State of California
The Resources Agency
Department of Water Resources

PHASE 2 REPORT
EVALUATION OF PROJECT EFFECTS ON INSTREAM FLOWS AND FISH HABITAT
SP F-16

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

The Oroville Project substantially controls flow in the Feather River from the fish barrier dam near Oroville to the confluence with the Sacramento River. Instream flows have been identified as an important factor for Chinook salmon and steelhead production in the Feather River (USFWS 1995). Minimum flow releases were established by a 1983 agreement between Department of Water Resources and California Department of Fish and Game. DWR and DFG jointly conducted an instream flow study utilizing Physical Habitat Simulation (PHABSIM) beginning in 1991. Initial analysis suggested that the maximum area of suitable Chinook salmon spawning habitat between the Fish Barrier Dam and Thermalito Afterbay Outlet occurred at a flow of approximately 1,000 cfs (Sommer et al. 2001). In the fifteen miles of river between the Thermalito Afterbay Outlet and Honcut Creek, maximum suitable spawning habitat area was indicated to occur at a flow of about 3,250 cfs (Sommer et al. 2001).

A study plan was prepared by the Oroville Facilities Relicensing Environmental Work Group (EWG 2002) to guide a review of the DWR instream flow studies as part of relicensing activities. The objective of the review was to examine existing PHABSIM results, collect and analyze additional hydraulic and biologic data to supplement existing data, and establish tools to evaluate future potential operational scenarios and other protection, mitigation, and enhancement measures. The primary evaluation tool is the weighted usable area (or relative suitability index) relationship between habitat area and discharge for Chinook and steelhead spawning and rearing. The review was completed in two phases: the Phase 1 review of existing information was previously reported in TRPA (2002a) and the remainder of the work is presented here.

Principal activities of Phase 2 included placing supplemental PHABSIM cross-section transects, measuring patterns of depth, velocity, substrate and cover along the transects, merging old and new data, calibrating revised PHABSIM computer models, and computing updated habitat indexes relating suitable spawning habitat to discharge in the two reaches. The revised analysis showed Chinook spawning habitat between the Fish Barrier Dam and Thermalito Afterbay Outlet to maximize between 800 and 825 cfs, and between the outlet and Honcut Creek at 1200 cfs.

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1.0 INTRODUCTION

In 1995, the Feather River Technical Team of the Anadromous Fish Restoration Program Core Group listed instream flows as an important limiting factor for Chinook salmon and steelhead production in the Feather River (USFWS 1995). The FRTT further suggested that inadequate flows may limit spawning and rearing habitat for anadromous salmonids. Minimum flows in the Feather River downstream of the Fish Barrier Dam were established by a 1983 agreement between DWR and DFG. The agreement establishes criteria for flow for the reach of the Feather River from the Fish Barrier Dam to the Thermalito Afterbay Outlet and the reach of the Feather River downstream of the Thermalito Afterbay Outlet to the confluence with the Sacramento River for preservation of salmon spawning and rearing habitat (DWR and CDFG 1983).

Flow releases specified by the agreement include a minimum of 600 cfs downstream of the Fish Barrier Dam and amounts ranging from 1,200 to 1,700 cfs during the primary spawning and incubation period (October-February), and from 1,000-1,700 cfs during March in the Feather River downstream of the Thermalito Afterbay Outlet, with some conditions. In practice, the flows are maintained less than 2,500 cfs from October 15 to November 30 to prevent spawning in the overbank areas (DWR 2001).

The FRTT suggested that instream flow studies be completed to determine what flows might be required to enhance the river's salmonid stocks. Additional flow between the Fish Barrier Dam and the Thermalito Afterbay Outlet from September through May could enhance spawning habitat without an adverse effect on rearing (USFWS 1995). Initial results from a jointly conducted DWR and DFG instream flow study utilizing PHABSIM suggested that spawning habitat in the reach from the Fish Barrier Dam to the Thermalito Afterbay Outlet would be maximized at higher flows than the present level of 600 cfs (DWR 1994). Additional PHABSIM analysis suggests that the maximum area of suitable spawning habitat in the upper segment was indicated to occur at a flow of approximately 1,000 cfs (Sommer et al. 2001). In the fifteen miles of river between the Thermalito Afterbay Outlet and Honcut Creek, maximum suitable spawning habitat area was indicated to occur at a flow of about 3,250 cfs (Sommer et al. 2001).

A study plan was prepared by the Oroville Facilities Relicensing Environmental Work Group (EWG 2002) to guide a review of the DWR instream flow studies. This review was conducted in two phases, the first of which examined existing PHABSIM studies (TRPA 2002a), and the second of which is presented here. Phase 2 derived from the conclusions of Phase 1 and includes collection of supplemental hydraulic data and incorporation of additional biological data to calculate revised habitat-flow relationships in the two reaches of the Feather River. Phase 2 establishes tools to evaluate future potential operational scenarios and other PM&Es.

This summary report of Phase 2 includes:

- A description of the project area, facilities, and operations
- Instream flow study methods
- Recalibration of the hydraulic data base
- Habitat criteria validation and selection
- Computation of habitat index relationships
- Conclusions and recommendations

Although habitat suitability criteria and weighted usable area were calculated for Chinook salmon and steelhead fry and juvenile rearing lifestages, the applicability of the results continue to be reviewed and analyzed and remains under consideration, and were not included in this report. Results derived for adult Chinook salmon and steelhead lifestages appear to remain applicable and are, therefore, included in the report.

1.1 BACKGROUND INFORMATION

1.1.1 Study Area

The study area for the SP F-16 Evaluation of Project Effects on Instream Flows and Fish Habitat consists of the 23.25 miles of the Feather River between the Fish Barrier Dam and Honcut Creek

1.1.1.1 Description

The study area for the SP F-16 Evaluation of Project Effects on Instream Flows and Fish Habitat consists of the 23.25 miles of the Feather River between the Fish Barrier Dam and Honcut Creek, which contains two river segments. The first segment (Upper Reach) extends from the Fish Barrier Dam at river mile (RM) 67.25 to the Thermalito Afterbay Outlet (RM 59). Substrates in this segment are composed of relatively large elements with armoring due to transport of gravels downstream out of the area (Sommer et al. 2001). The river drops a total of 37 feet in this 8.25 mile-long segment, for a stream gradient of about 0.08 percent.

The second river segment (Lower Reach) is the portion of the Feather River which extends from the Thermalito Afterbay Outlet downstream to the confluence with Honcut Creek, near Live Oak (RM 44) about 15 miles. The substrate in this segment of the Feather River tends to include relatively small gravel-sized particles transported from the upstream segment (Sommer et al. 2001). Stream gradient is about 0.06 percent.

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, 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.

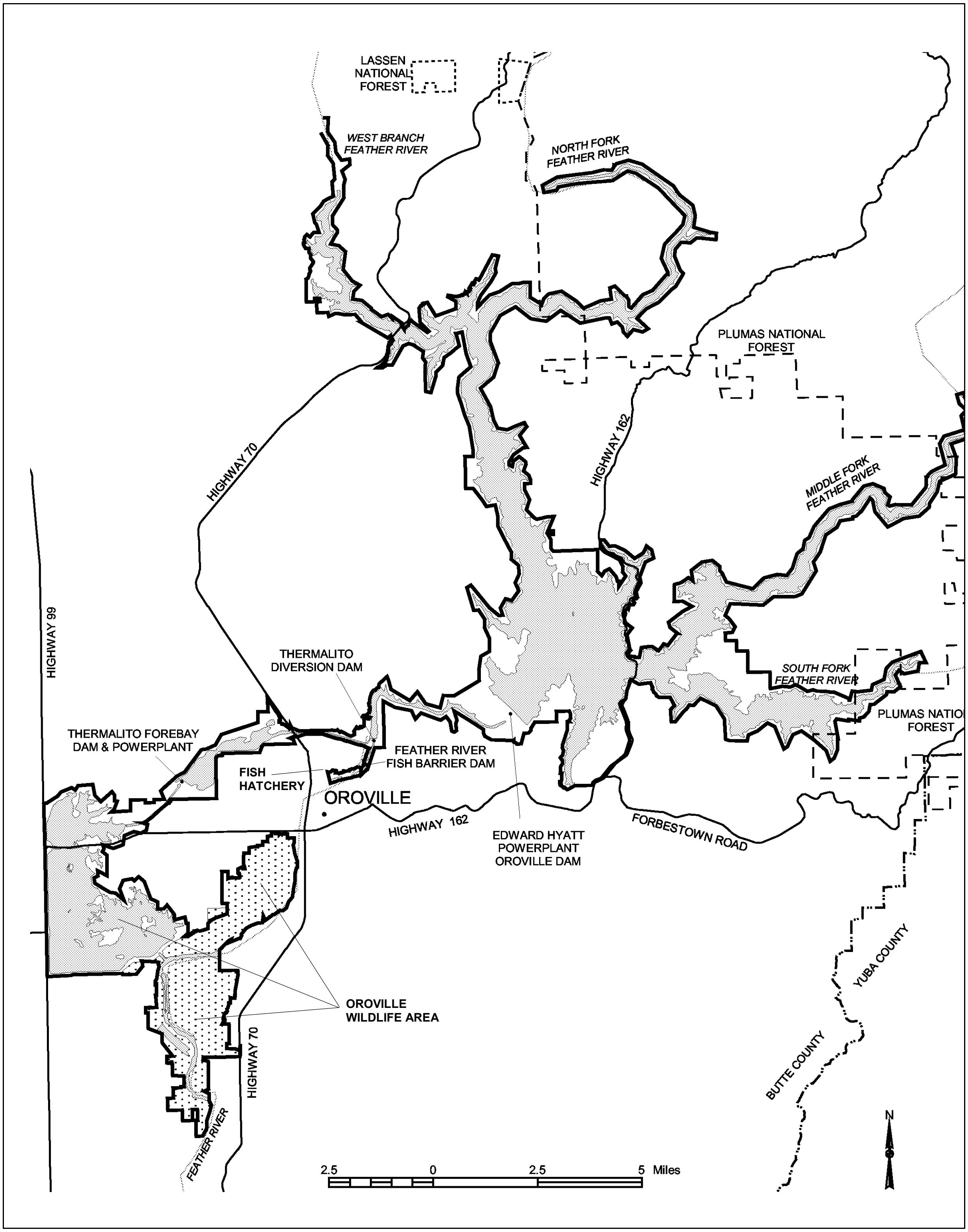

Figure 1.2-1. Oroville Facilities FERC Project Boundary.

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 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. 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.

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 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 April through November objectives.

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 Independent System Operator 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 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. 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

Conceptual Framework: Oroville Facilities project operations influence the water flow (i.e., volume, flow rate, fluctuations) and water temperature released into the Feather River. The effects on flow and temperature potentially influence salmonid habitat suitability and availability, and therefore salmonid spawning and rearing in the Feather River below the Fish Barrier Dam.

Flows released below hydroelectric projects are intended to protect, maintain, and enhance the aquatic ecosystem and, more specifically, those resources considered important from a commercial fishery, sport fishery, or threatened/endangered species perspective. Instream flows are almost universally specified in a FERC license and should be based on relevant site-specific information from the project area. Resource agencies participating in FERC relicensing processes commonly rely on information generated from PHABSIM instream flow studies to develop recommended instream flow regimes. FERC also will use these types of studies during their resource balancing deliberations prior to issuing long-term licenses.

Additional evaluations are needed to verify or identify appropriate instream flow levels in the Feather River below the Fish Barrier Dam. Additional analyses of existing data (site-specific or generic) using recent modeling and analytical techniques will help reduce uncertainty associated with previous analyses and improve the applicability of PHABSIM results to water management decisions. These analyses also may identify data supplementation and augmentation necessary to develop satisfactory flow-habitat relationships.

Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the FERC Application for License for major hydropower projects, including a discussion of the fish, wildlife and botanical resources in the vicinity of the project. The discussion needs 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 of the project. In addition to fulfilling these requirements, information developed in this study also may be used in determining appropriate PM&Es or other management actions for the project.

3.0 STUDY OBJECTIVES

The general objective of this study is to analyze flow-habitat relationships to evaluate potential project effects on anadromous salmonid spawning and rearing habitat within the study area. This study was designed as a two-phased approach with multiple objectives. The Phase 1 objective was to examine the existing PHABSIM studies for their applicability to the needs of FERC Oroville Relicensing study plans (EWG 2002). This included an evaluation of the changes in the Feather River since these other studies were completed, as those changes apply to determination of the amount of available habitat. Additionally, this evaluation included an assessment of the habitat suitability criteria generated in previous PHABSIM studies (DWR 1994), as well as recent habitat utilization data collected by DWR (Cavallo et al. 2003). The results of the Phase 1 Evaluation of Project Effects on Instream Flows and Fish Habitat were previously reported in TRPA (2002a).

3.1 APPLICATION OF STUDY INFORMATION

The objective of Phase 2 was to collect and analyze additional hydraulic and biologic data to supplement existing data for direct applicability to FERC Oroville Facilities Study Plans (TRPA 2002b). This study would also establish tools to evaluate future potential operational scenarios and other protection, mitigation, and enhancement measures.

3.1.1 Department of Water Resources/Stakeholders

The information from the SP-F16 Final Report will be used by DWR and the Environmental Work Group to evaluate potential project related resource effects and potential proposed Resource Actions. The PHABSIM model may be used to evaluate proposed changes to flow, stream channel shape or habitat enhancements of potential project operational changes, or potential Resource Actions. The model also could be used as a tool to evaluate and design flows or habitat modifications for salmonid spawning and rearing life stages.

3.1.2 Other Studies

The PHABISM results are not anticipated to be included in any other study plan report, but are anticipated to be incorporated into the Relicensing application documentation and can be used as a tool to evaluate project operational changes or PM&E, related to steelhead and Chinook salmon spawning and rearing life stages. No engineering and operations model output was required to complete this study.

4.0 METHODS

The basic approach to instream habitat analysis implemented in the SP F-16 studies is the Instream Flow Incremental Methodology (Bovee et al. 1998). IFIM is currently the most widely used and defensible technique worldwide for assessing instream flow requirements of fish (Dunbar et al. 1998, Tharme 2002). The IFIM includes a wide variety of analytical tools of varying complexity to address multiple aspects of riverine dynamics and ecology, including sophisticated computer models such as PHABSIM. PHABSIM was developed to calculate the quantity and usage of physical habitat within a stream or river system using channel structure, flow, and aquatic species criteria. PHABSIM uses either one-dimensional transect cross-sections or two-dimensional reach hydraulic models to simulate depths and velocities over a range of flows, then links these values with habitat suitability criteria to relate the match between flow and physical habitat. Results are typically referred to as weighted usable area (WUA) in units of square feet per 1000 linear feet, but a recent proposal uses the term relative suitability index (RSI) as a more accurate descriptor (Payne 2003).

A previous instream flow study by the DWR, DFG, and others also utilized the IFIM and PHABSIM and served as the basis for much of the present study. Many transects were measured to acquire hydraulic data and several years were spent making habitat observations of spawning Chinook salmon and rearing fry and juvenile Chinook and steelhead (DWR 1992, 1994; Sommer 1991, 2001; Cavallo et al. 2003).

4.1 STUDY DESIGN

4.1.1 Additional Hydraulic Data Collection

Analysis of the existing hydraulic data base for the DWR instream flow studies (TRPA 2002a) indicated that there were not enough transects available to adequately represent the current morphology of the Feather River and generate robust habitat index (WUA/RSI) functions. The specific reasons for this conclusion were: 1) high flows caused a degree of channel change since the transects were first measured and warranted new data; 2) common habitat types were represented by too few transects, especially straight flat water pool; 3) significant habitat areas were not included in the original study, such as lateral bar complex; 4) riffle transects did not specifically represent all available Chinook salmon spawning habitat; 5) the study site selection process description was incomplete and appeared somewhat subjective; 6) only half of some split channel transects were used and given double weight; and 7) many transects are calibrated with only two instead of three or more stage-discharge pairs.

Additional data collection under Phase 2 was conducted according to standard, established PHABSIM methods (Bovee 1997, Bovee et al. 1998), including reach delineation, macrohabitat delineation, transect/site selection and placement, flow level determination, depth, velocity, and substrate/cover data acquisition, computer model construction and calibration, species evaluation and WUA/RSI computation, and analytical procedures. The previous DWR approach to reach delineation, macrohabitat delineation, and transect/site selection and placement was judged to be thorough and defensible and was therefore followed for Phase 2. In the Phase 2 Study Plan (TRPA 2002b), six new transects were recommended to be placed in pool habitat in both the upper segment and lower segment, along with another six targeted spawning transects in both reaches (24 total). The target for weight of any given transect of any macrohabitat type was set at five percent or less to minimize potential uncertainty in WUA/RSI results.

4.1.2 Recalibration of Amended Hydraulic Data Base

Once the gaps in the hydraulic data base were corrected, all original transect and supplemental hydraulic data were recalibrated to current acceptable standards. Issues addressed in the modeling included bottom profile discrepancies, variation in flow computation by transect, stage-discharge rating curves (e.g., mean errors, slopes, intercepts), velocity simulation patterns (especially stream margin velocities), range of hydraulic simulation, and velocity adjustment factors.

4.1.3 Determine the Habitat Suitability of Deep Water

Although there was substantial effort put into deep-water surveys, there were relatively few observations of salmon; this may have been at least partially caused by lower visibility in deeper areas. Consequently, defining the suitability of deeper water for Habitat Suitability Criteria was somewhat subjective and prone to disagreement. A traditional method of assigning suitability to deeper water is to keep the value at 1.0 into infinity. Although this decision may be appropriate for some species and life-stages (e.g., adult sturgeon), for others it is likely to yield unrealistic results in a PHABSIM analysis. HSC are probability-of-use criteria, and while it may be accurate that spawning Chinook salmon, for example, can be found in deep water, it is less likely that they will be found there with the same probability as in shallower water.

Biologists working on the Feather River have indicated that Chinook salmon spawning in deep water is extremely unlikely due to unsuitable hydraulic characteristics and the lack of appropriately-sized gravels in deeper areas, and thus the spawning HSC curve should follow the decline in use to low suitability in deeper water.

4.1.4 Criteria Curve Development and Selection

After a continuation of the analysis of the existing DWR micro-habitat data and the ongoing 2002 results, this data would be evaluated for use in the Feather River. Various alternative approaches to combining the data could also be evaluated. One option might be to generate separate HSC for pools, run/glides, and riffles then weight each HSC according to the relative fish densities in each habitat type (so the habitat type with the highest densities would have the highest weighting factor), and combine and normalized into an HSC curve. This method would essentially simulate an equal-area sampling approach, where the relative number of fish observations per habitat type is determined by the density of fish in each habitat type. If a comparison of the weighted HSC and habitat availability data (also weighted to simulate equal-area sampling) suggests habitat limitations, the option of developing some form of use/availability (ratio) HSC could be explored. Other forms of HSC, including binary HSC, "envelope" HSC (Hardy and Addley 2001), or "composite" HSC (TRPA 2002a) will also be considered. All HSC developed from the DWR micro-habitat studies will be compared to HSC developed from other large California rivers.

4.2 HOW AND WHERE THE STUDIES WERE CONDUCTED

4.2.1 Phase 2 Scoping Process for Additional Hydraulic Data

The Phase 1 recommendations for additional study sites and transects were evaluated by interested Oroville Project Relicensing resource agencies and stakeholders. The first step in the scoping process was to distribute the Phase 1 evaluation report (TRPA 2002a) for review, discussion, revision, and concurrence as to the adequacy of existing data and need for and amount of additional data. The existing logistic framework established for the overall relicensing process, including technical review by the EWG, served as an instream flow study scoping mechanism. The Phase 1 review report was presented to and evaluated by the EWG, a Draft Phase 2 additional study plan was discussed by members of the EWG (TRPA 2002b), and a field trip was conducted to evaluate potential study sites and place additional transects.

The method outlined for site selection in DWR (1992) provided a template for identifying candidate sites, and the original decision-making process of site ranking was replicated. The transect types identified as deficient in the Phase 1 review were straight flat water pool and known spawning riffle and/or run/glide areas (TRPA 2002a). Transects could either be located in habitat units previously selected for the 1992 study or in previously unselected units that were highly rated by a collaborative ranking procedure described in the DWR (1992) report.

4.2.2 Geographic Study Area

The original IFIM study implemented by DWR and Technical Review Team defined the study area for PHABSIM transect placement as extending downstream from the Fish Barrier Dam to Honcut Creek. The salmonid studies will focus on the river segment where most of the spawning habitat occurs, from Feather River Hatchery to the Honcut Creek confluence (Painter et al. 1977). Habitat evaluation of the area below Honcut Creek (river mile 44) is of lower priority because of its lower habitat value to salmon. The Phase 2 scoping participants concurred with the definition of the instream flow study area as ending at Honcut Creek and restricted study site selection to upstream of the Feather River confluence with Honcut Creek (Figure 4.2-1).

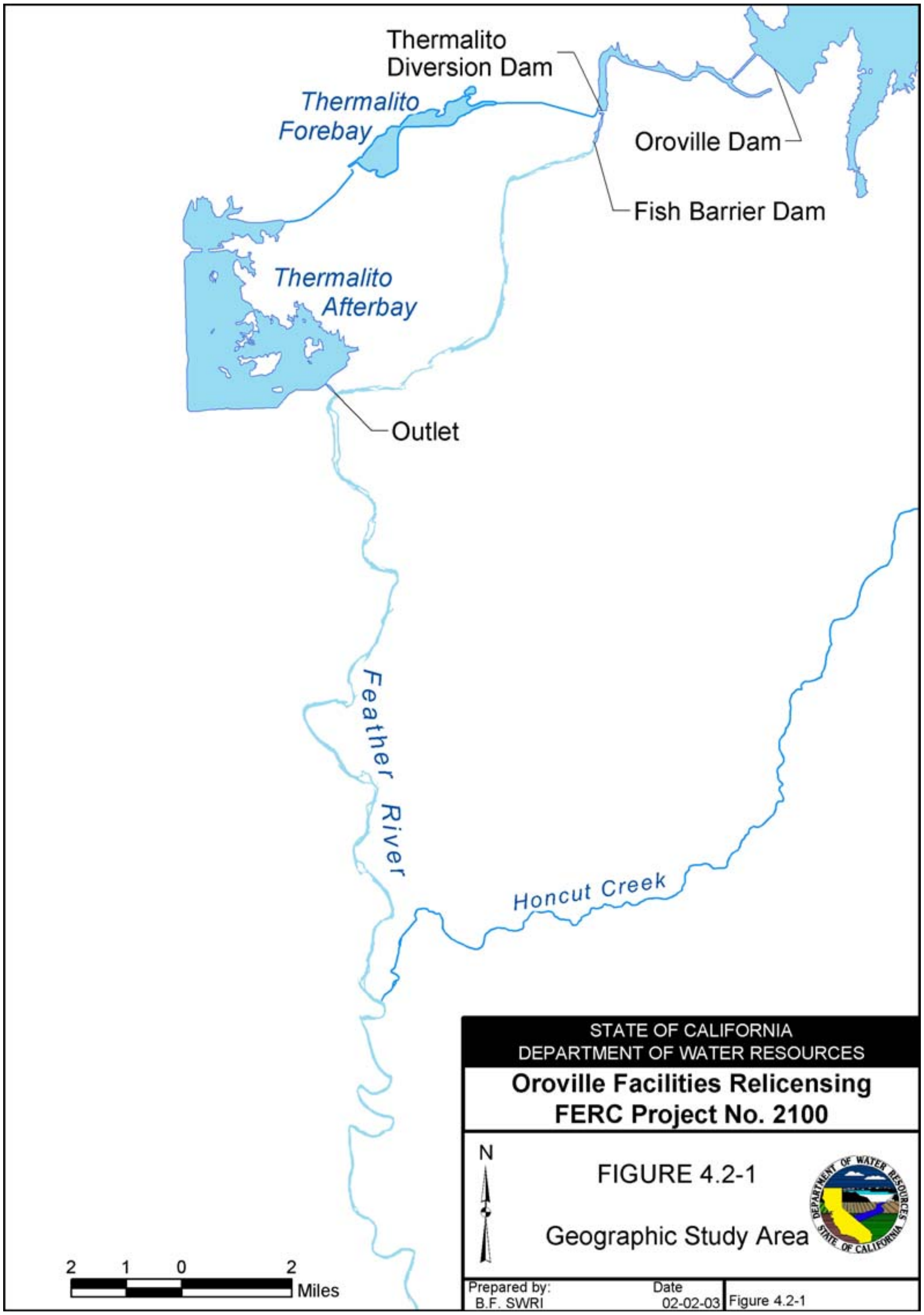

Figure 4.2-1. Geographic Study Area.

4.2.3 Instream Flow Study Methods

The DWR identified the IFIM in conjunction with temperature and sediment transport studies as the primary tools which will be used to evaluate proposed resource actions for the Oroville Facilities Relicensing process. These methods will be used in conjunction with other information, including expertise of scientists familiar with the area in making the assessments. Additional issues to be addressed in the study process include an evaluation of the potential impacts of expected flow changes on riparian habitat, threatened and endangered species, and recreational use of fish and wildlife. This process was selected, because an IFIM-type approach is considered the most defensible method of instream flow analysis in existence. A microhabitat approach such as PHABSIM is still state-of-the-art internationally for in-depth studies of flow/instream biota interactions (Dunbar et al. 1998).

4.2.3.1 Number of Study Sites

DWR (1992) established a total of fifteen study sites where cross-sectional transects were placed to collect hydraulic data for PHABSIM. These sites were distributed throughout the study area and were believed to reasonably describe the variability of Feather River longitudinal physical habitat conditions. The Phase 1 review concluded that some additional sites could be utilized to fill minor mesohabitat-type data gaps and provide further coverage of habitat variability (TRPA 2002a). Table 2 in the Study Plan (DWR 1992) identified Lower Eye Riffle as a highly rated site in the Upper Reach, and Hamilton Slough and McFarland Riffle in the Lower Reach.

For use in development of this Phase 2 Study Plan, the original process of site selection using ranking criteria was updated by DWR (Figures 1 and 2) in anticipation of a confirming field site visit. Three criteria for selecting study sites were established during preliminary scoping on 7 August 2002: 1) updated 1992 site ranking; 2) lateral bar complex (LBC) mesohabitat sites previously omitted; and 3) known salmon spawning areas. Selected study sites would have 1-D transects placed to represent straight flatwater pool and salmon spawning. The use of 2-D sites was recommended in the Phase 1 report; however, EWG discussions have demonstrated a greater degree of agency interest in 2-D modeling as a potential PM&E tool instead of as an existing habitat evaluation tool. Since some agencies had not yet made a formal decision regarding 2-D, the 7 August scoping meeting resulted in a decision to establish downstream control sections below potential 2-D sites as a “placeholder.” With a downstream control stage-discharge rating curve, the topography needed to develop a 2-D model can be collected under lower flow conditions, and a final decision on 2-D modeling was therefore deferred.

4.2.3.2 Number of Transects

A total number of 1-D transects in the range of 18-20 has been shown to define weighted usable area relationships as well as a substantially greater number (Payne et al. 2003). There were 15 usable transects measured in the Upper Reach and 16 in the Lower Reach, with the possibility of four more (two upper, two lower) available if they could be adequately calibrated. Six new transects were proposed in Phase 1 for placement in straight flatwater habitat type in each reach, plus up to another six transects in known spawning areas within each reach, for a total of 24 new transects. This would result in up to 29 transects in each reach and assure the computation of robust WUA/RSI habitat index functions.

4.2.3.3 Transect Placement Field Site Visit

Field site visits to select transect locations were conducted on 8 August 2002 in the Upper Reach and 9 August 2002 in the Lower Reach. Jet boat access was provided by DWR, and agencies and stakeholders were represented by National Marine Fisheries Service and U.S. Fish and Wildlife Service. Starting upstream in the Upper Reach, transects were placed at Auditorium Riffle (two pool, two spawning), Trailer Park (one pool, two spawning), Weir Riffle (two pool), and Eye Riffle (one pool), for a total of six pool (the recommended number) and 4 spawning transects. Fewer spawning transects than the recommended 6 were added because a consensus was reached that all spawning areas in the Upper Reach had been adequately represented. Hatchery Riffle, although an important spawning area, was too complex (mid-channel lateral flow) to model with 1-D. The pool transects at Auditorium Riffle, Weir Riffle, and Eye Riffle can also serve as 2-D study site placeholders.

In the Lower Reach, transects were placed in Conveyor Belt Riffle (one spawning), Upper Hour Riffle (one spawning), Lower Hour Riffle (one pool, one spawning), Palm Avenue Pool (one pool, one spawning), Hour Pool (1 pool), Big Bar (one pool), Upper McFarland (one pool), Boat Launch Pool (one pool), and Junkyard Riffle (one pool, one spawning). The total of pool transects (seven) is one more than recommended in Phase 1, and the total of spawning transects (five) is one less, but the consensus of participants was that all areas were adequately represented. The pool transects at Lower Hour and Junkyard Riffle can also function as 2-D study site placeholders.

Additional detail describing the rationale for selection specific transect sites is provided in Appendix A along with maps illustrating the general location of proposed transects and the specific locations of existing IFIM/PHABSIM transects along the Feather River.

4.2.3.4 Target Flow Levels

In the previous DWR study, model calibration data was obtained at flows of approximately 400, 600, and 1,000 cfs in the Upper Reach, and 1,000, 2,500, and 3,000 cfs in the Lower Reach. Data collection on additional supplemental transects did not have to occur at these precise flows, but were chosen to be roughly equivalent to allow for similar range of extrapolation when all transects were merged. Flow regimes in both reaches are different now than in 1992/93 and the changes constrained remeasurement of some previous flow levels. For example, the minimum release in the Upper Reach is currently 600 cfs instead of 400 cfs; minimum flows in the Lower Reach have also increased. Target flow levels for the additional work were therefore selected to be 600, 1,000, and 1,800 cfs in the Upper Reach, and 1,500, 2,750, and 5,000 cfs in the Lower Reach, reflecting both higher low flows and moderate differential between flows. These flows would be used for calibrating the stage-discharge relationships of both the 1-D and any future 2-D models.

Measurement of a single, high flow pattern of velocities extrapolated over the complete range of flows dictated by stage-discharge relationships has been shown to compute RSI results nearly identical to that computed from multiple velocity patterns (Payne and Bremm 2003). Velocity patterns on the additional Feather River transects were to be acquired at 1,800 cfs in the Upper Reach and 5,000 cfs in the Lower Reach but were acquired at all flows using the Acoustic Doppler Current Profiler.

4.2.3.5 Field Data Collection

Water velocity and depth profile data were collected along transects in the main river channel with an Acoustic Doppler Current Profiler (RD Instruments) mounted in an OceanScience fiberglass trimaran tethered alongside a Zodiac jet boat. Operation of the ADCP was controlled by radio frequency modem from a laptop computer set up on the riverbank, which initialized, started, and stopped data collection. An ADCP functions by sending a series of short-burst sonar pulses through transducer heads facing down in the water column. Echoes from the pulses are detected and analyzed by ADCP software to determine water depth (from pulse time delay) and velocity (from the doppler effect) down through the water column. Data is collected at a high rate of speed and compiled into data packets approximately every second for transmittal to the computer, where the data are displayed in real time and reviewed for quality. Velocities and depths in edge cells too shallow for the ADCP were measured at two-foot stationing with pigmy and Price AA current meters mounted on top-set wading rods. Water surface elevations were determined by standard differential leveling from established temporary benchmarks and reference pins at either end of each transect. Substrate and cover coding values were made visually at two-foot stationing across each transect and up each riverbank to above normal high water. Coding values at stations too deep to see were derived from the sound and feel of an extended probe.

4.2.3.6 Hydraulic and Habitat Index Computer Analysis

Analysis of Feather River hydraulic modeling and computation of habitat indices was conducted with RHABSIM, a commercial version of PHABSIM written by Thomas R.

Payne & Associates (Payne 1994). The program uses the same internal computations as the versions originally written by Milhous et al. (1984, 1989; Waddle et al. 2001), but in a more visual and user-friendly environment. RHABSIM allows overlays of multiple transect data sets, rapid error-checking, concurrent use of various velocity or water surface simulation algorithms, and convenient parameter sensitivity analysis. All computer modeling methods and calibration approaches used in the Feather River analyses were standard techniques commonly used in similar studies.

5.0 STUDY RESULTS

5.1 ADDITIONAL HYDRAULIC DATA COLLECTION

5.1.1 Additional Transects

Hydraulic data was collected on the transects selected under the process described in Section 4.2.2, Instream Flow Study Methods, between August 2002 and January 2003. Ten new transects were measured in the Upper Reach and twelve in the Lower Reach. Combining these new transects with the original DWR transects addressed the recommendation made in Phase 1 about collecting additional targeted hydraulic data. Specifically, they: 1) diluted any potential effect of channel changes caused by higher flows; 2) better represented common habitat types; 3) added rearing habitat areas not previously sampled; 4) supplemented the representation of known Chinook spawning habitat; and 5) expanded the site selection process. The remaining two parts of the Phase 1 recommendation are discussed in following sections.

5.1.2 Measured Flows

For data collection in the Lower Reach downstream of Thermalito Afterbay, telemetered stream gages were monitored and field crews mobilized when target flow levels were present. DWR project operators cooperated to the extent possible to maintain stable flows for the amount of time the field effort required. In the Upper Reach, DWR scheduled flow releases specifically for the instream flow study and provided notification of flow change according to established procedures. Target flow levels and actual measured flow levels agreed quite closely (Table 5.1-1). In the one case where they diverged somewhat (low flow, Lower Reach), the measured flow actually provided better separation for stage-discharge calibration than the expected low seasonal target flow. For reference purposes, the table also shows flow levels measured during the earlier DWR instream flow study (DWR 1992).

Table 5.1-1. Instream flow study data collection dates and measured flow levels.

Upper Reach	Field Collection Date	Target Flow (cfs)	Actual Flow (cfs)	DWR (1992)
High Flow	August 26-27, 2002	1800	1768	1000
Middle Flow	August 28, 2002	1000	1036	600
Low Flow	January 28-30, 2003	600	650	400
Substrate/Cover				
Lower Reach				
High Flow	August 20-21, 2003	5000	5000	3000
Middle Flow	October 3, 2002	2750	2713	2500
Low Flow	January 20-24, 2003	1500	1320	1025
Substrate/Cover				

5.2 DATA REDUCTION AND ENTRY

Use of an ADCP to collect PHABSIM field data requires a few additional steps for data reduction and computer file building than do standard velocity measurement methods. The high rate of data collection, for example, can generate more stations across a transect than the PHABSIM model is capable of processing. While the RHABSIM computer program can directly import some types of ADCP data, the Feather River data required the writing of a second interface program. This program (ADCPtoRHB) allows review of all measured data points and selective consolidation into discrete stations a specified intervals. Depth and velocity data in between the intervals is averaged and assigned to the intervals, which in the case of all Feather River transects, were specified at two feet. This interval corresponds to that used for edge cell measurements and substrate/cover coding and provided a much higher level of transect profile resolution than is commonly feasible.

All newly-collected data (stationing, depth profiles, velocities, substrate/cover codes) were entered into two RHABSIM computer files, one each for the Upper and Lower reaches. Internal data graphing routines were then used to review the bottom and velocity profiles for each transect separately and in context with others for quality control purposes. Any identified data gaps (e.g., missing velocities) or discrepancies (e.g., conflicting records) were corrected using available sources, such as field notes, photographs, or adjacent data points.

5.3 RECALIBRATION OF AMENDED HYDRAULIC DATA BASE

<u>5.3.1 Reconstruction of DWR (1992) Transects</u>

The electronic PHABSIM hydraulic data files used in the DWR (1992) studies were obtained, imported into RHABSIM, and reviewed as part of Phase 1. Under Phase 2, the raw field survey data notes for stationing, water depth, station velocity, and substrate/cover description and coding were also entered into RHABSIM as validation of previous modeling that relied on externally processed data.

The most common discrepancies found were due either to the greater capacity for significant digits in RHABSIM bottom profiles than available in PHABSIM or to computing bottom profiles from depth data in RHABSIM instead of from level survey data. In all cases where greater bottom profile resolution was entered, the discharges internally computed by depth and velocity data changed to more closely match the best estimates of flow previously identified by DWR. Other modifications made to the physical representation of the Feather River in the DWR files included adding some side channels and backwaters that had been removed because of calibration difficulties, and, where weeds were present, averaging depths between top of weeds and top of substrate. The former modifications retained more of the habitat complexity of the river and addressed the Phase 1 recommendation about the use of one-half of split channels, and the latter both improved discharge calculations and provided a better approximation of depths actually usable by fish.

Few calibration changes were made to the water surface elevations first used by DWR to develop stage-discharge rating curves, although in some cases the stage-of-zero-flow was altered based on similar relationships to nearby transects. (The SZF is subtracted from measured water surface elevations prior to computation of best-fit log-log regression of stage against discharge.) Changes to SZF tend to have negligible effect unless rating curves are excessively extrapolated, which for the flows of interest is not necessary in the Feather River hydraulic models. Resulting stage-discharge rating curves for all transects show the similarity in slope and character of the original and new sets of curves (Figures 5.3-1 and 5.3-2).

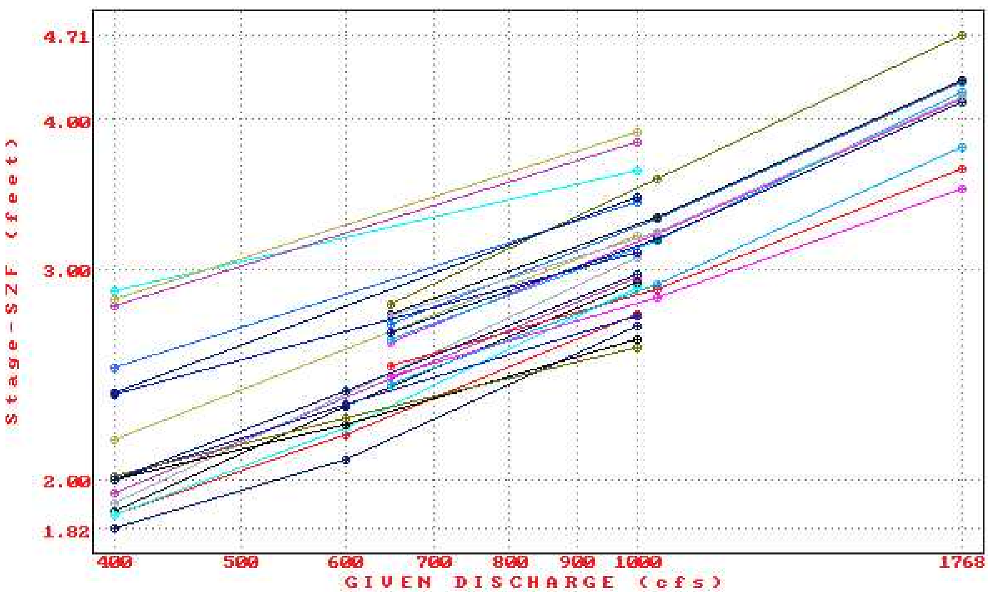

Figure 5.3-1. Stage-Discharge Rating Curves for the Upper Reach.

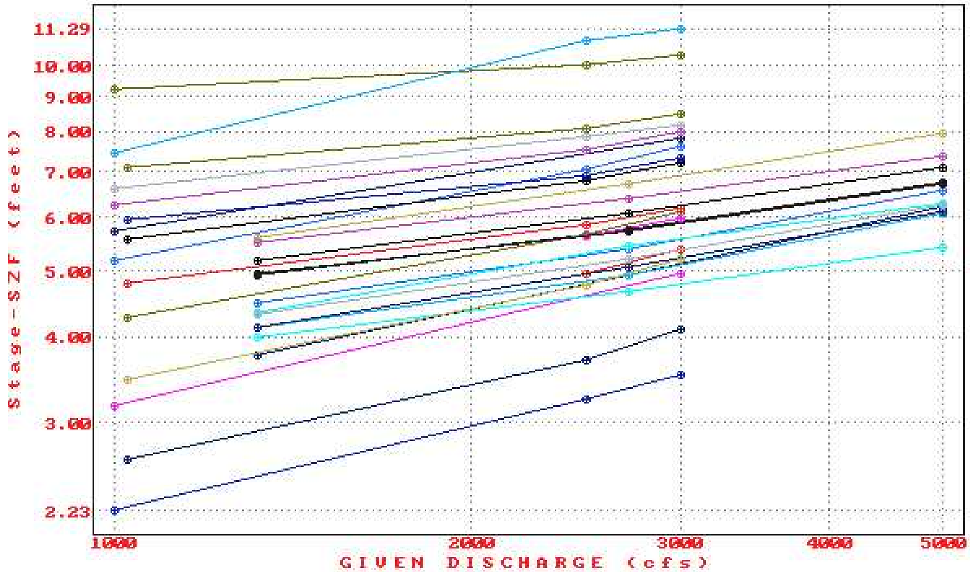

Figure 5.3-2. Stage-Discharge Rating Curves for the Lower Reach

5.3.2 Merging and Reweighting Transects

After building the new ADCP transects and confirming and/or revising the original DWR transects, all hydraulic data were merged into two data files for simulating hydraulics over a range of flows and computing habitat indices. One file for the upper reach between the fish barrier dam and Thermalito outlet contained 27 transects. The other, for the lower reach between Thermalito and Honcut Creek, contained 29 transects. Figures 5.3-3 and 5.3-4, respectively, illustrate example transects containing the standard data obtained by DWR and the ADCP data collected by TRPA.

Merging new and old transects then required a reweighting of each transect to assign proper representation of physical area in the Feather River corresponding to the habitat types where the transects were located. The DWR studies (1992) had stratified the study area into five major habitat categories (flatwater bend, island bar complex, lateral bar complex mid-channel bar, straight flatwater), each of which could contain three mesohabitat type strata (pool, run/glide, riffle). Transects were placed in pools, run/glides, and riffles in island bar complex and straight flatwater categories but not in categories which represented less than 15 percent of the river by length. This transect placement strategy assumes that habitat index responses for island bar complex pools, for example, will be different than index responses from straight flatwater, and should therefore be weighted differently.

The assumption was tested in the current study by generating habitat indices for all transects in each mesohabitat type strata, regardless of association with different categories, and plotting an overlay of the results. Four different generic habitat suitability criteria were used (deep/slow, deep/fast, shallow/slow, shallow/fast) in the three strata in both reaches, resulting in 24 plots. While there were some differences in the individual indices, cell-by-cell review showed them to be caused by transect-specific conditions, and not by the broader habitat categories. Analysis supported a conclusion that all pools, run/glides, and riffles could be assigned a weight based on the overall percentage by length of each type in the Feather River.

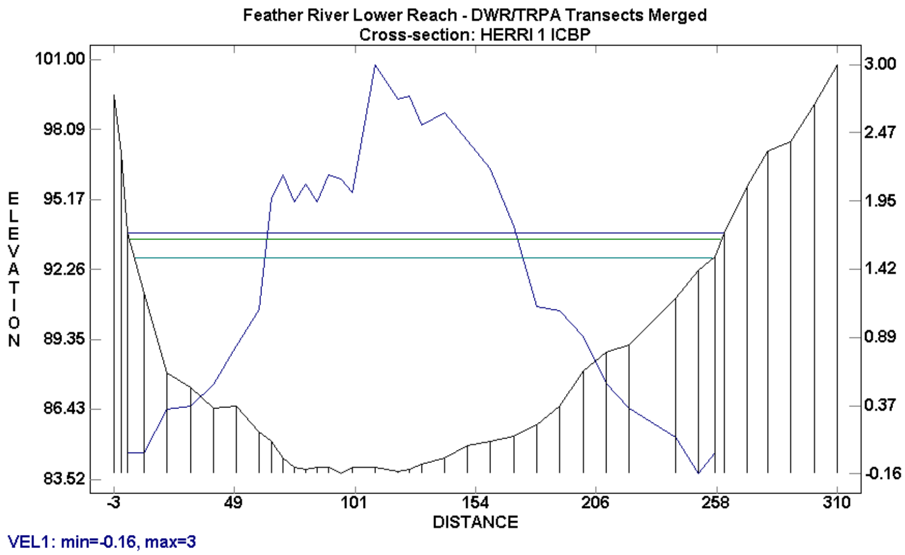

Figure 5.3-3. Example transect with standard data by DWR.

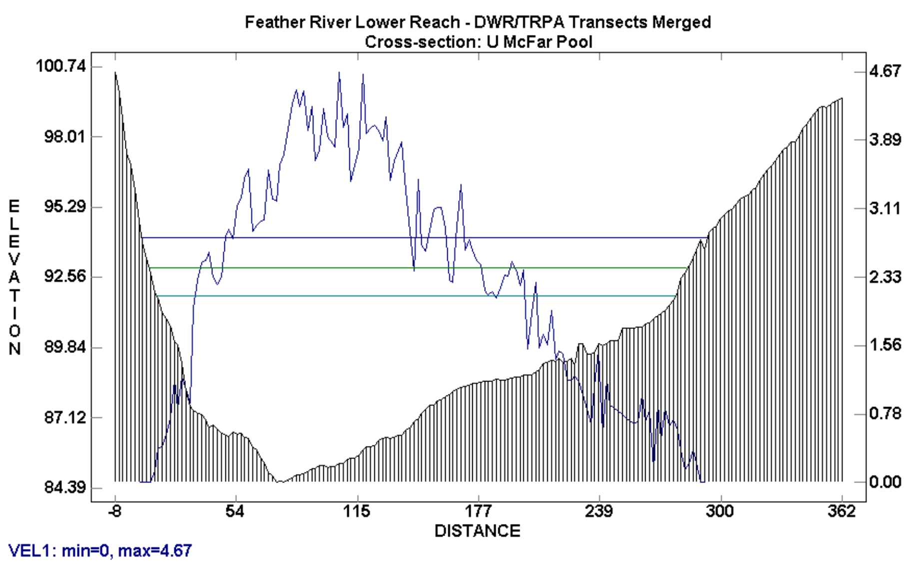

Figure 5.3-4. Example transect with ADCP data by TRPA.

Weights were derived from measuring the percent length of the three mesohabitat strata within the two study reaches on 1999 aerial photographs (on which the strata were previously identified in the field by DWR), and dividing the percent length of strata by the number of transects within the strata (Table 5.3-1).

Table 5.3-1. Weight of transects in the Feather River instream flow study.

Site/Habitat Type	Length (ft)	Percent	No. Transects	Percent Each
Lower Reach				
Pool	52959	67.13	12	5.59
Run/Glide	24124	30.58	9	3.40
Riffle	1805	2.29	8	0.29
Upper Reach				
Pool	32709	74.45	12	6.20
Run/Glide	8505	19.36	6	3.23
Riffle	2721	6.19	9	0.69

5.4 CRITERIA CURVE DEVELOPMENT AND SELECTION

Site-specific micro-habitat data was collected by DWR for spawning Chinook salmon in 1991 (DWR 1991) and in 1995 (Sommer et al. 2001) and spawning steelhead in 2003 (Cavallo et al. 2003). These data were used to develop HSC for instream flow analysis.

5.4.1 Adult Chinook salmon spawning

Micro-habitat characteristics were measured at 212 Chinook salmon redds in October 1991 within 100 ft of 32 transects previously established for the PHABSIM study (DWR 1991). Transects included in the spawning study were distributed in the upper reach (600 cfs) and the lower reach (1,000 cfs), and in pools, run/glides, and riffles. All redds were observed in riffles or run/glides. An additional 205 redd measurements were collected in the fall of 1995 under a higher flow regime (1,600 cfs in the upper reach and 2,500 cfs in the lower reach) (Sommer et al. 2001). Besides the redd data, 200 measurements of depth and velocity were taken at “unoccupied” locations within the search area to represent the “availability” of habitat conditions that were not chosen by spawners.

Chinook salmon spawning HSC were created by DWR for the 1991 data, the 1995 data, and/or the combination of data using a variety of curve fitting methods. The method of non-parametric tolerance limits (NPTL) was chosen and applied by DWR to frequency distributions of the 1991 and the 1991 + 1995 data sets for depth and mean column velocity. The current analysis utilized the adult Chinook salmon spawning criteria collected by DWR in 1991 and 1995 with a sample size near 410 redds, but were fit with polynomial functions to generate the final criteria. Polynomial curve fitting has advantages over other methods, including less sensitivity to interval bin size and smoothing gaps or spikes in frequency distributions.

A method to adjust HSC for deep water availability (Gard 1997) was suggested by the US Fish and Wildlife Service during review of the Phase 1 assessment, implemented, and found to have little effect on the original depth criteria. Both the addition of higher flow spawning observations and applying the Gard method address the issue of deep water habitat suitability for Chinook spawning. Substrate HSC for the present analysis were created from the 1991 data (substrate data was not collected in 1995) by normalizing the frequency distribution to the maximum value.

These criteria are similar in velocity suitability to those created for spawning Chinook in the Yuba River (Beak 1988) but have greater suitability for higher velocities than the Bovee (1978) criteria (Figure 5.4.-1). The DWR Feather River criteria show greater depths to be suitable than either the Beak (1988) or Bovee (1978) criteria (Figure 5.4-2). Because the DWR criteria are site-specific, have a large sample size, and were collected over a range of discharges, they should best represent spawning habitat suitability in the Feather River (Figure 5.4-3).

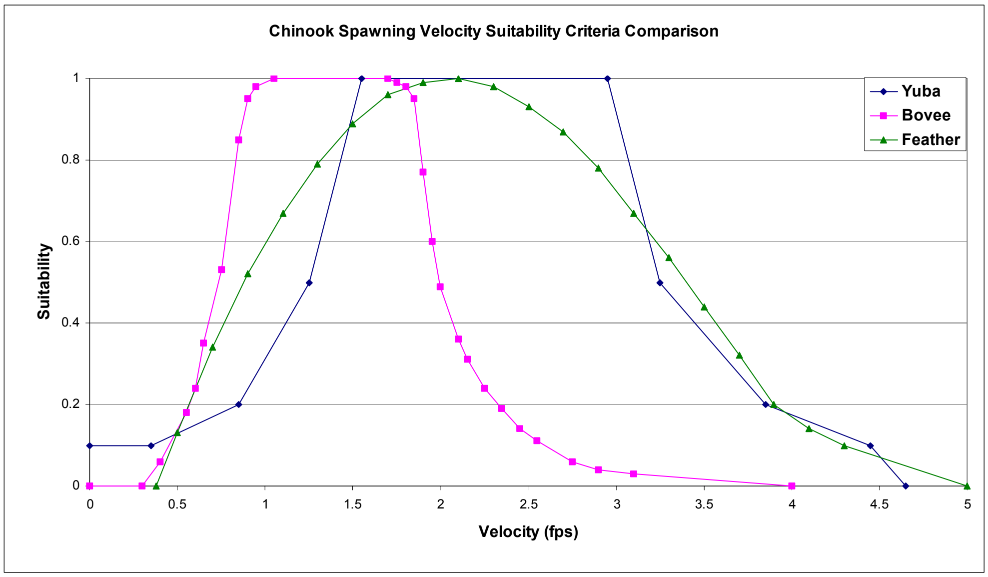

Figure 5.4-1. Chinook spawning velocity suitability criteria comparison

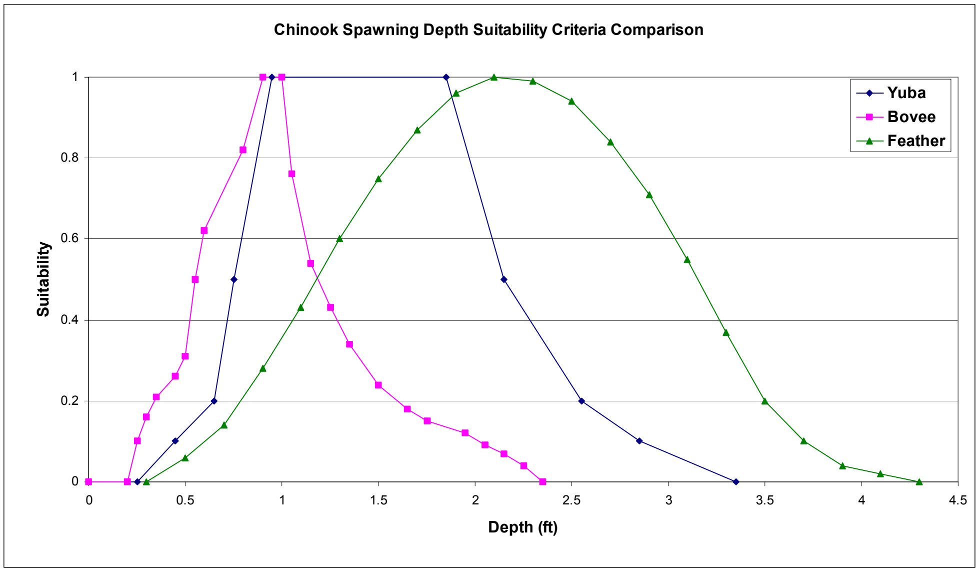

Figure 5.4-2. Chinook spawning depth suitability criteria comparisons

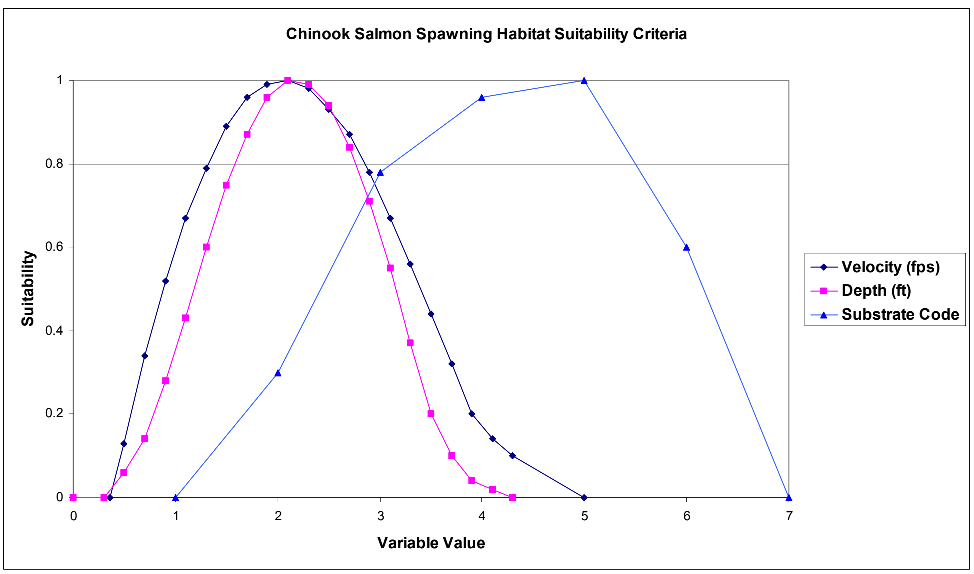

Figure 5.4-3. Chinook salmon spawning habitat suitability criteria

5.4.2 Adult steelhead trout spawning

During late winter 2002, DWR biologists collected velocity, depth, and substrate data on 76 steelhead redds in the Feather River (Table 5.4-1). Although this sample size is on the low end of standard sample sizes desired for the development of habitat suitability criteria (i.e., 200-300), polynomial curves were fit to the data for preliminary evaluation in the flow study. In comparison to two other sets of steelhead spawning criteria, the DWR curves bracket the suitability for velocity derived by Hampton (1997) on the Trinity

River and by Bovee (1978), and are slightly shallower for depth (Figures 5.4-4 And 5.4-5).

Table 5.4-1. Velocity, Depth, and Substrate Frequency Observations for Steelhead Trout Spawning, Feather River, 2002 (n=76)

Velocity in Feet per Second		Depth in Feet		Substrate Code	
Velocity Bins	**Frequency**	**Depth Bins**	**Frequency**	**Code Bins**	**Frequency**
0	0	0	0	2	0
0.2	0	0.2	0	2.5	19
0.4	0	0.4	1	3	38
0.6	5	0.6	6	3.5	17
0.8	2	0.8	18	4	1
1	4	1	18	4.5	0
1.2	9	1.2	13		
1.4	14	1.4	7		
1.6	3	1.6	1		
1.8	10	1.8	2		
2	11	2	0		
2.2	7	2.2	0		
2.4	5	2.4	0		
2.6	3	2.6	6		
2.8	1	2.8	1		
3	0	3	1		

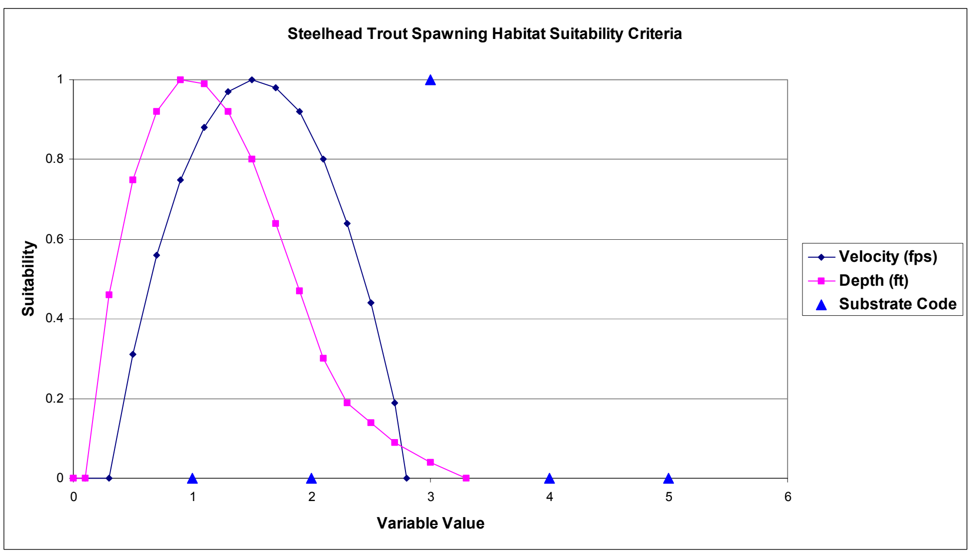

Figure 5.4-4. Steelhead trout spawning habitat suitability criteria

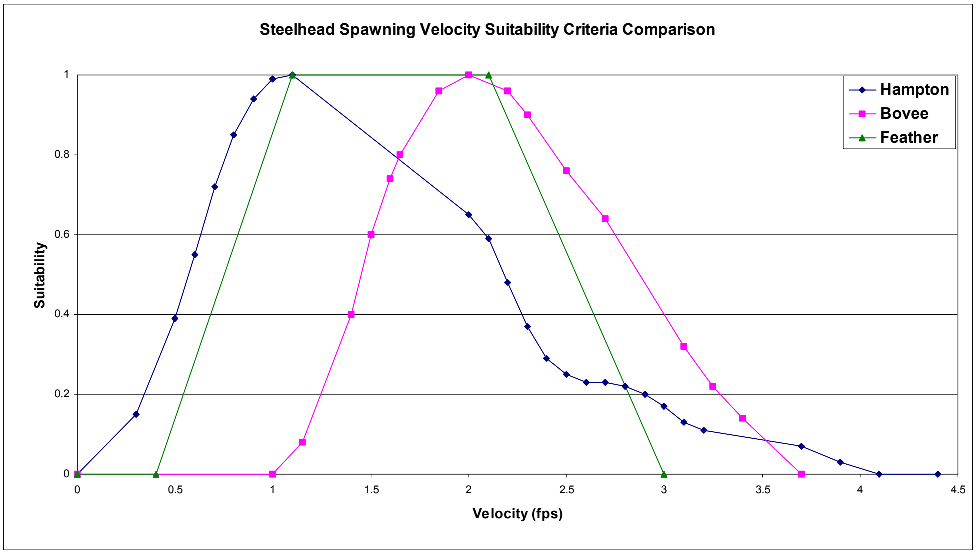

Figure 5.4-5. Steelhead spawning velocity suitability criteria comparison

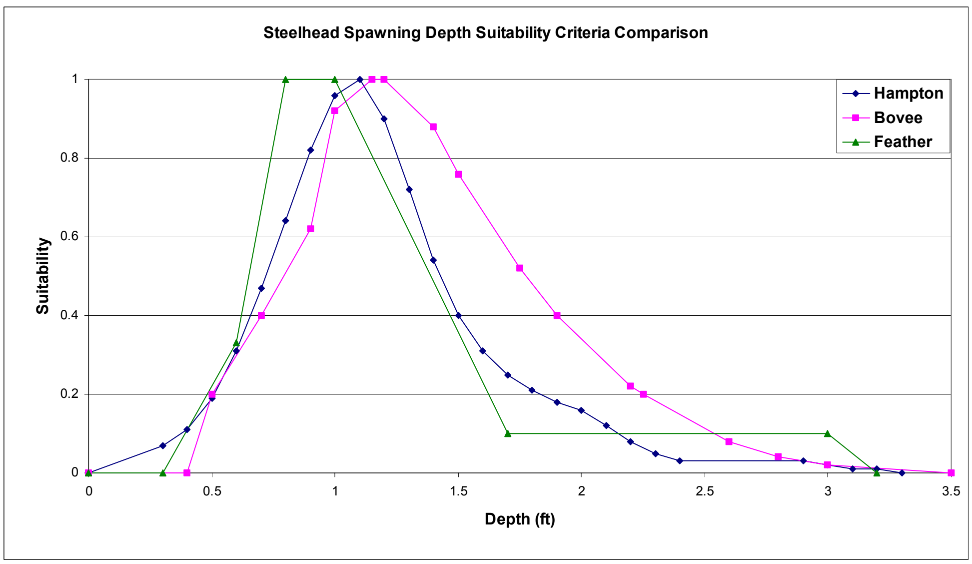

Figure 5.4-6. Steelhead spawning depth suitability criteria comparison

5.5 WEIGHTED USABLE AREA HABITAT INDEX COMPUTATION

Following the recalibration and merging of the transect hydraulic data and finalization of the habitat suitability criteria, the two sets of data were combined in the PHABSIM computer model to compute the weighted usable area index to habitat suitability for the two species and life stages in the two reaches. Weighted usable area (WUA), also known as a relative suitability index (RSI – Payne 2003), relates the extent of match between hydraulics and habitat suitability for flows specified in the models. The index is only a relative indicator of suitability, not actual physical area, and, being an index, cannot be directly related to numbers of fish that may occupy the Feather River at the modeled flows. It does provide the capacity to compare various flow regimes, however, for evaluating the suitability of alternatives.

5.5.1 Adult Chinook salmon spawning WUA/RSI

The results for the adult Chinook salmon spawning WUA/RSI in the upper reach between the fish barrier dam and Thermalito outlet are presented in Figure 5.5-1. From a low value at 150 cfs, the lowest flow modeled, the habitat index rises sharply to a peak near 800 cfs. Beyond the peak, the index falls sharply again out to about 1,600 cfs where the rate of fall begins to decline. If a fisheries management objective is to provide maximum physical opportunity for Chinook salmon spawning at a fixed (rather than variable) flow, this would be achieved with a flow of 800 to 825 cfs. The WUA/RSI in the lower reach is similar in relation to discharge, rising from a low level at the lowest modeled flow of 500 cfs to peak near 1,700 cfs, above which it again declines out to 7000 cfs (Figure 5.5-2). Maximum physical opportunity for Chinook salmon spawning in the broader, lower gradient lower reach occurs at a flow of 1,650 to 1,750 cfs, slightly more than twice the flow of the maximum index in the upper reach.

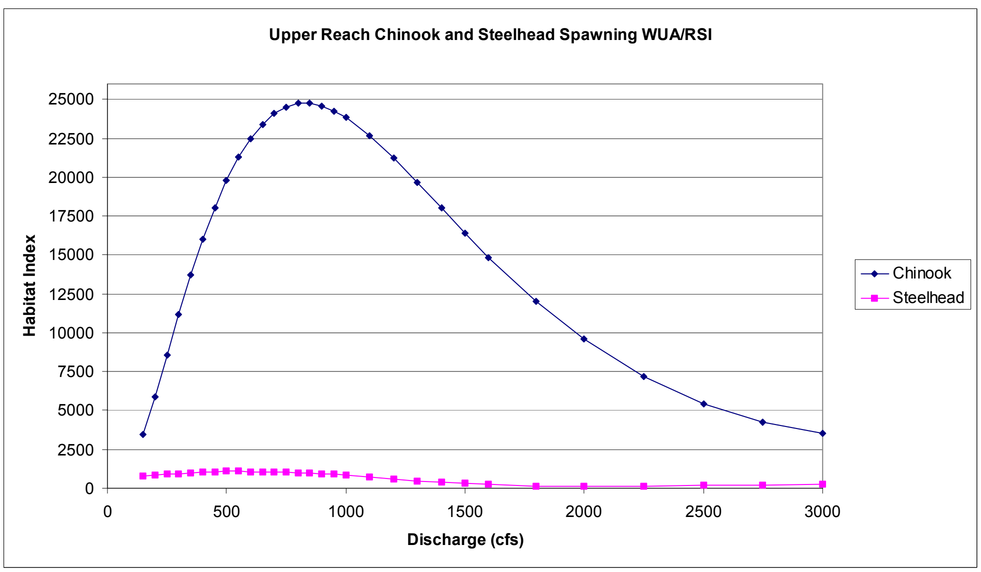

Figure 5.5-1. Upper Reach Chinook and Steelhead Spawning WUA/RSI.

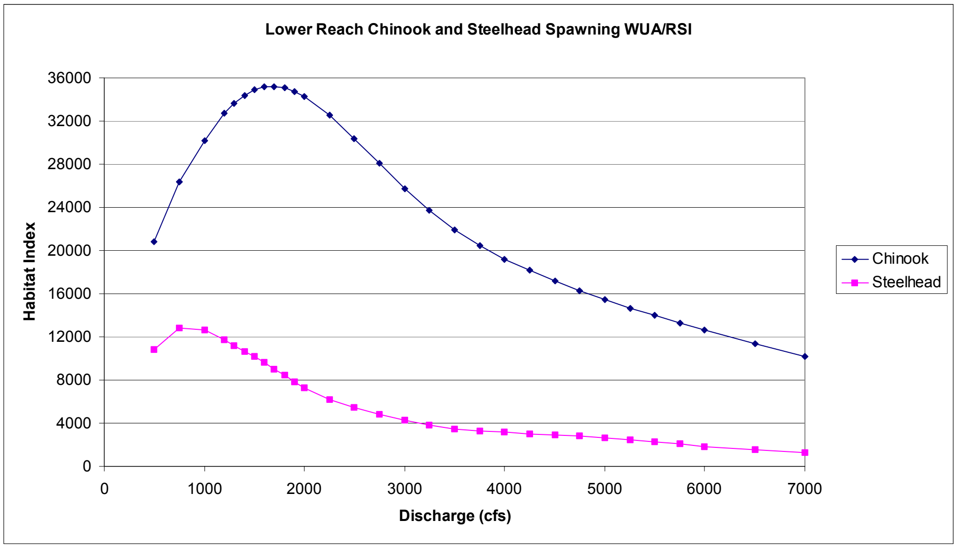

Figure 5.5-2. Lower Reach Chinook and Steelhead Spawning WUA/RSI.

5.5.2 Adult steelhead trout spawning WUA/RSI

Results for adult steelhead trout spawning in both reaches have a lower magnitude the Chinook spawning results, and also reach optimum levels at lower flows. The steelhead spawning habitat index in the upper reach has a very low magnitude and has no distinct optimum over the range of flow between 150 and 1,000 cfs. In the lower reach, there is a maximum in the index apparent at a flow just under 1,000 cfs. The difference in magnitude and peak can be attributed to the relative scarcity of smaller substrate particle sizes utilized by spawning steelhead (in comparison to adult Chinook) in Oroville project area of the Feather River.

6.0 DISCUSSION AND CONCLUSIONS

6.1 STATUS OF HYDRAULIC MODELS

The Phase 2 study corrected one of the primary weaknesses of the original PHABSIM studies, which was the excessive weight given to too few transects. Whereas three pool transects in the upper segment and three pool transects in the lower segment were originally weighted at 20.76 percent and 14.37 percent each, respectively, twelve pool transects are now weighted at 5.59 percent and 6.20 percent each in the two segments, respectively. Weights given the other habitat types are similarly reduced, thereby decreasing the potential for habitat index results to be driven by small sample size. Figures 6.1-1 and 6.1-2 illustrate the upper segment in plan view at 700 cfs with the original and revised transect weighting, respectively, for the same species and life stage of Chinook salmon spawning. The upper graph (Figure 6.1-1) has many fewer cells contributing to the sum total habitat index than does the lower graph (Figure 6.1-2). Confidence in the reliability of the results should be substantially increased with this number of transects. Other normal standards for hydraulic models are also met in the revised analysis, including slope and intercept of stage-discharge rating curves, percent error of stage-discharge rating curves, velocity simulation errors, and velocity adjustment factors.

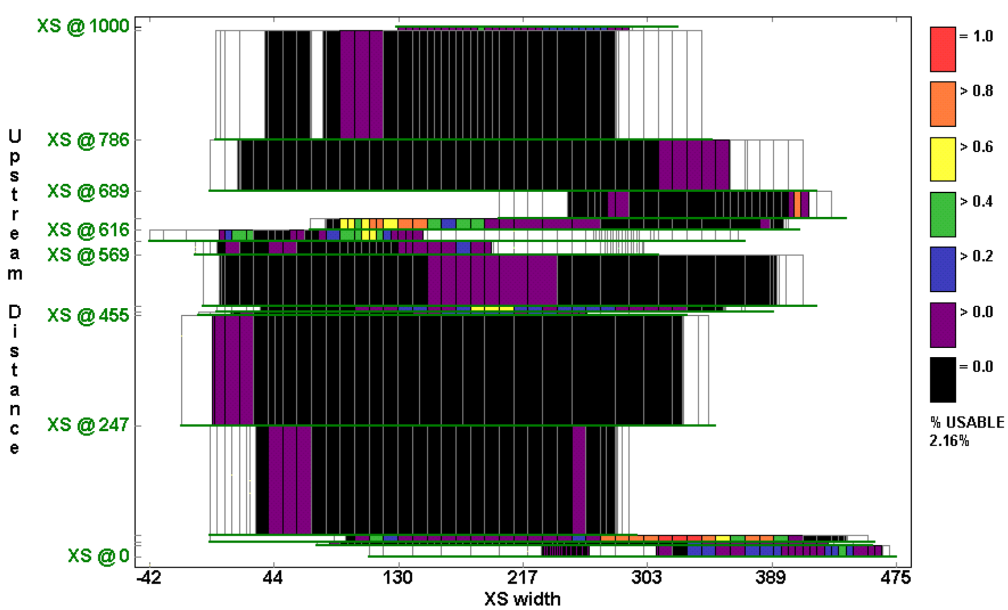

Figure 6.1-1. Example plan view of segment and original DWR transect weighting.

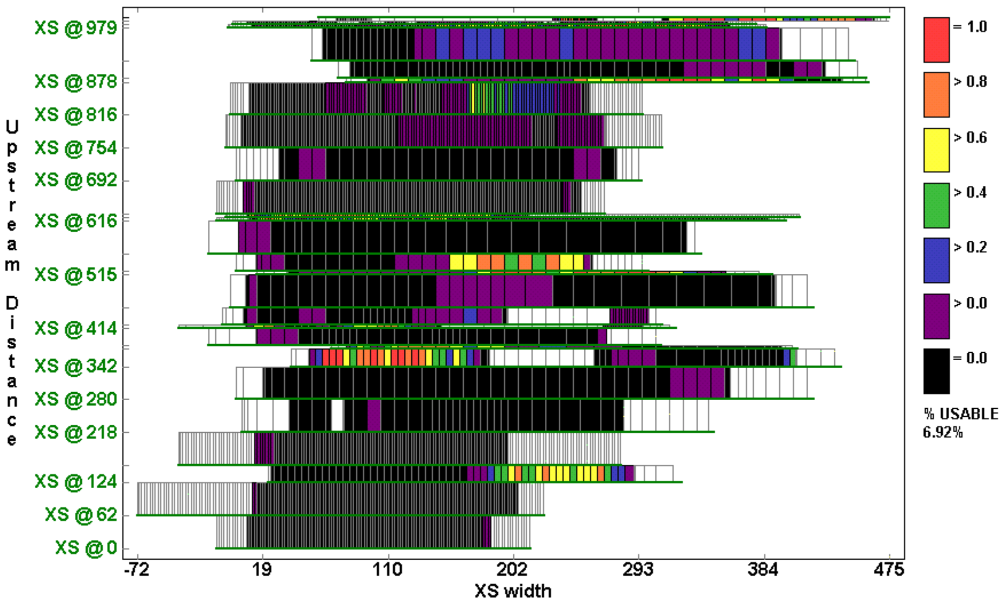

Figure 6.1-2. Example plan view of segment and revised transect weighting.

6.2 CHINOOK SALMON AND STEELHEAD SPAWNING

The weighted usable area/relative suitability index results for Chinook salmon and steelhead spawning are a combination of physical habitat conditions in the Feather River and habitat suitability criteria developed from the Feather River. If computed accurately, they should reflect the best available biological judgment for the simulated relationship. In other words, at flows judged by fisheries biologists to be suitable, the index should be high, and at flows judged to be unsuitable, the index should be low. From the limited perspective of having conducted the review of existing studies and collecting supplemental data on the river, the authors believe the results obtained for Chinook and steelhead spawning in the two reaches are reasonable. This is supported by many years of documentation of successful Chinook spawning in the upper segment at a flow just above 600 cfs, an indication that 800 to 825 cfs for the maximum index value (as shown by study results) is unlikely to be far from the true optimum flow under existing channel conditions. The steelhead spawning habitat index in the upper segment has no pronounced optimum, staying relatively low and constant between 150 and 1,000 cfs. This pattern is most likely reflective of the selection of spawning sites by steelhead in areas with smaller gravel out of the main river channel.

In the lower reach, the Chinook spawning index optimizes near 1,700 cfs, or about twice the flow of optimum index in the upper reach. The steelhead spawning index in the lower reach responds more to flow changes than the upper reach index, optimizing around 800 cfs. Differences in the magnitude of the steelhead spawning habitat index between the Chinook spawning index and among the two reaches are likely to be a result of river channel size differences and a lack of smaller gravels suitable for steelhead spawning. These differences, in turn, could be a result of channel changes since construction of the Oroville Project or naturally from the historic character of the different river reaches, a distinction which cannot be determined from the present study. Again, however, the limited experience of the authors based on channel observations during data collection lends support to these results as being reasonable.

6.3 HABITAT INDEX STABILITY

As noted above, there are differences in habitat index response for the modeled species between the upper and lower reaches of the Feather River study area. These differences may be due to either channel change since project construction or natural channel characteristics, and PHABSIM cannot determine which (or both) may be the principal cause. PHABSIM is a “fixed bed” model, and results will remain applicable only if the river channel maintains similar proportions of mesohabitat types, otherwise known as dynamic equilibrium. If the channel evolves through overall aggradation or degradation (often from changes in bedload volume), the habitat indices will no longer remain applicable. An indication of possible evolution in the river channel is the very low magnitude of the steelhead spawning index in the upper reach, which is principally derived from an absence of the smaller gravel sizes used by adult steelhead. Continued high flood flows combined with a reduction in bedload trapped behind Oroville Dam could be moving the smaller gravels out and leaving only larger gravels and cobbles.

In addition to gravel transport having an effect on PHABSIM habitat indices, they may also be changed by active habitat management. Human activities which could potentially change the current relationship between RSI/WUA over time include addition of gravels at certain locations, removal of levees and increased channel meander, creation of side channel or other complex habitat types, and riparian vegetation planting or removal. Natural changes or management actions that create an observable or quantifiable difference in existing channel characteristics would warrant a replication of the current study.

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APPENDIX A

DETAILED DESCRIPTION OF THE RATIONALE FOR THE SELECTION OF SPECIFIC TRANSECT SITES AND MAPS ILLUSTRATING THE GENERAL LOCATION OF PROPOSED TRANSECTS AND THE SPECIFIC LOCATIONS OF EXISTING IFIM/PHABSIM TRANSECTS ALONG THE FEATHER RIVER

According to *SP-F16, Evaluation of Project Effects on Instream Flows and Fish Habitat, Phase 2 Study Plan* additional transect locations were needed to accurately evaluate instream flows. Additional transect sites were selected during a field visit in which agencies and stakeholders participated.

Transects were placed at Auditorium Riffle (2 pool, 2 spawning), Trailer Park (1 pool, 2 spawning), Weir Riffle (2 pool), and Eye Riffle (1 pool), for a total of 6 pool (the recommended number) and 4 spawning transects. Fewer spawning transects than the recommended 6 were added because a consensus was reached among participating members of the transect selection team that all spawning areas in the Upper Reach had been adequately represented. Hatchery Riffle, although an important spawning area, was too complex (mid-channel lateral flow) to model with 1-D.

In the Lower Reach, transects were placed in Conveyor Belt Riffle (1 spawning), Upper Hour Riffle (1 spawning), Lower Hour Riffle (1 pool, 1 spawning), Palm Avenue Pool (1 pool, 1 spawning), Hour Pool (1 pool), Big Bar (1 pool), Upper McFarland (1 pool), Boat Launch Pool (1 pool), and Junkyard Riffle (1 pool, 1 spawning). The total of pool transects (7) was one more than recommended in Phase 1, and the total of spawning transects (5) was one less, but the consensus reached among the transect selection team was that all areas were adequately represented.

Detailed rationale for the selection of specific transect sites was provided in Attachment A, *Proposed transects for reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet (Upper Reach),* of *SP-F16, Evaluation of Project Effects on Instream Flows and Fish Habitat, Phase 2 Study Plan* and is summarized below. Figure A-1 and Figure A-2 illustrate the locations of additional transect sites. Maps illustrating the general location of proposed transects and the specific locations of existing IFIM/PHABSIM transects along the Feather River were provided in Attachment B, Maps 1-7, provided by DWR below.

Proposed spawning transects in Auditorium Riffle (2): Two additional spawning transects were proposed at this location because the area is highly utilized by spawning salmonids and warranted increased representation. Additionally, only one spawning transect existed at the site, which made it difficult to capture the lateral extent and diversity of spawning habitat. Addition of transects at Auditorium Riffle provided additional representation of the extent of spawning habitat.

Proposed pool transects downstream of Auditorium Riffle (2): Two additional pool transects were proposed at this location because the pool transect in the Auditorium Riffle area in the original study was dropped and therefore there was no pool transect representing this portion of the river. Additional representation of pools was necessary because pool habitat is a dominant habitat type and was underrepresented in the original study.

Proposed pool transect upstream of Trailer Park Riffle (1), proposed spawning transect at Trailer Park Riffle (1), and proposed spawning transect downstream of

Trailer Park Riffle (1): Three additional transects (one pool, two spawning) in the Trailer Park Riffle area are proposed because Trailer Park Riffle has experienced increased utilization as spawning habitat since the time of the original study. It was not included in the original study because it was not as heavily utilized by spawning salmonids at that time. Trailer Park Riffle was chosen to represent utilized spawning habitat that was not represented in the existing transects.

Proposed pool transects downstream of Weir Riffle (2): Two additional pool transects were proposed downstream from Weir Riffle because, using the existing Weir pool transect, a large percentage of WUA for fry and juvenile Chinook salmon for the whole Upper Reach came from one part of the Weir Pool Transect. During the site visit it was postulated that the potential inundation of benches on the western side of the river channel at high flows could be the reason that the Weir Pool Transect is driving the WUA. While such benches exist in the immediate vicinity of the Weir Pool Transect, they are not found throughout the Upper Reach of the river. As a result, the existing transect may be viewed as representative of the area, but not of the entire Upper Reach. Therefore, two additional pool transects were chosen to provide additional representation of pool habitat in the Upper Reach.

Proposed pool transect downstream of Eye Riffle (1): One additional pool transect was proposed downstream from Eye Riffle because an additional pool was needed in the Upper Reach to increase the representation of the straight flat water pool habitat. Additionally, the Eye Riffle area is hydraulically complex. The transect was located upstream of the current rotary screw trap site.

Proposed spawning transect at Conveyor Belt Riffle (1): One additional spawning transect was proposed at Conveyor Belt Riffle location because a pool and glide transect were originally taken in the Conveyor Belt Riffle area without a spawning transect. The transect was located in the area between the previously established pool and glide transects.

Proposed spawning transect at Upper Hour Riffle (1): One additional spawning transect was proposed at Upper Hour Riffle to augment the existing spawning transects in the Lower Reach and because the area is utilized by spawning salmonids. The transect stretched from the west shore to the point of the island and then across to the next island, making the transect a double dog leg transect across the head of the spawning area.

Proposed spawning transect (1) and pool transect (1) in Lower Hour area: One additional spawning transect was proposed because Lower Hour Riffle is used by spawning salmonids and was not included in the original study. The transect was placed across the island at Lower Hour Riffle in the spawning area. One additional pool transect was proposed because the pool habitat is typical of the area.

Proposed spawning transect (1) and pool transect (1) at Palm Avenue boat launch: One additional spawning and one additional pool transect were proposed in the Palm Avenue boat launch area because additional pools and spawning transects were needed to increase the representation of spawning and pool habitat to de-emphasize the proportional weight on existing transects. This transect pair was located near the Palm Avenue boat launch and provided representation of typical habitat in the area.

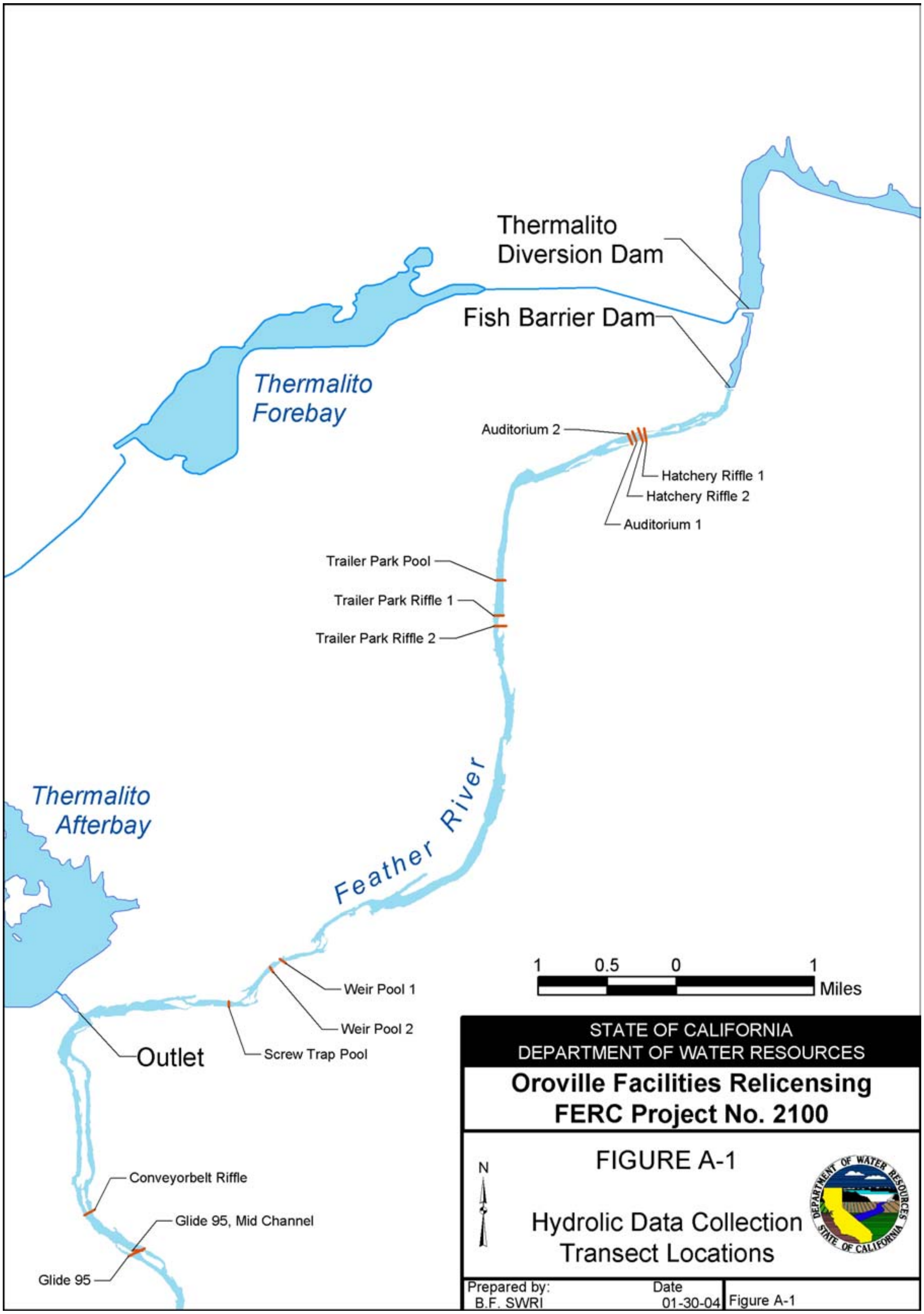
Proposed pool transect at Hour Pool (1): One additional pool transect was proposed at Hour Pool because additional straight flat water pools were necessary to increase representation of pool habitat in the Lower Reach and the pool was considered representative of the habitat in the area.

Proposed pool transect upstream of Big Bar (1) and Upper MacFarland pool transect (1): Two additional pool transects were proposed in the area because straight flat water pools are the dominant habitat type in the area and were underrepresented in the original study. Additionally, the area was not previously transected.

Proposed pool transect at Boat Launch Pool (1): One additional pool transect was proposed at Boat Launch Pool because the pool is characteristic of the straight flat water pools occurring between the Gridley boat launch and the confluence with Honcut Creek.

Proposed spawning transect (1) and pool transect (1) in Junkyard Riffle area: One additional spawning and one additional pool transect were proposed in the Junkyard Riffle area because additional transects were needed to increase the representation of spawning and pool habitat to de-emphasize the proportional weight on existing transects. The spawning transect was located at the head of Junkyard Riffle. The pool transect was placed downstream of Junkyard Riffle in Junkyard Pool.

During data gathering activities, the general locations of transect sites remained similar to those proposed in the Phase 2 Study Plan. In some cases, however, transect locations differed from the proposed transect locations. Because site conditions during data gathering activities required movement of some transect locations from the proposed locations, the actual locations shown in Figure A-1 and Figure A-2 were based on the best professional judgment of IFIM/PHABSIM experts and may differ from the general locations described above. Maps 1 through 7 show the locations of original transects sampled by DWR and the general locations of additional transects proposed in the SP-F16 Phase 2 Study Plan.


Thermalito Diversion Dam
Fish Barrier Dam
Thermalito Forebay
Auditorium 2
Hatchery Riffle 1
Hatchery Riffle 2
Auditorium 1
Trailer Park Pool
Trailer Park Riffle 1
Trailer Park Riffle 2
Thermalito Afterbay
Feather River
1 0.5 0 1
Miles
Weir Pool 1
Weir Pool 2
Screw Trap Pool
Outlet
Conveyorbelt Riffle
Glide 95, Mid Channel
Glide 95
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
Oroville Facilities Relicensing
FERC Project No. 2100
FIGURE A-1
N
Hydrolic Data Collection
Transect Locations
Prepared by:
B.F. SWRI
Date
01-30-04
Figure A-1

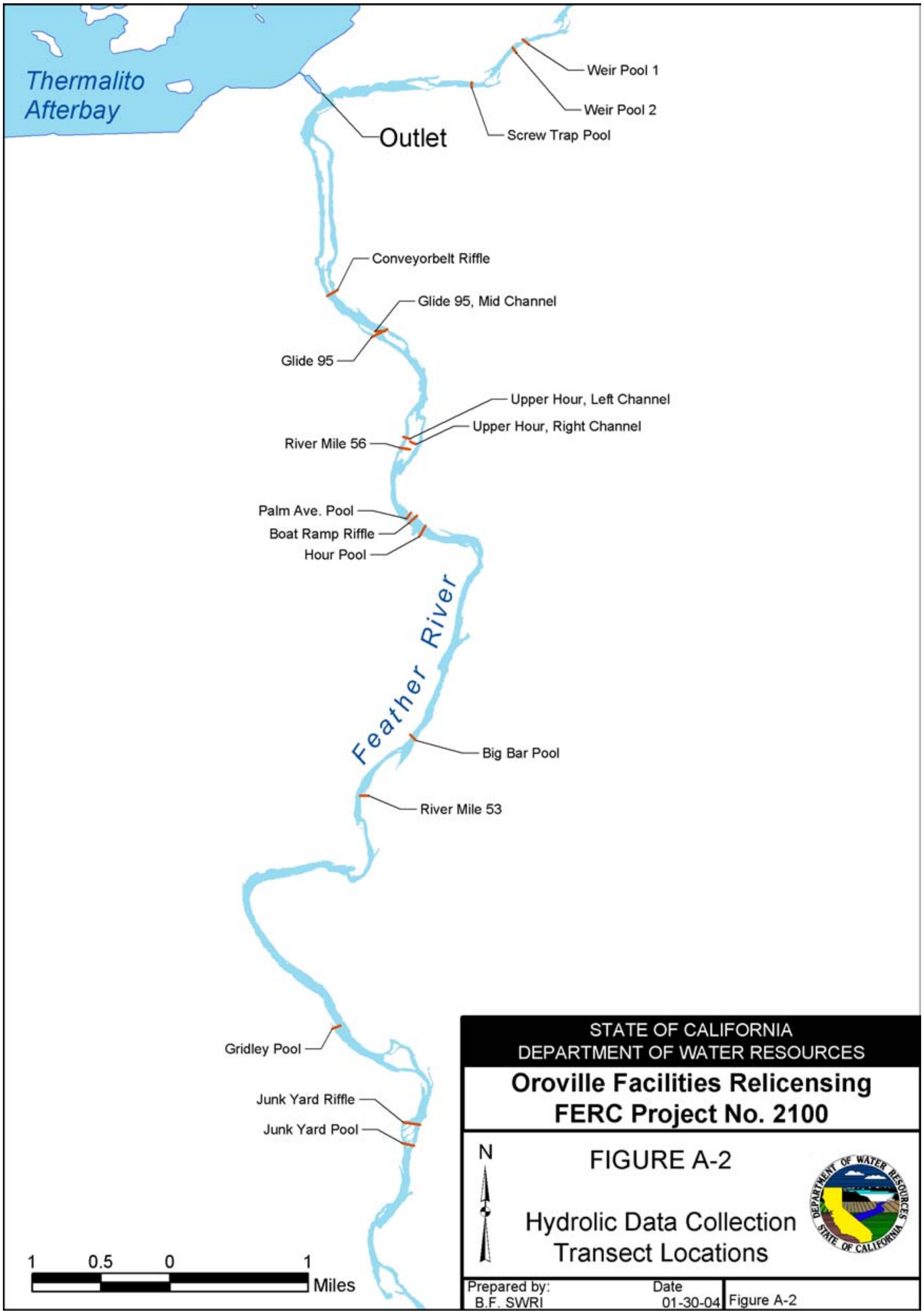

Thermalito
Afterbay
Outlet
Weir Pool 1
Weir Pool 2
Screw Trap Pool
Conveyorbelt Riffle
Glide 95, Mid Channel
Glide 95
Upper Hour, Left Channel
Upper Hour, Right Channel
River Mile 56
Palm Ave. Pool
Boat Ramp Riffle
Hour Pool
Feather River
Big Bar Pool
River Mile 53
Gridley Pool
Junk Yard Riffle
Junk Yard Pool
1 0.5 0 1
Miles
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
Oroville Facilities Relicensing
FERC Project No. 2100
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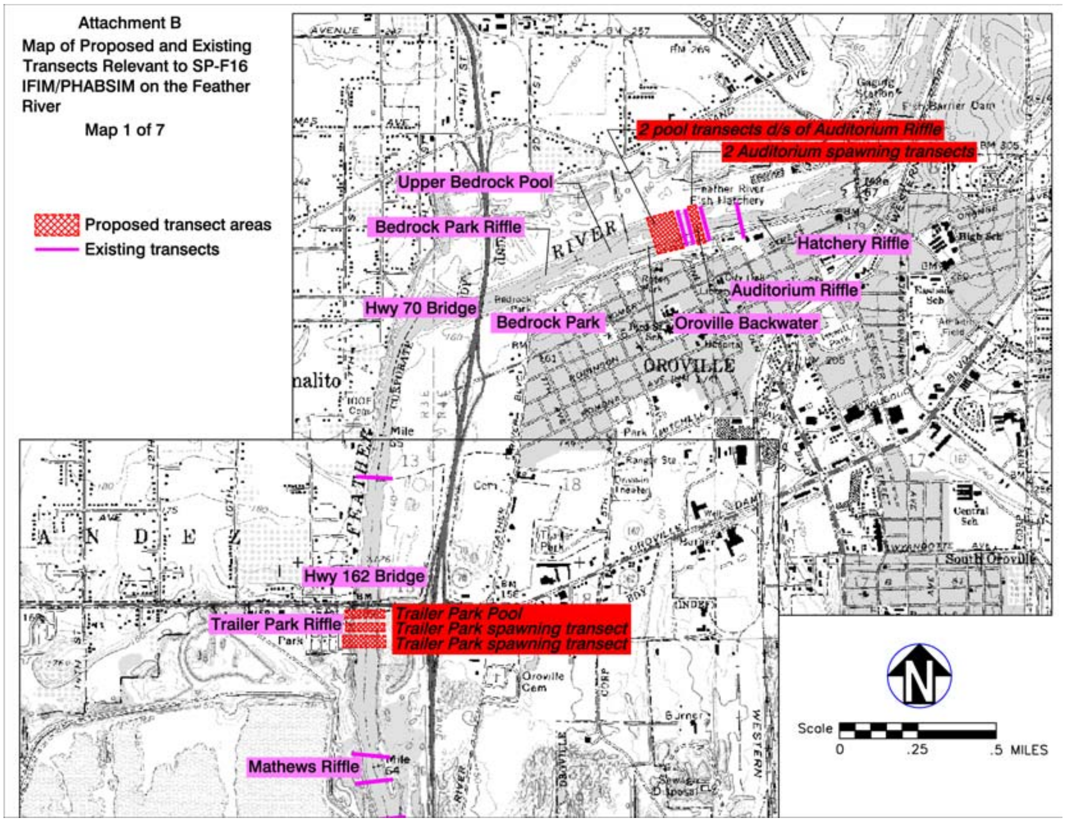
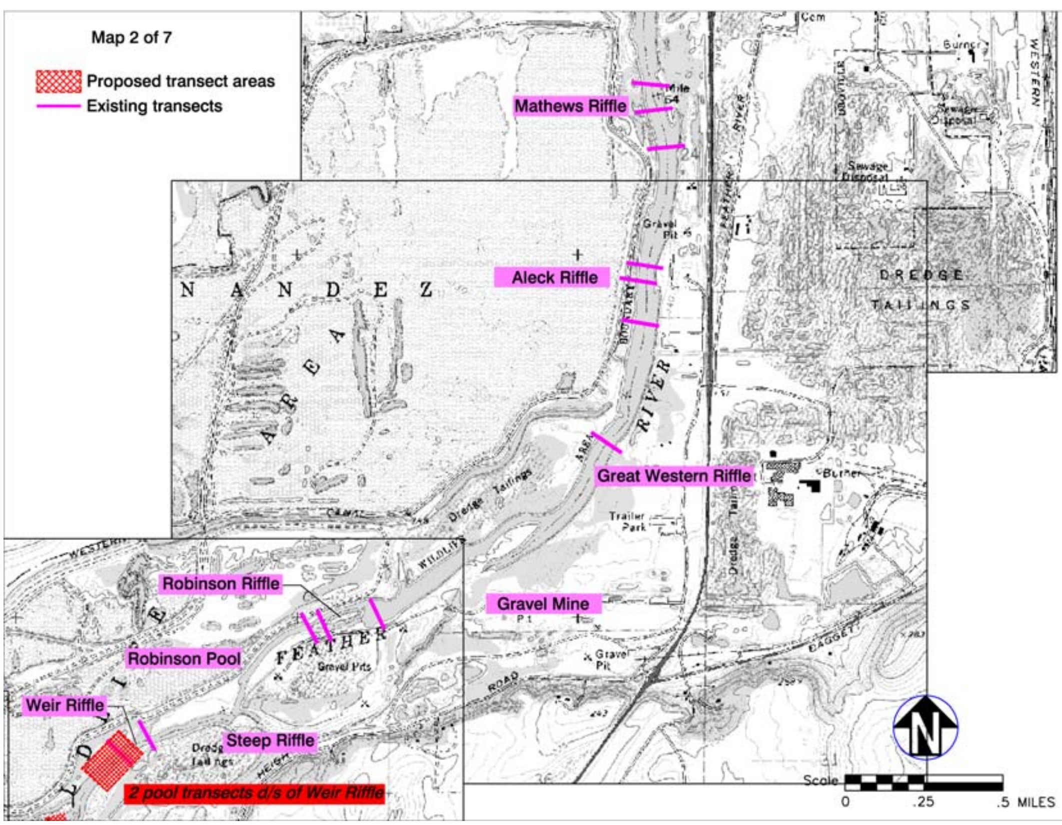
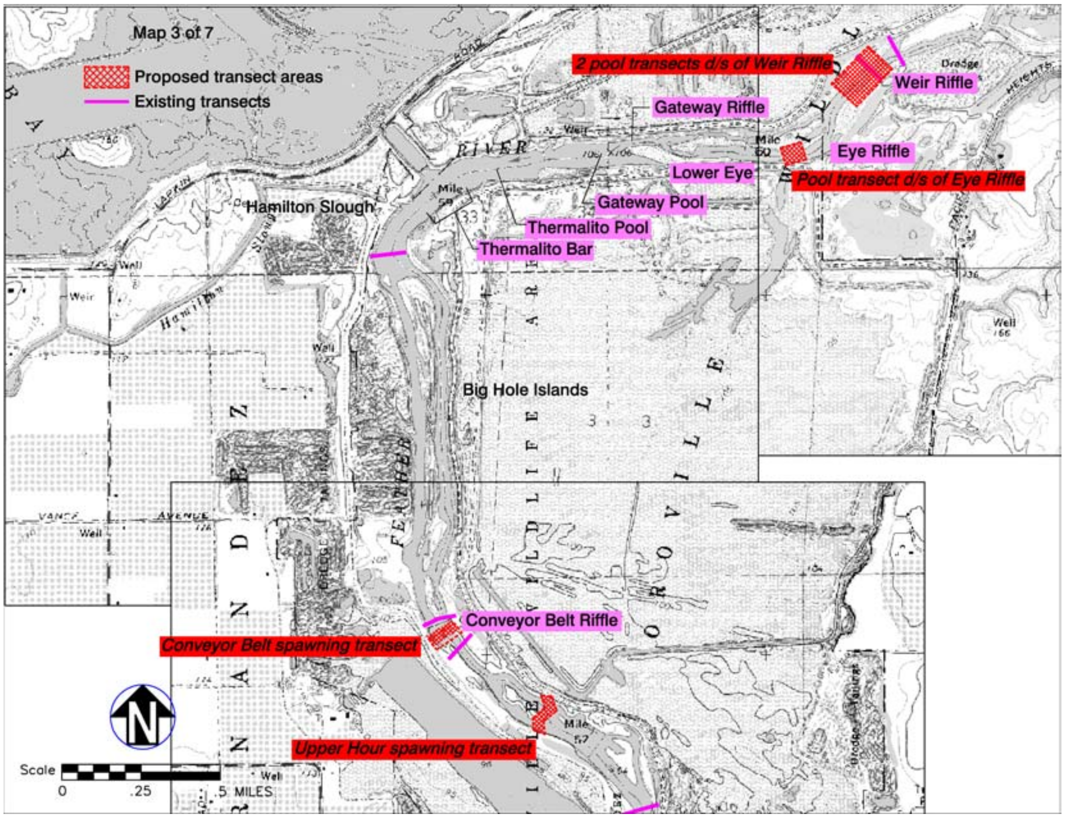
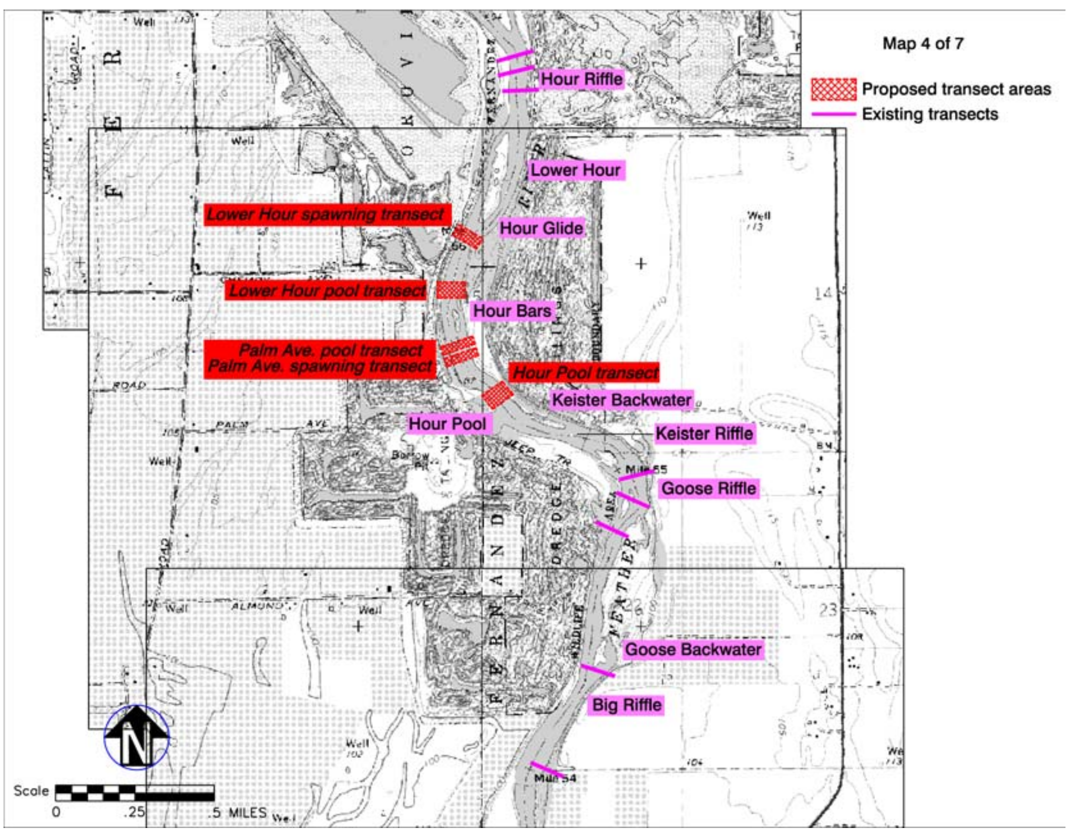
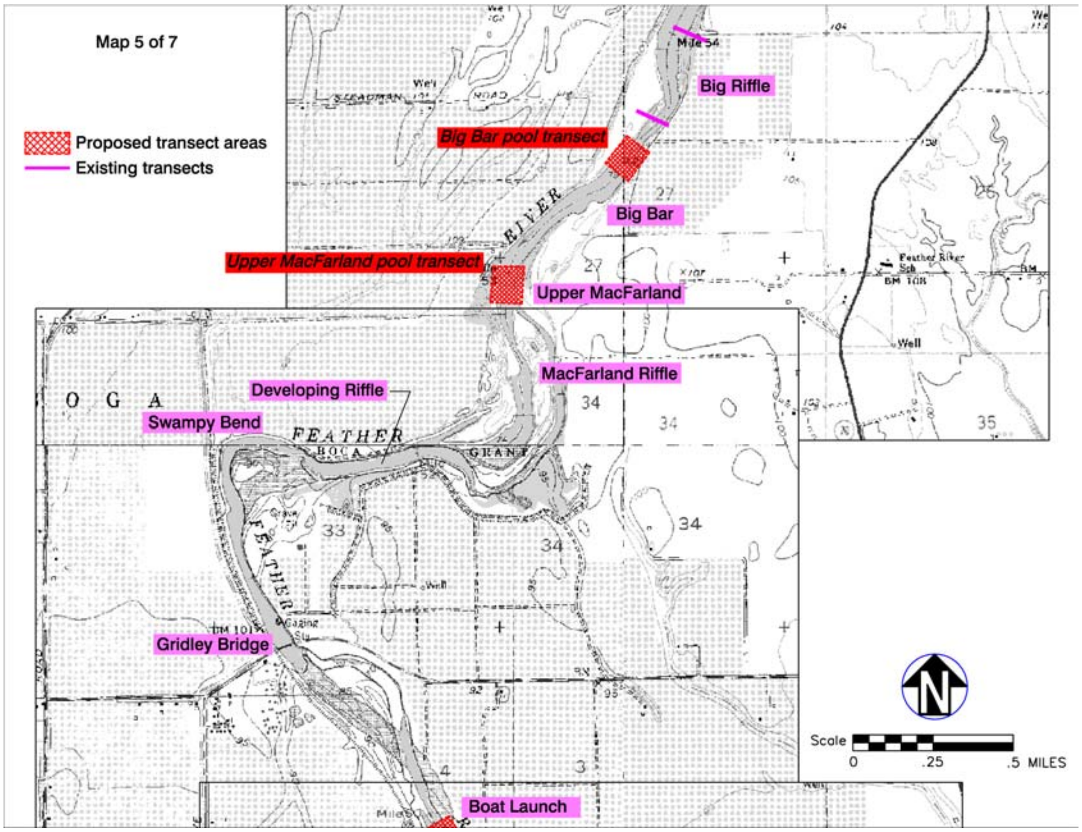
FIGURE A-2
Hydrolic Data Collection
Transect Locations
Prepared by:
B.F. SWRI
Date
01-30-04
Figure A-2

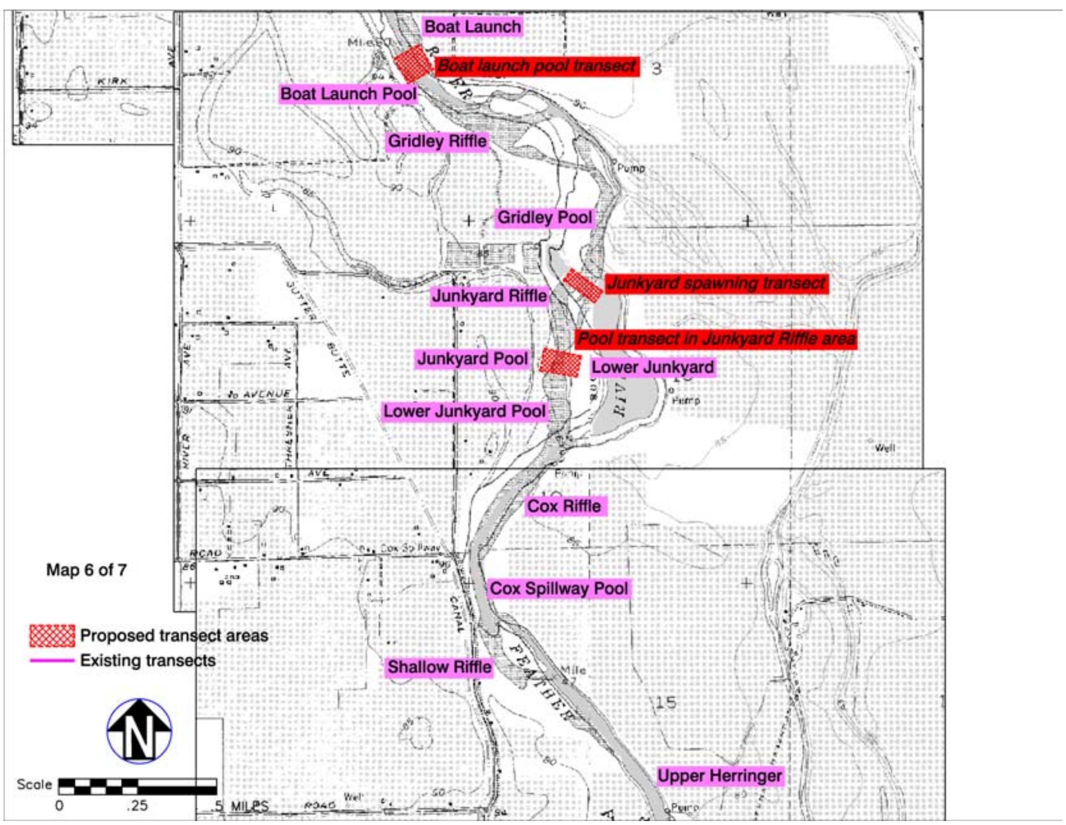

Attachment B
Map of Proposed and Existing Transects Relevant to SP-F16 IFIM/PHABSIM on the Feather River
Map 1 of 7
Proposed transect areas
Existing transects
2 pool transects d/s of Auditorium Riffle
2 Auditorium spawning transects
Upper Bedrock Pool
Bedrock Park Riffle
Hatchery Riffle
Auditorium Riffle
Hwy 70 Bridge
Bedrock Park
Oroville Backwater
OROVILLE
Hwy 162 Bridge
Trailer Park Riffle
Trailer Park Pool
Trailer Park spawning transect
Trailer Park spawning transect
Mathews Riffle
Scale
0 .25 .5 MILES

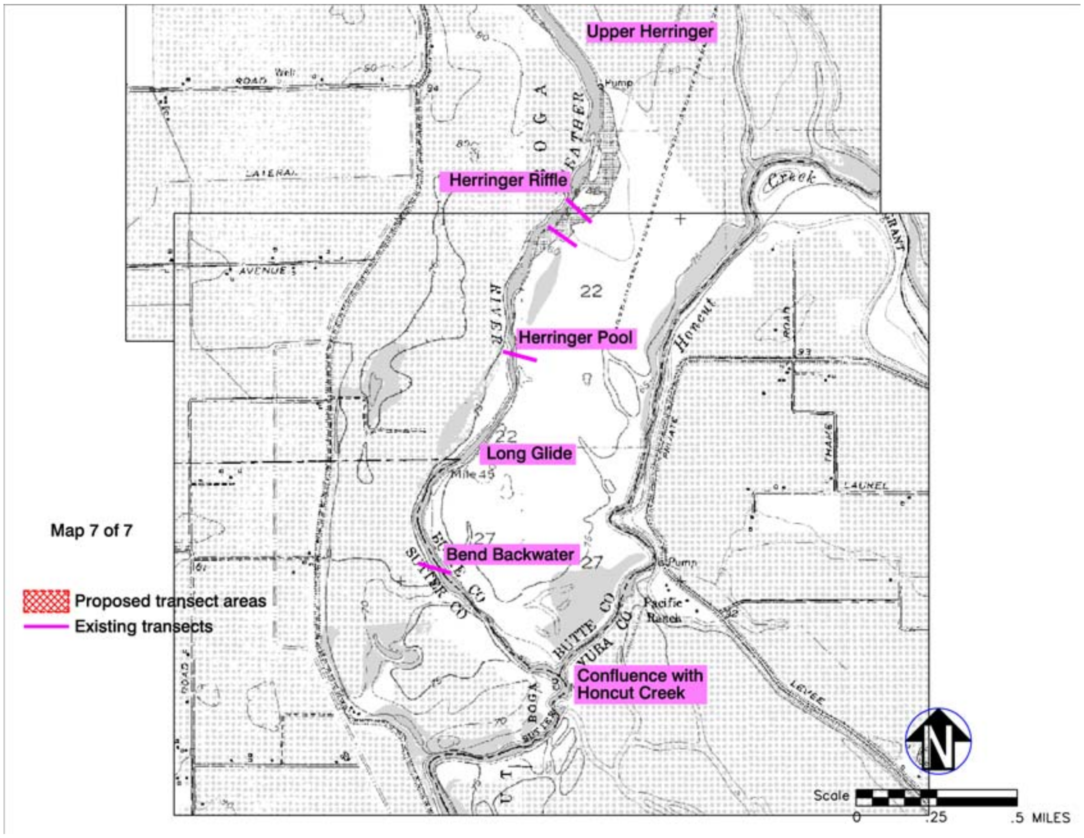

Map 2 of 7
Proposed transect areas
Existing transects
Mathews Riffle
Aleck Riffle
Great Western Riffle
Robinson Riffle
Gravel Mine
Robinson Pool
Weir Riffle
Steep Riffle
2 pool transects d/s of Weir Riffle
Scale
0 .25 .5 MILES


Map 3 of 7
Proposed transect areas
Existing transects
2 pool transects d/s of Weir Riffle
Weir Riffle
Gateway Riffle
Eye Riffle
Lower Eye
Pool transect d/s of Eye Riffle
Hamilton Slough
Gateway Pool
Thermalito Pool
Thermalito Bar
Big Hole Islands
Conveyor Belt Riffle
Conveyor Belt spawning transect
Upper Hour spawning transect
Scale
0
.25
.5 MILES


Map 4 of 7
Proposed transect areas
Existing transects
Hour Riffle
Lower Hour
Lower Hour spawning transect
Hour Glide
Lower Hour pool transect
Hour Bars
Palm Ave. pool transect
Palm Ave. spawning transect
Hour Pool transect
Keister Backwater
Hour Pool
Keister Riffle
Goose Riffle
Goose Backwater
Big Riffle
Scale
0
.25
.5 MILES


Map 5 of 7
Proposed transect areas
Existing transects
Mile 54
Big Riffle
Big Bar pool transect
Big Bar
Upper MacFarland pool transect
Upper MacFarland
MacFarland Riffle
Developing Riffle
Swampy Bend
FEATHER
Gridley Bridge
Boat Launch
Scale
0
.25
.5 MILES


Boat Launch
Boat launch pool transect
Boat Launch Pool
Gridley Riffle
Gridley Pool
Junkyard spawning transect
Junkyard Riffle
Pool transect in Junkyard Riffle area
Junkyard Pool
Lower Junkyard
Lower Junkyard Pool
Cox Riffle
Cox Spillway Pool
Shallow Riffle
Upper Herringer
Map 6 of 7
Proposed transect areas
Existing transects
Scale
0
.25
.5 MILES


Upper Herringer
Herringer Riffle
Herringer Pool
Long Glide
Bend Backwater
Confluence with
Honcut Creek
Map 7 of 7
Proposed transect areas
Existing transects
FEATHER
RIVER
Honcut
Creek
Pump
Pacific Ranch
BUTTE CO
YUBA CO
SUTTER CO
Mile 45
22
27
Scale
0
.25
.5 MILES