty-five feet long (USACE 2000). Figure 5.2-7 shows a typical raceway at the Feather River Fish Hatchery. Additionally, the holding raceways were proposed to be connected to the collection device by a flume that would allow direct movement of individuals from the collection device to the raceway. Although the Cougar Lake Project raceways have not yet been constructed, the design is more applicable to a potential fish passage program at Lake Oroville than existing hatchery raceways because the raceways proposed at the Cougar Lake Project are associated with a passage program and the design was not constrained by hatchery operations. However, because no permanent structures exist where raceways could be constructed near potential gulper locations in the arms of Lake Oroville, raceways associated with a gulper in Lake Oroville would be required to be designed to accommodate site-specific conditions, and likely would be smaller floating tanks rather than permanent concrete facilities.

Figure 5.2-7 Raceways at Feather River Fish Hatchery

Characteristics

Raceways generally are used at hatchery facilities to rear juvenile salmonids (DFG Website 2003; DFG Website 2004). However, raceways also are commonly used at fish passage projects to hold juvenile salmonids prior to transfer to tank trucks or barges

for downstream transport (Koski et al. 1990; Puget Sound Energy Unpublished Work; USACE 2000).

Koski et al. (1990) reported that fish passage projects on the Snake and Columbia rivers typically use raceways to hold juvenile salmonids prior to passage downstream. Specifically, facility operations at Lower Granite Dam and Little Goose Dam facilities, located on the Snake River, Washington and McNary Dam, located on the Columbia River, Washington involve holding juvenile salmonids in raceways prior to barge or truck transport below Bonneville Dam. The maximum holding capacity of the raceways at these facilities reportedly is 0.5 pounds of fish per gallon of water. Individual raceway water capacity was reported to be approximately 12,000 gallons of water at Snake River dams, 5,000 gallons of water at the seven permanent raceways at McNary Dam, and 7,400 gallons in the two temporary raceways at McNary Dam. The number of fish each raceway could potentially hold depends on the maximum water capacity of each raceway and the weight of each individual held in the raceways (Koski et al. 1990).

At the Cougar Lake Project, holding raceways were proposed for use with both proposed collection alternatives (instream screens and gulper). Two identical raceways sized to hold juveniles for approximately three days at expected peak collection rates (to allow for collection over a weekend without the need for transport) were proposed for construction at the instream screen facility. USACE (2000) calculated that 4,167 smolts per day would be the average collection rate at the Cougar Lake facilities while the peak collection rate was estimated to be approximately 12,500 smolts per day. Based on the amount of water required per pound of fish, it was calculated that raceways would be five feet wide by four feet deep by sixty feet long. An adult holding area was included in the design to accommodate steelhead kelts migrating downstream (USACE 2000). In addition to the holding facilities proposed for construction at the instream screen collection facility, three raceways would be located in the collection barge of the gulper. Like the raceways at the instream screen facility, the raceways in the collection barge would be sized to be able to hold fish for three days. Because three raceways would be constructed in the collection barge of the gulper, the raceways were slightly shorter than those proposed for use at the instream screen facility. The raceways to be constructed at the gulper were designed to be five feet wide by four feet deep by 45 feet long (USACE 2000).

Prentice et al. (1990b) reported holding survival rates for control groups (groups of fish that are handled but not tagged) in their PIT tagging investigations. Survival estimates for control groups reported by Prentice et al. (1990b) likely are representative of holding survival rates, in general. Survival rates for two control groups of 200 juvenile Chinook salmon with mean fork lengths of 77 mm were 99 percent and 100 percent over the 135-day test period. Survival rates for control groups of small presmolt, large presmolt, and smolt sockeye salmon were 99.5 percent, 98.5 percent, and 97 percent, respectively. Survival rates of three steelhead and two fall-run Chinook salmon control groups, ranging in mean FL from 67 mm to 171 mm, reportedly all were 100 percent

after a 14-day holding period. Control groups of yearling Chinook salmon and steelhead held at Lower Granite Dam reportedly had survival rates of 95 percent and 100 percent, respectively, 14 days after handling and release into holding raceways. Control groups of age-0 and yearling Chinook salmon held at McNary Dam had survival rates of 96 percent and 86 percent, respectively, 14 days after handling and release into the holding raceways (Prentice et al. 1990b).

The holding survival rate in raceways ranged from 86 to 100 percent in the literature reviewed. The mean holding survival rate for the investigations reviewed was 97 percent.

In order to satisfy the goals of a potential fish passage program, handling, stress, and mortality is required to be minimized. Locating holding structures at or in close proximity to collection devices would minimize the risk of creating stress during transfer from collection to holding devices. Furthermore, the construction of a transport conduit from the collection device to the raceways would minimize stress by allowing a hands-free transfer to occur. Therefore, adequate space for the collection and holding area to be located immediately adjacent to each other would be required. Additionally, transferring juveniles from holding raceways to transport vehicles also would require minimization of stress. Thus, physical access to the raceways via truck or barge also would be required.

Considerations

The use of raceways as holding structures for juvenile salmonids is a common practice at numerous fish passage projects throughout the Northwest (Koski et al. 1990; Puget Sound Energy Unpublished Work). Therefore, it is likely that holding raceways are compatible with the goals of a potential fish passage project at Lake Oroville. It also is likely that the design and construction of holding raceways would account for the various guidelines published in available literature associated with holding raceways. Holding criteria for downstream migrating juveniles at the Cougar Lake Project are described by USACE (2000), in which Mehann (1991) reports that 80 percent dissolved oxygen saturation or higher should be maintained with sufficient flow through the holding area. It also is suggested by USACE (2000) that collection facilities sort fish into two size groups to minimize stressful interactions between size classes. In addition, Bell, M. C. (1991) suggests that fish loading densities for raceways should not exceed 1.0 pound of fish per cubic foot of water.

Device 2 – Net Pens

Description

Net pens are fish holding devices that contain fish in a net attached to a floating structure. Net pens allow fish to be held in a more natural environment while being

protected from predators. Net pens typically are used to rear juvenile anadromous salmonids because they provide maximum exposure to natural in-river conditions while also providing protection from in-river predation.

The net pens described by Beeman and Novotny (1994), are typical net pens used to rear Chinook salmon. The pens were made from 0.2-inch mesh nets suspended from floating platforms. The enclosures measured approximately 20 ft by 20 ft and extended to a depth of 7 to 10 feet (Beeman and Novotny 1994). A net pen rearing study conducted by Rensel et al. (1988) used net pens measuring 8.5 meters by 8.5 meters and extended to a depth of 4.3 meters. The nets were constructed with 1.9 cm mesh. The total immersed volume of each pen was reported to be 243 m^3 (Rensel et al. 1988). Although all net pens are constructed to perform a similar function, the design of individual pens is dependent on the specific habitat conditions and program goals associated with each use.

Although normally used for extended rearing, net pens associated with a potential fish passage program at Lake Oroville likely would not be utilized as rearing pens. It is anticipated that net pen use would be limited to periods no longer than three days for holding captured juveniles prior to transport below Oroville Dam.

Characteristics

The majority of examples of net pen use described in available literature are associated with projects attempting to increase survival of hatchery-spawned juvenile salmonids (Beeman and Novotny 1994; Commercial Salmon Trollers Advisory Committee Website 2004; Rensel et al. 1988). Survival of released juveniles following net pen rearing reportedly is relatively high (Commercial Salmon Trollers Advisory Committee Website 2004).

Examples of the successful net rearing pen projects include the Monterey Bay Salmon and Trout Project and the Central Coast Salmon Enhancement project. The Monterey Bay Salmon and Trout Project uses net pens to increase the survival of FRFH Chinook salmon prior to their release. The Central Coast Salmon Enhancement project reported that, based on CWT studies, *"pen-reared salmon survive to enter the commercial and sport fisheries at exceptional levels"* (Commercial Salmon Trollers Advisory Committee Website 2004). A five-year study conducted by Rensel et al. (1988), evaluating the use of the marine net pens in Puget Sound, Washington, reported that juvenile coho salmon survival in net pens with 243 m^3 (8,580 ft^3) of immersed volume averaged 98.4 percent.

Beeman and Novotny (1994) reported that net pens with dimensions of approximately 20 ft by 20 ft with a depth of 7 to 10 feet have been used to raise pre-smolt Chinook salmon at densities of 18,000 fish per pen in the Columbia River system. Factors taken into consideration when calculating initial rearing densities reportedly were minimum flows likely to be encountered, maximum rearing water temperatures of 61° F, and

release weights of 45 fish per pound (Novotny et al. 1984 *in* Beeman and Novotny 1994).

Costs associated with net pens are dependent on multiple variables including net pen size, and net mesh size. Additionally, overall costs associated with net-pens in a fisheries resource management program, including a potential fish passage program, is dependent on the number of pens required and the lifespan of each pen. The size, mesh size, and number of pens that could be required for a potential fish passage program at Lake Oroville is unclear. The reported lifespan of each of the net pen components are seven years for the net and twenty years for the pen frames (Senn et al. 1984 *in* Beeman and Novotny 1994).

In order to satisfy the goals a potential fish passage program, handling, stress, and mortality is required to be minimized. Locating holding structures at or in close proximity to collection devices would minimize the risk of creating stress during transfer from collection to holding devices. Furthermore, the construction of a transport conduit from the collection device to the net pens would minimize stress by allowing a hands-free transfer to occur. Therefore, adequate space for the collection and holding area to be located immediately adjacent to each other would be required. Additionally, transferring juveniles from net pens to transport vehicles also would require minimization of stress. Thus, physical access to the raceways via truck or barge also would be required.

Considerations

Although regulatory criteria for net pen rearing were not available, holding criteria for downstream migrant fish at the Cougar Lake Project are described by USACE (2000), in which Mehann (1991) reports that 80 percent dissolved oxygen saturation or higher should be maintained with sufficient flow through the holding area. It also is suggested by USACE (2000) that collection facilities sort fish into two size groups to minimize stressful interactions between size classes. Additionally, loading densities and other factors associated with net pen rearing were described by Beeman and Novotny (1994) for net pens with a volume of 1,400 ft^3. It was reported that pre-smolt Chinook salmon could be held for extended periods at 18,000 individuals per pen. However, loading density is a function of volume and therefore criteria associated with the net pens in the study conducted by Beeman and Novotny (1994) should be interpreted with caution. In addition, it was suggested that water temperatures not exceed 61° F during net pen rearing (Beeman and Novotny (1994).

Although net pens are generally used for juvenile rearing, the reported success of net pens in increasing survival of hatchery reared juvenile salmon suggests that holding juvenile salmon in net pens for short periods of time (no more than 3 days) would also be successful (Beeman and Novotny 1994; Commercial Salmon Trollers Advisory

Committee Website 2004; Rensel et al. 1988). Therefore, it is likely that net pens would be appropriate for holding juveniles in a potential fish passage program at Lake Oroville.

Because net pens have been used to rear juvenile salmonids it is assumed that typical net pens could be modified, if needed, to be compatible with the potential juvenile collection methods analyzed in this report. Additionally, it is assumed that modification and use of typical net pens would be consistent with the goals of a potential fish passage program at Lake Oroville.

5.2.3.3 Conclusions

Both raceways and net pens would be suitable devices for holding juvenile salmonids in a potential fish passage program. Because the holding of juvenile fish after the capture and sorting process could occur in several different areas, net pens could be a more cost effective solution within the reservoir adjacent to the gulper system in each selected tributary, while, because of the potential for high flows to affect the facilities upstream, raceways could be more appropriate for use in adjacent to the upstream tributary screening systems. Specific engineering design considerations would be addressed on a site-specific basis, but in general raceways likely would be appropriate for use with both capture facilities, while net pens likely would be appropriate for use only with a gulper system in the reservoir.

5.2.4 Juvenile Fish Transfer and Transport

Juvenile fish transfer and transport are dependent upon the method selected for juvenile fish capture, location, and logistical access to the juvenile fish capture facilities. Juvenile transport would be accomplished by truck transport for the upstream tributary fish screens and for the gulper station locations with road access. For those gulper fish screen station locations without road access, juveniles likely would be transported first by barge, and then transferred to a truck at a marina or boat ramp. Additional transport transfers could result in increased stress, and potentially a compounded increase in the rate of juvenile mortality associated with transportation stress.

5.2.4.1 Location

Transfer would occur at all juvenile holding facilities selected in a potential fish passage program. These potential locations are discussed in Section 5.2.1 Juvenile Fish Collection.

5.2.4.2 Alternatives

Devices that could potentially be utilized for juvenile transport below Oroville Dam to the release site(s) include tank trucks, barges, helicopters and trains. However, the

methods of juvenile transport that were eliminated from further analysis were helicopter and rail transport.

Transporting fish downstream using a helicopter would involve placing fish in containers or holding tanks carried underneath the body of the aircraft. Fish would be transported downstream from Oroville Dam, where they would be released directly into the river. Similar systems are in use in British Columbia, Canada, and in the Pacific Northwest on the Columbia River. In British Columbia, fish are transported in specially designed containers with divided compartments to allow batches of individuals to be released at various locations downstream. Once flown to the release locations, batches of fish are released directly into a lake or stream while the helicopter hovers above (Ministry of Water, Land, and Air Protection Website 2004). In the Columbia River, fall-run Chinook salmon have been released using a similar technique. Three hundred fifty gallon aluminum tanks were loaded with three to four inch fish and transported by helicopter up and downstream of two hydroelectric dams as part of a survival study. The researchers claim that using helicopters “cuts transport and handling time of the fish from hours to minutes” (University of Florida Website 2004).

Although helicopter transport could potentially reduce stress associated with transport by reducing transport and handling times, the unit cost per fish would be substantially higher than the unit cost associated with trucked or barged fish. Additionally, the increased survival rates associated with helicopter transport would be only slightly higher than those associated with truck or barge transport. Therefore, the dramatic increase in the cost per fish associated with helicopter transport renders this method of juvenile transport impractical for use in a potential fish passage program at Lake Oroville.

Railroads also have been used to transport fish long distances as part of stocking programs. At the beginning of the 20th century, however, railroad transport of fish became less common as maintained roads and automobile use became more common. During the peak of railroad transport, railcars specifically designed for fish transportation were used. Fish were held in old milk cans prior to loading into the railcars (Wisconsin Natural Resources Magazine Website 2004). In order for a railroad transportation program to be feasible in a current or future potential fish passage program modified railcars, railroad tracks, access roads, and associated support facilities would need to be constructed. As a result, capital costs associated with rail transport would exceed those of truck or barge transport programs, but because survival associated with truck and barge transport is high, there would not be a substantial benefit to using railroad transportation. The costs associated with implementation of a rail transport program render the method infeasible for use as part of a potential fish passage program at Lake Oroville.

Device 1 – Transport Trucks

Description

Truck transport is a common method of transporting fish, used by both hatcheries and fish passage programs. Fish transport trucks generally are large trucks that have truck mounted or trailer mounted fish tanks that hold fish during transport (DWR 2001; Koski et al. 1990; Puget Sound Energy Unpublished Work).

Typical features of the fish transport trucks include stainless steel tanks, oxygen pipe lines installed throughout the live-haul tank substructure, site glasses on each compartment that allow the operator to control the amount of fish per compartment, aerators, oxygen monitors, and oxygen diffusers (Aqua-Life Website 2004). Trucks commonly used for transporting endangered species brood stock from hatcheries are insulated, stainless steel, single compartment live-haul trucks with water-to-water transfer systems. The size of the tanks installed on transport trucks or trailers typically varies from project to project, but 500 gallon tanks are commonly used to transport juvenile salmonids (DFG Website 2003; Puget Sound Energy Unpublished Work). Figure 5.2-8 shows a typical juvenile fish transport truck.

Figure 5.2-8. A typical juvenile fish transport truck.

One method commonly used to transfer juvenile fish from holding devices to transport vehicles is to crowd them into hoppers which can then be raised to the top of a truck for release into the truck tanks (Puget Sound Energy Unpublished Work). An alternative method of transferring fish from a holding structure is to pump the fish, via a hose, from the holding tank to the transport tank (Aqua-Life Website 2004; Water Management Technologies, Inc. Website 2004). Fish pumps are designed to minimize stress while maintaining appropriate water levels in the tank into which fish are released.

The number of fish loaded into each transport truck typically varies based on the size of the fish being transported. Typically, a maximum of 0.5 pounds of fish per pound of water are loaded into each tank and each tank generally is saturated with oxygen. Water temperature typically is maintained at ambient river water temperature (or within 3°F) using ice or chillers. Additionally, in some cases, the potential for inducing stress is reduced by the addition of salt to each fish tank (DWR 2001; Koski et al 1990).

Characteristics

At the FRFH, typical transport tank trucks are used to transport juvenile Chinook salmon and steelhead to release locations along the lower Feather River. Fish are loaded into the transport tank using a fish pump. The FRFH routinely uses two trucks, one with a 500-gallon maximum capacity, and a larger capacity truck with a 2,000-gallon maximum capacity (DWR 2001).

A survey of fish transportation equipment and techniques used by hatcheries, private producers, Native American reservations, and research laboratories revealed that among survey respondents, truck mounted tanks were more common than trailer mounted tanks, and a majority of transport vehicles carried only one tank. More than half of the loading volumes were reported to be between 60 gallons and 500 gallons. Tanks with loading volumes between 501 gallons and 1000 gallons were the second most common loading volumes reported. The survey also revealed that fiberglass tanks were the most common type of tank used among respondents and that tanks typically contained some type of insulation. Ice, rather than refrigeration units, was the most commonly used mechanism for water temperature maintenance, and 47 percent of respondents reported the use of some form of ventilation method. Although a variety of ventilation methods were reported, oxygenation by way of bottled oxygen, was the most common, while carbon stones were the most common method of dispersing the oxygen in water (Carmichael and Tomasso 1988).

At the upper Baker River Fish Passage Facility, a transport tank trailer is used to transport smolts to the mouth of the Baker River for release. The trailer carries a 400-gallon capacity fish tank equipped with aeration and oxygen diffusion mechanisms (Puget Sound Energy Unpublished Work).

At the fish passage facilities on the Snake and Columbia rivers, fish-hauling trucks are used to transport juvenile salmonids from various collection facilities below Bonneville Dam. The transport tanker trucks have a rating capacity of 3,500 gallons per truck. Chillers reportedly are used to maintain water temperature within 3°F of the ambient river temperature (Koski et al. 1990). Additionally, the transport programs in the Snake and Columbia River system load 0.5 pounds of fish per pound of water. Based on the size of the tanks and the loading density reported by (Koski et al. 1990), a fully loaded transport tanker truck could haul approximately 1,750 pounds of fish.

The mortality rate of juvenile salmonids transported by truck is defined as the percentage of juvenile salmon that die during truck loading or actual downstream transport by tank truck. Truck mortality rates reflect only the impacts of the trucking process and latent mortality, mortality due to experiences prior to being transferred to trucks, is assumed to be negligible.

There is general agreement that the most stressful factor in the transport of juvenile salmonids is the actual loading of the fish into the transport vehicle (Congleton et al. 2000; Maule et al. 1988; Specker and Schreck 1980). Mortality related to the transport of juvenile salmonids can be in the form of delayed (also referred to as indirect or latent) mortality, or immediate (also referred to as direct) mortality. Mortality of fish following transport reportedly is difficult to distinguish from mortality related to the release process or release environment, but truck transport studies performed using juvenile salmonids have shown delayed mortality rates to be between 10.4 to 20.4 percent for juvenile Chinook salmon and 3.8 percent for steelhead (Park, et al. 1980). In addition, delayed mortality rates reportedly were higher during periods when spring-run Chinook salmon were transported compared to periods when mostly fall-run Chinook salmon were transported, suggesting that fall-run Chinook salmon may be more tolerant of stresses associated with the transport process (Park et al. 1980).

The truck transport mortality rates reported in the literature vary from less than one percent to approximately 13 percent. The mortality rate reported for Snake River juvenile Chinook salmon transported by truck from Lower Granite Dam to Little Goose Dam, Washington was approximately two percent (USACE 1993 *in* Ward et al. 1997). The mortality rate of Chinook salmon transported by truck from Lower Granite Dam to Bradford Island in the Columbia River system was reported to have risen from 0.5 percent in 1988 to 0.9 percent in 1989 (Koski et al. 1990). Tank truck transport mortality rate for juvenile Chinook salmon transported from McNary Dam on the Columbia River was reported to range from 2.0 percent to 2.2 percent in 1982, 0.9 percent to 1.3 percent in 1983, 0.8 percent to 1.2 percent in 1984, 1.3 percent to 3.4 percent in 1985, 1.4 to 2.5 percent in 1986, 1.4 to 3.5 percent in 1987, 1.1 to 1.9 percent in 1988 and 1.6 percent to 2.0 percent in 1989 (Koski et al. 1990). The truck transport mortality rate for juvenile spring-run Chinook salmon transported from Lower Granite Dam on the Snake River to Bonneville Dam on the Columbia River in 1982 was reportedly approximately 12 percent (Matthews et al. 1986b).

A comparison of mortality rates of fish transported by truck and those transported by barge suggested differential survival between modes of transport. Maule et al. (1988) showed similar results and suggested that the observed differential survival between modes of transport is due to the length of time involved in the process and not the mode of transport. In this study, Maule et al. (1988) detected increased stress by measuring increased plasma cortisol levels and decreased white blood cell counts and found a recovery time of 12 to 48 hours was required for recovery from the initial handling stress incurred during the loading process. The length of time required for truck transport was

3 hours compared to a 16-hour trip by barge. Although barge transport requires more time for transport, it has the advantage of allowing fish access to a constant supply of fresh river water during transport (Maule et al. 1988).

Available literature revealed multiple sources of stress to salmonids during the transport process. Evidence suggests that handling and crowding are stressful to salmonids (Strange et al. 1977, 1978; Barton et al. 1980 *in* Bugert and Mendel 1997). Thus, the loading process is thought to be the most stressful component of the transport process (Maule et al. 1988). In addition, Specker and Schreck (1980) suggest that high fish loading densities are a source of stress during transportation. Furthermore, Kelsey et al. (2002) and Maule et al. (1988) reported that aggression by steelhead on Chinook salmon causes increased levels of stress that may lead to reduced survival of Chinook salmon. Sigismondi and Weber (1988), suggested that multiple stress events have a cumulative effect on juvenile salmonids and therefore exposure to multiple stressors during the transport process could lead to decreased survival rates in transported groups of fish (Sigismondi and Weber 1988 *in* Bugert and Mendel (1997).

As a component of salmon enhancement projects funded by The Salmon Stamp Program, salmon transport tank trailers were purchased to shorten the time needed to transport salmon from Central Valley salmon hatcheries to release locations in the San Francisco Bay. Three trailers initially were purchased with stamp funds for $30,000 each (Commercial Salmon Trollers Advisory Committee Website 2004). At the Cougar Lake fish passage project, the estimated operating costs for the juvenile transport trucks are $1,000 per month during the nine month migration season (USACE 2000).

In order to minimize transport related stress, transfer of fish from the holding area to transport tanks should be done with a minimal amount of fish handling. Consequently, the most important physical site requirement for the use of tank trucks is the close proximity of access roads to the fish collection and holding facility as well as to the release location within the lower Feather River.

Considerations

Although transport of juvenile salmonids is common, regulatory criteria for juvenile truck transport were unavailable. However, Baxter (1996) reported *in* USACE (2000) that densities for fish loading in truck tanks should not be greater than 0.5 pounds of fish per gallon of water and that water temperatures during transport should remain within 3°F of ambient water temperatures at the release site (USACE 2000).

The use of trucks to transport juvenile Chinook salmon and steelhead to release locations below the Oroville Dam would be appropriate in a potential fish passage program because available literature provided numerous examples of transport trucks used to transport juvenile salmonids as part of other programs including FRFH

operations (Commercial Salmon Trollers Advisory Committee Website 2004; Koski et al. 1990; Puget Sound Energy Unpublished Work; USACE 2000).

Because transport trucks commonly are used in the Columbia and Snake River system, reports on success of transported juveniles are relatively common. NOAA Fisheries (2000b) found no significant difference in straying between juveniles that were transported and those that migrated in-river in their review of Columbia River transport studies. In contrast, Bugert and Mendel (1997) showed a significantly higher straying rate for adult returns of hatchery reared juvenile Chinook salmon transported around part of their emigration route on the Snake River, Idaho (0.3% for fish released on station vs. 5.9% for transported fish).

It generally is agreed that stress causes an increased susceptibility to disease among juvenile salmonids (Budy et al. 2002; NOAA Fisheries 2000b). Budy et al. (2002) reported that transportation related stress lowers resistance to disease. Additionally, most juvenile salmonids carry the BKD pathogen, which can be activated by stress. Higher levels of stress also have been reported in juvenile Chinook salmon when transported concurrently with steelhead (Kelsey et al. 2002; NOAA Fisheries 2000b).

Device 2 - Barge

Description

Barges used to transport fish are modified cargo barges with holding tanks in the interior of the hull and release doors at the bottom of the barge.

The two types of barges used to transport fish at Lower Granite Dam on the Snake River, Idaho contain either four or six holding tanks and have dimensions of approximately 150 feet by 34 feet, and 200 feet by 40 feet. The largest barges used at Lower Granite Dam have capacities of up to 150,000 gallons. At the bottom of each holding tank there is an exit door that allows for the quick and safe release of fish directly into the surrounding water. Figure 5.2-9 shows a typical barge and fish transfer operation.

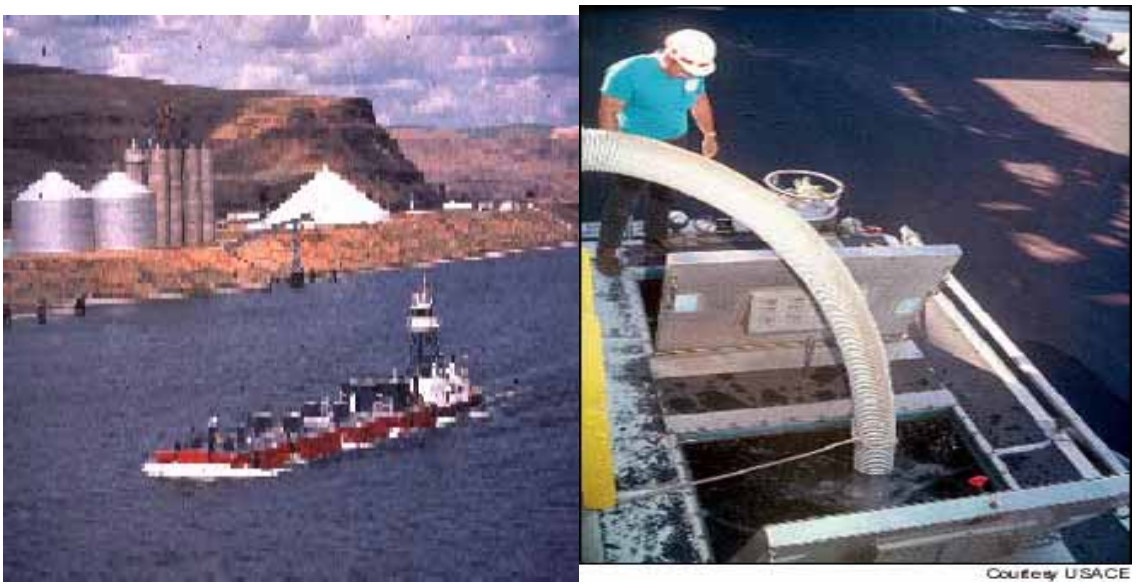

Figure 5.2-9. Barge and fish transfer operation on Columbia River

The most common method used to transfer juvenile fish from holding tanks to barges is to pump the fish, via a hose, from the holding tank to the transport tank within the barge (Aqua-Life Website 2004; Water Management Technologies, Inc. Website 2004).

During typical barge transport activities water is continuously pumped through the barge tanks to provide transported fish with water temperatures equivalent to the ambient river temperature throughout the transport process and to maximize the probability of homing success by allowing juveniles to imprint on river water as they move downstream. Fish are released from barges using gates or doors at the bottom of the barge tanks.

Characteristics

Barges are used at federal dams on the Columbia and Snake rivers to transport juvenile salmon downstream, past remaining projects, for release below Bonneville Dam.

According to the Salmon Information Center website (2004), USACE have been piping fish into barges for downstream transport in the Columbia River Basin for thirty years. Koski et al. (1990) reported that barges used at Columbia and Snake River dams are of two types, older barges that have 85,000-gallon capacities, and newer barges that have 100,000-gallon capacities. The largest fish transport barge used by USACE is 196 feet long by 40 feet wide with a 150,000-gallon capacity capable of accommodating 3 million Chinook salmon and 400,000 steelhead, ranging from four to ten inches in size. Fish are loaded into the barges using pumps, which allow fish to be piped into the tanks with minimal damage. Juveniles transported by barge on the Snake River endure a one and a half day trip through seven sets of locks before being released west (downstream) of Bonneville Dam. Release occurs at night with the doors on the bottom of the barge swinging open to allow the transported fish direct access to the river (Salmon

Information Center Website 2004). According to the Salmon Information Center Website (2004), 99 percent of fish barged to the Columbia River estuary survive the trip. It also has been reported that less than two adults return for every 100 smolts released, which suggests that barged fish are not exhibiting high survival rates after release (Salmon Information Center Website 2004). It is unclear, however if barging is directly related to the low return rates. Similarly, studies that compared adult return rates of barge transported juvenile Chinook salmon to on-station released juveniles from the Snake River, Idaho showed no significant improvement in adult returns for transported fish (Bugert and Mendel 1997). Although the cause of the low adult return rates in the Snake River have not been confirmed, stress and disease following barge transport have been suggested as two possible sources. Although research indicates that disease transmission during barge transport is not a significant cause of mortality, USACE biologists suggested that there may be an increase in disease transmission in the barges (Blue Fish Website 2004).

There is general agreement that the most stressful factor in the transport of juvenile salmonids is the actual loading of the fish into the transport vehicle (Congleton et al. 2000; Maule et al. 1988; Specker and Schreck 1980). The reported barge transport mortality rates in available literature vary from less than one to approximately thirty percent, depending on the species, age, and distance transported. The mortality rate for juvenile spring-run Chinook salmon transported from Lower Granite Dam to Bonneville Dam in barges in 1982 was reportedly approximately thirteen percent (Matthews et al. 1986a). Hetherman et al. (1997) reported that the barge mortality rate at the Lower Granite Dam collection facility on the Snake River, Idaho was 1.0 percent for juvenile Chinook salmon and 0.1 percent for steelhead (Hetherman et al. 1997 *in* Congleton et al. 2000). The mortality rate for Chinook salmon transported by barge from the Lower Granite and Little Goose dams to five miles below Bonneville Dam, on the Columbia River system, was reported to be approximately 1.9 percent. Steelhead transported from these same locations were reported to experience approximately 0.1 percent mortality (Koski et al. 1990). According to the Northwest Fish Letter (1997), survival of juvenile Chinook salmon transported by barge from the Lower Granite Dam to Little Goose Dam was 86 percent in 1995 and the survival rate for juvenile salmonids transported to McNary Dam on the Columbia River during the same year was 70 percent.

A comparison of mortality rates of fish transported by truck and those transported by barge suggested differential survival between modes of transport. Maule et al. (1988) showed similar results and suggested that the observed differential survival between modes of transport is due to the length of time involved in the process and not the mode of transport. In this study, Maule et al. (1988) detected increased stress by measuring increased plasma cortisol levels and decreased white blood cell counts and found a recovery time of 12 to 48 hours was required for recovery from the initial handling stress incurred during the loading process. The length of time required for truck transport was 3 hours compared to a 16-hour trip by barge. Although barge transport requires more

time for transport, it has the advantage of allowing fish access to a constant supply of fresh river water during transport (Maule et al. 1988).

Available literature revealed multiple sources of stress to salmonids during the transport process. Evidence suggests that handling and crowding are stressful to salmonids (Strange et al. 1977, 1978; Barton et al. 1980 *in* Bugert and Mendel 1997). Thus, the loading process is thought to be the most stressful component of the transport process (Maule et al. 1988). In addition, Specker and Schreck (1980) suggest that high fish loading densities are source of stress during transportation. Furthermore, Kelsey et al. (2002) and Maule et al. (1988) reported that aggression by steelhead on Chinook salmon causes increased levels of stress that may lead to reduced survival of Chinook salmon. Sigismondi and Weber (1988), suggested that multiple stress events have a cumulative effect on juvenile salmonids and therefore exposure to multiple stressors during the transport process could lead to decreased survival rates in transported groups of fish (Sigismondi and Weber 1988 *in* Bugert and Mendel 1997).

Considerations

Although transport of juvenile salmonids is common, regulatory criteria for juvenile truck transport were unavailable. However, Baxter (1996) reported *in* USACE (2000) that densities for fish loading in truck tanks should not be greater than 0.5 pounds of fish per gallon of water and that water temperatures during transport should remain within 3°F of ambient water temperatures at the release site (USACE 2000).

Barges are used successfully on the Snake and Columbia rivers as part of the USACE Fish Transportation Program to transport juvenile salmonids (Koski et al. 1990). Therefore, barges are appropriate transport vehicles for juvenile Chinook salmon and steelhead. It is unclear, however, whether barge transport would be compatible with the geomorphology of the lower Feather River or with the current recreational uses of the lower Feather River.

5.2.4.3 Conclusions

Utilization of tank trucks would be compatible with other elements of the juvenile downstream passage phase of a potential fish passage program and would be used at all locations where juvenile capture and holding could occur. Potential fish capture and holding locations were identified in Section 5.2.1. Road access to potential tributary capture locations also was identified in Section 5.2.1, although some modifications to access sites could be required. Such modifications could potentially include road and access location improvements to ensure adequate conditions for truck use. If a gulper is utilized in any of the tributary arms of Lake Oroville, multiple barges could be required to transport juvenile fish from the holding facility associated with the gulper to the shoreline for transfer to a tank truck. Alternatively, if a net pen were used to hold fish at the gulper, the net pen could potentially be towed to the shoreline to allow transfer via

fish pump to a tank truck. Specific engineering road or transfer site improvements would be addressed on a site-specific basis, however barge and tank truck use would be appropriate mechanisms by which to transport juveniles downstream to potential release locations.

5.2.5 Juvenile Fish Release

There are several different potential juvenile fish release locations possible for a potential fish passage program. The first versions of the fish passage model presented in the Final Report for SP-F15 Task 4 offered three optional mechanisms and locations for juvenile fish release. The first option was truck transport to locations on the Lower Feather River and direct release into the river. The second option was truck transport to the lower Feather River and release into net pens or barges that would transport juveniles to San Pablo Bay. The third option was direct release into San Pablo Bay after trucking from the upstream capture locations. Extensive discussions among DWR staff, regulatory agency representatives, and stakeholders of the merits and limitations of each of the originally proposed juvenile release alternatives revealed little support for the second or third options (net pen or barge transport to San Pablo Bay or direct tucking to San Pablo Bay). The lack of support for these options was due to logistical constraints associated with net pen or barge transport in the shallow lower Feather River, and due to increased straying and other factors associated with trucking directly to San Pablo Bay.

After analysis revealed that direct release into the lower Feather River remained a viable option for the juvenile fish release component of a potential fish passage program, several release locations were examined. Juvenile release into the lower Feather River could potentially occur from boat ramps and other access points from the Fish Barrier Dam downstream to Verona. Juvenile release locations and release times likely would be changed frequently to avoid increased juvenile losses as a result of predator habituation to release locations and times. Lower Feather River juvenile fish emigration habitat conditions and suitability are evaluated in the Final Reports for SP-F10 Task 4A and 4B.

5.2.5.1 Location

Juvenile fish release from trucks requires very little support infrastructure other than direct access to the river edge. Boat ramps or other direct access to the lower Feather River would provide potential locations for juvenile fish release. Juvenile fish release location selection criteria could include:

- Road access or boat ramp
- Areas with cover or shallow water refuge from predators
- Areas with low water velocities near shore

- Avoid areas with higher than normal predation pressure, e.g. Thermalito Afterbay Outlet Pool or backwater type mesohabitat

Juvenile release locations could include, but are not necessarily limited to: the FRFH fish ladder, Bedrock Beach, Gridley Boat Ramp, Live Oak Boat Ramp, Boyds Pump or Verona (Figure 5.2-10).

5.2.5.2 Alternatives

Two methods of juvenile fish release were considered in the feasibility analysis. The first release method involves pumping juveniles from transport tanks via a pipe and into receiving waters. Additionally, fish could be released using quick-acting release gates or doors that would evacuate the entire tank relatively rapidly. A corollary to directly releasing fish into receiving waters is to hold fish in cages or net pens buoyed in the release area to protect them from predation while allowing them to acclimate to the release environment.

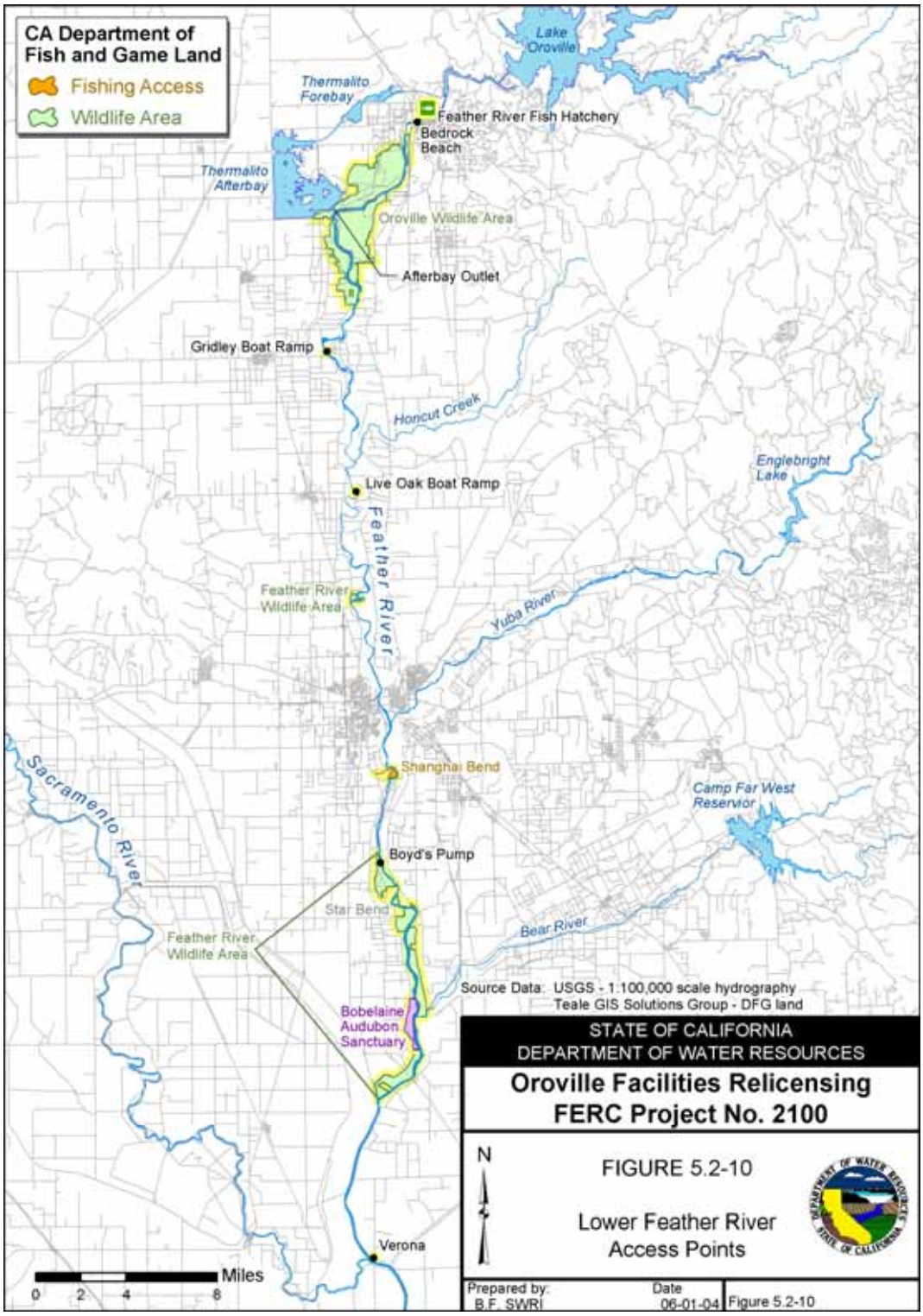

Figure 5.2-10 Potential Lower Feather River Juvenile Fish Release Locations.

It is generally believed that hatchery reared Central Valley juvenile salmonids released into their natal streams or rivers have higher homing rates than those juveniles released in the San Francisco Bay estuary (i.e. San Pablo Bay). However, it also is generally believed that juveniles released in the estuary are exposed to lower levels of predation and mortality prior to ocean entry because they do not migrate through the warm Sacramento and San Joaquin rivers. According to FRFH reports hatchery produced juveniles of a single brood year sometimes are released in multiple locations to maximize the likelihood of adult return (Kastner, A. 2003). Therefore, two main possibilities exist for juvenile release locations, in the lower Feather River, and in the San Francisco Bay estuary.

Because a major goal of a potential fish passage program at Lake Oroville would be to maximize the likelihood that a juvenile Chinook salmon captured upstream from Oroville Dam would return to the Feather River, the likelihood of straying would need to be minimized. In order to minimize the potential for straying, imprinting success would be maximized by releasing transported juveniles into the lower Feather River. Therefore, estuary release would not be consistent with the goals of a potential fish passage program.

Device 1 – Live Fish Transfer Pumps

Description

Fish transfer pumps typically are hydraulic driven pumps that allow fish to remain in water while transferring them from one water body to another via a hose or pipe. Pumps usually are constructed of lightweight aluminum with flexible hoses.

Fish pumps allow the transfer of fish from holding cages, tanks, or ponds to other locations without physical handling by humans. Although fish pump specifications vary depending on the application for which they would be used and by manufacturer, generally fish pumps allow fish transfer over relatively long distances, which can be up to 150 meters horizontally or up to 9 meters vertically (Aqua-Life Website 2004; Water Management Technologies, Inc. Website 2004). Figure 5.2-11 shows a typical fish pump. In the case of pumping fish into a tanker truck, one terminal end of the pump would be in the holding tank or net pen while the other discharge fish directly into the tank truck.

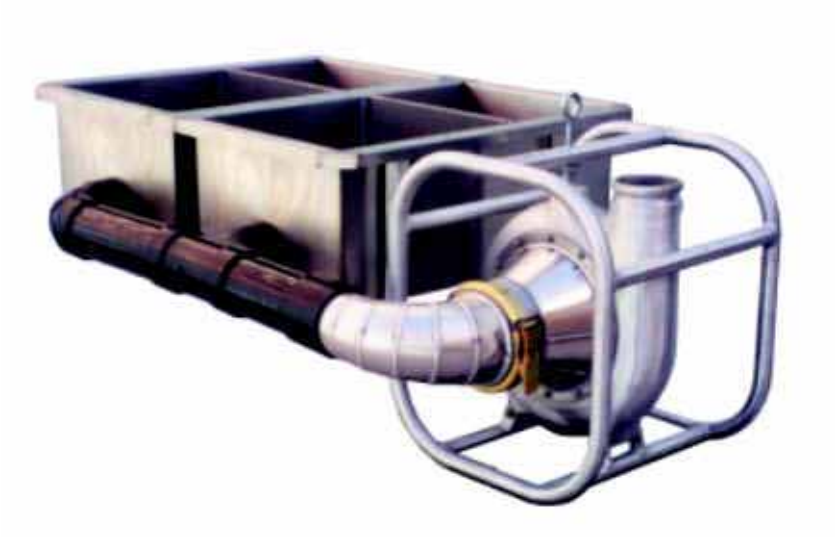

Figure 5.2-11. Typical fish pump.

Characteristics

Fish pumps currently are used as a part of FRFH transport operations to transfer juvenile salmonids from holding tanks to transport trucks, and from transport trucks to receiving waters. The pumps used by FRFH operators are typical fish pumps with the capability of pumping fish weighing up to 0.5 pounds (approximately 225 grams).

The maximum fish size and fish pumping capacity varies based on the size of the pump used. It is likely that a potential fish passage program would also use pumps similar to the one currently used by the FRFH. Various manufacturers rate pumps according to the number of fish that the pump is capable of transferring per hour. Some pumps reportedly are capable of transferring juvenile Chinook salmon at a rate of up to approximately 60,000 fish per hour while others reportedly transfer up to approximately eight tons of fish per hour. It is unclear whether transfer of juveniles using fish pumps causes increased stress or increased mortality, however, pumps are designed to minimize physical harm to transferred fish (Aqua-Life Website 2004; Water Management Technologies, Inc. Website 2004).

Considerations

Although fish pumps are commonly used in hatchery environments, regulatory agency criteria for fish pump use were unavailable. It is likely, however, that a juvenile fish passage program would be required to maintain a 95 percent survival rate (pers. com. D. White, 2003), which would include all aspects of a juvenile transport program including the use of fish pumps.

Fish transfer pumps were assumed to be appropriate for releasing juvenile fish from transport vehicles as a part of a potential fish passage program at Lake Oroville because pumps currently are used as part of FRFH operations.

Device 2 – Quick Release Gates

Description

Quick release gates allow fish to be batch released without the use of additional transfer methods. The gates typically are located on the bottom of transport barges and allow for emptying of an entire transport tank relatively rapidly.

Characteristics

Quick release gates typically are used to release fish from barges. USACE reportedly readily uses quick release gates as release mechanisms in the barges on Columbia and Snake rivers (Koski et al 1990). The benefit of quick release gates is that the entire contents of a transport tank are released at once, saving time. However, it is unclear what effects this release mechanism has on individuals. It is widely known that stresses associated with transport are highest during transfer into or out of transport vehicles, however it is unclear how specific transfer mechanisms affect stress levels (Congleton et al. 2000; Maule et al. 1988; Specker and Schreck 1980).

Considerations

Although quick release gates commonly are used in barging programs on the Columbia and Snake rivers, regulatory agency criteria for quick release gate use were unavailable. It is likely, however, that a juvenile fish passage program would be required to maintain a 95 percent survival rate (pers. com. D. White, 2003), which would include all aspects of a juvenile transport program including the use of quick release gates.

Although commonly used in other passage programs, it is unclear to what extent this release mechanism would be applicable to the lower Feather River. It is assumed that, if barges are to be appropriate for use on the lower Feather River, and if evidence exists indicating that quick release gates are not associated with increased juvenile mortality, then quick release gates would be compatible with the goals of a potential fish passage project at Lake Oroville.

Device 3 – Net Pens

Description

Net pens typically are fish holding devices that contain fish in a net attached to a floating structure. Net pens allow fish to be held in a natural environment while being protected from predators. Net pens typically are used to rear juvenile anadromous salmonids because they provide maximum exposure to natural in-river conditions while also providing protection from in-river predation.

The net pens described by Beeman and Novotny (1994), are typical net pens used to rear Chinook salmon. The pens were made from 0.2-inch mesh nets suspended from floating platforms. The enclosures measured approximately 20 ft by 20 ft and extended to a depth of 7 to 10 feet (Beeman and Novotny 1994). A net pen rearing study conducted by Rensel et al. (1988) used net pens measuring 8.5 meters by 8.5 meters and extended to a depth of 4.3 meters. The nets were constructed with 1.9 cm mesh. The total immersed volume of each pen was reported to be 243 m^3 (Rensel et al. 1988). Although all net pens are constructed to perform a similar function, the design of individual pens is dependent on the specific habitat conditions and program goals associated with each use.

Although normally used for extended rearing, net pens associated with juvenile salmonid release would not be utilized as rearing pens. It is anticipated that net pen use would be limited to periods no longer than three days for allowing released juveniles to acclimate to in-river conditions prior to actual release into the river.

Characteristics

The majority of examples of net pen use described in available literature are associated with projects attempting to increase survival of hatchery-spawned juvenile salmonids (Beeman and Novotny 1994; Commercial Salmon Trollers Advisory Committee Website 2004; Rensel et al. 1988). Survival of released juveniles following net pen rearing reportedly is relatively high (Commercial Salmon Trollers Advisory Committee Website 2004).

Examples of the successful net pen rearing projects include the Monterey Bay Salmon and Trout Project and the Central Coast Salmon Enhancement project. The Monterey Bay Salmon and Trout Project uses net pens to increase the survival of FRFH Chinook salmon prior to their release. The Central Coast Salmon Enhancement project reported that, based on CWT studies, *"pen-reared salmon survive to enter the commercial and sport fisheries at exceptional levels"* (Commercial Salmon Trollers Advisory Committee Website 2004). A five-year study conducted by Rensel et al. (1988), evaluating the use of the marine net pens in Puget Sound, Washington, reported that juvenile coho salmon survival in net pens with 243 m^3 (8,580 ft^3) of immersed volume averaged 98.4 percent.

Beeman and Novotny (1994) reported that net pens with dimensions of approximately 20 ft by 20 ft with a depth of 7 to 10 feet have been used to raise pre-smolt Chinook salmon at densities of 18,000 fish per pen in the Columbia River System. Factors taken into consideration when calculating initial rearing densities reportedly were minimum flows likely to be encountered, maximum rearing water temperatures of 61° F, and release weights of 45 fish per pound (Novotny et al. 1984 *in* Beeman and Novotny 1994).

Costs associated with net pens are dependent on multiple variables including net pen size, and net mesh size. Additionally, overall costs associated with net-pens in a fisheries resource management program, including a potential fish passage program, is dependent on the number of pens required and the lifespan of each pen. The size, mesh size, and number of pens that could be required for a potential fish passage program at Lake Oroville is unclear. The reported lifespan of each of the net pen components are seven years for the net and twenty years for the pen frames (Senn et al. 1984 *in* (Beeman and Novotny 1994).

In order to satisfy the goals of a potential fish passage program, handling, stress, and mortality is required to be minimized. Releasing juveniles into net pens to allow acclimation to occur would be consistent with the goal of minimizing mortality associated with juvenile release.

Considerations

Although net pens commonly are used to rear juvenile salmonids, regulatory agency criteria were unavailable. It is likely, however, that a juvenile fish passage program would be required to maintain a 95 percent survival rate (pers. com. D. White, 2003), which would include all aspects of the program including acclimation net pens.

Although net pens are generally used for juvenile rearing, the reported success of net pens in increasing survival of hatchery reared juvenile salmon suggests that holding juvenile salmon in net pens for short periods of time to acclimate to in-river conditions (no more than 3 days) would also be successful (Beeman and Novotny 1994; Commercial Salmon Trollers Advisory Committee Website 2004; Rensel et al. 1988). Therefore, it is likely that net pens would be appropriate for holding juveniles in a potential fish passage program at Lake Oroville.

5.2.5.3 Conclusions

The release of juvenile salmonids to allow continued unimpeded emigration to saltwater is the final step in the juvenile phase of a potential fish passage program. Devices used for release would likely include a combination of release mechanisms associated with

tank trucks and net pens. Direct release from barges likely would not be applicable because fish likely would not be barged to San Pablo Bay.

A review of available literature suggests that releasing juveniles from a tank truck to a temporary in-river structure such as a net pen may be the most effective method to reduce stress and mortality associated with juvenile transfer. Holding juveniles in an in-river structure for a short period of time prior to final release would allow fish to acclimate to the river environment and recover from stress induced by transport.

Potential release locations on the lower Feather River were identified in Section 5.2.5.1. Some of these locations such as Bedrock Beach, Gridley Boat Ramp, Live Oak Boat Ramp, and Boyd's Pump (Figure 5.2-10) have been used in the past for release of hatchery reared juvenile Chinook salmon from the Feather River Fish Hatchery.

5.3 EVALUATION OF OTHER FISH PASSAGE PROGRAMS

Available fish passage literature indicated that the most common method of providing anadromous fish access to habitat blocked by migration barriers is to develop structures that allow fish to move themselves over, around, or through migration barriers without ongoing active intervention. Because allowing fish to move themselves past barriers is the least labor-intensive method by which to transport individuals over barriers, it commonly is preferred over more labor intensive methods such as trap and haul programs (CNN Website 2004). In contrast to many facilities with single passage features or low obstacles to overcome, however, the Oroville Facilities contain multiple fish passage barriers including a high head dam and cannot accommodate a typical adult fish ladder with juvenile bypass. Evaluation of similar facilities with existing fish passage projects suggested that the implementation of a trap and haul program potentially would be the most appropriate method of providing adult fish access to upstream habitat for the Oroville Facilities. Although the Oroville Facilities are relatively unique, the experience gained at other projects utilizing trap and haul fish passage programs could provide useful insight into potential program successes to emulate as well as program failures to avoid.

5.3.1 Fish Passage Program 1 - Baker River Fish Passage Project

5.3.1.1 Passage Program Description

The Baker River hydroelectric project is located on the Baker River in northwestern Washington and consists of the Upper Baker Dam and the Lower Baker Dam developments. The 1925 construction of the Lower Baker Dam created Lake Shannon and the addition of the Upper Baker Dam in 1959 created Baker Lake. The Lower and Upper Baker Dams are 285 and 312 feet high, respectively. At normal full pool Lake Shannon and Baker Lake store 160,000 acre-feet of water and 285,000 acre-feet of water, respectively. According to Puget Sound Energy (2002) the entire escapement

was trapped below Lower Baker Dam after its completion in 1925. At the Lower Baker Dam, adult coho and sockeye salmon are captured at an adult trapping facility that resembles a fish ladder, and are loaded into a tank truck. Adult sockeye salmon are then transported above both facilities to the spawning beaches at Baker Lake, while coho salmon are transported to either Lake Shannon or Baker Lake. The juvenile passage facilities are located at both the upper and lower developments. Downstream migrants are captured at Lake Shannon and Baker Lake using gulper systems. Although the upper and lower dam gulpers are slightly different, both systems make use of "surface-to-bottom" guide nets that extend from the surface collector to each shoreline. The gulper system operates on the premise that individuals are guided to the surface collector opening by the guide net and are then drawn into the collection barge by a 160 cfs attraction flow created by the gulper pumps Puget Sound Energy (2002).

5.3.1.2 Capital and O&M Costs

In the *Fish Facility Operations Annual Report for 1992 through 1993* FERC (1993) reported that between June 1, 1992 and May 31, 1993, $454,585 were spent on operation and maintenance of the Upper and Lower Baker Dam fish facilities (FERC 1993).

5.3.1.3 Passage Program Performance

In the *Poe Project Fish Passage White Paper,* Pacific Gas and Electric Company (2003) reported that ninety percent of upstream migrants are collected by the Lower Baker Dam adult trapping facility. Additionally, Pacific Gas and Electric Company (2003) reported that the trap and haul methods used at the Baker River Fish Passage Project allowed 100,000 adult spawners to be returned to their historical native habitat above Upper Baker Dam. The proportion of juvenile sockeye salmon captured by the collection barge was reported in the *Poe Project Fish Passage White Paper* to be as high as sixty percent (Pacific Gas and Electric Company 2003). Similarly, FERC (1993) reported that gulper guidance effectiveness during a 1988 to 1992 fixed location hydroacoustic study at Baker Lake ranged from 67 percent to 79 percent (FERC 1993).

5.3.2 Fish Passage Program 2 - Umatilla River Basin Trap and Haul Program

5.3.2.1 Passage Program Description

The Umatilla River Basin Trap and Haul program is located at Three Mile Dam on the Umatilla River, Oregon. At twenty-four feet in height, Three Mile Dam is the highest dam on the Umatilla River (Bonneville Power Administration 1990). According to Pacific Gas and Electric Company (2003), excessive water withdrawals degraded much of the watershed and caused near extinction of salmon runs. The channel was later restored and re-watered to allow fish to reach the dam. Currently, adult fish are trapped at the dam and hauled to release sites in the upstream tributaries or the tribal hatchery. The

target fish species for the trap and haul program are fall-run and spring-run Chinook salmon, coho salmon, and steelhead. Three Mile Dam adult fish passage facilities consist of east and west bank facilities. The east bank facility includes a vertical slot fish ladder, a Denil fish ladder (steep pass), a raceway type holding pool, a lock system, and a handling and sorting complex. The west bank facility includes a vertical slot ladder, a combination V trap/holding pond, and a fish loading apparatus (Pacific Gas and Electric Company 2003). Passage of emigrating juvenile salmonids is achieved through the use of a juvenile bypass facility constructed in the West Extension Canal at Three Mile Dam. The bypass facility includes rotating drum screens, a bypass channel, inclined screens, a fish separator, holding tanks, and a bypass pipe leading to a bypass outfall. Fish attempting to enter the canal are either diverted to the bypass pipe and out the bypass outfall to be returned directly to the river or, during sampling and trapping operations, the inclined screen, fish separator, and transfer flume are installed to route fish to holding tanks prior to transport. Adult fish ladders at Three Mile Dam also have been reported to be a frequent bypass route for emigrating juveniles (Bonneville Power Administration 1990).

5.3.2.2 Capital and O&M Costs

No capital or O&M cost information for the Three Mile Dam fish passage program was obtained from available fish passage program literature.

5.3.2.3 Passage Program Performance

In the past decade, adult fish capture at Three Mile Dam reportedly has ranged from 3,800 to 6,300 individuals with between 895 and 3,800 of the total number of individuals capturedhauled upstream annually (Pacific Gas and Electric Company 2003). Mark and recapture studies were conducted at the Three Mile Dam juvenile bypass facility in order to evaluate juvenile fish passage safety and effectiveness. Results indicated that the mean drum screen efficiency at the bypass facility was 99.78 percent. An evaluation of alternative passage routes indicated that subyearling fall-run Chinook salmon using the passage section of the east bank fish ladder as a bypass route suffered descaling and mortality rates of 19.2 percent and 3.2 percent (Cameron et al. 1997).

5.3.3 Fish Passage Program 3 - Wells Dam

5.3.3.1 Passage Program Description

Wells Dam is located on the Columbia River near the town of Chelan, Washington. The dam is 175 feet in height and is a hydrocombine hydroelectric facility that provides a unique configuration that places the spillways directly above the turbine intake ceiling (Nordlund and Rainey 2000). Upstream adult fish passage is accomplished by two conventional pool and weir type fish ladders located at the east and west endwall of the

dam. Each ladder consists of 73 pools with provisions for fish sorting and trapping at pool number 40, a fish counter at pool number 64, and PIT tag detection weirs towards the top of each ladder at pools 67 and 68 (USACE 2002).

The juvenile fish passage system at Wells Dam makes use of both the hydrocombine dam design and the placement of the spillways to bypass juveniles. Specifically, the design creates a funnel effect that directs all flow to the hydrocombine that, when coupled with the relatively high forebay velocity and the placement of the spillways immediately above the turbine intakes, creates a surface flow system that guides juvenile salmonids away from turbines and into a spill bay area. In addition, to increase the attraction flow to the spill bay area from the forebay, the spill bays are modified so that the even numbered spill bays are partially constricted with barriers (USACE 2002).

5.3.3.2 Capital and O&M Costs

In a study of 50 FERC regulated hydroelectric projects, (Francfort et al. 1994) examined upstream and downstream fish passage mitigation capitol costs for the most common mitigation methods. Based on the examination of 16 case studies it was reported that the “mitigation-related” levelized annual total cost (over twenty years) of the two pool and weir fish ladders at Wells Dam was $2,461,000. The levelized annual total cost (over twenty years) for juvenile hydrocombine bypass was $1,756,000 (Francfort et al. 1994).

5.3.3.3 Passage Program Performance

Pacific Gas and Electric Company (2003) reported that based on PIT tag detection data collected at the Wells Dam fish ladders, 77,105 adult Chinook salmon, 9,475 adult steelhead, 10,586 adult sockeye salmon, and 132 adult coho salmon were passed above Wells Dam in 2002. As of August 27, 2003, PIT tag detections at Wells Dam indicated that a total of 47,509 Chinook salmon, 2,094 steelhead, 2,807 sockeye salmon, and no coho salmon thus far had passed the fish ladders in 2003 (Pacific Gas and Electric Company 2003).

The Wells Dam hydrocombine hydroelectric facility was reported to have the first successful surface collector system on the Columbia River and as a model for surface collector designs at other dams along the lower Columbia and Snake rivers including Bonneville Dam, The Dalles Dam, John Day Dam, Ice Harbor Dam, Lower Granite Dam, Wanapum Dam, Rock Island Dam, and Rocky Reach Dams (Nordlund and Rainey 2000). The success of the Wells Dam surface collection system stems from the hydrocombine design, which allows for the implementation of a “hydrocombine spill” strategy for surface collection. In general, the hydrocombine provides favorable hydraulic conditions for surface collector use. With fish passage rates ranging from approximately 84.3 to 95.0 percent for spring migrants and 76.5 to 89.0 percent for summer migrants, the Wells Dam collection facility was reported to have the highest

passage rates of any juvenile bypass system on the Columbia and Snake rivers (Skalski 1996 *in* Nordlund and Rainey 2000).

5.3.4 Fish Passage Program 4 - Cougar Lake Fish Passage Project

5.3.4.1 Passage Program Description

Cougar Dam is located on the South Fork McKenzie River, approximately 42 miles east of Eugene, Oregon. Cougar Dam is a rockfill dam 1,600 feet in length and 435 feet in height. The facility contains a gated chute spillway that has a design discharge of 76,140 cfs. The outlet works consist of a 13.5-foot tunnel with a maximum discharge of 13,500 cfs when pool surface elevation is at 1,699 feet. The power plant has two generating units with a rated capacity total of 25,000 kilowatts and a maximum discharge of 1,350 cfs. Cougar Lake has a maximum pool surface elevation of 1,699 feet and maximum pool storage capacity of 219,000 acre-feet (USACE 2000). Because existing fish passage facilities associated with the hydroelectric facilities were not achieving expected results, facilities upgrades were proposed in 2000 (USACE 2000).

The original adult collection facility below Cougar Dam was built in the tailrace channel but in an evaluation conducted by Ingram and Korn (1968) it was found that the cold temperature of the water from the tailrace of the powerhouse reduced fish attraction to the trap. Following the construction of the dam, fish became attracted to the regulating outlet channel, which contained water that was approximately 10°F warmer than the tailrace (Ingram and Korn 1968 *in* USACE 2000). The previous juvenile bypass facilities at Cougar Lake consisted of a fingerling bypass system integrated into the intake tower structure. Four portals located on the side of the tower allowed fish to enter into horizontal pipes that connected to vertical pipes, which allowed fish to drop down into a regulating outlet conduit. In the 1960s, the bypass was determined to be unsuccessful and use was discontinued.

USACE (2000) discussed project specific upstream and downstream fish passage alternatives at Cougar Dam designed to improve the downstream passage survival of juvenile salmonids and to propose collecting and transporting adult Chinook salmon and Bull trout over the dam.

The proposed alternative for adult upstream fish passage at the Cougar Lake Fish Passage Project is a vertical slot fish ladder for upstream adult fish collection combined with truck transport past the dam. The main structures of the vertical slot ladder include a “dump seal” cofferdam, a rubber dam, and a concrete fish ladder. Within the fish ladder there is a diffusion channel, holding pool, and a diffusion chamber.

The proposed alternatives for juvenile downstream fish collection and passage are an instream low velocity screen collection system, and a gulper with a guide net collection

system. The juvenile collection alternatives also include the combined use of both collection, and passage methods to ensure capture effectiveness (USACE 2000).

The main components of the instream low velocity screen collection system are a rubber dam (used to direct fish through a v-screen system), an ogee crest dam (used to maintain water level through the screen area), a v-screen (the fish screen facility), 2 holding raceways, and the adult fish ladder located between the rubber dam and screen facility. Although a majority of the juveniles should be collected at the v-screen system, the fish ladder is expected to provide passage to a small number of juveniles.

The main components of the gulper system are a guide net, a shear boom to prevent large debris from accumulating in the guide nets, a gulper constructed of portable barges or floats, a collection barge with holding raceways, and a transport barge.

5.3.4.2 Capital and O&M Costs

The estimated construction cost of the proposed Cougar Lake adult upstream fish passage facility did not take account of sales tax but did include a thirty percent contingency and a six percent additional cost for inflation yielding a total estimated capital cost approximately $2,600,00(USACE 2000). The annual operation and maintenance costs for the adult upstream fish passage are estimated to be $80,000 per year (USACE 2000).

The annual operation and maintenance costs for the proposed adult upstream fish passage system at Cougar Lake are based on the following twelve assumptions (USACE 2000):

1. The presence of one operator seven days a week for six hours per day during the six month adult fish passage season.
2. The transport truck and driver are required for twenty hours per week during the 6 month adult immigration season
3. The personnel cost is assumed to be twenty-five dollars per hour ($52,000 per year) including benefits; costs for personnel assistants is eighteen dollars per hour
4. The transport truck operating costs are $1,000 per month during the adult immigration season
5. Equipment such as backhoes and cranes are not included in cost estimate
6. An assistant working 28 hrs per week is required during the adult immigration season
7. Operation of the generator costs $0.50 per kilowatt-hour
8. Average generation output is 70% of the 85 kw capacity (generator used for electrical hoist and rubber dam)
9. The generator will run 20 hours per week during the 6 month adult immigration season

10. The intake fish screen will be kept clean manually by the site attendant
11. The site attendant will assist in loading the transport truck
12. The start up and shut down of facilities each year is assumed to cost $3,000

The estimated construction cost of the instream low velocity screens proposed for the Cougar Lake project is $6,400,000. The estimated annual operation and maintenance costs of the proposed instream low velocity screens for Cougar Lake is $180,000 (USACE 2000).

The estimated annual operation and maintenance costs for instream low velocity screens proposed for implementation at the Cougar Lake project are based on the following eleven assumptions (USACE 2000):

13. One operator is present seven days per week for eight hrs per day during the 9 months of juvenile fish emigration
14. The transport truck and driver are required for twenty hours per week during the juvenile emigration season
15. The personnel cost is assumed to be twenty-five dollars per hour ($52,000 per year) including benefits
16. The transport truck operating costs are $1,000 dollars per month during the 9 month juvenile emigration season
17. Equipment such as backhoes and cranes are not included in cost estimate
18. A full time assistant is required during the migration season
19. Operation of the generator costs $0.50 per kilowatt- hour
20. Average generation output is fifteen kilowatts
21. The trash rack will be kept clean by the site attendant
22. The site attendant will assist in loading the transport truck
23. The start up and shut down of the facilities will take two person weeks

The estimated construction cost of the gulper system proposed for the Cougar Lake project is $9,800,000. The estimated annual operation and maintenance costs for the gulper system proposed for Cougar Lake is $240,000 (USACE 2000).

The estimated annual operation and maintenance costs for the gulper system proposed for implementation at the Cougar Lake project are based on the following fourteen assumptions (USACE 2000):

24. One operator present seven days per week for eight hours per day during the 9 months of juvenile fish passage
25. The transport truck and driver are required for twenty hours per week during the juvenile emigration period
26. Personnel cost is assumed to be $25 per hour ($52,000 per year) including benefits

27. Transport truck operating costs are $1,000 per month during the 9 month juvenile emigration period
28. Equipment such as backhoes and cranes are not included in cost estimate
29. A full time assistant is required for the juvenile emigration season
30. The trash rack and manually cleaned screens will be kept clean by site attendant
31. The site attendant will assist in loading the transport barge
32. The site attendant will operate the winches to keep barges in position
33. The transport barge operator is required for twenty hours per week during the juvenile emigration period
34. Startup and shutdown of the facilities each year will take three person weeks
35. Maintenance of the transport barge is assumed to be $1,500 per month during juvenile emigration period
36. Electrical costs are $0.04 per kilowatt-hour
37. All pumps are assumed to be operating throughout the collection period

The third alternative for juvenile downstream passage is the use of both the instream low velocity screens and a gulper system, which has an estimated construction cost of $15,500,000The estimated annual operation and maintenance costs for the proposed use of both instream low velocity screens and the gulper system for implementation at the Cougar Lake project are derived from the combined costs of the two facilities (USACE 2000).

5.3.4.3 Passage Program Performance

The Cougar Lake Fish Passage Project currently is in the construction phase of implementing the new upstream and downstream fish passage alternatives, so fish passage performance information is not yet available for this project.

5.3.5 Passage Program Evaluation Summary

The four preceding fish passage programs were selected for evaluation and characterization in this report based on a combination of their similarities to the Oroville Facilities potential fish passage conditions and challenges as well as the quality and availability of information on these programs.

Passage program costs and performance were available for three of the four passage projects evaluated. One project reported costs but had not been implemented, so performance information was not available. One project reported performance, but not cost information. In general, cost and performance information was poorly reported, incomplete, and infrequently available. Many other passage programs exist, but were not included in the review due to the limitations of the quality, applicability, and availability of information to characterize them.

Of the four fish passage programs profiled in this report, three are trap and haul type passage programs. Only one of the fish passage programs reviewed in this report passed adult fish without truck transport. Wells Dam is 175 feet tall and adult fish passage is feasible with the use of fish ladders. Oroville Dam is 770 feet tall and a fish ladder over this project feature was dismissed as biologically infeasible and not cost effective early in the evaluation process. Passage programs selected for evaluation in the report were biased towards those using trap and haul type programs to maximize the opportunity to learn trap and haul program procedures, challenges, costs, and efficiencies.

Three of the fish passage programs characterized in this report targeted Chinook salmon and two of the passage programs included steelhead. Chinook salmon were the most abundant fish passed when they were included as a target species in the fish passage programs evaluated. None of the projects reported specific project operations or passage program modifications to accommodate a specific species.

Only two of the fish passage programs evaluated reported a range of the number of fish passed annually, which were reported as ranging from approximately 900 to 3,800 annually and 50,000 to 100,000 annually. Baker Lake reported 11,442 adult fish passed in the 1992-1993 season, but it is unknown if this is a representative number for the program. The Final Report for SP-F15 Task 2 estimated that the maximum number of spawning Chinook salmon that the upstream tributaries could accommodate below the first identified fish barrier is approximately 28,500 adults. Given the range of the number of adult fish passed in the passage programs evaluated, the Oroville project could be considered small if only one tributary was operated or medium sized if all potential fish spawning habitat below the first fish barrier was used to capacity. None of the projects evaluated reported the number of river miles of potential fish habitat that were accessed through their passage programs.

None of the projects evaluated reported selectively passing fish based on adult immigration timing or by individual identification using fish tags. All four of the projects evaluated appear to be operated to pass all adult fish of the target species. The only fish tagging reported was for fish passage program performance monitoring. A potential fish passage program at Lake Oroville would be forced to select the individuals to be passed because there are many more Chinook salmon in the lower Feather River than there is spawning habitat capacity in the upstream tributaries below the first fish barriers.

Of the four passage programs evaluated, The Baker River Fish Passage Project probably is the most physically similar to the Oroville Facilities. The Baker Lake facilities and the Oroville Facilities both have multiple facilities that act as fish passage barriers and both projects would have multiple adult release and juvenile collection locations. The combined storage capacity of the Baker Lake project is the largest of the reservoirs evaluated at approximately 445,000 acre-feet. Lake Oroville is almost 8

times larger with a storage capacity of approximately 3,538,000 acre-feet. Even with these similarities stated, there are many physical and geographic differences between the project conditions that could necessitate substantial differences in the alternatives and options selected for the fish passage programs.

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

Task 3, herein, is a subtask of SP-F15, *Evaluation of the Feasibility to Provide Passage for Targeted Species of Migratory and Anadromous Fish Past Oroville Facility Dams.* Task 3 fulfills a portion of the FERC application requirements by evaluating the methods and devices that could potentially be considered in each element of a fish passage program. Additionally, information collected for this task could serve as a foundation for future evaluation and development of potential Resource Actions.

Because the Oroville Facilities are a barrier to upstream migrating adult salmonids and sturgeon, DWR is addressing the feasibility of a fish passage program around the Oroville Facility Dams on the lower Feather River. Currently, no complete fish passage program is in place on the Feather River. Therefore, during the analysis of the methods and devices that could potentially be used in a complete fish passage program, information from dams outside the Feather River watershed that have attempted fish passage was collected and evaluated.

Analysis was performed on available information regarding passage of upstream migrating adults and on downstream migrating juvenile salmon, steelhead, and sturgeon, and adult steelhead and sturgeon was performed for each of the five elements of a passage program. The five elements are:

- Capture of migrating fish
- Sorting and tagging (optional) captured fish
- Holding captured and sorted fish
- Transporting fish to a release location upstream (adults) or downstream (juveniles) of the Oroville Dam.
- Release of fish

Although the Oroville Facilities do not incorporate a complete fish passage program in their current operating procedures, some elements of the program do exist to a limited degree. A fish ladder designed for use by upmigrating adult Chinook salmon and steelhead exists at the Feather River Fish Hatchery and is operated from about the first of September through the end of March (DWR 2001).

In addition to the fish ladder used to collect adult salmonids, a second element of fish passage is currently in place on the Feather River. Beginning in April, juvenile Chinook salmon are transported via truck to the various release locations in the Feather River, the Sacramento River, San Pablo Bay, and various inland reservoirs including Lake Oroville (DWR 2001).

Although not part of a complete fish passage program, portions of the analysis of the feasibility and ability of the Oroville Facilities to implement a fish passage program took into account the existence of the FRFH ladder and the current juvenile transport program. Cost and efficiency estimates for the capture of upmigrating adult salmonids in the context of a complete fish passage program were determined, in part, by examining current operations of the existing hatchery ladder. Additionally, determination of the methods and feasibility of juvenile transport within the context of a complete fish passage program and release was aided by examination of the current juvenile transport program.

6.2 PROJECT RELATED EFFECTS

The Fish Barrier Dam, as part of the Oroville Facilities, is the first migration barrier encountered by upmigrating adult salmonids and sturgeon. Because DWR recognizes that the Oroville Facilities impact historic migration patterns of Chinook salmon, steelhead, and sturgeon, an evaluation was conducted on the methods and devices that could potentially be used in a potential fish passage program that would transport upmigrating adult fish upstream from Oroville Dam and outmigrating juvenile fish downstream from the Oroville Dam.

The results of a review of available literature on existing fish passage facilities and programs as well as information on potential physiological effects on individual fish are presented in Section 5, Study Results, above. Overall, the body of literature describing fish passage programs and their effects on watersheds, fish populations, and reservoir operations is sparse. However, an attempt was made to relate the existing information to the Oroville Facilities and the Feather River in general.

If a potential fish passage program at Lake Oroville were implemented, there would be a number of implications and potential impacts to the current management of the Oroville Facilities and Lake Oroville, that would need to be considered and potentially further evaluated depending on the fish passage options and alternatives selected.

6.2.1 Disease

6.2.1.1 Exposure Of Hatchery Water Supply to Fish Diseases

Providing anadromous salmonids passage to areas upstream from the Fish Barrier Dam creates a potential risk of infecting the FRFH water supply with the infectious hematopoietic necrosis virus (IHNV). In California, IHNV reportedly has been eliminated from most of its historic range by dam construction and the blocking of inland waters from spawning and rearing anadromous salmonids. Historically, IHNV was endemic to the entire Sacramento, American, Merced, and Feather River drainages. Currently, only those portions of these watersheds below terminal dams blocking anadromous salmonids contain IHNV (pers. com. W. T. Cox, 2003).

Eliminating the risk of infected water entering the Feather River Hatchery would require either an alternative water source or a method to disinfect the incoming water supply. Hatchery operations currently require a continuous water supply of up to 130 cfs of which an ultraviolet light system disinfects 12 cfs. The cost of disinfecting the additional flow requirement is estimated at $25,000,000 for initial installation plus $100,000 to $200,000 annually (pers. com. T. Veek, 2003), based on capital and operating costs of an ozonation system installed at the Coleman National Fish Hatchery.

According to the Water Management Technologies, Inc. Website (2004) three ultraviolet light (UV) disinfection systems were installed at Lahonton National Fish Hatchery to treat inflow for the parasite Ichthyophthirius (Ich). The systems are open channel Integrated Modular Filtration (IMF)-style UV systems that utilize filtration and UV irradiation as disinfection mechanisms and are capable of disinfecting 5,000 gpm (approximately 11 cfs) at a UV nominal dose rate of 35,000 uw-sec/cm2.

The Water Management Technologies, Inc. Website (2004) estimated that, based on preliminary application information, the total project budget price for a filtration and UV system with an application of 18,000 gpm or 40 cfs is approximately $500,000 if inflow has less than 10 mg/L of suspended solids.

An alternative to disinfecting the water supply would be to locate and use an alternate water source. Potential alternate water sources include groundwater or agricultural diversions upstream from the first fish passage barriers in the upstream tributaries to Lake Oroville (i.e.: Miocene Canal), or some combination of different sources. A combination of different sources would probably be more likely because the amount of water required is fairly substantial. For example, one potential alternate water source could Miocene Canal, which diverts water from the West Branch upstream from Miocene Dam. However, during October 2003 flow in the canal averaged approximately 30 cfs (California Data Exchange Center Website 2003). Another potential water source is the Oroville-Wyandotte irrigation ditch with an average flow of 24 cfs (Oroville Wyandotte Irrigation District 2001). Because the FRFH requires approximately 130 cfs, multiple additional water sources would be required or hatchery operations wild need to be modified. Slant wells under the Diversion Pool are another potential alternate water source, but a detailed feasibility analysis beyond the scope of this report would be required.

Energy costs associated with groundwater pumping are estimated at $0.132 per acre-foot per foot of lift (Agricultural Issues Center, University of California, Davis Website 2004). Ground water levels in the Oroville area are estimated at a depth of 70 feet (DWR Website 2003), which would result in an estimated energy cost of $9.24 per acre-foot of water if groundwater were utilized as an alternate water source for the hatchery.

Because the overall hatchery requirement of 130 cfs (approximately 260 acre feet/day) is relatively high, clean water would likely be required to come from a combination of sources. In order to determine the most cost effective and physically feasible solution to a potential IHN-infected water source problem would require an additional feasibility analysis.

6.2.1.2 Increased Risk of Fish Kills in Hatchery

Without alternate or disinfected water sources there could potentially be an increased risk of fish kills due to disease at the hatchery. The risk associated with potential losses of hatchery-produced fish would have to be weighed against the cost of implementing alternate water source programs. It should be noted that hatcheries in the Pacific Northwest face similar problems, but colder water supplies in those facilities may reduce risk of infection.

6.2.1.3 Exposure of Reservoir and Upstream Tributary Fisheries to Disease

The risk of transmission of IHNV infection of hatchery fish from transported fish to the upper Feather River watershed could be low. Steward and Bjornn (1990) reported that, “in spite of the comparatively high incidence of disease among some hatchery fish stocks, there is little evidence to suggest that diseases or parasites are routinely transmitted from hatchery fish to wild fish.” Additionally, Foott et al. (2000) were unable to induce infection of natural Chinook salmon by placing them in close proximity to infected fish. It was concluded that the low virulence of the Sacramento River strain of IHNV reduced the likelihood of initial infection progressing to a morbid state in juvenile Chinook salmon. It also was concluded that the releases of infected hatchery fish to the Sacramento River presents a low ecological risk to natural populations. However, it is unclear what effect infected or sub-clinical wild fish would have on hatchery fish. Wild juveniles could potentially be resistant to IHN while hatchery stocks could potentially be less resistant. Additionally, it is likely that hatchery conditions such as high stocking densities increase the likelihood of disease outbreaks.

6.2.1.4 Increased Cumulative Disease Pressure Throughout Downstream Feather River System

There could potentially be a cumulative effect of increasing pathogens in the Feather River system associated with the possibility of transporting infected fish past the Oroville Facilities. Even if water is disinfected for hatchery purposes, there still could be the potential of virus entering the Thermalito Forebay, Thermalito Afterbay, and LFC. Although transmission of the disease to salmonids in these areas is not likely, the potential risk should still be considered in any risk analysis associated with allowing upstream passage of anadromous salmonids.

Because available literature provided little insight into the likelihood of disease transmission associated with a potential fish passage program, a detailed analysis of the potential for disease transmission should be conducted. A detailed cost-benefit analysis of potential hatchery impacts associated with a potential fish passage program including the likelihood of disease outbreaks also should be conducted.

6.2.2 Genetics

6.2.2.1 Potential Genetic Introgression of Steelhead With Resident (Non-Native Strains Stocked) Rainbow Trout

The potential for genetic introgression between steelhead and rainbow trout was discussed in the Final Report for SP-F5/7 Task 1, but focused on populations downstream from the Lake Oroville. Allowing the passage of steelhead into tributaries upstream from the Lake Oroville could pose a much more significant threat because there currently exist naturally self-sustaining populations of rainbow and brown trout upstream from Lake Oroville. The Middle Fork Feather River has been designated a Heritage Trout Water by DFG (DFG Website 2004). Other Tributaries of the Feather River upstream from Lake Oroville also are popular recreational trout fisheries suggesting that large numbers of rainbow and brown trout could be present. Leary et al. (1995) suggest a one percent threshold of introgression is acceptable while higher percentages present a risk of altering the biological characteristics of the native fish assemblage. A recent study completed by Nielsen et al. (2003) showed little genetic distinctness between Feather River hatchery-produced and naturally spawned Feather River steelhead. Generally, however, there do exist substantial genetic differences between above and below dam trout populations. Although rainbow trout upstream from Lake Oroville were not tested, above and below dam populations on the Yuba River were reportedly genetically distinct populations (Nielsen et al. 2003). The current rainbow trout population size in the upper Feather River watershed likely greatly exceeds any potential steelhead broodstock population that could be transported to the upper Feather River watershed. Thus, it is likely that any genetic distinctness between the two populations would be removed. There are however, reports of sympatric steelhead and rainbow trout populations that are reproductively isolated (Zimmerman and Reeves 2000).

Because the likelihood of genetic introgression and potential population effects of genetic introgression is unclear, the potential for reproductive isolation should be investigated prior any upper Feather River steelhead re-introductions.

6.2.2.2 Separation of Spring-Run vs. Fall-Run Chinook (If They Can Be Reliably Differentiated)

Adult spring-run Chinook salmon reportedly begin entering the Feather River in March with the run typically lasting through June (Sommer et al. 2001). They hold in the river

until sexually mature and reportedly spawn from August through October (DFG 1998; DWR and USBR 2000; Moyle 2002).

During the holding period spring-run Chinook salmon inhabit deep pools with cool, well oxygenated water (DWR and USBR 2000). Moyle (2002) reports that spring-run Chinook salmon select pools that are usually greater than two meters (6.6 ft) deep, typically with bedrock bottoms and water velocities ranging from 15-80 cm/sec (0.49-2.6 ft/sec). Adult spring-run Chinook salmon reportedly utilize overhanging ledges, deep pockets, and “bubble curtains” created by high velocity inflow as cover during the day (DFG 1998; DWR and USBR 2000; Moyle et al. 1995; Moyle 2002). It also has been reported that holding fish utilize “pocket water” behind large rocks as velocity refuges in faster moving water (Moyle et al. 1995; Sommer et al. 2001). During the holding period, adult fish reportedly do not necessarily stay in one pool throughout the summer, but move between pools, generally with a net upstream movement (Moyle 2002). Pools are reported to generally be located near spawning areas, which may be at the tails of holding pools (DFG 1998; DWR and USBR 2000; Moyle 2002).

Adult fall-run Chinook salmon reportedly typically begin entering the Feather River in late August and spawn from October through December while egg incubation continues through February (Moyle 2002). Unlike spring-run Chinook salmon, fall-run Chinook salmon are relatively sexually mature upon river entry and spend a comparatively short time holding in the river prior to spawning. Because dam construction on the west slope of the Sierra Nevada blocked anadromous salmonid access to upper watershed spawning areas, genetic introgression of Central Valley Chinook salmon stocks likely has occurred. Additionally, hatchery influences likely have contributed to the difficulty in being unable to differentiate between stocks when selecting broodstock for spawning (Yoshiyama et al. 2000).

If some method of passage past the Oroville Facilities is provided it could potentially be possible to use the temporal division between spring and fall-run Chinook salmon to collect appropriate broodstock for upper Feather River tributaries. Because some fall-run Chinook salmon exhibit stream-type life history behavior (i.e. adult spring-run timing) temporal differentiation between different genetic stocks may not be absolutely effective.

One possible mechanism of run segregation using arrival time as an indicator of genetic identity could be the construction of one or more weirs in the LFC that could provide passage only to those individuals that arrive during certain times of the year. For example, a weir could be open for fish passage from April through June allowing passage of spring-run Chinook salmon, and then closed preventing fall-run Chinook salmon passage. The same weir could be re-opened in January allowing passage of steelhead. One or more weirs would have the added benefit of providing a counting facility allowing more accurate estimates of anadromous salmonid spawning escapements. Additionally, weir operation in the lower Feather River would lessen the

likelihood impacts to spring-run Chinook salmon due to redd superimposition in the LFC.

Because spawning run introgression likely has occurred in the lower Feather River, and because a goal of a potential fish passage program could be to maintain genetic separation between spring-run and fall-run Chinook salmon in the Feather River, a detailed genetic analysis of Chinook salmon in the Feather River should be conducted prior to implementation of a potential fish passage program.

6.2.2.3 Potential Removal of Rainbow Trout From Tributaries

Establishing a naturally reproducing population of steelhead upstream from Lake Oroville could potentially require the extirpation of the current naturally self-sustaining rainbow trout population in order to prevent genetic introgression. However, reproductively isolated populations of sympatric rainbow trout and steelhead have been reported (Zimmerman and Reeves 2000).

Removal of rainbow trout could potentially be a difficult and costly project, and could involve the use of poison. It also is likely that use of a piscicide would have a low probability of success. Additionally, removal of rainbow trout from the upper Feather River tributaries likely would result in resource use conflicts among regulatory agencies, recreational, and environmental groups.

Because the likelihood of genetic introgression is unclear, and because mechanisms by which genetic introgression could be prevented are unclear, a detailed analysis of the potential to occur, the effects from, and potential measures to minimize genetic introgression should be performed prior to implementation of a potential fish passage program.

6.2.2.4 Minimum Number of Fish to Achieve a Genetically Sustainable Population

Shaffer (1981) defined minimum population size as “a minimum viable population for any given species in any given habitat is the smallest isolated population having a 99% chance of remaining extant for 1000 years despite the foreseeable effects of demographic, environmental and genetic stochasticity, and natural catastrophes.” Ecologists have developed several models to determine minimum viable population sizes. These models have been categorized as population viability analysis (PVA) models. The basic model is defined by Taylor (1995) as

$$N_{t+1} = \lambda N_t$$

where:
N = population size
t = time

λ = discreet rate of population growth

If $\lambda = 1$ the population is stable, $\lambda < 1$ the population is declining and $\lambda > 1$ the population is growing.

A conceptual model for salmon producing a $\lambda = 1$ would require that two adults return to spawn from each redd produced by the previous generation (assuming a that each female spawns with only one male). A simple hypothetical PVA model for Feather River Chinook salmon would be:

$$\lambda = (E \times S_1 \times S_2 \times (S_3)^y \times S_4)$$

where:
E = eggs in redd
S_1 = egg to fry survival rate
S_2 = fry to smolt survival rate
S_3 = annual ocean survival rate
y = years in ocean
S_4 = migration to spawning ground survival

Because the mean age for Chinook salmon in the Sacramento River is estimated at slightly over four years (three years in the ocean)(Healey 1991), y = 3 in the model. If redds are used as a surrogate for adult spawners, the result would have to be divided by 2 if the assumption that one female mates with one male is true.

A model including detailing survival rates during each phase of a potential fish passage program at Lake Oroville was developed as part of SP-F15 Task 4. The Final Report for SP-F15 Task 4 presents the model, which includes losses during each phase of the hypothetical life cycle of a population of individuals in a potential fish passage program. For example, adults would be exposed to immigration mortality, capture mortality, adult pre-spawn mortality, and in-vivo egg mortality. Detailed explanation of each phase of the model is presented in Appendix A of the Final Report for SP-F15 Task 4. Prior to implementation of potential a fish passage program detailed analyses of model results should be performed.

6.2.2.5 Straying Rates Affecting Sustainability of a Genetically Distinct Population

If a goal of a potential fish passage program is to establish genetically distinct populations of Chinook salmon in individual tributaries, straying could be an important consideration. Adult spring-run Chinook salmon would likely be transported past the Oroville Facilities several months prior to spawning and would have sufficient time to disperse to non-target tributaries. Leary et al. (1995) suggested that an inflow of a maximum of one percent of foreign genes would ensure a population's genetic integrity.

If, for example, a small founder population of 250 pairs of spring-run Chinook salmon were transported to the North Fork while another 250 pairs were transported to the Middle Fork, straying of only three fish could potentially threaten the genetic integrity of the population.

Because straying between tributaries upstream from Lake Oroville would allow for gene flow between tributary populations, the goals of a potential fish passage program should be clearly defined prior to determining the potential for straying between tributaries. If a goal of a potential fish passage program would be to maintain genetic isolation among tributary populations, then a detailed analysis of the potential for straying between tributaries, and the effects of straying on maintaining genetic integrity among populations should be conducted.

6.2.3 Predation

6.2.3.1 Predation On and From Resident Fish Population

In a potential fish passage program it would be necessary to capture and transport out-migrating juveniles to a location downstream from the Fish Barrier Dam. Juvenile anadromous salmonids, naturally spawned in tributaries of the Feather River above Lake Oroville, would be subject to predation from both native and non-native species during their rearing and out-migration prior to capture for transport and after release in the lower Feather River. Additionally, if steelhead were included in a potential fish passage program, naturally spawned yearling steelhead could become predators on both young-of-year Chinook salmon and steelhead.

Depending on capture methods and location of capture, out-migrating juvenile salmonids may be subject to two distinctively different suites of predators. Juveniles captured in tributaries would be subject to predation from stream dwelling predators while juveniles bypassing tributary screening facilities and are captured later in Lake Oroville would be subject to stream and lake dwelling predatory species. Native and introduced predatory species have been documented in the upstream tributaries and in the arms of Lake Oroville.

Stream dwelling predatory species include Sacramento pikeminnow, steelhead, rainbow trout, and brown trout. DWR biologists have documented Sacramento pikeminnow and rainbow trout in all surveyed tributaries upstream from Lake Oroville, while brown trout have been documented in both the Middle Fork and the West Branch.

It has been reported that pikeminnow account for 78 percent out-migrating juvenile salmonid losses from predation in the Snake River, Idaho (Bennett 1998). Poe et al. (1991) showed that juvenile salmonids make up 67 percent of the diet of pikeminnow during out-migration. Another study reported that juvenile Chinook salmon are favored over steelhead in pikeminnow diets (Normandeau Associates, Inc. 2001). Rieman et al.

(1991) estimated that overall juvenile salmonid mortality ranges from 9 to 19 percent during out-migration through the John Day system in Oregon and that pikeminnow account for 78 percent of this mortality.

Non-anadromous rainbow trout and brown trout have been introduced to tributaries above Lake Oroville, and currently support a high quality sport fishery. Rainbow trout were the most frequently observed species in snorkeling and electro-fishing surveys conducted DWR in upstream tributaries. Tabor and Piaskowski (2000) studied predation of juvenile Chinook salmon by rainbow trout and found fairly low rates. They calculated a consumption of .05 to .07 juvenile Chinook salmon per day per rainbow trout. Naturally spawned steelhead in upper tributaries could potentially remain in fresh water for up to two years and would reach sufficient size to prey on juvenile Chinook salmon. Brown trout, while not as numerous as rainbow trout, could also become significant predators on juvenile Chinook salmon and steelhead. Tabor and Wurtsbaugh (1991) showed significant predation occurred on juvenile rainbow trout by brown trout in a reservoir system in Utah. Stuber et al. (1985) reported similar results in a Colorado system.

Out-migrating juvenile salmonids that are not captured at tributary screening facilities would encounter an additional and different suite of predators as they enter Lake Oroville. Reservoir dwelling predators include several species of black bass and stocked inland coho salmon. Largemouth bass over 200mm in length reportedly are known to prey on juvenile salmonids (Shrader and Moody 1998). However, Shrader and Moody (1998) also found that trout only became a significant portion largemouth bass diets during June and July, which could have been was a result of warmer water temperatures. If water temperature is associated with largemouth bass prey preferences, a temporal separation between emigrating anadromous salmonids and largemouth bass in Lake Oroville could occur for a proportion of the emigration period. Smallmouth bass are the most significant non-native predators of anadromous salmonid juveniles in the Snake River system of Idaho (Bennett 1998). In contrast, Poe et al. (1991) reported that smallmouth bass are not important predators on juvenile salmonids in the John Day Reservoir on the Columbia River. Loomis (1998) reported that smallmouth bass do not become significant predators until water temperatures rise above 60° F and they prefer river reaches or lake areas with water temperatures above 70° F. Tabor et al. (1993) report smallmouth bass consuming 1.0 to 1.4 juvenile Chinook salmon per day. Tabor et al. (1999) found smallmouth bass to be more significant predators on juvenile salmonids than largemouth bass. Both smallmouth bass and largemouth bass have been documented by DWR staff in Lake Oroville.

Coho salmon currently are stocked in Lake Oroville. Stocking protocols are designed to minimize escape of coho salmon to the lower Feather River. Although some may escape they are not likely to pose a significant threat to juvenile Chinook salmon downstream from the Fish Barrier Dam. If Chinook salmon are re-introduced to the upstream tributaries to Lake Oroville, coho salmon could become a part of the suite of

predators that feed on juvenile Chinook salmon. Pearsons and Fritts (1999) reported juvenile coho salmon preying on juvenile Chinook salmon up to 47 percent of their length, which implies that juvenile Chinook salmon (age 0) would be preyed on by yearling coho salmon (age 1). Steelhead tend to be much larger than Chinook salmon during the out-migration period and should be relatively immune from predation by yearling coho salmon. Juvenile steelhead entering the lake during outmigration could be targeted by older coho salmon, however. Additionally, if older coho salmon migrate upstream from Lake Oroville they could prey on juvenile steelhead in the tributaries.

Because a potential fish passage program would introduce ESA listed species to the upper Feather River tributaries, a detailed analysis of predation potential and effects of predation on survival rates of juveniles produced in the upper Feather River should be conducted.

6.2.3.2 Potential Predation Impacts on Other ESA Species

Other ESA listed endangered or threatened aquatic and semi-aquatic species in the area include the red-legged frog (*Rana aurora draytonii*), conservancy fairy shrimp (*Branchinecta conservatio*), vernal pool tadpole shrimp (*Lepidurus packardi*), and the vernal pool fairy shrimp (*B. lynchi*) (DWR 2001). Both ESA consultation and NEPA compliance would be required if introduction of potential predators to these species was implemented.

6.2.4 Competition

6.2.4.1 Competition with Resident Salmonids for Food and Habitat

The re-introduction of Chinook salmon and steelhead to the upper Feather River watershed may create competitive interactions with resident salmonids. Naturally reproducing rainbow trout populations have been established upstream from Lake Oroville likely filling part of the habitat niche once used by anadromous steelhead. It also is likely that these upstream areas are less productive than they once were because dams block upstream transfer of marine derived nutrients in the form of salmon carcasses.

Competition between juvenile steelhead and rainbow trout may be particularly acute as they utilize the same resources. Additionally, juvenile steelhead may spend up to two years in their natal streams before beginning seaward migration. During this time they will likely compete for resources with juvenile rainbow trout in the same area.

Competition between Chinook salmon juveniles and other salmonids will probably be limited as most Chinook salmon emigrate as sub-yearlings. Chinook salmon and steelhead are sympatric in most Pacific watersheds and likely partition resources rather than directly compete. However, detailed analysis of the potential for competition

among re-introduced salmonids and resident species should be conducted prior to implementation of a potential fish passage program.

6.2.5 Coldwater Fisheries Management

6.2.5.1 Reduction in Manageability and Quality of the Reservoir Salmonid Fisheries

Management of the coldwater fishery in Lake Oroville could potentially become more complicated with the introduction of federally listed anadromous salmonids upstream from or in the lake. Based on reported adult salmonid migration behavior patterns it is likely that some percentage of transported adult Chinook salmon would residualize in the reservoir. Additionally, uncaptured juveniles could potentially survive in-river and in-reservoir predation to become resident adults in the reservoir. The legal status of transported and residualized adult fish or uncaptured juveniles could potentially lead to a resource use conflict between the separate mandates for recreational use and endangered species protection.
Reservoir fishing regulations likely would require amendment and sport angling could potentially be abolished altogether. Additionally, the stocking of Lake Oroville with potential predators of juvenile Chinook salmon may present management and regulatory compliance conflicts (i.e.: coho salmon and largemouth bass could feed on uncaptured juveniles).

Because introduction of ESA listed salmonids to the upper Feather River watershed likely would result in regulation changes affecting fisheries management practices in Lake Oroville, detailed analysis of the legal, social, and economic impacts of changes in fisheries management activities should be conducted prior to implementation of a potential fish passage program.

6.2.5.2 Recreation Impacts

Recreation impacts also are discussed in this report in Section 6.2.9 Cross Resource Impacts. The introduction of ESA listed species to the upper Feather River tributaries likely would generate impacts to current recreational lresource uses. For example, fishing regulations likely would have to be modified to prevent the take of Chinook salmon and steelhead. Rainbow trout regulations would present specific challenges because juvenile rainbow trout are indistinguishable from juvenile steelhead. Additionally, construction activities associated with construction of boat ramps, campgrounds, and river access points would be subject to ESA consultation and NEPA compliance.

Because introduction of ESA listed salmonids to the upper Feather River watershed likely would result in regulation changes affecting recreation in Lake Oroville, detailed

analysis of the impacts of ESA listed salmonid introduction should be conducted prior to implementation of a potential fish passage program.

6.2.6 Reproduction/Spawning

6.2.6.1 Upstream Nutrient and Energy Transfer

The construction of the Oroville facilities blocked the nutrient transfer from saltwater to freshwater by anadromous salmonids potentially reducing productivity in tributaries currently upstream from Lake Oroville. Because of the dramatic decline in the size of wild salmon runs in the Pacific Northwest, it is estimated that the amount of marine-derived nutrients now delivered to the regions watersheds is less than 10% of its historical level (Gresh et al. 2000) The Final Report for SP-F8 examined the effects of nutrient and organic matter transfers to the upstream tributaries. Several studies have been completed documenting increased stream productivity following the planting of anadromous salmonid carcasses in streams or comparing stream productivity in streams with anadromous salmon spawning runs to nearby streams without anadromous salmon spawning runs (Schuldt and Hershey 1995; Johnson et al. 1997; Bilby et al. 1998; Wipfli et al. 1998; Minkawa and Gara 1999; Finney et al. 2000; Minkawa et al. 2002; Naiman et al. 2002). Gresh et al. (2000) cite both increased over-winter survival and increased body lengths for coho salmon in streams following salmon carcass additions. The Final Report for SP-F8 contains a detailed analysis of the potential effects associated with the addition of salmon carcasses to the upper Feather River.

Because introduction of ocean-derived nutrients reportedly increases productivity in streams, the passage of adult salmonids past the Oroville Facilities likely also would increase productivity. However, detailed analysis of the potential effects of increasing nutrient loads in the upper Feather River should be conducted.

6.2.6.2 Reduction in Redd Superimposition And Resulting Egg Mortality in Lower Feather River

Redd superimposition occurs when spawning salmonids construct redds over existing, previously constructed redds. The extent of redd superimposition in the project area was evaluated in SP-F10 Task 2B. In 1995, based on a Chinook salmon spawning escapement of 44,111 in the LFC, a superimposition index of 1.57 was calculated (Sommer et al. 2001). Superimposition index is a measure of superimposition calculated by dividing the number of female spawners by the number of redds. An index value of 1.57 indicates that more than half the redds constructed during the spawning run in 1995 were constructed on top of existing redds. The spawning escapement estimate in 2003 in the LFC was 58,468. The estimated superimposition index in the LFC was 3.16. In 1995 spawning escapement in the HFC was 15,572

yielding a superimposition index of 0.47. The spawning escapement estimate in 2003 in the HFC was 39,600, yielding a superimposition index of 1.58.

McNeil and Ahnell (1964) reported that egg loss during pink salmon spawning increases as the density of female spawners increases and that the losses are mostly caused by redd superimposition. Conclusions drawn from the study indicate that, in streambeds where spawning occurs over an extended period of time, mortality from redd superimposition would have its greatest impact on the progeny of early spawning fish; and in years of large escapement, it is conceivable that late-spawning fish could nearly destroy the progeny of early-spawning fish McNeil and Ahnell (1964). Fukushima et al. (1998) examined egg losses due to redd superimposition in pink salmon in Alaska and found that of 500 females that spawned in a 350 m reach, the equivalent of 300 redds were completely destroyed. The density of spawning reported by Fukushima et al. (1998) is slightly higher than spawning density reported in the LFC of the Feather River in 1995, but lower than the spawning density in 2003. Hayes (1987) investigated competition for spawning space between rainbow and brown trout in a lake tributary in New Zealand. Brown trout spawned from April to June and rainbow trout from April through October in the tributary. Hayes (1987) found that redd superimposition of brown trout redds by rainbow trout caused a 94% reduction in the spawning success of brown trout. In the studies conducted by Fukushima et al. (1998), Hayes (1987), and McNeil and Ahnell (1964), it was assumed that the primary cause of redd superimposition was lack of habitat. In contrast, Essington et al. (1998) reported that redd superimposition was not necessarily a function of habitat availability but that some female salmonids display a behavioral preference to spawn on existing redd sites, suggesting that factors other than habitat may determine redd site selection.

Spring-run Chinook salmon reportedly begin spawning in late August and continue through October (DFG 1998; DWR and USBR 2000; Moyle 2002). Fall-run Chinook salmon reportedly begin spawning in October and continue through December (Moyle 2002). Therefore, spring-run Chinook salmon redds are the most likely to be superimposed upon. Steelhead generally begin spawning in late December and continue through March (Busby et al. 1996; California Bay Delta Authority Website 2004; McEwan 2001), potentially superimposing redds on existing Chinook salmon redds. Although spawning escapements for steelhead in the LFC were unavailable, the Final Report for SP-F10 Task 3B report reported that 75 redds were observed in the LFC during the 2003 spawning season.

Because high escapements of Chinook salmon in the lower Feather River along with limited spawning habitat cause high rates of redd superimposition, it is likely that transporting a proportion of the population past the Oroville Facilities would reduce redd superimposition rates in the lower river. Additionally, transport of steelhead past the Oroville Facilities also could reduce steelhead redd superimposition on Chinook salmon redds. It is unclear, however how large an impact, passage would have on redd superimposition because the proportion of the population that would be passed likely

would be small. Additionally the proportion of egg mortality in each redd that is superimposed upon is unknown.

6.2.6.3 Non-Self Sustaining Coldwater Fishery in Oroville Reservoir

The FRFH recently halted an inland Chinook salmon stocking program in Lake Oroville due to an outbreak of IHN in the hatchery. However, during the period when Chinook salmon were stocked, individuals had access to the tributaries during the spawning period. However, the stocked population did not develop into a self-sustaining fishery. Although no specific surveys have been conducted, according to DWR and DFG staff, no stocked Chinook salmon have been observed spawning in the upstream tributaries. It is unclear whether spawning was attempted, however.

Because no self-sustaining population developed during the period when Chinook salmon were stocked in Lake Oroville, a detailed analysis to determine the likelihood of Chinook salmon spawning success in the upped Feather River should be conducted.

6.2.6.4 Increased Fish Production

One of the goals of a potential fish passage program could be to increase the total salmonid production of to contribute to fishery recovery goals. In order to achieve maximum salmonid production, fish that would be transported past the Oroville Facilities would need to produce at least as many returning offspring as they would have produced if they had been allowed to spawn in the lower Feather River.

Because there are multiple uncertainties associated with a potential fish passage program, a detailed analysis of the potential production associated with a potential fish passage program were examined in a upper Feather River production model in the Final Report for SP-F15 Task 4. Model results indicate a great degree of uncertainty remains between the best, expected, and worst-case scenarios for overall production of a potential fish passage program. Given the current values and assumptions utilized in the model, the results indicate the expected performance of a potential fish passage program would result in levels of return of adults substantially below the level required for a sustainable fish passage program.

6.2.7 Protect or Enhance Genetic Integrity

6.2.7.1 Access to Habitat Conditions More Closely Approximating Historical Habitat

Literature on the historical range of Chinooks salmon and steelhead in upper Feather River was reviewed in SP-F8; *Transfer of Energy and Nutrients by Anadromous Fish Migrations.* Historical records indicate that Chinook salmon and steelhead spawned in all four major tributaries of the upper Feather River upstream from the present location

of Lake Oroville. Spring run Chinook salmon reportedly spawned in the higher reaches and headwaters while fall run spawned in lower tributaries and mainstem river areas.

Spring-run Chinook salmon and steelhead were present in the Feather River prior to the completion of Oroville Dam in 1967, but the Oroville Project eliminated access to their historical spawning habitat in the upper tributaries (DFG 1993; Yoshiyama et al. 2001). Run sizes of spring-run Chinook salmon and steelhead populations were estimated DFG from 1963 to 1966 at a counting facility near the city of Oroville. During four years of counting prior to dam construction, an average of 1,362 spring-run Chinook salmon and 582 steelhead returned annually (ranges: 296 to 3,362 spring-run Chinook salmon and 416 to 914 steelhead) (Painter et al. 1977).

In the North Fork, spring-run Chinook salmon reportedly probably used Indian Creek, Yellow Creek, and Spanish Creek for spawning (Yoshiyama et al. 2001). In the Middle Fork, Chinook salmon reportedly probably ascended the Fall River up to Feather Falls (Yoshiyama et al. 2001). In the South Fork, Chinook salmon reportedly used McCabe Creek and Powell Creek (Silverson 2003 and McCarthy 2003 *in* DWR 2003)). Fry (1961) reported that most of the spring-run Chinook salmon utilized the Middle Fork for spawning.

Menchen (1966) reported that an average of 1,700 spring-run Chinook salmon spawned in the Feather River from 1953 to 1962, with annual spawning estimates ranging from 0 to 4,000 individuals. The entire spring-run was believed to spawn upstream from the present site of Oroville Dam. All of these estimates reportedly were considered to be minimal estimates of escapement Fry (1961). DFG estimated that 5,200 spring-run Chinook salmon, 2,300 fall-run Chinook salmon, and 2,000 steelhead were present upstream from the dam site. Unfortunately the report did not provide estimates of the distribution or abundance of these fish among the four branches of the Feather River (DWR 2003).

DFG estimated the historical extent of river available to anadromous fishes to be 211 miles (DFG Website 2004). The current extent of the river available is 64 miles or 30.3% of the historical estimate.

6.2.7.2 Access to Increased Quantity and Quality of Fish Spawning Habitat

The Final Report for SP-F3.1 Task 1A evaluated passage impediments to anadromous salmonids upstream from Lake Oroville. Four main tributaries were evaluated as well as several smaller streams off of these tributaries. The major areas assessed were the West Branch, the North Fork, the Middle Fork, and the South Fork. The Final Report for SP-F3.1 Task 1C evaluated fish habitat in these tributaries. Preliminary findings indicate the following probable barriers to upstream fish passage.

- West Branch of the North Fork Feather River – Salmon Falls appears is a fish barrier that is impassable at most flows that is slightly over two miles upstream from the confluence with Concow Creek. Although this feature is not a "complete fish passage barrier at all flows", it represents the extent of spawning habitat that would be available on a consistent and reliable basis for access and use in a potential fish passage program. Similarly, Miocene Dam likely is passable at some flows that occur infrequently. The upstream barrier that is most likely to be a complete fish passage barrier on the West Branch is the Falls Below Big Kimshew Creek.
- North Fork Feather River – Big Bend Dam represents the first fish passage barrier on the North Fork. It is located approximately 0.5 miles downstream from the Poe Powerhouse. The dam is passable when the reservoir is near full pool. The next upstream fish barrier is Poe Dam.
- Middle Fork Feather River – Bald Rock and Curtain Falls present the first fish passage barriers on the Middle Fork. The falls are located approximately 1 to 2 miles upstream from the confluence with the Fall River. Bald Rock Falls is approximately 300 yards downstream of Curtain Falls.
- South Fork Feather River – Ponderosa Diversion Dam presents an impassable barrier to salmonids on the South Fork. The dam is located near the high-water mark of Lake Oroville.

The total new riverine habitat available to anadromous fish upstream from Lake Oroville, from high pool to the first probable fish passage barrier at normal flows, is estimated at approximately 16 miles.

DWR reported mesohabitat for portions of the Lake Oroville Reservoir high pool, the West Branch, and the Middle Fork in the Final Report for SP-G1. Mesohabitat was determined by conducting field surveys and delineating mesohabitat units from the 1995 Brush Creek digital orthophoto quarter-quadrangle (DOQQ), and from 1990, 1996, and 2001 aerial photos. Based on the Mesohabitat data reported in the Final Report for SP-G1, the approximate total area of the "riffle" habitat in the West Branch is 3.4 acres and in the Middle Fork is 10 acres. Based on an average redd size of 55 square feet and assuming no redd superimposition, approximately 2,693 pairs of salmonids could be accommodated in the West Branch and approximately 7,920 pairs in the Middle Fork.

DWR monitored water temperatures in the tributaries above Lake Oroville during most of 2003. Preliminary analysis indicates that sustained water temperatures above 63° F (17° C) occur from late May through mid-September. These water temperatures reportedly are not ideal for spring-run Chinook salmon holding (NOAA Fisheries 1997a). From October through April, water temperatures are below 58° F (14° C) and should be suitable for spawning and egg incubation. Water temperatures for steelhead spawning and egg incubation are also within established ranges during this time period.

Water temperature and habitat suitability analyses for anadromous salmonid spawning are addressed in the Final Report for SP-F15 Task 2.

Based on analyses presented in the Final Reports for SP-F3.1 Task 1A, SP-G1, and SP-F15 Task 2, transporting adult anadromous salmonids past the Oroville Facilities would add an additional 16 miles of potentially suitable habitat below the first impassable fish barriers under normal flow conditions, which could increase available habitat by up to 38% of the historical range.

A detailed cost-benefit analysis should be conducted to determine if the benefits of allowing Chinook salmon access to 16 miles of habitat would outweigh the financial and land use costs associated with implementing a potential fish passage program

6.2.7.3 Access To Increased Quantity of Fish Spawning Habitat During High Flow Events

Based on available habitat mapping and water temperature information, there likely is additional spawning habitat upstream from the first functional fish passage barriers encountered on each of the four major tributaries. Although these first fish passage features are not “complete fish passage barriers at all flows,” they represent the extent of spawning habitat that would be available on a consistent and reliable basis for access and use in a potential fish passage program. Additional habitat above these locations could be available intermittently, during high-flow years, or adult passage to these areas could be provided as part of the fish passage program.

6.2.7.4 Access to Increased Quantity and Quality of Fish Rearing Habitat

Available water temperatures in the tributaries to Lake Oroville indicate that, from mid-May through September, water temperatures were suitable for juvenile steelhead rearing in the Middle Fork, but not at any other water temperature logger locations. Water temperatures in the Middle Fork were above reportedly suitable water temperatures from late June through early August. Water temperatures also were above reported suitable ranges for juvenile Chinook salmon rearing in all tributaries except the Middle Fork from mid June through early September.

Water temperature and habitat suitability analyses for anadromous salmonid rearing are addressed in the Final Report for SP-F15 Task 2.

6.2.7.4 Access to Increased Quantity of Fish Rearing Habitat During High Flow Events

If adult passage beyond the first functional fish passage barrier upstream from Oroville Dam occurs, either from a high flow event or during a potential fish passage program, significant amounts of juvenile rearing habitat likely would be available. Analysis of

additional available rearing habitat above the firs functional fish barriers in the tributaries upstream from Lake Oroville is presented in the Final Report for SP-F3.1 Task 1C.

6.2.8 Other Anadromous Fish Species

6.2.8.1 Steelhead Post-Spawning Survival

Although most anadromous salmonids die following spawning a small percentage of steelhead survive and are able to spawn repeatedly. If, in the Feather River, a substantial number of steelhead are repeat spawners, then it would be necessary to evaluate methods of re-capturing outmigrating adults and transporting them downstream below the Oroville Dam. However, little is known about Feather River steelhead repeat spawning, and in other steelhead populations the number of individuals exhibiting repeat spawning behavior has been reported to be somewhat variable (Ward and Slaney 1988; Withler 1966). Ward and Slaney (1988) reported ten percent of adult steelhead spawned repeatedly in a British Columbia coastal stream while Withler (1966) reported that between 4.4% and 31.3% of adult steelhead spawned repeatedly in three different British Columbia Rivers. If the incidence of Feather River steelhead that spawn repeatedly is low, it may not be necessary to attempt to recapture outmigrating post spawning adults. Conversely, if the proportion of fish exhibiting this spawning survival characteristic is high, a substantial effort to recapture these fish would be required. Successful recapture of adult steelhead may pose substantial challenges and the stress experienced during recapture could increase post-spawning mortality compared to that, which would have otherwise occurred naturally.

6.2.8.2 Adult Steelhead Passage Efficiency

Little literature exists on steelhead spawner survival passage through hydroelectric facilities. Available literature generally appeared to be focused on outmigration passage routes and on success rates of outmigrating adult steelhead. However, in a study conducted by Wertheimer et al. (2001), post spawn surviving female steelhead were radio tagged and then released to evaluate downstream migration behavior through a passage system. The study results indicated that passage route selection was not influenced by origin or release location and that evaluation of the Prototype Surface Collector at Power House I Bonneville Dam on the Columbia River bordering Oregon and Washington showed good potential for surface flow bypass in routing fish away from turbines (Wertheimer et al. 2001).

In contrast to the use of surface bypass flows for adult steelhead outmigrant routing, intake screen systems displayed poor efficacy in guiding fish away from turbine units (USACE 2000; Wertheimeret al. 2001). Wertheimer et al. (2001) suggested that the poor efficiency of intake screen systems was a result of individuals selecting areas of high flows. Additionally, it was suggested that further evaluation is needed to

understand the effects of turbine and spillway passage on in-river survival and subsequent reproductive productivity of steelhead (Wertheimer 2001).

A similar adult steelhead outmigrant passage assessment was conducted by Puget Sound Energy (Unpublished Work) that evaluated the passage of steelhead below the Upper Baker Dam at Baker Lake, Washington. The tracking of individual fish was accomplished by using fixed location tracking as well as manual tracking to record fish locations to determine the feasibility of using existing facilities to transport post spawning adult steelhead below the dam. The juvenile passage facilities at Upper Baker Dam consist of a gulper system, which was designed for the purpose of guiding juveniles downstream for release below the dam (Puget Sound Energy Unpublished Work). It was reported that eight of the tagged steelhead successfully migrated to the forebay area and that the greatest number of detections was made at the gulper entrance (Puget Sound Energy Unpublished Work). The report did not document the success rate of adult steelhead capture using the gulper system.

A detailed analysis of steelhead post spawning survival and potential passage efficiency should be conducted prior to implementation of a potential fish passage program.

6.2.8.3 Green Sturgeon

Relatively little less reportedly is known about green sturgeon compared to white sturgeon in Pacific Coast watersheds (Moyle 2002). Erickson et al. (2002) reviewed available literature on green sturgeon and suggest that less is known about this species than any of the other 25 known species of sturgeon. Additionally, Erickson et al. (2002) tracked the movement of adults entering the Rogue River, Oregon, spawning, and migrating back to the ocean. It was found that green sturgeon enter the river system in late spring and hold in deep slow moving pools for up to six months. Spawning reportedly occurs in deep turbulent portions of the main river (Beamesderfer and Webb 2002). The only known spawning populations of green sturgeon in North America reportedly occur in the Sacramento River, the Klamath River, and the Rogue River (Erickson et al. 2002). Juveniles may spend from one to four years in freshwater before beginning seaward migration to the ocean (Beamesderfer and Webb 2002). Green sturgeon are thought to be the most marine oriented of the genus (Erickson et al. 2002). Some green sturgeon from the Sacramento River reportedly have been recaptured off the coast of Washington (Miller 1972).

There are two different types of programs that could potentially implemented to re-introduce green sturgeon to the upper Feather River watershed. The first potential program would involve the capture and transport of adults to areas above Oroville Dam coupled with the capture of progeny for transport downstream from the dam. Implementation of this scenario would mimic the natural life cycle of green sturgeon, but would likely be the most technically challenging. The second potential program that could be implemented would be to transport adults above Oroville Dam for several

years in an attempt to produce a naturally reproducing inland population. A review of available literature on green sturgeon did not indicate whether the species was capable of completing its life history in fresh water. Regardless of which scenario is chosen to re-introduce green sturgeon to the upper Feather River watershed, it would likely be many years before success of the program could be determined because green sturgeon reportedly do not reach sexual maturity until 20 years of age, and then only spawn every 4 to 11 years (Beamesderfer and Webb 2002).

6.2.9 Risks and Alternative Methods to Accomplish Fish Passage Goals

6.2.9.1 Net Fish Production of the Passage Program

Net productivity of any selected fish passage program would be difficult to assess, and depend on the definition of “net productivity”. If, for instance, net productivity were defined as smolt output it would be the number of smolt progeny transported downstream divided by the number of adults transported upstream the previous year. This figure could be compared to the total number of smolts emigrating from the Feather River to determine one measure of success of the program.

6.2.9.2 Opportunity Cost of Loss of Spawning Fish From Lower Feather River

There is a potential for reduction of spawning in the lower Feather River if significant numbers of Chinook salmon and steelhead were transported upstream of Lake Oroville. However, because Chinook salmon spawning in the LFC of the Feather River is at such a high density, it is unlikely that transport of several hundred to several thousand adult fall-run Chinook salmon to upstream tributaries would have a substantial detrimental effect on current spawning escapements. Additionally, transport of a proportion of the spawning fall-run Chinook salmon population upstream from the Oroville Facilities could potentially provide a beneficial effect on the spawning population of Chinook salmon remaining below the dam because high utilization of the current habitat available in the lower Feather River results in redd superimposition potentially causing egg mortality and related productivity losses.

The total number of spring-run Chinook salmon in the lower Feather River are not definitively known. Thus, the number of fish available for a potential passage program with the goal of maintaining genetic integrity between runs of Chinook salmon and the potential risks to spring-run Chinook salmon from the depletion of the spawning numbers in the lower river for the fish passage program are not known.

A detailed analysis should be conducted to determine the opportunity costs to the ESA listed spring-run Chinook salmon population in the lower Feather River prior to implementation of a potential fish passage program.

6.2.9.3 Risks of Fish Passage Program Failures

Although the potential risks associated with fish passage program failure could include potential negative impacts to an ESA listed species, a detailed risk analysis should be conducted prior to implementation of a potential fish passage program.

6.2.9.4 Alternative Methods to Accomplish Passage Program Goals

Specific goals associated with fish passage would need to be defined to help guide the development of a potential fish passage program. Potential goals for the fish passage program include: increased total salmonid production, protection and enhancement of distinct genetic stocks, access to additional quantities of habitat, and access to habitat conditions more closely approximating historical spawning conditions.

All of the identified goals of a potential fish passage program could potentially be accomplished without implementation of a potential fish passage program with the exception of the goal of accessing habitat conditions more closely approximating historical spawning conditions. Specifically, habitat enhancement and creation in the lower Feather River coupled with altered flow regimes and construction of a barrier weir to spatially separate spawning spring-run and fall-run Chinook salmon could potentially accomplish three of the four identified goals of a potential fish passage program. However, a detailed cost-benefit analysis would be required and should be conducted to determine if implementation of alternate Resource Actions would accomplish the goals of a potential fish passage program and whether the costs associated with implementation of each Resource Action, including fish passage, would be fiscally feasible given the benefits gained.

6.2.10 Preliminary Cross Resource Impacts

6.2.10.1 Recreation

The introduction of ESA listed species to the upper Feather River tributaries could potentially result in impacts to current recreational uses. For example, angling regulations could potentially be modified preventing the take of Chinook salmon and steelhead. Additionally, angling regulations regarding rainbow trout could be substantially affected because yearling steelhead are indistinguishable from rainbow trout. Construction activities such as installation of boat ramps, campgrounds, and river access points would be subject to ESA consultation in addition to NEPA compliance.

6.2.10.2 Traffic

If the method chosen for fish passage involves the use of trucks to transport adults past the Oroville Facilities, then there could potentially be an increase in traffic on roads into the upper watershed. The increase in traffic could be significant because transporting

several hundred adult fish would involve numerous round trips per day by multiple trucks. Likewise, the transport of juveniles from the upper watershed downstream from the dam would require numerous trips. Heavy truck traffic on these roads could also increase road maintenance requirements. Road maintenance in areas near the river could be required to be limited to certain temporal construction windows to accommodate spawning or emigration of ESA listed species.

6.2.10.3 Introduction of ESA Species into New Areas

The introduction of ESA listed fish species upstream from Lake Oroville could potentially conflicts with landowners or other entities involved in watershed management and recreational activities. Future and on-going activities in the area would be required to comply with ESA regulations including formal consultation that may complicate or delay projects. Additionally, any actions proposed in the area by federal agencies would require NEPA compliance.

6.2.10.4 Native American Tribal Fishing Rights

Upon reintroduction of the anadromous fish into the upstream tributaries, it is possible that the Native American tribes may invoke their “usual and accustomed” fishing rights in their historical fishery.

6.3 FISH PASSAGE PROGRAM ALTERNATIVES CONCLUSIONS

A potential fish passage program would have many elements, potential alternatives, and options. Discussion of the each potential fish passage program alternative with consideration of interdependencies, synergisms and compatibility, as well as recommendations for operating guidelines presented with respect to each potential fish passage program goal, when applicable, is presented below.

6.3.1 Adult Fish Collection

Use of the current hatchery ladder as the adult salmonid fish collection device has the following favorable attributes in comparison to the alternative of construction of a new fish ladder and related facilities.

- No irreconcilable conflicts between a potential fish passage program and current hatchery operations have been identified
- Using the existing ladder avoids the cost of construction of new facilities
- The current fish ladder is in the most favorable location for highest ladder capture efficiency
- The fish ladder provides for volitional capture of both Chinook salmon and steelhead
- A fish ladder induces the lowest amount of stress from handling

- A fish ladder has the highest capture efficiency of the potential adult capture options

Operating rules for adult fish capture would vary depending on the goal of a potential fish passage program. If the goal of a potential fish passage program would be to benefit the Chinook salmon exhibiting early upmigrant life history behavior, then the adult capture facilities should be operated from March through June. If the goal would be to protect or enhance the genetic integrity of a fish stock, the collection period should include the arrival period of all tagged fish that are progeny from the fish passage program. Implementation of measures to assure achievement of this fish passage program goal would include passage of any fish passage program tagged fish arriving from March through December. If the goal of the program would be to increase total Chinook salmon production, any fish could be collected at any time from March through December. If the fish passage program goal would be to benefit steelhead, the adult capture facility would be operated from September through mid-April with expected peak activity occurring during October and November. The current fish ladder likely would not successfully function for potential sturgeon fish capture.

6.3.2 Adult Fish Sorting

Fish sorting and tag reading (optional) would most efficiently be accomplished at the FRFH using facilities purpose built and scaled to the maximum number of fish intended to be included in a potential fish passage program. Design elements and capacity criteria of the sorting and tag reading facilities depend on the goals selected for a potential fish passage program as well as the phasing anticipated on the number of fish to be included in the program. If the ability to reliably identify returning adults from juvenile fish passage program releases to isolate a specific group of fish with the goal of protecting or restoring the genetic integrity or distinctness of the species or run selected for a potential fish passage program, a sophisticated tag reading system would be required. Additionally, if large numbers of fish are intended to be passed in a potential fish passage program, then an automated sorting system would be important to the success of the program. Costs and complexity of the sorting and tag reading system would be directly proportional to the sophistication and capacity of the system design. Another sorting operational goal could be to achieve a 1:1 sex ratio to maximize biological productivity of the fish passed.

Hand sorting (after appropriate anesthetizing) and hand tag readers are recommended over the automated sorting alternative for the following reasons:

- The maximum capacity of the upstream tributaries for the number of fish that could be passed in a fully implemented fish passage program, assuming currently available estimated spawning habitat and no redd superimposition, is approximately 28,000 adult fish. 28,000 fish handled over a 3-month period of

time could successfully be accomplished manually without the added cost and complexity of automated sorting systems.

- Chinook salmon, steelhead, and green sturgeon could easily be manually distinguished from non-target fish species with very little likelihood of identification error.
- Hand scanners could be effective for reliably detecting tags if personnel are properly trained.
- Manual sorting and hand scanners require less capital expenditure than automated tag readers and their associated sorting systems.
- Automated sorting and tag reading systems could always be added at a later phase of the fish passage program if desired either for labor cost savings or to reduce sorting-related stress.

6.3.3 Adult Fish Holding

Adult fish holding also is recommended to occur at the existing FRFH if no irreconcilable conflicts are found with the current or anticipated hatchery operations. A recommended operational guideline for adult holding is to minimize the duration of holding to 24 to 48 hours or less. New holding tanks to facilitate water to water transfer from sorting to truck transport would need to be constructed or modified from existing holding tanks. The size and flow requirements of the holding tanks depends on the number of fish to be included in the fish passage program, the temporal distribution of arriving adult salmonids, the holding density tolerances, flow requirement per adult, and the holding duration of the fish. The FRFH currently has 4 holding tanks with a capacity of approximately 2,000 fish each (based on appropriate short term duration holding densities). Assuming a minimum duration of fish holding and the maximum number of fish that could potentially be included in a potential fish passage program, the existing hatchery tanks would accommodate peak periods of adult immigration.

6.3.4 Adult Fish Transfer and Transport

Adult truck transport is the alternative transportation mode that was found to be the most cost effective, logistically flexible, and had the highest survival rate of transported fish compared to other transportation mode alternatives examined. The use of trucks for adult fish transport is well understood with low operating risks and readily available appropriate equipment sources. Additionally, the use of the same trucks for both adult and juvenile transport at different locations and at different timing of peak utilization was an additional favorable and synergistic attribute for the truck transportation alternative. The number of trucks required would be dependent upon the number of fish included in the fish passage program, the temporal distribution of the arrival of adult fish, the design capacity of trucks for the specified fish transport density, and on the adult fish release location option selected. The SP-F15 Task 4 Fish Passage Model provides a calculation to determine the number of trucks based on all of the fish passage program variables identified above.

Adult fish transfer from holding tanks to trucks is recommended to be conducted via water to water transfer, which would require specific design of the holding and truck transfer facilities, and may require additional facilities costs. However, water to water transfer has several desirable attributes compared to netting or tube transfer of fish including:

- Reduced fish stress and associated mortality
- Reduced labor and handling costs
- Reduced or eliminated need for fish anesthetizing for transport (and the associated fish stress and operational costs)

Adult release from the trucks would be recommended to be accomplished by quick release gates if direct access to the waters edge at the release location is feasible because it is the cheapest and least complex release mechanism alternative. If direct access is not available, the release mechanism can be supplemented with a relatively low cost flume or chute.

6.3.5 Adult Fish Release Location

There are two primary alternatives for adult fish release, in the upstream tributaries at or near the spawning locations or in Lake Oroville. The Lake Oroville adult fish release alternative is not considered desirable for the fish passage program for the following reasons:

- Surface water temperatures in Lake Oroville during the later portion of the anticipated early upmigrant Chinook salmon immigration period are warm enough to be harmful to the adult fish briefly exposed during release (see Figure 5.1-9)
- Adult release in Lake Oroville would provide more opportunity and cumulative disease pressure potential for the FRFH and lower Feather River than the alternative of the adult release in the upstream tributaries
- Lake Oroville release provides the potential for straying of program salmon into unrecoverable or incorrect tributaries causing either loss of progeny or genetic contamination of the population in other tributaries (if distinct stocks in different tributaries is a fish passage program goal)
- Lake Oroville release provides the potential opportunity for residualization of adult fish in the lake
- Although the current operations associated with Lake Oroville releases indicate that there is always some available coldwater pool habitat at some location within the lake (see F3.1 Task 2C Final Report), there was not suitable coldwater habitat in all tributary arms of the lake at all times evaluated. Changes in water temperature management in the lower Feather River may potentially affect the availability and distribution of coldwater pool habitat in the reservoir in the future

- Release of ESA listed species into Lake Oroville would likely require changes in the fishing regulations and could potentially reduce the management flexibility of the stocked coldwater fishery
- Operation of surface flow collectors in the tributary arms of the reservoir with their associated guide nets may effectively block adult immigration through the juvenile emigration period (mid-November through June), which may not be a conflict if the adults are placed upstream of the surface flow collector locations in the tributary arms or if the adults hold in the reservoir until after the juvenile collection period is completed
- Water temperatures in the lake epilimnion and tributary inflow temperatures could potentially present potential thermal barriers to salmonid immigration
- Sediment wedges in the upstream tributary arms of the reservoir could present a migration barrier to adults at some times (see F3.1 Task 1A Final Report). In years immediately following the formation of sediment wedges in the reservoir, upstream passage may be substantially affected. Based on analysis of current sediment wedge conditions, there may be delays in upstream migration during some years
- Big Bend Dam on the North Fork Feather River would only passable by immigrating adults during periods when Lake Oroville is at full pool or near full pool conditions (see SP-F3.1 Task 1A Final Report). In years when the reservoir is at or near full pool during the majority of the adult immigration period there would be no substantial effects on fish accessing upstream habitat, but in years when the reservoir is at or near full pool for only a portion of the adult immigration period, delays in upstream migration could result or late immigrating fish could be blocked from reaching the spawning areas. In years that the reservoir does not approach full pool at any time during the adult immigration period, disruption in adult upstream migration could occur. Future Oroville operations anticipate that the reservoir elevations may be reduced earlier in the year than historical operations, which may potentially reduce the frequency and duration of the passability of this potential fish passage barrier
- Big Bend Dam also is a potential site for nitrogen supersaturation to occur on the North Fork, which could lead to gas bubble disease under certain conditions, especially if fish are holding below the dam awaiting passable high reservoir stage elevation conditions
- Salmon Falls and Miocene Dam on the West Branch are only passable to immigrating adults during periods of high tributary flow (see SP-F3.1 Task 1A Final Report). In years when high tributary flows occur during the majority of the adult immigration period there would be no substantial problems with fish accessing upstream habitat, but in years when the high tributary flows occur only during a portion of the adult immigration period, delays in upstream migration could occur or late immigrating fish could be blocked from spawning areas. In years that high tributary flows do not occur at any time during the adult immigration period, serious disruption to the success of the fish passage program could occur. Salmon Falls also is a potential site for nitrogen supersaturation to

occur, which could lead to gas bubble disease under certain conditions, especially if fish are holding below the falls awaiting passable high tributary flow conditions

For the reasons described above, the release of the adult fish directly into the upstream tributaries was considered to be a more desirable option for a potential fish passage program than the alternative of adult release in Lake Oroville. In addition to the upstream tributary adult release option not having the potential problems identified with adult release in Lake Oroville, the upstream tributary release has some additional favorable characteristics for consideration.

- Adult fish access to holding conditions more closely approximates likely historical conditions
- Increased control over the spawning habitat utilization by putting only as many adult fish in an individual tributary area wherethere is sufficient spawning habitat to support them
- Placing a selected fish population within a tributary increases the likelihood of being able to achieve the potential fish passage program goal to protect or restore the genetic distinctness of a specific species or run

The upstream release locations would be determined by which tributaries were selected to be active in a potential fish passage program, by the spawning reaches targeted to be utilized, and by available physical road access opportunities (see Section 5.1.5.2). If upstream tributary fish screens are selected as a juvenile fish collection alternative, then the adult fish release location should be at or upstream from the anticipated juvenile collection locations.

Of the four main tributaries to Lake Oroville for consideration for inclusion in the fish passage program, the most potentially suitable for the fish passage program are the West Branch and North Fork. The Final Report for SP-F15 Task 2 provides detailed analyses of available habitat for each life stage of Chinook salmon and steelhead by tributary. Additional water temperature monitoring or experimental releases of adult or juvenile fish could be required to definitively determine habitat suitability of these tributaries.

If the West Branch were selected for inclusion in a potential fish passage program, the recommended adult release location would be just above the Miocene Dam. The West Branch at Miocene Damhas the following favorable characteristics.

- It is the farthest downstream location with identified road access above the Oroville reservoir for the West Branch
- The location provides access to the most quantity of potential spawning and rearing habitat

- The location is the site of the most favorable location for juvenile fish capture using an off-channel fish screening facility
- Higher flows just upstream of the Miocene Canal Diversion provide increased likelihood of suitable water temperatures for salmonid holding and spawning

If the North Fork were selected for inclusion in the fish passage program, the recommended adult release location would be just above the Poe Powerhouse outlet. The North Fork above the Poe Powerhouse Outlet adult release location has the following favorable characteristics.

- It has the best road access available in the North Fork
- The location provides access to the most quantity of potential spawning and rearing habitat
- The location is the site of the most favorable location for juvenile fish capture using off-channel fish screens

The Middle Fork is not currently recommended as an option for inclusion in the fish passage program for the following reasons:

- There is no road access to the Middle Fork above Lake Oroville high pool and below the first upstream impassable fish barrier
- Tributary flows during juvenile emigration and steep terrain make the feasibility of tributary juvenile collection facilities unlikely (see SP-F15 Task 4 Appendix A – Biological Relationships, Proportional Juvenile Capture)
- Capture of juvenile outmigrants using only a gulper system in the reservoir would result in low fish passage program production efficiencies. Gulpers reportedly have 22percent to – 79 percent capture efficiencies, which would not be conducive to establishing a successful rate of production
- The Middle Fork is designated by DFG as a “wild and heritage trout” stream and a “wild and scenic river” by the Interagency Wild and Scenic Rivers Coordinating Council, which includes: Bureau of Land Management, National Park Service, U.S. Forest Service, and U.S. Fish and Wildlife Service. A potential fish passage program would conflict with the ability of fish to move into the tributary and in the case of a potential steelhead program could cause potential non-volitional inclusion of resident wild and heritage trout into the fish passage program and the potential construction of access roads or fish capture facilities could potentially conflict with the “wild and scenic river” designation

The South Fork is not recommended for inclusion as an option in the fish passage program as there is no spawning habitat available above the fluctuation zone and below the first impassable fish barrier in this tributary. Juvenile rearing habitat is similarly not available above the fluctuation zone and below the first impassable fish barrier. Habitat quality within the fluctuation zone is subject to seasonal and annual availability from

reservoir inundation, low tributary flows, little cover and periodic sediment wedge deposition.

6.3.6 Juvenile Fish Collection

There are two types of juvenile fish collection alternatives, tributary fish screen facilities and in-reservoir surface flow collector (gulper) systems. These alternatives can be potentially be utilized individually or in combination. Due to the disadvantages listed below, the tributary fish screen is the more desirable option for the fish passage program.

Disadvantages of the in-reservoir surface flow collector include:

- Comparatively low fish capture efficiencies of 22 percent to 79 percent compared to tributary fish screen efficiencies of 95percent
- Capital costs of approximately $10,000,000 per tributary
- Annual operating and maintenance costs of approximately $1,300,000 to $2,000,000 per tributary (see SP-F15 Task 4 Final Report)
- Guide nets potentially block upstream migration of adult salmonids released into Lake Oroville for the fish passage program
- Guide nets conflict with boating recreation access and boating safety as well as restrict resident reservoir fish movements

The in-reservoir surface flow collector is not recommended for operation in conjunction with the upstream tributary fish screen facility due to the small incremental fish capture efficiency improvement and the resulting substantial increase in the program cost for the surface flow collector. For example, if the upstream off channel fish screen is designed with a 95 percent capture efficiency (per NOAA Fisheries performance requirements) and the facility is sized to accommodate 95 percent of the flows that occur during juvenile emigration then the total effective tributary screen juvenile capture would theoretically be approximately 92.5 percent of the emigrating juvenile salmonids. The 92.5 percent estimate makes many assumptions and is useful for illustrative purposes only, but theoretically would mean that a surface flow collector would only have the opportunity of capturing approximately 7.5 percent of the emigrating juveniles that passed the tributary screens. The surface flow collector capture efficiency ranges from 22 percent, 50 percent, and 79 percent efficiency for worst case, expected and best case scenarios in the Fish Passage Model respectively (See SP_F15 Task 4, Appendix A for justification of capture efficiency ranges). At the expected efficiency of 50 percent, this would mean that the surface flow collector would capture approximately 3.75 percent of the total emigrating juveniles. The incremental 3.75 percent of fish captured would more than double the juvenile collection costs even with the most expensive of tributary fish screen collection cost assumptions. Given the capital and O&M costs of the surface flow collector and the small incremental improvement that it would be expected to contribute to the overall juvenile salmonid capture efficiency, the surface

flow collector used in conjunction with the tributary fish screen is not recommended for inclusion in a potential fish passage program.

There are two types of upstream tributary fish screen facilities considered for inclusion in a potential fish passage program; removable fish screens in the tributary channel, and an off-channel fish screen facility. Although the removable screens are low capital cost, because they are limited application to flow ranges of less than approximately 1200cfs (See SP-F14 Task 4, Appendix A for justification). The flows of all of the potential upstream tributary river reaches average flows are substantially higher than the 1200 cfs index value, so the amount of time that the removable fish screen would be operable during the juvenile salmonid emigration period would be limited. Therefore, the effective capture efficiency of removable instream screens is relatively low. The off-channel flow diversion fish screen facility is substantially more expensive than the removable screen, but the off-channel screen capacity can be designed to match the flow ranges in the tributary reach during the juvenile emigration period to ensure high effective juvenile fish capture efficiencies. Physical off-channel space is required for this type of tributary juvenile fish capture device. Several locations on the West Branch and North Fork Feather River may be suitable to this type of installation.

Of the four main tributaries to Lake Oroville the most potentially suitable for purposes of implementing a potential fish passage program are the West Branch and North Fork. The Final report for SP-F15 Task 4 provides detailed evaluation of the habitat suitability of the tributaries to Lake Oroville for juvenile salmonids. Additional water temperature monitoring or experimental releases of juvenile fish may be required to definitively determine habitat suitability of these tributaries. No suitable locations for an off-channel screening facility were identified in the Middle Fork or South Fork and as such they are not recommended for inclusion in a potential fish passage program.

The recommended location for the juvenile collection facility on the West Branch is at Miocene Dam, which has the following desirable characteristics for a potential juvenile capture facility location.

- Upstream from Miocene Dam was the recommended location for adult fish release for the West Branch. Juvenile collection should be below the location of adult release
- Miocene Dam is the downstream most location identified for West Branch access
- This location provides the most potential quantity of rearing habitat without having to move juvenile capture into the reservoir, which is not recommended
- Miocene Dam has existing road access and physical space adequate to potentially support a juvenile capture facility
- It may be possible to engineer the fish capture facility onto the existing structure, which may reduce the construction costs
- Miocene Dam diverts a substantial portion of the summer flows in the West Branch, so collecting the juvenile salmonids at this facility prevents the fish from

being subjected to potentially elevated water temperatures associated with the reduced flows lower in the tributary

The recommended location for a tributary juvenile fish collection facility for the North Fork Feather River is just upstream from the Poe Powerhouse, which has the following desirable characteristics for a potential juvenile capture facility location.

- This location was the recommended location for adult fish release for the North Fork. Juvenile collection should be at or below the location of adult release
- This location has good road access and adequate physical space for an off-channel fish screen facility
- The Poe Powerhouse return increases the flows in the North Fork, so selecting a location upstream from the powerhouse the flow criteria for the screen design and provides the most potential quantity of rearing habitat

Fish screens can generally cost approximately $1500 per cfs of design criteria (pers. com. C. Hanson, 2004). Ninety-fifth percentile of flows at the Yankee Hill gage station on the West Branch, which could be used as a target flow capacity for an off-channel fish screen are 1,720 cfs and would result in an approximate cost of $2,500,000 for construction. The North Fork has 95th percentile flows of 6,070 cfs during the juvenile Chinook salmon emigration period at the Pulga gage station, and would result in a facility cost of approximately $9,100,000. These estimates do not include the costs for environmental permitting or land purchase, but both screen options are lower capital and annual O&M cost than the other juvenile salmonid collection option of a surface flow collector system in the reservoir.

6.3.7 Juvenile Fish Sorting and Tagging (optional)

Juvenile fish sorting facilities are recommended at each juvenile collection facility selected for the fish passage program. The sorting facilities at each juvenile collection location is more desirable for the fish passage program than a single centralized fish sorting option for the following reasons.

- Avoids compounding stress and associated mortality due to multiple handling events associated with transporting fish to a centralized sorting facility
- Eliminates any fish collected that are not to be included in the fish passage program and allows for their return to their appropriate tributary and location with minimum disruption to resident fish that may be collected, e.g. resident rainbow trout

Utilization of a large screen mesh or bar size exclusion sorter between the juvenile collection device and the temporary holding tanks to allow juveniles into holding facilities while excluding adult or larger sized fish is the first step recommended in a fish sorting process. The mesh size should be large enough to accommodate larger juvenile

salmonids for stream type rearing behavior. The size of the screen or bars may need to be adaptively managed to optimize the exclusion of predators and maximize the juvenile fish capture.

Juvenile fish collected should then be sorted to eliminate any non-target species from tagging or holding. In the beginning of the fish passage program, manual sorting is recommended because the ability to differentiate Chinook salmon fry and par from other species present is considered reliable. In the case of a steelhead fish passage program, differentiation of resident rainbow trout from steelhead fish passage program progeny may be impossible and is a potentially significant conflict with rainbow trout fisheries management in the upstream tributaries. Manual fish sorting has a low capital cost for the associated facilities, but is labor intensive in proportion to the number of fish to be sorted. As a potential fish passage program matures and the number of fish passed increases, the capital intensive option of automated sorting may need to be re-evaluated.

Juvenile fish tagging is recommended for the fish passage program as a tool to monitor and evaluate various elements of the fish passage program performance and efficiencies. Different types of tagging programs would be required depending on the potential goals of a potential fish passage program.

Although one of the most important goals of a potential fish passage program is to restore or protect the genetic integrity of a fish stock, a potential fish passage program would need to be able to reliably and consistently identify the returning adults that were juveniles released from the program in order to achieve the goal. Reportedly, only a few percent of fish from outside of an isolated population would affect the genetic distinctness of the entire group. In order to be able to reliably identify all of the returning adults to isolate a distinct genetic population, all of the juveniles released from the fish passage program would need to be tagged. PIT tagging can reliably identify returning individuals without having to sacrifice the fish, which makes it functionally suitable to support this potential fish passage goal. PIT tagging requires juvenile fish to be 60mm or longer and even with prolonged stream type rearing behavior, many of the captured juveniles may not be large enough to tag. One potential solution to this juvenile fish size at capture problem would be to hold the fish until they were large enough to tag, but this would conflict with the premise of the fish passage program to minimize the number of times and duration of interactions with the fish. PIT tagging is expected to cost approximately $4.50 per juvenile fish and tagging all juvenile fish would be very costly as an annual O&M expense. For example, the current juvenile release to adult return ratio expected in the SP-F15 Task 4 Fish Passage Model is 1 adult per every 122 juveniles released would return. The one returning adult in this example would have cost over $550 in tag costs alone. If a modest fish passage program were only passing 1,000 adults this would contribute $550,000 to the annual O&M costs. For all of these reasons, PIT tagging is not recommended as a means to reliably isolate a genetic population to protect or restore its' genetic integrity. PIT tagging is still a viable tool for

selected monitoring programs to evaluate the performance of specific fish passage program elements, but would only be recommended for use in specifically designed and limited experiments.

CWT's are much less expensive per fish and do not have a juvenile fish size tagging constraint, but they do require that a fish be sacrificed in order to be able to read the tag. Tag reading typically is performed in a laboratory, so it cannot be used as a "real time" data source for fish management (i.e..egg removal from a sacrificed passage program fish). CWT's may be potentially viable to identify a specific group of fish if it is combined in a unique combination with another tagging method. Current hatchery practices are to adipose fin clip all CWT'd fish. If a potential fish passage program uses CWT's on all juveniles released and does not remove any adipose fins, then passage program fish could potentially be reliably distinguished from hatchery tagged individualsReliably identifying the returning adults released as juveniles from a potential fish passage program relies upon the assumption that all other CWT'd fish are adipose fin clipped. Use of this method to isolate a returning adult population would require the use of automated scanners in adult fish sorting chutes in the hatchery. Scanners cost between $5,000 and $10,000 and will require labor to push individual fish through the process and to manually determine the presence of an adipose fin of those fish with tags. All adults passing into the hatchery would need to be scanned for CWT's.

If the fish passage program goal is to increase salmonid production, CWT's are recommended as an effective tool to measure and evaluate the fish passage program performance and contribution to increased salmonid production. Monitoring the fish passage program performance is essential to ensure that the program is providing positive benefits to the target species. Information from this tagging and evaluation program also would lead to potential insights on opportunities for fish passage program and performance improvements. Because the initial performance of the fish passage program is uncertain, significant portions (30 percent to 50 percent), of the juveniles captured should be tagged in the first 3 to 5 years of the program. After the initial performance of the program can be evaluated, the fractional marking program could potentially be revised to less intensive and less expensive levels.

CWT's can either be collected at the hatchery as the adults are captured or from a carcass survey in the upstream tributaries to Lake Oroville. In either case, additional O&M costs for reading the tags will be proportional to the number of tags read. Because fish must be sacrificed to read CWT's tag reading does not provide real time results. Early upmigrant adult Chinook salmon and steelhead generally are not sexually mature at the time of immigration, thus, removal of the eggs or sperm of a fish collected at the hatchery is not a feasible fish passage program option. Fish sacrificed from sampling at the hatchery would effectively be lost returns from the program. If the program is returning close to a 1:1 adult release to adult return ratio, then sacrificing enough fish to establish statistically reliable performance measures may conflict with the ability of the program to be sustainable. Carcass surveys are labor intensive, add to the

annual fish passage program O&M costs, and would be difficult to implement in the rugged terrain in the upstream tributaries to Lake Oroville. Deep pools and physically inaccessible reaches of the upstream tributaries would reduce carcass recovery efficiencies. Although the carcass survey would add to the annual O&M costs of the program, the survey is recommended as the method for CWT recovery at the outset of the program. The survey would have the added benefit of improving the program's knowledge of the spawning temporal and spatial distribution and habitat utilization. The carcass survey results could lead to insights that could improve spawning habitat utilization, improve adult upstream tributary release location selection, and improve target numbers of fish to be released in each tributary reach. The carcass survey would not need to be implemented until the third year of the program because that would be the year that enough CWT's from the first year's release would be expected to provide the first evaluations of the overall fish passage program performance. The cost of the carcass surveys in the upstream tributaries was not included SP-F15 Task 4 Fish Passage Model cost calculations.

If the fish passage goal is to provide access to conditions more closely approximating historical conditions, then the program is still recommended to incorporate a CWT monitoring program as described for the fish passage program goal for increasing total salmonid production. Monitoring of the fish passage program performance is recommended to ensure that the program is providing benefits to the target species or run selected in the fish passage program. If the program is not monitored then there is a risk that the number of adult fish returning to the program would be substantially lower than the number of fish passed, effectively reducing total salmonid production and creating an artificial disadvantage to the target fish at a substantial program cost that could otherwise be applied to other Resource Actions that could potentially provide benefits to the same target fish at a lower cost and a lower risk of failure.

6.3.8 Juvenile Fish Holding

Juvenile fish holding is recommended to occur at each location of juvenile collection selected for the fish passage program. The fish holding tanks are recommended to be adjacent to the fish sorting and tagging station and should be designed for water to water transfer to the transport trucks through the use of either gravity or pumps, depending on the physical conditions at the upstream juvenile fish capture facilities. Net pens would be recommended for juvenile fish holding at the surface flow collectors (surface collectors are not recommended for juvenile capture). Use of the net pens late in the juvenile collection season during May, should be monitored for surface water temperatures in the Lake that may not be suitable for juvenile fish holding. In either holding option, the fish are recommended to be transported within 24 to 48 hours or less to minimize fish stress and duration of holding.

6.3.9 Juvenile Fish Transport

Juvenile fish transport could be accomplished either by trucking from the upstream tributaries or from a combination of barge and truck transport from the surface flow collectors in the Lake Oroville tributary arms. Because the juvenile collection option of using surface flow collectors is not recommended, the barge and truck option also is not recommended. The recommended transportation option for juvenile fish transport is trucking from the selected upstream tributary capture locations to the lower Feather River. This transportation mode eliminates one transfer of juveniles from barge to truck and reduces the amount of juvenile fish mortality and costs associated with juvenile fish transport. Juvenile fish transport is expected to occur during the juvenile Chinook salmon emigration period of mid-November through May with the peak emigration expected to be completed by the end of March if the juvenile emigration temporal distribution is similar to that observed in the lower Feather River. The timing of peak truck utilization is complimentary to the expected timing of peak early upmigrant Chinook salmon immigration timing occurring in May and June. If the fish passage program includes steelhead, the smolt emigration period is January through June. Expected peak adult immigration timing of steelhead in October and November would also provide for complimentary utilization timing of trucks. It is anticipated that trucks designed for adult transport would be large enough to accommodate all of the juveniles that would be anticipated to be collected at a single juvenile collection facility with one trip per day. Round trip times from the upstream tributary juvenile collection locations to various juvenile fish release locations in the Lower Feather River are expected to range from 3 to 6 hours, indicating that a truck would be able to make from 4 to 8 trips per day. This truck utilization assumes up to 3 working shifts per day during peak truck utilization.

6.3.10 Juvenile Fish Release

Juvenile fish release locations originally were considered for various locations in the lower Feather River for in-river releases, net pen barging down portions of the lower Feather River for release in San Pablo Bay, or for truck transport to San Pablo Bay for release. The later two juvenile release options were eliminated from further consideration due to their lack of practicality in the case of the net pen barge, and for loss of fish emigration exposure to predator avoidance behavior development and the undesirable resulting straying rates of those fish deprived of the opportunity to develop homing cues during natural emigration through the river systems. As a result, juvenile fish release at various locations in the lower Feather River is recommended for the fish passage program. Release locations are recommended to be varied in timing and location to reduce the amount of predation concentration that could otherwise develop. Location and timing of juvenile fish release should be adaptively managed to maximize juvenile emigration survival.

One potential operational strategy for juvenile release to improve emigration survival rates would be to begin a sequence of juvenile releases at the most upstream portion of the lower Feather River and progressively move downstream in subsequent fish

releases to create a pulse of emigrating juvenile fish. This release strategy is designed to overload the predator community during the pulses of juvenile fish passing and would likely not be successful under some combinations of conditions. Additionally, the strategy is dependent upon the range of uniformity of juvenile emigration rate, knowledge of the juvenile emigration rate (i.e. through monitoring with RST's), and the number of juvenile fish to be released in proportion to the consumption capacity of the predator base.

6.4 FISH PASSAGE PROGRAM FEASIBILITY ASSESSMENT AND IMPLEMENTATION PHASING CONSIDERATIONS

Before a potential fish passage program is implemented there should be a reasonable expectation that the program would achieve the minimum sustainable goal of a 1:1 ratio of 1 adult returning for each adult transported past the Oroville Facilities or there should be a limited and specific program of testing those fish passage program variables that are critical to the success of the fish passage program to reduce the level of uncertainty and determine if a sustainable fish passage program is reasonably feasible.

The SP-F15 Task 4 Fish Passage Model presents expected results for an adult return to adult passed ratio that currently is 0.56:1, using the model values and assumptions that are current as of June 14, 2004. The current model alternatives selected utilize the combination of program components and options that result in the highest fish passage program biological performance possible, regardless of program cost. An adult return to adult passed ratio of 0.56:1 indicates that, given the options selected to be part of the passage program in the model including the biological values developed in cooperation with the Environmental Work Group Task Force, a fish passage program would need to perform almost twice as well as currently expected in order to be successful and sustainable. Justification of the biological values chosen for inclusion as default values in the Fish Passage Model is presented in Appendix A of the Final Report of SP-F15 Task 4. Although there potentially are opportunities to continue to refine some of the biological values utilized in the model, it is unlikely that further refinements would lead to substantial changes in the model outcome. The last round of refinements completed at the request of the collaborative participants resulted in a reduction in the expected performance of the fish passage program. Comparisons of elements of the Fish Passage Model results to observed results of juvenile release to adult return ratios in the Feather River and other systems indicate that the model is fairly robust and provides values that are relatively similar to these "reality" tests. Because of the level of testing of the biological values used in the model provides results consistent with program reality tests, it is considered unlikely that the actual fish passage program could be expected to perform over 179 percent better than predicted in the model.

If the feasibility of the fish passage program remains uncertain, then the fish passage model could be used to establish performance targets that would be required for an actual fish passage program to achieve to meet the performance target of a 1:1 adult

passed to adult return ratio. A systematic program for testing the actual performance for these critical variables can be developed and should include the following elements and considerations.

Significant contributors to overall fish passage biological performance that are within the ability of the fish passage program to influence include adult prespawn mortality, and egg to smolt survival (includes egg deposition through in-river rearing to initiation of smolt emigration). Other fish passage program variables are expected to have very small proportional contributions to overall biological performance or are biological performance variables that are beyond the influence of a potential fish passage program (i.e. ocean cycle survival).

Components of adult prespawn mortality and egg to smolt survival can be tested systematically for potential performance in the West Branch and North Fork. The first tests would require detailed upstream water temperature monitoring data collection for Chinook salmon and steelhead holding pools and spawning riffles. A preliminary plan for the water temperature data collection has been drafted by DWR, but has not yet been approved for implementation. The water temperature monitoring results could be compared to the immigration and holding, and the spawning and egg incubation life stages water temperature index values developed for Chinook salmon and steelhead to determine water temperature suitability to support a potential fish passage program. A similar analysis of water temperature suitability for these fish species and life stages was conducted in SP-F15 Task 2 report, but the analysis was limited by the availability of comprehensive water temperature data that definitively characterized the conditions in these specific habitat types.

The second analysis of the suitability of the upstream tributary water temperature data could subsequently be evaluated for the proportion of egg survival from adult arrival (in-vivo) through egg deposition, to the end of egg incubation to determine the percentage of egg survival that would be expected with the temporal distribution of spawners and water temperature regimes recorded in the upstream tributaries. This evaluation could be accomplished by adapting the USBR's LSALMON 2 salmon mortality model for the lower Feather River. The results of the survival rates from the salmon mortality model could be used to refine the SP-F15 Task 4 Fish Passage Model biological values to reflect the expected productivity based on observed conditions in the upstream tributaries. Potential future changes in the water temperatures in the North Fork from water temperature management actions at upstream hydroelectric facilities could also be evaluated using the described evaluation strategies.

If the model value refinements from the upstream water temperature evaluations improve the fish passage model results to a 1:1 or better adult return to adult released ratio, then the fish passage program could potentially be viable. Only if these results were inconclusive or close to a 1:1 adult return to adult passed ratio would the next phase of actual experimental adult releases be recommended to further evaluate the

feasibility of the fish passage program. Experimental releases would involve the release of 30 to 50 radio tagged adult Chinook salmon in the upstream tributary for monitoring of holding and spawning habitat utilization preferences, timing of spawning, and adult prespawn mortality rates. Experimental permits would be required from NOAA Fisheries, disease concerns of CDFG would need to be resolved, and appropriate fish would need to be captured, tagged, transported, released, and monitored in the upstream tributaries. Additionally, if redds are successfully constructed and located, a redd cap or emergent fry trap could be deployed over a selected number of redds to measure the number of emergent fry produced per redd. These salmonid production rates would be used to refine the biological values used in the fish model to determine if the actual conditions could achieve the target performance levels required to achieve a sustainable fish passage program.

Only if these results were inconclusive or if the range of remaining uncertainty in the likely outcome of the fish passage program performance were still in question would the following incremental extension of the above experiment be recommended. The emergent fry captured in the redd cap could be tagged and released to rear in the river for recapture downstream either through seining, fyke net or an RST during juvenile emigration to determine juvenile rearing survival rates. The juvenile capture efficiencies of these devices tend to be low, so a substantial emigrating juvenile capture effort would need to be applied in order to achieve a high enough recapture rate to have statistically reliable results for use in refining the model values. The combined survival from egg deposition through smolt emigration values could then be used as the basis for refined values in the fish passage model to determine if the actual performance of these critical fish passage variables was sufficient to achieve a sustainable level of performance for the fish passage program. If the performance of the model was close to a 1:1 return ratio after further refinement using observed in-river rearing survival rates, a predation management program could be evaluated to determine if the mortality contribution of in-river predation to in-river juvenile rearing survival rates could be reduced to a level that would allow the program to be successful.

In the event that the fish passage program is determined to be feasible as well as cost effective and desirable, the program should be phased into operation to manage the incremental introduction of complexity and capital cost requirements. Factors for consideration for the phased implementation of the fish passage program include:

- Number of adults available to start to initiate the program from the selected target fish. This number of available fish would be determined by the number of fish vs. the biological risk of the program to the viability of the remaining population
- A minimum number of tributaries should initially be selected to accommodate starting number of fish
- The first tributary activated in the program should be the one with the best quality habitat and existing compatible infrastructure, which would probably be the North Fork

- Low numbers of fish could be sorted and tagged manually and automated sorting and tagging capabilities and capital investments could be implemented at a later phase of the program
- The fish passage program should only be expanded beyond the initial levels if the first returning year class fish indicate a sustainable fish passage program performance. If performance levels are below sustainable levels, the program should be evaluated for opportunities for improvement and those programs should be implemented successfully if the program is to be continued
- Additional tributaries should only be added as the maximum habitat capacity is reached to maximize the utilization efficiency of the fish passage program assets.

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