State of California
The Resources Agency
Department of Water Resources

FINAL REPORT
ASSESSMENT OF POTENTIAL PROJECT EFFECTS ON SPLITTAIL HABITAT
SP-F3.2 TASK 3B

Oroville Facilities Relicensing
FERC Project No. 2100

JULY 2004

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REPORT SUMMARY

The purpose of SP-F3.2 Task 3B is to assess potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. Operations of the Oroville Facilities affect instream flow, river stage, and water temperature in the lower Feather River, which affects splittail spawning, incubation, and initial rearing habitat quantity, quality, and distribution. The results of this study provide information regarding the frequency with which potential splittail spawning and initial rearing habitat is inundated during the splittail spawning, egg incubation, and initial rearing period, as well as the frequency with which water temperatures fall within splittail tolerance levels. Additionally, the results of this study may support the identification or evaluation of potential Resource Actions that could increase the quantity or quality of splittail spawning and initial rearing habitat.

A review of available literature on Sacramento splittail life history was conducted to determine the period of analysis during which project operations could affect splittail habitat. Based on the results of the literature review, February through May was determined to be the appropriate time period for analysis of splittail habitat during the splittail spawning, egg incubation, and initial rearing period in the lower Feather River. A review of the literature also was used to determine suitable splittail spawning, egg incubation, and initial rearing habitat characteristics for water depth and water temperature. Splittail spawning, incubation, and initial rearing habitat is generally described as submerged vegetation typically found in riparian zones flooded to a depth between three and six feet.

The Department of Water Resources, through photo-interpretation and ground-truthing, created a GIS polygon data set depicting vegetation within the lower Feather River floodplain. The GIS data set was attributed using a modified version of the Holland Classification System. Two vegetation associations, *gravel/sandbar* and *mixed emergent vegetation*, were determined to be suitable for potential splittail spawning and were selected for further field survey. In November of 2003, 10 of the GIS polygon locations were surveyed to determine the range of absolute surface elevations within each habitat unit. The surveyed sites comprised approximately 23 percent of the total area that was classified as *gravel/sandbar* or *mixed emergent vegetation*. Stage-discharge curves from lower Feather River USGS transects were used to calculate potential habitat within each polygon and the total potential habitat for all 10 polygons. An index of relative habitat availability or Index of Usable Flooded Area (UFA) was created based on the results of the field surveys. UFA is defined as the relative amount of habitat inundated to a minimum depth of 3 feet and a maximum depth of 6 feet during the defined spawning, incubation, and initial rearing period according.

Feather River flows and duration of potential splittail spawning and initial rearing inundation are highly correlated with splittail year-class strength as reported by the California Department of Fish and Game (DFG). In this report, 21 years of instream

flow data were analyzed. Within the 21 years, 8 years were reported by DFG as producing strong year-classes, which correlated to high flows in the Feather River, 6 years were described as producing weak year-classes, which correlated to low flows in the Feather River, and 7 years were reported to have produced either intermediate or unknown year-class strengths, which correlated with intermediate flows in the Feather River. Available literature suggests that, because of the high fecundity, broad environmental tolerances, and relatively long life span of the Sacramento splittail, the population is resilient and able to recover quickly after a period of drought. Consecutive years of high flows creating significant habitat for spawning, egg incubation, and initial rearing are reported not to be necessary to ensure continued persistence of the species.

Because published studies on Sacramento splittail spawning, egg incubation, and initial rearing have focused on floodplains outside the area directly influenced by Oroville Facility operations, the relative importance of habitat availability within the lower Feather River for continued splittail persistence is unknown. Likewise, studies on splittail abundance have focused on juvenile captures in the delta, which is an indicator of basin wide productivity rather than specific production in the Feather River. Based on the results of the analysis of lower Feather River flows vs. splittail year class strength, and in the absence of specifically directed studies on lower Feather River splittail population dynamics, it does not appear likely that continued operations of the Oroville Facilities, under current operating practices, would create conditions unfavorable to splittail spawning, egg incubation, and initial rearing habitat.

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1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Ongoing operation of the Oroville Facilities has the potential to influence potential; splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. Operations of the Oroville Facilities affect the flow, stage and water temperature in the Feather River downstream of the Thermalito Diversion Dam and these factors influence splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. As a component of study plan (SP)-F3.2, *Evaluation of Project Effects on Non-salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam,* Task 3 of SP-F3.2 evaluates potential project effects on sturgeon and splittail habitat. Task 3B, herein, assesses potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period.

1.1.1 Statutory/Regulatory Requirements

The purpose of SP-F3.2 Task 3B is to assess potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. On February 8, 1999, Sacramento splittail (*Pogonichthys macrolepidotus*) was designated as Threatened under the Endangered Species Act (ESA) by the U.S. Fish and Wildlife Services (USFWS) (USFWS 1999). Splittail were listed as Threatened throughout their entire range, which includes the Feather River (USFWS 1999). On September 22, 2003, the USFWS issued a Notice of Remanded Determination for the Sacramento Splittail (USFWS 2003). This removed the Sacramento Splittail from the Endangered Species List. The fish is however, still considered a Species of Special Concern with a threatened status by the California Department of Fish and Game (DFG).

In addition to 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.

As a subtask of SP-F3.2, Task 3B fulfills a portion of the FERC application requirements by assessing the frequency with which splittail habitat is inundated during the splittail spawning, egg incubation, and initial rearing period, as well as the frequency with which water temperatures fall within splittail tolerance levels. 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-F3.2, *Evaluation of Project Effects on Non-salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam,* encompasses the Feather River downstream from the Thermalito Diversion Dam to its confluence with the Sacramento River. The Thermalito Diversion Dam was named as the upstream extent of all tasks in SP-F3.2 because of the potential for Resource Actions to suggest allowing in-river fish passage of primarily salmonids into the Fish Barrier Pool. The area extending from the Thermalito Diversion Dam to the Fish Barrier Dam is a small reservoir called the Fish Barrier Pool. This reach was included as part of the study area for the tasks in SP-F3.2 primarily to allow collection and analysis of data to evaluate potential a Resource Action suggesting passing salmonids into the Fish Barrier Pool. However, because splittail prefer the reach of the Feather River downstream of the confluence with Honcut Creek (see section 1.1.2.2 History) and because flows in the HFC could be manipulated using the Thermalito Afterbay Outlet, Task 3B, herein, will focus on the section of the Feather River extending from the Thermalito Afterbay Outlet to the confluence with the Sacramento River. The Feather River confluence with the Sacramento River is the downstream boundary of this study plan because of the potential influence of flow releases on inundation of benches, which could potentially serve as splittail spawning habitat when submerged.

1.1.2.1 Description

Physical habitat: Flow regime

The reach of the Feather River extending from the Fish Barrier Dam to the Sacramento River is composed of two operationally distinct segments. The upstream segment extends from the Fish Barrier Dam at river mile (RM) 67.25 to the Thermalito Afterbay Outlet (RM 59), while the downstream segment extends from the Thermalito Afterbay Outlet (RM 59) to the confluence of the Feather and Sacramento Rivers (RM 0). The flow regime associated with each of these segments is distinct and is summarized below.

Minimum flows in the lower Feather River were established in the August 1983 agreement between the California Department of Water Resources (DWR) and the California Department of Fish and Game (DFG) (DWR 1983). The agreement specifies that DWR release a minimum of 600 cubic feet per second (cfs) into the Feather River from the Thermalito Diversion Dam for fisheries purposes. Therefore, the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet is operated at 600 cfs all year, with variations in flow occurring rarely, only during flood control releases or in the summer in order to meet downstream temperature requirements for salmonids.

For a Lake Oroville surface elevation greater than 733 feet, the minimum in-stream flow requirements on the Feather River below the Thermalito Afterbay Outlet are provided in Table 1.1-1 as follows:

Table 1.1-1 Minimum instream flow requirements in the lower Feather River.

Percent of normal[1] runoff (%)	Oct.-Feb. (cfs)	Mar. (cfs)	Apr.-Sep. (cfs)
> 55	1,700	1,700	1,000
< 55	1,200	1,000	1,000

[1] Normal runoff is defined as 1,942,000 acre-feet, which is the mean (1911 – 1960) April through July unimpaired runoff near Oroville.

Source: (DWR 1983)

Unlike the constant flow regime in the Low Flow Channel (LFC) of the Feather River, the flow regime in the reach of the Feather River extending from the Thermalito Afterbay Outlet (RM 59) to the confluence of the Feather and Sacramento rivers (RM 0) varies depending on runoff and month. Although the minimum flow requirements are described above, flow in the reach of the Feather River extending from the Thermalito Afterbay Outlet to the confluence of the Feather and Sacramento rivers typically varies from the minimum flow requirement to 7,500 cfs (DWR 1982b). Flow in this reach is, therefore, more highly varied than flow in the upstream segment. Flow in the downstream segment is additionally influenced by small flow contributions from Honcut Creek and the Bear River, and by larger flow contributions from the Yuba River.

Physical habitat: geomorphology/topology/vegetation

The LFC is categorized by a sequence of shallow riffles, 2 to 5 meter deep pools and island bar complexes.

The river drops a total of 37 feet in this 8.25 mile-long segment, for a stream gradient of about 0.09 percent (DWR 1982a). Flow in this reach is dictated by a 1983 agreement between the California Department of Water Resources (DWR) and the California Department of Fish and Game (DFG), which states that flow in this reach of the river is maintained at a constant flow of 600 cfs year-round (DWR 1983). Water temperature regimes in the LFC are driven by Feather River Fish Hatchery (FRFH) objectives described in an agreement between DWR and DFG that was signed in 1983 (DWR 1983; DWR 2001). Hatchery water temperature objectives are depicted in Table 1.1-2. A water temperature range of plus or minus 4°F is allowed for objectives, from April through November. Meeting these water temperature objectives is facilitated by a shutter controlled intake gate system at the Oroville Dam that selects water for release from different reservoir depths (DWR 2001). Additionally, this section of the river channel is confined by cobble levees that restrict overbank flooding and provide lateral channel control (DWR 2001). Because of the confinement within levees, this section of the river is generally less complex than the downstream segment, with fewer meanders and less area for channel migration. Substrates in this segment are composed of relatively large elements with armoring due to lack of recruitment of gravel to the system and transport of gravels downstream out of the area (Sommer et al. 2001). Streambank vegetation in the area is seldom inundated due to the maintenance of constant flow regimes.

Table 1.1-2. Feather River Fish Hatchery water temperature objectives.

Period	Temperature (ºF)
April 1 - May 15	51º
May 16 – May 31	55º
June 1 - June 15	56º
June 16 – August 15	60º
August 16 – August 31	58º
September 1 – September 30	52º
October 1 – November 30	51º
December 1 – March 31	55º

Source. (DWR 1983; DWR 2001)

The second river segment is the reach of the Feather River which extends from the Thermalito Afterbay Outlet (RM 59) downstream to the confluence with the Sacramento River at Verona (RM 0). Flow in this downstream reach is also governed by the 1983 agreement between DWR and DFG, which sets the minimum flow requirements in the Feather River below the Thermalito Afterbay Outlet at 1,000 to 1,700 cfs depending on the runoff at Oroville and the time of year (DWR 1983). Typically, flows in this reach vary from the minimum flow requirement to 7,500 cfs (DWR 1982a). In this reach, the river is not confined by levees over the entire reach and the channel bed and banks become more variable (DWR 1982b; DWR 2001). The river flows through undisturbed older alluvium and floodplain deposits, and active erosion contributes to siltation of gravels downstream (DWR 1982b; DWR 2001). Because the active channel in this reach is broader and wider than in the upper segment, more meanders and gravel bars occur in this reach. The width between confining levees in this reach varies dramatically. In some places, the width is about the same as the stream channel. In other places, several miles of floodplain exist between the levees. The substrate in this segment of the Feather River tends to include relatively small gravel-sized particles transported from the upstream segment of the river (Sommer et al. 2001). Streamside vegetation in this area is more frequently inundated, particularly in the spring, during high flow periods.

Chemical/Physical habitat: water temperature

Water temperature in the reach of the Feather River extending from the Thermalito Afterbay Outlet to the confluence with the Sacramento River is typically warmer than water temperature in the upper reaches of the Feather River. Water temperature in this lower reach is directly influenced by the water releases from the Thermalito Afterbay Outlet. Because the Thermalito Afterbay is a large, shallow, reservoir, water that is released from the Thermalito Afterbay Outlet is typically warmer than the water originating from the upstream reach of the main channel of the Feather River. Typically, the contribution to the total flow in the Feather River from the Thermalito Afterbay Outlet is generally greater than flow contribution from the upper reach of the Feather River, and water temperatures in the river downstream of the Thermalito Afterbay Outlet are generally warmer than water temperatures in the reach upstream of the Thermalito Afterbay Outlet. For additional details regarding water temperature operational requirements, see section 1.3.1.2, Temperature Requirements.

Biological context

The lower Feather River supports a variety of fish species. The Feather River warmwater sport fishery is composed of fish of the Centrarchidae (sunfish) family including four species of black bass (*Micropterus punctulatus*, *M. salmoides*, *M. dolomieui*, and *M. coosae*), three species of sunfish (*Lepomis macrochirus*, *L. cyanellus*, and *L. microlophus*), and two species of crappie (*Pomoxis nigromaculatus* and *P. annularis*) (DWR 2001). Additionally, striped bass (*Morone saxatilis*) and American shad (*Alosa sapidissima*) are also common targets for anglers. The Feather River also provides habitat for many other fish species, including native fish (e.g., Sacramento pikeminnow (*Ptychocheilus grandis*), hardhead (*Mylopharodon conocephalus*), Sacramento sucker (*Catostomus occidentalis*), Sacramento splittail (*Pogonichthys macrolepidotus*), river lamprey (*Lamptera ayresi*), Pacific lamprey (*L. tridentata*), tule perch (*Hysterocarpus traski*), hitch (*Lavinia exilicauda*), green sturgeon (*Acipenser medirostris*), and white sturgeon (*A. transmontanus*)), and introduced fish (e.g., carp (*Cyprinus carpio*), wakasagi (*Hypomesis nipponensis*), and threadfin shad (*Dorosoma petenense*)). In addition to these species, the Feather River also supports annual runs of spring and fall Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*).

1.1.2.2 History

The Sacramento splittail is a member of the minnow family (*Cyprinidae*) and is the only living member of its genus (USFWS 1995b). Sacramento splittail were historically found as far north as Redding, California but are no longer found in this area (USFWS 1995b). These fish have been collected from the Merced River at Livingston and from the San Joaquin River at Fort Miller. There are also reported catches from the southern San Francisco Bay and at the mouth of Coyote Creek in Santa Clara County, but recent surveys indicate that splittail are no longer present in these areas (USFWS 1995b). Moyle (2002) reports that, in most years, Sacramento splittail are confined to the Delta, Suisun Bay, Suisun Marsh, the lower Napa River and the lower Petaluma River. Important spawning areas for splittail include both the Yolo and Sutter bypasses, adjacent to the Sacramento River, and the Tuolumne River (Moyle 2002). Splittail are also known to utilize the Feather River for spawning (USFWS 1995b). Splittail also support a small sport fishery (Caywood 1974; Wang 1986).

In wet years, Sacramento splittail may migrate up the Sacramento River as far as Red Bluff and into the lower Feather and American rivers (Moyle 2002). In the Feather River, Sacramento splittail have been collected as far upstream as Oroville (USFWS

1995b). From January 1997 through August 2001, Seesholtz et al. (2003) conducted seining and rotary screw trap operations in the lower Feather River and found Sacramento splittail ranking 20th and 23rd in abundance of species collected with the seines and screw traps respectively. This ranking was out of 29 different species identified and collected during the study. Of those splittail collected in the lower Feather, all were found in the High Flow Channel, below the Thermalito Afterbay Outlet (Seesholtz et al. 2003).

Sacramento splittail spawning can occur anytime between late February and early July but peak spawning occurs in March and April (Moyle 2002). A gradual upstream migration begins in the winter months to forage and spawn, although some spawning activity has been observed in Suisun Marsh (Moyle 2002). During wet years, upstream migration is much more directed and fish tend to swim further upstream (Moyle 2002). Attraction flows are necessary to initiate travel on to floodplains where spawning occurs (Moyle et al. 2003). Spawning generally occurs in water with a depth of 3.0 to 6.6 ft (0.9 to 2.0 m) over submerged vegetation where eggs adhere to vegetation or debris until hatching (Moyle 2002; Wang 1986). Caywood (1974) reports that older fish are generally the first to spawn. Sacramento splittail are reported to lay between 5,000 and 100,800 eggs (Wang 1986). The largest splittail females typically lay over 100,000 eggs (Moyle 2002). Daniels and Moyle (1983) sampled 20 splittail over 175 mm (6.9 in) and found numbers of eggs ranging from 17,500 to 266,000.

Eggs normally incubate for three to seven days depending on water temperature (Moyle 2002). Under laboratory conditions, eggs incubated at 19^{o}C (66.2^{o}F) started to hatch after 96 hours (USFWS 1995a). After hatching, splittail larvae remain in shallow weedy areas until water recedes, and then they migrate downstream (Meng and Moyle 1995). The largest catches of Sacramento splittail larvae occurred in 1995, a wet year when outflow from inundated areas peaked during March and April (Meng and Matern 2001).

Juvenile Sacramento splittail prefer shallow-water habitat with emergent vegetation during rearing (Meng and Moyle 1995). Water temperature preferences are reported to be between 71.6 and 75.2^{o}F (22 to 24^{o}C) during this time period (Young and Cech Jr. 1996). Young found that splittail in the Yolo Bypass floodplain were more abundant in the shallowest areas of the wetland with emergent vegetation (Sommer et al. 2002). Juvenile splittail are classified as benthic foragers (USFWS 1995b). Downstream movement of juvenile splittail appears to coincide with drainage from the floodplains between May and July (Caywood 1974; Meng and Moyle 1995; Sommer et al. 1997).

Sacramento splittail attain sexual maturity by the end of their second winter at a length of 180 to 200 mm (7.1 to 7.9 in) (Daniels and Moyle 1983). Normal lifespan of Sacramento splittail ranges from 5 to 7 years (Caywood 1974; Meng and Moyle 1995). Adults can attain a length of over 300 mm (11.8 in) (USFWS 1995b). Adults are normally found in relatively shallow (<4 m) water in brackish tidal sloughs, such as Suisun Marsh, but can also occur in freshwater areas with either tidal or riverine flows

(Moyle et al. 2003). In the Suisun Marsh, Sacramento splittail forage extensively on opossum shrimp, benthic amphipods, and harpactacoid copepods, while in upstream areas, prior to spawning, they feed primarily on earthworms in flooded areas (Moyle 2002). Splittail are also known to withstand very low dissolved oxygen levels (<1 mg O_2 l^{-1}), a wide range of water temperatures (5 – 24^{o}C) and salinities of 6 – 10 ppt (Moyle et al. 2003).

Floodplain inundation during March and April appears to be the primary factor contributing to splittail abundance. Sacramento River flow must exceed 56,000 cfs at Verona before the Fremont Weir spills into the Yolo Bypass (Sommer Unpublished Work). Sommer (Unpublished Work) speculates that during dry years, the frequency and duration of floodplain inundation is not sufficient to support high levels of foraging, spawning and rearing. Moyle et al. (2003) reports that moderate to strong year classes of splittail develop when floodplains are inundated for six to ten weeks between late February and late April. Reportedly, when floodplains are inundated for less than a month, strong year classes are not produced (Sommer et al. 1997).

Sommer et al. (1997) discuss the resiliency of splittail populations and suggest that because of their relatively long life span, high reproductive capacity and broad environmental tolerances, splittail populations have the ability to recover rapidly even after several years of drought conditions. This suggests that frequent floodplain inundations are not necessary to support a healthy population. Moyle et al. (2003) reports that the ability of at least a few splittail to reproduce even under the worst flow conditions insures that the population will persist indefinitely, despite downward trends in total population size during periods of droughts.

Other than incidental observations of Sacramento splittail in the Feather River (Seesholtz et al. 2003; USFWS 1995b), there have been no directed studies of abundance in this area. Because splittail have been observed in the Feather River it is assumed that some spawning takes place but the relative importance of splittail spawning habitat on the Feather River to overall population viability is unknown.

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.

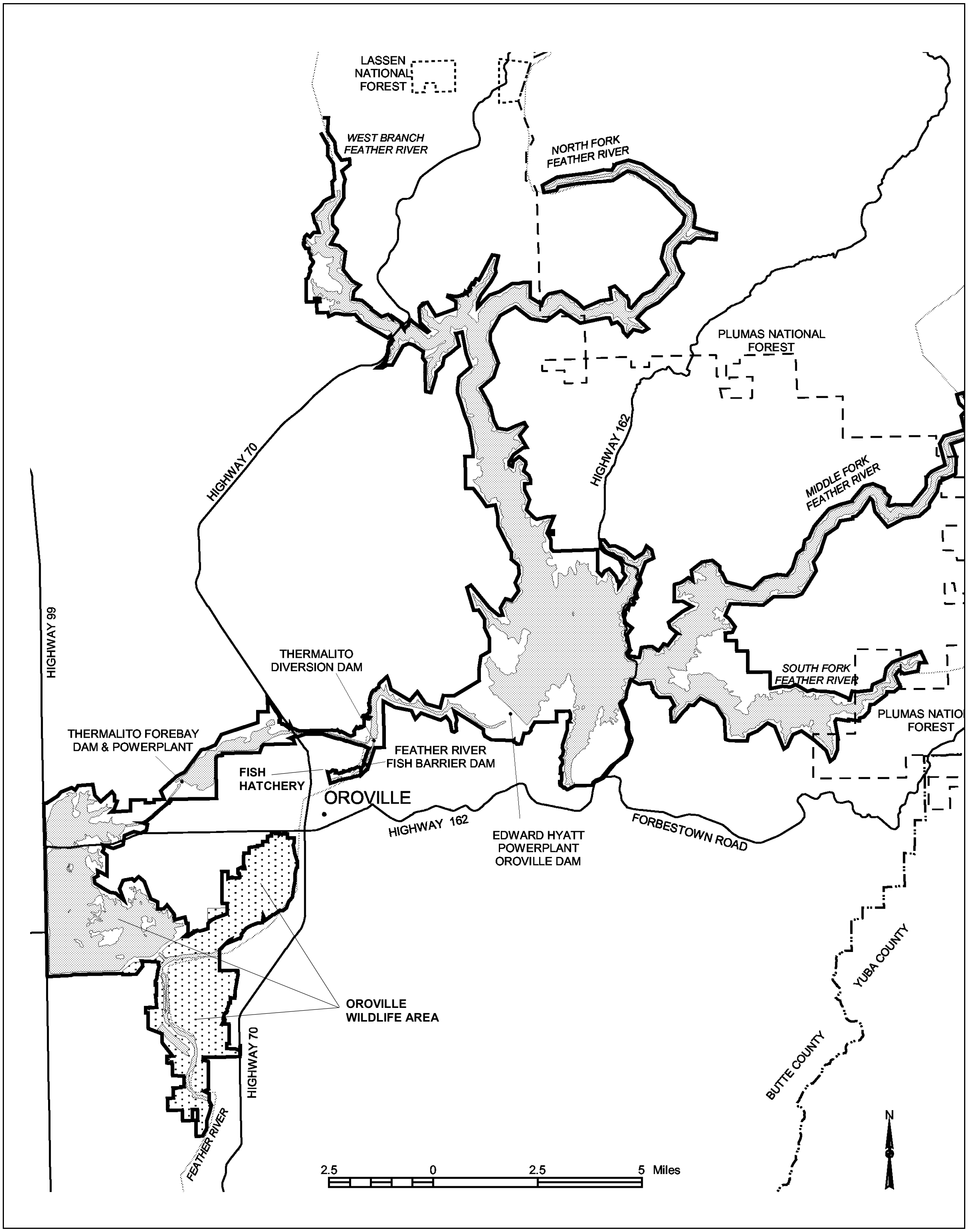

Figure 1.2-1. Oroville Facilities FERC Project Boundary.

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.

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 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

As a subtask of SP-F3.2, *Evaluation of Project Effects on Non-salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam*, Task 3B fulfills a portion of the FERC application requirements by assessing the frequency with which splittail habitat is inundated during the splittail spawning, egg incubation, and initial rearing period, as well as the frequency with which water temperatures fall within splittail tolerance levels. Performing this study is necessary, in part, because operations of the Oroville Facilities affect the flow, stage and water temperature in the Feather River and the flow, stage and water temperature in the Feather River influences potential splittail habitat quality, quantity. In addition to fulfilling statutory requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

3.0 STUDY OBJECTIVE(S)

3.1 APPLICATION OF STUDY INFORMATION

The purpose of SP-F3.2 Task 3B is to assess potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. Data collected in this task also serves as a foundation for future evaluations and development of potential Resource Actions.

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 potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. Additionally, data collected in this task serves as a foundation for future evaluations and development of potential Resource Actions.

3.1.2 Other Studies

As a subtask of study plan (SP)-F3.2, *Evaluation of Project Effects on Non-salmonid Fish in the Feather River Downstream of the Thermalito Diversion Dam,* Task 3 of SP-3.2 evaluates potential project effects on sturgeon and splittail habitat. Task 3B, herein, assesses potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. Task 3A of SP-F3.2 identifies green sturgeon distribution and habitat use patterns. For further description of Tasks 3A see SP-F3.2 and associated interim and final reports.

3.1.3 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). 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, 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.

3.1.4 Settlement Agreement

In addition to statutory and regulatory requirements, SP-F3.2 Task 3B could provide information to aid in the development of potential Resource Actions to be negotiated during the collaborative process.

4.0 METHODOLOGY

4.1 STUDY DESIGN

4.1.1 Evaluation of original study plan

The purpose of SP-F3.2 Task 3B is to assess potential project effects on splittail habitat availability during the splittail spawning, egg incubation, and initial rearing period. The SP-F3.2, Task 3B study plan originally specified that, "*In order to assess potential splittail spawning habitat, transects in the reach of the Feather River near its confluence with the Sacramento River (obtained from SP-G2) will be evaluated to determine the flows at which the benches near the mouth of the Feather River become inundated. From this data, stage-inundation relationships will be established. This information will be overlaid with the vegetation characterization (provided by SP-T4) to determine the amount of inundated vegetation (splittail spawning and rearing habitat) that would occur under a variety of flows*." In addition to the analysis of potential flow-related impacts to potential splittail habitat availability, the original study plan also specified that, "…*water temperature information from SP-W6 will be compared to splittail water temperature preferences for both spawning and rearing life stages. Water temperature preferences will be described in the literature review (Task 2), and will be compared to existing temperatures (SP-W6) to determine how project operations affect availability of water temperatures suitable to splittail.*" The fundamental analytical framework originally proposed in SP-F3.2 Task 3B was followed for all components of the analysis. With the exception of a change in the source of data used to establish the stage-inundation relationships for the analysis of flow-related impacts to potential splittail spawning habitat availability, the analysis was conducted in accordance with the original study plan proposal. The change in source data for establishing the stage-inundation relationships is described in detail below. In addition, the following section explains the consequences of use of alternative data sources as it applies to the assessment of splittail habitat availability during splittail spawning, egg incubation, and initial rearing. A detailed description of the analytical procedures utilized in the analyses is provided in Section 4.1.3, Section 4.1.4, and Appendix A.

In order to assess potential splittail spawning habitat, transects in the reach of the Feather River near its confluence with the Sacramento River were to be evaluated to determine the flows at which the benches near the mouth of the Feather River become inundated. Task 3B of SP-F3.2 called for establishment of stage-inundation relationships using transect data obtained from SP-G2. However, SP-G2 transect data for benches near the mouth of the Feather River were not available. In the absence of the expected transect data from SP-G2, an alternative source of data that could be used to establish stage-inundation relationships was required. Although several sets of detailed transect data have been collected in the reach of the Feather River between the Fish Barrier Dam and the Thermalito Afterbay Outlet for the SP-F16 PHABSIM report, comparatively little transect data have been collected in the lower reaches of the

Feather River downstream from Honcut Creek. However, the United States Army Corps of Engineers (USACE) collected transect data in the lower portions of the Feather River as part of the Sacramento-San Joaquin Basins Comprehensive Study in 1997 and 1998. In the absence of site-specific transect data from SP-G2, the USACE transect data represent the best available alternative data source. These data were used by DWR to construct the Feather River flow-stage model, the details of which are presented in SP-E1.6 *Feather River Flow-Stage Model Development*. The transect data from the *Sacramento-San Joaquin Basins Comprehensive Study* were used to construct the stage-inundation relationships for the Feather River at 10 locations as described in detail in Appendix A.

Because transect data utilized for analysis in this study were collected by USACE as part of another data collection effort, the results do not represent a site-specific habitat availability analysis, but rather represent an index of potentially available splittail habitat throughout the lower reaches of the Feather River. Therefore, the results of this analysis are presented as an index of relative habitat suitability. One consequence of using transect data collected by USACE in the absence of recently collected site-specific data is the lack of reliable transect data from RM 0 to RM 8. When using the USACE's transect data to create a flow-stage model for the entire Feather River, DWR (2003) noted that "*natural channels are constantly experiencing dynamic changes in response to changes in flows, sediment loads, and other factors. In the lower reach of the Feather River* [RM 0 to RM 8]*, this effect appears to be more significant due to the frequent backwater effects from the Sacramento River. As the topographic data was obtained back in year 1997 and 1998, the channel geometry could have changed since the survey was taken. As modifying the channel geometry was the only effective way to match the recorded stages at Nicolaus gage, it cannot be determined if it was the result of the natural river movement or the incorrect topographic data.*" In addition, DWR (DWR 2003) recommended that "…*a hydrographic re-survey of the reach from RM 0.0 to RM 8.0 is recommended to obtain the up-to-date river channel topographic data to supplement or replace the information in the model*." Because the integrity and applicability of the topographic data for the reach of the Feather River extending from RM 0.0 to RM 8.0 was questioned by DWR (2003), only transect data upstream of RM 8.0 was utilized in this analysis. Despite not including the reach of the lower Feather River extending from RM 0.0 to RM 8.0 in the analysis, USACE's transect data from the *Sacramento-San Joaquin Basins Comprehensive Study* represents the best available data set for constructing stage-inundation relationships in the lower portion of the Feather River. Although a site-specific habitat analysis approach as originally envisioned in the study plan could not be achieved using these data, an index that will facilitate a comparative assessment of the relative availability of splittail habitat could be created.

4.1.2 Definition of splittail spawning, egg incubation, and initial rearing period

A review of available literature on Sacramento splittail life history was conducted to determine the period during which the potential effects of project operations on splittail habitat should be assessed. Because flow, stage, and water temperature in the Feather River influences splittail habitat availability during the period that splittail are in residence in the Feather River, the appropriate time period for assessing potential flow-related and water temperature-related affects on splittail habitat availability includes periods when splittail life stages are present in the Feather River. The literature review conducted focused on determining the peak time periods for life stages in which splittail would likely be found in the Feather River. The literature indicates that adult splittail migrate into inundated areas during February (Moyle 2002), and that peak splittail spawning occurs from March through April (Moyle 2002). Spawning reportedly is followed by three to seven days of egg incubation (Moyle 2002), and the larvae remain in the vegetation for another seven to 10 days, feeding on zooplankton. Approximately 10 to 14 days after splittail eggs are fertilized, they reportedly develop into free swimming larvae (Sommer et al. 1997). Juvenile rearing continues until juvenile splittail have transformed into benthic-feeding juveniles (approximately 20 mm to 25 mm total length). After floodplain waters begin to recede, juveniles of approximately 25 mm to 40 mm total length (TL) leave the floodplain and begin to migrate downstream to brackish waters. Juvenile splittail begin appearing at delta salvage pumps in April and peak during late April, May, and June suggesting that most juvenile out-migration from the Feather River has occurred by the end of May (Daniels and Moyle 1983; Sommer Unpublished Work). Based on review of available literature, February through May was determined to encompass the period of splittail spawning, egg incubation, and initial rearing in the lower Feather River for most splittail. The February through May time period was used to assess the frequency and duration of habitat inundation and to assess the frequency with which water temperature falls within the thermal tolerance range of spawning, incubating, and initial rearing splittail.

4.1.3 Assessment of flow related splittail habitat availability during splittail spawning, egg incubation, and initial rearing

Section 4.1.1 describes the use of an index of relative habitat suitability to facilitate a comparative assessment of the availability of splittail habitat under differing flow conditions. The index created for use in this analysis to describe splittail spawning, egg incubation, and initial rearing habitat availability is referred to as the Index of Useable Flooded Area (UFA). A detailed, technical, mathematical description of the definition of UFA, including formulas, assumptions and analytical techniques are presented in Appendix A. The section below summarizes the methods used to create the UFA.

4.1.3.1 Definition of usable flooded area

There is general agreement in available literature that splittail that year-class strength is highly correlated with floodplain inundation and with the duration of floodplain inundation (Caywood 1974; Daniels and Moyle 1983; Moyle et al. 2003; Sommer et al. 1997; Sommer Unpublished Work; Sommer et al. 2002; Wang 1996). Therefore, this analysis principally focused on potential splittail spawning and initial rearing habitat unit inundation frequency and on the duration of potential habitat flooding in the HFC of the lower Feather River during the period of splittail spawning, egg incubation and initial juvenile rearing (February through May). As described in SP-F3.2, Task 3B, this analysis combines three different metrics to create UFA: stage-inundation relationships, vegetative characterization data, and water depth criteria for splittail spawning. Each component will be described briefly below.

The initial step of this analysis was establishing stage-inundation relationships using transect data from the lower portions of the Feather River. Section 4.1.1 and Appendix A describe how USACE’s transect data from the *Sacramento-San Joaquin Basins Comprehensive Study* were used to establish stage-inundation relationships in the reach of the Feather River extending from RM 9.0 to RM 25.25. The stage-inundation relationships were then overlaid with splittail spawning requirements, including vegetation types used for splittail spawning and initial rearing, and water depths suitable for splittail spawning. Criteria used to determine vegetation types used for splittail spawning, egg incubation, and initial rearing, and water depths used for spawning are described below. The methods for incorporating vegetation and depth into the Index of Usable Flooded Area describing splittail spawning, egg incubation, and initial rearing relative habitat availability also are described below.

A literature review was conducted to determine the characteristics of suitable substrate for splittail spawning, egg incubation, and initial rearing habitat. Splittail spawning habitat is generally described as submerged vegetation typically found in riparian zones (Caywood 1974; Daniels and Moyle 1983; Moyle et al. 2003; Sommer et al. 2002). When describing spawning, egg incubation, and initial rearing habitat, researchers typically use very general descriptors of vegetation over which splittail spawn. For example, typical descriptors include “flooded vegetation” (Moyle 2002), “submerged vegetation and debris” (Moyle 2002), “emergent and floating vegetation” (Caywood 1974), “flooded terrestrial habitat” (Sommer et al. 1997), “ephemeral flooded areas” (Sommer et al. 1997), “inundated floodplain” (Sommer et al. 1997), “submerged vegetation (dense beds of bermuda grass)” (Sommer et al. 2002), “emergent vegetation (partially submerged terrestrial vegetation)” (Sommer et al. 2002), inundated “dense growths of annual terrestrial plants”, and flooded “annual and perennial vegetation”. The descriptions of splittail spawning habitat are qualitative and provide generalized characterizations of the flooded vegetation over which splittail spawn.

Vegetation characterization was incorporated into the Index of Usable Flooded Area by using vegetation data provided by SP-T4. DWR, through photo-interpretation and ground-truthing, created a GIS polygon data set depicting vegetation within the lower Feather River floodplain (SP-T4). The GIS data set was attributed using a modified version of the Holland Classification System (SP-T4). Of the vegetation associations detailed and mapped by SP-T4, two vegetation associations, *gravel/sandbar* and *mixed emergent vegetation*, best represented the descriptions of splittail spawning habitat provided in available literature. Therefore, the *gravel/sandbar* and *mixed emergent vegetation* associations were selected for further field research. In November 2003, 10 polygons containing these associations were surveyed to further determine splittail habitat availability. The 10 surveyed sites comprised approximately 23 percent of the total area that was classified as *gravel/sandbar* or *mixed emergent vegetation* and represented potential splittail habitat in the reach of the Feather River extending from RM 9 to RM 25.25. During these surveys, the maximum and minimum absolute elevations within each polygon were recorded.

A literature review was conducted to determine the suitable water depth range for splittail spawning. Within available literature, there were few quantitative descriptions of water depth used by splittail during spawning. The quantitative data that do exist were frequently the result of gross estimates or few observations. Moyle (2002) suggests that splittail spawning occurs at depths typically between 0.5 and 2 m. Moyle and others also note that observations on the Cosumnes floodplain suggest splittail spawning occurs in areas <1.5 m deep, while in the Sutter Bypass, splittail spawning sites have an approximate water depth of 2 m. Caywood (1974) notes that water depth near observed spawning locations ranged from 1 m to 2 m. Sommer (Unpublished Work) suggest that water depths greater than 3 feet (0.91 m) provide splittail protection from predation by avian predators, and that water depths greater than 6 feet (1.83 m) may not provide suitable habitat for splittail spawning.

Although each reported water depth range for splittail spawning habitat suggests a slightly different range, an index range of 3 ft to 6 ft (0.91 m to 1.83 m) for splittail spawning water depth represents a reasonable integration of the available quantitative data. The values chosen for use in the Index of Usable Flooded Area as representative of splittail spawning habitat should not be thought of as the upper and lower limits of water depth for splittail spawning; rather they should be thought of as index values that represent the water depth at which a majority of splittail would be expected to spawn in the Feather River based on available information.

For each of the 10 index polygons described above and in Appendix A, stage-inundation relationships and water depth criteria (3 ft to 6 ft) were applied to the elevations recorded during the field surveys of the potential splittail spawning and initial rearing habitat to create UFA. UFA was therefore defined as an index of the relative amount of habitat classified as *gravel/sandbar* or *mixed emergent vegetation* and inundated to a minimum depth of 3 feet and a maximum depth of 6 feet under a variety of flows. Because the 10 polygons used to calculate UFA comprised approximately 23 percent of the total area that was classified as *gravel/sandbar* or *mixed emergent vegetation* and represented potential splittail habitat over a large portion of the downstream reaches of the Feather River (RM 9 to RM 25.25), the 10 polygons used are considered representative of potential relative abundance of splittail spawning, egg incubation, and initial rearing habitat within the HFC. An index of map of the potential splittail habitat polygon locations used to develop UFA is depicted in figure 4.1-1. Figures 4.1-2 through 4.1-4 provide a more detailed overview of the polygons.

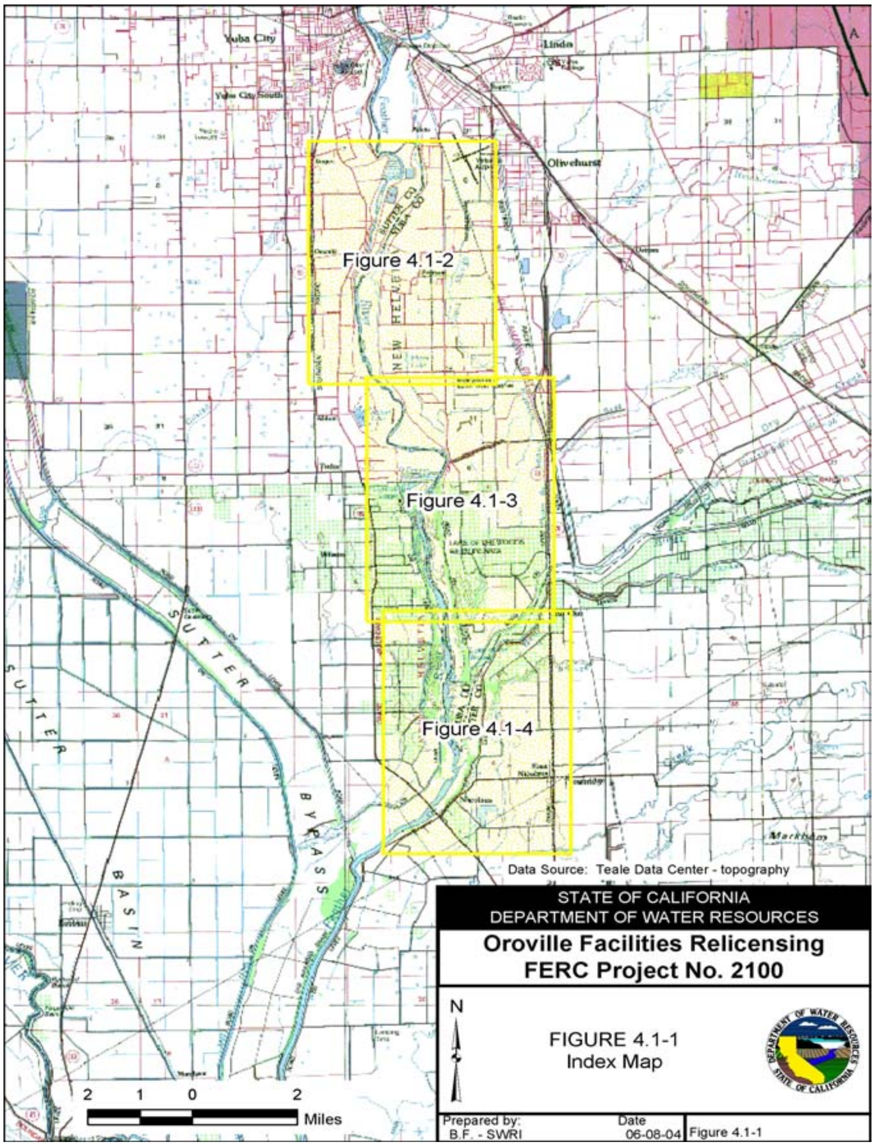

Figure 4.1-1 Index map of representative habitat polygons within the study area.

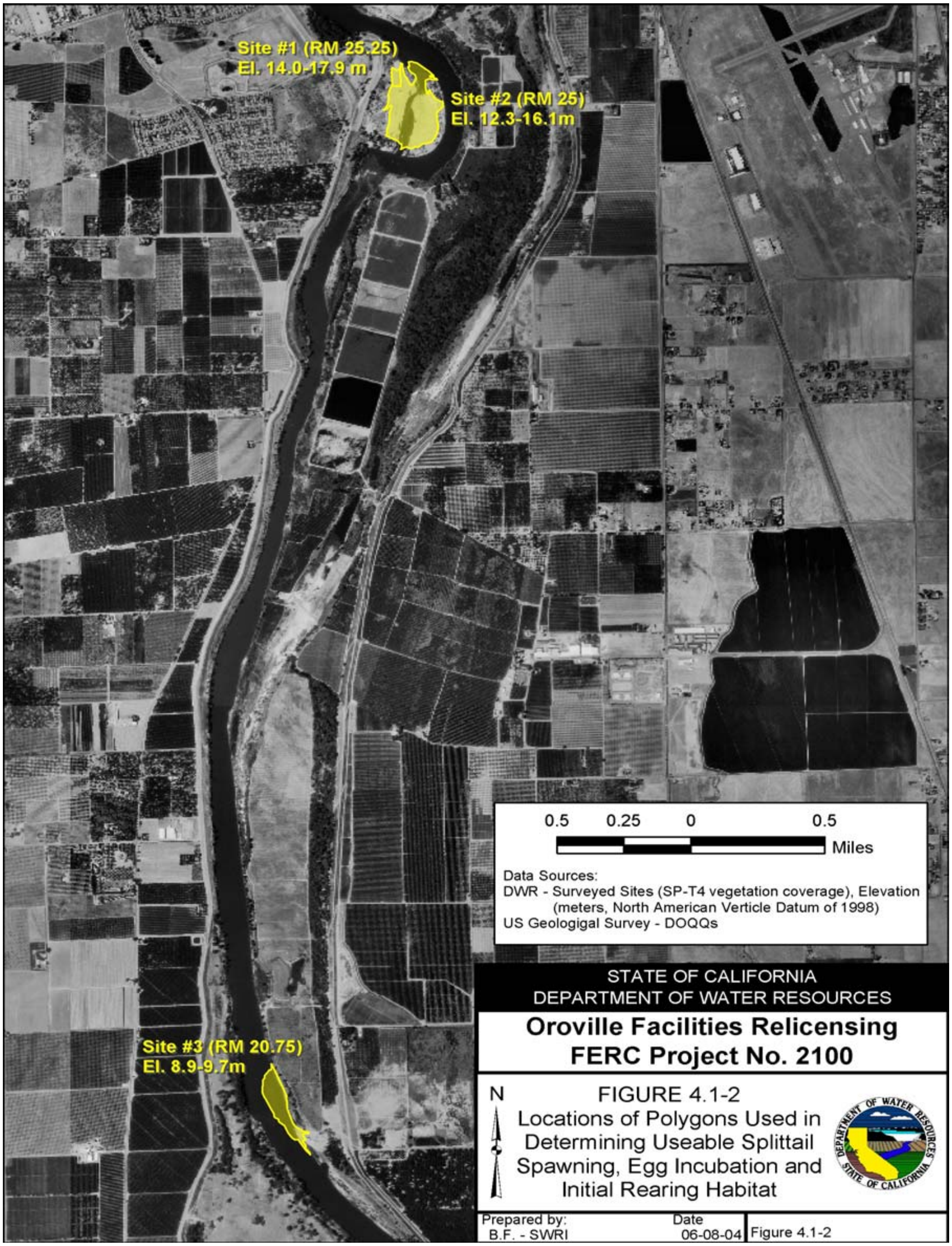

Figure 4.1-2 Locations of three polygons between river mile 25.25 and river mile 20.75 used in splittail habitat determination in the lower Feather River.

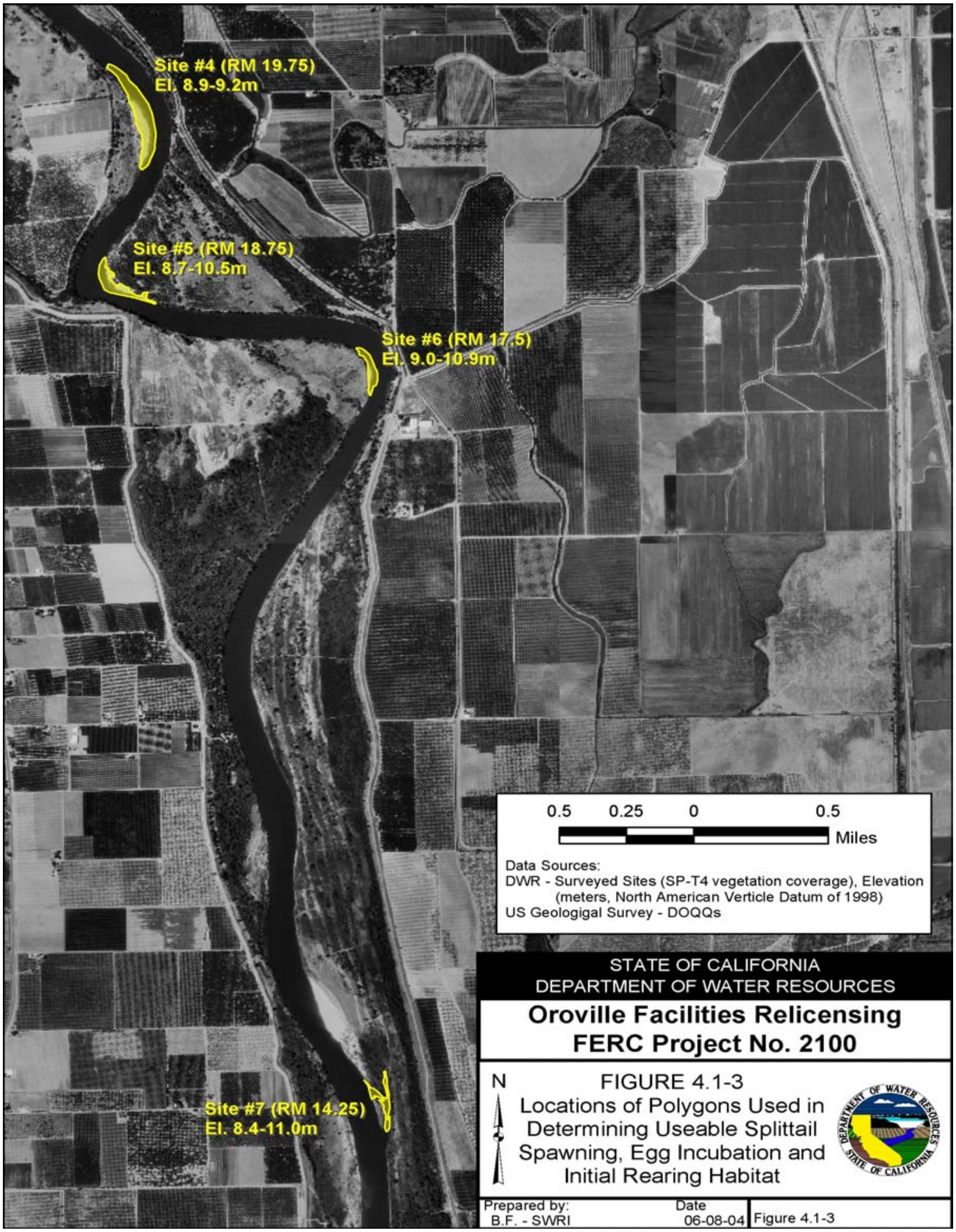

Figure 4.1-3 Locations of four polygons between river mile 19.75 and river mile 14.25 used in splittail habitat determination in the lower Feather River.

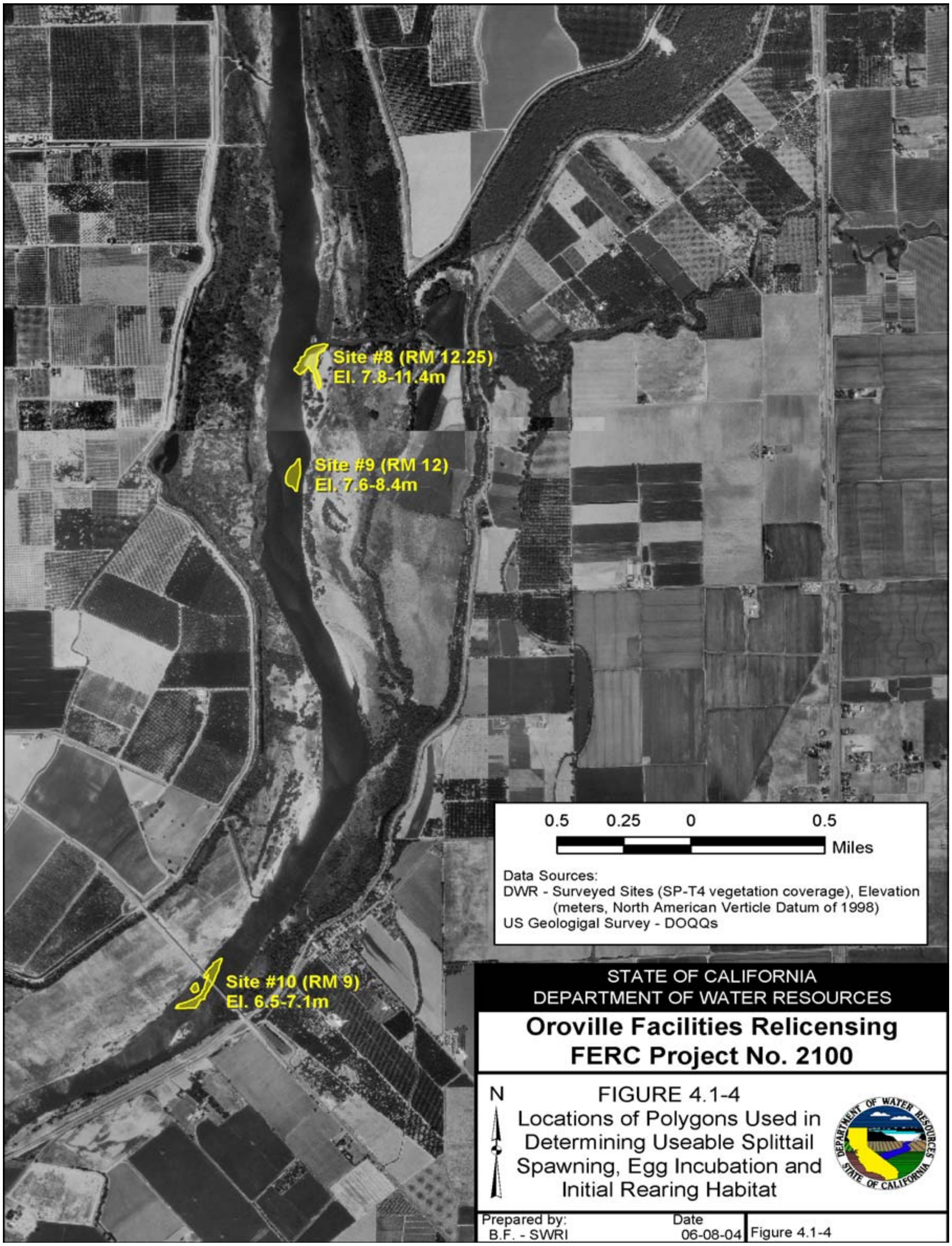

Figure 4.1-4 Locations of three polygons between river mile 12.25 and river mile 9.00 used in splittail habitat determination in the lower Feather River.

Appendix A describes the technical methodology for combining the stage-inundation relationships, the vegetative characterization data, and the water depth criteria for splittail spawning to create UFA and contains detailed, technical, mathematical descriptions of the definition of UFA, including formulas, assumptions, and analytical techniques.

4.1.3.2 Assessment of the frequency with which potential splittail habitat is inundated during the spawning, egg incubation and initial rearing period

In order to assess the frequency with which potential splittail habitat is inundated during the splittail spawning, egg incubation, and initial rearing period, historical flow data from the Feather River was compared to UFA representing relative habitat availability during the splittail spawning, egg incubation, and initial rearing period. Complete Feather River flow data from 1969 through 1983 were available from the USGS gage station 11425000 on the lower Feather River near Nicolaus. Additionally, complete flow data was available from the DWR California Data Exchange Center (CDEC) for 1990, 1993, 1995, 1999, 2000, and 2003. These data were used to determine the magnitude, frequency, and duration of potential splittail habitat unit inundation during the February through May time period of each year.

For analysis of the frequency with which splittail habitat is inundated during the splittail spawning, egg incubation, and initial rearing period, the total UFA (10 sites combined) for the lower Feather River was divided into four distinct flow classes based on the proportion of the maximum UFA (0, 0.01 to 0.33, 0.34 to 0.66, and 0.67 to 1.0) expected to be inundated at each flow. The maximum UFA was considered 1, which represented the maximum amount of potential habitat being inundated for the entire peak spawning period at a depth between three feet and six feet in areas that were surveyed. Class 1 included flows that result in a UFA of 0 (0 cfs to 7,300 cfs). Class 2 included all flows resulting in UFA between 0.01 and 0.33 (7,300 – 7,836 cfs and 15,788 – 52,000 cfs). Based on the hydraulics of the HFC, the resultant flow-inundation curve (Figure 5.1-1) indicates, that there are two sets of flow ranges that could result in UFA index values between 0.01 and 0.33. Class 3 included flows that result in UFA between 0.34 and 0.66 (7,838 – 7,968 cfs and 12,855 – 15,788 cfs). Class 4 included all flows resulting in UFA between 0.67 and 1.0 (7,969 – 12,854 cfs). For every year for which complete flow data was available for the February through May period, the number of days with flows in each UFA class was graphed.

<u>4.1.4 Assessment of water temperature suitability during splittail spawning, egg incubation, and initial rearing</u>

In order to assess the frequency with which water temperatures fall within the splittail thermal tolerance range, reported thermal tolerance ranges for splittail were compared to existing water temperatures during the splittail spawning, egg incubation, and initial rearing period. The definition of suitable water temperatures and the analytical methods are presented below.

4.1.4.1. Definition of suitable water temperatures

Splittail thermal tolerances were examined in available literature. Although there are several observational statements in available literature with regard to water temperature preferences for splittail, a single water temperature tolerance study was available (Young and Cech Jr. 1996). The study investigated thermal tolerances for small age-0, large age-0, age 1 and age 2 splittail in a laboratory study (Young and Cech Jr. 1996). The researchers reported several measures of water temperature tolerance, including the mean critical thermal maxima and an estimated “upper limit of sate temperature” (ULST). The mean critical thermal maximum was determined after acclimating splittail in both ago-0 age classes at 17^{o}C and 20^{o}C (62.6^{o}F and 68^{o}F) and after acclimating splittail in the age-1 and age-2 age classes at 12^{o}C and 17^{o}C (53.6^{o}F and 62.6^{o}F). The critical thermal maximum was determined by increasing water temperature at a rate of 0.1^{o}C/minute (approximately 0.2^{o}F/minute) until reaching a water temperature at which individuals lost the ability to maintain equilibrium. The lowest mean critical thermal maximum for fish acclimated at the highest water temperature for their age class was 28.9^{o}C (SE = 0.34^{o}C) (84^{o}F, SE = 0.61^{o}F) for the age-1 age class and the highest mean critical thermal maximum was 33.0^{o}C (SE = 0.33^{o}C) (91.4^{o}F, SE = 0.59^{o}F) for the large age-0 age class. The ULST was calculated based on a safety factor of 5^{o}C (9^{o}F). Therefore, the lowest (most conservative) estimate of ULST was 24^{o}C for the age-1 age class. Therefore, 24^{o}C (approximately 75.2^{o}F) was chosen as the upper limit of water temperature tolerance for splittail in the Feather River. For splittail acclimated at 12^{o}C (53.6^{o}F) rather than 17^{o}C (62.6^{o}F), the mean critical thermal maxima (and therefore the ULST) was lower than those reported above for fish acclimated at 20^{o}C (68^{o}F). The reason that the ULST for fish acclimated at 17^{o}C (62.6^{o}F) was chosen was because it is unlikely that splittail in the Feather River would experience rapidly increased water temperatures after having been acclimated at lower water temperatures. Because of the nature of warming patterns and project operations, it is unlikely that if water temperature was 12^{o}C (53.6^{o}F) at the time of river entrance, it would increase to over 17^{o}C (62.6^{o}F) rapidly enough to prevent acclimation at 17^{o}C (62.6^{o}F). Therefore, ULST values were chosen for splittail acclimated to higher water temperatures.

Laboratory tests to determine the mean critical thermal minima were conducted using the same method as described above, but with a rate of decrease in water temperature of 0.08^{o}C/minute (approximately 0.15^{o}F/minute). The highest mean critical thermal minimum (most protective) was 7.3^{o}C (45.1^{o}F). No additional limits of safe water temperature were calculated for lower critical thermal minima. Therefore, 7.3^{o}C (45.1^{o}F) was chosen for use as the lower water temperature tolerance limit for splittail in the Feather River. Because the critical thermal minimum was calculated when individuals were acclimated at water temperatures ranging from 12^{o}C to 20^{o}C (53.6^{o}F to 68^{o}F), it is likely that the critical thermal minimum is conservative. For example, Moyle

(Moyle 2002) suggests that splittail are typically found between 5°C and 24°C (41°F to 75.2°F).

4.1.4.2. Assessment of the frequency with which water temperatures fall within splittail tolerance levels

In order to assess the frequency with which water temperatures would fall within the suitable water temperature range for splittail spawning, incubation, and initial rearing (7.3°C to 24°C), water temperatures in the HFC during the splittail spawning, egg incubation, and initial rearing period were examined. Water temperatures in the lower Feather River were collected by DWR from March 26, 2002 through April 2004. Maximum, minimum, and mean water temperature data were recorded approximately every fifteen minutes from 24 different monitoring locations in the lower Feather River and averaged to obtain daily mean water temperatures. In certain instances, water temperature data were missing and/or sample dates were inconsistent as a result of dewatered logging stations, vandalism, or equipment malfunction. Therefore, no single location recorded a complete record for the February through May time period when water temperature loggers were in operation. Water temperature data from six different locations in the HFC were averaged to estimate overall HFC water temperatures. The thermograph logging station locations are listed in Table 4.1-1.

Table 4.1-1 Lower Feather River water temperature monitoring stations

Site Name	River Mile
Feather River Near Verona	0.3
Feather River at Nicolaus	9.3
Feather River at Star Bend	18.2
Feather River at Shanghai Bend	25.2
Feather River at Yuba River Mouth	27.5
Feather River Upstream from Yuba River	28.2

4.2 HOW AND WHERE THE STUDIES WERE CONDUCTED

The focus of this report is assessment of potential project effects on splittail habitat availability during the splittail spawning, egg incubation and initial juvenile rearing period. The report covers the geographic area in the lower Feather River from the Thermalito Afterbay Outlet to the confluence with the Sacramento River. The focal area for the analysis of the potential Splittail spawning and initial rearing habitat is defined in the index map, 4.1-1 and the analyses conducted in this report were conducted in accordance with the methods described in section 4.1.

5.0 STUDY RESULTS

5.1 HABITAT AVAILABILITY

Habitat availability for splittail spawning, egg incubation and initial juvenile rearing in the lower Feather River was assumed to be likely only in the HFC and is dependent upon the inundation of potential habitat during the spawning and rearing period from February through May. For purposes of this report, potential habitat was defined as inundated floodplain habitat with a depth of 3 feet to 6 feet (0.91 to 1.83 m). The depth range of 3 feet to 6 feet was based on splittail habitat preferences and a conceptual splittail habitat model described by Sommer (Unpublished Work), and is further explained in Section 4.1.3.1 *Definition of Usable Flooded Area*. The quantity, quality, and distribution of potential splittail habitat is dependent on flow regimes within the lower Feather River because different flow regimes result in different river stage elevations leading to different amounts of potential habitat inundation. Potential habitat inundated to a minimum depth of 3 feet and a maximum depth of 6 feet is defined as Useable Flooded Area (UFA).

For purposes of this report, flow regimes in the HFC of the lower Feather River are divided into four categories based on resultant UFA calculations. The four flow regimes and the associated proportion of maximum UFA in the HFC are: 1) instream flows lower than 7,300 cfs result in a relative suitability index value (UFA) of 0, which represents no inundated potential splittail habitat at locations surveyed, 2) instream flows between 7,300 cfs and 7,836 cfs or above 15,788 cfs result in a relative suitability index value of approximately 0.3, which represents an estimated 33 percent UFA in the portions of the HFC of the lower Feather River that were surveyed (flows above 15,788 cfs probably equate to significant potential habitat inundations outside project influence, i.e. Yolo Bypass), 3) instream flows between 7,838 cfs and 7,968 cfs or between 12,855 cfs and 15,788 cfs result in a relative suitability index value of 0.66, which represents en estimated 66 percent UFA in the HFC in areas that were surveyed, and 4) instream flows between 7,968 cfs and 12,854 cfs result in a relative index value of approximately 1, which represents the maximum potential UFA in the areas of the HFC that were surveyed (i.e. 100 percent of potential floodplain area within the sample transects would be inundated between 3 feet and 6 feet). Figure 5.1-1 presents a graphical representation of UFA as a function of HFC flows. Note that UFA begins to decrease as flows surpass 12,000 cfs. The reduction in UFA at flows above 12,000 cfs occurs because flooded area exceeds six feet in depth, which was considered to be the maximum depth for splittail spawning (Sommer Unpublished Work).

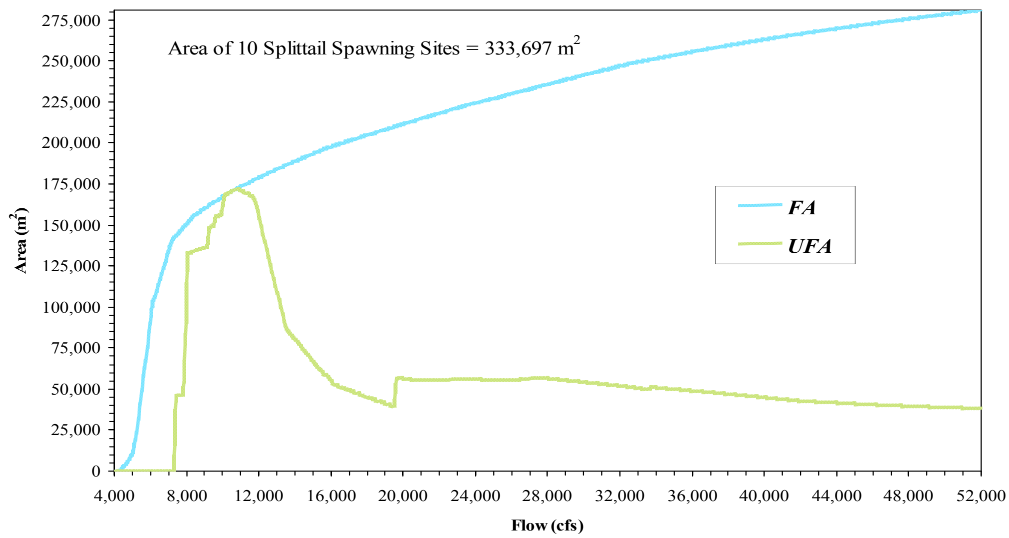

Figure 5.1-1 Useable Flooded Area (UFA) in the HFC as a function of flow (FA = Flooded Area).

Studies on splittail populations have reported that splittail year-class strength is highly correlated with "wet years" resulting in floodplain inundation (Moyle et al. 2003; Sommer et al. 1997). Sommer et al. (1997) further reported that, when floodplains are inundated for less than a month, strong year classes are not produced. Daniels and Moyle (1983) analyzed splittail abundance each year from 1969 through 1981 and assigned relative strengths to the year-classes based on abundance estimates with 3 designating a strong year-class, 2 an intermediate year-class, and 1 a weak year-class. Additionally, Sommer (1997) reported that both 1982 and 1983 were strong year-classes for splittail. Based on these relative indices, Figure 5.1-2 presents Feather River flows in the HFC for this time period combined with the year-class strength designations presented by Daniels and Moyle (1983). The distinction between strong and weak year-classes in the figure is clear. In addition, it should be noted that the red portion of the vertical bars represent high flows where both the Yolo and Sutter bypasses may be inundated, creating splittail spawning habitat outside the area of project influence. The light blue portions of each column reflect the amount of time maximum useable habitat was available in the lower Feather River while the darker blue portions of each column reflect the amount of time that no UFA occurred within the HFC. Note that when flows are within the range where the lowest amount of UFA occurs, the year class of the splittail is lowest and the potential habitat is inundated for the shortest duration. Year-class strength reflects overall splittail abundance based on juvenile sampling in the delta and is not necessarily reflective of abundance in the lower Feather River.

The same data are presented chronologically in Figure 5.1-3. In this figure, weak year-classes also are clear (1972, 1976, 1977, 1981). In 1976 and 1977, there were no flows above 7,300 cfs, resulting in no useable spawning habitat in the Feather River. No available habitat would be consistent with the findings of Daniels and Moyle (1983), which indicated that both of these years produced weak year-classes of splittail.

Evidence for the resilience of the splittail population as reported by Sommer et al. (1997) is seen in 1978, which was a strong year-class preceded by two consecutive weak year-classes.

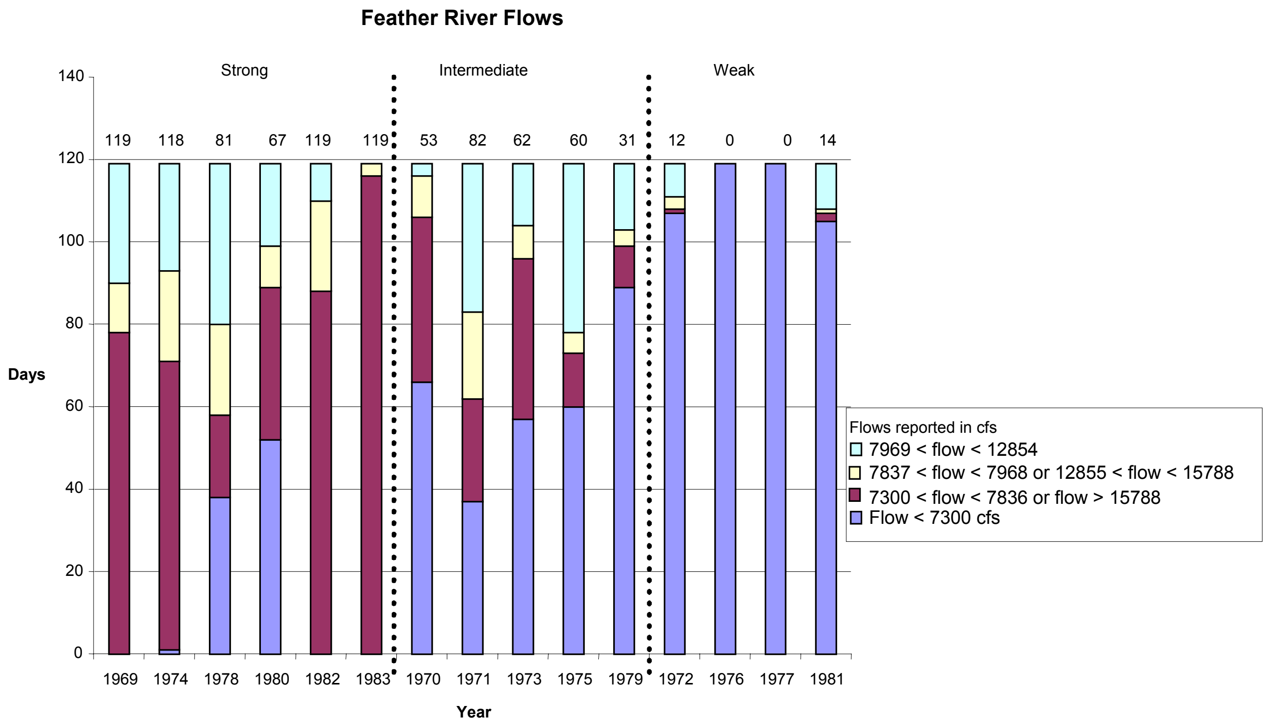

Figure 5.1-2. Splittail year-class strength compared with HFC flows (numbers above each column represent consecutive days with at least some floodplain inundation).

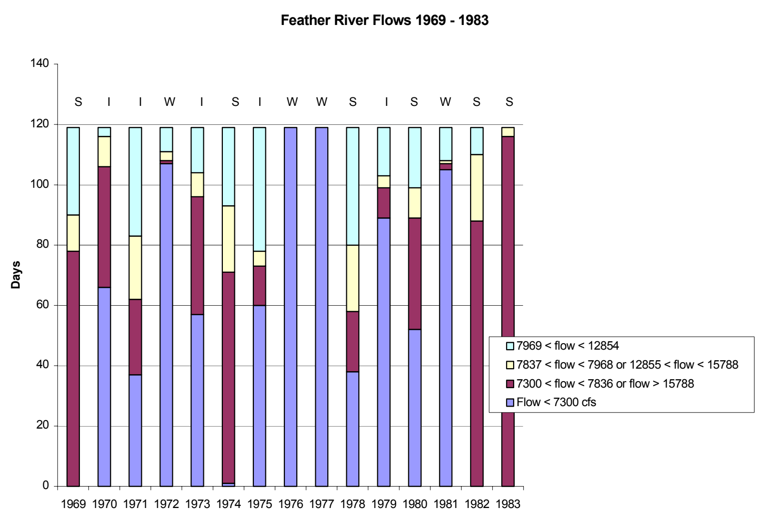

Figure 5.1-3 Splittail year-class strength compared with HFC flows (chronologically – S, I, or W above column represent strong, intermediate and weak splittail year-classes respectively)

Figure 5.1-4 presents more recent flow data although relative year-class strengths are not indicated because criteria for determining year-class strength may have been inconsistent with that used during the 1969 through 1983 time period reported by Daniels and Moyle (1983) and Sommer et al. (1997). Several authors reported that 1995 was a strong year-class for splittail (Baxter et al. 1996; Sommer et al. 1997; Wang 1996). Sommer (Unpublished Work) reported 1990 as creating a weak year-class. Baxter (2000) reported a strong year-class in 1998 with significant spawning activity in both the Yolo and Sutter bypasses. All of these findings are consistent with a visual examination of Figure 5.1-4. According to Sommer et al. (1997), 1995 produced a very strong splittail year-class even though seven of the eight preceding years were considered drought years.

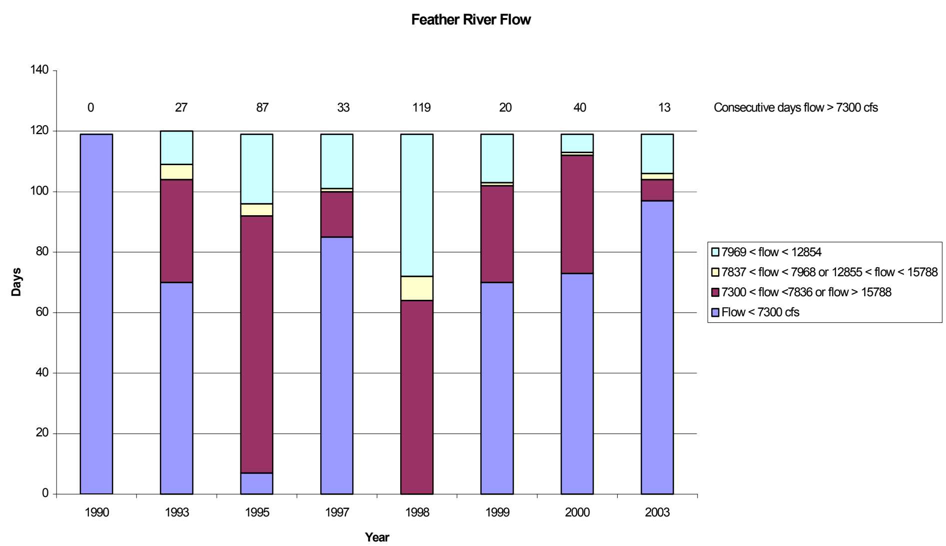

Figure 5.1-4 HFC flow regimes for selected years 1990 – 2003.

5.2 WATER TEMPERATURE SUITABILITY

Young and Cech Jr. (1996) investigated thermal tolerances for juvenile splittail and reported a tolerance range of 7°C to 32°C (44.6°F – 89.6°F). Caywood (1974) reported splittail spawning in water temperatures from 9°C to 20°C (48.2°F – 68.0°F). Sommer et al. (2002) reported splittail spawning in water temperatures from 11°C to 24°C (51.8°F – 75.2°F). Based on these reports, index values of 45°F to 75°F are established as a range of suitable splittail spawning water temperatures. Figure 5.2-1 presents average HFC water temperatures recorded during April through May 2002, February through May 2003, and February through April 2004. Assuming that peak splittail spawning occurs in March and April, as reported by Moyle (2002), water temperature ranges within the HFC, the reach assumed to contain all potential splittail spawning habitat, fell between the selected index values.

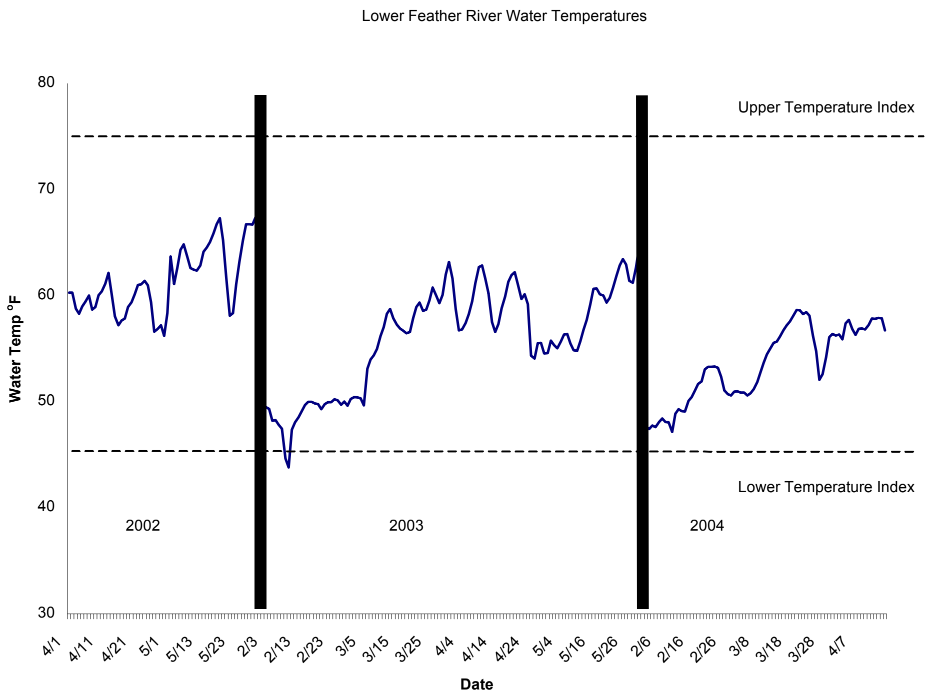

Figure 5.2-1 Average water temperatures recorded from six thermographs in the HFC during the spawning, egg incubation, and initial rearing period of Sacramento splittail.

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

Task 3B is a subtask of SP-F3.2, *Assessment of Potential Project Effects on Splittail Habitat*, and fulfills a portion of the FERC application requirements by identifying and characterizing the potential effects of project operations on the relative quantity and quality of Sacramento splittail spawning and initial rearing habitat. Sacramento splittail are designated as a federal Species of Concern and a state Species of Special Concern by the California Department of Fish and Game.

A literature review was conducted to determine the characteristics of splittail habitat for spawning, egg incubation, and initial juvenile rearing. Additionally, the time of year that splittail are likely to be in the Feather River was determined. Habitat requirements for splittail during spawning, egg incubation, and initial juvenile rearing are characterized as floodplains inundated to a depth between 3 feet and 6 feet. Floodplain inundation was estimated by computing useable flooded areas from instream flow and stage data on ten separate polygons representative of appropriate lower Feather River habitat.

Although the presence of splittail in the lower Feather River is well documented, the relative importance of spawning habitat within the lower Feather River watershed to overall splittail population dynamics is unknown. In general, it was assumed that low flows in the lower Feather River correspond to low flows throughout the basin. Evidence to support this assumption is provided in Figures 5.1-3 and 5.1-4 and associated text in Section 5.1 *Habitat Availability.* At higher flows the lower Feather River provides splittail spawning habitat, as is likely with other areas of the basin.

6.2 PROJECT RELATED EFFECTS

Floodplain or vegetated in-channel bench inundation during March and April appears to be the primary factor contributing to splittail abundance. Daniels and Moyle (1983) analyzed splittail abundances from 1969 through 1981 and assigned relative strengths to the year-classes based on abundance with 3 designating a strong year-class, 2 an intermediate year-class, and 1 a weak year-class. These year-class strengths are based on juvenile captures at Suisun Bay and in the Sacramento Delta and are likely influenced by contributions from other areas within the watershed. Although relative abundance estimates or year-class strengths have not been Feather River specific, there is a strong correlation between Feather River flows and these relative estimates. Flows in the Feather River determine habitat availability for splittail spawning, egg incubation, and initial juvenile rearing. Figure 6.2-1 illustrates the relationship between lower Feather River flows and relative potential splittail habitat availability. The position of the numbers 1, 2, or 3 overlaid on the figure correspond to average flows that occurred during investigation (February through May) conducted by Daniels and Moyle (1983) during the 1969 to 1983 time period. The strong year-classes, designated by 3's on the figure, are likely the result of extensive potential splittail habitat being created by inundation of the Sutter and Yolo bypasses.

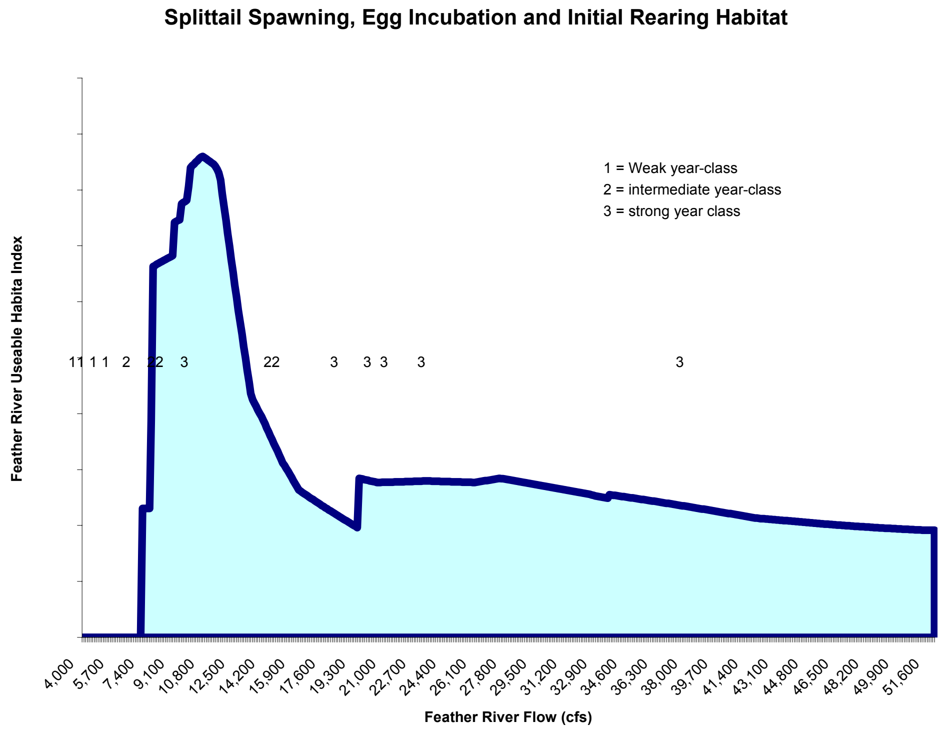

Figure 6.2-1 Relative potential splittail spawning and initial rearing habitat in the HFC as a function of flow.

The low relative abundance of potential splittail spawning and initial rearing habitat below approximately 7,300 cfs could potentially be the result of channel entrenchment from Placer mining sediment deposition, channel confinement from levees, and reduced fluvial processes and channel migration from a moderated flow regime. The peak of the relative habitat availability at approximately 10,000 cfs could, in general, be due to the inundation of the initial channel bank. The relative reduction of available habitat at the higher flow ranges could be due to the lower banks being inundated deeper than the spawning and initial rearing habitat criteria and the flows being constrained within the flood control levees.

In addition to floodplain inundation, Moyle et al. (2003) and Sommer et al. (1997) both report that duration of floodplain inundation is an important factor in determining splittail year-class strength. Sommer et al. (1997) further report that when floodplains are inundated for less than a month; strong year classes are not produced. Figure 6.2-2 shows the relative index of potential splittail habitat in the lower Feather River (blue line) as a function of flow. Superimposed on this graph is the instream flow profile from 1981 (pink). Daniels and Moyle (1983) described 1981 as a year that produced a weak year-class of splittail. The figure illustrates the close correlation between duration of floodplain inundation and initial year-class strength, because instream flows inundated potential splittail habitat relatively infrequently and for relatively short durations between March and April 1981. There was some floodplain inundation, however the duration apparently was not sufficient to allow completion of the spawning, egg incubation, initial rearing cycle.

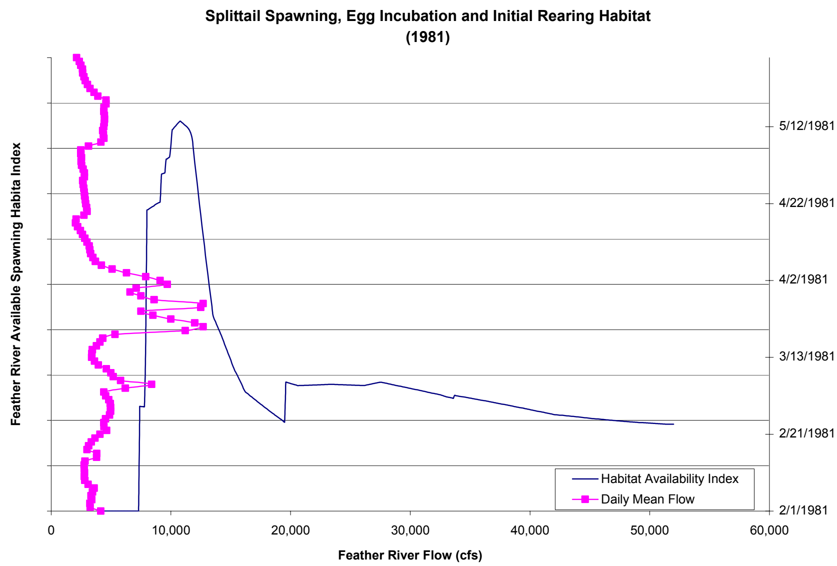

Figure 6.2-2 Splittail spawning, egg incubation, and initial rearing habitat as a function of flow in the HFC with the 1981 flow profile superimposed.

In contrast, Figure 6.2-3 shows the instream flow profile for 1978, a year described by Daniels and Moyle (1983) as producing a strong splittail year-class. In 1978, instream flow remained high enough to inundate a substantial amount of floodplain habitat for a long enough duration (above 7,300 cfs between March and April) to produce a strong initial year-class.

Although only limited water temperature data were available for this analysis, it appears that lower Feather River water temperatures are within the range of reported splittail tolerance levels (Figure 5.2-1). Peak spawning activity occurs from March through April (Moyle 2002) when lower Feather River water temperatures average approximately 58^{o}F (14.4^{o}C). Caywood (1974) reported splittail spawning in water temperatures from 9^{o}C to 20^{o}C (48.2^{o}F to 68.0^{o}F) and Sommer et al. (2002) reports splittail spawning in water temperatures from 11 to 24^{o}C (51.8^{o}F to 75.2^{o}F).

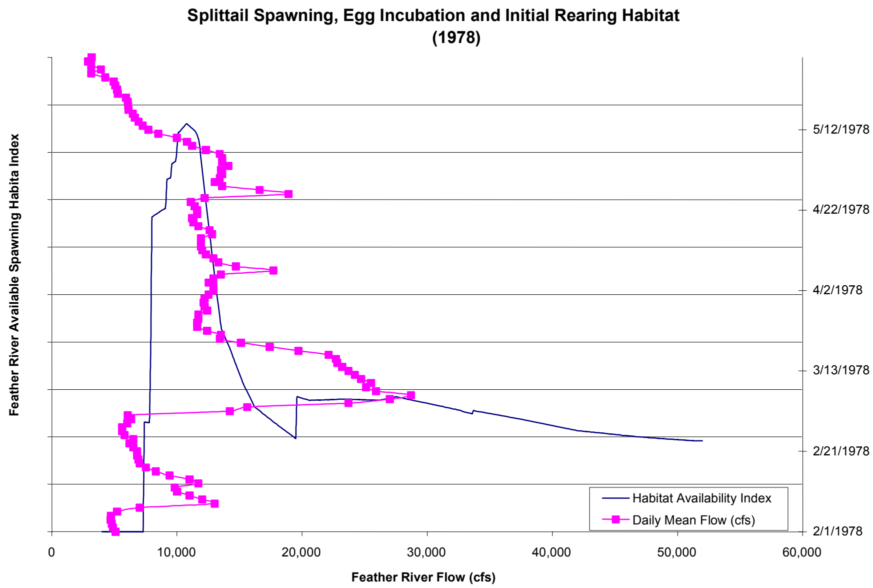

Figure 6.2-3 Splittail spawning, egg incubation, and initial rearing habitat as a function of flow in the HFC with the 1978 flow profile superimposed.

Because published studies on Sacramento splittail spawning, egg incubation, and initial rearing have focused on floodplains outside the area directly influenced by Oroville Facility operations such as the Yolo and Sutter bypasses, the relative importance of habit availability, within the lower Feather River, for continued splittail persistence is unknown. Likewise, studies on splittail abundance have focused on juvenile captures in the San Francisco Bay Delta, which is an indicator of basin-wide productivity. Splittail presence in the lower Feather River has been well documented and it is assumed that some spawning does occur. Based on results of analysis within this study, splittail habitat suitable for spawning, egg incubation, and initial rearing does exist in the lower Feather River on a periodic basis. Sommer et al. (1997) reported on the resilience of splittail populations in the Sacramento-San Joaquin Estuary and suggests that the relatively long life span, broad environmental tolerances, and high fecundity of the species allows rapid population recovery, even after several consecutive years of drought. Sommer et al. (1997) also reported that, even during very dry years, some recruitment does occur. Twenty-one years of flow data were used to calculate potential splittail spawning, egg incubation, and initial rearing habitat availability, which was presented as a relative index of habitat availability. Within the 21-year period of record, 8 years were described as producing strong year-classes, which correlated to high flows in the Feather River, 6 years were described as producing weak year-classes, which correlated to low flows in the Feather River, and 7 years produced either intermediate or unknown year-class strengths, which correlated with intermediate flows in the Feather River.

Two potential alternative approaches to providing additional splittail habitat in the lower Feather River were identified. Physical habitat modification or a flow modification could potentially increase splittail initial year-class strength. Physical habitat modification could potentially include cutting benches into the existing channel banks to provide areas that are inundated at lower flows during the splittail spawning and initial rearing period. Flow based splittail habitat enhancement could potentially include providing flows in the HFC greater than approximately 7,300 cfs for a continuous 30-day period during the splittail spawning and initial rearing period.

Because flows in the Feather River are likely indicative of relative flows throughout the basin, caution should be used before suggesting a causal relationship between Feather River flows and splittail year-class strength. However, Sommer et al. (1997) suggest that, although splittail population levels fluctuate, the frequency of wet years and subsequent high flows in the Sacramento River basin including the lower Feather River has allowed adequate splittail population recovery, even after periods of several consecutive dry years. Additionally, Moyle et al. (2004) and USFWS (2003) suggest that the resilience shown by splittail populations in the Central Valley indicates that splittail are unlikely to become extinct in the foreseeable future. Because changes in future Oroville Facilities operations are not anticipated to alter the frequency of wet year flows, and are not anticipated to alter the mass balance hydrology in the Sacramento River system, it does not appear likely that continued operations of the Oroville Facilities would create conditions unfavorable to splittail spawning, egg incubation, and initial rearing habitat.

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Appendix A

Determination of Area Available for Splittail Spawning and Initial Rearing

1.0 ESTIMATION OF AREA AVAILABLE FOR SPLITTAIL SPAWNING AND INITIAL REARING

The Department of Water Resources, through photo-interpretation and subsequent ground-truthing created a GIS polygon dataset depicting vegetation within the lower Feather River floodplain (SP-T4). The GIS dataset was attributed using a modified version of the Holland Classification System (SP-T4). Two vegetation associations, *gravel/sandbar* and *mixed emergent vegetation*, were determined to be suitable for splittail spawning and were selected for further field research. The latitude and longitude of each polygon centroid was calculated for the selected polygons containing the *gravel/sandbar* and *mixed emergent vegetation* types.

Equipped with the geographic coordinates of potentially suitable splittail habitat, DWR surveyed 10 sites in November 2003. The survey team used a GPS unit to determine the lowest and highest elevations for each of the 10 sites based on the North American Vertical Datum of 1988 (NAVD 88). Using ESRI's ArcMap software, the two-dimensional area of each surveyed site was calculated. The surveyed sites comprised approximately 23 percent of the total area that was classified as *gravel/sandbar* or *mixed emergent vegetation*.

The GIS vegetation data set and field survey data provided the following for each of the 10 splittail spawning habitat sites (i = {1,2 ...10}):
Lowest habitat site elevation (L_i), measured in meters; and
Highest habitat site elevation (H_i), measured in meters.
Two-dimensional area of the habitat site (A_i), measured in square meters.

The following table (Table A-1) displays the elevations, and relative positions (in river miles) associated with the 10 splittail spawning habitat sites identified in this study.

Table A-1. Lowest (L_i) and highest (H_i) habitat site elevations and site area (A_i), for the 10 splittail spawning habitat sites in this study.

Splittail Spawning Site	Location (River Mile)	Elevations (m)		A_i (m^2)
		L_i	H_i	
1	25.25	13.969	17.880	5,772.88
2	25.00	12.306	18.822	126,917.95
3	20.75	8.860	9.744	46,135.92
4	19.75	8.903	9.207	54,935.67
5	18.75	8.687	10.498	22,603.57
6	17.50	9.034	10.916	12,658.45
7	14.25	8.354	10.994	12,713.23
8	12.25	7.794	11.375	20,682.80
9	12.00	7.625	8.365	11,644.44
10	9.00	6.497	7.129	19,632.48

In addition to the previous variables, two constants describing the depth limits that potentially provide suitable spawning conditions for splittail were used based on Sommer's "Splittail Conceptual Model" (Sommer Unpublished Work). These constants are:

1) The minimum depth limit that potentially provides suitable spawning conditions for splittail (MinD), assumed to be 3 ft (0.9144m) and
2) The maximum depth limit that potentially provides suitable spawning conditions to splittail (MaxD), assumed to be equal to 6 ft (1.8288 m).

It should be noted that, while water deeper than 6 feet has often been mentioned as not capable of providing suitable spawning conditions to splittail, the optimal minimum depth limit has not been reported in available literature. In this study, a MinD = 3 ft has been assumed because it is expected that water levels less than 3 feet in depth may increase the susceptibility of juveniles to bird predation (Sommer Unpublished Work).

The variables L_i and H_i, and the constants MinD and MaxD were used to calculate two additional variables that describe the percentage of the area of an individual habitat site (A_i) that would be flooded (FA_i) and the percentage of the area that that would be flooded and potentially used for spawning by splittail (UFA_i), at a particular river stage (St) and flow.

The first step in the analysis was to calculate the FA and UFA as functions of river stage for each of the 10 splittail spawning habitat sites identified in the study. Because each site had a unique set of lowest (L_i) and highest (H_i) habitat site elevations, the shapes of the site-specific FA and UFA were different.

The percentage of the area of an individual habitat site *i* that would be flooded at a particular river stage (*St*) was defined as follows:

1) $FA_i = 0$, if $St \leq L_i$;
2) $FA_i = 100(St - L_i)/(H_i - L_i)$, if $L_i < St \leq H_i$; and
3) $FA_i = 100$, if $St > H_i$.

The percentage of the area of an individual habitat site i that would be flooded and potentially used for spawning by splittail at a particular river stage (St) was defined as follows:

1) $UFA_i = 0$, if $St < (L_i + MinD)$;
2) $UFA_i = FA_i$, if $(L_i + MinD) \leq St < (L_i + MaxD)$;
3) $UFA_i = FA_i - (St - L_i - MaxD)/(H_i - L_i)$, if $(L_i + MaxD) \geq St > (H_i + MaxD)$; and
4) $UFA_i = 0$, if $St \geq (H_i + MaxD)$.

For example, Figure A-1 illustrates the percentages of the area of potential habitat at site 7, with elevations L_i = 8.35 and H_i = 10.99, that would be flooded (FA), and the percentages of the area that would be flooded and potentially used for spawning by splittail (UFA) at river stages between 8 m and 13.5 m.

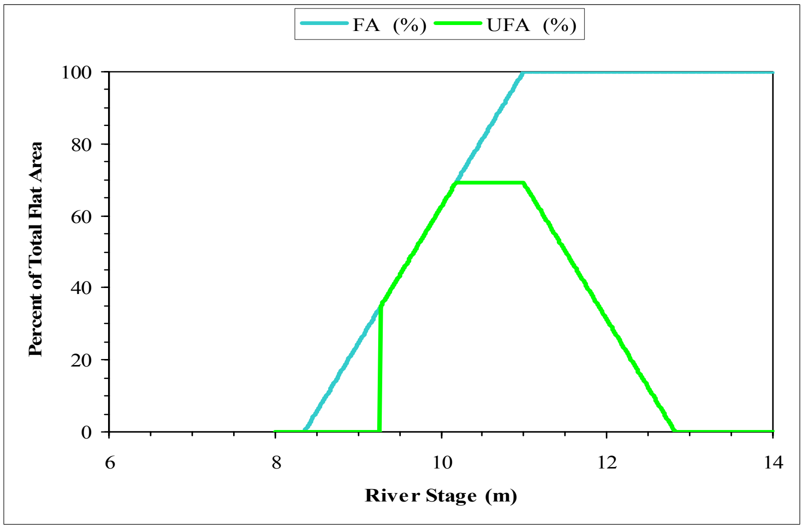

Figure A-1. Percentage of total area of splittail habitat at Site 7 (river mile 14.25) that would be expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as a function of river stage (m).
Note: The variables Li and Hi are the lowest and highest elevations recorded at Site 7 and are equal to 8.354 m and 10.994 m, respectively. The constants MinD and MaxD are the minimum and maximum depth for splittail spawning, they were assumed to be Stage (St) plus 0.9144 m and 1.8288 m, respectively.

The second step in the analysis was to generate the FA and UFA as functions of river flow for each of the 10 potential splittail spawning habitat sites surveyed. Stage-discharge relationships were utilized to obtain flows at which each measured elevation would be inundated. Stages predicted by the stage-discharge relationship model were based on the National Geodetic Vertical Datum of 1929 (NGVD 29). In order to compare the modeled stages to the surveyed elevations, the modeled stages were converted to the NAVD 88 datum by adding 0.7 meters. Table A-2 displays these data sets by each potential splittail spawning habitat site. The regression coefficients, coefficients of determination (r^2), and significance values (P) for each of the 10 polynomial fits are displayed in Table A-3.

Table A-2. Flows and river stages at each of the potential splittail spawning habitat sites used during stage-discharge relationship creation.

Splittail Spawning Site	1	2	3	4	5	6	7	8	9	10
River Mile	25.25	25	20.75	19.75	18.75	17.5	14.25	12.25	12	9
Flow (cfs)	River Stage (m)									
1,000	10.99	10.99	7.95	7.73	7.63	7.35	7.00	6.74	6.61	5.25
2,000	11.15	11.14	8.30	8.10	7.98	7.78	7.39	7.13	7.04	5.69
4,000	11.43	11.42	8.82	8.64	8.50	8.31	7.86	7.54	7.43	6.25
6,000	11.70	11.67	9.22	9.04	8.89	8.69	8.18	7.80	7.69	6.69
8,000	11.94	11.90	10.13	9.97	9.79	9.58	8.95	8.48	8.39	7.61
10,000	12.17	12.12	10.52	10.36	10.17	9.95	9.29	8.83	8.74	8.01
12,000	12.38	12.32	10.87	10.72	10.51	10.28	9.60	9.12	9.05	8.36
20,000	13.37	13.29	12.05	11.90	11.68	11.43	10.67	10.21	10.14	9.56
40,000	15.47	15.37	14.16	14.00	13.75	13.47	12.61	12.18	12.14	11.69
60,000	16.79	16.66	15.50	15.33	15.00	14.74	13.90	13.54	13.51	13.22

Source: DWR, March 2003.

Table A-3. Regression coefficients, coefficients of determination (r^2), and significance values (*P*) for the polynomial regression functions that correspond to the 10 potential splittail spawning habitat sites.

Splittail Site	Regression coefficients							r^2	*P*
	Intercept	Stage	Stage^2	Stage^3	Stage^4	Stage^5	Stage^6		
1	1,491,882.1	-477,302.2	55,830.9	-2,852.1	54.64			0.99996	0.000
2	1,656,737.6	-532,196.3	62,564.6	-3,213.8	61.86			0.99995	0.000
3	8,939,937.9	-5,137,922.0	1,212,807.8	-150,558.6	10,369.4	-375.64	5.60	0.99982	0.000
4	8,459,724.7	-4,933,620.4	1,181,577.5	-148,793.8	10,393.4	-381.78	5.77	0.99982	0.000
5	8,440,402.1	-5,018,605.1	1,225,551.2	-157,390.7	11,214.3	-420.31	6.48	0.99981	0.000
6	9,234,002.9	-5,573,853.4	1,382,719.7	-180,475.7	13,073.5	-498.27	7.81	0.99980	0.000
7	10,300,203.9	-6,571,782.3	1,724,194.0	-238,140.5	18,263.0	-737.16	12.24	0.99980	0.000
8	10,957,196.3	-7,202,052.4	1,946,836.4	-277,089.1	21,901.8	-911.27	15.60	0.99977	0.000
9	10,910,926.3	-7,237,208.1	1,973,358.7	-283,177.4	22,557.3	-945.43	16.29	0.99975	0.000
10	1,611,661.5	-1,244,928.5	390,401.7	-63,661.8	5,700.3	-265.55	5.04	0.99983	0.000

By applying the corresponding polynomial regression to the stage values in the site-specific relationships of FA and UFA as functions of river stage, the site-specific relationships of FA and UFA as functions of flow were obtained. Figure A-2 illustrates the percentages of the area of the habitat at Site 7 (elevations L_i = 8.35 and H_i = 10.99) that would be flooded (FA), and the percentages of the area that would be flooded and potentially used for spawning by splittail (UFA) at flows corresponding to the river stages between 8 m and 13.5 m.

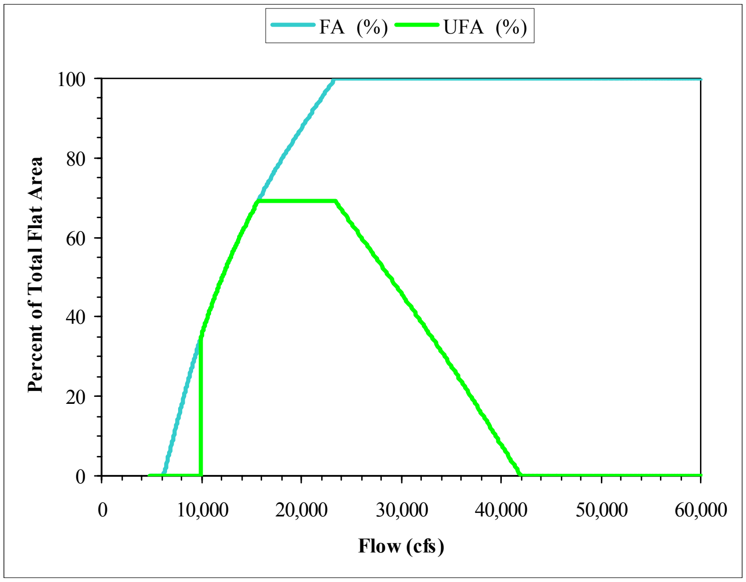

Figure A-2. Percentage of total area of potential splittail habitat at Site 7 (river mile 14.25) expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as a function of flow (cfs).

The third step in the analysis was to obtain the actual areas (m^2) corresponding to the percent values of FA and UFA for each of the 10 potential splittail spawning habitat sites (Figures A-3 through A-12), and by summing across sites to generate the total area expected to be flooded, and the total area flooded and potentially used for spawning by splittail under different flows. Figure A-13 summarizes this final result for flows ranging between 4,000 cfs and 52,000 cfs.

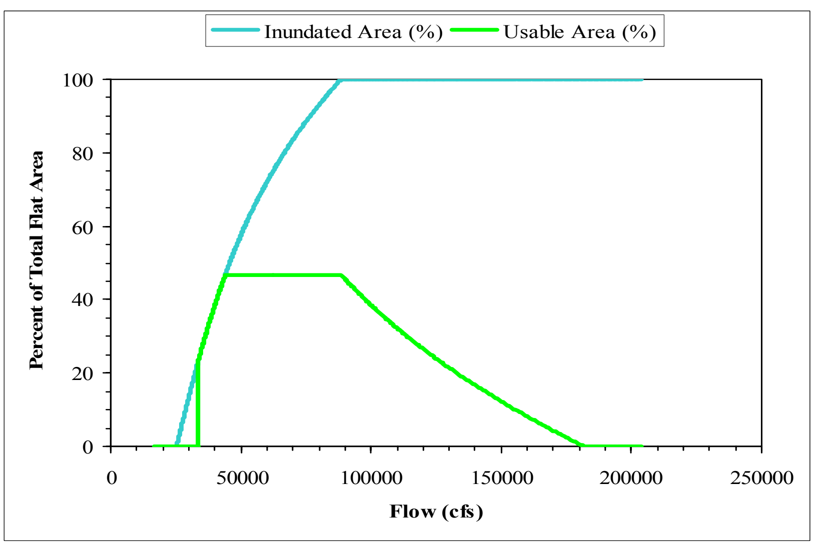

Figure A-3. Percentage of total area of splittail habitat at Site 1 (river mile 25.25) expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

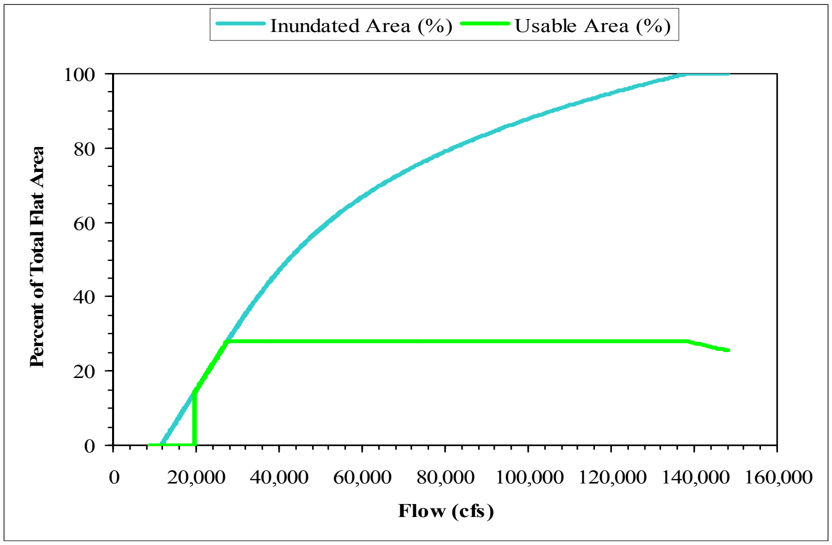

Figure A-4. Percentage of total area of splittail habitat at Site 2 (river mile 25.00expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

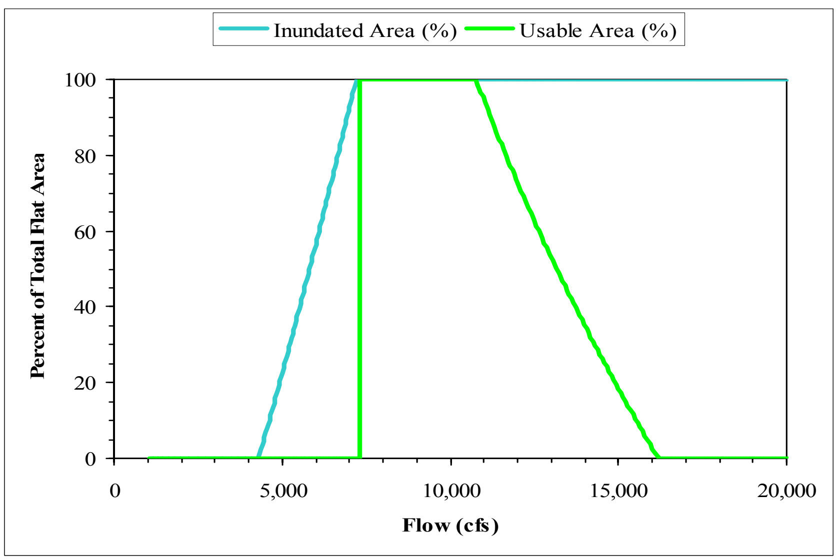

Figure A-5 Percentage of total area of splittail habitat at Site 3 (river mile 20.75 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

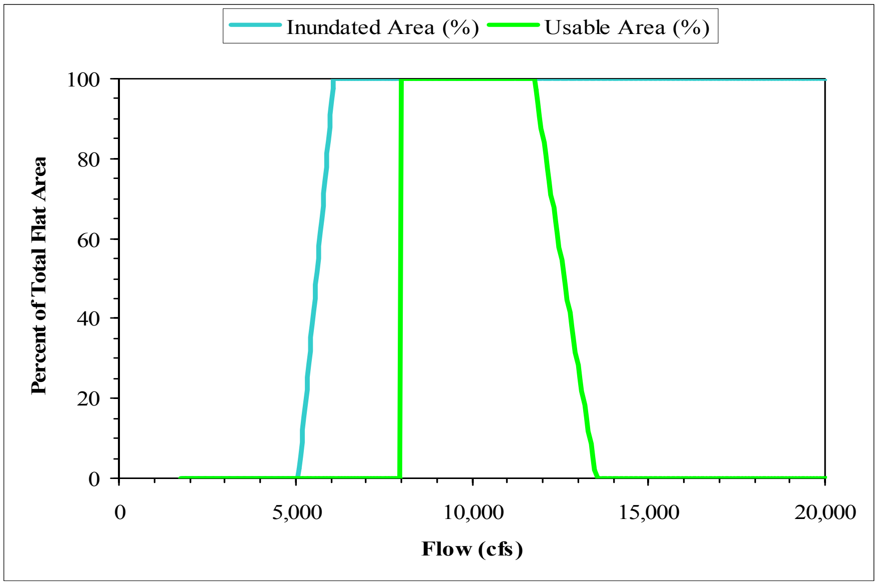

Figure A-6 Percentage of total area of splittail habitat at Site 4 (river mile 19.75 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

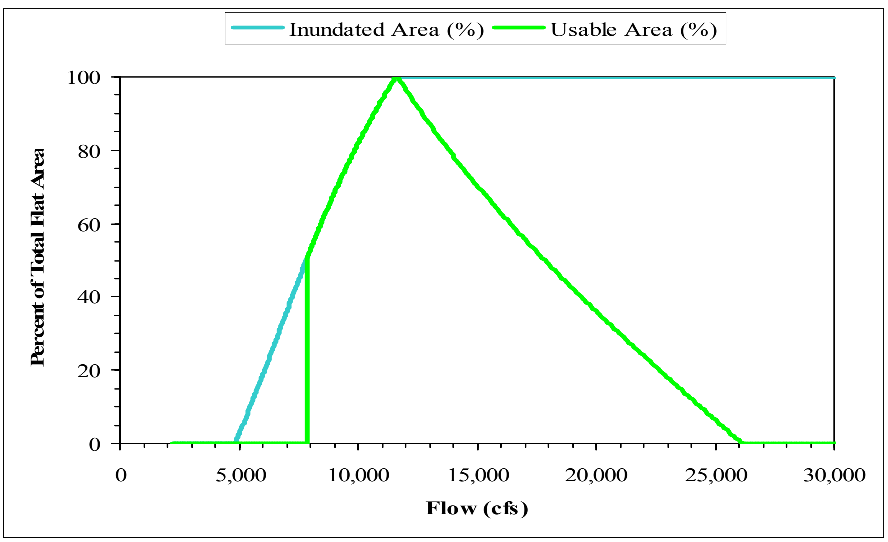

Figure A-7 Percentage of total area of splittail habitat at Site 5 (river mile 18.75 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

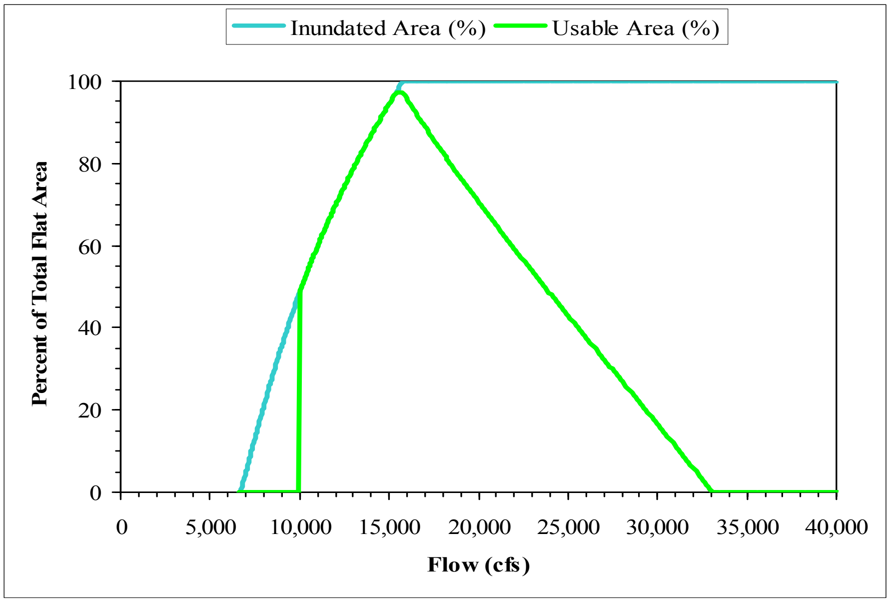

Figure A-8 Percentage of total area of splittail habitat at Site 6 (river mile 17.50 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

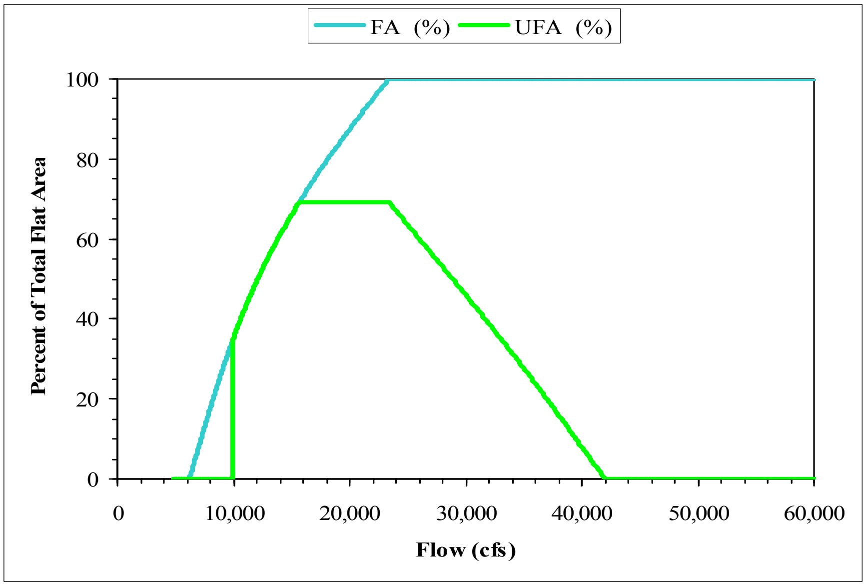

Figure A-9 Percentage of total area of splittail habitat at Site 7 (river mile 14.25 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

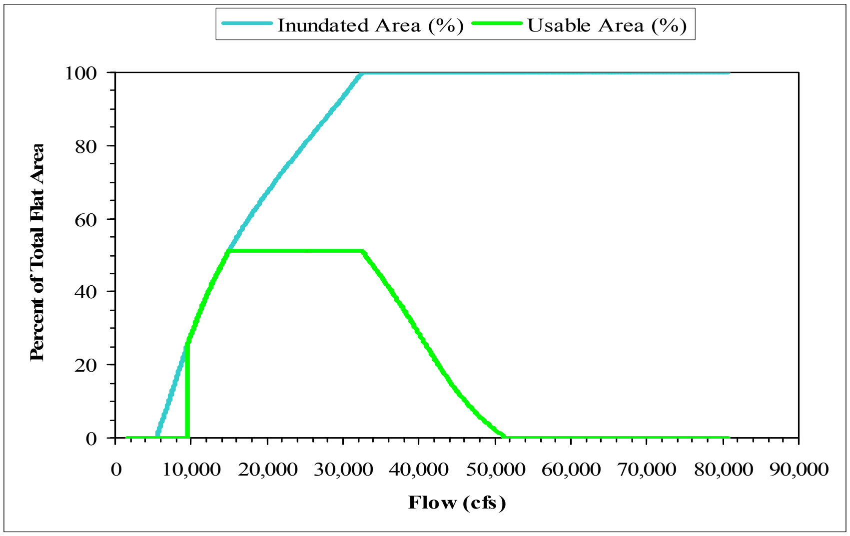

Figure A-10 Percentage of total area of splittail habitat at Site 8 (river mile 12.25 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

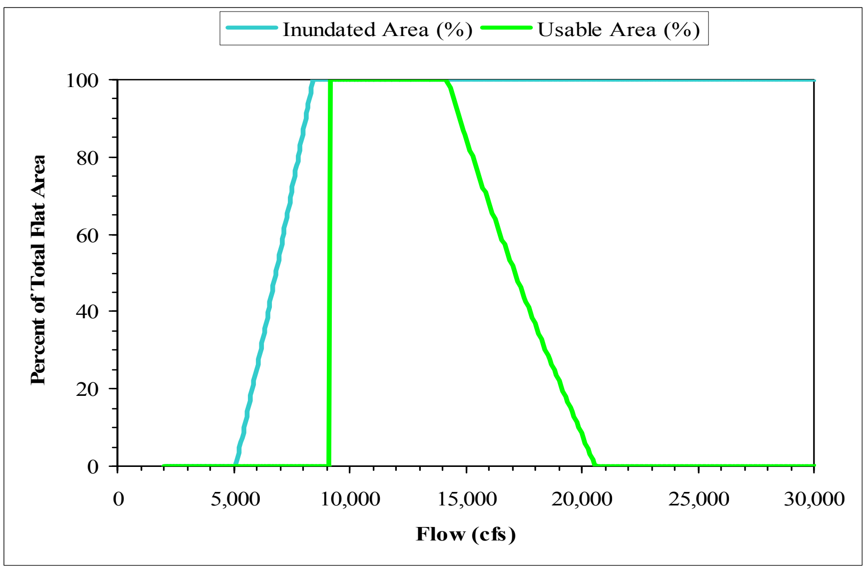

Figure A-11 Percentage of total area of splittail habitat at Site 9 (river mile 12.00 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

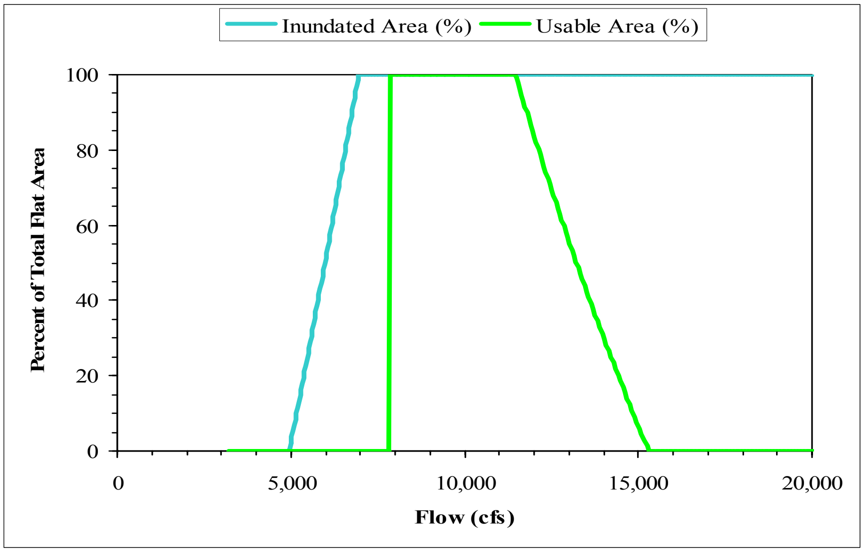

Figure A-12 Percentage of total area of splittail habitat at Site 10 (river mile 9.00 expected to be flooded (FA), and percentage of total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).

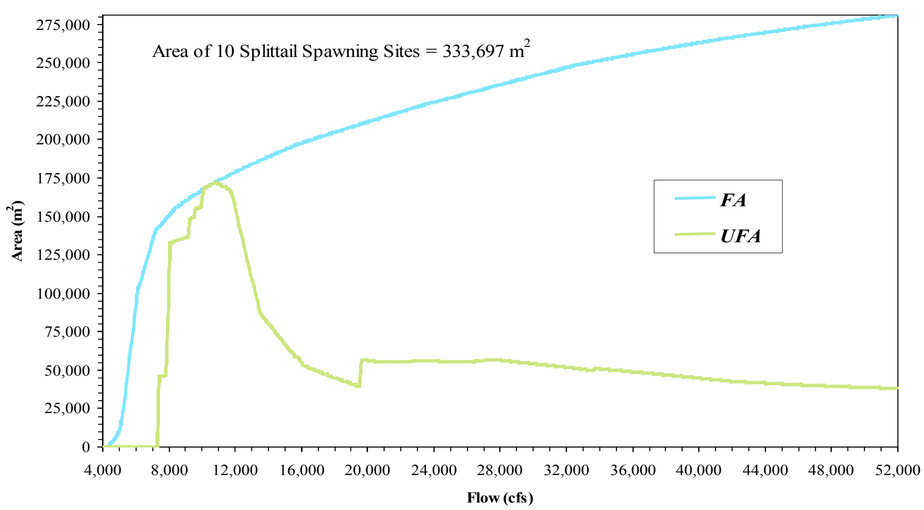

Figure A-13. Total area of 10 potential splittail habitat sites expected to be flooded (FA), and total area expected to be flooded and potentially used for spawning by splittail (UFA) as function of flow (cfs).