State of California
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SP-W9 PROJECT EFFECTS ON NATURAL PROTECTIVE PROCESSES

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

This study assesses the effectiveness of natural protective processes on biological, physical, and chemical integrity within the Project area and the need to modify or mitigate project operations. A review of the general literature on ecosystem function of rivers identified two areas of a riverine ecosystem as the primary locations of the metabolic processes of rivers: the riparian areas and their associated wetlands, and the hyporheic zone of the instream riffles.

The first portion of this report discusses the findings of the literature review of the known effects of riparian areas and associated wetlands on water quality. Geographic data was incorporated into the following discussion, and compared with the findings from the literature. Field checking was performed to assess both the quality of the riparian stands and the potential impacts. The published literature demonstrates that the riparian zone can affect stream water quality in a variety of ways. Well developed riparian areas can buffer a stream from streamside activities, upland land use, and other anthropogenic impacts. Nutrients, metals, and minerals found in the surface water of the stream or in the groundwater are utilized by the plants and other organisms within the riparian zone. Sub-lethal increases, whether artificial or natural, in the loading of nutrients, metals, or minerals can be taken up and sequestered by riparian plants for later use by new growth, and thus can reduce the overall contaminant load in the water. The physical structure of the riparian vegetation can slow the velocity of polluted runoff to allow for sediment and attached contaminants to settle out before reaching the surface water of the stream.

The dominant riparian vegetative type along the lower Feather River was disturbed riparian, which is a type that indicates that a stand has invasive exotic plant species, damage, or both. Natural large-tree stands, cottonwood forest, and valley oak riparian forests comprise only about a tenth of the total acreage. The riparian stands along the lower Feather River are reduced along most of the river's length, primarily from adjoining land use, flood control, and damage from extensive recreational use, creating a reduced capacity of the riverine ecosystem to alleviate potential water quality problems.

The second portion of this report discusses the literature review of the protective processes of riffles and incorporates geographic data into this discussion. These findings are then compared to the results of water quality sampling performed in some of the riffles in the upper portion of the lower Feather River. The interstitial water from eleven riffles was sampled from July 2002 to March 2004 for water temperature, dissolved oxygen, conductivity, and total ammonia, and compared to surface water sampling performed under SP-W1. As a general trend, surface water temperatures tended to be warmer than interstitial water temperatures in the summer months but were sometimes cooler in winter months. Dissolved oxygen concentrations in surface waters were normally found to be above 8.0 mg/L, ranging from 7.8 mg/L to 14.4 mg/L. The majority of the measurements in the surface waters were above 10.0 mg/L.

Interstitial dissolved oxygen concentrations were normally above 5.0 mg/L, and ranged from 5.6 mg/L to 13.0 mg/L. There were only six occurrences of low dissolved oxygen (less than 2.0 mg/L) in interstitial gravels over 20 months of sampling. Conductivity did not show any significant differences between surface and interstitial measurements or among the interstitial measurements, and ranged from 62 to 190 µmhos/cm. Surface measurements of pH ranged from 7.1 to 7.7, which was similar to interstitial measurements, which ranged from 7.1 to 7.5. Most surface and interstitial measurements were within 0.2 pH units at the time of sampling.

Results from this study do not indicate any direct adverse effects on water quality from the riparian areas or the riffle habitats. On the contrary, these types of habitats generally have a beneficial effect on water quality. At two stations in the late summer, the interstitial dissolved oxygen content was reported below the accepted criterion, but this did not have any discernible effect on the surface water dissolved oxygen content. However, the low interstitial dissolved oxygen, caused by the high silt/fines content in these two riffles, could have an impact on interstitial macroinvertebrates and fish egg/larvae survival at these two sites. The major influence to the water quality of the lower Feather River appears to be the continuing imposition of an unnatural water regime. Long-term effects of the artificial imposition of a water regime by project facilities could also include adverse impacts to water quality through the reduction or loss of the beneficial functions of both riparian areas and riffles.

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1.0 INTRODUCTION

The natural protective processes of a riverine system are a complex and, in many cases, overlapping array of interactions of the river's waters with the biological and physical structure around it, including the riparian zone (and adjacent wetlands) and in-stream riffles. The riparian areas of rivers and lakes, which include adjacent wetlands, are thought to perform a variety of natural protective processes, primarily through the filtration and uptake of nutrients, minerals, and other water-borne constituents, by vegetation and subsurface bacteria. These areas are fed by the adjacent river during higher stages, and subsequently recharge the river during lower stages. The quality of this recharge, therefore, could affect the quality of the water in the river. Riparian areas are also thought to shade the river's waters in many areas to reduce or maintain cooler water temperatures. Sediments, especially fine material, are deposited in riparian areas. These areas also tend to have the highest densities and diversity of wildlife and fisheries, which depend on these areas as rearing grounds, cover, food supply, and for other biological functions.

The ecosystem processes in riffles are not quite as well understood, though riffles do perform many of the same ecosystem functions as the riparian areas. Highly oxygenated stream water flows into the riffle at its shallower upstream end (the head of the riffle), percolates down into and through the gravels, and exits the riffle at its deeper downstream end (the tail of the riffle). The steady input of stream water provides oxygen and nutrients to the interstitial waters. The interstitial microbial communities of the riffle perform a variety of metabolic functions that mediate and transform the impact of dissolved substances, such as the various nitrogen compounds. Since the riffle is the primary location of salmon redds, this passage of water is vital for salmon egg and fry development.

To adequately describe the potential project effects on the complex ecological processes, an ecosystem level approach is necessary. Therefore, while developing new studies, this study incorporated data from related geology, terrestrial, and water quality studies. Literature was reviewed to document the known effects of riparian areas and riffles on water quality to evaluate the relation between project operation and water quality. Information about changes in riparian areas and riffles from ongoing or potential changes in project operations were obtained from Study Plans T3/5. Water quality information was obtained from Study Plan SP-W1 for the Feather River. Information from these sources was used to evaluate potential effects to water quality from changes or potential changes in the riparian vegetative communities.

The first portion of this report discusses the findings of the literature review of the known effects of riparian areas and associated wetlands on water quality. Geographic data were incorporated into the following discussion, and compared with the findings from the literature. The second portion of this report discusses the literature review of the protective processes of riffles and incorporates geographic data into this discussion.

These findings are then compared to the results of water quality sampling performed in some of the riffles in the upper portion of the lower Feather River.

1.1 BACKGROUND INFORMATION

The issue of the potential for project effects to natural processes of the Feather River was a concern to the Environmental Work Group, though with no clear definition of what those processes were or how they could be affected. A review of the general literature on ecosystem function of rivers identified two areas of a riverine ecosystem as the primary locations of the metabolic processes of rivers: the riparian areas and their associated wetlands, and the hyporheic zone of the instream riffles.

1.1.1 Study Area

The Study Area includes waters and lands within the project boundary, and along the Feather River within the levee system or the extent of the riparian/wetland vegetation. The focus of this study was that portion of the Feather River downstream from the Fish Barrier Dam to the mouth of the Feather River where it joins the Sacramento River.

The portion of the study that focused on the riparian area processes concentrated on the area of the lower Feather River downstream from the Fish Barrier Dam to the mouth of the Feather River, which is a distance of 67.13 river miles. The riffle portion of the study focused on the lower Feather River downstream from the Fish Barrier Dam to the immediate area just downstream from the Thermalito Afterbay Outlet, which is a distance of 15.5 river miles. However, the geomorphic description of riffles discusses the known riffles for the length of the Feather River from the Fish Barrier Dam to the mouth.

The Low Flow Channel extends from the Fish Barrier Dam just above river mile 67 downstream to the Thermalito Afterbay Outlet at river mile 59. Minimum flows in the Low Flow Channel are 600 cfs, while below the Thermalito Afterbay Outlet flows normally range from 1,000 to 1,700 cfs. Water temperature in the lower Feather River, which is directly influenced by water releases from the Thermalito Afterbay Outlet, is typically warmer than water temperature in the Low Flow Channel.

1.2 DESCRIPTION OF FACILITIES

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

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area, Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet 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. 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 and 5,610 cubic feet per second, 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 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 15,000 to 20,000 adult fish annually.

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

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

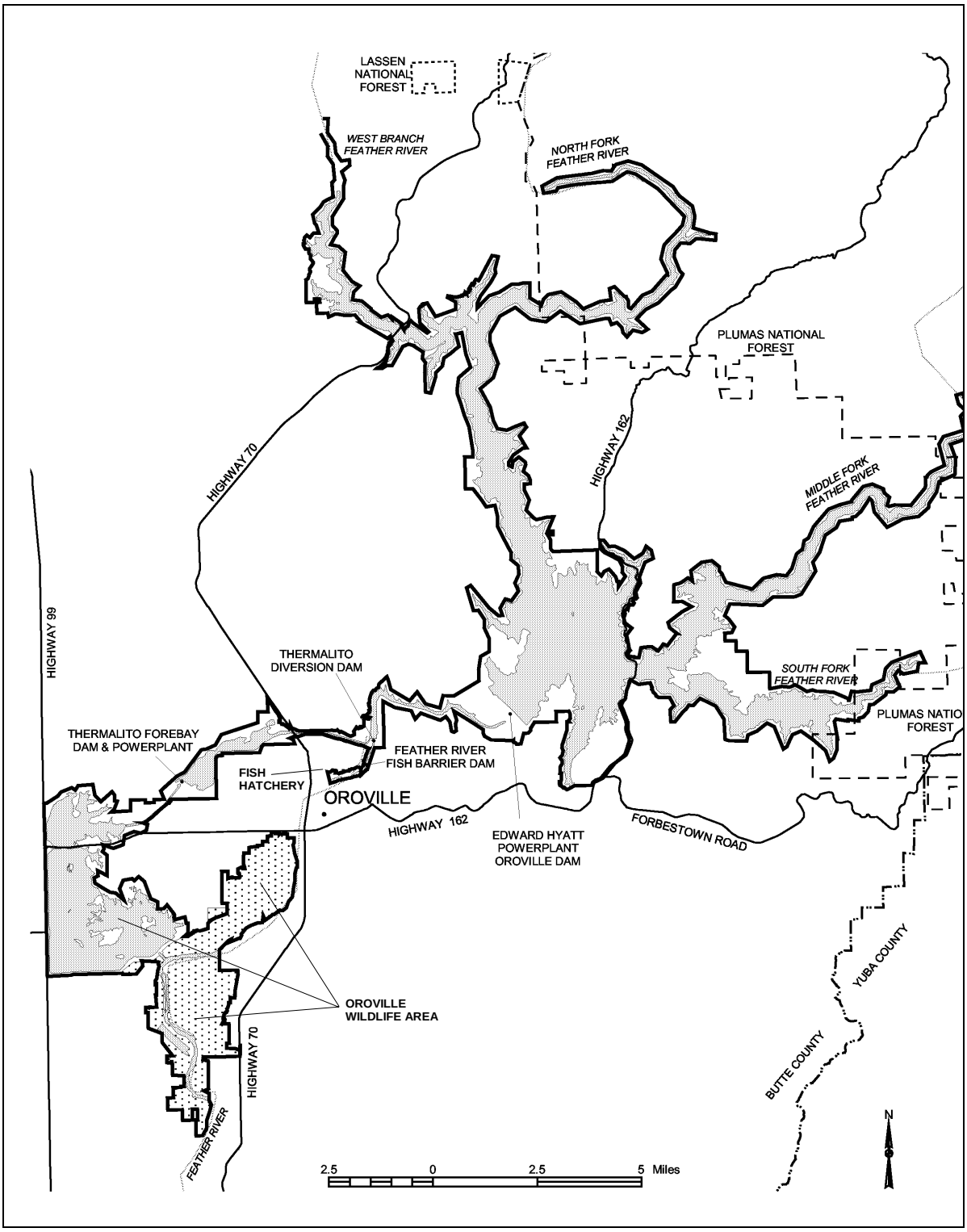

Figure 1.2-1. Oroville Facilities FERC Project Boundary.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet; 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 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 ºF for September, 51 ºF for October and November, 55 ºF for December through March, 51 ºF for April through May 15, 55 ºF for last half of May, 56 ºF for June 1-15, 60 ºF for June 16 through August 15, and 58 ºF for August 16-31. A temperature range of plus or minus 4 ºF 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 ºF 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 ºF from approximately April through mid May, and 59 ºF 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) acre-feet are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

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

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers. Under these requirements, Lake Oroville is operated to maintain up to 750,000 acre-feet 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 million acre-feet 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

Riparian areas perform a variety of natural protective processes within a riverine ecosystem, primarily through the filtration and uptake of nutrients, minerals, and other water-borne constituents, by vegetation and subsurface bacteria. These areas are fed by the adjacent river during higher stages, and subsequently recharge the river during lower stages. The quality of this recharge, therefore, could affect the quality of the water in the river. Riparian areas are also thought to shade the river's waters in many areas to reduce or maintain cooler water temperatures. Sediments, especially fine material, are deposited in riparian areas. These areas also tend to have the highest densities and diversity of wildlife and fisheries, which depend on these areas as rearing grounds, cover, food supply, and for other biological functions. The riparian areas of the major rivers of the Sacramento Valley, including the Feather River, have been greatly reduced in extent and quality over the past century through the spread of urban and agricultural land-uses.

Riffles are the primary re-oxygenators of waterways, while also serving as spawning grounds and cover for various fishes, including salmonids, and habitat for macroinvertebrates. The oxygenation process in riffles also plays a significant role in the reduction of nutrient and mineral loading in a riverine system. Riffles are sensitive to water level fluctuations and loss of gravel recruitment. Without sufficient flow, movement of cold water, oxygen, and nutrients into and through riffles and removal of biological waste products are depleted. According to the Initial Information Package, salmonid egg survival to emergence is around 5 to 15 percent. This low level of survival may be due, in part, to the lack of oxygenation or removal of metabolic waste products. This study evaluates the loss of oxygenation, waste product removal, and other protective processes in the Feather River due to the project.

The study assesses the post-project effectiveness of natural protective processes on biological, physical, and chemical integrity within the Project area and the need to modify or mitigate project operations. The U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration (NOAA) Fisheries requires this information to determine project effects on the habitat of listed species, including salmon and steelhead.

3.0 STUDY OBJECTIVE(S)

The objective of the study is to determine the effect of the project on natural protective processes that affect water quality of those areas adjacent to and under the influence of project waters. This study will provide information to be used to identify potential protection, mitigation and enhancement measures.

4.0 METHODOLOGY

This study evaluates project effects to natural water quality protective processes in riparian and wetland areas as Task 1 and riffle areas as Task 2.

4.1 STUDY DESIGN

4.1.1 Task 1 – Riparian and Wetland Areas

Literature was reviewed to document the known effects of riparian areas on water quality and used to evaluate the relation between changes in riparian areas and water quality. Information about changes in riparian areas from ongoing or potential changes in project operations was obtained from Study Plan SP-T3/5. Water quality information was obtained from Study Plan SP-W1 for the Feather River and SP-W5 for ponds in the Oroville Wildlife Area. Information from these sources was used to evaluate potential effects to water quality from changes or potential changes in the riparian vegetative communities.

Data collection efforts focused primarily on literature review of the direct effects on pollution control and other functions of riparian zones. Geographic data for the riparian vegetation was derived from the ArcView base data developed by the Geographic Information Center at California State University, Chico, from aerial photographs taken by CDWR in 1999. Ground truthing of the riparian stands along the Lower Feather River was performed as part of the large woody debris survey under Study Plan SP-G2 in conjunction with the bank mapping done by the Northern District Geology Section personnel.

4.1.2 Task 2 – Riffle Areas

Published literature was reviewed for known effects of riffle areas on protection and improvement of water quality, factors that decrease those natural protective processes, and water quality conditions needed for successful salmonid egg and alevin survival. Under Study Plan SP-G2, pools, riffles, and runs were mapped and compared to historical maps to assess the extent of change. Study plan SP-G2 also analyzed sediment composition of riffles, which affect the rate of water flow through the interstices. Several of the mapped riffles were included in water quality Study Plan SP-W1, which measured dissolved oxygen, temperature, conductivity, pH, and other parameters in the water column, and analyzed aquatic macroinvertebrate communities. This study plan measured dissolved oxygen, water temperature, conductivity, and pH within the riffle gravels with calibrated meters and probes at several of the mapped riffles monitored for water quality in Study Plan SP-W1.

Ammonia, a product of the breakdown of organic matter that may affect salmon egg and alevin survival, was sampled from the interstitial waters through aspiration. Study Plan

SP-F10 indicates that incubation in gravels of eggs and alevins of chinook salmon and steelhead trout occurs from mid August through March and December through June, respectively. Therefore, interstitial water quality was measured throughout the year at monthly intervals, and more frequently (i.e., twice monthly) if water quality conditions were identified that may affect egg or alevin survival. Riffle areas cleansed by spawning salmonids and areas uncleansed were sampled. This study used these data to determine the effects of the project on the natural protective process of riffles in oxygenation, waste product removal, and other protective processes in the Feather River.

Eleven riffles at or near the current SP-W1 water quality stations along the Lower Feather River were sampled starting in the summer of 2002 (Table 4.1.2-1, Figure 4.1.2-1).

A perforated steel pipe was inserted into the gravels and the standing water in the pipe was pumped out until the water ran clear (approximately 10 minutes) to avoid any excessive sediments . Dissolved oxygen, water temperature, conductivity, and pH was measured with calibrated meters and probes. Total ammonia, a product of the breakdown of organic matter that may affect salmon egg and alevin survival, was sampled from the interstitial waters pumped using the perforated pipe.

The original study plan proposed simultaneous sampling of the interstitial waters and the surface water at each site for direct comparison. However, the Environmental Work Group removed the surface sampling portion of this study plan to avoid duplication of effort with the surface water quality sampling being performed under Study Plan SP-W1. Therefore, the results of the sampling of the interstitial water quality were compared to the results obtained from the SP-W1 sampling location that was the closest in space and time. For example, the riffle water quality stations downstream and upstream from the Sewage Commission Oroville Region discharge outlet and the station at the SCOR outlet island were compared to the SP-W1 water quality station on the Feather River downstream from the SCOR outlet.

Analysis of the macroinvertebrate communities was proposed to evaluate effects to natural water quality protective processes of riffles for macroinvertebrate communities. However, macroinvertebrate sampling was not performed under this study plan to avoid duplication with the macroinvertebrate sampling under SP-W1, which is using these organisms as indicators of water quality. Project effects to macroinvertebrates is evaluated in SP-F1.

Table 4.1.2-1. Riffle interstitial gravel water sampling stations.

IG Station	River Mile	Latitude Longitude	Corresponding SP-W1 Station	Distance to IG Station
FR US Hatchery	66	N39° 31' 4.800" W121° 33' 4.392"	FR US Hatchery	On site
FR A Spawning Channel	66	N39° 30' 57.995 W121° 33' 27.396"	FR US Hatchery; FR DS Hatchery	0.25 mi upstream; 0.25 mi downstream
FR A Auditorium Riffle	66	N39° 30' 57.995 W121° 33' 25.272	FR US Hatchery; FR DS Hatchery	0.25 mi upstream; 0.25 mi downstream
FR DS Hwy 162	64	N39° 29' 47.868 W121° 34' 45.696	FR DS Hwy 162	On site
FR A Robinson Riffle	62	N39° 28' 3.576" W121° 35' 35.268"	FR A Robinson Riffle	On site
FR US Afterbay Outlet	59	N39° 27' 22.788" W121° 37' 49.187	FR US Afterbay Outlet	On site
FR DS Afterbay Outlet	58	N39° 26' 58.488" W121° 38' 18.671	FR DS Afterbay Outlet	On site
FR US SCOR Outlet	58	N39° 27' 9.467 W121° 38' 16.979	FR DS SCOR Outlet	0.25 mi downstream
FR DS SCOR Outlet	58	N39° 27' 5.58" W121° 38' 17.483	FR DS SCOR Outlet	On site
FR DS SCOR Island	58	N39° 27' 3.743 W121° 38' 18.744"	FR DS SCOR Outlet	0.25 mi upstream
FR nr Mile Long Pond	57	N39° 25' 55.488" W121° 38'1.391	FR nr Mile Long Pond	On site

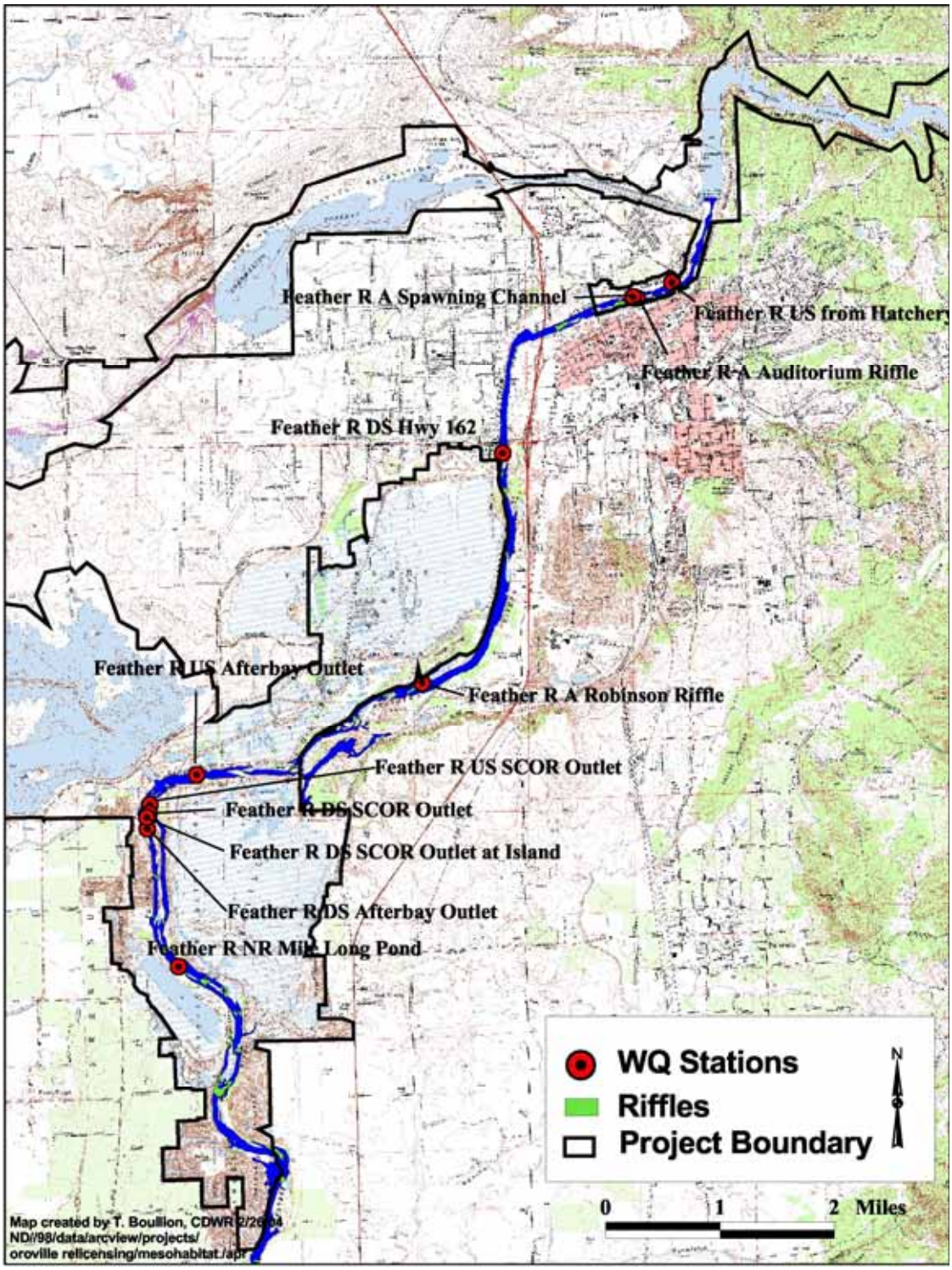

Figure 4.1.2-1. Riffle water quality sampling sites, lower Feather River (July 2002 to January 2004).

5.0 STUDY RESULTS

5.1 TASK 1 – RIPARIAN AND WETLAND AREAS

The potential for effects of the continuing operation of the Oroville Facilities on the riparian and wetland areas of the lower Feather River were assessed through a review of the available literature and habitat mapping.

5.1.1 Literature Review

Data collection efforts focused primarily on literature review of the effect of riparian and wetland areas on water quality and responses of local riparian communities. Additional field observations of stand quality and potential impacts in local plant communities were also useful for assessing the habitat changes that could adversely impact the beneficial water quality functions of the riparian areas.

5.1.1.1 Description

The riparian zone is that area of land that occurs immediately adjacent to streams, rivers, lakes, or other water bodies (Klapproth and Johnson, 2000) at the interface of the terrestrial and aquatic ecosystems (Gregory *et al.*, 1987; Meyer and Couch, 1999). Riparian areas generally have distinct ecological characteristics due to the interaction with the aquatic ecosystem (Gregory *et al.*, 1991; Naiman *et al.*, 2000). Their ecological boundaries, while they can be gradual and indistinct in some areas (Klapproth and Johnson, 2000), can be sharply delineated by changes in soil conditions, vegetation, and other factors that reflect this aquatic-terrestrial interaction (Naiman *et al.*, 2000). Riparian areas differ greatly from the adjoining uplands by their high level of soil moisture, frequent flooding, and the unique assemblage of plant and animal communities that could be found there (Klapproth, 1999). The nature of the riparian zone in any particular area of a stream is determined by a variety of factors, including the climate and elevation (Harris, 1986, 1988, 1989), stream valley structure and channel morphology (Gregory *et al.*,1987; Harris, 1986,1988,1989; Moore and Gregory,1989), stream flow dynamics and disturbance (Heede, 1980; Lake, 2000), instream flow-regime (McKinney *et al.*, 1999; Ward and Stanford, 1995a, 1995b), and the adjacent land-use (Fischer and Martin, 1999; Gregory *et al.*, 1991; Hall, 1988; Klapproth, 1999; Klapproth and Johnson, 2000; Kondolf, 1989; Meyer and Couch, 1999; Naiman *et al.*, 2000; Pollock *et al*., 1998).

One of the most important areas of the riparian area is the underlying hyporheic zone. The hyporheic zone has been variously described as the interstices of stream sediments (Bass and Walker, 1992; White, 1993) and as the interface between the surface and groundwaters (Boulton *et al.*, 1998; Brunke and Gonser, 1999; Scarsbrook and Halliday, 2002; Vervier *et al.*, 1992). Some authors describe the hyporheic zone as the sediments directly beneath and adjacent to the stream bed (Boulton *et al.*, 1998).

Others have found that, especially in those rivers with permeable or semi-permeable sediments, the hyporheic zone will extend fully under the riparian zone (Edwards, 2000), or vary in extent beyond the riparian zone (Valett *et al.*, 1997), sometimes for up to 1.75 miles from the surface water body (Stanford, 2000; Stanford and Gaufin, 1974; Stanford and Ward, 1988, 1993). It is in the hyporheic zone that the subsurface transport of water from and into the streambed occurs (Space *et al*., 1989; Wondzell and Swanson, 1996a), transporting nutrients and organic matter in and out of the stream (Baker *et al*., 1999; Boulton *et al.*, 1998; Naegeli and Uehlinger, 1997) normally on a seasonal basis (Wroblicky *et al*., 1998). A significant amount of the ecosystem metabolism and nutrient exchange known to occur in the riparian area actually occurs in the hyporheic zone beneath it (Lamontagne *et al*., 2001; Lowrance and Leonard, 1988; Naegeli and Uehlinger, 1997; Wondzell and Swanson, 1996b).

5.1.1.2 Functions of the Riparian Zone

Although the riparian zone comprises only a small percentage of the landscape (often less than one percent), they frequently perform a disproportionate amount of ecological functions when compared to upland habitats (Fischer and Fischenich, 2000). In recognition of the varied functions of riparian areas, the Bureau of Land Management, as part of their 1991 Riparian-Wetland Initiative, presented in their annual report to the U.S. Congress the following definitions (USDI BLM, 1993):

> ***Riparian Area*** *– A form of wetland transition between permanently saturated wetlands and upland areas, which exhibit vegetation or physical characteristics reflective of permanent surface or subsurface water influence. Lands along, adjacent to, or contiguous with perennially and intermittently flowing rivers and streams, glacial potholes, and the shores of lakes and reservoirs with stable water levels are typical riparian areas. Excluded are such sites as ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil.*
>
> ***Proper Functioning Condition*** *– Riparian-wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to dissipate stream energy associated with high waterflows, thereby reducing erosion and improving water quality; filter sediment, capture bedload, and aid floodplain development; improve floodwater retention and ground-water recharge; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; and support greater diversity. The functioning condition of riparian-wetland areas is a result of interaction among geology, soil, water, and vegetation.*
>
> ***Functional-At-Risk*** *– Riparian-wetland areas that are in functional condition but an existing soil, water, or vegetation attribute makes them susceptible to*

degradation.

***Nonfunctional Condition** – Riparian-wetland areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows and thus are not reducing erosion, improving water quality, etc., as listed above. The absence of certain physical attributes such as a floodplain where one should be are indicators of nonfunctioning conditions.*

Riparian areas are first generally associated with wildlife habitat (Bilby, 1988; CDFG, 1985; Fischer and Martin, 1999; Newton *et al.*, 1996; Roberts *et al*., 1977; West, 1988) and fisheries (Beschta, 1991,1997; Beschta *et al.*, 1987; Bisson *et al.*, 1987; Murphy *et al.*, 1986). However, other distinct and valuable functions of riparian areas have been recognized, including large woody debris recruitment areas (Murphy *et al.*, 1986; Reid and Hilton, 1998; Sedell *et al.*, 1988; USFWS, 2000) and plant diversity and productivity reserves (Clawson *et al.*, 2001; Naiman *et al.*, 2000; Roberts *et al*., 1977). Riparian forests also are known to provide important physical protection of the stream through physical buffering and streambank stabilization (Bohn, 1986; Klapproth, 1999).

5.1.1.2.1 Flood Control

Flood control is not a function usually associated with riparian areas. However, the value of riparian areas to flood control can be readily illustrated by the lack of riparian areas within urbanized areas. Urban engineers design ‘channel improvements’ based on applications of hydraulics research on sediment-free water in a relatively simple artificial pipe. The design of flood control seeks to minimize the right-of-way of the flood control channel, usually by eliminating bank vegetation and lining the channel with smooth reinforced concrete to induce very fast, shallow ‘supercritical’ flow. When supercritical flow develops, the channel cross-section and right-of-way can be substantially reduced, allowing for economy in construction and maintenance (Williams and Swanson, 1989) and infringing as little as possible on urban living space (Booth, 2000). However, the modification of the land surface during urbanization changes both the magnitude and type of runoff that reaches a stream, invalidating many of the assumptions behind this research (Weak *et al*., 1998). The end result is a concrete-lined channel that actually overtops its banks at flows considerably smaller than their design flood (Williams and Swanson, 1989). Further, this channelization and hardening of the channel designed within this hydraulically-driven paradigm reduces or eliminates stream function and metabolism within urban areas, and ironically tends to worsen the effects of erosion downstream of the concreted areas (Booth, 1998; CEES2003; Mount, 1995; Williams and Swanson, 1989). To this day, as a result of decades of ‘channel improvements’, riparian zones within many urban areas tend to be small, disjunct, and relatively ineffectual (Booth, 2000).

5.1.1.2.2 Water Quality

Water quality protection is an important role that has been increasingly recognized by many as one of the most vital of functions of riparian wetlands (Evans *et al*., 1996; Correll, 1999; Tjaden and Weber, 1997a, 1997b). Non-point pollution from widespread land uses is the largest source of pollution into streams, now that point sources are closely regulated under the Clean Water Act (CEES, 2003b). Non-point pollution, which includes sediment, nutrients, pesticides, animal wastes, and other substances (Anderson and Masters, 1993), enter surface waters in subsurface or surface flows in dissolved forms or attached to soil particles (Klapproth and Johnson, 2000). Streamside management or near-stream upland land use activities have been found to directly affect water quality in streams (Meyer and Couch, 1999). Three types of land uses of the riparian and near-stream upland areas, including agriculture, forestry, and urbanization, have had the most significant impacts on stream water quality in the U.S. (Lowrance *et al.*, 1984, 1985; Hanson, 1997).

Water quality protection by the riparian zone is well known among forestry (Brown and Binkley, 1994; Kopperdahl *et al.*, 1971; MacDonald *et al.*, 1991; Reid and Hilton, 1998) and agricultural researchers (Klapproth, 1999; Klapproth and Johnson, 2000; Lowrance *et al.*, 1984; Monohan, 2003; Peterjohn and Correll, 1984). Much of the water quality improvement techniques in agriculture and forestry are primarily concerned with the preservation of riparian buffers around intense land use, such as clear cutting (Reid and Hilton, 1998) or intensive row crops (Udy *et al.*, 2000), though the establishment of riparian buffers has been supported by many agencies (Dosskey, 1997a, 1997b, 2002; Fischer and Martin, 1999; Klapproth, 1999; Klapproth and Johnson, 2000). However, some of the adverse effects of long-term adjacent land use on streams was found to be persistent in some heavily impacted watersheds for many decades regardless of reforestation of riparian areas (Harding *et al*., 1998). Urban planners usually do not address pollution from urban runoff as much as they address flood risk, although regulatory agencies have required the issue of polluted urban runoff to be addressed (Mount, 1995; Williams and Swanson, 1989). Several urban planners have proposed the re-establishment of riparian corridors, rather than the usual engineering solutions, in response to both the experiences of the past few decades and regulatory requirements (Mount, 1995).

5.1.1.2.3 Nutrient Transport and Uptake

While nutrient transport from watersheds is a natural part of nutrient cycling, excessive nutrients from manure or decaying vegetation can exceed the capacity for a stream ecosystem to absorb them, leading to pollution (George, 1995). The composition of the biological communities associated with the riparian zone , including the above ground vegetation, the subsurface microbial community, and even the wildlife and fish, controls the nutrient cycling. For example, salmon carcasses can act as a net source of nutrients to the system, while beavers can modify the physical structure and hydrologic

characteristics of the riparian corridor (McClain *et al*., 1998). Retention of particulate and dissolved nutrients in streams affects food availability for stream biota (Lamberti *et al*., 1989).

Riparian ecosystems can act as nutrient sinks from runoff waters through deposition in riparian soils (Clawson *et al*., 2001; Fernald *et al*., 2001; Lamberti *et al*., 1989), by direct uptake by riparian vegetation (Clawson *et al.*, 2001; Pinay *et al.*, 1998;, Pinay *et al*., 2002) or by microbial processes in the riparian soils (Komor and Magner, 1996). In streams with low nutrient concentrations, a deciduous riparian forest can act as a nutrient source (Sabater *et al.*, 2000; Triska *et al*., 1990). The efficacy of nutrient uptake by riparian areas has been called into question by some. Nutrient uptake efficiency was found to be highly correlated to the relative amount of subsurface flow that passes directly through the root zone of the vegetation within the riparian zone (Lamontagne *et al*., 2001). Omernik *et al.* (1981) hypothesized that nutrient balance (uptake equals output) can occur in mature riparian forests, resulting in a zero or even a minus uptake of nutrients by a particular riparian area. Lowrance *et al.* (1984) found that, while this does occur in a few cases, nutrient balance or export from riparian areas can be avoided if trees were harvested periodically to ensure a net uptake of nutrients. However, Sabater *et al.* (2000) found that large-scale removal of riparian vegetation increased nutrient fluxes and loss of stream nutrient retention efficiency. Pinay *et al*. (1998), testing the effectiveness of three types of riparian vegetation buffers on agricultural non-point pollution, found that reduction in groundwater nutrient levels along the Garonne River (France) was due primarily to mixing with nutrient poor surface water. However, they pointed out that most of the riparian areas along the river had long been cleared and the floodplains were intensively farmed and resulted in high levels of nutrients in the groundwater. They felt that the reduced condition of the riparian vegetation within such a large watershed (virtually absent across much of the landscape) coupled with the intense land use, reduced the effectiveness of riparian vegetation in controlling non-point pollution (Pinay *et al*., 1998). Narrow riparian strips in limited areas are ineffective if poor land management techniques are permitted elsewhere within the broader landscape of the watershed (Price and Lovett, 2002).

Nutrient levels, especially dissolved inorganic nitrogen, have been found to be significantly reduced, though variable, in the groundwaters of the upland and riparian areas in a natural system (Brandes, 1996; Chestnut and McDowell, 2000; Lamontagne *et al*., 2001; Lowrance *et al*., 1988). This type of nutrient uptake from shallow groundwaters by riparian vegetation has been recognized as a possible control to the impacts from excessive nutrient levels in the groundwater of catchments where agriculture predominates (Klapproth, 1999; Klapproth and Johnson, 2000; Udy *et al.*, 2000). Nutrient concentrations in shallow groundwaters were reduced substantially as the groundwater moved from croplands through an adjacent riparian forest (Peterjohn and Correll, 1984), especially in natural riparian buffers (Klapproth, 1999; Klapproth and Johnson, 2000) or in artificially-enhanced natural riparian areas (Barden *et al.*, 2003; Dosskey, 1997b, 2002; Hanson, 1997). In fact, natural riparian buffers between

agricultural fields and small streams have been found to reduce nitrate in subsurface flows by 90 percent and phosphorus by 50 percent before the water enters the surface waters of the stream (Gilliam *et al.*, 1997). Many agricultural researchers and cooperative extension services have offered the public information circulars about water quality research (CRJC, 2000; Correll, 1999; Dosskey, 1997a) and designs of riparian filter strips for use in agricultural areas, usually of fast-growing grasses (Barden *et al.*, 2003; Dosskey, 1997b; Fogle *et al.*, 1994; Newton *et al.*, 1997) or fast-growing trees, such as poplars (Haycock and Pinay, 1993). Although there have not been many studies comparing vegetation class (trees, shrubs, or herbaceous), Verhoeven *et al*. (2001) found that the type of dominant vegetation class significantly affected nutrient uptake and interstitial water chemistry in saturated soils of constructed and natural wetlands.

5.1.1.2.4 Metals

Dissolved metals can also be affected by the presence of riparian vegetation. While plants in general require varying amounts of metals for growth, it appears that the metals essential for growth are not the only metals taken up by riparian plants. For example, significant amounts of lead, chromium, copper, nickel, zinc, cadmium, and tin were found in the floodplain sediments of the Chickahominy River downstream from Richmond, Virginia (Hupp et al., 1993). Analyses of the woody tissues of the floodplain trees found these metals were also taken up by the trees (Klapproth and Johnson, 2000). Lemly (1999) found that water-borne selenium was sequestered by rooted plants into long-term cycling of selenium.

5.1.1.2.5 Water Temperature

Cooler water temperatures are vital for many aquatic species, especially salmon (Beschta, 1997; Beschta *et al.*, 1987; Zwieniecki and Newton, 1999). Riparian vegetation performs a unique function simply due to its presence at the stream margin, influencing the temperature of stream waters (Maloney *et al*., 1999; Rishel *et al.*, 1982). The exchange of heat at the margins of a stream is influenced by the riparian vegetation through shading, moderation of air temperature and relative humidity through plant respiration, and wind reduction (Lowney and Orlob, 2001). It was found that any increase in direct sunlight through riparian vegetation removal could account for 90 percent of a stream's temperature change (Brown and Krygier, 1970; McGurk, 1989). The presence or absence of riparian vegetation to moderate stream water temperature can significantly influence both the fish and the macroinvertebrate community in a stream (Nakamoto, 1998) with significant differences found in macroinvertebrate community composition and the numbers of fishes in an affected stream (Binkley and Brown, 1993b; Hetrick *et al*., 1988; Keith *et al*., 1998; Meehan, 1996), an assertion initially disputed by forestry researchers (Brown, 1974; Brown and Krygier, 1970). However, some of these same researchers then developed techniques primarily to

predict the change in stream temperature due to riparian vegetation removal and the possible effect to aquatic organisms (Beschta, 1997; Brown, 1970; McGurk, 1989).

5.1.1.2.6 Sedimentation

Erosion is a natural process that can be accelerated by land use activities (George, 1995). Movement of soil particles into streams may be the most visible connection between most forms of land use and adjacent streams (Binkley and Brown, 1993b; Fogle *et al*., 1994). The more intense the land use (i.e., row cropping in agricultural areas or clear-cutting in forests) the greater the potential exists for excess sediment reaching the stream (Binkley and Brown, 1993a, 1993b). Agricultural runoff is considered to be the single largest source of sediment into surface waters of the U.S. (Fogle *et al*., 1994).

Sedimentation of streams can have a significant adverse effect on stream water quality and biota (Klapproth and Johnson, 2000), reducing instream habitat diversity (Packer and Haupt, 1965), aquatic biota community abundance and composition (Meehan, 1996), and stream water quality (Binkley and Brown, 1993a, 1993b). The riparian area acts as a sediment sink for runoff, both physically and physiologically (Klapproth, 1999; Klapproth and Johnson, 2000; Murphy *et al*., 1981). The presence of the riparian vegetation intercepts the flow of runoff, slowing surface flows for increased uptake or storage time (Klapproth, 2000), allowing for deposition which has been measured at up to 470,000 pounds of sediment particles per acre (Lowrance et al., 1986). The vegetation reduces soil moisture retention through uptake and transpiration and consequently results in discharge of shallow groundwaters into the stream (Keppeler, 1998; Klock and Lopushinsky, 1980). Summer flows and annual yields of groundwater discharge have increased after intensive management or site preparation of upland and near-stream forest stands (Brown, 1989; Heede, 1991; Keppeler, 1998; Ziemer, 1981). This increase in subsurface flows were found to transport sediment into the streams through mass failures and soil creep due to the occurrence of overland flow in those steep forested areas where overland flow is normally very rare (Swanson *et al*., 1987), increased erosion (Brown, 1989), or increased flooding (Swanson *et al*., 1998).

Of all land use activities that can occur in forested near-stream areas, road construction has been considered by many to cause the greatest amount of sedimentation in streams, even more than aggressive clear-cutting (Beschta, 1978; MacDonald *et al*., 1991; Packer and Haupt, 1965). The presence of unpaved roads and associated road fill can be a source of sediment to streams for decades (Adams and Ringer, 1994; Binkley and Brown, 1993b), especially if they are located where the muddy runoff is discharged directly into the stream (George, 1995). The construction of roads in riparian areas, even those roads that do not directly affect the stream, has been found to cause widespread geomorphological changes in the stream and a consequent loss of instream habitat (Adams and Ringer, 1994; Bolstad and Swank, 1997; George, 1995; Heede, 1991). The aquatic fauna of streams, such as amphibians (Lisle and Hilton,

1991; Welsh and Ollivier, 1998), can be directly impacted by the sedimentation caused by road construction (Henley et al., 2000), especially some fishes (Baxter *et al*., 1999).

Livestock grazing, which is one of the most intense and adverse forms of land management, has been found to significantly increase upland and bank erosion primarily by reducing the riparian vegetation through grazing or trampling. Direct bank destruction by livestock has been found to increase sedimentation through increased upland runoff and bank mass failures (Maloney *et al*., 1999). Maloney *et al*. (1999) found that the loss of bankside and riparian structure, more than other factors, could physically increase the intensity and velocity of upland surface runoff into a stream. Livestock trails down to the water could act as conveyances of sediment-laden runoff to the stream (Maloney *et al*., 1999).

5.1.1.3 Effects of Dams to Riparian Zones

The flow regime could be the most significant influence on riparian zones in major rivers. Dams tend to even out the low flow/high flow duration curve, lower the peak stages, and increase the base flow (Leopold *et al*., 1964; Sprenger *et al*., 2002). The reduced differences between base flow and flood stage can drastically alter or curtail sediment transport, with the net effect of reducing the recruitment of sediment and nutrients to the riparian vegetation (Kondolf, 1995; Sprenger *et al*., 2002). Sediment transport truncated by the presence of a dam could result in channel degradation for many miles downstream through sediment starvation (Kondolf, 1995, 1997). This degradation could lead to deepening of the channel (channel incision) and a consequent lowering of ground water levels (Ward and Stanford, 1995a). The lowering of the water table through the deepening of the channel can effectively strand those riparian plants that depend largely on groundwater as their source of water during low flows (Space *et al*., 1989).

In those streams that experience periodic drying, as in desert streams, the hyporheic zone is the only reservoir of water in the stream (Valett *et al*., 1990). The hyporheic invertebrate communities burrow deeper into the underlying wetter sediments to avoid the effects of drying or leave drought-resistant forms (Clinton *et al*., 1996). However, in the hyporheic zone of the riparian forest that has a near-constant flow regime, the hyporheic zone can be adversely affected by the lowering of the water table through channel incision, with many of the hyporheic microbial and invertebrate communities eventually dying out (Clinton *et al*., 1996).

In those channels where incision is not a problem, the near-constant flow levels could maintain the water table at an artificially high level. Establishing trees in the riparian zone require an eventual drawdown of the water table. Their roots grow into the deeper soils, with the consequence that they become firmly rooted and resistant to high flows (Mahoney and Rood, 1998). Without this seasonal drawdown, the newly-established trees remain shallowly rooted and prone to uprooting in a high flow (flood) event

(CalFed, 2000). Other organisms, adapted to the periodic drawdown, eventually are out-competed by those species tolerant to constant high water (Clinton *et al*., 1996; Hauer and Stanford, 1982).

Early succession floodplain tree species require channel movement, periodic flooding, and sedimentation for recruitment and regeneration (Mahoney and Rood, 1998; Winfield and Hughes, 1995). Higher flows, especially naturally-occurring episodic events on the scale of decades, periodically establish new bed conditions and vegetation patterns necessary to maintain characteristic riparian vegetation (Hecht, 1994). These events create fresh surfaces for the colonization of seedlings through channel migration, point bar deposition, and meander cutoff, while the slow recession of flood waters can facilitate seedling establishment and survival (CalFed, 2000). Dams eliminate or substantially reduce the episodic flows necessary to sustain diverse and widespread riparian areas, leading to fragile and isolated monocultural stands (Hecht, 1994). Dams can even facilitate invasions of exotic species through the reduction of high flow events that destroy water-stress intolerant exotic plant competitors (Decamps *et al*.,1995). The lack of these episodic flows results in riparian vegetation invading those alluvial surfaces that are normally re-worked and unvegetated (Elliott and Hammack, 2000).

5.1.1.4 Conclusion

The published literature demonstrates that the riparian zone can affect stream water quality in a variety of ways. Well developed riparian areas can buffer a stream from streamside activities, upland land use, and other anthropogenic impacts. Nutrients, metals, and minerals found in the surface water of the stream or in the groundwater are utilized by the plants and other organisms within the riparian zone. Sub-lethal increases, whether artificial or natural, in the loading of nutrients, metals, or minerals can be taken up and sequestered by riparian plants for later use by new growth, and thus can reduce the overall contaminant load in the water. The physical structure of the riparian vegetation can slow the velocity of polluted runoff to allow for sediment and attached contaminants to settle out before reaching the surface water of the stream.

5.1.2 Habitat Mapping

The Geographic Information Center at California State University, Chico, had typed and mapped into “units” in ArcView 3.2 the lower Feather River riparian area for CDWR using aerial photographs that CDWR had taken in 1999. Physically, a unit is defined as an area of vegetative or physical homogeneity that can be mapped. For example, a cottonwood forest unit is a single measurable stand of vegetation with cottonwoods dominating the stand overstory, while a gravel unit is a single homogeneous area denuded of vegetation and dominated by gravels, cobbles, and boulders (but not bedrock). In GIS, a unit is an enclosed polygon of a single attributable type (cottonwood forest, gravel, etc.). The riparian areas along the Feather River consists of 2,236 units of twelve types totaling 18,478 acres (Table 5.1.2-1). Additionally, bank typing by

CDWR Geology staff under study plan SP-G2 provided additional information about riparian areas.

Table 5.1.2-1. Lower Feather River riparian types and acreages.

Habitat Types	Number of Units	Total Acreage	Mean Acreage	Minimum Acreage	Maximum Acreage
Blackberry shrub	80	109	1.4	0.01	10
Cottonwood forest	454	1,856	4.1	0.04	84
Disturbed non-riparian	39	927	23.8	0.03	255
Disturbed riparian	186	6,727	36.2	0.02	2,651
Gravel	364	1,372	3.8	0.03	109
Herbaceous riparian	85	923	10.9	0.10	175
Mixed non-riparian	33	77	2.3	0.02	10
Mixed forest	510	4,711	9.2	0.01	271
Mixed riparian	1	10	-	-	-
Non-vegetated	7	84	11.9	0.15	44
Riparian shrub	445	1,446	3.3	0.04	477
Valley oak riparian	32	236	7.4	0.10	88
Total	**2,236**	**18,478**	**8.3**	**0.01**	**2,651**

The dominant riparian vegetative type along the lower Feather River was disturbed riparian, with 186 units comprising 6,727 acres, or 36 percent of the total. This type of stand contains riparian vegetation of some sort (usually a mixed vegetative class stand) with at least half of its area that has been partially impaired or reduced through instream processes, such as bank erosion, or land use streamside activities, such as recreation, road building, tailings deposition, encroachment by adjacent land use, and other anthropogenic activities. An additional 927 acres (5 percent) consists of disturbed non-riparian type, which could consist of an area with any mixed non-riparian form of vegetation that has been impaired or reduced through natural processes or human activities. The blackberry shrub (109 acres) is also a type of disturbed non-riparian vegetative stand, with each unit dominated primarily by invasive non-native blackberry thickets.

The cottonwood forest and valley oak riparian forest types are the classic riparian floodplain forests, with more than 50 percent of each stand dominated by a single species, with varieties of understory species of smaller trees and shrubs. These types of stands comprise 486 units (22 percent of the total units) totaling 2,092 acres (11 percent of total acreage), with an average stand size of 4.3 acres per unit. Many of the forest units are impacted by invasive non-native species of plants and/or human streamside activities, and appear to be dominated by even-age overstories. The mixed riparian (10 acres) and riparian shrub (1,446 acres) types are dominated by riparian

vegetation but with no clear dominant species or class (tree, shrub, or herbaceous). The herbaceous riparian consists of 923 acres and is dominated by an herbaceous layer of vegetation. The gravel type (1,372 acres) is an unvegetated area that is dominated primarily by exposed gravels and cobbles, such as gravel pits, mining tailing piles, and elevated gravel bars. The non-vegetated units (84 acres) are exposed soils devoid of vegetation, but without the gravel/cobble substrate.

The width of the riparian zone is determined primarily by the adjacent land use, which includes the urbanization, gravel mining, orchards, and other agricultural uses (Figures 5.1.2-1 though 5.1.2-7). Much of the Feather River is hardened by well maintained levees, especially outside of the Oroville Wildlife Area. In many places along the Feather River, the riparian zone has been eliminated completely by the presence of levees in conjunction with adjacent land use (see Figures 5.1.2-1, 5.1.2-4, and 5.1.2-5). Additionally, hardening of the waterline edge of some banks with riprap, as exemplified by the banks upstream of Verona along river miles 0 to 6 and upstream of Yuba City from river mile 28 to river mile 30 (Figure 5.1.2-3), has prevented the establishment of vegetation in some areas. The hardening of the banks is an effort to slow or inhibit bank erosion and channel migration, thus preventing new streamside areas from opening to riparian vegetation recruitment.

The riparian zone is well developed along the Feather River upstream from the Sutter Bypass at river mile 7 to about river mile 18 near Olivehurst (Figure 5.1.2-2). This area has set-back levees and an active floodplain that can reach over 0.75 miles in width, especially in the area where the Bear River enters the Feather River. The riparian vegetation is dominated by mixed forests, herbaceous riparian, and riparian shrub areas. The riparian vegetation in this area does not show much disturbance. There is little or no encroachment from the surrounding land use due to the set-back levees and little disturbance from recreational use due to lack of easy access.

The Oroville Wildlife Area has the greatest amount of riparian development along the entire length of the Feather River (Figure 5.1.2-6). However, much of that riparian area is disturbed riparian, bare gravel, or disturbed areas, with the soils dominated by dredger tailings and reduced riparian vegetation. Recreation is high in this area, with numerous roads, trails, cartop boat access points, and parking areas cut into the riparian areas. Some elevated roadbeds were constructed to allow access to the Feather River across the tailings, further isolating vegetative stands. Compaction of the soils is high in many of the areas from vehicle passage or maintenance activities. Much of the existing riparian vegetation in the OWA is isolated from the Feather River by elevated roads and levees of dredger tailings. Along some parts of the OWA, levees constructed for flood control are also in place and tend to isolate the riparian zone from the River. Small dredger pits, usually connected by subsurface flow to the Feather River, have developed into isolated wetlands within this area. Some of these wetlands have become isolated from the subsurface flow over time and, with the advent of warmer summer temperatures, can become eutrophic. Some of the shallower pits dry

periodically, preventing the viability of fish populations in these pools. With the absence of fish predators, these wetlands then become mosquito breeding areas, and can pose a human health risk (James Camy, Butte County Mosquito and Vector Control District, pers. comm., 2002).

The issue of bank hardening is especially true within the urbanized areas along the Feather River, where issues concerning property ownership and urban facilities come into play. Within the City of Oroville, the riparian vegetation is reduced to a remnant found within the active channel of the river or has been eliminated along the river by streamside development. Much of the bank is hardened for bank protection, while levees provide the city with flood protection. Some of the riparian vegetation has been established along the left bank of the river within the City of Oroville, but this is a relatively short, narrow band between the active channel of the river and the levee (Figure 5.1.2-7). Yuba City and Marysville have developed much of the banks of the Feather and Yuba Rivers (Figure 5.1.2-3). Most of the banks of the Feather River within these cities are lined with levees and hardened with riprap, concrete, or rock. The City of Marysville has developed a city park at the confluence of the two rivers, with athletic facilities, picnic grounds, boat launch, and other recreational facilities. A sewage treatment and control facility is located adjacent to this park. The riparian zone in this area consists of small isolated bands of vegetation at the water's edge.

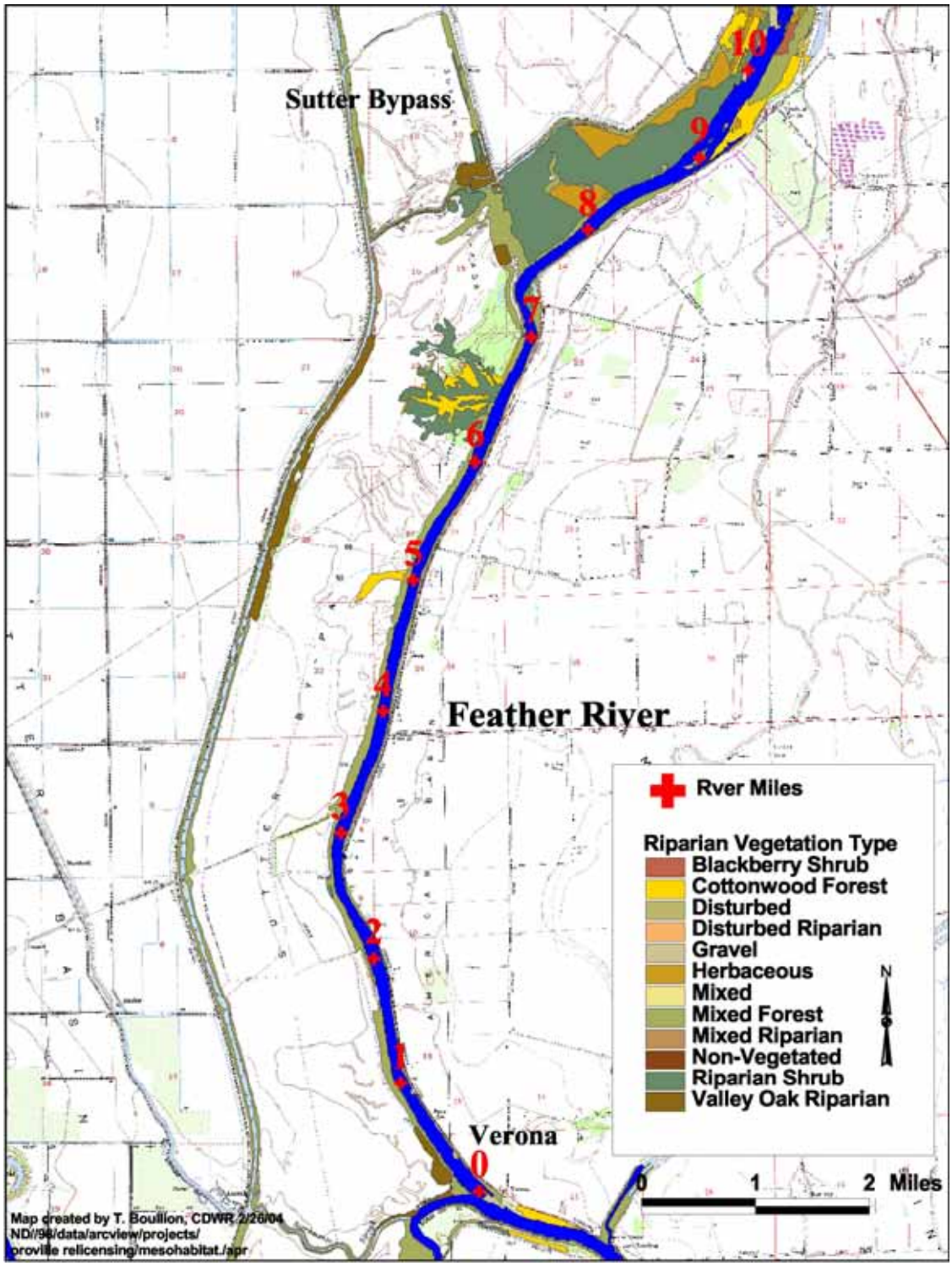

Figure 5.1.2-1. Riparian habitat along the lower Feather River (river mile 0 to river mile 10).

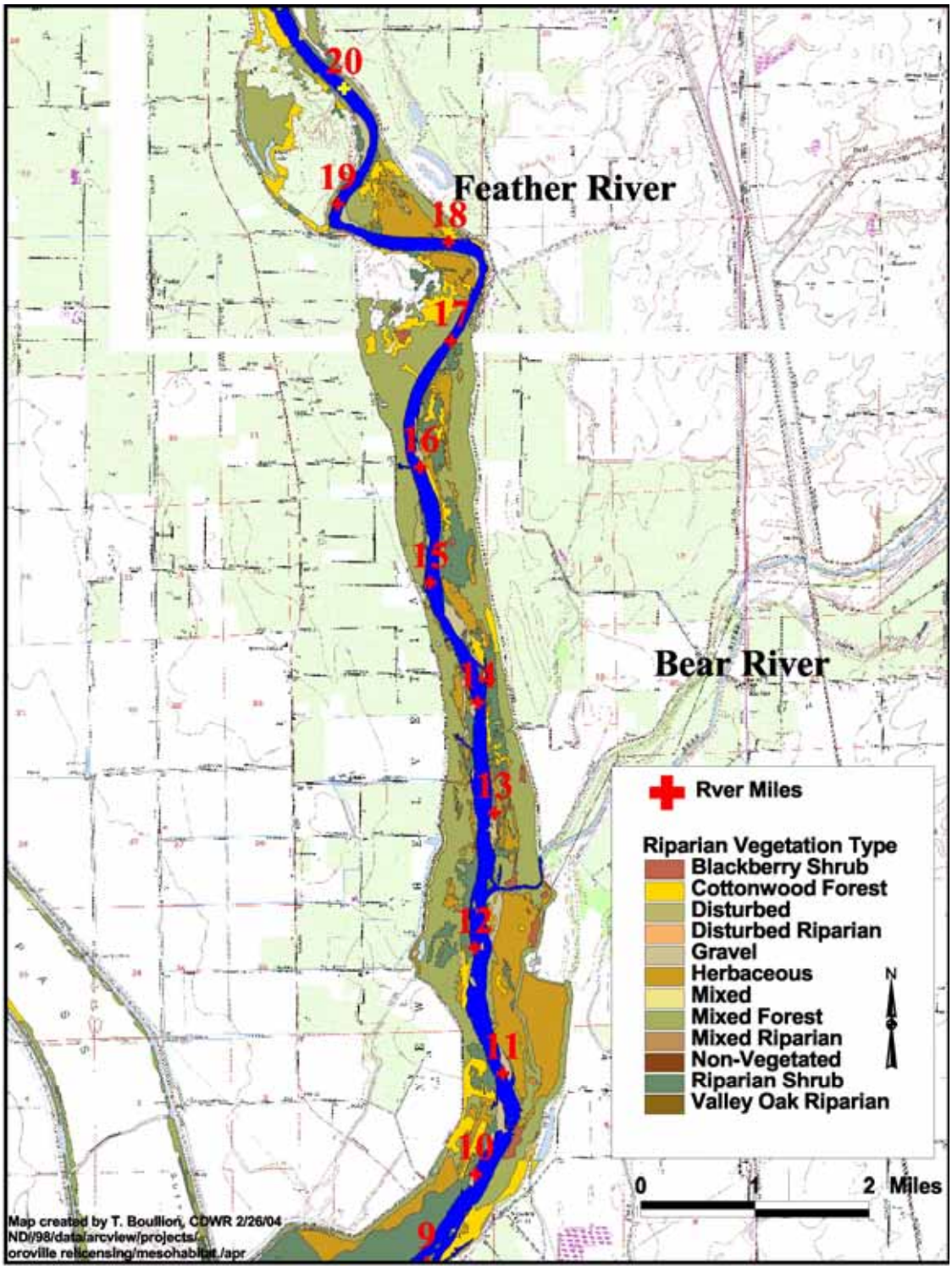

Figure 5.1.2-2. Riparian habitat along the lower Feather River (river mile 10 to river mile 20).

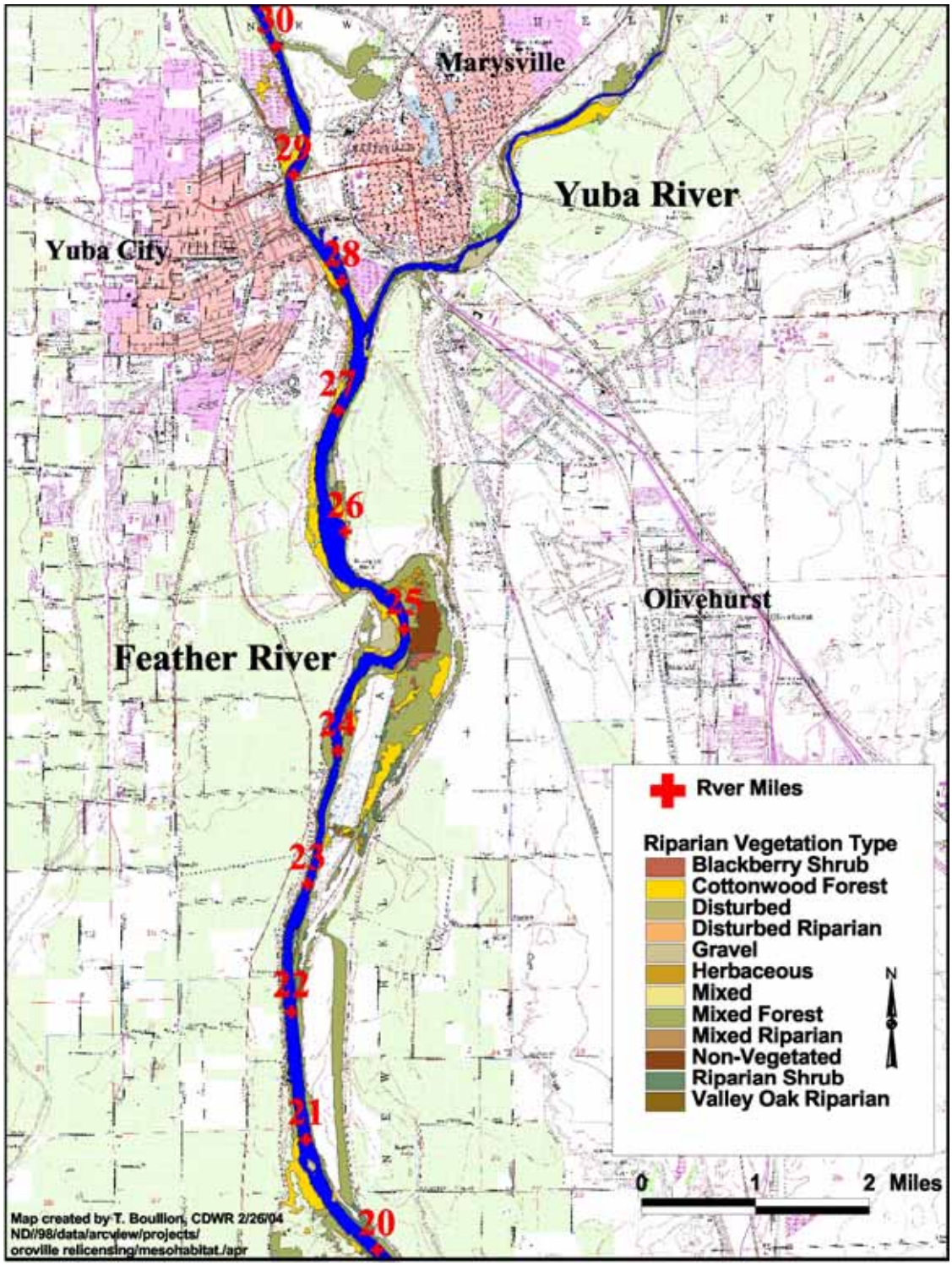

Figure 5.1.2-3. Riparian habitat along the lower Feather River (river mile 20 to river mile 30).

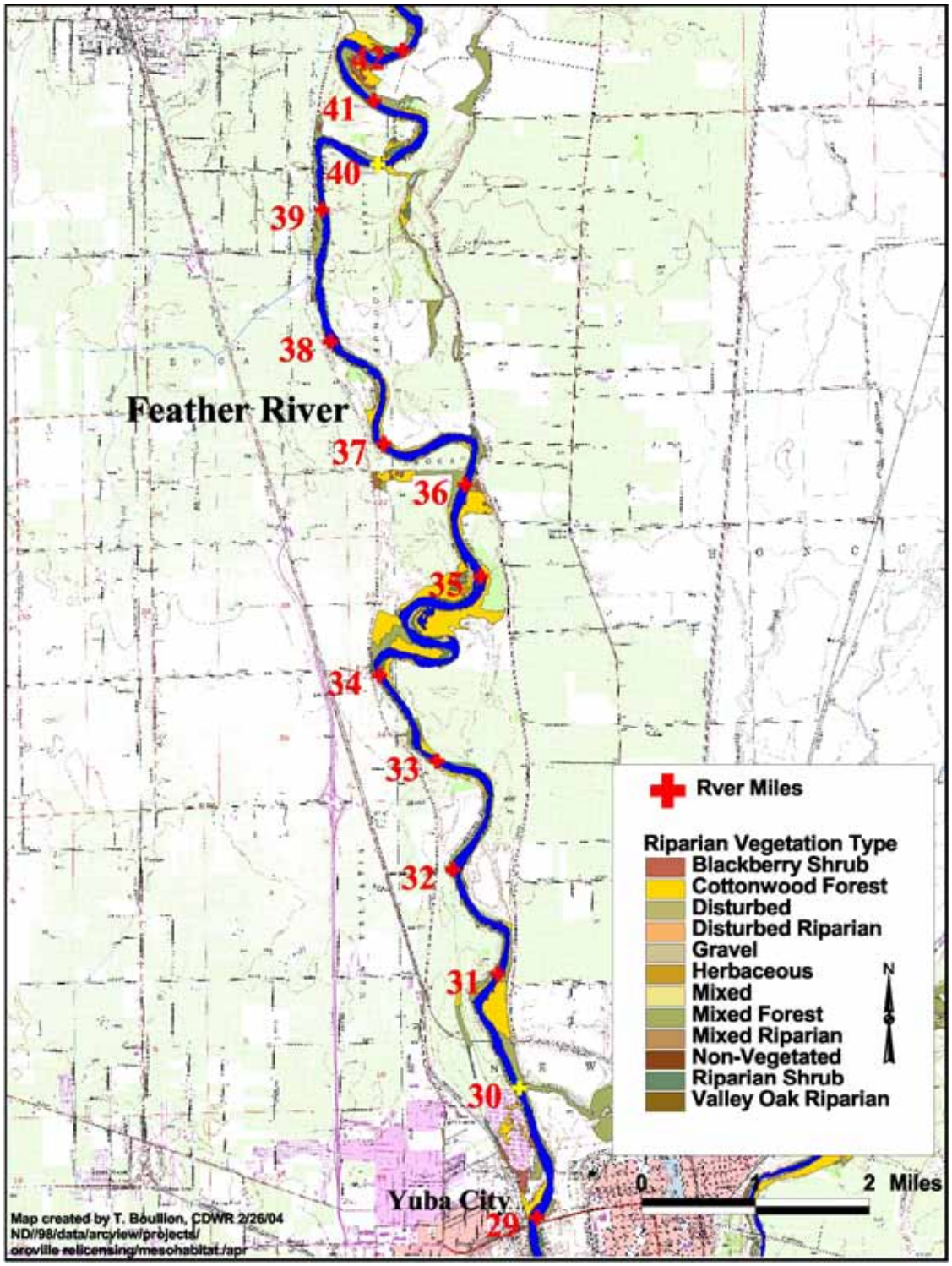

Figure 5.1.2-4. Riparian habitat along the lower Feather River (river mile 30 to river mile 40).

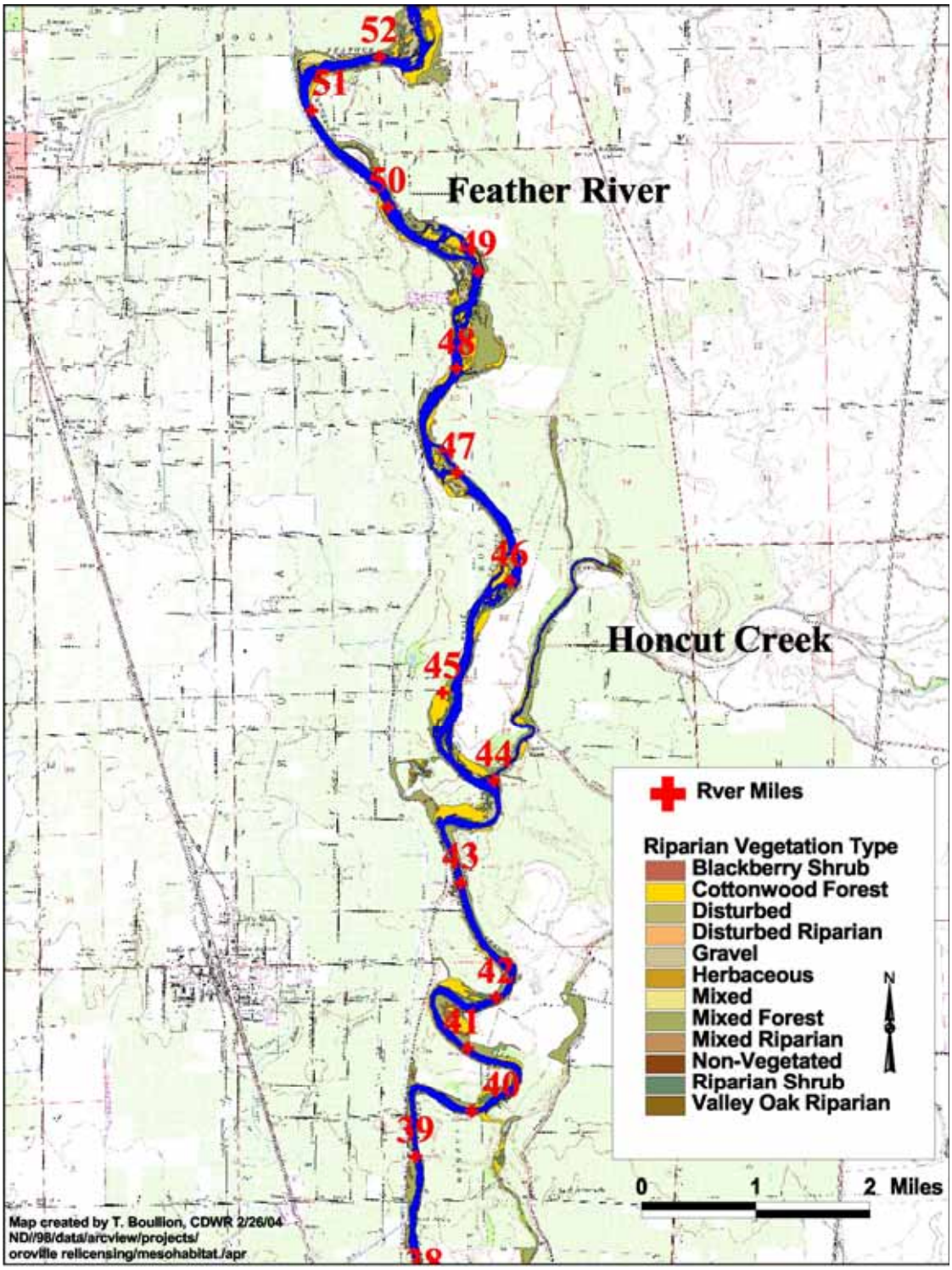

Figure 5.1.2-5. Riparian habitat along the lower Feather River (river mile 40 to river mile 50).

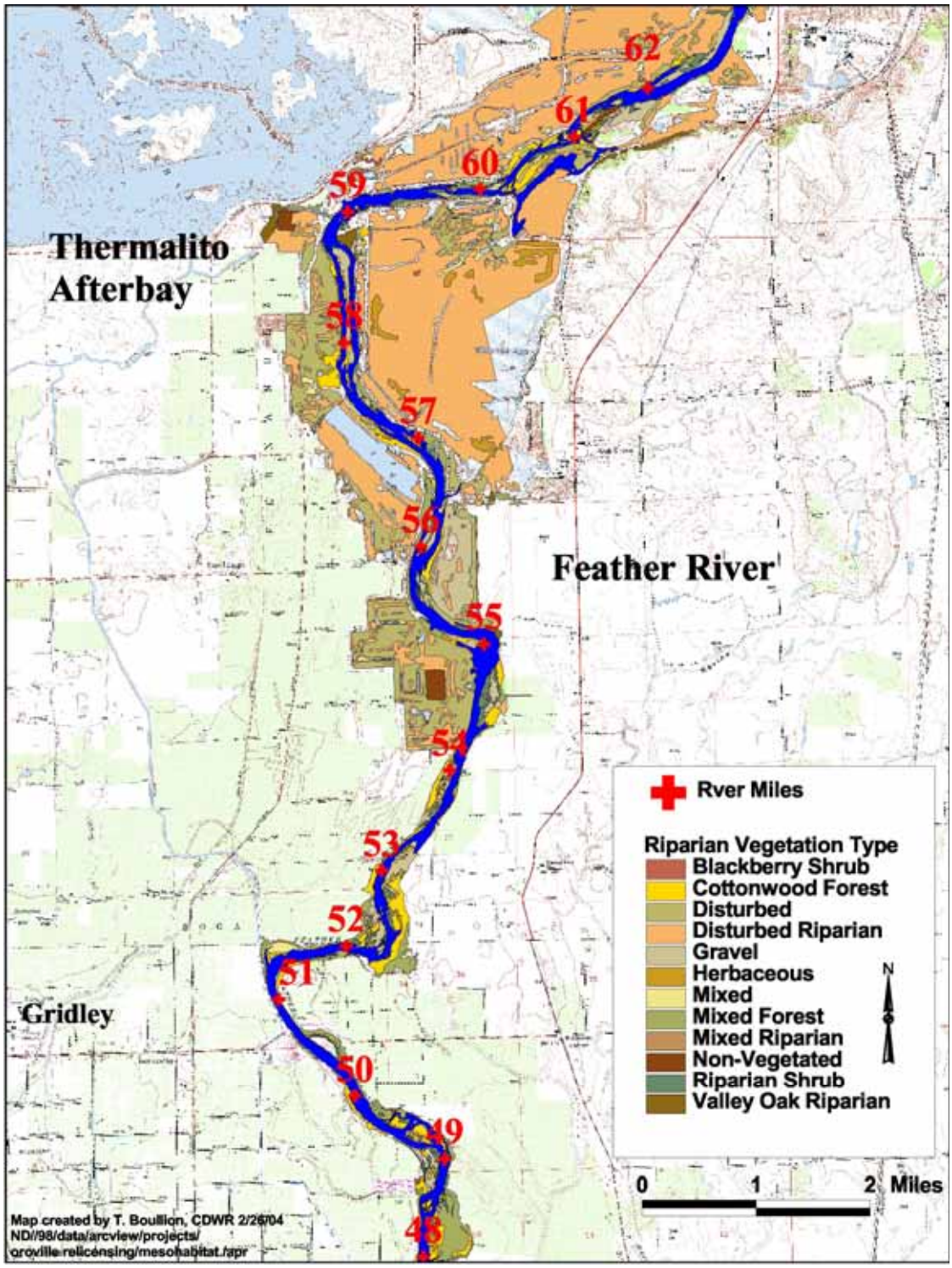

Figure 5.1.2-6. Riparian habitat along the lower Feather River (river mile 50 to river mile 60).

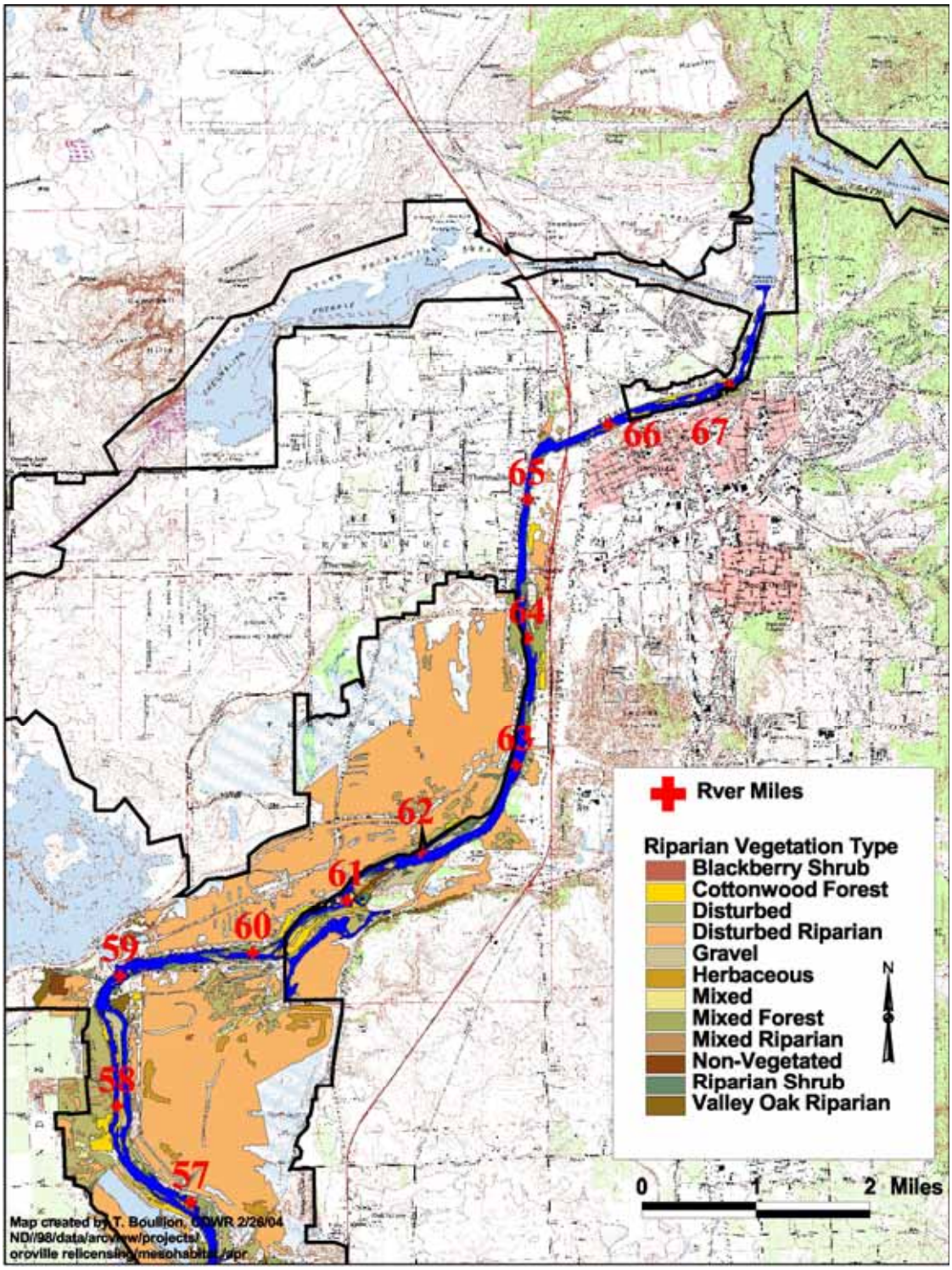

Figure 5.1.2-7. Riparian habitat along the lower Feather River (river mile 60 to river mile 67).

5.2 TASK 2 – RIFFLE AREAS

The potential for effects of the continuing operation of the Oroville Facilities on the instream riffle habitats of the lower Feather River were assessed through a review of the available literature and habitat mapping.

5.2.1 Literature Review

Data collection efforts focused primarily on literature review of the effects of riffles on water quality and the possible impacts of dam operation to riffles. Additional field observations was also useful for assessing habitat changes.

5.2.1.1 Description

The profile of a river bed is made up of a series of alternating high and low gradients, known as pools and riffles, with the riffles the high points on a bed profile (Leopold, 1962). The alternating pool and riffle structure is considered the geomorphic and ecological unit of an alluvial river (Trush *et al*., 2000), characteristic of all gravel-bed streams (Leopold *et al*., 1964). Typically spaced five to seven channel widths apart (Heede, 1980; Leopold et al., 1964), riffles usually consist of the coarsest bedload of sediments transported by the river (Mount, 1995), and are characterized by constant surface water infiltration into the interstitial spaces beneath the streambed. This subsurface area of the riffle is the classically known hyporheic zone (Stanford and Gibert,1994; Stanford and Ward, 1993).

5.2.1.2 Functions of Riffles

The hyporheic zone is considered one of the most important regions of the stream, where many vital ecosystem functions occur, such as water and nutrient exchange (Boulton *et al*., 1998; Naegeli and Uehlinger, 1997; Naegeli *et al*., 1996; Stanford and Ward, 1993; Valett *et al*., 1990), fish spawning and egg rearing (Edwards, 2000; Geist, 2000; Geist et al., 2002; Stuart, 1953, as cited by Leopold *et al*., 1964), and macroinvertebrate production (Brown and May, 2000; Brunke and Gonser, 1999; Clinton *et al*., 1996; Malard *et al*., 2003; Scarsbrook and Halliday, 2002; Valett *et al*., 1990). Some authors point out that the primary functions of the adjacent riparian zone would be reduced or virtually eliminated without the underlying hyporheic zone (Mount, 1995; Naegeli and Uehlinger, 1997; Stanford and Gibert,1994; Stanford and Ward, 1993)

The hyporheic zone of riffles performs a variety of metabolic functions. It has been estimated that roughly half of the nitrogen retained in streams occurs in the hyporheic zone (Fernald *et al*., 2000; Findlay and Sobczak, 1996). Naegeli and Uehlinger (1997) found that, in the River Necker (Switzerland), the hyporheic zone was the dominant site of ecosystem metabolism, with the hyporheic community respiration accounting for 75

to 90 percent (average 87 percent) of total ecosystem respiration, which is a result comparable to other cited studies in the U.S. (Naegeli and Uehlinger, 1997).

There is a typical pattern of flow through a riffle (Franken *et al*., 2001; Leopold *et al*., 1964). The water enters the gravels at the head of the riffle in a high-pressure downwelling zone, caused by the decreasing depth. The entering water displaces the interstitial water, slowing substantially as it passes through the riffle (Saenger *et al*., 1999). The increasing depth of the stream then creates a low-pressure upwelling zone at the tail of the riffle and the water re-enters the stream (Franken *et al*., 2001). The flow pattern through the riffle usually carries highly oxygenated, slightly warmer surface water through the gravels, with a subsequent decrease in dissolved oxygen and temperature as the water travels through the riffle and comes into contact with the low temperature, oxygen-low groundwaters of the hyporheic zone (Franken *et al*., 2001) and microbial communities (Naegeli and Uehlinger, 1997). Water samples taken at the downwelling and upwelling zones of the riffle show significant differences in temperature, dissolved oxygen, pH, and nitrate levels (Franken *et al*., 2001), though the difference (higher versus lower dissolved oxygen, etc.) could be affected by season (Franken *et al*., 2001) and the nature of hyporheic community (Fernald *et al*., 2000; Naegeli and Uehlinger, 1997). In the hyporheic zone of freshly constructed salmon redds, Soulsby *et al*. (2001) found that the water had the same hydrochemical consistency as the overlying stream water for the first few months. In the weeks and months after redd construction, they found that the interstitial waters had become significantly lower in dissolved oxygen than stream waters, reflecting the increasing influence of underlying groundwaters and stream hydrological processes (Soulsby et al., 2001), which are perhaps significant factors in salmon development (Edwards, 2000; Geist, 2000; Geist et al., 2002).

Riffles require constant replenishment of bed material from the upper reaches of the watershed to replace the gravels and cobbles lost to downstream transport (Kondolf and Swanson, 1993; Kondolf, 1997). Dams and instream gravel mining can adversely affect riffles downstream through the interruption of this upstream supply of coarse bed materials (Kondolf and Swanson, 1993; Kondolf, 1995; Vick and Kondolf, 2000; Ward and Stanford, 1995a). The trapping of sediments by dams results in ‘clean’ or ‘hungry’ water, high in energy and low in sediment (Kondolf, 1997). This typically leads to channel incision, bank erosion, undercutting, and a decline in the alluvial water table (Kondolf, 1995). High flows released from dams of the sediment-free water can eliminate formerly important spawning gravels, as was found along the Sacramento River (CalFed, 2000). Dams also reduce flood peaks, potentially depriving riffles of the high flows needed to flush fine sediment from spawning gravels (Kondolf, 1995, 1997).

Conversely, excessive sedimentation, especially by fines and sands, can adversely and directly affect riffle-pool complexes through pool filling and riffle armoring (King and Gonsior, 1980; Lisle and Hilton, 1991, 1999). Excess fine sediment in the riffle spawning areas can also affect the eggs and larvae of salmonids directly, as was seen

recently when silt killed 500,000 trout eggs at the Mount Shasta Fish Hatchery (Redding Record Searchlight, January 31, 2004).

Disturbance can have significant, though short lived, impacts on the aquatic fauna within riffles. Stone and Wallace (1998) found that benthic macroinvertebrate community structure changed significantly in a stream that suffered a disturbance from streamside clearcut logging, becoming less diverse (Harr and Krygier, 1972). Studies of the recovery of stream biotic assemblages after short-term disturbances (e.g., logging, point-source pollution) have shown relatively rapid recovery (Jones *et al*., 2000). Rather, it is sustained anthropogenic disturbance, such as long-term agriculture, that adversely alters and diminishes the instream biotic communities (Harding *et al*., 1998).

As far as water quality is concerned, the value of riffles is considered by some to be open to debate. In conditions of oxygen depletion, riffles can increase dissolved oxygen content in the water as large intra-gravel flows pass through and over the riffle (Clifford and French, 1998). The hyporheic microbial and invertebrate communities of riffles utilize many of the excess nutrients and substances that constitute pollution (Baker *et al*., 1999; Bass and Walker, 1992; Hendricks, 1993; Stanford and Ward, 1993). However, riffles may also act as a long-term storage site of pollutants (especially metals attached to invasive fine sediments), with a consequent slow release of these pollutants (Bencala *et al*., 1984). The occasional flushing flow can then release these sediments and their attached pollutants in one pulse (Clifford and French, 1998).

5.2.1.3. Effects of Dams to Riffles

The construction of a dam across a major river inserts a large knickpoint (an abrupt elevation and energetic change) in the stream profile (Kondolf, 1997; Mount, 1995). Some of the effects of this new knickpoint are immediate and obvious, such as blocking of fish migration, altered thermal, nutrient, and sediment loading, and a newly imposed unnatural flow regime (Power *et al*., 1996). Other secondary effects include increased algae productivity, reduced aquatic biodiversity, disruption of aquatic food webs (Power *et al*., 1996), reduction in channel-bed mobility (Kondolf, 1995), and channel degradation (Ward and Stanford, 1995b), which become obvious only after some time has passed.

Dams trap coarse sediment and release water stripped of these energy-absorbing materials (Kondolf and Swanson, 1993; Kondolf and Williams, 1999). This clean high-energy water can physically affect the structure of the streambed, especially riffles. Sediments are transported out of the riffle at a greater than normal rate, but then are not replaced due to the now sediment-starved water (Kondolf, 1995; Kondolf and Curry, 1986). In the higher energy reaches of a river, this would lead to an overall coarsening of the sediments, eventually increasing the average size of particles in a riffle beyond the habitat requirements of spawning fish (Kondolf *et al*., 1991; Kondolf, 1997). Fine sediments, which are the only type not trapped by a dam, can infiltrate the riffle

interstitial spaces and render the riffle less permeable in the slower reaches of the river. This would impede fry emergence and, by reducing the oxygen levels in the riffles, cause high mortality to eggs and fry (Burns, 1970). These fine sediments have been found to affect water quality by transporting metals and reducing dissolved oxygen downstream of a dam (Ashby *et al*., 1999). The reduction of dissolved oxygen in a redd is critical simply due to the high biological oxygen demand of the developing eggs (Thurow and King, 1991).

The reduction of natural high flows at flood stage reduces the amount of coarse sediment that can be transported (Barta *et al*., 1994; Minshall *et al*., 2000). The rate of sediment transport typically increases as a power function of the flow, in that doubling the flow more than doubles the sediment transport (Richards, 1982). Most of the sediment transport in a river occurs during flood, which are virtually eliminated by dams (Kondolf, 1997; Simon, 1979; Stanford and Ward, 1979).

The flow regime imposed by a dam affects the downstream geomorphology of the river (Kondolf, 1995; Simons, 1979; Stanford and Ward, 1979; Ward and Stanford, 1995a). The river is simplified through channel incision, artificially creating a narrow constrained valley for the river that can inundate the adjacent floodplains only rarely (Kondolf, 1995). This type of channel has been found to have a greatly reduced capacity for nutrient and particulate retention, reducing the overall productivity of the river (Lamberti *et al*., 1989; Pinay *et al*., 2002). The reduction of flooding events greatly reduces the capacity of the river for meander, which also simplifies the river habitat (Kondolf, 1999).

The hydrologic regime imposed by a dam directly affects the thermal regime of the river water. Generally, in order to accommodate fisheries requirements, water temperatures are usually kept artificially low in the river downstream from a dam (relative to pre-dam conditions) by using higher than normal releases in summer or by releasing water from the hypolimnion. Hauer and Stanford (1982) found that the increase of the cold-water days downstream from a newly constructed dam changed the composition of the invertebrate fauna in the main stem of the river to reflect the population structure usually found in lower-order streams, being both less abundant and diverse. In addition, the unnaturally colder temperatures of the stream water below a dam may have caused a sizeable proportion of the observed population declines in native yellow-legged frogs, probably by retarding the development of eggs and larvae of the native frogs and by increasing the amount of suitable habitat for the non-native bullfrog, a suspected predator of native frogs (Lind *et al*., 1996).

In those streams below a dam that have substantially reduced the average flows, the average water temperature could be higher in the summer than would be found under the natural flow regime. Increased stream temperatures below a dam can stimulate invertebrate population numbers, while decreasing population diversity (Fraley, 1979).

5.2.1.4 Conclusion

The published literature demonstrates that riffles can affect stream water quality in a variety of ways. Riffles aid in the oxygenation of the stream water through the turbulence caused by their structure. Nutrients, metals, and minerals found in the surface water of the stream or in the groundwater are utilized by the organisms within the hyporheic zone of riffles, and can be stored or released into the system in the hyporheic zone.

One of the most significant influences on riffles in a regulated river is the imposition of an artificial flow regime. The lack of high flushing flows reduces the transport of material within the system and eventually starves the riffles of streambed material. Flushing flows also remove fine sediments and sands from the interstitial spaces within a riffle. If the flushing flow mechanism is reduced or eliminated, then riffles can fill with fine sediments and sands, which reduces the interstitial flushing of wastes, allowing accumulation of contaminants associated with sediments, and reducing dissolved oxygen content, among others. These impairments to the water quality of riffles subsequently reduce the quality of the riffle for aquatic macroinvertebrates and spawning fish.

5.2.2 Habitat Mapping

The instream habitat of the lower Feather River was typed and mapped into ArcView by Northern District Geology Section personnel. The riffle areas along the Feather River consist of 83 units (27 percent of the total number) totaling 102 acres, or 3 percent of the total acreage of the instream habitat (Figures 5.2.2-1 to 5.2.2-7; Table 5.2.1-1).

Table 5.2.2-1. Lower Feather River instream habitat types and acreages.

Habitat Type	Number of Units	Total Acreage	Mean Acreage	Minimum Acreage	Maximum Acreage
Backwater	57	84	8.4	0.01	23
Boulder run	1	1	-	-	-
Glide	75	2,203	29.4	0.04	1,347
Pool	79	552	7	0.1	87
Riffle	**83**	**102**	**1.2**	**0.1**	**8**
Run	7	66	10	0.8	43
Total	**302**	**3,008**	**10.0**	**0.01**	**1,347**

The lower Feather River above Honcut Creek contains 84 percent of the riffles (70 out of 83 riffles) found in the lower Feather River (Figures 5.2.2-4 to 5.2.2-7). Since, in a typical river, riffles occur roughly every five to seven channel widths, this 24 mile section of the Feather River, at an average of roughly 300 feet across, could expect to have a riffle-pool complex every 1,500 to 2,100 feet, or roughly three pool-riffle complexes per mile. In this reach, there are 2.9 pool-riffle complexes per mile, which is very close to the ideal. However, below Honcut Creek, this does not hold true. Rather than the 132 expected riffles (roughly 3 riffles per mile for 44 miles), there are only thirteen riffles for a distance of 44 miles, which is an average of 0.29 riffles per mile. Of these thirteen riffles, only one riffle occurs downstream from the Yuba River, which is the large 8-acre riffle complex at Shanghai Bend (at river mile 25, approximately 2.25 river miles downstream from the confluence of the Feather and Yuba Rivers). Excluding the lower reach below the Yuba River, the 17 mile reach from Honcut Creek to the Yuba River (river miles 27 to 44) contains 0.7 riffles per mile, which is still far below the average in the reach above Honcut Creek. These differences reflect the changes in riverine geomorphology found along the Lower Feather River, as described by CDWR Northern District Geology staff (Table 5.2.2-2).

Table 5.2.2-2. Geomorphic reaches of the lower Feather River.

Reach	River Miles	Bed Composition	Bank Composition	Stream Type	Sinuosity
FR-1	0.0 - 7.0	Sand	Sand and Silt over Slickens*	Alluvial Stable	low
FR-2	7.0 - 12.5	Sand	Sand and Silt over Slickens	Alluvial Meandering	low
FR-3	12.5 - 17.0	Sand	Sand and Silt over Slickens	Alluvial Geologic Control	low
FR-4	17.0 - 28.0	Sand	Sand and Silt over Slickens	Alluvial Geologic Control	moderate
FR-5	28.0 - 33.5	Sand	Sand and Silt over Slickens	Alluvial Stable	low
FR-6	33.5 - 35.5	Sand and Gravel	Sand and Silt over Slickens	Alluvial Erodible	high
FR-7	35.5 - 39.5	Sand and Gravel	Sand and Silt over Slickens	Alluvial Stable	low
FR-8	39.5 - 46.5	Gravel	Sand and Silt over Slickens	Alluvial Erodible	moderate
FR-9	46.5 - 53.5	Cobble and Gravel	Cobble and Gravel	Alluvial Stable	low
FR-10	53.5 - 64.0	Cobble and Gravel	Cobble and Gravel	Dredger Tailings	NA
FR-11	64.0 - 68.0	Bedrock	Cobble and Bedrock	Bedrock	NA

* Slickens –deposits of clay-rich, light yellow-brown sediments resulting from increased sedimentation from hydraulic mining on the Feather River

The lower reaches of the Feather River below Yuba River (reaches FR-1 to FR-5) are low-gradient and relatively slow moving, and are primarily dominated by sand from river mile 0 to river mile 33.5. The streambed within reach FR-1 is dominated by moving bars of sand, especially during low fall and spring flows. These reaches are very low in

sinuosity, with much of the banks hardened by levees. This portion of the Feather River is totally dominated by this hydraulic control, and has a low degree of meander.

The middle reaches of the Feather River from the Yuba River to Honcut Creek (FR-5 to FR-8) form a transition zone from a sand-dominated streambed just upstream from the Yuba River to a gravel streambed just downstream from Honcut Creek. This stretch of the river is dominated by alluvial soils of silt, sand, and gravels of various sizes. This reach appears to have a higher degree of river meander than the lower reach.

The Feather River upstream from Honcut Creek is dominated primarily by alluvial soils high in gravels and cobbles. Upstream from Honcut Creek (reaches FR-9 to FR-11), the streambed of the Feather River is dominated primarily by gravels, cobbles, and bedrock, while the banks are dominated by cobble and gravel. Riffles are dependent on a stable input of gravels and cobbles, which are normally recruited from the headwaters of the watershed (Leopold, 1964). Although much of this reach is under some sort of hydraulic control through downcutting or bank hardening, the banks and streambed are rich in the right types of material to support the riffles.

Sediments larger than silt tend to be blocked by Oroville Dam from migrating from the upper reaches of the Feather River into the lower Feather River, which could have an in-filling effect on the riffle-pool habitats (Lisle and Hilton, 1999) that are the very habitats salmon require. However, the riffles in the Feather River upstream from Honcut Creek appear to be sustained in fair condition by the suspension of fine bed materials from high-energy flows (Lisle and Church, 2000; Lisle and Hilton, 1991,1999), and through the recruitment of gravel-cobble materials from streambed incision and bankcutting.

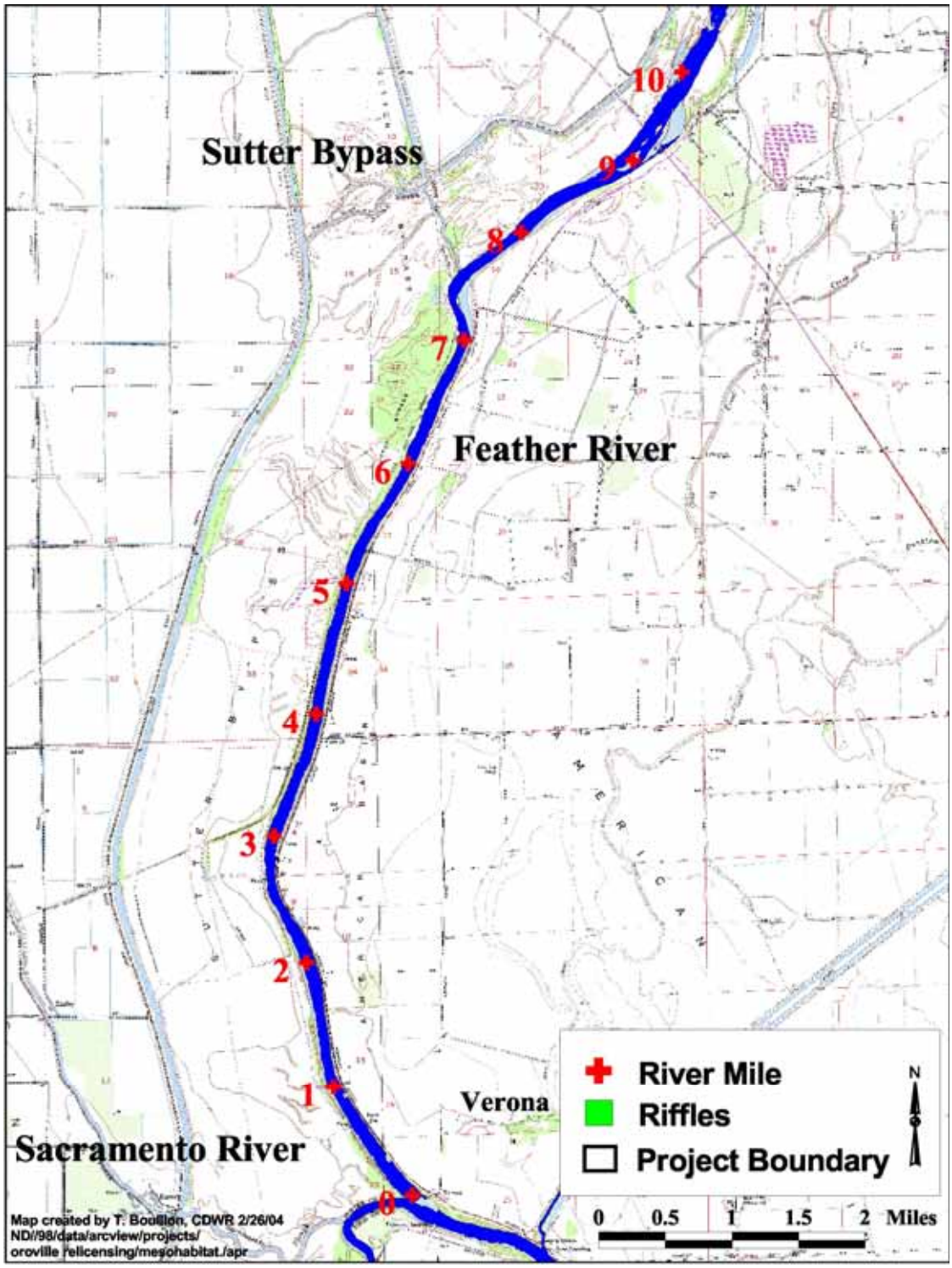

Figure 5.2.2-1. Riffle habitats along the lower Feather River (river mile 0 to river mile 10).

Figure 5.2.2-2. Riffle habitats along the lower Feather River (river mile 10 to river mile 20).

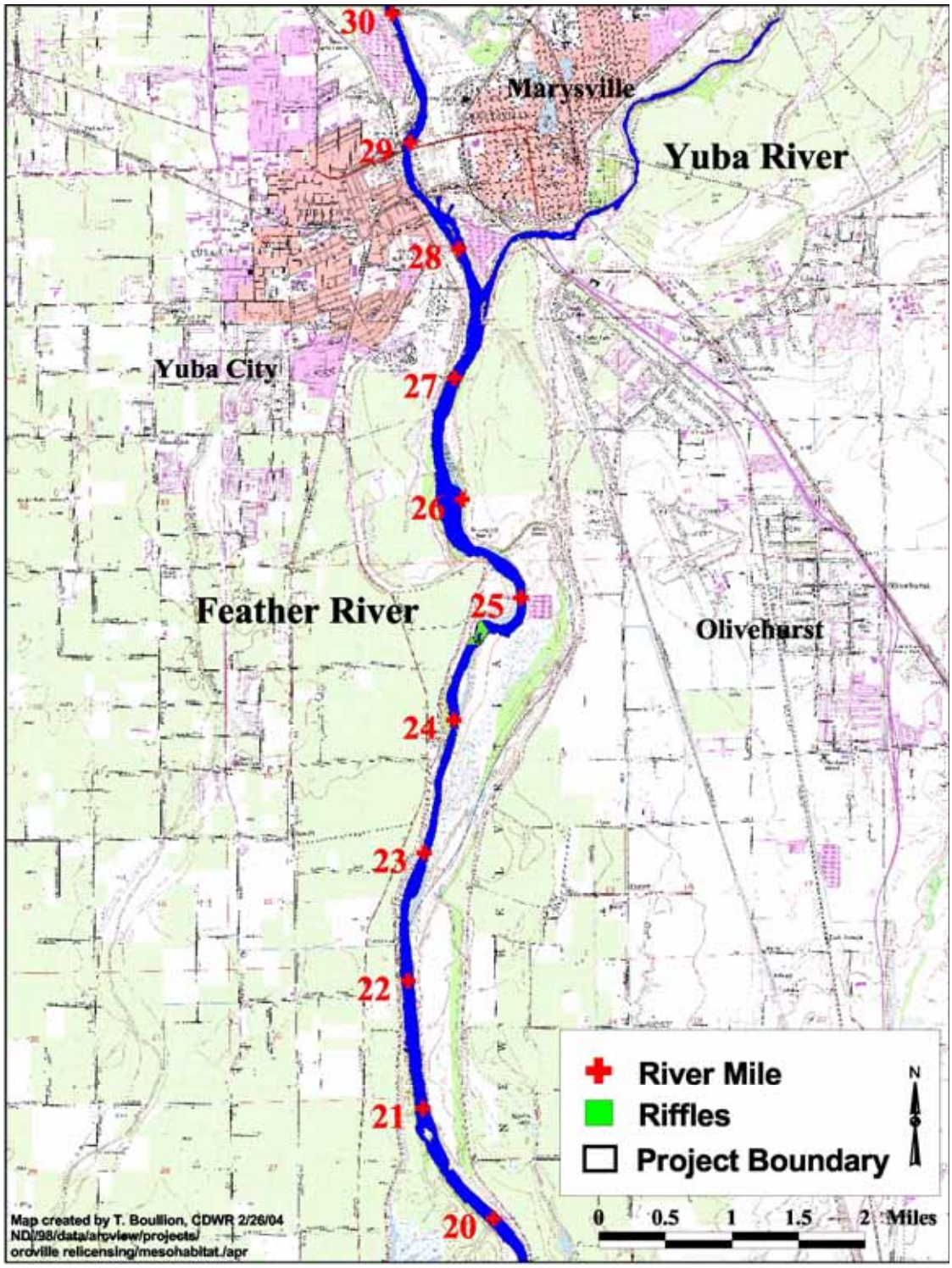

Figure 5.2.2.3. Riffle habitats along the lower Feather River (river mile 20 to river mile 30).

Figure 5.2.2-4. Riffle habitats along the lower Feather River (river mile 30 to river mile 40).

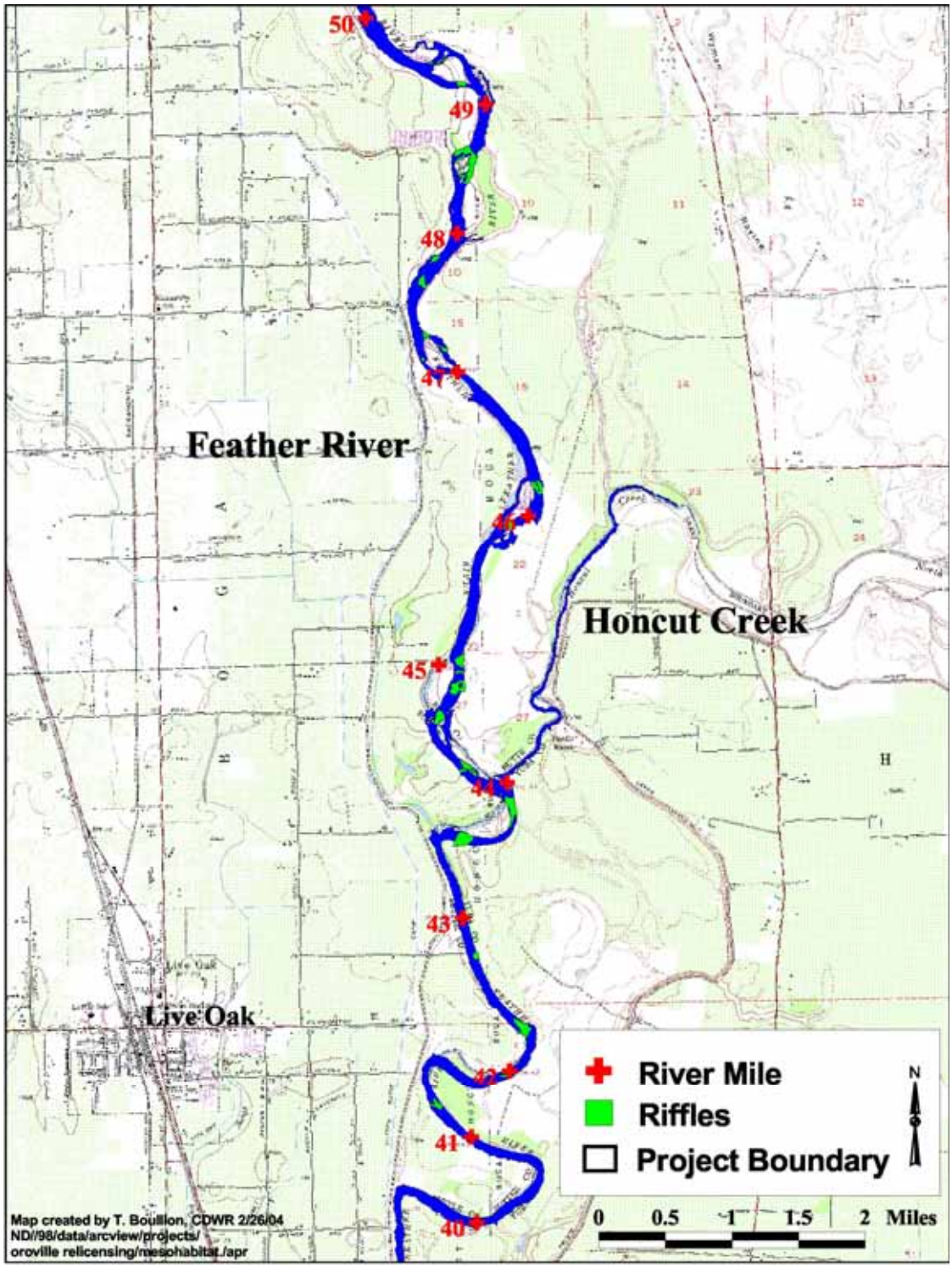

Figure 5.2.2-5. Riffle habitats along the lower Feather River (river mile 40 to river mile 50).

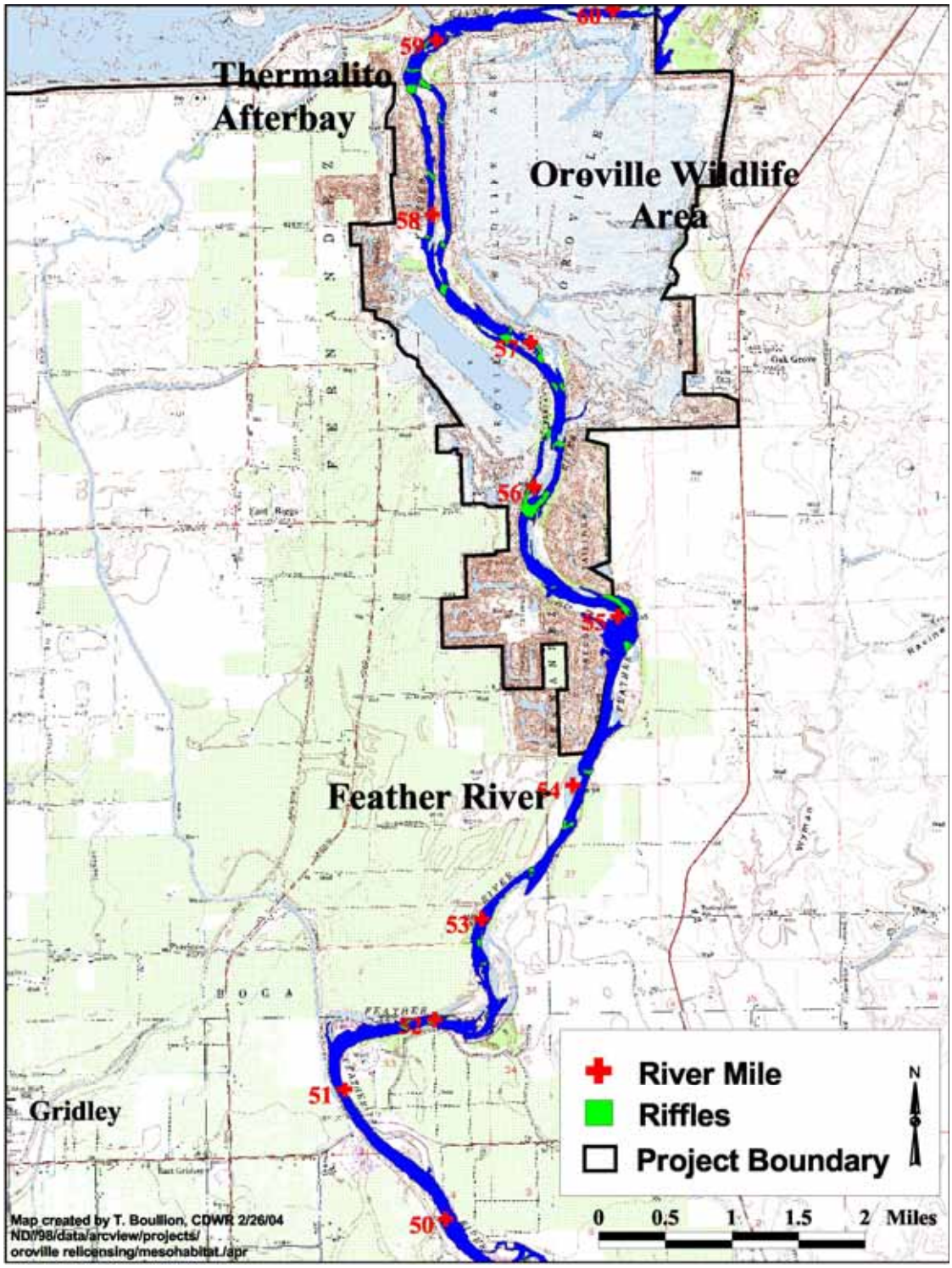

Figure 5.2.2-6. Riffle habitats along the lower Feather River (river mile 50 to river mile 60).

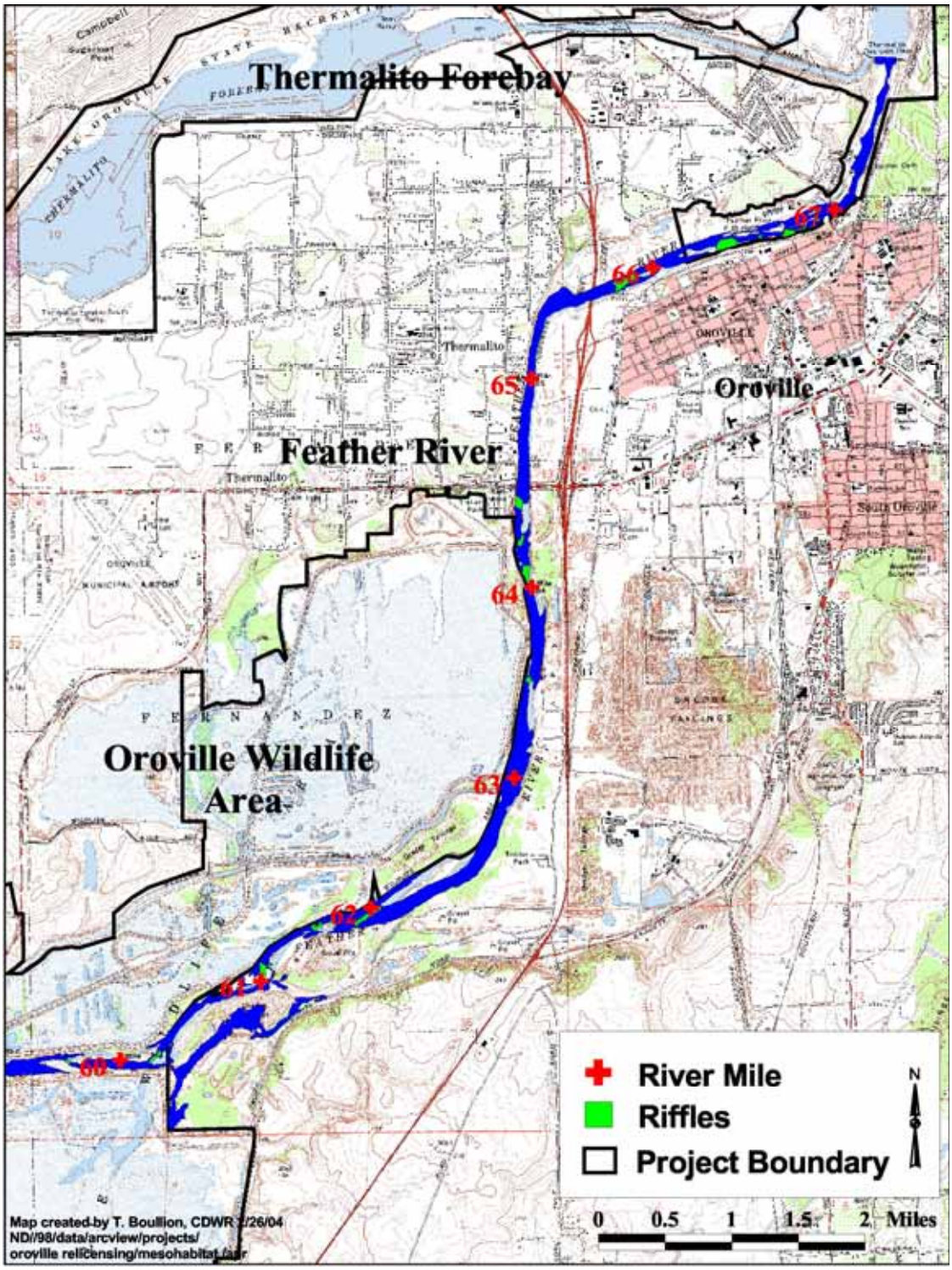

Figure 5.2.2-7. Riffle habitats along the lower Feather River (river mile 60 to river mile 67).

5.2.3 Water Quality

The eleven riffle water quality sampling sites are located in the Feather River from Mile Long Pond approximately 1.5 miles downstream from the Thermalito Afterbay Outlet to upstream of the Fish Hatchery within the city of Oroville (Figure 5.1-1). Physical parameters were measured and water samples were taken for nutrient analyses within the gravels of these riffles. Measurements taken during the period of sampling (April 2003 to March 2004) show that the physical parameters in the surface waters do not exhibit much variability throughout the year. The surface water quality is controlled primarily by the releases from Oroville Dam. The results were compared to the surface water measurements and nutrient analyses found in SP-W1 (Appendix A).

5.2.3.1 Water Temperature

The comparison of results for water temperature did show some differences between the surface and interstitial waters. The surface water temperatures tended to be higher than the interstitial gravel water temperatures, and differences could range 0.5 to 13.0 ºF (Appendix B). In many of the winter months, the water temperatures between the surface and interstitial waters tracked fairly closely, usually within 2 ºF, but sometimes with the surface waters cooler than the interstitial waters. In the summer months, the disparity between surface and interstitial water temperatures was greater, reaching a 13 ºF difference. Surface temperatures varied so greatly between measurements at some sites that surface water temperatures could be up to 5 ºF less than interstitial water temperatures and then subsequently up to 13 ºF higher on the next visit (e.g., see Feather River at Spawning Channel chart in Appendix B). This effect could be readily seen on those sampling events when the surface water sampling and interstitial water sampling events were within a day or two.

NOAA Fisheries requires CDWR to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) to less than or equal to 65 ºF on a daily average from June 1 through September 30. Most of the surface water temperatures regularly exceeded the criterion during the summer months, while the interstitial water temperatures rarely did. Those sites where interstitial water temperature exceeded the criterion were downstream from Robinson Riffle (Appendices A and B).Interstitial water temperatures at the Robinson Riffle site exceeded the criterion only once in July by slightly less than 3 ^{o}F. Upstream from Robinson Riffle, the water temperature criterion was exceeded in the interstitial waters once in July of 2002 and once in July of 2003 at the Feather River downstream from the Highway 162 bridge.

5.2.3.2 Dissolved Oxygen

Comparisons of results of dissolved oxygen concentrations showed some differences between the surface and interstitial waters (Appendices A and C). Dissolved oxygen concentrations in surface waters were normally found to be above 8.0 mg/L, ranging

from 7.8 mg/Lat the Feather River at Robinson Riffle in January of 2003 to 14.4 mg/L at the Feather River near Mile Long Pond in November of 2003. The majority of the measurements in the surface waters were above 10.0 mg/L. Interstitial dissolved oxygen concentrations were normally above 5.0 mg/L, ranging from5.6 mg/L at the Feather River downstream from the SCOR outlet in August 0f 2002 to 13.0 mg/L at the Feather River at Robinson Riffle in February of 2003. However, one station, the Feather River upstream from the SCOR outlet, measured less than 2.0 mg/L of dissolved oxygen four times during the fall-winter of 2003-2004 and 3.4 mg/L in September of 2003 (Appendix C). During these times of low interstitial dissolved oxygen, the dissolved oxygen concentrations in the surface waters were measured at 9.0 mg/L and above.

Two stations, the Feather River downstream from the SCOR outlet and the Feather River upstream from the Afterbay outlet, had single occurrences of low dissolved oxygen in the summer of 2003. The surface water dissolved oxygen concentrations were greater than 10.0 mg/L. In gravel fractionation studies performed in the significant riffles between the Fish Barrier Dam and Honcut Creek, interstitial dissolved oxygen was measured at depths of six, twelve, and eighteen inches at the upstream end, mid-point, and downstream end of each riffle (CDWR, in prep.). At most of the riffles tested, the dissolved oxygen and temperature were fairly uniform at all three depths and locations. Two riffles, the Bedrock Park and Mathews riffles, had low dissolved oxygen at the downstream end of the riffle at the lowest depth. Salmon redds were present in these riffles (CDWR, in prep.).

The USEPA coldwater dissolved oxygen criterion for the protection of aquatic life is a minimum of 5.0 mg/L of dissolved oxygen in intergravel water when early life stages are present (USEPA, 1986; Appendix D). The dissolved oxygen levels usually met this criterion in all of the sampling sites throughout the sampling period, and normally ranged from 5.7 mg/L to 13.0 mg/L (Appendices A and C). Measurements taken in 2003 on September 4 and 19 and October 3 in the Feather River upstream from the SCOR outlet and on September 4 in the Feather River upstream from the Afterbay Outlet were below the criterion level. These sites are atypical in that the sand and silt content at the sampling sites are high and redds have never been observed there.

5.2.3.3 pH

Comparisons of results for pH did not show any significant differences between the surface and interstitial water measurements (Appendix A), with values ranging from 7.1 to 7.7 in surface waters and 7.1 to 7.5 in interstitial waters. The pH values for the surface and interstitial waters were usually within 0.2 pH units of each other. The USEPA criterion for aquatic freshwater life is an instantaneous maximum of 6.5 to 9.0 units (CVRWQCB, 2003). All of the pH measurements taken during this study were within this criterion range.

5.2.3.4 Conductivity

Conductivity did not show any significant difference between the surface water and interstitial water measurements or among the interstitial measurements (Appendix A). Interstitial values ranged from 72 to 190 µmhos/cm, with 88 percent of all measurements at or below 100 µmhos/cm. Surface water measurements displayed a similar result, with values ranging from 62 to 151 µmhos/cm, with 73 percent of all measurements at or below 100 µmhos/cm. There is no USEPA conductivity criterion for aquatic freshwater life (CVRWQCB, 2003). The only goal that may be relevant is the agricultural water quality limits, which is set at a maximum of 700 µmhos/cm (Ayers and Westcot, 1985). All of the measurements taken in this study were well below that goal.

5.2.3.5 Total Ammonia

The USEPA criterion for total ammonia is dependent on pH and temperature (Appendix E), with values for when fish early life stages are present or absent. Neither surface nor interstitial water samples exceeded any limit for total ammonia at any time. Usually, the amount of total ammonia did not reach detectable levels (which is less than the criterion), so a comparison of ammonia content in surface and interstitial waters was not feasible.

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

The purpose of this study was to determine any effects to water quality from the natural processes associated with riparian areas or riffle habitat in the Feather River downstream from the Fish Barrier Dam. This included a literature review of the potential effects of riparian areas and riffles to water quality and of the presence of a dam and its enforced hydrologic regime to riparian areas and riffles. Water quality sampling was performed from July 2002 until April 2004 at thirteen riffles to assess the potential effects of riffles on water quality.

6.1.1 Riparian Areas

The types of riparian areas that perform the greatest amount of nutrient uptake are native large-tree riparian areas of appropriate stand size, vegetative diversity (Newton *et al*., 1996; Klapproth and Johnson, 2000), and mixed age-class composition (Reid and Hilton, 1998). In the case of the lower Feather River, the cottonwood and valley oak types would fit this description, though age-class diversity appears to be low to moderate among the dominants. While these two types of riparian areas comprise 21 percent of the total units, they only contain 11 percent of the total acreage, with an average unit size of 4.3 acres. Appropriate riparian stand size (width) has been defined as twice the “site potential tree height” or the average maximum height of the tallest dominant trees, while the optimal distance from the water’s edge was determined to be the average height of trees in a stand (Reid and Hilton, 1998). The average height along the lower Feather River does not appear to exceed 250 feet, so most of the forested stands appear to meet the stand size parameter. Most of the forested riparian stands along the lower Feather River are at or close to the water’s edge, so distance from the water’s edge is well within the optimal.

However, connectivity between stands is considered vital for stand and wildlife population viability (Newton *et al*., 1996). Analysis of the mapping reveals that the riparian areas along the lower Feather River are disjunct, with little or no connectivity between units of the same type or even class (tree, shrub, or herbaceous). Additionally, field observations of the vegetative communities in the riparian areas have shown that many of the forested areas seem to have some degree of impact from human use (i.e., erosion from vehicles, dumping of trash, encroachment from adjacent land use, etc.) and invasive non-native plants.

Many riparian areas are impacted by levees, either accidentally or deliberately constructed. Within the Oroville Wildlife Area portion of the river, many of the levees are constructs from an earlier period when dredging tailings from hydraulic mining were deposited on the nearby banks. In these areas, some sparse riparian vegetation has adapted to growing on these accidental levees, since there is little or no active levee

maintenance in these areas. In some reaches, especially downstream from Yuba City, the levees were specifically constructed for flood control and are located at the water's edge to maximize their flood control efficiency and minimize the width of the river. There are many areas where there is no riparian vegetation along the river, or as in a few areas of this reach, some riparian vegetation grows in extremely narrow strips along the water.

6.1.2 Riffles

The majority of the riffles in the lower Feather River are concentrated in the uppermost reaches above Honcut Creek, where the majority of natural salmon spawning in the Feather River is known to occur. This part of the river is dominated by alluvial gravel/cobble soils and banks, which appear to maintain the existing riffles through erosion. This portion of the river still has some areas of braided channels, more conducive to the formation of riffles, as opposed to the narrow, single-thread type of channel found elsewhere (Mount, 1995).

The results of the water quality sampling in the riffles generally do not indicate any adverse water quality effects. Most parameters that were monitored met criteria for the protection of aquatic life, though dissolved oxygen was at times at some sites less than the required minimum.

Interstitial dissolved oxygen was measured in many of the riffles in the stretch of the lower Feather River from the Fish Barrier Dam to the Thermalito Afterbay Outlet by CDWR Northern District Geology staff. They took measurements at three depths (6", 12", and 18") and at three locations within each riffle (head, middle, and tail of the riffle). In most of the measurements, dissolved oxygen was well within the acceptable parameters for salmonid development. In a few cases (such as Bedrock Park), the dissolved oxygen content reached hypoxic levels (<2.0 mg/L) at the tail of the riffle at 18" (CDWR, in prep.). However, salmonids generally do not dig redds that deep, especially in the lower Feather River where the maximum observed egg burial depth in redds was 13" (Kindopp, 1999).

6.2 PROJECT RELATED EFFECTS

6.2.1 Riparian Areas

Since riparian areas can affect stream water quality in a variety of ways, reduction in quality and quantity of the riparian areas could adversely affect water quality. In the past, the rivers of the Sacramento Valley had extensive riparian forests, with dense stands of vegetation and associated swamps and marshes, sometimes reaching two to three miles in width (USFWS, 2000). However, the riparian zones of the Sacramento Valley have been reduced to less than two percent remaining (CalFed, 2000), through a

combination of urbanization, land clearing for agriculture, or flood control measures (CalFed, 2000; Thompson, 1977).

The Oroville Facilities were developed to store and distribute water to water users, and are also operated for flood management and power generation. In the past few years, Oroville Dam has been releasing water to improve water quality in the Delta, provide recreation, and enhance fish and wildlife. However, these beneficial uses are accomplished by increasing flows during the summer dry season, a period of the year where water levels are historically very low (Mount, 1995). This has the effect of eliminating the natural levels of summer low flow from the Feather River, which can have severe consequences to streamside vegetative communities (Mount, 1995; Sprenger *et al*., 2002; Winfield and Hughes, 1995).

One major impact noted along the Feather River is the amount of habitat disruption and destruction from streamside recreational uses. Unpaved gravel river access roads and trails, constructed or accidental, cut through most of the riparian areas along the river. The amount of nutrient uptake by the impacted stands along the lower Feather River could be reduced by the impacts to the riparian stands, especially those suffering from impacts from recreational use of those areas. The compaction of the soil could reduce the permeability of the riparian area soils for interstitial water transport. Seedling recruitment could be inhibited through this compaction of soils and through direct destruction of seedlings. The uptake of water and associated nutrients as well as metals could be reduced through the reduction or destruction of riparian vegetation. Additionally, unpaved boat access sites can be found at numerous spots along the river. These sites, some heavily used, can and do lead to bank destruction and severe erosion, releasing fine sediments and sands into the river.

The riparian areas of the lower Feather River do not exhibit any direct short-term impacts from the current operations of the Project facilities, other than those shown in any regulated river, which includes the deepening of the river channel, the coarsening of streambed materials, reduction in size and diversity of riparian areas and riffles, and the loss of river meander. Long-term impacts from continuing operations, including further loss of riparian areas, do seem to be a possibility. Any substantial reduction of the riparian areas, qualitatively or quantitatively, would greatly reduce or even eliminate the water quality benefits from these areas.

6.2.2 Riffles

One of the most important influences on the instream structure of the Feather River is the continuing presence of Oroville Dam. Oroville Dam regulates the Feather River through the amount and timing of the releases of water. Most of the rivers in California (and much of the American West) had a seasonally-based flow regime, with high flows and floods in the winter and low flows in the summer (Mount, 1995). The flow levels in

the Feather River tend to show the typical regulated-river flow regime, with mid- to late-summer high water releases and winter storage.

The riffles in the Feather River downstream from Oroville Dam exhibit some adverse impacts associated with any regulated river, including loss of riffle gravels suitable for salmon spawning, armoring, and siltation, from the current operations of the Project facilities. Long-term impacts from continuing operations probably include a further loss of riffles due to gravel starvation and/or increased sedimentation due to deposition of fine silts in those riffles currently present in the river. In addition to decreasing oxygen transport through riffle gravels and flushing of metabolic wastes, sediments can adversely affect water quality from metals that can be adsorbed to the sediment particles. The high-energy, sediment-starved water released from a dam deepens the river channel by transporting resident gravels out of riffles. Loss of riffles can reduce water quality from reduced metabolism of water-borne constituents by the interstitial microbial and invertebrate communities. Loss of riffles can also reduce the aeration of the surface waters caused by the turbulence associated with their physical structure.

The overall effect of the Oroville Dam is that sediments in sizes required for the long-term maintenance of riffles are trapped by the Dam, with only suspended fines passing through the Dam. This has led to a coarsening (increase in average particle size) of the streambed materials in the riffles in the lower Feather River since the construction of the Oroville Dam (Koll Buer, pers. comm.).

Two riffles (Feather River upstream from the Thermalito Afterbay Outlet and Feather River upstream from the SCOR outlet) had interstitial dissolved oxygen below the criterion. These sites are atypical in that they are high in silts, fines, and sands content (CDWR, in prep.). These two riffles are located adjacent to and on the opposite bank from the Thermalito Afterbay Outlet. Both stations are under the hydrologic influence of the Thermalito Afterbay Outlet, which releases water into the Feather River perpendicular to the river's flow.

The Thermalito Afterbay Outlet appears to be acting as a hydrologic dam to the Feather River upstream from the Thermalito Afterbay Outlet (also known as the Low-Flow Channel), with the flow in the river substantially slowed and, at times of very high summertime releases, backed up (Bruce Ross, pers. comm.). The water dam acts very much like a physical dam, with suspended sediments dropping out in the lower water velocity upstream of the Outlet and being deposited in the immediate area. Since the riffle upstream of the Outlet is an elevational knickpoint, the flow tends to back up to that point and deposit a large portion of the sediments there.

The riffle upstream from the SCOR outlet is downstream from the Outlet, but still within the influence of the Outlet release plume. The Outlet has scoured a fairly deep pool in the Feather River and formed an off-bank gravel bar roughly parallel to the river's flow. This gravel bar extends far enough downstream to form a backwater (Figure 6.1.2-1).

Since the riffle sampling location is directly downstream of this bar within the influence of this small backwater, sediment deposition could be expected in the gravels at this site. These factors probably render these two riffles less than suitable as salmonid spawning sites. In fact, salmon redds have been observed in the riffle just downstream of the SCOR outfall, but not in the two affected riffles (Scott McReynolds, pers. comm.).

Figure 6.2.2-1. The release plume from the Thermalito Afterbay Outlet.

Figure 6.2.2-2. Riffle water quality sampling locations near the Thermalito Afterbay Outlet.

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