November 2003

SHASTA LAKE
WATER RESOURCES INVESTIGATION

OFFICE REPORT

Ecosystem Restoration Opportunities in the Upper Sacramento River Region

U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region

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Mid-Pacific Region

Shasta Lake Water Resources Investigation, California

Office Report

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EXECUTIVE SUMMARY

The primary purpose of this office report is to identify potential ecosystem restoration opportunities that address the planning objectives of the Shasta Lake Water Resources Investigation (SLWRI) and should be considered further in future feasibility scope studies. This report highlights: existing environmental conditions and problems, ongoing conservation and environmental restoration programs in the study area, potential ecosystem restoration opportunities, and potential ecosystem restoration plan components for consideration in future planning efforts.

BACKGROUND

In 2000, the U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region (Reclamation) reinitiated a feasibility investigation to evaluate the potential for enlarging Shasta Dam for increased water supply and operational flexibility. Increases in demands for water supplies and attention to ecosystem needs in the Central Valley of California have renewed interests on expanding the facility. The SLWRI is being conducted under the general authority of Public Law 96-375 (1980). A Mission Statement Milestone Report for the study was completed in March 2003 to guide project planning efforts; it outlines the resource problems, study objectives, and mission statement for the SLWRI.

Study Area

The primary study area includes Shasta Lake and vicinity; the lower reaches of rivers and streams tributary to Shasta Lake, including the Sacramento, McCloud, and Pit rivers; and the Sacramento River downstream from Shasta Dam to about the Red Bluff Diversion Dam. Discussions in this office report are separated into two geographic sub-areas: the Shasta Lake and Tributaries sub-area, and the Sacramento River from Shasta Dam to Red Bluff sub-area.

Plan Formulation Process

Formulation of alternative plans for the SLWRI, including ecosystem restoration components, is guided by the study objectives and mission statement developed in the Mission Statement Milestone Report. There are two primary study objectives, and three secondary study objectives. The primary objectives are:

- Increase the survival of anadromous fish populations in the Sacramento River primarily upstream from the Red Bluff Diversion Dam.

- Increase water supplies and water supply reliability for agricultural, M&I, and environmental purposes to help meet future water demands, with a primary focus on enlarging Shasta Dam and Reservoir.

The secondary objectives represent features that are to be included, to the extent possible, through the pursuit of the primary objectives:

- Preserve and restore ecosystem resources in the Shasta Lake area and along the upper Sacramento River.

- Reduce flood damages along the Sacramento River.

- Develop additional hydropower capabilities at Shasta Dam.

The ecosystem restoration measures developed herein address the primary objective to increase the survival of anadromous fish populations and/or the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area and along the upper Sacramento River.

The mission statement developed for the SLWRI is as follows:

> *To develop an implementable plan primarily involving the enlargement of Shasta Dam and Reservoir to promote increased survival of anadromous fish populations in the upper Sacramento River; increased water supply reliability; and to the extent possible through meeting these objectives, include features to benefit other identified ecosystem, flood control, and related water resources needs.*

ENVIRONMENTAL PROBLEMS

The study area has experienced a general decrease in the quantity and quality of native habitat, and a subsequent decrease in the population of many individual plant and animal species. This has resulted in a growing number of threatened and endangered species inhabiting the region. Key environmental problems identified in the two study sub-areas are include:

Shasta Lake and Tributaries Sub-Area

- Reductions in warm-water and cold-water fisheries in Shasta Lake, resulting primarily from (1) acid mine drainage, (2) lack of shallow-water, shoreline habitat, and (3) human disturbances.
- Reductions in fisheries in the tributaries to Shasta Lake, resulting primarily from (1) modification of seasonal flows, (2) loss of access to historic spawning and rearing areas, and (3) acid mine drainage.
- Reductions in riparian and wetland habitat in the sub-area, resulting primarily from increased erosion and sediment input, and non-native species.

Shasta Dam to Red Bluff Sub-Area

- Reductions in anadromous fish in the upper Sacramento River, primarily resulting from (1) water temperature, (2) physical migration barriers, (3) diversions and flow regulation, (4) reduction in suitable spawning gravels, (5) acid mine drainage, and (6) unnatural predation rates.

- Reductions in riparian, floodplain, and wetland habitat in the Shasta Dam to Red Bluff sub-area, primarily resulting from (1) changes to natural geomorphic processes, (2) urban and agricultural encroachment, and other land management changes, and (3) invasive species.

RELATED RESTORATION AND CONSERVATION PROGRAMS

Various Federal and State agencies, local working groups, and private organizations are active in environmental restoration and conservation in the study area. Several of the programs that were influential in identifying restoration opportunities are highlighted below.

- **Central Valley Project Improvement Act (CVPIA), 1992** – The CVPIA amended the authority of Reclamation's Central Valley Project and included a directive to develop and implement actions to promote the recovery of anadromous fish in Central Valley streams. Numerous actions to improve the natural production of anadromous fish have been recommended and/or funded by the Anadromous Fish Restoration Program through the CVPIA, including various completed and ongoing projects in the study area.

- **CALFED Bay-Delta Program (CALFED)** – CALFED is a cooperative effort among State and Federal agencies and California's environmental, urban and agricultural communities to address environmental and water supply problems associated with the Bay-Delta system. One of CALFED's programmatic elements, the Ecosystem Restoration Plan (ERP), identifies and recommends restoration actions in several ecological management zones, two of which fall within the SLWRI study area. In the North Sacramento Valley Ecological Management Zone, the ERP recommends actions on Clear, Cow, Bear, and Battle creeks; CALFED has helped to fund several of these restoration efforts. In the Cottonwood Creek Ecological Management Zone, recognized as the primary source of coarse sediments and spawning gravel for the Sacramento River, recommendations include flow augmentation, instream habitat restoration, revegetation, and other actions to preserve and restore the watershed.

- **Sacramento River Conservation Area Program** – Established by California Senate Bill 1086, the Sacramento River Conservation Area Program has an overall goal of preserving remaining riparian habitat and reestablishing a continuous riparian ecosystem along the Sacramento River between Redding and Chico. Specific actions recommended by the program in the SLWRI study area include: spawning gravel replenishment; development of side-channel spawning areas; elimination of short-term flow fluctuations; maintaining instream flows through coordinated operation of water facilities; acid mine drainage reduction; and various fisheries improvements on Clear, Battle, and Cottonwood creeks.

Resource conservation districts, coordinated resource management groups, and various private organizations in the region have also produced studies and implemented programs related to fisheries and habitat restoration that were useful in identifying environmental problems and opportunities in the study area.

ECOSYSTEM RESTORATION OPPORTUNITIES

Over 40 preliminary ecosystem restoration measures were identified to address the primary and secondary study objectives, based on the environmental problems and needs and the recommendations of other ongoing restoration programs. The preliminary measures were compared and screened based on the following criteria: (1) ability to fulfill one or more of the study objectives, (2) relative likelihood of physical implementation, (3) ability to provide consistent and reliable benefits, (4) the degree of future actions required to achieve or maintain benefits, (5) potential to negatively impact an existing beneficial use or create significant mitigation obstacles, and (6) efficiency based on relative cost and accomplishments. Of the ecosystem restoration measures identified, nine were selected that are believed to warrant further consideration for possible consideration in future formulation of multi-purpose alternatives for the SLWRI. These preliminary ecosystem restoration components are summarized in Table ES-1. Upon further evaluation, six of the measures were given high recommendations.

CONCLUSIONS

Although numerous public and private groups are actively pursuing ecosystem restoration in the upper Sacramento River area, there remains significant opportunities to implement actions to help restore ecosystem values in the study area, consistent with the goals and objectives of the SLWRI. It is believed that future plan formulation efforts for the SLWRI should include consideration of the nine identified ecosystem restoration measures, with emphasis placed on the six highly recommended measures. Although additional study and refinement are required, each of the highly recommended measures are believed to be (1) capable of significantly contributing to the study objectives, (2) consistent with the goals and objectives of CALFED and other Sacramento River management programs, and (3) capable of support from a non-federal sponsor.

TABLE ES-1
PRELIMINARY ECOSYSTEM RESTORATION PLAN COMPONENTS

ID No.	Measure Description	First Cost[1] Annual Cost[2]	Benefits/ Advantages	Implementation Issues/Disadvantages	Comments and Conclusions
A1	**Construct Shoreline Fish Habitat around Shasta Lake** *20 acres of shallow-water habitat restoration around Shasta Lake*	$1.6 million Moderate-High	Improve shallow, warm-water fish habitat in drawdown area; improve juvenile rearing; increase angling opportunities	May create submerged hazards for watercraft; likely high operation and maintenance, as structures would need to be replaced periodically.	• **High recommendation** • Good potential to combine with other measures • Moderate uncertainty
A5	**Construct Instream Fish Habitat on Tributaries to Shasta Lake** *8 miles aquatic habitat restoration along lower reaches of perennial tributaries to Shasta Lake.*	$0.6 million Moderate-High	Improved spawning and rearing habitat in Shasta tributaries.	Habitat structures would need to be replaced periodically; site access may be problematic.	• **High recommendation** • Good potential to combine with other measures • Low uncertainty
A7	**Restore Inactive Gravel Mines on Sacramento River** *Restoration of 150 acres of land formerly mined for gravel.*	$8 million Moderate	Provides benefits for both aquatic and floodplain habitats; reduced mortality at pits and improved spawning success.	Land acquisition would be required to ensure long-term benefits.	• **High recommendation** • Good potential to combine with other measures • Benefits both terrestrial and aquatic habitats • Low uncertainty
A8	**Construct Instream Habitat Downstream from Keswick Dam** *¾ mile of aquatic habitat restoration on the Sacramento River downstream from Keswick Dam.*	$0.8 million Moderate-High	Improved spawning success in a reach currently unsuitable for spawning; reduced mortality below dam.	Design and construction constraints related to site conditions and dam releases; high operation and maintenance, as habitat structures would need to be replaced periodically; low potential for inclusion in Federal projects.	• High long-term cost for restoring a relatively small, although strategically located, reach of river • Moderate uncertainty • Potential for non-federal consideration
A9	**Replenish Spawning Gravel in Sacramento River** *10,000 tons spawning gravel injected at three sites between Keswick Dam and Red Bluff.*	$0.4 million Very High	Improved aquatic habitat/ spawning success; gravel may become limiting factor in fisheries restoration; benefits would continue as gravel moves through system	Very high operation and maintenance, as gravel injections would need to be repeated at frequent intervals to maintain benefits over project life; concerns over downstream impacts to infrastructure; low potential for inclusion in Federal projects.	• Very low initial cost but higher long-term cost • Moderate uncertainty • Potential for non-federal consideration
A10	**Additional Modifications to Shasta Dam for Temperature Control** *Expansion of existing temperature control device at Shasta Dam.*	Similar to existing TCD Low	Improved temperature control would support spawning success	Potential for high initial cost depending on other modifications to Shasta Dam.	• **High Recommendation** • High potential to combine with other measures • Moderate uncertainty
A12	Enlarge Shasta Lake Cold Water Pool Raise Shasta Dam between about 6.5 and 18 feet and enlarge Shasta Reservoir by between 290,000 and 630,00 acre-feet, respectively.	$210–290 million Low	Increased cold water release capability from Shasta Dam would improve meeting downstream water temperature goals and spawning and rearing success and likely water supply reliability, hydropower, and lake	High initial costs; adverse impacts to reservoir rim physical and natural resources requiring significant mitigation measures.	• **High Recommendation** • Consistent with CALFED • High initial costs • Strong potential to combine with other measures • Low uncertainty

ID No.	Measure Description	First Cost[1] Annual Cost[2]	Benefits/ Advantages	Implementation Issues/Disadvantages	Comments and Conclusions
			area recreation and benefits		
A13	**Modify Storage and Release Operations at Shasta Dam** *Reoperate Shasta Dam to benefit anadromous fisheries*	Low (without mitigation) Low	Greater flexibility in meeting fishery needs would improve spawning and rearing success.	Would only be feasible with measures to mitigate likely adverse impacts to water supply reliability and other resources.	• **High recommendation** • Good potential to combine with other measures • Moderate uncertainty
B10	**Riparian and Floodplain Restoration along Sacramento River** *500 acres of floodplain and riparian habitat restoration near tributary confluences.*	$9 million Moderate-High	Restores floodplain and riparian habitat, with residual benefits to aquatic habitat (source of shade and woody debris); restore natural processes.	Land acquisition would be required to ensure long-term benefits.	• Good potential to combine with other measures • Benefits both terrestrial and aquatic habitats • Low uncertainty

Notes:
1. First Cost includes initial construction, real estate, planning, engineering, and design; represents the initial cost required to implement the measure.
2. Relative comparison to first cost. Annual Cost includes annual monitoring, operation, and maintenance costs, and any periodic or recurring costs associated with the measure.

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INTRODUCTION

BACKGROUND

In 2000, the U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region (Reclamation) reinitiated a feasibility investigation to evaluate the potential for enlarging Shasta Dam for increased water supply and operational flexibility. Increases in demands for water supplies and attention to ecosystem needs in the Central Valley of California have renewed interests on expanding the facility. The Shasta Lake Water Resources Investigation (SLWRI) is being conducted at the direction of Congress, and supports other Federal interests within the study area. Expansion of storage in Shasta Reservoir as part of the Central Valley Project (CVP) is one of five potential surface water storage projects identified in an August 2000 Record of Decision (ROD) for the CALFED Bay-Delta Program (CALFED), currently the California Bay-Delta Authority. The ROD identified the potential for expansion of Shasta Reservoir to help increase the pool of cold water available to maintain lower Sacramento River water temperatures needed by certain fish and provide other water management benefits, such as water supply reliability.

A Mission Statement Milestone Report (MSMR) for the study was completed in March 2003. It outlines the resource problems, study objectives, and mission statement for the SLWRI, and puts forth several concepts to address the identified problems.

PURPOSE AND SCOPE

The primary purpose of this office report is to further identify potential ecosystem restoration opportunities that address the planning objectives of the SLWRI. To the maximum extent practical, features to promote the survival of anadromous fish in the upper Sacramento River and to help restore ecosystem values in the study area are to be incorporated into each alternative plan formulated for the study. The ecosystem restoration measures described herein are developed to a level of detail necessary to determine if they should be considered in alternative plans for the SLWRI.

STUDY AREA

The primary study area includes Shasta Lake and vicinity; the lower reaches of rivers and streams tributary to Shasta Lake, including the Sacramento, McCloud, and Pit rivers; and the Sacramento River downstream from Shasta Dam to about the Red Bluff Diversion Dam (RBDD). The primary study area is shown in Figure 1. The RBDD is the point at which releases from Shasta Dam begin to have a negligible effect on Sacramento River water temperatures and the river landscape changes to a broader, alluvial stream system.

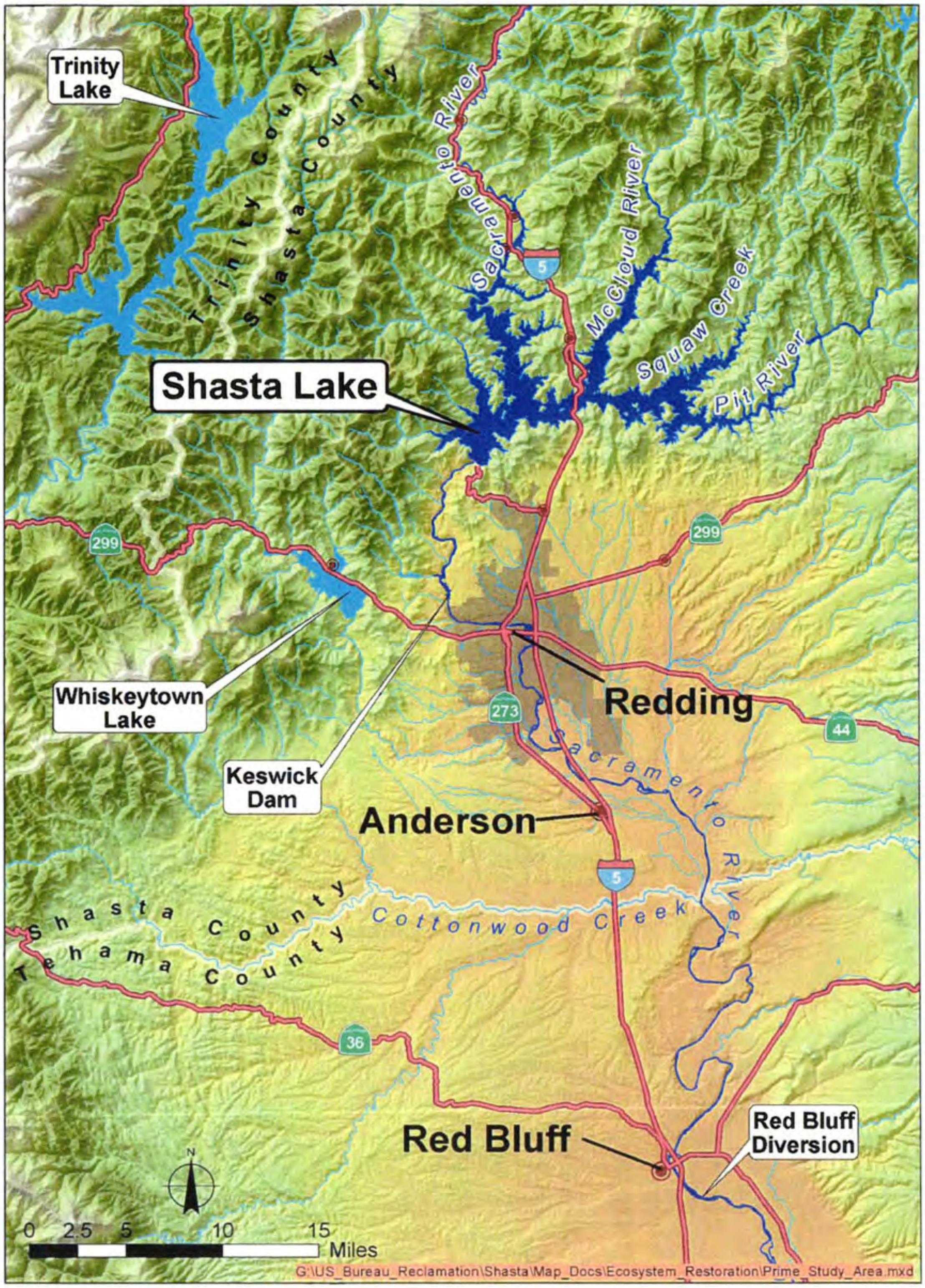


Figure 1 – Primary Study Area

Due to the potential for water resources changes at Shasta Dam to have effects outside the primary study area in the Central Valley, the extended study area includes the upper watershed of the Sacramento River; the Sacramento River Basin downstream to the Delta, and the San Joaquin and Tulare Lake basins. Ecosystem restoration opportunities associated with this study will be located within the primary study area. Accordingly, this report does not address conditions throughout the Central Valley extended project area. For the purpose of this document, discussions will be separated into two geographic sub-areas: the Shasta Lake and Tributaries sub-area, and the Sacramento River from Shasta Dam to Red Bluff sub-area.

Land uses in the primary study area are principally agricultural and open space, with urban development focused along highway corridors and in the cities of Red Bluff and Redding. The region has extensive tracts of Federal and State lands, including portions of the Shasta-Trinity, Lassen, Plumas, and Mendocino National Forests. Other public lands include State recreation areas and wildlife management areas.

Shasta Lake and Tributaries Sub-area

The Shasta Lake and Tributaries Sub-area is illustrated in Figure 2, and includes Shasta Lake and the lower reaches of its major tributaries. The 533-feet high, 4.55 million acre-feet (MAF) Shasta Dam and Reservoir are located on the upper Sacramento River, about nine miles northwest of the City of Redding. Shasta Lake has about 370 miles of shoreline and controls runoff from about 6,420 square miles, including four major tributaries and numerous minor creeks and streams. Elevations in the watershed range from 1,070 feet at Shasta Lake to more than 14,000 feet on Mount Shasta and more than 10,000 feet in the Warner Range. The four major 'arms' of the reservoir, the Sacramento River, McCloud River, Squaw Creek, and Pit River, are described below.

Sacramento River Arm

The Sacramento River upstream of Shasta Lake drains an area of over 400 square-miles. Its headwaters include the southwestern slopes of Mount Shasta and the Trinity and Klamath Mountains. The river flows south for about 40 miles until it enters Shasta Lake near Riverview (upstream of Lakehead). The river corridor is deeply entrenched in the steep mountain terrain, and flows primarily over bedrock. Tributaries to the Sacramento River Arm of Shasta Lake include Backbone and Little Backbone creeks; West Squaw Creek; Middle Salt Creek; Salt Creek (fed by Nelson, Coal, and Salt creeks); and O'Brien Creek. West Squaw Creek should not be confused with the larger Squaw Creek tributary to Shasta Lake that enters from the east. Minor tributaries include Shoemaker Gulch, Butcher Creek, Alder Creek, Elmore Creek, Little Sugarloaf Creek, Sugarloaf Creek, Indian Creek, Gregory Creek, Lick Gulch, and Frost Gulch.

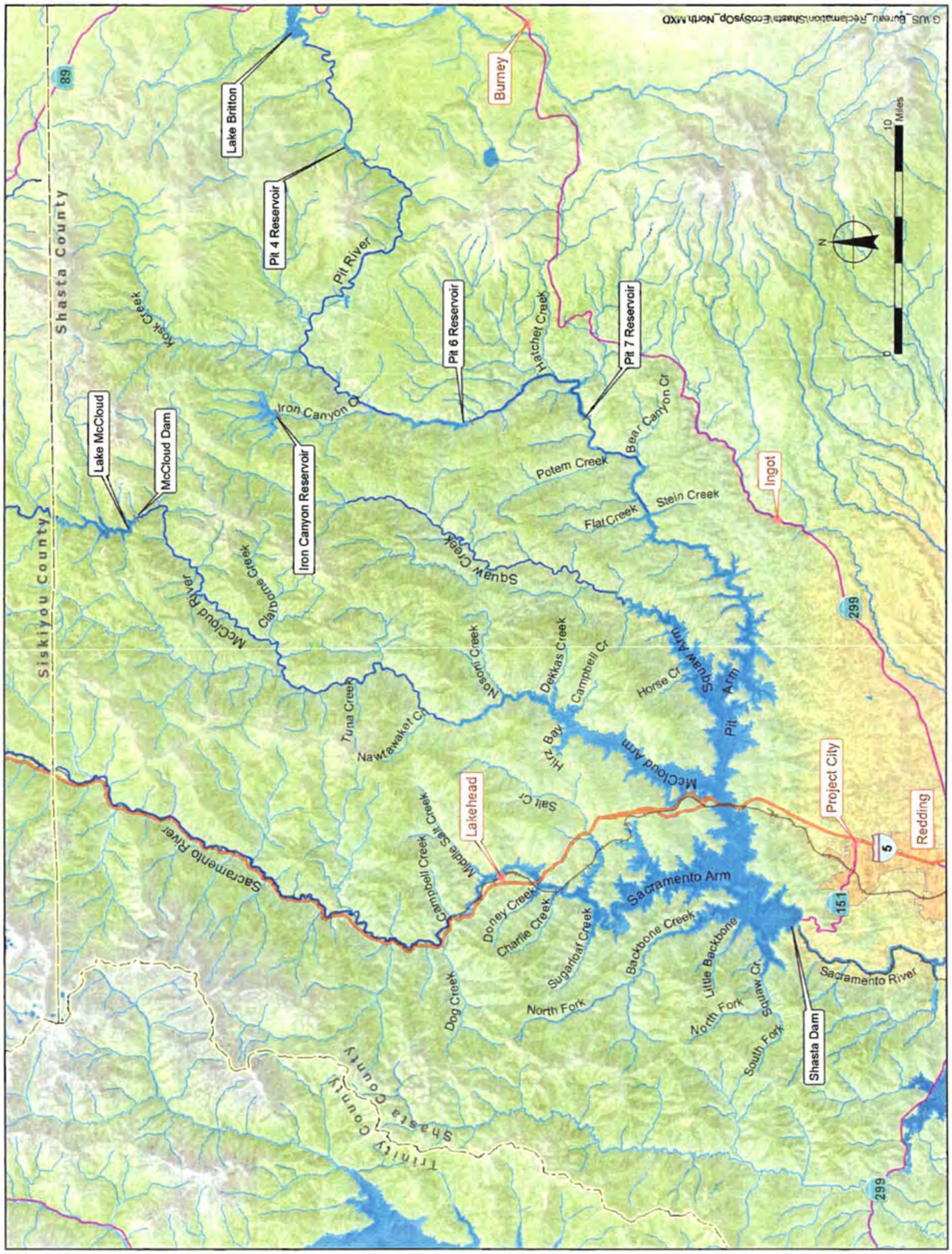


Figure 2 – Shasta Lake and Vicinity

McCloud River Arm

The McCloud River Arm consists of a deep canyon that was inundated by Shasta Lake after construction of Shasta Dam. Tributaries to the McCloud Arm of Shasta Lake include Goat, Ycotti, Keluche, Hirz, Ellery, Nosoni, Dooles, Mathles, Dekkas, Campbell, Curl, Marble, and Potter creeks. The McCloud River basin drains an area of over 600 square-miles in Shasta and Siskiyou counties. The river flows southwesterly from its headwaters at Colby Meadows for approximately 50 miles to its terminus at Shasta Lake. Snowpack and glaciers on Mount Shasta provide the principal source of flow for the McCloud River. The free-flowing stretches of the McCloud River are protected under the California Wild and Scenic River Act (Public Resources Code Section 5093.50), although the Act does not declare it Wild and Scenic. The Wild and Scenic legislation made the following recommendations for the McCloud:

- The continued management of the river resources in their existing natural conditions represents the best way to protect the unique fishery of the McCloud River, and

- Maintaining the McCloud River in its free-flowing condition to protect its fishery is the highest and most beneficial use of the waters of the McCloud River within the segment from 0.25 miles below McCloud Dam to the McCloud River Bridge.

McCloud Dam was constructed upstream from Shasta Lake as part of the Pacific Gas and Electric (PG&E) McCloud-Pit project. The lower McCloud River is highly regulated by this reservoir, which diverts approximately 75 percent of McCloud River flows into the Pit River by way of Iron Canyon Reservoir. The river above Lake McCloud is relatively flat, while the lower McCloud River runs through a deep bedrock canyon.

Pit River and Squaw Creek Arms

The 4,700 square-mile Pit River watershed extends into northeastern California and southeastern Oregon. The North Fork of the Pit River originates at the outlet of Goose Lake, and the South Fork originates in the south Warner Mountains in Lassen County. The main stem of the Pit River is formed by the junction of its North and South Forks near Alturas. The Fall River joins the Pit River in the western portion of the watershed. There are over twenty named tributaries to the Pit River system, totaling about 1,050 miles of perennial streams. Tributaries to the Pit River Arm of Shasta Lake include Jones River; Cove, Azelle, Fort, Reynolds, Dead Horse, and Arbuckle creeks; and Brushy, Reno, Murphy, Browns, Sugarpine, Dark, Blue, Fanther, and Wildcat canyons. There are several hydropower facilities and diversions that affect seasonal flows in the Pit River.

The Squaw Creek watershed is located east of Shasta Lake and drains over 100 square miles. The terrain is primarily steep and includes over 108 miles of perennial streams. Tributaries to the Squaw Creek Arm of Shasta Lake include: Zinc Creek, Town Creek, Lick Canyon, Museum Canyon, Flume Canyon, Frenchman Gulch, and McClure Gulch.

Sacramento River from Shasta Dam to Red Bluff Sub-area

The Shasta Dam to Red Bluff Sub-area consists of the Sacramento River corridor and lower reaches of its tributaries between Shasta Dam and Red Bluff, as shown in Figure 3. Downstream from Shasta Dam, the Sacramento River flows through a narrow, rock canyon before entering the broader floodplain of the northern Central Valley near Redding. There are three major water control structures between Shasta Dam and Red Bluff: Keswick Dam, the Anderson-Cottonwood Irrigation District (ACID) Diversion, and the RBDD. Keswick Dam is located approximately 10 miles downstream from Shasta Dam and the ACID diversion dam is located near Redding. The ACID diversion is gravity-fed and removes an average of 300 cubic feet per second (cfs) from the Sacramento River between April and October. The RBDD is located in Red Bluff and diverts water to the Tehama Colusa and Corning canals.

Major tributaries to the Sacramento River within the sub-reach include Clear Creek, Battle Creek, Cow Creek, and Cottonwood Creek. Minor tributaries include Olney, Ash, Bear, Churn, Stillwater, Inks, and Paynes creeks. None of the tributaries between Keswick Dam and Red Bluff are controlled by major dams, with the exception of Whiskeytown Dam on Clear Creek. However, there are numerous smaller impoundments and diversion structures that affect flows on the tributaries. The reach of the river between Keswick Dam and Balls Ferry flows through the most urbanized portion of the study area, the communities of Redding and Anderson, and is subject to urban encroachment in floodplain areas.

Clear Creek is the first major tributary downstream from Keswick Dam, entering the Sacramento River from the west about 12 miles downstream from the dam. Whiskeytown Reservoir on Clear Creek was created as part of the Trinity River Division of the CVP in December of 1963, and was designed to divert water from the Trinity River Basin to the Sacramento River for the purpose of power generation and water supply. All but about 13 percent of the flows in Clear Creek are diverted through the Spring Creek Tunnel into the Sacramento River above Keswick Dam. Minor tributaries to lower Clear Creek include Dog Gulch, Orofino Gulch, Paige Boulder Creek, Kanaka Creek, South Fork Clear Creek, Andrews Creek, Little Kanaka Creek, Stony Gulch, and Niles Canyon.

Cow Creek flows into the Sacramento River from the east and ranks third, behind Cottonwood Creek and Stony Creek, for producing the largest peak inflows to the Sacramento River within the northern Sacramento Valley. There are eight hydroelectric facilities and over 190 water diversions in the Cow Creek watershed. Major tributaries to Cow Creek include Little Cow Creek, Oak Run Creek, Clover Creek, Old Cow Creek, and South Cow Creek. Elevations in the watershed range from 350 feet to over 7,300 feet.

Battle Creek originates in the Cascade Mountains and drains the western slopes of Mount Lassen. The creek flows through several narrow canyons before its confluence with the Sacramento River downstream from the Balls Ferry Bridge. The Coleman National Fish Hatchery is located near the mouth of Battle Creek and is the largest chinook salmon fish hatchery in the world. There are numerous water diversion and hydropower facilities in the Battle Creek stream system that can significantly alter flows during the dry season.

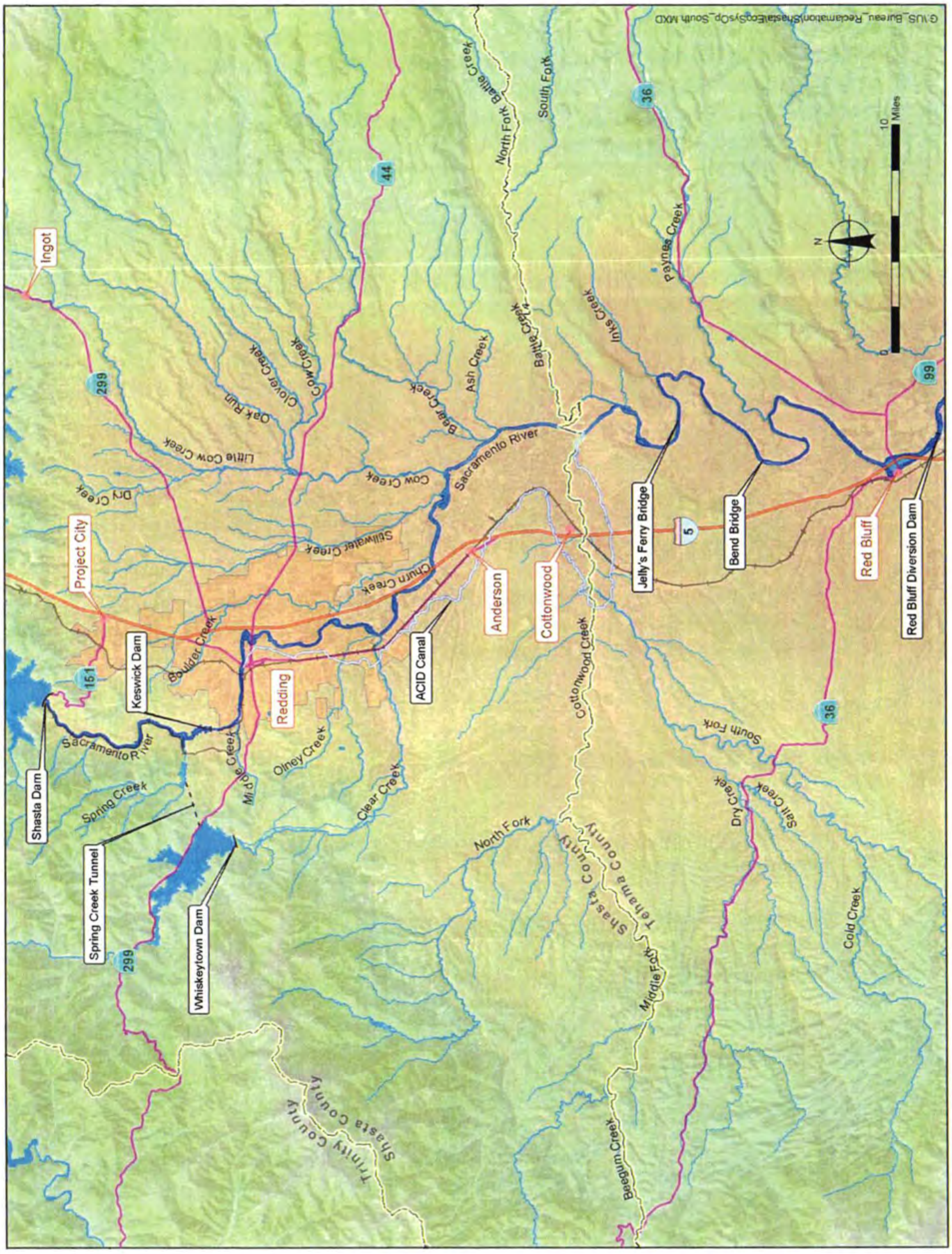


Figure 3 – Sacramento River between Shasta Dam and Red Bluff

Cottonwood Creek is the largest uncontrolled tributary to the Sacramento River north of the Sacramento-San Joaquin Delta. It originates in the northeastern slopes of the Coast Range and the southeastern slopes of the Trinity Mountains, with watershed elevations ranging from 8,000 feet in the mountains to 150 feet near the mouth. Peak flows in Cottonwood Creek can exceed 90,000 cfs during severe floods. Tributaries include the North Fork Cottonwood Creek, Beegum Creek, and the South Fork Cottonwood Creek. Rainbow Lake, created by Misselbeck Dam in 1920, is the only major reservoir in the watershed and has a capacity of 4,800 acre-feet.

MISSION STATEMENT AND FORMULATION PROCESS

Six water resources problems and needs were identified in the MSMR. They included (1) anadromous fish survival problems in the upper Sacramento River, (2) water supply reliability needs in the extended study area, (3) ecosystem restoration needs in the primary study area, (4) residual flood problems along the upper Sacramento River, (5) hydropower needs in California, and (6) water-oriented recreation needs in Northern California. From these problems, primary and secondary planning objectives were developed for the SLWRI:

- Primary Objectives
    - Increase the survival of anadromous fish populations in the Sacramento River primarily upstream from the Red Bluff Diversion Dam.
    - Increase water supplies and water supply reliability for agricultural, M&I, and environmental purposes to help meet future water demands with a primary focus on enlarging Shasta Dam and Reservoir.
- Secondary Objectives

To the extent possible through pursuit of the primary planning objectives, include features to help:

- Preserve and restore ecosystem resources in the Shasta Lake area and along the upper Sacramento River.
- Reduce flood damages along the Sacramento River.
- Develop additional hydropower capabilities at Shasta Dam.

From these planning objectives, and considering a set of constraints, guiding principles, and evaluation criteria, a mission statement for the study was developed as follows:

> *To develop an implementable plan primarily involving the enlargement of Shasta Dam and Reservoir to promote increased survival of anadromous fish populations in the upper Sacramento River; increased water supply reliability; and to the extent possible through meeting these objectives, include features to benefit other identified ecosystem, flood control, and related water resources needs.*

Alternatives developed during the planning process will likely consist of a combination of several measures to address the primary and secondary study objectives consistent with the mission statement. Individual measures or potential components of an alternative need not address all of the study objectives by themselves. Ecosystem restoration measures, at minimum, should address the primary objective to increase the survival of anadromous fish populations and, to the extent possible, the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area and along the upper Sacramento River. Because the SLWRI was initiated specifically to examine opportunities to enlarge Shasta Dam and Reservoir, ecosystem restoration measures should complement potential storage increases at Shasta Dam or be closely connected to the area of influence of such actions. Measures should not preclude or act contrary to other study objectives unless these negative impacts can be mitigated.

CHAPTER II
ENVIRONMENTAL CONDITIONS

As in much of the Central Valley, environmental conditions in the primary study area are largely a result of human development and use of limited land and water resources. Human settlers were originally drawn to the area by its farming opportunities, but came in greater numbers in the mid- and late 1800s to exploit the mineral resources discovered there, including gold, copper, and other metals. As mining began to diminish, water resources in the region were tapped for water supply and hydropower generation. Today, recreation, timber harvesting, and farming are the primary human uses of lands within the primary study area. Just as the benefits of these human uses extend throughout the State, the resulting environmental impacts have also extended beyond the region. For example, impacts to fisheries and streamflow from Shasta Dam can be felt as far downstream as the Delta.

This section provides an updated summary of existing environmental conditions in the primary study area. Because environmental conditions vary throughout the study area, the discussion is divided into the two sub-areas identified previously, the Shasta Lake and Tributaries sub-area and the Shasta Dam to Red Bluff sub-area. This information is intended to supplement the MSMR.

SHASTA LAKE AND TRIBUTARIES

Climate, Hydrology, and Water Resources

Mild, wet winters and hot, dry summers typify the climate of the sub-area. The area experiences average annual precipitation of about 70 inches, with snow typically accumulating above 4,000 feet in elevation. Hydrologic features of the study area include perennial, intermittent, and ephemeral stream channels, and natural water bodies and wet meadowlands.

The climate, topography, and hydrology of the project area are favorable to water resources development. Consequently, streamflow hydrology on the major tributaries to Shasta Lake has been significantly modified by the development of water control and hydroelectric facilities. In addition to the CVP hydroelectric facilities associated with Shasta Dam and Reservoir, PG&E and other private companies operate numerous hydroelectric projects within the primary study area, as shown in Table II-1. While dams and reservoirs have provided power and water to feed growth in the state, they have taken a significant toll on the natural environment. Water levels can fluctuate rapidly from diversions, inter-basin transfers have altered historic flow patterns, dams have blocked fish passage, and reservoirs have replaced stream environments.

Flow has been reduced in many streams, particularly during periods of high water or power demand, due to water diversions. For example, much of the flow in the upper McCloud River is diverted to the Pit River watershed at the McCloud Dam for the purpose of hydropower generation. To reduce impacts to river environments, minimum streamflow requirements are established by the FERC license for each hydroelectric facility. Minimum flows are typically based on the minimum environmental needs of organisms in the river, helping to regulate temperatures and streamflows for aquatic life and species of concern.

TABLE 11-1
PRIVATE HYDROPOWER PROJECTS IN THE PRIMARY STUDY AREA

FERC No.	Project Name	River	County	Capacity (Watts)	Owner	License Issued	License Expires[1]
3948	Bailey Creek – EEK	Bailey Creek	Shasta	750	Bailey Creek Ranch	11/2/81	Exempt
8357	Ponderosa/Bailey	Bailey Creek	Shasta	1100	Snow Mountain Hydro	6/14/85	5/31/35
8671	Burney Creek	Burney Creek	Shasta	3447	Snow Mountain Hydro	6/15/87	Exempt
6905	T&G Hydro	Canyon Creek	Shasta	350	T&G Hydro	5/27/83	Exempt
2888	Whiskeytown	Clear Creek	Shasta	3530	City of Redding	3/10/83	2/28/33
7057	Clover Leaf Ranch	Clover Creek	Shasta	224	Highl & Hydro Construction Inc.	7/12/83	Exempt
5306	Mega Hydro No. 1	Clover Creek	Shasta	1000	Mega Hydro Inc.	8/4/83	Exempt
12086	Hillcrest Hydro	Lower Cow Ck	Shasta	105	Trinity Meadows L.P.	4.17.02	Exempt
8361	Olsen	Old Cow Creek	Shasta	4400	Olsen Power Pms	4/7/87	3/31/37
606	Kilarc – Cow Creek	South Cow Ck	Shasta	4400	PG&E	2/8/80	3/27/07
6594	Marrow-Stone	South Cow Ck	Shasta	100	Webb Morrow	12/15/82	Exempt
6952	Water Wheel Ranch	No Fk Cow Ck	Shasta	999	McMillan Hydro Inc	6/3/83	Exempt
6548	Goose Valley	Goose Creek	Shasta	224	Denny L&&Cattle Co	11/26/82	Exempt
2661	Hat Creek EEK	Hat Creek	Shasta	2000	PG&E	10/29/75	9/30/00
4794	Hat Creek Hereford Ranch	Hat Creek	Shasta	100	Robert Thompson	8/26/82	Exempt
9078	Cove	Hatchet Creek	Shasta	5000	Snow Mountain Hydro	11/30/88	Exempt
5931	Hatchet Creek	Hatchet Creek	Shasta	6890	Mega Renewables	5/9/85	4/30/35
9334	Bidwell Ditch	Lost Creek	Shasta	1800	Mega Renewables	2/10/87	Exempt
3863	Lost Creek No. 1	Lost Creek	Shasta	1100	Snow Mountain Hydro	5/18/88	4/30/38
5130	Lost Creek No. 2	Lost Creek	Shasta	455	Snow Mountain Hydro	5/29/87	4/30/37
4826	Baker Kosh Creek	Kosh Creek	Shasta	270	Joseph Vermilyea	9/30/81	Exempt
7178	Arbuckle Mtn	M. Fk Cottonwood	Shasta	400	Arbuckle Mtn Hydro	9/20/85	8/31/35
2106	McCloud-Pit	McCloud River	Shasta	340500	PG&E	8/18/61	7/31/11
4283	Sutters Mill	Millseat Creek	Shasta	150	Fred N. Sutter, Jr.	3/1/82	Exempt
3590	Montgomery Creek	Montgomery Creek	Shasta	2600	El Dorado Hydro	6/23/82	Exempt
9029	Grasshopper Flat	Nelson Creek	Shasta	1100	Nelson Creek Power Inc.	3/11/87	2/28/37
233	Pit 3-4-5	Pit River	Shasta	317000	PG&E Company	2/26/81	10/31/03
2687	Pit No 1	Pit River	Shasta	6000	PG&E Company	11/6/70	12/31/95
8296	Muck Valley	Pit River	Lassen	29900	Malacha Hydro Part	12/2/86	11/30/36
7282	Roaring Creek	Roaring Creek	Shasta	2000	Roaring Cr Ranch, Mega Renewables	12/28/84	11/30/34
5766	Nichols HydroPower	So Fk Bear Ck	Shasta	3200	Tko Power Inc	4/22/82	Exempt
8975	Silver Springs	Silver Springs	Shasta	600	Mega Renewables	9/17/85	Exempt
3908	Slate Creek	Slate Creek	Shasta	3800	Catalyst State Ck Hydro	5/25/82	Exempt
6634	Prather Ranch	Prather Creek	Siskiyou	100	Ralph Ranches Inc	2/1/83	Exempt
2796	Lake Siskiyou	Sacramento Riv	Siskiyou	5000	Synergies Inc	1/20/83	Exempt
1121	Battle Creek	Battle Creek	Tehama	36100	PG&E	8/13/76	7/31/26
1992	Fire Mountain Lodge	Fern Springs Ck	Tehama	15	Ken Willis	5/6/80	4/30/10
5697	Nikola I	Digger Creek	Tehama	30	Lassen Research Co	4/19/82	Exempt
4714	Digger Creek	South Digger Ck	Tehama	675	Rugraw, Inc.	9/29/81	Exempt

Source: Federal Energy Regulatory Committee https://www.ferc.fed.us/hydro/hydro2.htm, updated 7 October 2002.
Notes: Those listed as “Exempt” are projects exempt from licensing requirements of the Federal Power Act

In addition to altering flows and moving water between watersheds, the physical hydropower infrastructure itself (dams, powerhouses, canals, etc.) also effects environmental resources. For example, dams can block sediment movement and prevent the movement of fish and other aquatic species along stream corridors. Water levels in reservoirs can fluctuate significantly, and habitat within the reservoirs often differs from the natural stream habitat that existed historically.

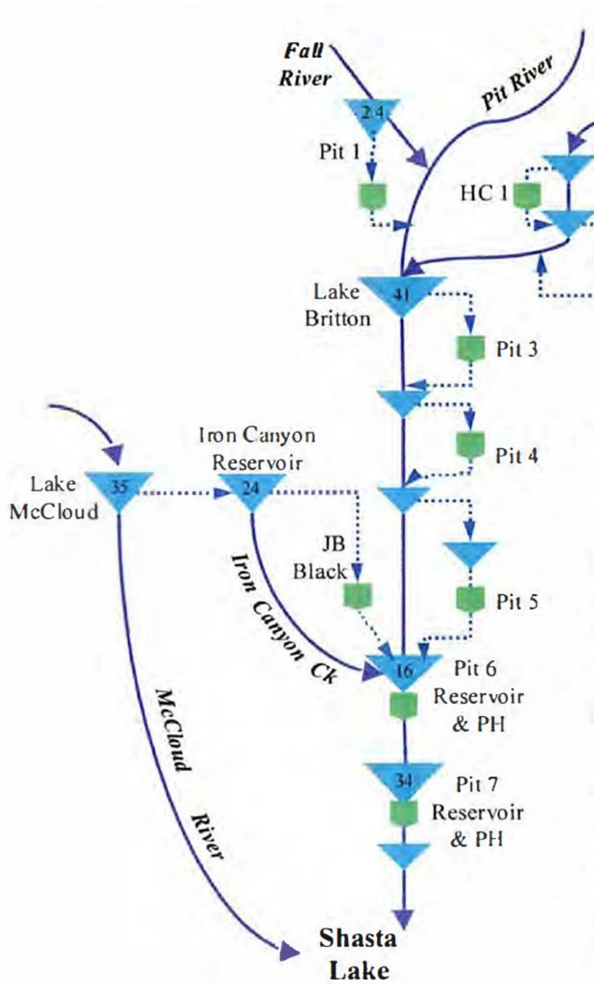
Within the Shasta Lake and Tributaries sub-area, the largest hydroelectric project not associated with Shasta Dam is the Pit-McCloud Project, owned and operated by PG&E. The storage and power facilities associated with the project are summarized in Table II-2.

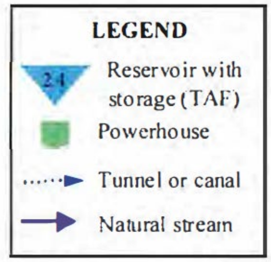
TABLE 11-2
SUMMARY OF PG&E HYDROPOWER FACILITIES
ON THE PIT AND MCCLOUD RIVERS

Facility Group	Reservoirs	Storage Capacity (AF)	Powerhouses	Max Capacity (cfs)	Power (MW)	Minimum Flows (cfs)
Hat Creek	Cassel Pond (Hat 1)	48	Hat Ck No. 1	548	8.5	2 d/s Cassel Pond
	Baum Lake (Hat 2)	629	Hat Ck No. 2	690	8.4	8 d/s Baum Lake
	Total	*677 AF*		*Total*	*17 MW*	
Pit River – Upper	Pit 1 Forebay	2,451	Pit 1	2,065	61	500 Pit River d/s from Fall River
	Pit 1 Diversion Res.	-				
	Total	*2,451 AF*		*Total*	*61 MW*	
Pit River - Middle	Lake Britton (Pit 3)	41, 887	Pit 3	3,315	70	150 d/s Britton
	Pit 4 Forebay	1,970	Pit 4	4,000	90	150 d/s Pit 4 dam
	Pit 5 Diversion Res.	314	Pit 5	3,880	160	120 d/s Nelson Ck
	Pit 5 Open Conduit	1,044				
	Total	*45,215 AF*		*Total*	*325 MW*	
Pit River – Lower	McCloud Reservoir	35,234				40-50 McCloud R.
	Iron Canyon Res.	24,197	James B Black	2,165	172	3 Iron Creek
	Pit 6 Forebay	15,605	Pit 6	7,620	80	
	Pit 7 Forebay	34,302	Pit 7	8,350	112	150 d/s Pit 7
	Pit 7 Afterbay					
	Total	*109,338 AF*		*Total*	*364 MW*	

Notes: AF= Acre Feet; MW= Megawatt (1,000,000 watts)
Source: PG&E, Draft Environmental Impact Report for Hydropower Divestitures, November 2000.

The Pit-McCloud Project is comprised of a series of dams and pump stations in the Pit River and McCloud River watersheds, shown schematically in Figure 4. Most of the reservoirs within the Pit-McCloud Project are relatively small and act as flow-through regulating facilities, but Lake Britton, Lake McCloud, and Pit 7 Reservoir can store water for release later in the season, depending upon streamflow and storage conditions. The most northerly grouping of facilities in the Pit River Project consists of the Pit 1 Forebay and Pit 1 Powerhouse on the Fall River, immediately upstream from its confluence with the Pit River. The Hat Creek unit consists of two reservoirs and two powerhouses located entirely on Hat Creek, a Pit River tributary. Hat Creek flows into Lake Britton, the largest regulating reservoir in the Pit River Project at just over 40,000 acre-feet. Lake Britton regulates flows into the middle Pit River unit, which consists of three additional storage facilities and three powerhouses, all along the Pit River.





Source:
Adapted from PG&E Hydropower Divestiture Draft EIR/EIS, November 2000

Figure 4 – Schematic of the Pit River Hydroelectric Project

To the west, Lake McCloud exports water from the McCloud River watershed through a seven-mile tunnel to Iron Canyon Reservoir. From Iron Canyon, water is conveyed through another tunnel to the J.B. Black Powerhouse on the Pit River. Discharges from the J.B. Black Powerhouse and Pit 5 Powerhouse flow into the Pit 6 Reservoir. Outflows from Pit 6 Reservoir flow through a powerhouse then into the Pit 7 reservoir and powerhouse. Outflows from the Pit 7 Afterbay flow down the Pit River to its terminus in Shasta Lake.

Geology

The geology of the study area is highly complex, containing portions of five geomorphic provinces: the Coast Range, KJamath Mountains, Great Valley, Cascade Range, and Modoc Plateau. Geologic formations in the western portion of the sub-area include Balaklala Rhyolite, Kennett, and Bragdon formations. The Balaklala Rhyolite group of rhyolitic flows, pyrite, and other pyroclastic rocks was the primary source of base-metal ore bodies that supported copper, zinc, gold, and silver mining operations in the sub-area. Other geologic formations include Mesozoic formations of sedimentary and volcanic fragments, which include mudstone, shale, sandstone, and conglomerate. Volcanic components typically arise in the east from the Klamath Mountain Belt and include basalt, andesite, breccia, agglomerate, and tuff. Alluvial deposits overlay a large portion of the sub-area.

The McCloud limestone formation, in the northeastern portion of the sub-area, is a unique feature to the study area. This formation is of paleontological significance because it is composed primarily of coral reefs and other marine formations that hold the fossilized remains of a diverse group of fauna. Paleontological findings and information from the McCloud limestone have provided the basis for current scientific knowledge of invertebrate and vertebrate development in California. Today, limestone caves also provide unique habitat for several cave-dwelling species in the sub-area, including the Shasta salamander, Shasta eupatorium, Howell's cliff-maids, and Shasta snow-wreath.

The geology of the study area has played a significant role in human settlement, economic development, and ecosystem conditions. Following the discovery of copper and gold in the region in the late 1800s, Shasta County became one of the largest copper mining and smelting regions in the United States. In general, copper mining was concentrated to the west of what is now Shasta Lake while iron and barite were typically mined on the eastern tributaries. Other mining products have included zinc, silver, platinum, cadmium, limestone, and crushed stone. The Shasta County Department of Resource Management estimates that over 700 million pounds of copper and 2 million ounces of gold have been produced in Shasta County.

Impacts from the various mining operations in the watershed include:

- Acid mine drainage, which results when precipitation and exposed ore form sulfuric acid;
- Accelerated erosion due to the removal of vegetation and topsoil, exposure of mine tailings, and clearing of timber for ore smelters;
- Changes in stream morphology due to increased sediment input and the deposit of mining waste soils in area streams;
- Air pollution caused by ore smelters, which destroyed large amounts of vegetation and further increased erosion; and
- Physical changes to the landscape, including open mine excavation and the artificial erosion of large gullies and other landforms.

Ore smelters, including those at Bully Hill and Coram, produced toxic gasses that killed thousands of acres of vegetation within the region. Accelerated erosion from vegetation-denuded hillsides caused the loss of topsoil and, in many areas, formed deep, steep-sided gullies in the landscape. Erosion continued for many years following the closure of ore smelters in 1910, and these erosional features still exist in the landscape.

The most intensive mining occurred along western tributaries to the Sacramento River, including the Backbone Creek and West Squaw Creek arms of Shasta Lake. Several mines were inundated by the formation of Shasta Lake. There are currently no active mines in the vicinity of Shasta Lake. Remedial activities have been performed at several area mines, but public agencies have had difficulty in funding remediation work on privately held mines due to liability concerns. Mines that currently impact environmental conditions in the Shasta Lake and Tributaries sub-area include the following:

- **Mammoth Mine** – This large, abandoned copper mine is located on a drainage of Little Backbone Creek. Acid mine drainage has eliminated most aquatic life in Little Backbone

Creek. Restoration and remediation actions at the mine, including a mine-sealing program, have been only moderately successful in controlling drainage from the site. The mine is privately owned.

- **The Golinksi Mine** – This abandoned copper mine is located on a tributary to Little Backbone and West Squaw creeks. Acid drainage from the mine is controlled by on-site remediation facilities, but effluent from the mine has destroyed aquatic life in Little Backbone Creek and resulted in periodic fish kills in Shasta Lake during periods of heavy rainfall runoff. The mine is located on land owned by the U.S. Department of Agriculture, Forest Service (FS).

- **Balaklala and Shasta King Mines** – These former copper and gold mines are located on tributaries to the South Fork of West Squaw Creek. Acid drainage from these mines has killed most aquatic life in the streams below the mines and caused frequent fish kills where West Squaw Creek enters Shasta Lake. Limited onsite remedial work has been performed by the private landowner. There may be an opportunity for the owner to sell the property to a public resource agency for recreational development, with funds from the sale to be used for acid mine drainage control.

- **Shasta Iron Mine** – The Shasta Iron Mine is located on the peninsula between the McCloud and Squaw/Pit arms of Shasta Lake. Both iron and copper were removed from the site, which has had no significant remedial actions to control runoff. The mine is located on private land.

- **Bully Hill and Rising Star Mines** – Placer gold, silver, and copper were extracted from these former mine sites near the Squaw Creek Arm of Shasta Lake. Bully Hill is the closest abandoned mine to the current shoreline Shasta Lake. A large ore smelter was once located at Bully Hill. Portions of the tailings and a debris dam at Bully Hill are inundated when the reservoir is full. Additional remedial actions have been proposed to control runoff from these mines, including removing or capping extensive tailings. Acid mine drainage from these mines affects Town and Horse creeks and localized water quality in Shasta Lake. Both mines are located on private land.

Geomorphology

Sedimentation and erosion are natural features of the mountainous streams tributary to Shasta Lake. Many of the tributaries are well-balanced stream systems, where flows, sediment bedload, and the delivery of large woody debris are in dynamic equilibrium. This equilibrium contributes to the formation and maintenance of favorable fisheries habitat, including pools, riffles, complex woody structures, and desirable spawning areas within the tributaries.

Landslides are relatively common in the area and range from small mudflows and slumps to large debris slides, debris flows, or landslides. Slides and sheet wash typically supply debris and sediments to the streams during the rainy season. Volcanic eruptions and mudflows have periodically affected channel morphology, often changing habitat conditions in area streams. The most active volcanic feature in the sub-area is Mount Shasta, which is estimated to have erupted 13 times in the last 10,000 years. The last major mudflow, which occurred on Mud

Creek in 1924, sent sediment down the McCloud River that was observed as far downstream as San Francisco Bay.

The natural geomorphology of the sub-area has been altered by changes to seasonal stream flows and sediment influxes formed by accelerated erosion in the watersheds, predominantly caused by human activity. Early in the 20th century, erosion in some areas upstream of what is now Shasta Lake was greatly accelerated by removal of timber for mining operations and destruction of vegetation by fumes from ore smelters. Following the creation of Shasta Lake, intensive erosion control programs, including revegetation, were employed to minimize hillside erosion in the affected areas. Current issues of concern regarding sediment and erosion in the Shasta watershed include runoff associated with timber harvest activities and erosion from unpaved roads, including logging and forest roads.

The human land use activity that has had the greatest impact on stream morphology is probably fire suppression. Wildfires have historically effected stream morphology and sediment movement in the sub-area, but these effects have intensified in the last 100 years because wildfires have become increasingly intense and destructive. Severe wildfires have been reported locally since the late 1800s, including the following:

- 1872 – North Fork Pit River to Chatterdown Creek, 150,000 acres (estimated)
- 1898 – Location within Shasta watershed unspecified, similar in size to the 1872 fire
- 1924 – Minnesota Mountain north to Nosoni Mountain, 4,600 acres
- 1935 – West of Horse Mountain, 2,100 acres
- 1939 – Horse Mountain, 4,600 acres
- 1999 – Shasta High Complex, 1,430 acres of high intensity burn and 4,760 acres of moderate intensity burn

The affect of wildfires on sedimentation, erosion, and habitat appears to have increased since human settlement in the region. Fire suppression, which began in the early 1900s, has resulted in the accumulation of dense undergrowth and development of thicker forest stands than would have occurred historically. Thick undergrowth burns hotter and tends to be more destructive, often killing older, taller trees that may have survived fires in the past. It is more difficult for forests to recover from such severe wildfires, resulting in increased erosion and sediment input into streams. Subsequent changes in stream morphology have often resulted in degraded aquatic habitat and the loss of adjacent wetland areas.

Vegetation and Habitat

Shasta Lake is surrounded by mountainous terrain forested primarily by brushy, hardwood stands, chaparral, oak woodlands, mixed conifer forests and ponderosa pine-dominated conifer stands. Vegetation diversity tends to be high in the area, due largely to the favorable climate and varying geology. Elevation and sun exposure create variation in the forest stands around the lake. Vegetation types include: Douglas Fir-Mixed Conifer Forest, Mixed Conifer, Ponderosa Pine, Canyon Oak Woodland, Black Oak Woodland, Gray Pine Woodland, and Chaparral.

Lower elevation vegetation consists of a mix of chaparral and hardwoods, and mid-elevation slopes fall within a transitional zone that contains both chaparral/hardwood mix and a mixed conifer component. The higher elevations are dominated by mixed conifer overstory with brush species in the understory. Riparian corridors are found along area streams, where conifers can span from lower to upper elevations. Vegetation types and age influence water quality, erosion, fire danger, habitat, and wildlife in the sub-area.

The FS manages various land allocations within the Shasta-Trinity National Forest, including Riparian Reserves, Late-Successional Reserves, and Matrix areas. These allocations determine forest management prescriptions and appropriate land uses, including timber harvesting, vegetation management, and fire suppression. With the exception of fire suppression, FS management has had an overall positive effect on vegetation within public lands. Fire suppression activities during the 1900s have generally increased the amount of vegetation in the watersheds surrounding Shasta Lake, particularly understory brush and other forest floor vegetation. In general, increased vegetation in these areas contributes to lower rainfall runoff (more water retained in the soil) and slower erosion processes. As noted previously, thick understory brush tends to burn hotter and wildfires become more devastating, with fewer trees and other large vegetation surviving. Wildfires in the area over the last century have resulted in significant loss of mature vegetation and slower forest recovery. Most of the recent logging in the sub-area has occurred on private lands, with the exception of salvage logging on lands affected by forest fires.

Timber harvesting, water resources development, and environmental disasters have affected riparian vegetation systems in the sub-area. The riparian forests along the lower Sacramento, McCloud, and Pit rivers began diminishing as early as the mid- 1800s when trees were harvested and floated downstream to support ore smelters. Water development and hydropower projects, including associated channelization, dam construction, and streamflow regulation, have also altered natural riparian systems and contributed to vegetation loss along major stream corridors. In particular, riparian vegetation succession has been significantly hampered on the lower Pit River due to water diversions and flow fluctuations. On the upper Sacramento River, vegetation along the river corridor was nearly completely destroyed in 1991 when a railroad car overturned and spilled a toxic herbicide into the river. The riparian vegetation has since recovered and associated aquatic and terrestrial wildlife are increasing in numbers. More recently, urbanization and recreation have contributed to the loss of riparian vegetation along the lower tributaries and shoreline of Shasta Lake.

Shoreline vegetation around Shasta Lake provides important cover for aquatic species and shade to maintain cooler water temperatures. Within the drawdown area of the lake, fluctuating water levels, wave action, and erosion have resulted in the loss of all but the heartiest vegetation. The lack of vegetation along the shoreline at certain reservoir levels negatively affects shallow aquatic habitat, which is the primary rearing habitat for juvenile fish in the lake.

Also of concern in the sub-region are non-native plant species, which were introduced to the region by early settlers. Some of the more invasive exotic species out-compete native vegetation and have required management actions within the sub-area to prevent loss of habitat. However, these management actions have been limited and confined primarily to areas adjacent to campgrounds and FS facilities. Non-native species include yellow star thistle, Klamath weed (St. John's Wort), hedge parsley, several exotic grasses, and Himalayan blackberry. The region provides habitat for several special status plant species, as summarized in Table 11-3.

TABLE 11-3
POTENTIAL HABITAT IN THE SHASTA LAKE WATERSHED
FOR SPECIAL STATUS PLANTS

Species	Status	Habitat
Arnica venosa Veiny arnica	Endemic	Hot dry slopes under pine, black oak and Douglas fir; usually on North-facing aspects or ridge-tops, elevation: 1500-5000 feet
Cypripedium faciculatum Clustered lady's slipper	Sensitive	Mixed conifer or oak forests on a variety of soil types, often but not always associated with streams; 1300-6000 feet elevation; widespread but sporadic
Cypripedium montanum Mountain lady's slipper	Sensitive	Mixed conifer or oak forests on a variety of soil types, often but not always associated with streams; 1300-6000 feel elevation; widespread but sporadic
Lewisia cantelovii Cantelow's lesisia	Sensitive	Moist rock outcrops in broad-leaf & conifer forests; 500 to 3000 feet
Neviusia cliftonii Shasta snow-wreath	Sensitive	North facing slopes on limestone-derived soils, within riparian zones; 2400 to 3000 feet elevation

Source: Shasta Lake West Watershed Analysis, U.S. Forest Service, 2001.
Note: Elderberry bushes are present but not common in the region surrounding the lake, and tend to be too small or sparse to support the Valley Elderberry Longhorn beetle.

Aquatic and Fishery Resources

The following discussion of aquatic resources in the Shasta Lake and Tributaries sub-area is divided into two categories: resources within the lake itself, and resources within its tributaries.

Shasta Lake

Shasta Lake supports both a warm-water and cold-water fishery. Warm-water fish are primarily non-native, and include spotted bass, small-and largemouth bass, black crappie, channel catfish, and bluegill. Cold-water habitat in the lake is considered good and supports native rainbow trout, brown trout, kokanee salmon, and chinook salmon. Other native species found in the lake include white sturgeon, Sacramento blackfish, hardhead minnow, riffle sculpin, Sacramento sucker, and Sacramento squawfish. The principal non-fish aquatic resource of Shasta Lake is plankton, which forms the base of the food chain. Zooplankton is prey for the youngest lifestages of the reservoir's fish populations and for the most important forage species, threadfin shad. Prior to the construction of Shasta Dam, anadromous chinook salmon migrated into the upper Sacramento, McCloud, and Pit Rivers above the current location of Shasta Lake. At present, however, all chinook salmon in Shasta Lake are resident hatchery-raised fish. Rainbow trout, also native to the Sacramento River basin, are also planted in Shasta Lake during spring through summer, although some natural reproduction occurs in the tributaries to the reservoir.

Lake fisheries are significantly influenced by water temperature, with water temperatures above about 68 degrees Fahrenheit favoring warm-water fish such as bass and catfish, and lower temperatures favoring cold-water fish such as trout and salmon. Cooler temperature conditions in the major tributaries to the lake tend to attract fish to their outlets, particularly trout. For this reason, the lower reaches of the major tributaries provide important spawning habitat for resident lake fish. Habitat for warm-water species is influenced primarily by fluctuations in lake level and the availability of shoreline cover. The shoreline of Shasta Lake is generally steep, which limits shallow warm-water habitat and is less conducive to the establishment of vegetation or other shoreline cover. High rainfall and flood periods often deliver large woody debris to the lake; although woody structures provide valuable shoreline aquatic habitat, they are removed annually because they pose a hazard to boaters.

Tributaries to Shasta Lake

Fisheries in the tributaries to Shasta Lake include both native and planted species. Smaller streams entering the lake tend to be intermittent and only support fisheries during high flow or high reservoir fill periods. Rainbow trout is the principal game species of the lower reaches of the major tributaries to Shasta Lake, although brown trout and smallmouth bass also inhabit these streams. Other fishes include brook lamprey, redband trout, brook trout, speckled dace, chub, hardhead, Sacramento pikeminnow, carp, golden shiner, Sacramento sucker, brown and black bullhead, catfish, bluegill, sunfish, crappie, and sculpin. Other aquatic species that inhabit area streams or riverine corridors include crayfish, beaver, river otter, waterfowl, and various species of amphibians and reptiles including frogs, salamanders, and turtles. The following sections describe aquatic conditions and resources in the major tributaries to Shasta Lake.

- **Sacramento River Arm Tributaries** – The Sacramento River, Big Backbone Creek, and Sugarloaf Creek are perennial streams that support resident salmonids and native warm-water species, including rainbow trout, brown trout, Sacramento sucker, and Sacramento pikeminnow. Little Backbone and West Squaw creeks do not support fisheries due to acid mine drainage. During periods of high rainfall runoff, effluent from these drainages can cause fish kills in Shasta Lake. Aquatic resources in the Sacramento River are still affected by the 1991 spill of a toxic herbicide into the river, but fisheries have recovered significantly.

- **McCloud River Arm Tributaries** – The McCloud River's world-class sport-fishing reputation dates back to the late 1800s, when the first California fish hatchery was established on the McCloud River. The Baird and Greens Creek hatcheries collected McCloud River trout and trout eggs for export around the world, renown for their size and sport-angling qualities. The famed McCloud River bull trout were last found in the river during the mid-1970s and their extirpation has been attributed primarily to the construction in 1965 of McCloud Dam, which blocked spawning migrations and inundated prime spawning and rearing habitat. Attempts to reintroduce bull trout to the McCloud River from an Oregon population have been unsuccessful. Today, most of the land along the lower McCloud River is privately owned and fisheries resources are managed primarily for recreational sport fishing. The lower McCloud River is designated a Wild Trout Area and supports rainbow trout, brown trout, riffle sculpin, Sacramento pike minnow, Sacramento sucker, and hardhead. The McCloud River Preserve, owned by TNC, manages several miles of the McCloud River below McCloud Dam.

- **Pit River Arm Tributaries -**The Pit River is the most highly developed of the major tributaries to Shasta Lake. The numerous dams and hydropower diversions along the lower Pit River control flows and water temperatures and prevent movement of fish between river reaches. Nevertheless, the cold, clear waters and reservoirs of the lower Pit River support a healthy native and non-native fishery, including rainbow trout, brown trout, Sacramento Sucker, Pit sculpin, and smallmouth bass. Recently, a large influx of sand and other fine sediments entering the Fall River system has degraded submerged vegetation in the Pit River. Cattle grazing on lands immediately adjacent to area waterways has also degraded aquatic habitat and water quality.

Aquatic Species of Concern

Table II-4 summarizes threatened, endangered, and special status species that may occur in Shasta Lake or the lower reaches of its tributary rivers and streams.

TABLE 11-4
AQUATIC SPECIES OF CONCERN IN
THE SHASTA LAKE AND TRIBUTARIES SUB-AREA

Species	Status	Habitat Specifics
Federal and State Threatened and Endangered Species		
California red-legged frog	FT	Still or slow-moving water w/shrubby riparian vegetation. Extinct in project area.
Bull trout	SE, FT	McCloud River
Rough sculpin	ST	Pit River drainage
Shasta crayfish	SE, FE	Middle Pit River drainage
Species of Special Concern		
Hardhead Minnow	SC	Shasta Reservoir and mouths of tributaries
Bigeye marbled sculpin	SC	Pit River drainage
Pit roach	SC	Middle and lower Pit River
McCloud River redband trout	SC	Upper McCloud River
Foothill yellow-legged frog	SC	Shallow river and streams with gravel bottoms
Western spadefoot toad	SC	Vernal pools and ponds
Northwestern pond turtle	SC	Moderate to deep slow-moving rivers, ponds and streams with sunny banks.
Nugget pebblesnail	SC	Aquatic snail found in shallow-water habitats
California tiger salamander	SC	Wetland and vernal pools and adjacent uplands

FE= Federally endangered, SE= State endangered, FT= Federally threatened, ST= State threatened
SC= Regarded by the FWS, FS, and/or DFG as a species of special concern.
Note: Some of the species listed in this table have not been observed in the sub-area but are present in adjacent watersheds; or, thev are listed because suitable habitat is found in the sub-area.

Several of the species listed in Table 11-4 reside in the Pit River drainage. Some of theses species were impacted by the conversion of river habitat to reservoir habitat following the development ofhydropower facilities, such as rough, hardhead, and bigeye marbled sculpin, while others were impacted by fluctuating flows and power diversions.

The Pit River system also supports a population of endangered Shasta crayfish, the only species of crayfish native solely to California. This medium-sized crayfish prefers cool, spring-fed waters and volcanic cobbles. The Shasta crayfish is limited to the middle Pit River, including the Fall River and Hat Creek tributary drainages. The decline of the Shasta crayfish is due primarily to competition and predation by the signal crayfish, a non-native invasive species. The largest population was located on Sucker Springs Creek, where the California Department of Fish and Game (DFG) once operated the Pit River Hatchery. Artificial barriers to signal crayfish were removed when the hatchery was decommissioned in 1997, leading to a decline in the Shasta crayfish population. DFG is currently engaged in restoration and recovery actions for the Shasta Crayfish. Today, the largest population is found in Spring Creek, a Fall River tributary.

Wildlife Resources

A variety of wildlife are present in the areas surrounding Shasta Lake, including black-tailed deer, elk, black bear, lion, bobcat, gray squirrel, turkey, and rabbit. Avian species include quail, falcon, eagle, turkey, dove, pigeon, hawk, woodpecker, ash-throated flycatcher, Hutton's and warbling vireos, and house sparrow. The area provides excellent habitat for deer and elk, and suitable habitat for numerous bat species, although there have been few confirmed bat sightings. Several other wildlife species inhabited the sub-area prior to European settlement but were extirpated by over-hunting or because they were seen as threats, including grizzly bear, wolf, and various species of elk.

Timber harvesting, fire suppression, recreation, and wildfires have also affected the population and distribution of wildlife in the region. Fire suppression, which has generally increased understory vegetation, has had mixed effects on wildlife. Bear, deer, and birds that prefer near-ground vegetation for food and cover have generally benefited, while birds requiring aerial foraging, such as the golden eagle, peregrine falcon, and great-horned owl, have declined. Species that have adapted or thrived in the altered human environment include coyote, raccoons, and various late-successional species. Potential bat habitat, found primarily in the limestone formations to the north and east of the lake, has suffered from increased use by recreational rock climbers and spelunkers. Wildlife may also be impacted by a lack of contiguous travel corridors in certain portions of the sub-area that prevent species from moving between remaining suitable habitat.

Threatened, endangered, and special status wildlife species that inhabit, or are believed to inhabit, the Shasta Lake and tributaries sub-area are included in Table II-5. Shasta Lake is home to the largest concentration of nesting bald eagles in California. There are three bald eagle territories on the Sacramento River arm alone: Little Squaw, Bass Point, and Frost Gulch. Bald eagles also nest near Lake Britton and along the lower Pit River. The High Complex Fire of 1999, which killed numerous large pines, may have affected potential nesting and roosting areas around Shasta Lake.

TABLE 11-5
SPECIAL ST A TUS WILDLIFE IN THE
SHASTA LAKE AND TRIBUTARIES SUB-AREA

Species	Status	Habitat Specifics
Federal and State Threatened and Endangered Species		
American Peregrine falcon	FE, SE	Limestone formations and vertical cliffs with ledges
Bald Eagle	FT, SE	Riparian zones along larger rivers and open water areas w/large trees for nesting and roosting
Northern spotted owl	FT	Mature, late-successional and old growth forests
Shasta salamander	ST	Cool, moist microclimates around limestone caves or outcrops
Valley elderberry longhorn beetle	FE	Riparian; requires mature elderberry bushes
Willow flycatcher	SE	Large clumps of willow
Wolverine	ST	Heavily forested areas
Yellow-billed cuckoo	SE	Riparian forests greater than 50 acres
Species of Special Concern		
American Marten	SC	Mature mixed conifer forest under 4,000 feet
California quail	SC	Forested areas near riparian zones
Cooper’s hawk	SC	Riparian zones
Fringed myotis	SC	Upland habitat including caves, mines, or other roost sites
Golden Eagle	SC	Riparian zones along larger rivers and open water
Merlin	SC	Riparian zones for wintering habitat
Northern goshawk	SC	Conifer forests
Osprey	SC	Riparian zones along larger rivers and open water areas w/large trees for nesting and roosting
Pacific fisher	SC	Mature, dense forest under 6,000 feet
Pallid bat	SC	Upland habitat including caves, mines, or other roost sites
Purple marten	SC	Riparian forests
Small-footed myotis	SC	Upland habitat including caves, mines, or other roost sites
Sharp-shinned hawk	SC	Riparian zones
Townsend’s big-eared bat	SC	Upland habitat including caves, mines, or other roost sites
Vaux’s swift	SC	Coniferous (Douglas fir) habitat; snags
Yellow warbler	SC	Riparian scrub/forests

FE= Federally endangered, SE= State endangered, FT= Federally threatened, ST= State threatened, SC= Regarded by the FWS, FS, and/or DFG as a species of special concern.
Note: Some of the species listed in this table have not been observed in the sub-area but are present in adjacent watersheds; or, they are listed because suitable habitat is found in the sub-area.

Potential habitat for spotted owl in the vicinity of Shasta Lake are too fragmented by fire and logging activities to be viable at this time. Survey and Manage species identified in the Northwest Forest Plan (NFP) that inhabit the Shasta Lake area include hesperion snail, church sideband snail, long-eared myotis, fringed myotis, long-legged myotis, pallid bat, and silver-haired bat. Survey and Manage species are provided with additional protection under the NFP, which provides guidelines for species surveys, management, and mitigation measures. Around the Sacramento River arm in particular, habitat for Survey and Manage species has been degraded by wildfires.

Water Quality

The following discussion on water quality in the sub-area is divided into issues associated with Shasta Lake itself and those associated with its tributaries.

Shasta Lake

Water quality within Shasta Lake is generally considered good, due largely to the continual inflow of cool, high-quality water from the major tributaries to the lake. The average annual inflow volume to Shasta Lake is approximately one and one half times the total storage volume in the lake, contributing to a high turnover rate of water within the reservoir (about a one-year residence time). Water temperatures in Shasta Lake support both warm- and cold-water habitats. Water temperatures in the upper surface layer can peak at 80 degrees Fahrenheit during the summer. Deeper layers of the lake provide cold-water habitat throughout the year.

The primary water quality concerns in the lake are acid mine drainage and turbidity, typically associated with heavy rainfall events that move toxic runoff and soils from abandoned mines into the lake. Periods of high acid mine drainage into the lake have caused localized fish kills, particularly in the Little Backbone and West Squaw Creek areas. Sediment enters the lake from tributary streams; fine sediment has increased over the past century due to human activity such as timber harvesting, wildfire suppression, and road construction. In addition to sediment entering from tributaries, shoreline erosion caused by wavewash or reservoir drawdown also contributes to turbidity problems in the lake. High turbidity impairs juvenile feeding and egg viability in resident lake fishes. Secondary water quality issues include waste discharges from houseboats and pollution from personal watercraft engines.

Tributaries to Shasta Lake

Water quality is excellent in the lower reaches of the major tributaries to Shasta Lake: the Sacramento River, the McCloud River, Squaw Creek, and the Pit River. The primary water quality concerns are turbidity and acid mine drainage. Fine sediment derived from unpaved roads is a significant water quality concern, particularly in smaller streams. Accelerated erosion from high-intensity wildfire sites and natural mass-wasting also contributes to bedload in area streams. Water quality in the western tributaries to Shasta Lake is impaired primarily by acid mine drainage and heavy metals contamination. Little Backbone Creek and West Squaw Creek are considered biologically dead due to effluent from abandoned mines. Water temperature, another indicator of water quality, can be effected by the removal of vegetation and natural forest canopy. In the Pit River watershed, livestock grazing adjacent to waterways has degraded water quality by increasing sediment input and introducing fecal coliform and other bacteria.

SACRAMENTO RIVER FROM SHASTA DAM TO RED BLUFF

Downstream from Shasta Dam, the Sacramento River flows through a narrow canyon until it reaches Redding, where it enters the northern limits of the Central Valley. Immediately below Keswick Dam the river is deeply incised in bedrock with very limited riparian vegetation. Near Redding, the river flows into a somewhat broader floodplain of alluvium derived from tributary streams entering from the east and west, with riparian and floodplain ecosystems adjacent to the river and forming corridors along the tributaries. Downstream from Red Bluff the river landscape changes significantly as it enters the broad alluvial floodplain of the Sacramento Valley.

Climate, Hydrology, and Water Resources

The sub-area generally has a Mediterranean-type climate with hot, dry summers and cool, wet winters. Average temperatures range from about 60 degrees Fahrenheit in the low valley regions to about 40 degrees Fahrenheit in mountain areas. Summer temperatures in the Valley tend to be very warm, often exceeding 100 degrees Fahrenheit. Rainfall varies throughout the sub-area, with some lower valley areas receiving less than 20 inches and some mountainous areas experiencing more than 70 inches. Snowfall occurs in the adjacent mountains and foothills, with a semi-permanent snowpack generally occurring over 5,000 feet in elevation. Major floods are typically a result of rain-on-snow events that result in a rapid melting of the winter snowpack. Eastside tributaries to the Sacramento River typically originate in the Cascade Range and include Stillwater, Cow, Bear, Battle, and Paynes creeks. Perennial and intermittent westside tributaries originate in the Klamath Mountains or foothills, and include Clear and Cottonwood creeks.

Water resources development, including the construction of dams and diversions, has impacted the hydrology, geomorphology, and ecology of the sub-area. Many of these impacts have been detrimental to local habitats and species. Prior to the construction of Shasta Dam, the Sacramento River typically experienced large fluctuations in flow driven by winter storms, with late-summer flows averaging 3,000 cfs or less. These fluctuations and periodic floods moved large amounts of sediment and gravel out of the mountainous tributaries and down the Sacramento River. The completion of Shasta Dam in 1945 resulted in a general dampening of historic high and low flows, reducing the magnitude of winter floods while maintaining higher summer flows between 7,000 and 13,000 cfs. As shown in Figure 5, the annual volume of flow in the Sacramento River (top portion of figure) continues to vary significantly from year to year. However, average monthly flows for periods prior to and following the construction of Shasta Dam (bar charts at bottom of figure) no longer exhibit pronounced seasonal winter highs and summer lows. This is due primarily to winter flood control operations that have reduced peak flood flows, and summer releases made for water supply purposes.

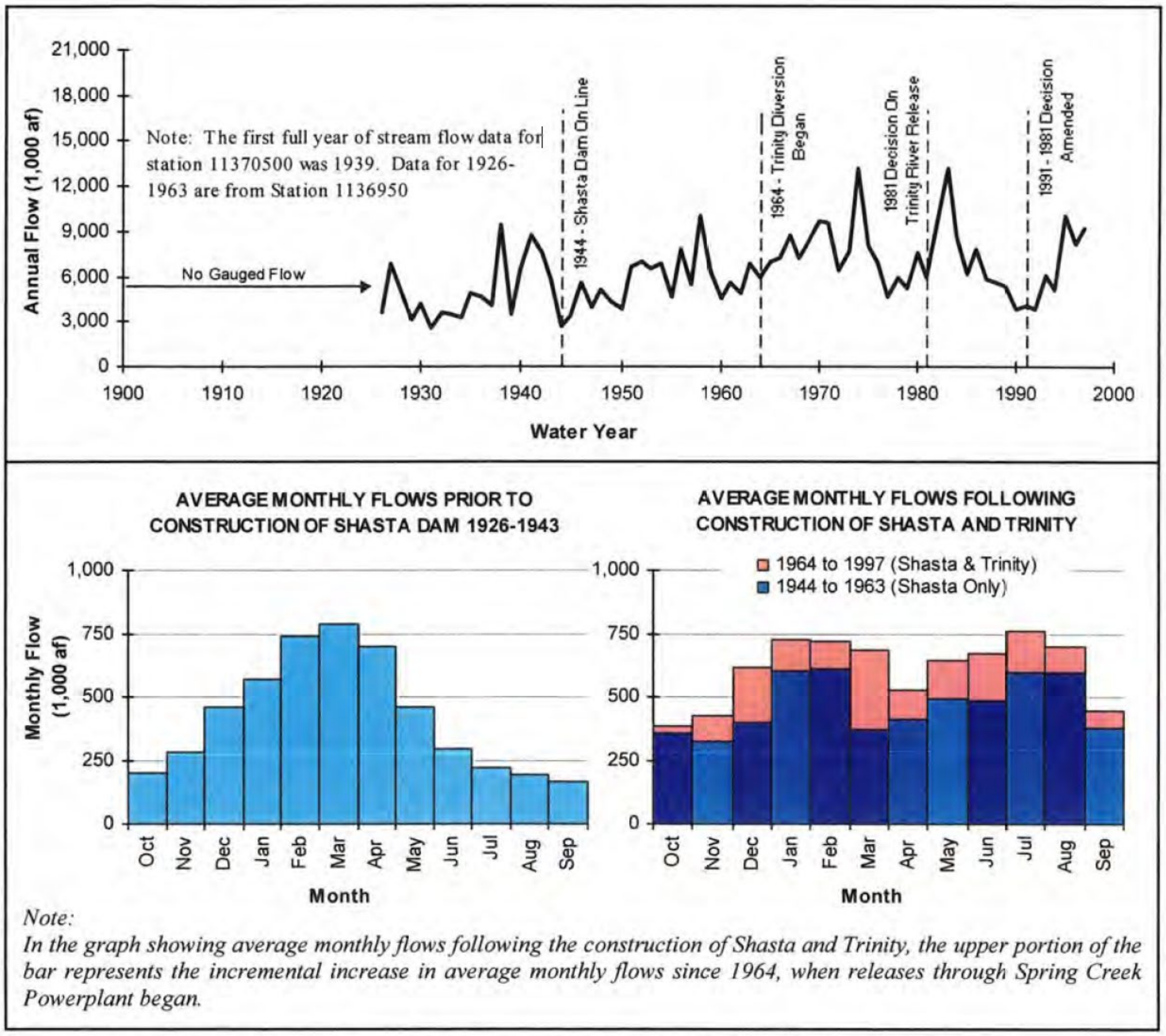


Figure 5 - Historic Streamflow in the Sacramento River below Keswick Dam

The major hydropower and water resources development projects in the sub-area - Shasta Dam, Keswick Dam, and the Spring Creek Tunnel - were constructed as part of the Shasta-Trinity Division of the CVP. These and other major hydroelectric facilities in the sub-area are discussed below and summarized in Table 11-6.

TABLE 11-6
MAJOR HYDROELECTRIC FACILITIES IN THE SHASTA DAM TO RED BLUFF SUBAREA

Facility Group	Reservoirs	Storage Capacity (acre-feet)	Powerhouse	Power (MW)
Shasta-Trinity Division CVP	Shasta Keswick Whiskeytown *Total*	4,552,000 20,000 240,000 *4,812,000 AF*	Shasta Keswick Spring Creek *Total*	629 117 180 *926 MW*
Kilarc-Cow Creek (PG&E)	Kilarc Forebay Cow Creek Forebay *Total*	30 5 *35 AF*	Kilarc Cow Creek *Total*	3.2 1.8 *5 MW*
Clover Creek (Olson Power)	No significant storage		Clover Creek	5
Battle Creek (PG&E)	North Battle Ck Reservoir Macumber Reservoir Lake Grace Lake Nora Coleman Forebay *Total*	430 1,090 50 10 80 *1,660 AF*	Volta No. 1 Volta No. 2 South Inskip Coleman *Total*	9 0.9 7 8 13 *40 MW*

Source: Data for Cow Creek and Battle Creek projects provided by PG&E Draft Environmental Impact Report for Hydropower Divestitures, November 2000

- Shasta Dam - The 4.5 MAF reservoir impounded by Shasta Dam provides water supply for agricultural, environmental, and municipal/industrial users throughout the CVP. The facility also provides flood control, temperature control for the Sacramento River, and hydropower. The Shasta Powerplant has five generating units with a total rated capacity of 629 megawatts (MW).
- Keswick Dam - was constructed on the Sacramento River downstream from Shasta Dam for the primary purpose of power generation. It is a concrete gravity dam, 157 feet high, 1,046 feet long, and 20 feet wide at the crest. The Keswick Powerplant has three generating units with a total capacity of 117 MW.
- Whiskeytown Reservoir - Whiskeytown Reservoir on Clear Creek receives water from the Trinity River Basin and delivers it to the Sacramento River via the Spring Creek Tunnel. All but about 13 percent of the flows in Clear Creek are diverted through the Spring Creek Tunnel and discharged into Keswick Reservoir. The only other major dam on Clear Creek, McCormick-Saeltzer Dam, was removed in the 1990s. The Spring Creek Powerplant receives flow from Whiskeytown Lake via the Spring Creek Tunnel. The tunnel and powerplant discharge into Keswick Reservoir and are often used to dilute releases of acid mine drainage from the Spring Creek system.
- Cow Creek - There are eight small hydroelectric facilities, seven dams, and over 150 water diversions in the Cow Creek watershed. Most of the water diversions supply local agriculture.

- **Battle Creek** – There are numerous water diversion facilities in the Battle Creek stream system that can significantly alter flows, particularly during the dry season. A complex system of canals, flumes, and diversions conveys water between the various Battle Creek branches and tributaries, primarily for the purpose of hydropower. PG&E owns and operates the majority of these facilities, and has primary control over flows in Battle Creek. The Eagle Canyon, Wildcat, and Coleman dams have been evaluated by Reclamation previously for potential removal to restore access to historic salmonid spawning grounds.

There are two major diversions from the Sacramento River within the sub-area: the ACID Diversion Dam in Redding, and the RBDD in Red Bluff. Diversions from the ACID facility can cause fluctuations in Sacramento River flows that impact anadromous fish. Fish ladders at the ACID diversion facility were reconstructed in 2000. The RBDD facility includes two fish ladders and raises its gates during critical spawning periods, but nevertheless, poses a barrier to upstream migration of anadromous fish. High mortality often occurs in Lake Red Bluff, formed by the RBDD, where predatory fish and birds prey on in- and out-migrating fish.


ACID Diversion Dam near Anderson
Source: NOAA Photo Library

Geology

The sub-area encompasses portions of the Cascade Range, Klamath Mountains, and Great Valley geomorphic provinces. The Cascade Range to the east is comprised primarily of volcanic formations and volcanic sedimentary deposits, including the Tuscan Formation and Montgomery Creek Formation. The Klamath Mountains to the north and west are comprised of older bedrock materials, sedimentary basin deposits, and volcanic deposits, and includes the Bully Hill Rhyolite, Pit, and Hosselkus Limestone formations. The lower valley areas fall within the Great Valley geomorphic province, a large, elongated trough filled with loose sediments ranging from Jurassic to recent. Principal formations include the Tehama, Riverbank, Chico, and Red Bluff formations, which contain marine and non-marine sedimentary rocks eroded from the surrounding Cascade Range and Klamath Mountains. These fluvial formations are comprised of silt, sand, clay, and gravel.

Not unlike the Shasta Lake and Tributaries sub-area, mineral resources spurred settlement and urban development in the mid-1800s. Gold was discovered along Clear Creek in the 1840s, leading to hydraulic mining and the release of large amounts of sediment into the Sacramento River. Cottonwood Creek, in particular, was intensively mined for gold and large deposits of dredge tailings can still be found within the watershed. Although gold was not mined on the eastside of the Sacramento River, copper, coal, gravel, and stone have been mined extensively in the eastern portion of the sub-area. Copper mines and smelters were numerous in Shasta County, including the Afterthought and Donkey Mines, Coram Smelter downstream from Shasta Dam, Keswick Smelter near Clear Creek, and the Ingot Smelter located in the Cow Creek watershed. Sulfur emissions from smelters are estimated to have damaged or destroyed over 150,000 acres of vegetation in Shasta County, extending as far south as Red Bluff. Although most of the mines are closed today, acid drainage from the mines has resulted in high concentrations of metals in many area streams. Several mines that currently impact the sub-area are described below.

- **Iron Mountain Mine** - Perhaps the largest and most damaging mining operation in the subarea is the Iron Mountain Mine, located approximately nine miles northwest of Redding. The Iron Mountain ore body is estimated to have contained 20,000,000 tons of sulfide ore prior to the onset of mining activity in 1865. Copper, zinc, gold, silver, and pyrite were mined at the site between the 1860s and I 960s. The primary concern associated with the mine is acid mine drainage, which results when oxygen and water react with exposed sulfide deposits and form sulfuric acid. Sulfuric acid then leaches metals out of the soil, which are carried to and concentrated in area streams. It is estimated that during the winter of 1984, almost 2,000 pounds per day of copper, zinc, and cadmium were discharged from the mine site. The site is drained by several creeks tributary to Spring Creek, which enters the Sacramento River about a mile upstream of Keswick Dam. Many of these drainages are highly contaminated and devoid of aquatic life. Water impounded in Keswick Reservoir helps to dilute acid mine drainage entering the Sacramento River from Spring Creek during periods of high runoff. The higher pH of the waters in Keswick Reservoir causes metals to precipitate out, forming several distinct sediment deposits of heavy metals in the reservoir. It is believed that drainage from the mine has been partially responsible for the decline in fisheries populations in the Sacramento River. The U.S. Environmental Protection Agency (EPA) became involved in cleanup activities at the mine when it was designated a Superfund Site, one of the largest in the United States. A key remediation action involved the diversion of Upper Spring Creek through the Clear Creek Tunnel to Keswick Reservoir, to help regulate releases to the Sacramento River. Other actions have included capping areas of the mine, diverting smaller drainages, construction of detention dams, and onsite remediation of acid mine drainage. Cleanup actions are estimated to have reduced the acid and metal contamination leaving the site by up to 80 percent.

Iron Mountain Mine
Source: NOAA Photo Library

- **Afterthought Mine** - This abandoned mine located near Ingot in the Cow Creek watershed produced gold, copper, zinc, and some silver. An onsite smelter operated at the mine for eight years. Current issues at the mine site include high levels of mercury, zinc, lead, arsenic, and iron; acid mine drainage into Little Cow Creek; exposed tailings and tailing ponds; and access to mine portals. The mine is privately owned, and the State Water Resources Control Board has imposed fines for waste discharges in the past.

- **Greenhorn Mine** - This abandoned mine is located west of Redding and discharges to Willow Creek, a tributary to the Whiskeytown Lake National Recreation Area. Acid mine drainage impacts aquatic life and recreational uses in the area. A feasibility study was prepared by California Department of Water Resources (DWR) under contract to the Regional Water Quality Control Board, but no remediation actions have been performed.

Today, sand and gravel are probably the most important mineral resources in the sub-area. For example, the Shasta County Department of Resource Management reported that in 1996 Shasta County produced 441,000 tons of sand and gravel, 621,000 tons of crushed stone, and 77,000 tons of volcanic cinders. There are numerous active and inactive gravel mines along or adjacent to the Sacramento River and its tributaries, as summarized in Table II-7.

TABLE 11-7
INSTREAM AND OFFSTREAM GRAVEL MINES
IN THE SHASTA DAM TO RED BLUFF SUB-AREA

Stream System	Type	Status	Yield (cu-yd/yr)
Blue Tent Creek	Instream	Active	25,000
Blue Tent Creek	Instream	Inactive	
Blue Tent Creek	Instream	Inactive	
Boulder Creek	Instream	Inactive	
Churn Creek	Offstream	Active	5,000
Churn Creek	Instream	Inactive	
Churn Creek	Offstream	Inactive	
Churn Creek	Offstream	Inactive	
Clear Creek	Offstream	Active	100,000
Clear Creek	Instream	Active	40,000
Clear Creek	Offstream	Active	50,000
Clear Creek	Offstream	Active	2,500
Clear Creek	Offstream	Active	5,000
Clear Creek	Offstream	Active	2,360
Clear Creek	Varies	Active	N/A
Clear Creek	Varies	N/A	
Cottonwood Creek	Instream	Active	40,000
Cottonwood Creek	Instream	Active	265,000
Cottonwood Creek	Instream	Active	20,000
Cottonwood Creek	Instream	Inactive	
Cottonwood Creek	Offstream	Inactive	
Cottonwood Creek	Varies	Inactive	
Cottonwood Ck Trb	Offstream	Inactive	
So FK Cottonwood	Offstream	Inactive	
Cow Creek	Offstream	Active	5,000
Little Cow Creek	Offstream	Active	100,000
Little Cow Creek	Instream	Inactive	
Little Cow Creek	Instream	Inactive	
Dibble Creek	Instream	Active	20,000
Dibble Creek	Instream	Active	10,000
Hooker Creek	Instream	Active	60,000
Hooker Creek	Instream	Active	50,000
Hooker Creek	Instream	Inactive	
Olinda Creek	Instream	Inactive	
Sacramento River	Offstream	Active	N/A
Sacramento River	Instream	Inactive	
Sacramento River	Offstream	Inactive	
Sacramento River	Offstream	Unknown	30,000
Sacramento R d/s Keswick	Instream	Inactive	
Sacramento R d/s Keswick	Offstream	Inactive	
Sacramento R d/s Keswick	Offstream	Inactive	
Sacramento R d/s Keswick	Offstream	Inactive	
Sacramento R u/s Olney	Offstream	Inactive	
Sacramento R d/s Clear Ck	Offstream	Inactive	
Sacramento R d/s Clear Ck	Offstream	Inactive	
Tributary d/s Clear Ck	Offstream	Inactive	
Sacramento R nr Red Bluff	Instream	Inactive	
Stillwater Creek	Instream	Inactive	
Stillwater Creek	Instream	Inactive	
Stillwater Creek	Instream	Inactive	
Stillwater Creek	Instream	Inactive	
Stillwater Creek	Instream	Inactive	
Stillwater Creek	Offstream	Inactive	

Instream gravel mining can cause undesirable damage to fish and wildlife resources by changing stream morphology, causing channel downcutting, damaging riparian vegetation, and removing potential sources of spawning gravel. Stream systems that have been heavily impacted include Clear, Cottonwood, Cow, and Dibble creeks. Several area mines are required to provide gravel to DFG for spawning gravel replacement on the Sacramento River as part of their operating agreements.

Geomorphology

In alluvial river sections, bank erosion and sediment deposition cause migrations of the river channel that are extremely important in maintaining instream and riparian habitats. In the Sacramento River, these processes are most important in the major alluvial section of the river, which begins downstream of the RBDD. The river channel in the Keswick Dam to RBDD reach is more constrained by erosion-resistant volcanic and sedimentary formations and, therefore, is more stable.

The Sacramento River below Keswick Dam *is scoured to bedrock, with little instream gravel resources for spawning. Source: NOAA Photo Library*

The main effect of Shasta and Keswick Dams on sediment transport has been to block the sediments that would normally have been transported from the upper Sacramento River Basin. The result has been a net loss of sediment in the Sacramento River below Keswick Dam. The high winter and spring flows discharged from Keswick Dam contain a low sediment load and therefore transport sediments from the riverbed below the dam further downstream. One consequence of this process has been a steady loss of spawning gravels from the river in the Keswick Dam to Clear Creek reach. Sediment-free flows from Keswick Dam tend to scour the river channel downstream from the dam, leaving only the coarsest boulders and cobbles. Below Clear Creek, tributary streams increase in importance as a source of spawning gravels to the Sacramento River.

The problem of gravel availability in the Sacramento River is exacerbated downstream from Keswick Dam by dams constructed on Sacramento River tributaries, bank protection measures along the mainstem of the Sacramento River, and instream gravel mining. In the recent past, Reclamation, DWR and DFG have cooperated in actions to artificially replenish salmon spawning gravel in the reach.

On the tributaries, human induced impacts to river morphology include livestock grazing, urbanization and related infrastructure construction, riparian vegetation removal, gravel mining, bank protection, dams, and water diversions. The major tributary streams have developed multiple terraces adjacent to the stream channels. Some have developed small fan deposits of gravels at their mouths, but large fans are more typical of the tributaries downstream from Red Bluff. Some tributaries also include artificial deposits of mine tailings, such as Cottonwood Creek, either washed downstream from mining in the mountains or left by floating dredges. The eastside streams tend to produce less gravel because they drain steep, resistant volcanic terrain. The westside streams produce the majority of gravel entering the Sacramento River because they flow through gravelly alluvial deposits subject to tectonic uplift. Sediment and gravel discharge changes from year to year depending upon hydrology and conditions in the watersheds, such as fires, mass wasting, timber harvesting, road construction, and changing land uses.

Vegetation and Habitat

The type and diversity of vegetation in the Shasta Dam to Red Bluff sub-area has changed significantly over the last 150 years. The primary factors influencing changes in vegetation and habitat are fire suppression and timber harvesting, land conversion, and invasive species. Fire suppression and timber harvesting methods through the mid-1900s created forests that were smaller, younger (less age diversity), and denser than those that existed prior to settlement. This resulted in intense and devastating wildfires in the late 1900s, leading to modern fuel reduction and prescribed burn practices. Intensive grazing and conversion of habitat to agriculture also affected some areas, particularly lowland grasslands and riparian areas.

In the mid-1800s, settlers brought cattle and other grazers that imported non-native grasses and other plants. Many of the exotic plants flourished and out-competed native vegetation. Today, numerous noxious and invasive plants are known to inhabit the sub-area, including yellow star thistle, arundo (giant reed), pampas grass, cheat grass, hydrilla, Scotch broom, Himalayan blackberry, medusahead, tree of heaven, and edible fig. These non-native species have significantly altered native habitats, particularly riparian and grassland communities, by changing vegetation density, water demand, and overall ecology.

Habitat communities in the Shasta Dam to Red Bluff sub-area include valley and foothill grasslands, chaparral, riparian forests, blue oak and foothill pine woodlands, and coniferous forests. Non-native habitats include agricultural fields and grazing lands. These habitats and associated environmental conditions are described briefly below.

Grassland habitats are typically located in the lower elevation foothills and valley floor. Grassland communities have been the most sensitive to non-native invasive species, as well as fire suppression. Today, native grasslands typically only exist in small patches within non-native grasslands and agricultural rangelands. Chaparral habitat is most common in the more arid valley and foothill areas to the east of the Sacramento River, extending to an elevation of about 3,500 feet. Chaparral communities include Oregon oak, whiteleaf and common manzanita, and other shrub species.

Vegetation in the river corridor varies from oak/gray pine and chaparral communities with very limited riparian vegetation above Redding, to riparian ecosystems and agricultural lands from Redding to Red Bluff. While flooding of the lands adjacent to the river was an annual event lower in the Sacramento River system, the river above Red Bluff is more confined and entrenched. Consequently, riparian habitats are limited to areas immediately adjacent to the Sacramento River and along tributary streams. Historically, these small areas probably did not contain the breadth of habitat necessary to support the complex riparian ecosystem found in the gallery riparian forests south of Red Bluff. Riparian forest communities in the sub-area include cottonwood, alder, ash, sycamore, walnut, willow, and Valley oak.

A breakdown of riparian habitats within the 100-year floodplain between Keswick Dam and Red Bluff is shown in Table II-8. Non-native species, urban development, and water resources development have reduced and fragmented riparian communities, particularly along the Sacramento River, Battle Creek, and Cow Creek. Freshwater marsh, vernal pools, seeps, Montane wet meadows, and other wetland communities are also highly fragmented and scattered throughout the sub-area.

TABLE II-8
RIPARIAN AND RELATED HABITATS WITHIN THE 100-YEAR FLOODPLAIN, SACRAMENTO RIVER BETWEEN KESWICK DAM AND RED BLUFF

Vegetation Type	Acres	Percent of Land Surface Area
Riparian Forests	2,801	15%
Riparian Scrub	1,439	8%
Valley Oak Woodland	315	2%
Marsh	58	<1%
Blackberry Scrub	61	<1%
Total Riparian Vegetation	***4,674***	***26%***

Woodland communities in the sub-area include Blue Oak, Foothill Pine Oak, Open Foothill Pine, and Non-Serpentine Foothill pine woodlands. These communities occur within the mid- to upper foothills, with elevations ranging from valley floor to over 3,500 feet. Unlike the highly fragmented riparian communities, woodland communities are found along nearly continuous elevation bands or belts, both to the east and west of the Sacramento River. The primary factor influencing woodland habitat communities has been fire suppression, which has affected the regeneration of taller, overstory species and encouraged the development of dense shrub communities. Understory vegetation includes manzanita, poison oak, California redbud, and various non-native species.

Mixed conifer forests occur in the higher foothill and mountain elevations within the sub-area, typically above 2,000 feet. Dominant species include ponderosa pine, incense cedar, sugar pine, Douglas fir, and white fir. Fire suppression has been the major factor affecting the health of mixed conifer habitat within the region, resulting in increasingly dense understory vegetation. A limited amount of white fir and red fir true conifer forest exists to the mountains to the east of the Sacramento River, primarily above 5,000 feet.

Table II-9 includes a list of special status plant species that inhabit, or may inhabit, the sub-area.

TABLE II-9
POTENTIAL HABITAT IN THE SHASTA DAM TO RED BLUFF SUB-AREA FOR SPECIAL ST ATOS PLANTS

Species	Status	Habitat
Paronychia ahartii Ahart's Paronychia	Endemic	Well-drained, rocky outcrops, vernal pool edges, and volcanic uplands below 1650 feet
Eleocharis quadrangulate Four Angled Spike Rush	Sensitive	Freshwater wetlands and marsh habitats; Shasta and Tehama counties
Orcuttia Tenuis Slender Orcutt Grass	Federal Threatened/ State Endangered/ Endemic	Bottom of vernal pools typically underlain by volcanic substrates, between 100 and 5800 feet elevation
Cordylanthus palmatus Palate-Bracted Bird's Beak	Federal Threatened/ State Endangered/	Valley and foothill grasslands and scrub habitat
Gratiola heterosepala Boggs Lake hedge-hyssop	State Endangered	Vernal pools, marshes, and shallow lake-margin habitat
Limnanthes Floccosa SSP Bellingeriana Bellinger's Meadowfarm	Endemic	Meadoes and seeps, woodland, and damp stony flats
Eriastrum brandegeae Brandegee's Eriastrum	Sensitive	Chaparral habitats and open woodlands
Cryptantha crinita Silky Cryptantha / Ribbed Cryptantha	Endemic	Gravelley soils, usually non-wetland
Clarkia Borealis SSP Arida Shasta Clarkia	Endemic	Endemic to Shasta County woodlands
Neviusia cliftonii Shasta snow-wreath	Sensitive	North facing slopes on limestone-derived soils, within riparian zones; 2400 to 3000 feel elevation
Neviusia cliftonii Shasta snow-wreath	Sensitive	North facing slopes on limestone-derived soils, within riparian zones; 2400 to 3000 feet elevation
Astagalus tener var. ferrisiae Ferris' Milk-vetch	Sensitive	Chaparral, open woodlands, valley and foothill grasslands; primarily found in serpentine areas

Aquatic and Fishery Resources

The Upper Sacramento River system once supported large populations of anadromous fish that migrated from the Pacific Ocean into the cool, clear tributary streams to spawn and rear. But human activity in the upper Sacramento River has had a profound effect on both anadromous and native resident fisheries in the Shasta Dam to Red Bluff sub-area. Water resources development in the region began with the construction of small water supply diversions and hydropower facilities in the late 1800s and early 1900s, and culminated in the construction of large water resources projects such as Shasta and Keswick dams. These facilities have modified seasonal flow regimes, water temperature, gravel recruitment, and fish migration corridors. This section will discuss these and other conditions associate with aquatic and fisheries resources in the Sacramento River and its tributaries between Shasta Dam and Red Bluff.

Existing Aquatic Resources in the Sacramento River

Keswick Reservoir provides intermediate habitat for both warm-water and cold-water fisheries. This intermediate habitat is largely a result of the speed at which water moves through the nine-mile long reservoir, and water temperatures in the reservoir. Residence time in Keswick Reservoir is about a day, compared with a residence time of about a year for water in Shasta Lake. Consequently, water temperatures tend to be controlled by releases from Shasta Dam and average less than 55 degrees Fahrenheit. Despite the cool temperatures, the reservoir supports both warm-water and cold-water fishes, including largemouth bass, crappie and catfish, and rainbow trout.

Downstream from Keswick Dam, the Sacramento River flows for about 59 miles to the RBDD. The river in this reach has a stable, largely confined channel with little meander. Despite net losses of gravel since the construction of Shasta Dam, riffle habitat with excellent gravel substrates and deep pool habitats are present. The sub-reach contains a large assemblage of resident and anadromous fish species. It is unique among rivers in North America because is supports four separate runs of chinook salmon. Central Valley steelhead trout also occur in the Sacramento River upstream of Red Bluff. Central Valley steelhead may have lost comparatively more spawning habitat after the construction of Shasta and Keswick dams because they historically migrated even further up the Sacramento River and its tributaries than chinook salmon.

In addition to anadromous salmonids, the Sacramento River contains resident rainbow trout and other native and introduced fish. Rainbow trout are particularly abundant, largely attributed to cool summer flows designed to enhance habitat conditions for winter-run salmon. Other native species that reside in the Sacramento River upstream of Red Bluff include Sacramento pikeminnow, Sacramento sucker and hardhead minnow. White sturgeon and green sturgeon are native anadromous species that have been found at the RBDD, but it is not known whether these species migrate upstream of the dam.

Hatcheries play an important role in supporting fisheries resources in the sub-area. Today, the fall-run, late fall-run and winter-run chinook salmon stocks and the Central Valley steelhead stocks in the Keswick Dam to Red Bluff reach are augmented by production from the Coleman National Fish Hatchery on Battle Creek. However, concern is growing that the release of large numbers of hatchery fish can threaten wild fish populations. Potential impacts include direct competition for food and other resources between wild and hatchery fish, predation of hatchery fish on wild fish, genetic dilution of wild fish stocks by hatchery fish allowed to spawn in rivers, and increasing fishing pressure on wild stocks due to hatchery production.

Decline in Anadromous Fish Species

Many factors have contributed to the decline in chinook salmon and other anadromous fish in the upper Sacramento River, but the elimination of access to hundreds of miles of historic spawning habitat with the construction of Shasta Dam is widely considered the most important factor.

Fortunately, cold water released from Shasta Dam created new spawning habitat in the reach below Keswick Dam. Without these cold-water releases, the winter-run would possibly have been extirpated. At present, winter-run spawning habitat is almost entirely restricted to the Sacramento River between Keswick Dam and the RBDD and, thus, the survival of winter-run chinook is strongly tied to habitat conditions in this reach.

In addition to blocking upstream migration, the construction of Shasta Dam eliminated the primary source of coarse gravel recruitment in the upper Sacramento River. Historically, gravel was transported downstream from mountainous tributaries by high flows, armoring the streambed. The reduction in gravel supply is particularly evident in the first 15-20 miles downstream from Keswick Dam, where the river channel is degraded and streambed and bank erosion have occurred. Below Clear Creek, tributary streams increase in importance as a source of spawning gravels to the Sacramento River, particularly Cottonwood Creek. Although current gravel resources are considered by some to be adequate to support existing adult salmonid spawning populations, gravel resources may become a limiting factor as the population increases.

Streamflow also influences the quantity, quality, and distribution of chinook salmon and steelhead spawning and rearing habitat. Streamflow directly affects the amount of available habitat, facilitates downstream migration of juveniles and smolts, provides environmental cues for upstream migrating adults, and indirectly affects water temperature and other water quality parameters. Flow reductions during the incubation period potentially cause inadequate intragravel flow and dewatering of redds, while high flushing flows can remove harmful quantities of sediment and plant growths from the spawning gravels. Flow fluctuations often result in stranding of juveniles in side channels. Stranding of juvenile winter-run chinook salmon has occurred in the upper Sacramento River following rapid flow reductions associated with operation of the ACID diversion dam. Reclamation provides minimum flows below Keswick Dam for fall-run chinook salmon that range from 2,300 to 3,900 cfs in normal water years and from 2,000 to 2,800 cfs in critically dry years, and it has reduced flow fluctuations, or ramping rates, from September through December.

Fish passage problems continue to plague the salmon and steelhead runs in the Sacramento River downstream from the major dams. Entrainment of juvenile salmon and steelhead in agricultural diversions is an important source of mortality on the Sacramento River and its tributaries. The ACID diversion canal is screened but diversion operations can cause rapid fluctuations in Sacramento River flows that disrupt upstream migration. Farther downstream, construction of the RBDD inundated salmon spawning habitat in the Sacramento River upstream of the dam, but more importantly, the dam impeded passage of upstream-migrating adult salmon past the dam and caused excessive losses of downstream-migrating juvenile fish due to predators. To improve upstream passage of adult winter-run chinook salmon upstream past the dam, Reclamation raises the gates at the dam from September through May and operates two fish ladders. Reclamation is currently participating in a study to develop alternatives for improving fish passage at dam.

Although largely unquantified, water quality impacts on fish populations in the Sacramento River and its tributaries include effects related to heavy metal pollution (primarily related to acid mine drainage releases from Spring Creek Dam), high suspended sediment levels, and elevated nutrient, herbicide, and pesticide levels from agricultural drainage.

Aquatic Resources on Tributary Streams

The tributaries to the Sacramento River also support important aquatic resources, and many provide suitable habitat for anadromous and resident fish. This includes both perennial and intermittent tributary streams. However, aquatic resources on many of the tributaries have suffered from the same problems experienced on the Sacramento River, including dams, diversions, and hydropower projects. The following describes aquatic resource conditions on the major tributaries: Clear Creek, Battle Creek, Cow Creek, and Cottonwood Creek.

Clear Creek

The lower reaches of Clear Creek support limited anadromous and resident fisheries. Aquatic habitat on Clear Creek has been affected by diversions to the Spring Creek Powerplant, leaving only 10 percent to 15 percent of flows within Clear Creek. Aquatic habitat has been further degraded by heavy sedimentation, pollution from abandoned mines, urban encroachment on riparian corridors, and reduction of spawning gravels. Clear Creek has been identified by the Upper Sacramento Fisheries and Riparian Habitat Management Plan as having the potential to support additional anadromous fisheries, including chinook salmon and steelhead, if improvements are made in the lower 16 miles of the river. Several of these improvements have already been initiated, including the removal of McCormick Saeltzer Dam, gravel replenishment programs, and riparian habitat and channel restoration work.

Cow Creek

Lower Cow Creek supports fall-run chinook salmon and a limited late-fall-run, but is not believed to support endangered winter-run chinook salmon. Steelhead have been observed in Cow Creek and some of its tributaries, but the extent to which they inhabit the stream system is unknown. DFG and FWS have identified Cow Creek as a candidate for restoration of anadromous fisheries, but several limiting factors make the creek less favorable than other Sacramento River tributaries. The Cow Creek Watershed Analysis identifies the following limiting factors: elevated water temperature, low fall and summer flows (primarily due to agricultural water diversions), and water quality impairment (due to sedimentation and livestock grazing).

Physical barriers to fish passage are also located on all five of the main Cow Creek tributaries, and include diversion dams, hydropower facilities, and natural geologic barriers. Cow Creek supports various native resident fisheries, including rainbow trout, Sacramento pikeminnow, hardhead, California Roach, speckled dace, Sacramento sucker, and riffle sculpin. Exotic species in the Cow Creek watershed are primarily warm-water fish introduced for sport fishing, including brown trout, carp, green sunfish, small-mouth bass, large-mouth bass, and bullheads.

Battle Creek

Battle Creek is one of the only streams in the Sacramento River basin that harbors four runs of chinook salmon. However, the same characteristics that attract anadromous fisheries – abundant flows – also led to the development of hydropower facilities and water diversions in the 1900s, described previously. Many of these facilities pose a barrier to the migration of salmon and steelhead to historic spawning grounds in the upper, cool-water reaches of the Battle Creek watershed. Battle Creek also supports a healthy resident fishery consisting of native and introduced rainbow trout, brown trout, bass, cutthroat, and others. Battle Creek supports several public and private fish hatcheries, described below:

- **Coleman National Fish Hatchery** – The Coleman National Fish Hatchery is the largest salmon hatchery in the continental United States. It was established in 1942 as part of mitigation measures for the loss of historic spawning grounds following the construction of Shasta and Keswick dams. The hatchery is located at the mouth of Battle Creek and is operated by FWS. The hatchery raises fall-run and late-fall run chinook salmon, and steelhead trout. A fish trap at Keswick Dam supplies adult fish to the hatchery. To reach upstream spawning habitat on Battle Creek, fish must pass through the fish ladders at Coleman National Fish Hatchery. A satellite facility, the Livingston Stone National Fish Hatchery located just downstream from Shasta Dam, rears endangered winter-run chinook salmon.

- **Darrah Springs Hatchery** – This facility is located on Baldwin Creek, a Battle Creek tributary, and is operated by the DFG. The hatchery raises trout for sport fishing, including Pit River rainbow and Mt Shasta rainbow.

- **Mount Lassen Trout Farms, Inc.** – Mount Lassen Trout Farms is a private company that operates 12 hatcheries in the Battle Creek watershed, primarily around the base of Mount Lassen. The hatcheries raise rainbow trout and brown trout for stocking of private ponds and lakes throughout California.

Cottonwood Creek

Because water resources in the Cottonwood Creek watershed remain relatively undeveloped, it still supports a healthy anadromous and resident fishery. The absence of dams and other physical barriers permits access to about 130 miles of Cottonwood Creek and its tributaries. Cottonwood Creek is one of the largest uncontrolled tributaries on the upper Sacramento River. River hydrology varies seasonally and is characterized by high flows during the winter and early spring, and low summer flows. It is a major gravel recruitment watershed for the Sacramento River, although instream gravel mining has depleted some of these sources.

Cottonwood Creek supports significant runs of fall- and late-fall chinook salmon, a small spring-run, and steelhead. Resident fish species include bullhead, bluegill, brown trout, California roach, carp, golden shiner, green sunfish, hardhead, hitch, bass, mosquito fish, pacific lamprey, prickly sculpin, rainbow trout, riffle sculpin, Sacramento pikeminnow, Sacramento sucker, speckled dace, perch, and catfish. The primary problems effecting aquatic resources in the watershed include sedimentation or siltation, loss of gravel resources, warm summer water temperatures, and scouring by extreme high flows. Many of these problems are related to land use and land management practices in the watershed, including grazing, timber harvesting, gravel mining, and fire suppression.

Aquatic Species of Concern

Table II-10 summarizes aquatic species of concern that inhabit, or may inhabit, the Shasta Dam to Red Bluff sub-area.

TABLE 11-10
AQUATIC SPECIES OF CONCERN OCCURRING IN THE SHASTA TO RED BLUFF SUB-AREA

Species	Status	Habitat Specifics
Federal and State Threatened and Endangered Species		
Chinook salmon (winter run)	FE, SE	Sacramento River and tributaries
Chinook salmon (spring run)	FT, ST	Sacramento River and tributaries
California red-legged frog	FT	Still or slow-moving water w/shrubby riparian vegetation. Extinct in project area.
Steelhead	FT	Sacramento River and tributaries
Vernal pool tadpole shrimp	FE	Vernal pools and swales
Species of Special Concern		
California tiger salamander	SC	Wetland and vernal pools and adjacent uplands
Chinook Salmon (fall/late-fall run)	SC	Sacramento River and tributarie
Foothill yellow-legged frog	SC	Shallow river and streams with gravel bottoms
Hardhead Minnow	SC	Sacramento River and mouths of tributaries
Leech's chaetarthian water scavenger beetle	SC	Ponds, slow-moving streams, and other water bodies
Northwestern pond turtle	SC	Moderate to deep slow-moving rivers, ponds and streams with sunny banks
Nugget pebblesnail	SC	Aquatic snail found in shallow-water habitats
Western spadefoot toad	SC	Vernal pools and ponds

FE= Federally endangered, SE= State endangered, FT= Federally threatened, ST= State threatened,
SC= Regarded by the FWS, FS, and/or DFG as a species of special concern.
Note: Some of the species listed in this table have not been observed in the sub-area but are present in adjacent watersheds; or, they are listed because suitable habitat is found in the sub-area.

Wildlife Resources

The diverse habitats present in the Shasta Dam to Red Bluff sub-area support a variety of wildlife. Because animals are highly dependent upon their choice habitats, changes in the quality and quantity of various habitat types has likewise impacted area wildlife. The wildlife most affected have been those associated with riparian and grassland habitats, which have been highly impacted by land use, water resources development, and land management practices. Wildlife populations are also influence by the age and density of the vegetation within the various habitat types. The general trend toward more dense underbrush in foothill and mountain habitats, due to fire suppression, has favored species that rely on dense vegetation for cover or foraging while negatively impacting raptors and other wildlife that require open areas for foraging. Land conversion and the introduction of non-native species have had similar positive and negative effects on wildlife in riparian and grassland areas. Although mountainous terrain in the sub-area tends to be less developed, timber harvesting and fire suppression has changed the suitability of some areas to various types of wildlife.

While riparian habitat is limited in the sub-area, it supports the greatest variety and abundance of wildlife. Species inhabiting riparian areas include a variety of avian species, including waterfowl and raptors; rodents such as skunks and opossums; frogs, toads, and other amphibians; bats; coyote and fox; garter snake and other reptiles. Lower elevation grasslands and oak woodlands host a variety of seasonal game species and other wildlife, such as deer, jackrabbit, coyote, hawk and other raptors, gopher snake, pheasant, fox, raccoon, and quail. The grasslands and foothills also support vernal pools and other seasonal wetlands that provide unique habitat for waterfowl and various small aquatic organisms. More arid chaparral habitat and scrub habitat support a variety of reptiles, weasel, wild pig, skunk, coyote, and larger mammals such as deer, bobcat, and mountain lion. Bird species that forage and nest in brush habitat within the sub-area include wild turkey, pigeon, California thrasher, California towhee, and California quail. Higher elevation forest habitats support woodpeckers, martens, fishers, owls, eagles, forest floor amphibians such as newts, a variety of reptiles, black bears, gray fox, mountain lions, deer, and feral pigs. Due to a sharp decline in deer populations, deer herds are managed within portions of the sub-area, including the Yolla Bolly Deer Herd in the Cottonwood Creek watershed and the Cow Creek Deer Herd.

Exotic wildlife species include the brown-headed cowbird, feral pigs, wild turkey, pheasant, chukar, elk, and bullfrog. Some of these exotic species have been detrimental to native vegetation and wildlife, such as the cowbird (which parasitizes the nests of other birds) and feral pigs (which uproot native vegetation and the nests of ground-nesting birds).

The various habitats found in the sub-area host several special status wildlife species. For example, one of the largest known populations of pallid bat is found at the Cottonwood Bridge over lower Cottonwood Creek. Table II-11 summarizes special status wildlife that inhabit, or may inhabit, the Shasta Dam to Red Bluff sub-area.

Water Quality

The principal water quality issues for the Sacramento River in the Shasta Dam to Red Bluff sub-area include water temperatures between Keswick Dam and RBDD, acid mine drainage, and associated heavy metal contamination from abandoned mines.

Water temperature is a very important water quality issue for the sub-area primarily because of the specific habitat requirements for salmonids. Maximum survival of incubating salmon and steelhead eggs and yolk-sac larvae occurs at water temperatures between 41 and 56 degrees Fahrenheit, with no survival occurring at 62 degrees Fahrenheit or higher. Winter-run and spring-run chinook salmon, which lost their historic upper elevation spawning habitats when Shasta Dam was built, spawn during late spring and summer and are particularly vulnerable to water temperature conditions in the river.

TABLE II-11
SPECIAL STATUS WILDLIFE IN THE SHASTA DAM TO RED BLUFF SUB-AREA

Species	Status	Habitat Specifics
Federal and State Threatened and Endangered Species		
Bald eagle	FT,SE	Riparian zones along larger rivers and open water areas w/large trees for nesting and roosting
Bank Swallow	ST	Riparian and lowland habitats alongside waterways with vertical banks or cliffs of fine-textured soils
Northern spotted owl	FT	Mature, late-successional and old growth forests
Valley elderberry longhorn beetle	FE	Riparian habits with mature elderberry bushes
Vernal pool fairy shrimp	FT	Vernal pools and swales; endemic to grasslands of Central Valley
American Peregrine falcon	FE ,SE	Limestone formations and vertical cliffs with ledges
Willow flycatcher	SE	Large clumps of willow
California red-legged frog	FT	Still or slow-moving water w/shrubby riparian vegetation. Extinct in project area.
Ring-Tailed Cat	SE	Woodland and upland habitats
Shasta Salamander	ST	Cool, wet oak woodland or chaparral vegetation
Sierra Nevada Red Fox	ST	Densely vegetated forest with rocky outcrops
Yellow-billed cuckoo	SE	Riparian forests greater than 50 acres
Species of Special Concern		
Prairie Falcon	SC	Upper and lower watersheds; cliffs and ledges
Osprey	SC	Riparian zones along larger rivers and open water areas w/large trees for nesting and roosting
Ferruginous Hawk	SC	Arid grasslands
Cooper's hawk	SC	Riparian zones
Northern goshawk	SC	Conifer forests
Sharp-shinned hawk	SC	Riparian zones
Golden Eagle	SC	Riparian zones along larger rivers and open waters
Western burrowing owl	SC	Grasslands and open woodlands
White-faced ibis	SC	Grasslands and marshes
Yellow warbler	SC	Riparian scrub/forests
Tailed frog	SC	Montane hardwood-conifer habitats
Pacific fisher	SC	Mature, dense forest under 6,000 feet
Townsend's big-eared bat	SC	Seeks caves, mines, bridges, and other suitable cover
Fringed myotis bat	SC	Upland habitat including caves, mines, or other roost sites
Small-footed myotis bat	SC	Upland habitat including caves, mines, or other roost sites
Yuma myotis bat	SC	Seeks caves, mines, bridges, and other suitable cover
Pine Marten	SC	Mature mixed conifer forest
Shasta Sideband Snail	SC	Limestone terrain
California quail	SC	Forested areas near riparian zones
Purple marten	SC	Riparian forests

FE= Federally endangered, SE= State endangered, FT= Federally threatened, ST= State threatened, SC= Regarded by the FWS, FS, and/or DFG as a species of special concern.

Note: Some of the species listed in this table have not been observed in the sub-area but are present in adjacent watersheds; or, they are listed because suitable habitat is found in the sub-area.

In the 1980s and 1990s, Shasta Lake storage releases were increased to satisfy increasing spring and summer agricultural and urban water demands. The increases depleted the cold-water pool, resulting in warmer water in the river and high mortalities of salmon eggs. The National Oceanic and Atmospheric Administration Fisheries Biological Opinion for winter-run chinook (1993) established water temperature objectives for the river upstream of Jelly's Ferry (near RBDD) of 56 degrees Fahrenheit for the period April 15 through September 30 and 60 degrees for October. Recent changes in reservoir operations, including greater carry-over storage, increased imports of cold water from Trinity River system and, most importantly, installation of the temperature control device on Shasta Dam, have substantially improved water temperature conditions in the reach.

Keswick Reservoir has a very high flushing rate and receives most of its water from Shasta Lake, so water quality in Keswick Reservoir is largely determined by the water quality in Shasta Lake at the depth from which the water is discharged. The southern-most part of Keswick Reservoir also receives flow from the Spring Creek drainage and diversions from the Trinity River Basin, and these sources occasionally have important effects on water quality in the lower reservoir and in the Sacramento River downstream from Keswick Dam. There are large deposits of heavy metals in Keswick Reservoir that precipitate when acid mine drainage enters from Spring Creek. Water temperatures in Whiskeytown Reservoir are generally low and have been used to reduce the temperature of releases from Keswick Dam for fish protection.

Sacramento River Tributaries

Water quality concerns vary in the tributaries, but include acid mine drainage from the Iron Mountain and Afterthought mines, water temperatures, and bacteria from livestock grazing. Turbidity in the tributary streams can fluctuate significantly, depending upon precipitation and runoff conditions, but is generally low. Water quality in the major tributaries to the sub-reach is described below:

- The Spring Creek drainage is a major source of acid mine drainage and heavy metals contamination in the upper Sacramento River basin. Effluents from the mine complex, tributary to Spring Creek, are extremely acidic and contain high concentrations of copper, zinc and other metals. Spring Creek flows into Keswick Reservoir and periodically causes fish kills in the reservoir and the Sacramento River. Although cleanup actions at Iron Mountain and construction of the Spring Creek Debris Dam have significantly reduced the amount of acid mine drainage, the area still contributes a significant amount of metals to the Sacramento River. Levels of copper and zinc periodically reach levels exceeding the tolerance thresholds for salmonids in the Sacramento River.

- The high water quality in Battle Creek led to the placement of the Coleman National Fish Hatchery on lower Battle Creek. Temperature and turbidity conditions in Battle Creek are generally favorable to anadromous and cold-water resident fisheries. However, water diversions and hydropower projects cause localized increases in temperature.

- Water temperatures in Cow Creek tend to be somewhat higher than in Battle Creek. Turbidity and fecal coliform are significant water quality impairments in some portions of the Cow Creek watershed due to livestock grazing adjacent to the creek. Grazing also tends to reduce riparian vegetation that helps maintain cooler instream water temperatures.

- Water quality in Cottonwood Creek is generally good. Water temperatures in Cottonwood Creek generally follow natural seasonal fluctuations, but the loss of riparian vegetation along the banks of the creek can increase summer temperatures. Irrigation runoff and groundwater inflows can also affect water temperatures in lower Cottonwood Creek. The lower reaches of Cottonwood Creek, where urban development is more concentrated, have occasionally experienced periods of high coliform levels during low flows, due to effluent from adjacent septic tanks. Land management practices, fire suppression, and the construction of roads have contributed to a general increase in turbidity.

Other Water Quality Concerns

Agricultural drainage can be problematic in downstream reaches of the river by increasing water temperature and turbidity, and introducing pesticides and livestock waste products (fecal coliform). Elevated pesticide levels have been found at some sites in the Sacramento River Valley for a number of years, but these sites are typically located downstream from Red Bluff. Storm water runoff from Redding and other urban areas likely flushes contaminants into the Sacramento River, but the volume of flow in the river typically provides sufficient dilution. Dioxins, a group of highly toxic compounds, have been discharged into the Sacramento River from a paper mill near Anderson. However, the mill has greatly reduced these discharges and a health advisory on consumption of fish from the river between Redding and Red Bluff was subsequently lifted.

CHAPTER III
ENVIRONMENTAL PROBLEMS

Based on the existing environmental conditions described previously, the following discussion identifies water-related environmental problems in the primary study area. Overall, there has been a general decrease in the quantity and quality of native habitat, and a subsequent decrease in the population of many individual plant and animal species. This has resulted in a growing number of threatened and endangered species inhabiting the region.

SHASTA LAKE AND TRIBUTARIES SUB-AREA

The follow discussion of environmental problems in the Shasta Lake and Tributaries sub-area is divided into two categories: problems related to warm-water and cold-water fisheries, and problems related to wetlands and riparian habitat.

Warm-water and Cold-water Fisheries

Within Shasta Lake itself, the primary problems related to warm-water and cold-water fisheries are acid mine drainage; lack of shallow-water, shoreline habitat; and human disturbances.

- **Acid mine drainage** – Acid mine drainage causes periodic fish kills in Shasta Lake, primarily during periods of high rainfall runoff. The areas of Shasta Lake most affected by acid mine drainage are the Little Backbone and West Squaw Creek arms, and the peninsula between the McCloud and Squaw Creek arms. Remedial actions have not been taken at many area mines contributing to fish kills.
- **Lack of shallow-water, shoreline habitat** – The shoreline of Shasta Lake provides important shallow-water habitat for warm-water fisheries and juvenile fish. However, shoreline cover in the form of vegetation and wood debris is very limited around the lake. This is primarily due to annual fluctuations in lake level that prevent the establishment of vegetation and accelerate shoreline erosion within the drawdown area. Other contributing factors include wavewash erosion from watercraft and the annual removal of woody debris.
- **Human disturbances** – Human disturbances have also contributed to a reduction in native fisheries in Shasta Lake. These include physical disturbances caused by watercraft (particularly around the mouths of tributaries) and pollution from houseboats and personal watercraft.

Problems related to fisheries differ somewhat on the tributaries to Shasta Lake, and include modification of seasonal flows; loss of access to historic spawning and rearing areas; and acid mine drainage.

- **Modification of seasonal flows** – Seasonal flow patterns have been significantly modified on some tributaries to Shasta Lake by dams and hydropower diversions, particularly the McCloud and Pit rivers. Most of the flow in the McCloud River is diverted to the Pit River at the McCloud Dam, significantly changing the hydrology of the lower McCloud River. Similarly, there are numerous hydropower diversions along the Pit River that reduce flow in the stream channel, increase water temperatures, and cause rapid fluctuations in hydropower diversion impoundments. Changes in seasonal flow patterns are significant because they can alter the geomorphic characteristics of a river channel, disturbing sediment transport, impair water quality, and reduce instream aquatic and riparian habitat.

- **Loss of access to historic spawning and rearing areas** – Water resources development on the tributaries to Shasta Lake has also blocked access to historic fish spawning and rearing habitat, primarily on the McCloud and Pit rivers. Loss of historic spawning habitat on the McCloud River after the construction of McCloud Dam lead to the extirpation of the McCloud bull trout population. Similarly, populations of native fish are prevented from moving along the lower Pit River by numerous dams and reservoirs.

- **Acid mine drainage** – Acid mine drainage is problematic on numerous smaller tributaries to Shasta Lake, including Little Backbone Creek and West Squaw Creek. Aquatic life can no longer be supported in several tributaries due to toxicity from acid runoff and high metal concentrations in streambed soils. Abandoned mines also contribute large amounts of sediment to area streams, which can increase turbidity and reduce juvenile fish survival. As noted previously, the tributaries to Shasta Lake provide important spawning and rearing habitat for native fish species.

Riparian and Wetland Habitat

Problems related to riparian and wetland habitat in the Shasta Lake and Tributaries sub-area include increased erosion and sediment input, and non-native species.

- **Increased erosion and sediment input** – Increased erosion and sedimentation can degrade riparian and wetland habitat in tributaries to Shasta Lake. Excessive sediment input to area streams can impede riparian vegetation succession and prematurely fill-in wetland and meadowland areas. The increase in erosion and sediment input is due to a combination of factors, including fire suppression, severe wildfires, timber harvesting, unpaved forest roads, livestock grazing, and other land management practices.

- **Non-native species** – Non-native species have colonized large portions of the primary study area and replaced native habitats, especially riparian habitats. Invasive exotic species can out-compete native vegetation and change the type, density, and/or value of habitat provided. Invasive species of concern include yellow star thistle, Himalayan blackberry, Scotch broom, and various grasses. Mitigation for exotic species has been limited to small sites adjacent to Shasta Lake.

SHASTA DAM TO RED BLUFF SUB-AREA

Environmental problems in the Shasta Dam to Red Bluff sub-area are separated into two categories: problems related to anadromous fish, and problems related to riparian, floodplain, and wetland habitat.

Anadromous Fish

The primary problems related to anadromous fish in the Shasta Dam to Red Bluff sub-area include water temperature; physical migration barriers; diversions and flow regulation; reduction in suitable spawning gravels; acid mine drainage, and unnatural predation rates.

- **Water temperature** – Water temperatures that are too high, or too low, during certain periods can be detrimental to anadromous fish. High water temperatures can harm spawning adults, reduce egg viability, increase juvenile fry mortality, reduce overall water quality, and generally diminish the resulting ocean population and number of return spawners. Temperatures that are too cold, on the other hand, can slow the growth of fall- and late fall-run juveniles and reduce their chance of successful out-migration. Minimum flow requirements and the construction of a temperature control device on Shasta Dam have improved water temperature conditions on the Sacramento River, but there is still a need for cooler water during dry and critically dry years. Temperature conditions on tributaries also play an important role in sustaining anadromous fish populations. Agricultural water diversions and the loss of streamside riparian habitat can elevate water temperatures on the tributaries, notably on Battle, Cow, and Cottonwood creeks.

- **Physical migration barriers** – One of the most significant factors contributing to the decline in anadromous fish populations is the construction of dams and other physical migration barriers that have blocked access to hundreds of miles of historic spawning and rearing habitat. These migration barriers are present along the Sacramento River as well as many of its tributaries, including Battle Creek and Cow Creek. Barriers and impediments along the Sacramento River include the RBDD, ACID Diversion Dam, Keswick and Shasta dams. While fish passage is permitted at the Red Bluff and ACID diversion dams via fish ladders and gate operations, they nevertheless pose a significant impediment to upstream and downstream migration. Dams on Battle and Cow creeks block access to cooler, upper watershed stream habitat.

- **Diversions and flow regulation** – Diversions from the Sacramento River, and its tributaries, can significantly reduce flows during low-flow periods. These flow reductions, in turn, can affect anadromous fish by increasing water temperatures, increasing predation, and disorientating migrating adults and juveniles. Diversions can also cause rapid fluctuations in river flows that result in sidebar stranding and juvenile mortality. Flow regulation and diversions on important spawning tributaries, such as Clear Creek and Battle Creek, can cause similar problems for anadromous fish. Flow regulation also effects the natural, geomorphic processes that help to maintain and replenish healthy aquatic habitat; this includes processes that move gravel downstream, flushing flows that clean spawning gravels, and channel-forming processes that help establish pools/riffles and shaded riparian aquatic habitat.

- **Reduction in suitable spawning gravels** – While physical migration barriers have blocked access to historic spawning areas, they have also blocked historic instream gravel resources. The mountainous tributaries upstream from Shasta Dam once provided a significant source of high-quality gravels to the Sacramento River. Loss of these gravel recruitment sources has resulted in an overall decrease in the amount of suitable spawning gravel for anadromous fish in the upper Sacramento River. This is most clearly evidenced by the scoured, bedrock channel immediately downstream from Keswick Dam. Smaller dams and other water resources projects on Sacramento River tributaries downstream from Keswick Dam, including Clear Creek and Battle Creek, have further reduced the amount of gravel entering the Sacramento River. Instream gravel mining operations on the Sacramento River and tributaries such as Cottonwood Creek have also reduced the amount of available spawning gravel. Spawning gravel could become a limiting factor in the recovery of anadromous fish populations in the Sacramento River basin.

- **Acid mine drainage** – Acid mine drainage can be a key contributor to water quality problems in the Sacramento River, resulting in periodic fish kills and aquatic habitat degradation. One of the largest contributors to acid mine drainage in the Sacramento River is the mine complex, west of Keswick Reservoir. Toxic runoff from this area enters Keswick Reservoir, and releases from Keswick Damcan be adjusted to reduce the impact on Sacramento River water quality. However, the drainage continues to contribute large amounts of copper, cadmium, and other heavy metals to the Sacramento River.

- **Unnatural predation rates** – Fish predation can be unnaturally high in the impoundments created by water diversions and dams. High predation occurs in Lake Red Bluff and in pool areas just downstream from the diversion dam. High predation can also occur at the downstream side of fish ladders, where fish often rest or queue before entering the ladder. Unusually low flows during dry and critically dry years can also increase fish predation by reducing the number of deep pools, limiting access to cover, and stranding fish in streamside channels or gravel pits.

Riparian, Floodplain, and Wetland Habitat

The primary problems related to riparian, floodplain, and wetland habitat in the Shasta Dam to Red Bluff sub-area include: changes to natural geomorphic processes; urban and agricultural encroachment and other land management changes; and invasive species.

- **Changes to natural geomorphic processes** – Flow regulation, dams, and diversions have changed the natural flow patterns in the Sacramento River and many of its tributaries. These changes have altered channel geomorphology and changed how channels interact with adjacent floodplains. Channel-forming processes drive riparian habitat succession and are integral to the health of floodplain habitats. Changes in channel geomorphology have resulted in a decline in the quantity, quality, and connectivity of riparian and floodplain habitat. Some floodplain areas no longer interact with adjacent stream channels due to decreased streamflows. In other reaches, river channels experience less lateral movement, impairing the regeneration and succession of streamside riparian vegetation.

- **Urban and agricultural encroachment, and other land management changes** – Land development has had a significant impact on riparian, floodplain, and wetland habitat in the sub-area. Urban encroachment along the Sacramento River in the Red Bluff to Redding reach has reduced the quality, quantity, and connectivity floodplain and riparian habitat. Lower Clear Creek has experienced similar problems along its riparian corridor. Riparian habitat is highly fragmented in many areas and gravel mining has modified floodplains. Along the tributaries to the Sacramento River, cattle grazing adjacent to streams and wetlands, gravel mining, timber and ranchland management practices, and urban/agricultural encroachment have decreased the quality and quantity of riparian corridors.

- **Invasive species** - Non-native species have colonized large portions of the primary sub-area and changed native habitats, especially riparian and grassland habitats. Competition by non-native invasive species has reduced the diversity of riparian habitats and the wildlife that use these habitats. Invasive species of concern include yellow star thistle, Himalayan blackberry, arundo (giant reed), pampas grass, fig, Scotch broom, and various grasses.

OTHER ENVIRONMENTAL CONDITIONS IMPACTED BY HUMAN USES

Several human-induced environmental impacts have been discussed in the previous sections, including the impacts of mining operations, dams and hydropower development, and fire suppression. Other environmental impacts from human settlement and uses of lands within the sub-area include those associated with transportation and forest roads, recreation, and urbanization. These impacts tend to be similar in both of the study sub-areas, and generally less damaging than the problems previously discussed.

- **Transportation** - Road development within the study area tends to be low on public lands and denser on privately owned lands, particularly those lands that are used for timber harvesting. Many forest roads are not surfaced (paved or graveled) or regularly maintained, leading to erosion and accelerated transport of sediment into area streams. Recently, the FS has been identifying and decommissioning forest roads that are no longer needed for management of public lands or access to private lands. Major roads may also pose migration barriers to area wildlife, particularly Interstate 5.

- **Recreation** – Recreation in the region includes boating and water skiing, angling, camping, hiking, spelunking, and sightseeing. Negative environmental impacts include water and noise pollution, which result from the use of marinas, watercraft, campgrounds, off-road vehicles and OHV parks, and other recreation facilities, and wildlife disturbance. Because the quality of recreation in the region is often associated with its natural beauty and remoteness, many recreation facilities are low-use or low-density and have less significant environmental impacts.

- **Urbanization** – Urban development is limited within the region to the Redding and Red Bluff areas, various small communities, seasonal recreational facilities, and summer homes. Urban impacts are primarily related to water quality (stormwater and waste runoff) and noise pollution. However, the environmental impacts of urbanization and infrastructure tend to be site-specific compared with far-reaching effects of other human activities, such as timber harvesting and mining.

CHAPTER IV
RESTORATION AND CONSERVATION PROGRAMS AND PROJECTS

Various Federal and State agencies, and numerous local working groups and private organizations, are active in environmental restoration and conservation in the study area. This section describes some of the ongoing programs and potential projects specific to the primary study area. Although this is not an all-inclusive list of the participation of various groups in the study area, it highlights some of the key environmental resource problems and solutions that have been identified in the upper Sacramento River region.

BUREAU OF RECLAMATION

As the owner and operator of Shasta Dam and Reservoir, Keswick Dam and Reservoir, and various related components of the CVP in the study area, Reclamation has a significant effect on environmental resources in the region. Ongoing projects or continuing programs relevant to the primary study area are described below.

Central Valley Project Improvement Act

Enacted in 1992, the Central Valley Project Improvement Act (CVPIA) amended the authority of the CVP to include fish and wildlife protection, restoration, and mitigation as having equal priority with other purposes. A portion of this authority directed the development and implementation of actions to ensure that, by 2002, the natural production of anadromous fish in Central Valley streams would be sustainable, on a long-term basis, at levels at least twice the average levels of natural production in the 1967 through 1991 baseline period.

The Anadromous Fish Restoration Program (AFRP) was established under the CVPIA in 1995 and determined baseline production estimates for Central Valley streams for naturally produced chinook salmon and other anadromous species. The six species identified for restoration under this program are chinook salmon, steelhead, striped bass, American shad, white sturgeon, and green sturgeon. Numerous actions to improve the natural production of anadromous fish have been recommended and/or funded by AFRP through the CVPIA program, including numerous projects in the study area. Several specific projects include: improvements to the intakes at the Coleman National Fish Hatchery on Battle Creek; the installation of a temperature control device on Shasta Dam; removal of McCormick-Saeltzer Dam on Clear Creek; land acquisition and watershed planning on Battle Creek; and a spawning gravel replenishment program.

Battle Creek Salmon and Steelhead Restoration Plan

In 1999, a Memorandum of Understanding was established between Reclamation, PG&E, U.S. Fish and Wildlife Service (FWS), NOAA Fisheries, and the DFG that outlines activities to be undertaken on Battle Creek to promote anadromous fish passage for winter-run, spring-run, fall- and late-fall run chinook salmon and steelhead. As shown in Figure 6, there are numerous natural and man-made barriers in the Battle Creek watershed that prevent access to valuable cold-water spawning grounds. Actions include the removal of dams, construction of fish screens and ladders, and flow augmentation to increase salmonid habitat. Actions are expected to enhance and re-establish connection with over 40 miles of habitat, increase steelhead populations by 5,700, and increase the adult winter- and spring-run chinook salmon population by 2,500. Various federal, state, and local entities, including FWS and the Western Shasta Resource Conservation District, are implementing different phases of the project. Construction of initial features began in 2002.

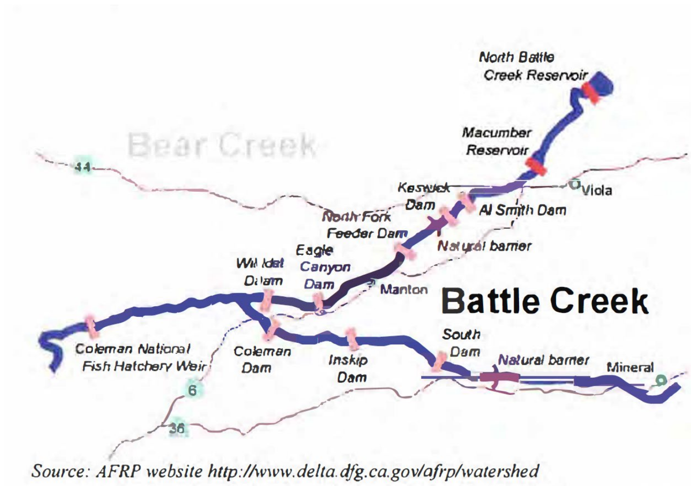


Figure 6 – Barriers to Fish Passage in the Battle Creek Watershed

Red Bluff Diversion Dam Fish Passage Improvement Project

The Red Bluff Diversion Dam Fish Passage Improvement Project on the Sacramento River is a cooperative effort led by Reclamation and the Tehama-Colusa Canal Authority. The project is developing a long-term solution to relieve conflicts between fish passage and agricultural diversion needs. The two primary fish passage issues associated with the RBDD are (1) the delay and blockage of adults migrating upstream, and (2) the impedance and losses of juveniles emigrating downstream. The reach of the Sacramento River upstream of RBDD is the primary spawning habitat for the endangered winter-run chinook and the fall- and late fall-run chinook salmon. Fish ladders located on each abutment of the dam have been ineffective, limiting access to remaining spawning habitat between Keswick Dam and Red Bluff. Predation is also problematic in Lake Red Bluff.

Red Bluff Diversion Dam on the Sacramento River

Five alternatives have been identified by the fish passage improvement project:

- The **4-Month Improved Ladder Alternative** proposes that the RBDD gates-in operational period remain the same (May 15 to September 15), but the left and right fish ladders be expanded and improved.
- The **4-Month Bypass Alternative** also proposes that the gates-in period remain the same and that the right fish ladder be expanded an improved, but proposes a fish bypass channel be constructed on the left bank rather than improving the existing ladders.
- The **2-Month Improved Ladder Alternative** suggests a reduced 2-month gates-in period (July and August). This option would allow for gravity diversion into the Tehama-Colusa Canal systems during the two highest irrigation demand months, July and August, but would require additional pumping during the extended gates-out period. The right and left abutment fish ladders would also be expanded and improved.
- The **2-Month Alternative with Existing Ladders** also proposes a 2-month gates-in period (July and August), but the existing ladders would remain unchanged.
- The **Gates-out Alternative** proposes to leave the gates out at all times of the year, eliminating both the fish passage barrier and the formation of Lake Red Bluff. Additional pumping facilities would need to be constructed to meet the high summer irrigation needs.

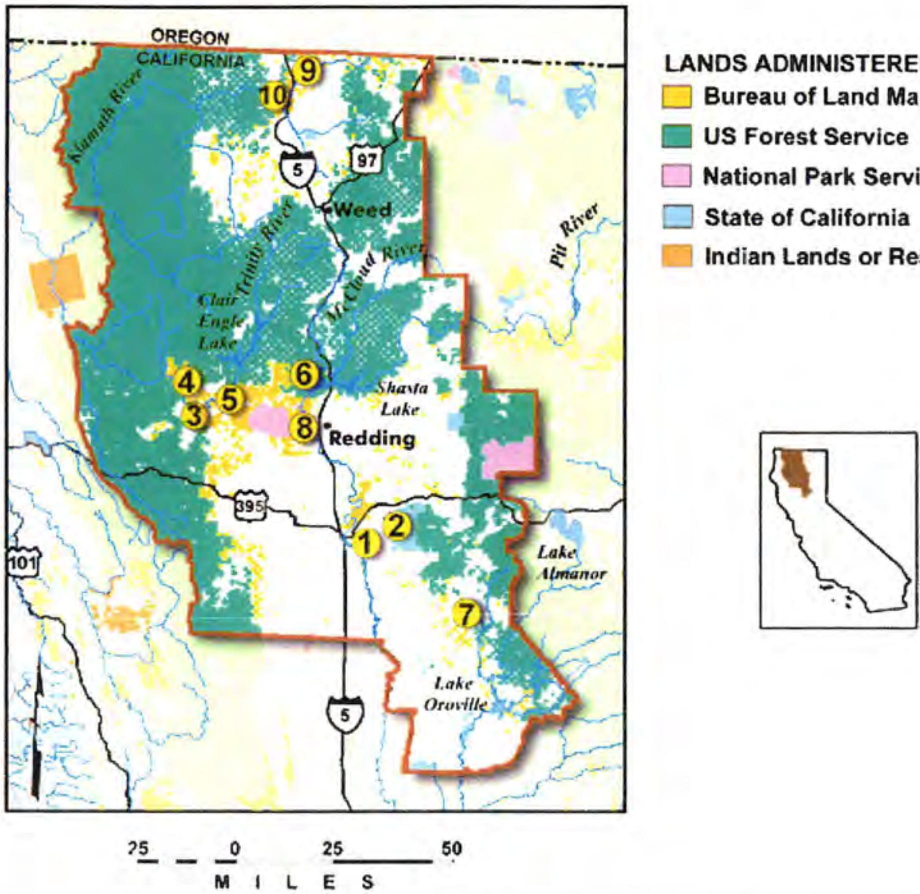
The public comment period ended in November 2002 for the Draft Environmental Impact Statement/Environmental Impact Report released in August 2002. The environmental review process is currently in the "respond to comments – develop final EIS/EIR" stage. The environmental document is currently scheduled to be completed at the end of 2004. The schedule has been delayed pending completion of the Reclamation Operations Criteria and Plan Process (OCAP).

BUREAU OF LAND MANAGEMENT

The U.S. Department of the Interior, Bureau of Land Management (BLM) is responsible for the administration of natural resources, lands, and mineral programs on approximately 250,000 acres of public land in Northern California. BLM lands within the study area, shown in Figure 7, are located predominantly west of the Sacramento River, and include the 17,000-acre Sacramento River Bend area south of Jelly's Ferry, and off-highway vehicle areas near Shasta Lake. BLM has been involved in numerous restoration and conservation projects in area watersheds, including the Clear Creek Floodplain Restoration Project. BLM is also a responsible party in implementation of the NFP.

Over 40,000 acres of public lands along the Sacramento River between Redding and Red Bluff have been proposed for designation as National Conservation Areas. Designation as a National Conservation Area would prevent the construction of dams or other instream infrastructure, and ensure continued public access to the lands. Other areas that have been proposed for National Conservation Area or National Wilderness designations within the primary study area include the Backbone/Sugarloaf wilderness area, the Girard Ridge area (northeast of Shasta Lake), the Devil's Rock area adjacent to Squaw Creek near Shasta Lake, and the Beegum area in the

Cottonwood Creek watershed. The BLM determined that 25 miles of the Sacramento River and about seven miles of Paynes Creek are eligible for National Wild & Scenic River status, and acquired roughly 17,000 acres in the Sacramento River Bend management area. Congressional action is required to confirm these proposed designations.



Source: Bureau of Land Management website http://www.blm.ca.gov/redding.

Figure 7 – Lands Administered by BLM and other Public Agencies

FISH AND WILDLIFE SERVICE

The U.S. Department of the Interior, Fish and Wildlife Service (FWS) has participated in numerous projects and programs within the study area, many related to species listed under the Federal ESA. The upper Sacramento River is recognized as critical habitat for endangered winter-run chinook salmon and other threatened or endangered species. Activities include investigations at the Coleman National Fish Hatchery, the Battle Creek Restoration Program, Clear Creek Restoration Program, ACID Program, and RBDD Fish Passage Improvement Project. FWS is also instrumental in the implementation of the AFRP and the NFP, providing scientific research, monitoring, environmental compliance, and restoration planning support.

NATIONAL MARINE FISHERIES SERVICE

The U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) is involved in comprehensive recovery planning for listed salmonid species in the Central Valley. NOAA Fisheries is required under the Federal ESA to assess factors affecting the species, identify recovery criteria, identify the entire suite of actions necessary to achieve these goals, and estimate the cost and time required to carry out the actions.

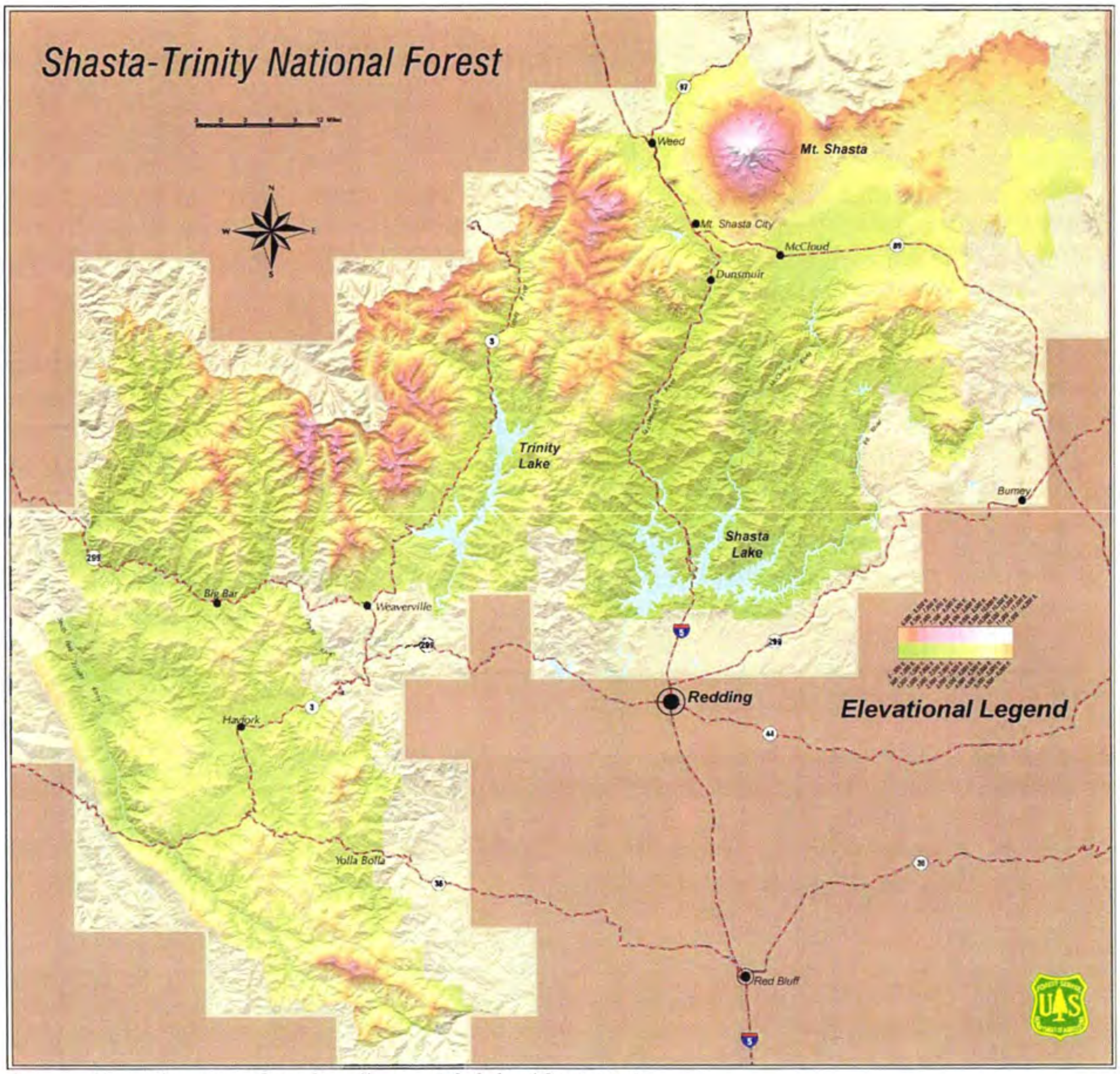
NOAA Fisheries has designated Critical Habitat for the Federally listed winter-run chinook salmon to be the Sacramento River from Keswick Dam downstream to the Golden Gate Bridge. The Central Valley recovery planning domain also includes Central Valley spring-run chinook salmon, Central Valley steelhead, and also Federal candidate species fall/late fall-run chinook salmon. Clear, Cow, Bear, Battle, and Cottonwood creeks have been identified as Essential Fish Habitat. The *Proposed Recovery Plan for Sacramento River Winter-Run Salmon*, August 1997, presents restoration goals and actions, some of which would be applied within the SLWRI study area. Proposed elements include the following:

- **Provide suitable water temperatures for spawning, egg incubation, and juvenile rearing between Keswick Dam and Red Bluff** – Actions include operating the CVP to consistently attain water temperature objectives; operating and maintaining temperature control curtains at Whiskeytown and Lewiston reservoirs; and regulating the river and reservoir system using a comprehensive temperature monitoring program and model.
- **Reduce pollution in the Sacramento River from Iron Mountain Mine** – Actions include alleviating pollution problems from the mine during the winter-run incubation periods; treating and/or controlling heavy metal waste prior to discharge to the Sacramento River; diluting heavy metal waste discharges through effective water management; eliminating scouring of toxic metal-laden sediments in the Spring Creek and Keswick reservoirs; and monitoring metal concentrations and waste flows.
- **Provide optimum flows in the Sacramento River between Keswick Dam and Chipps Island** – Actions include maintaining flows of 5,000 to 5,500 cfs from October through April, when possible; eliminating adverse flow fluctuations by modifying the ACID's dam operations, or by modifying or replacing the facility; inventory and assess water withdrawal sites and take action to increase streamflows.
- **Protect and maintain gravel resources in the Sacramento River and its tributaries between Keswick Dam and Red Bluff** – Actions include restoring and replenishing spawning gravel in the Sacramento River; implementing a plan to protect natural sources of spawning gravel along the Sacramento River and its tributaries; and controlling excessive silt discharges from tributary watersheds to protect spawning gravel.

Some of these actions are ongoing or are currently under study.

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

The U.S. Department of Agriculture, Forest Service (FS) is responsible for lands within the Shasta-Trinity National Forest, shown in Figure 8, including the Whiskeytown-Shasta-Trinity National Recreation Area and Shasta McCloud Management Unit. The FS is involved in fire hazard and fuel reduction projects, forest health and ecosystem management, timber sales, conservation planning, wildlife monitoring, recreation facilities, and administration of the NFP.



Source: Forest Service website http://www.r5.fs.fed.us/shastatrinity.

Figure 8 – Shasta-Trinity National Forest

The FS manages the majority of the land and facilities surrounding Shasta Lake. It also owns a 299-acre parcel at the Red Bluff Recreation Area (not shown in Figure 8), which is undergoing restoration in cooperation with the Sacramento River Discovery Center. The 1995 Shasta-Trinity National Forest Land Management Plan provides guidance for national forest lands and includes the designation of Riparian Reserves. Riparian Reserves are located along all perennial and intermittent streams and provide special protection to riparian and aquatic values in these areas.

U.S. ENVIRONMENTAL PROTECTION AGENCY

The EPA is involved in remediation and cleanup activities related to the Iron Mountain Mine Superfund site in the Clear Creek drainage, west of the Sacramento River. Acid mine drainage from the former copper mine has significantly impacted the Clear Creek watershed and caused fish kills in the Sacramento River. This site is being addressed through interim emergency actions and long-term remedial phases, focusing on water management, cleanup of major sources in Boulder Creek, the Old Mine/No. 8 Mine, area source acid mine drainage discharges, and sediments. Remedial actions taken to date have significantly reduced the acid and metal contamination in surface water. Other planned activities include construction of an acid mine drainage treatment plant in the Boulder Creek watershed. Other agency participation in cleanup activities related to the mine complex is discussed later in this section.

U.S. ARMY CORPS OF ENGINEERS

The U.S. Army Corps of Engineers (Corps) participates in the planning, design, construction and operation of water resources projects, including navigation, flood control, and environmental protection. The Corps administers a regulatory program providing environmental protection for wetlands and waterways under the Rivers and Harbors Act of 1899 and Clean Water Act of 1972. The Corps recently formalized a set of "Environmental Operating Principles" applicable to all of its decision-making and programs. The principles are geared toward environmental sustainability and recognition of our dependence upon the physical environment.

The Sacramento and San Joaquin River Basins Comprehensive Study, California is a joint effort between the Corps and the State of California, Reclamation Board. Initiated by an act of Congress following the devastating 1997 flood event in the Central Valley, the project has dual objectives of flood damage reduction and environmental restoration. The December 2002 Interim Report presents guiding principles and an implementation strategy for future projects within the flood management system such that flood management and ecosystem values can coexist. The report does not present any specific recommendations for the Sacramento River between Shasta Dam and Red Bluff, but the Reclamation Board's jurisdiction covers the entire Central Valley, including all tributaries and distributaries of the Sacramento River. Through the Comprehensive Study there is a potential, if approved by Congress, to significantly change the existing flood management system and implement many of the projects proposed by CALFED.

CALIFORNIA DEPARTMENT OF FISH AND GAME

The California Department of Fish and Game (DFG) is responsible for managing California's fish and wildlife resources and oversees the restoration and recovery of threatened and endangered species under the California Endangered Species Act. DFG participates in conservation planning, environmental compliance and permitting, coordinated resource management planning, and restoration and recovery programs. They are involved in numerous investigations, projects, and monitoring activities in the study area including fish passage, riparian restoration, and aquatic habitat restoration. The Wildlife Conservation Board (WCB), established under DFG, administers a capital outlay program for wildlife conservation and related recreation projects. Within the study area, the WCB has participated in restoration activities at Turtle Bay, the Nature Conservancy's Lassen Foothills Project, and various local projects in Redding and Red Bluff.

The DFG oversees three mitigation banks in the project area: the Cottonwood Creek, Battle Creek, and Stillwater Plains mitigation banks. DFG also manages several Wildlife Areas and other properties within the study area:

- **Battle Creek Wildlife Area, Shasta & Tehama Counties** – 582 acres of riparian forests, marshes and oak woodland adjacent to the Coleman National Fish Hatchery.
- **Mouth of Cottonwood Creek Wildlife Area, Shasta & Tehama Counties** – 571 acres located at the confluence of Cottonwood Creek and the Sacramento River.
- **Tehama Wildlife Area** – 46,862 acres of oak woodland, rugged canyons, grassland and chaparral east of Redding near Paynes Creek.
- **Cantara - Ney Springs Wildlife Area, Siskiyou County** – 93 acres of mixed conifer, hardwoods and riparian vegetation along the upper Sacramento River.
- **Anderson River Park** – 264 acres managed by the City of Anderson.

CALIFORNIA DEPARTMENT OF WATER RESOURCES

The California Department of Water Resource (DWR) is involved in numerous restoration and conservation actions in the study area, managed primarily through their Northern District in Red Bluff. Technical services provided by DWR include monitoring, habitat and hydrologic mapping, restoration planning, resource investigations, and other support services. Activities include:

- **Sacramento River Fishery Restoration** – coordination with CVPIA, CALFED, local watershed groups, and other government agencies.
- **Sacramento River Riparian Habitat** – technical support for Sacramento River Conservation Area (SRCA), site specific planning and geospatial support.
- **Tributary Riparian Habitat Conservation** – habitat inventory and mapping services, and technical support to local watersheds groups and other government agencies.
- **Spawning Gravel Restoration Programs** – including studies of instream and offstream gravel mining and gravel replenishment programs between Keswick Dam and Red Bluff.

CALFED BAY-DELTA PROGRAM

The CALFED Bay-Delta Program is a cooperative effort among State and Federal agencies and California's environmental, urban and agricultural communities to address environmental and water management problems associated with the Bay-Delta system. CALFED has taken a broad approach to addressing four problem areas: (1) water quality, (2) ecosystem quality, (3) water supply reliability, and (4) levee system integrity. Program implementation began following circulation of the final programmatic Environmental Impact Statement/Environmental Impact Report (EIS/EIR), the signing of the ROD, and the EIR being adopted by the Reclamation Board on 28 August 2000.

The Preferred Program Alternative (PPA) in the CALFED-ROD consists of programmatic elements that set the long-term direction of the program. The PPA has seven interrelated programs: Levee System Integrity Program, Water Quality Program, Ecosystem Restoration Program (ERP), Water Use Efficiency Program, Water Transfer Program, Watershed Program, and Storage and Conveyance. The ERP is the principal Program component designed to restore the ecological health of the Bay-Delta system. It identifies and provides recommendations for actions in several ecological management zones, two of which fall within the primary study area: The North Sacramento Valley Ecological Management Zone, and the Cottonwood Creek Ecological Management Zone.

North Sacramento Valley Ecological Management Zone

The North Sacramento Valley Ecological Management Zone includes four sub-units: the Clear Creek, Cow Creek, Bear Creek, and Battle Creek ecological management units. CALFED has helped to fund several projects in the zone, including removal of McCormick-Saeltzer Dam and work on Battle Creek. Problems and recommendations for the units are described below.

- **Clear Creek Ecological Management Unit** – The ERP recognizes Clear Creek's unique potential to provide cool flows for anadromous fisheries, including fall- and late fall-run chinook salmon. It identifies water diversions and subsequently depressed flows, former gravel mining operations, impeded gravel production from upper reaches by dams and other facilities, and fish passage and escapement as key environmental problems. Recommendations include increasing gravel production by 25 to 50 tons per year, removing diversions or supplying alternate water sources, supplemental sediment injections and channel re-configuration in lower Clear Creek, and increasing flows by 150 to 200 cfs.
- **Cow Creek Ecological Management Unit** – The ERP recognizes Cow Creek for its support of fall-run and late-fall-run chinook salmon, although warm summer water temperatures do not provide suitable conditions for spring-run. It identifies unscreened agricultural diversions, reduced flow resulting from water and power diversions, past gravel mining practices, the destruction of riparian habitat by grazing animals, and urban encroachment as problems within the watershed. Recommendations include increasing flows by 25 to 50 cfs, fencing selected riparian areas, screening diversions, and improving fish passage.
- **Bear Creek Ecological Management Unit** – The ERP notes limited runoff and agricultural diversions as contributing to low use of Bear Creek by anadromous fish. Unscreened irrigation diversions operating during the juvenile emigration period were identified as

significantly reducing survival rates. The ERP recommends a cooperative program among water users to increase streamflows by 10 to 20 cfs.

- **Battle Creek Ecological Management Unit** – Battle Creek is noted as having the best connection between the Sacramento River and mountainous areas of any of the ecological management units. However, hydropower operations divert as much as 98 percent of base streamflows and the Coleman National Fish Hatchery blocks fall-run salmon migration, greatly reducing salmon and steelhead populations in upper reaches. Recommendations include screening or removing diversions on the North and South forks, increasing streamflows, halting the removal of gravel that accumulates at diversions, fish hatchery improvements, and water supply management. These issues are being addressed by Reclamation's Battle Creek Salmon and Steelhead Restoration Plan (discussed previously) and related community efforts.

Cottonwood Creek Ecological Management Zone

The Cottonwood Creek Ecological Management Zone is recognized as the primary source of coarse sediments and spawning gravel for the Sacramento River, supplying almost 85 percent of the gravel between Redding and Red Bluff. Cottonwood Creek has an extensive riparian and riverine aquatic plant community, plays an important role in supplying flows and controlling temperatures in the Sacramento River, and provides habitat for chinook salmon and steelhead. The zone is divided into two ecological management units: the Upper Cottonwood Creek and Lower Cottonwood Creek Fan ecological management units.

- **Upper Cottonwood Creek Ecological Management Unit -** Recommendations in the unit include maintaining coarse sediment recruitment, improving habitat for salmon and steelhead, improving habitat corridors, and restoring riparian and riverine plant communities, primarily though the development of a watershed management plan.
- **Lower Cottonwood Creek Fan Ecological Management Unit -** Recommendations for the unit include restoring, reactivating, and maintaining coarse sediment supply, floodplain and flood processes, gravel recruitment, and stream meander.

Potential actions include augmenting summer and fall flows, instream habitat enhancement and reconstruction, preserving the 2 percent to 1 percent floodplain, revegetating disturbed lands, installing stream grade control structures, relocation of instream gravel mining activities, and finding alternative water sources in the upper watershed.

SACRAMENTO RIVER CONSERVATION AREA PROGRAM

California Senate Bill 1086 called for a management plan for the Sacramento River and its tributaries to protect, restore, and enhance both fisheries and riparian habitat. The Sacramento River Conservation Area Program has an overall goal of preserving remaining riparian habitat and reestablishing a continuous riparian ecosystem along the Sacramento River between Redding and Chico, and reestablishing riparian vegetation along the river from Chico to Verona. The program is to be accomplished through an incentive-based, voluntary river management plan. The *Upper Sacramento River Fisheries and Riparian Habitat Management Plan*, January 1989, identifies specific actions to help restore the Sacramento River fishery and riparian habitat between the Feather River and Keswick Dam. The *Sacramento River Conservation Area Forum Handbook*, 2002, is a guide to implementing the program.

The Keswick Dam to Red Bluff portion of the Conservation Area includes areas within the 100-year floodplain, existing riparian bottomlands, and areas of contiguous valley oak woodland, totaling approximately 22,000 acres. The 1989 fisheries restoration plan recommended several actions specific to the study area that have not yet been completed:

- Fish passage improvements at Red Bluff Diversion Dam (under study)
- Potential modification of Spring Creek Tunnel intake for temperature control
- A spawning gravel replacement program
- Development of side-channel spawning areas, such as those at Turtle Bay in Redding
- Structural modifications to the ACID dam to eliminate short-term flow fluctuations
- Maintaining instream flows through coordinated operation of water facilities
- Improvements at the Coleman National Fish Hatchery (partially complete)
- Measures to reduce acute toxicity caused by acid mine drainage and heavy metals
- Various fisheries improvements on Clear Creek (partially complete)
- Flow increases, fish screens, and revised gravel removal practices on Battle Creek
- Controlling gravel mining, improve spawning areas, improve land management practices in the watershed, and protect and restore riparian vegetation along Cottonwood Creek.

IRON MOUNTAIN MINE RESTORATION PLAN

The Iron Mountain Mine Trustee Council, formed by the FWS, DFG, NOAA Fisheries, BLM, and Reclamation, developed the *Final Restoration Plan for Natural Resource Injuries from Iron Mountain Mine*, April 2002. The plan identifies restoration actions to address injuries to, or lost use of, natural resources resulting from acid mine drainage from the Iron Mountain Mine complex. The specific goals of the plan are to restore the following resources affected by toxic mine releases: salmonids, riparian habitat, and instream ecological functions. Proposed actions are located along the Sacramento River and its tributaries between Keswick Reservoir and the RBDD. Injured resources identified in the plan include the following:

- **Anadromous fish** – fall-run chinook salmon.
- **Instream resources of creeks draining the mine** – acid mine drainage and toxic metals have sterilized many creeks, including Boulder, Slickrock, Flat, and Spring creeks.
- **Riparian habitat** – acid mine drainage and toxic metals have severely impacted stream-side soils and habitats along Boulder, Slickrock, Spring, and Flat creeks, resulting in a loss of approximately 39 acres of riparian habitat; stream hydrology has also been altered by diversion dams constructed to collect affected drainage.

- **Lost human-use** – loss of recreation and other public uses of the land.

Restoration actions were also chosen from those listed in the CALFED ERP, including the following:

- **Fish passage improvements** – removal of culvert crossings, modification or removal of locally-owned dams and diversions, fish screens, acquisition of water rights from willing sellers to increase flows, and gravel replenishment in the Sacramento River ranging from 10,000 to 20,000 cubic yards annually.
- **Instream habitat restoration** – large-scale habitat development including artificial riffles, placement of woody debris, and programs to address turbidity and other water quality impairments.
- **Riparian restoration** – livestock exclusion fencing, stream bank restoration and plantings, riparian land acquisition from willing sellers, conservation easements, and invasive species management.

Ongoing restoration actions are funded by $9 million set aside from the approximately $160 million settlement paid by the mine owner for release from all environmental liability. The solicitation and funding of restoration projects occurs through the CALFED program and BLM's Interlakes Special Recreation Management Area recreation planning process.

RIPARIAN HABITAT JOINT VENTURE

The Riparian Habitat Joint Venture (RHJV) was initiated in 1994 and includes signatories from eighteen Federal, State, and private agencies. The RHJV promotes conservation and restoration of riparian habitat to support native bird populations. The three goals of the RHJV are:

- Promote an understanding of the issues affecting riparian habitat through data collection and analysis;
- Double riparian habitat in California by funding and promoting on-the-ground conservation projects; and
- Guide land managers and organizations to prioritize conservation actions.

The RHJV's conservation and action plans are documented in the *Riparian Bird Conservation Plan* of August 2000. The conservation plan targets fourteen 'indicator' species of riparian-associated birds and provides recommendations for habitat protection, restoration, management, monitoring, and policy. The report notes habitat loss and degradation as one of the most important factors causing the decline of riparian birds in California. The RJHV has participated in monitoring efforts within the Sacramento National Wildlife Refuge Complex and other conservation areas. The RHJV's conservation plan identifies Lower Clear Creek as a prime breeding area for Yellow Warblers and Song Sparrows, advocating a continuous riparian corridor along lower Clear Creek. Other recommendations of the conservation plan apply to the SLWRI study area in general.

RESOURCE CONSERVATION DISTRICTS

There are numerous resource conservation districts (RCDs) within the study area. Once known as Soil Conservation Districts, RCDs are established under California law with a primary purpose to implement local conservation measures. Although RCDs are locally governed agencies with locally appointed, independent boards of directors, they often have close ties to county agencies and the National Resource Conservation Service. RCDs are empowered to conserve resources within their districts by implementing projects on public and private lands and to educate landowners and the public about resource conservation. They are often involved in the formation and coordination of watershed working groups and other conservation alliances. In the Shasta Lake and upper Sacramento River vicinity, districts include the Western Shasta County RCD and the Tehama County RCD. To the east are the Fall River and Pit River RCDs, and to the west and north are the Trinity County and Shasta Valley RCDs. Several of the RCDs and their activities relevant to the study area are described in the following sections.

Western Shasta Resource Conservation District

The Western Shasta Resource Conservation District (Western Shasta RCD) is a partner in resource management, watershed management, conservation, and restoration programs within western Shasta County. *The Western Shasta Resource Conservation District Strategic Plan for 1999-2003* established strategic areas of focus for the district, one of which is watershed restoration. Recognizing that an important resource issue in the region is anadromous fisheries, the district has also placed emphasis on improving spawning habitat. The Western Shasta RCD has participated in numerous comprehensive watershed analyses in the primary study area, including studies of the Cow Creek, Cottonwood Creek, Squaw Creek, Upper Clear Creek, and McCloud watersheds. These reports evaluate environmental resource conditions within watersheds, identify problems, and make recommendations for future management actions.

Ongoing restoration work by the District includes erosion control and vegetation management; agreements on the timing of water flows from area dams; assisting local landowners and interested parties in forming watershed groups; spawning gravel injections at strategic locations; isolating deep gravel pits to eliminate fish stranding; and channel reconstruction at former instream mining locations. Other areas of concern include noxious and non-native weeds, erosion control, and fire and fuels reduction. The Western Shasta RCD is participating in the following ongoing programs in the primary study area:

- **Lower Clear Creek Floodway Rehabilitation Project** – The Western Shasta RCD has participated in this multi-agency channel and floodplain restoration project along the lower reaches of Clear Creek. The project has filled former gravel pits, realigned segments of the channel to a more natural state, revegetated floodplains, and constructed wetlands. Elements of the project that have not yet been funded or completed include channel reconstruction and revegetation at a former gravel mining location; annual spawning gravel injections; erosion control at the Saeltzer Dam site and Sunrise Bluffs; channel realignment at Pirate's Den; and channel re-grading to prevent fish stranding.
- **Battle Creek** – The Western Shasta RCD is a local participant in the Battle Creek Community Strategy and is assisting in the implementation of the Battle Creek Salmon and

Steelhead Restoration Plan. Various program components are yet to be implemented, including the removal of dams, construction of fish screens and ladders, and flow augmentation to increase salmonid habitat.

- **Shasta West Watershed** – The Western Shasta RCD developed a watershed assessment for the Shasta West Watershed that recommended restoration activities along various western tributaries to the Sacramento River. Recommended projects that have not yet been completed include culvert removals along Salt Creek; debris cleanout at Swasey Dam; spawning gravel injections on Middle, Salt, and Olney creeks; and erosion control along various creeks to reduce fine sediment input.
- **Cow Creek** – The Western Shasta RCD recently completed a watershed assessment on Cow Creek and began implementing restoration recommendations. Projects that have not yet been funded or implemented include various fish passage and diversion projects; installation of fish screens on diversions; water quality improvement for fecal coliform contamination (due to grazing); and instream spawning area restoration.

Tehama County Resource Conservation District

The Tehama County Resource Conservation District (Tehama County RCD) encompasses about 1.7 million acres within Tehama County, excluding the incorporated cities of Red Bluff, Corning, and Los Molinos. Waterways in the district include Battle, Mill, Paynes, and Cottonwood creeks. The mission of the Tehama County RCD is to manage natural resources at a watershed level through the education and cooperation of residents and stakeholders, focusing on upper watershed and riparian health, water quantity, and water quality.

Fall River Resource Conservation District

The Fall River RCD encompasses over 1.1 million acres of land within Lassen, Modoc, Shasta, and Siskiyou counties. The district includes the Fall River, Pit River, Hat Creek, and Burney Creek watersheds. One of the most prominent environmental resource issues in the district is management of erosion and sedimentation, which has significantly impaired aquatic habitat in numerous streams and creeks. Management measures include 1) controlling bank erosion by livestock exclusion fencing, muskrat control, and boat speed regulation enforcement, 2) restoring and protecting high priority stream and meadow systems in Upper Bear Creek and Dry Creek, and 3) sediment removal activities on Fall River. The district is participating in the Fall River Restoration Project and received funding in 2000 from the McConnell Foundation to purchase conservation easements.

OTHER PROGRAMS AND PRIVATE ORGANIZATIONS

Sacramento Watersheds Action Group

The Sacramento Watersheds Action Group (SWAG) is a non-profit corporation that secures funding for, designs, and implements projects that provide: watershed restoration, streambank and slope stabilization, erosion control, watershed analysis, and road removal. SWAG has successfully worked with local groups, agencies, and organizations to fund and complete restoration projects on the Sacramento River and tributaries downstream from Keswick Dam, including development of the Sulphur Creek Watershed Analysis and Action Plan; the

Whiskeytown Reservoir Shoreline Erosion Control Project; the Sulphur Creek Streambank Stabilization and Channel Reconstruction Projects; the Secret Canyon Stream Crossing Restoration Project; and the Lower Sulphur Creek Realignment and Riparian Habitat Enhancement Project. SWAG is a potential local sponsor for watershed restoration actions in the study area.

Sacramento River Watershed Program

The Sacramento River Watershed Program is an effort to bring stakeholders together to share information and work together to address water quality and other water-related issues within the Sacramento River watershed. The group is funded congressionally through the EPA. The program's primary goal is "to ensure that current and potential uses of Sacramento River watershed resources are sustained, restored, and where possible enhanced while promoting the long-term social and economic vitality of the region." Additional goals of the program are to:

- Sustain effective processes to improve watershed quality and protect beneficial uses of water that meet the interests of all stakeholders in the Sacramento River basin.
- Provide dependable and accessible information through scientifically sound monitoring.
- Provide sound information to support decisions and actions of watershed stakeholders.
- Provide and support an effective process that supports locally led and community based environmental management that meets state and Federal regulatory requirements in locally appropriate ways.
- Develop a stewardship approach to collaborative, whole watershed management.
- Ensure that the interests represented in the development of policies, programs, and activities of the program reflect the diversity of interests represented by all stakeholders of the watershed.

The Sacramento River Watershed Program manages grants for the Sacramento River Toxic Pollutants Control Program, performs extensive water quality monitoring, data collection, and data management for the watershed, and is instrumental in the study and monitoring of toxic pollutants. Although the program does not implement restoration projects, it is a potential provider of technical information for future water quality improvement programs in the study area.

McCloud River Coordinated Resource Management Plan

Participants and signatories to the McCloud River Coordinated Resource Management Plan (CRMP) include Federal, State, and local government agencies, private landowners, industry, and environmental groups. One of the principal objectives of the CRMP is to protect the free-flowing nature of the McCloud River. Also of concern is the river's fishery, which supports a significant commercial sport-fishing industry. The CRMP has several active working groups, including a Research and Monitoring group, but specific projects have not been identified at this time.

Pit River Watershed Alliance

The Pit River Watershed Alliance is a collaborative effort between private and public interests and local landowners to improve aquatic habitat in the Pit River watershed. Environmental concerns include water quality, threatened and endangered species, and noxious weeds. Participants include the Fall River, Central Modoc, Pit and Goose Lake RCDs. The Alliance is a potential partner for environmental restoration actions in the Pit River watershed.

Clear Creek Coordinated Resource Management Plan

The Clear Creek CRMP Group, which consists of stakeholders and local landowners, has been involved since 1995 in planning, implementation, and monitoring of multi-disciplinary restoration projects to promote anadromous salmonids on Clear Creek. Activities to benefit fishery populations that are proposed for implementation include increased water releases from Whiskeytown Dam; improving upstream passage for migrating chinook salmon and steelhead to historical habitat; spawning gravel augmentation; restoration of sediment transport; and reducing fine sediment input from upland erosion.

Battle Creek Watershed Conservancy

The Battle Creek Watershed Conservancy is actively involved in monitoring the actions connected to the Battle Creek Salmon and Steelhead Restoration Project. The conservancy participates in numerous working groups associated with projects on Battle Creek, including the Battle Creek Working Group, Adaptive Management Working Group, Coleman National Fish Hatchery meetings, Spring-Run Group, Steelhead Group, and CALFED Watershed Program Workgroup. The Conservancy administered the first phase of projects on Battle Creek, including conservation easements, noxious weed controls, and restoration in the lower watershed. The group is a potential partner in future restoration actions in the Battle Creek watershed.

Sulfur Creek Coordinated Resource Management Plan

The mission of the Sulphur Creek CRMP is to promote the restoration and enhancement of the Sulphur Creek Watershed near Redding, by providing a forum for communication and cooperation among interested individuals, groups, businesses and local, State, and Federal agencies. Key issues identified by the CRMP include protecting and enhancing the watershed's natural and cultural resources (riparian and upland plant communities, fish and wildlife habitat, water quality); education and recreation opportunities in the urbanizing Redding region; and linking the Sulphur Creek watershed with other natural areas and parkways. A watershed analysis revealed that extensive instream mining, road building, and railroad construction within the watershed, and backwater from the Sacramento River, have resulted in channel degradation and deterioration of aquatic and riparian habitat. The CRMP has participated in several streambed restoration projects with financial assistance from SWAG, CALFED, DWR, and the Cantara Trust.

Cow Creek Watershed Management Group

The Cow Creek Watershed Management Group is a nonprofit organization formed by citizens to manage the resources of the Cow Creek Watershed in a way that "meets the needs of today without infringing on the needs of future generations." The Western Shasta RCD assists the group in an advisory capacity and secured grants from the SWRCB and the Packard Foundation to conduct the *Cow Creek Watershed Assessment* in 2001. Action options considered in the watershed assessment include:

- Installation of fish screens and/or ladders on diversions
- Screening pump intakes in Old Cow Creek and the main stem of Cow Creek
- Increasing flows in Cow Creek and tributaries through irrigation efficiency, vegetation management, purchasing water rights from willing sellers, developing alternate water sources during important flow periods, and implementing a conjunctive use program
- Obtaining landowner easements along key habitat corridors and conducting riparian habitat restoration
- Restore and protect oak woodlands in the lower watershed
- Initiate a prescribed fire/burn program to enhance habitat
- Eradication or control programs for non-native invasive plants
- Consider augmenting streamflows by offsite storage and retention of winter flood flows to improve habitat for fish and wildlife
- Vegetation management to augment streamflows and improve habitat
- Improve spawning substrate in upper reaches.

Cottonwood Creek Watershed Group

This mission of the Cottonwood Creek Watershed Group is to work to preserve the environment, private property and water rights, and economic resources of the Cottonwood Creek watershed through responsible stewardship, liaison, cooperation, and education. Watershed stewardship issues include timber harvesting, fuel management and fire suppression, erosion control, maintaining riparian zones, sediment supply and floodplain processes, and spawning and rearing habitat for salmon in the lower watershed. Specific recommendations are being developed, and fish passage projects are underway in coordination with the FWS.

Sacramento River Preservation Trust

The Sacramento River Preservation Trust is a private, non-profit organization that is active in environmental education and advocacy to preserve the natural environmental values of the Sacramento River. The Trust has participated in various conservation and land acquisition projects, including the securing of lands for the Sacramento River National Wildlife Refuge. Although the group has had limited activity in the study area, it is pursuing the designation of a portion of the Sacramento River between Redding and Red Bluff as a National Conservation Area (see previous discussion on BLM activities).

Shasta Land Trust

The Shasta Land Trust is a regional, non-profit organization dedicated to conserving open space, wildlife habitat, and agricultural land. The Trust works with public agencies and private landowners and is funded primarily through membership dues and donations. It employs various voluntary programs to protect and conserve valuable lands using conservation easements, land donations, and property acquisitions. Current efforts include work in the Cow Creek and Bear Creek watersheds. The Shasta Land Trust has purchased or negotiated conservation easements in the Fenwood Ranch of southern Shasta County and for various properties east of Redding. The Trust is a potential local partner for restoration activities in the Shasta Dam to Red Bluff sub-area.

The Trust for Public Land

The Trust for Public Land is a national, non-profit organization involved in preserving lands with natural, historic, cultural, or recreational value, primarily through conservation real estate. The Trust's Western Rivers Program has been involved in conservation efforts along the Sacramento River between Redding and Red Bluff (the BLM's Sacramento River Bend Management Area), Battle Creek, Paynes Creek, Inks Creek, and Fenwood Ranch in Shasta County. The group promotes public ownership of conservation lands to ensure public access and enjoyment.

Cantara Trustee Council

The Cantara Trustee Council was established to administer settlement funds stemming from the 1991 spill of metam sodium into the Upper Sacramento River, upstream from Shasta Lake. Over 19,000 gallons of the herbicide were released into the Sacramento River when a Southern Pacific train derailed on the Cantara Loop, a rail line near Dunsmuir. The spill resulted in the destruction of nearly all aquatic life within the Upper Sacramento River between the spill and Shasta Lake. The Cantara Trustee Council includes representatives from the DFG, FWS, Central Valley Regional Water Quality Control Board, California Sportfishing Protection Alliance, and the Shasta Cascade Wonderland Association. The Council monitors fish and wildlife along the affected reach and has concluded that major components of the ecosystem have successfully recovered from the spill. The Council also administers a grant program that has provided funding for numerous environmental restoration projects in the primary study area, including programs in the Fall River watershed, Sulphur Creek, upper Sacramento River, Middle Creek, lower Clear Creek, Battle Creek, Salt Creek, and Olney Creek. The Council is a potential local sponsor for future restoration actions in the primary study area.

The Nature Conservancy

The Nature Conservancy (TNC) is a private, non-profit organization involved in environmental restoration and conservation throughout the United States and the world. TNC approaches environmental restoration primarily through strategic land acquisition from willing sellers and obtaining conservation easements. Some of the lands are retained by TNC for active restoration, research, or monitoring activities while others are turned over to government agencies such as the FWS or DFG for long-term management. Lower in the Sacramento River Basin, the TNC has been instrumental in acquiring and restoring lands in the Sacramento River National Wildlife

Refuge and manages several properties along the Sacramento River. It has also pursued conservation easements on various properties at tributary confluences, including Cottonwood and Battle creeks. Within the study area, TNC manages the McCloud River Preserve and lands within the Lassen Foothills Project, described below.

McCloud River Preserve

The McCloud River Preserve was initially formed in 1974 when the McCloud River Club, one of the oldest private fishing clubs in the state, donated 2,330 acres of their stream-front land to TNC. The preserve is located just downstream from McCloud Dam and Lake on the lower McCloud River, and hosts the famous McCloud River trout. The public is permitted limited access in order to maintain the wild nature of the preserve, and prevent fish poaching and other disturbances.

Lassen Foothills Project

Launched in 1997, the Lassen Foothills Project encompasses about 900,000 acres of grasslands, oak woodlands, and streamside forests in the upper Sacramento Valley, roughly between Red Bluff and Mount Lassen. The project has focused on purchasing and obtaining conservation easements on large, working ranches in the area, preventing urbanization and land development while developing wildlife-friendly ranching practices. Land management practices and research projects have included prescribed burning, rotational grazing, reseeding native grasses, research on Blue Oak Woodlands, and various methods to control invasive weeds. Restoration actions have included riparian habitat projects along the lower floodplains and streams

One of the first management properties in the project was the 37,540-acre Gray Davis Dye Creek Preserve, located in the foothills below Mount Lassen. The Dye Creek Ranch came under TNC management in 1987 as the result of a 25-year lease with the State of California. TNC continues to operate the ranch, and the preserve supports a variety of habitat types and native wildlife. The preserve hosts education and research activities, land management and prescribed burn experiments, and various habitat restoration projects, primarily along lower Dye Creek.

The latest addition to the Lassen Foothills Project is the 1,844-acre Wildcat Ranch in the upper Sacramento Valley, also part of the Battle Creek Restoration Project. TNC has assisted the Battle Creek Restoration Project in arranging for the removal of several dams and the construction of fish ladders to promote anadromous fisheries migration within the ranch. Working with the BCWC, agreements were reached with PG&E and various government agencies to open over 40 miles of migratory fish habitat. The partners in the project received the 1999 Governor's Environmental and Economic Leadership Award for environmental restoration and rehabilitation.

California Trout

California Trout (CalTrout) is a private, non-profit organization with a mission to protect and restore wild trout and steelhead and their waters throughout California. CalTrout conservation priorities include the Wild Trout Campaign, grazing reform on public lands, hydropower and dam regulation, and the Steelhead Recovery Campaign. In 1999 CalTrout completed the *Conservation Plan for the New Millennium*, which sets forth restoration policies and details site-specific restoration projects or actions to support steelhead and trout fisheries statewide. CalTrout focuses much of its efforts on flow regulation, including the operation of dams and hydropower facilities to benefit native fisheries. CalTrout has been involved in numerous Federal Energy Regulatory Commission (FERC) dam relicensing projects, including the current relicensing efforts on the Pit and Hat rivers. Other activities include stream restoration and protection projects. CalTrout is a potential partner in future fisheries restoration programs in the study area.

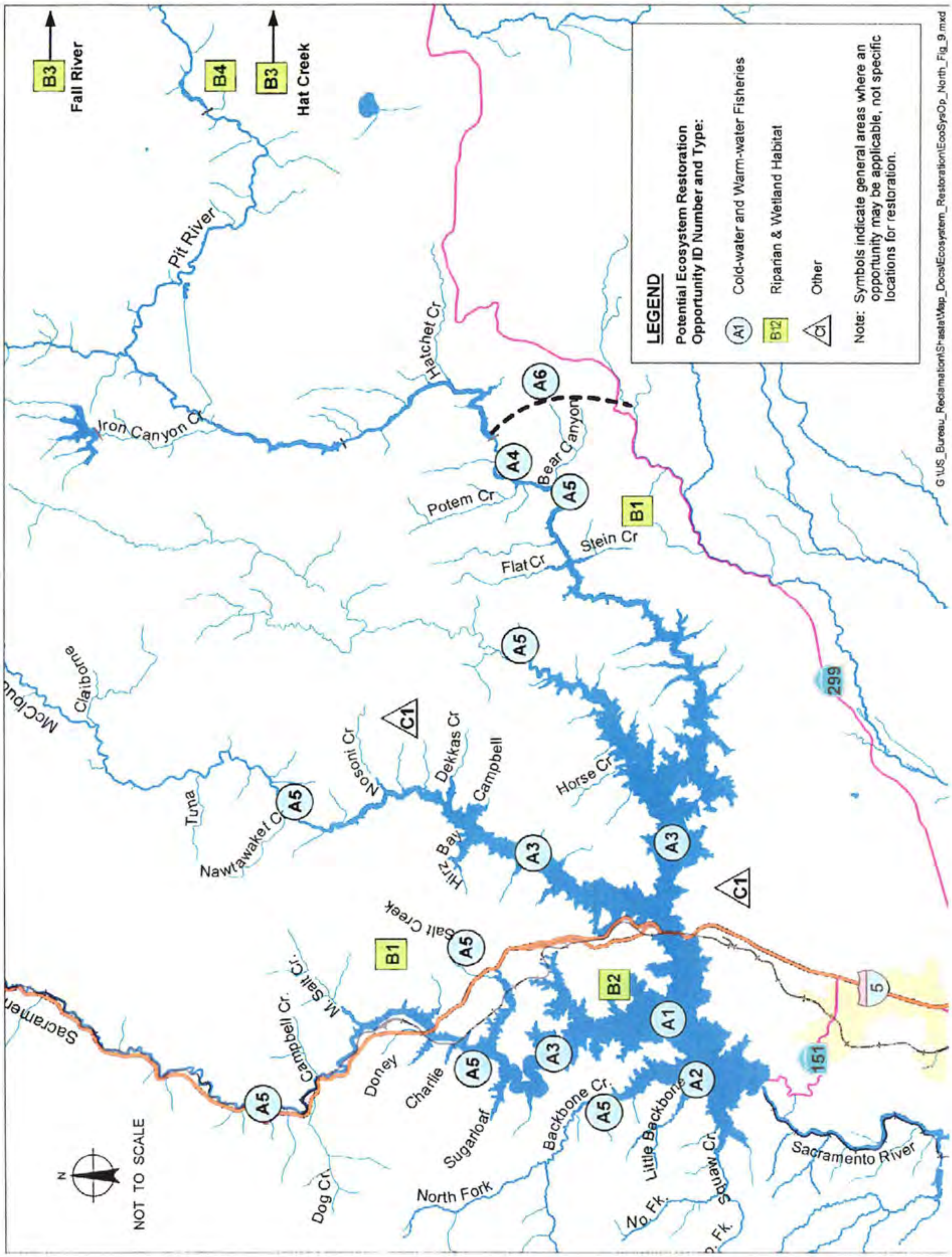


Figure 9 – Potential Ecosystem Restoration Opportunities, Shasta Lake and Tributaries

- **Actions** – Actions would include installation of artificial fish cover including anchored complex woody structures and boulders, and/or plantings of resistant vegetation within the reservoir drawdown area. Specific applications would be chosen as appropriate to shoreline conditions, including rates of erosion, proximity to tributaries or sediment inputs, bank slope, and presence of existing cover or vegetation. Structures would require monitoring after initial installation to determine which applications were most successful.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area. Increased shallow-water fish survival would also enhance recreational sport-fishing opportunities.
- **Implementation Issues and Cost** – DFG participates in fish stocking and monitoring in Shasta Lake and is a potential non-federal sponsor for this measure, possibly through the WCB. Potential implementation issues include the ability to gain access to restoration sites and creation of submerged hazards to boaters. This measure would complement potential measures to raise Shasta Dam because dam raises are likely to increase the shoreline drawdown area subject to erosion and degradation. The cost of this measure would be low relative to the cost of other measures identified herein. Long-term maintenance would not be required, but the effective life of the treatments could vary significantly depending upon site conditions.

A2 – Reduce Acid Mine Drainage Entering Shasta Lake

There are opportunities to reduce the negative impacts of former mining operations on aquatic conditions in Shasta Lake and its tributaries. According to the Regional Water Quality Control Board, abandoned mines are a significant contributor of copper loads to Shasta Lake, and copper, cadmium, zinc, and other trace metals are transported to the Sacramento River downstream from the dam. The greatest contributors to acid mine pollution in Shasta Lake are the abandoned mines located to the west of the lake, tributary to Backbone, Little Backbone, and West Squaw creeks. Runoff from mines in this area continue to cause fish kills and impact water quality in Shasta Lake, and many of the tributary streams themselves are devoid of aquatic life. Remediation activities at several of these mines have been limited because they are located on private land.

- **Actions** – Actions would vary depending upon the mine sites chosen for remediation. Actions could include debris impoundment construction or improvements, capping and mine shaft closure, soil restoration at mines/smelters, and removal of tailings or other debris that can contribute to acid mine drainage. Candidates for further remedial actions include the Mammoth, Balaklala, Keystone, Shasta King, and Bully Hill mines, as described below.
  - **Mammoth Mine** – This large abandoned copper mine discharges acid drainage with average annual copper loads in excess of 30 kg/day to Little Backbone Creek and Shasta Lake, according to the USGS. The owner, Mining Remedial Recovery Company, has implemented a mine sealing program but results have been unsatisfactory according to the U.S. Geological Survey. Substantial modification of the sealing program or a new control strategy, such as collection and treatment, may be required to address the problem.

- **Balaklala, Keystone, and Shasta King Mines** – Drainage from the Balaklala, Keystone, and Shasta King mines have average annual copper loads of 9.0, 1.1, and 0.5 kg/day, respectively, according to the USGS. The owner, Alta Gold Company, has performed some remedial work but comprehensive restoration may be beyond their financial capability. There may be an opportunity for a public agency to purchase the property and utilize recreation-related fees to fund remedial actions.
- **Bully Hill** – The Bully Hill mine is the closest abandoned mine to the shoreline of Shasta Lake. Portions of the tailings are submerged when the reservoir is full; a dam raise would potentially inundate large portions of the extensive tailings and smelter waste piles. Additional remedial actions have been proposed at Bully Hill, including solid waste containment and portal sealing. Mine lands are privately owned.

- **Benefits** – Because toxic discharges into Shasta Lake from abandoned mines contribute to trace metal contamination in the Sacramento River downstream from Shasta Dam, remedial actions would support the primary study objective of increasing the survival of anadromous fish populations in the Sacramento River. This measure would also support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving water quality and aquatic habitat in Shasta Lake and affected tributaries. Increased fish survival would also enhance recreational sport-fishing opportunities.

- **Implementation Issues and Cost** – There are numerous implementation issues associated with mine remediation, but the most significant is liability. The mines identified above as some of the greatest contributors to acid mine drainage in Shasta Lake are all located on private lands; it is difficult for public agencies to perform remediation on private lands due to liability concerns. This would make public sponsorship difficult. The cost for remediation at any of the mines identified above would be high to very high relative to the cost of other measures identified herein. Long-term maintenance costs would be associated with certain remedial actions.

A3 – Reduce Motorcraft Access to Upper Reservoir Arms

There is an opportunity to improve the spawning success of fish in Shasta Lake by restricting the use of motorcraft, to the greatest extent possible, in the upper reaches of reservoir arms. Many resident lake fish spawn and rear in the mouths of the lake's tributaries, which are also popular spots for boaters, fishermen, and personal watercraft users.

- **Actions** – This measure would involve imposing boating and personal watercraft restrictions in portions of Shasta Lake. Portions of the lake are already closed to water-skiing and personal watercraft during drawdown periods, and a 5mph speed limit is imposed within 100 feet of the shoreline throughout the lake. Additional restrictions could include reduced speed limits in upper reaches of reservoir arms or restricting access to portions of the lake during key spawning/rearing periods. Appropriate signage or restrictive buoys may be employed.

- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by reducing juvenile fish mortality. Increased juvenile fish survival would enhance recreational sport-fishing opportunities, but boat access to near-shore fishing areas would be reduced.

- **Implementation Issues and Cost** – Boating on Shasta Lake is regulated by State and Federal boating laws, Shasta County, and the FS. The Shasta County Sheriff's department enforces boating regulations. It is likely that this measure could be implemented through an order issued by the supervisor of the Shasta-Trinity National Forest. The cost associated with such an order would be minimal, as boating regulations on Shasta Lake are updated and printed annually. The cost of enforcing additional boating regulations is expected to be minimal. The overall cost of this measure would be very low relative to other measures identified herein.

A4 – Increase Instream Flows on Pit River

There may be opportunities to increase instream flows on the lower Pit River to benefit native fish and aquatic habitat. Flows on the Pit River are highly dependent upon hydropower operations, which divert flows through a complex series of bypasses and power stations. Increasing instream flows would enhance aquatic habitat, benefiting resident fish and birds of prey such as the endangered Bald Eagle.

- **Actions** – Actions could include power buy-outs, altering power generation operations, or removing selected water diversions or diversion facilities. The FERC license for hydroelectric facilities on the Pit River is scheduled for renewal in 2011; the relicensing process could provide opportunities for reoperation or increases to minimum flows. In addition, the Pit-McCloud Hydroelectric Project is among hydropower assets that PG&E has offered for sale.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving conditions for native fish on the Pit River. The Pit River is a source of high-quality, cold water flows into Shasta Lake. Improving aquatic habitat on the lower Pit River would enhance recreational sport-fishing opportunities in the area.
- **Implementation Issues and Cost** – The Pit River project is owned an operated by PG&E, although it is an asset identified for potential divestiture/sale. The measure could negatively impact hydropower production. The cost of implementing this measure could vary significantly, from low to high relative to the other measures identified, depending upon the actions required to bring about increased flows. The least cost method of implementation would probably be achieved though modification of minimum flows associated with the FERC license renewal. The highest cost method of implementation would involve power or facilities buyouts; no potential non-federal sponsor has been identified for this method of implementation. Power buyouts would involve recurring costs.

A5 – Construct Instream Fish Habitat on Tributaries to Shasta Lake

There is an opportunity to improve instream aquatic habitat along the lower reaches of the tributaries to Shasta Lake using various structural techniques to trap spawning gravels in deficient areas, create pools and riffles, provide instream cover, and improve overall instream habitat conditions. Both perennial and intermittent streams are potential candidates for structural habitat improvements.

- **Actions** – Structural treatments would vary depending upon stream conditions, but include the installation of gabions, log weirs, boulder weirs and other anchored structures. Rearing habitat can be created for juveniles by providing cover with large root wads and by the use of drop structures, boulders, or logs that cause scouring and help clean gravels. If sites chosen for restoration are not already in public ownership or protected under the NFP, easements or other real estate interests may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving aquatic habitat conditions. Both native and non-native fish would benefit, including some lake fish that spawn in the tributaries. It could also benefit steelhead, as some natural reproduction occurs on the lower reaches of the tributaries to Shasta Lake. Improving aquatic habitat would also enhance recreational sport-fishing opportunities in the area.
- **Implementation Issues and Cost** – DFG, the Cantara Trust, and the McCloud River CRMP are potential non-federal sponsors for instream habitat restoration. Each have participated in similar activities in the past. The cost for this measure would be low to medium relative to other measures identified herein, depending upon the number of sites selected for restoration. Long-term maintenance would not be required after initial construction. However, habitat structures would require replacement periodically, depending upon site conditions. Monitoring would be beneficial to determine the effectiveness of various structural treatments.

A6 – Construct a Migration Corridor from Sacramento River to Pit River

Potential opportunities have been suggested to provide access to spawning areas upstream from Shasta Dam via a manmade fish migration corridor. It has been suggested that anadromous fish in the Sacramento River could be provided with access to the Pit River via a combination of the natural channels of Cow Creek, Little Cow Creek, and other creeks and a manmade canal excavated in the lowest elevation saddle between the Cow Creek basin and Pit River basin.

- **Actions** – Major actions would include excavating a fish channel or large diameter tunnel between the Cow Creek basin and the Pit 7 Dam at the upstream end of Shasta Lake on the Pit River; constructing a fish barrier to prevent fish from entering Shasta Lake; installing fish screens and flow control structures at various locations along the natural and manmade migration route to prevent straying; and providing instream flows for fish attraction and survival. If the stream reaches and alignment chosen for the migration corridor is not already in public ownership, easements or other real estate interests may be required to implement the measure and ensure long-term operational performance.
- **Benefits** – This measure would support the primary study objective to increase the survival of anadromous fish populations in the Sacramento River by providing access to additional cold-water spawning habitat in the Pit River. The Pit River is one of the largest tributaries to Shasta Lake and a source of high quality, cold streamflows. However, the numerous hydropower facilities along the lower Pit River would limit the amount of spawning habitat that could be made available.

- **Implementation Issues and Cost** – The fish migration corridor would require a highly complex design and need to operate under a variety of streamflow conditions in order to prevent fish stranding and maintain attraction flows. For this reason, there is a great deal of uncertainty associated with the operational feasibility of this measure. It is likely that portions of the fish migration system would not be capable of passive operation (i.e., would require some type of manual or active control). Currently, water temperatures in the Cow Creek watershed are often higher than desired by migrating salmonids. It is likely that the system would not be capable of operation in dry and critically dry years. The cost of this measure would be high to very high relative to the other measures identified herein. There would be long-term costs associated with maintenance of the fish channel or tunnel, fish barrier, fish screens, and water control structures; a responsible party would need to be identified for long-term maintenance. Further, the amount of increased fish habitat on the Pit River would be limited due to the numerous flow restrictions, such as hydroelectric facilities.

Riparian and Wetland Habitat

B1 – Enhance Forest Management to Preserve Bald Eagle Nesting Habitat

There are opportunities to improve habitat for bald eagles around Shasta Lake and along the lower Pit River. Mature nesting trees were damaged and killed in some areas by severe wildfires in the 1990s, and are threatened by pests, disease, and disturbance by recreational users. Silvicultural techniques could be applied to existing and potential nesting trees within about one mile of Shasta Lake and along the lower Pit River to maintain habitat health.

- **Actions** – Actions would include thinning, application of insecticides to reduce mortality from bark beetles and other pests, control stocking in conifer stands to encourage growth of large trees, and underbrush management to protect important stands from wildfires. Specific locations include Jones Valley on the Pit River arm, Hirz Bay on the McCloud River arm, and Flume Canyon and Frenchman Creek on the Squaw Creek arm.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving habitat conditions for the endangered bald eagle. Shasta Lake supports the largest concentration of nesting bald eagles in California.
- **Implementation Issues and Cost** – This measure is within the purview of existing FS management programs. The cost for this measure would be low relative to other measures identified herein. Periodic monitoring and continuation of silvicultural treatments would be required to maintain long-term benefits.

B2 – Remove and Control Non-Native Plants around Shasta Lake

There is an opportunity to remove and control non-native species in various locations around Shasta Lake. Non-native vegetation has the potential to out-compete native vegetation and alter the suitability of habitat for native wildlife, including special status species. Candidate areas for exotic vegetation control include Wheeler Ranch (yellow start thistle) and Chirpchatter Campground (Himalayan blackberry).

- **Actions** – Actions include removal of invasive species around Lake Shasta, including Himalayan blackberry, scotch broom, and other aggressive plants. Removal methods could include herbicides, physical removal, or controlled burning.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving overall habitat conditions and preventing conversion of native habitats.
- **Implementation Issues and Cost** – This measure is within the purview of existing FS management programs if implemented on National Forest lands. The California Department of Food and Agriculture and the Shasta County Department of Agriculture have also participated in noxious weed abatement programs on private lands in Shasta County. The cost for this measure would be low relative to other measures identified herein. Periodic monitoring and continuation of abatement actions would be required to maintain long-term benefits.

B3 – Restore Wetlands along Fall River and Hat Creek

There are opportunities to restore important marshlands and wetlands along Fall Creek and the Hat River, in the Pit River watershed. Such restoration actions could restore valuable marshland habitat and improve water quality in the Pit River system by helping to regulate water temperatures and sediment input.

- **Actions** – Actions would include structural measures such as log weirs, grade control structures, sediment traps, excavation and channel reconstruction; revegetation; and exclusive fencing to restrict cattle grazing in affected areas. If sites chosen for restoration are not already in public ownership, easements or other real estate interests may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving wetland habitat conditions and the secondary values that wetlands support, including water quality and habitat diversity.
- **Implementation Issues and Cost** – The Fall River RCD and Pit River RCD have participated in similar wetland and marshland restoration projects in the watershed, and are potential non-federal sponsors. RCDs are uniquely positioned to implement this type of measure due to their working relationships with private landowners, but they usually rely on outside funding assistance to implement projects. The cost for this measure would be low relative to other measures identified herein.

B4 – Preserve Upper Pit River Riparian Areas

There are opportunities to install exclusive fencing around valuable riparian corridors to prevent damage from livestock. The majority of cattle grazing in the sub-area occurs in the eastern and southeastern portions of the upper Pit River watershed. Access to riparian areas in the lower reaches of tributary rivers and creeks is limited by provisions of the NFP.

- **Actions** – Actions would include obtaining a real estate interest, such as an environmental easement, installing fencing and natural vegetation barriers around riparian corridors affected by grazing animals. Specific sites have not been identified at this time. Unless the riparian areas selected are already in public ownership, easements or other real estate interests may be required to implement the measure and ensure that the livestock barriers remain in place.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving riparian habitat conditions. Exclusive fencing provides a variety of benefits, including protection of water quality (turbidity, temperature, and fecal coliform) and maintenance of diverse riparian habitats.
- **Implementation Issues and Cost** – Resource conservation districts are potential non-federal sponsors for this measure due to their relationships with local landowners, but RCDs usually rely on outside funding assistance to implement projects. The cost for this measure would be low relative to other measures identified herein.

Other

C1 – Control Erosion and Restore Affected Habitat in Shasta Lake Area

There are opportunities to restore highly erodible lands in the watershed that have been impacted by timber harvest, historic smelter blight, and other human activities. Accelerated erosion can have far-reaching impacts in a watershed, contributing to loss of wildlife habitat, turbidity and sedimentation in streams, stream morphology changes and aquatic habitat degradation, and increased rainfall runoff. Ore smelters that once operated in the region denuded hillsides of vegetation and lead to the loss of topsoil and formation of artificial gullies and other landforms that are still apparent today. Today, intense timber harvesting practices and severe wildfires have similar effects, increasing erosion and sedimentation in area streams, altering stream morphology and degrading habitat. It is often difficult for these areas to recover due to accelerated erosion and loss of topsoil.

- **Actions** – Actions would include sediment traps and barriers, natural erosion protection, sediment removal, and revegetation. Specific sites have not been identified at this time, but it is anticipated that they would be located on public lands. If sites chosen for restoration are not already in public ownership, easements or other real estate interests may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving terrestrial and aquatic habitat conditions.
- **Implementation Issues and Cost** – Erosion control projects often fall within the purview of resource conservation districts or the FS, but local districts usually rely on outside funding assistance. The cost for this measure would be low to moderate relative to other measures identified herein, depending upon the extent and types of treatment employed.

SACRAMENTO RIVER FROM SHASTA DAM TO RED BLUFF SUB-AREA

The key environmental problems within the Shasta Dam to Red Bluff sub-area that were summarized in Chapter III fell into two general categories: those related to anadromous fisheries, and those related to wetland and riparian habitat. Potential environmental restoration measures are grouped likewise below, with an additional category for other potential actions that may not fit strictly within either category. Approximate locations where each measure could be applied are shown in Figure 10.

Anadromous Fisheries

A7 – Restore Inactive Gravel Mines on Sacramento River

There are opportunities to restore and reclaim inactive gravel mining operations along the Sacramento River. Abandoned gravel pits are the cause of fish stranding and high predation rates. Due to changes in flow regime and reductions in coarse sediment input, the river is not capable of refilling and restoring these pits naturally.

- **Actions** – The Shea Pits near Redding are separated from the river by levees; actions could include reconnection of the mining area to the river via removal of levees, filling and re-contouring the site, and restoring aquatic, riparian, and floodplain habitat alongside the Sacramento River. Similar opportunities exist at inactive mining sites near Anderson and Red Bluff. If sites chosen for restoration are not already in public ownership, easements or other real estate interests may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by eliminating stranding in abandoned gravel pits and creating new aquatic, riparian, and wetland habitat. Restoring stream habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining spawning areas available to anadromous fish. The measure also supports the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River through the restoration of riparian and floodplain habitat.
- **Implementation Issues and Cost** – DFG or DWR are potential non-federal sponsors for this measure. There appears to be a high degree of public agency and local interest for gravel pit restoration. This measure would complement potential measures to raise Shasta Dam because improved release flexibility would enable anadromous fish to take greater advantage of restored spawning areas. The cost for this measure would be moderate relative to other measures identified herein.

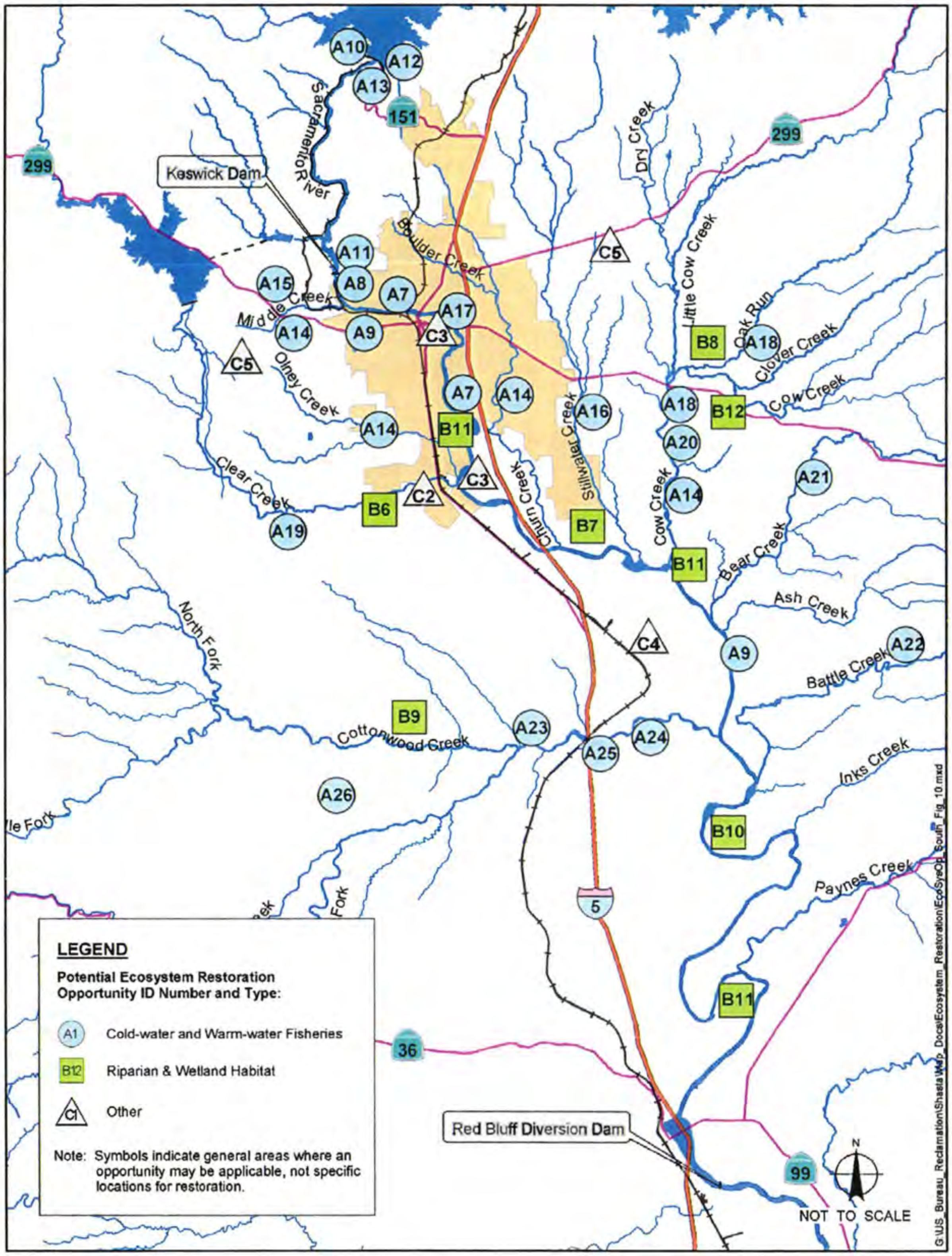


Figure 10 – Potential Ecosystem Restoration Opportunities, Shasta Dam to Red Bluff

A8 – Construct Instream Habitat Downstream from Keswick Dam

There are opportunities to construct complex instream habitat in the Sacramento River downstream from Keswick Dam. This reach of the river is entrenched in bedrock and has few sources of large woody debris, gravels, and instream structures providing complex fish habitat. However, the area attracts spawners because stream temperatures immediately below Keswick Dam typically remain favorable due to cold-water releases from Shasta Dam. Predation can be high due to the lack of cover.

- **Actions** – Actions could include constructing manmade instream structures using anchored root wads and other natural materials and strategic placement of large boulders. Such structures would improve the complexity of the aquatic habitat in this reach, help trap sediment, and benefit juvenile rearing. Additional actions include gravel replenishment and the construction of side channels for spawning and rearing immediately below Keswick Dam.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by restoring important spawning habitat below Keswick Dam. Restoring aquatic habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining spawning areas available to anadromous fish.
- **Implementation Issues and Cost** – DFG or DWR are potential non-federal sponsors for this measure. There may be a high degree of public agency interest for restoration in this reach. This measure would complement potential measures to raise Shasta Dam because improved release flexibility would enable anadromous fish to take greater advantage of restored spawning areas. The cost for this measure would be moderate relative to other measures identified herein. Operation and maintenance of this measure would be high compared to other measures.

A9 – Replenish Spawning Gravel in Sacramento River

There are opportunities to replenish spawning gravel in the Sacramento River and along the lower reaches of its tributaries. The reach immediately downstream from Keswick Dam has no natural gravel sources and provides marginal spawning habitat. The lower reaches of Sacramento River tributaries, including Clear Creek and Battle Creek, also provide valuable spawning habitat for salmonids. Instream gravel mining and the construction of dams and other barriers have reduced gravel recruitment in many of the tributaries. These gravel sources could be artificially replaced by gravel injections.

- **Actions** – Actions would include injecting suitable gravels into the Sacramento River immediately below Keswick Dam, and in tributaries that provide important spawning habitat such as Clear Creek and Battle Creek. Structural treatments may be required below Keswick Dam to prevent the gravel from being washed downstream prematurely by releases. Temporary construction easements could be required to gain access to injection sites.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by restoring spawning gravels in

stream channels that no longer have adequate gravel resources. After water temperature, the presence and quality of spawning gravel is probably the most important factor contributing to the reproductive success of anadromous fish. The availability of suitable spawning gravels may be a limiting factor in the restoration of anadromous fish populations in the Sacramento River.

- **Implementation Issues and Cost** – Spawning gravel replenishment programs have been successful along the Sacramento River in the past, inferring a high likelihood of effective implementation. DFG, DWR, and the Western Shasta RCD are potential non-federal sponsors for this measure. This measure would complement potential measures to raise Shasta Dam because improved release flexibility would enable anadromous fish to take greater advantage of restored spawning habitat. The cost for this measure would be moderate relative to other measures identified herein. Operation and maintenance of this measure would be very high compared to other measures.

A10 – Additional Modifications to Shasta Dam for Temperature Control

There is an opportunity to improve water temperature conditions in the Sacramento River through additional structural modifications to the temperature control device (TCD) at Shasta Dam. Modifications in addition to those associated with the existing TCD could allow even greater flexibility in making cold-water releases during critical spawning periods and extend the area of suitable spawning habitat in the Sacramento River.

- **Actions** – Actions would include reducing leakage of warmer water at the existing TCD, increasing the capacity of the existing low-level outlets, and/or increasing the depth from which water can be released from the reservoir.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by improving the ability to provide desirable water temperatures for spawning, rearing, and out-migration. Water temperature is one of the most important factors contributing to the success of anadromous fish reproduction.
- **Implementation Issues and Cost** – This measure would complement potential measures to increase storage in Shasta Dam because additional temperature control improvements could be incorporated into the design of a dam raise and further improve cold-water releases. The cost for this measure would be high to very high relative to other measures identified herein.

A11 – Improve the Fish Trap below Keswick Dam

There is an opportunity to improve the fish trap below Keswick Dam to increase the survival of anadromous fish captured at the facility, providing additional adults and increased egg production for fish hatchery operations. Fish trapped at Keswick Dam are transported to the Coleman National Fish Hatchery on Battle Creek.

- **Actions** – Actions would include reconstructing the existing fish trap and making channel improvements downstream from the trap.

- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by reducing mortality at the Keswick fish trap and increasing the number of adults available to the fish hatchery.
- **Implementation Issues and Cost** – The cost for this measure would be moderate to high relative to other measures identified herein.

A12 – Enlarge Shasta Lake Cold Water Pool

There is an opportunity to increase the volume of the cold water pool in Shasta Lake to help maintain cooler releases for anadromous fish during certain periods by raising Shasta Dam and enlarging Shasta Reservoir. There are certain periods especially during dry and critically dry periods when meeting temperature needs for certain runs of anadromous fish is not possible. Increasing the cold water pool in Shasta Lake could help reduce these periods. There are certain periods when additional releases could be made from the enlarged lake storage space to help dilute acid mine drainage from Spring Creek. This measure could also help address the other primary planning objective and the secondary objectives. This measure is consistent with the objectives of the California Bay-Delta Authority (CALFED).

- **Actions** – Primary actions would include raising Shasta Dam. Low raises could be made with relatively minor required mitigation to reservoir area natural resources and infrastructure.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by improving temperature, flow, and aquatic habitat conditions. It could also benefit other primary and secondary planning objectives.
- **Implementation Issues and Cost** – This measure would be very costly. There may be little interest by a non-federal sponsor to share in the cost of this measure if it were accomplished solely for the objective of increasing the survival of anadromous fish.

A13 – Modify Storage and Release Operations at Shasta Dam

This measure includes modifying reservoir storage and release operations at Shasta Dam to benefit anadromous fisheries. Releases from Shasta Dam are currently made with a major focus on maintaining temperature objectives downstream for anadromous fish. Release changes may have the potential to increase cold-water discharges during certain periods, which could extend the downstream reach of suitable habitat conditions for spawning by salmonids in the river. Changing the timing and magnitude of releases, especially from an increased pool (see A12), would have the potential to improve aquatic habitat by cleaning spawning gravels, and would improve attraction flows that cue in-migration and temperatures that cue out-migration. Releases could also be increased to dilute acid mine drainage from Spring Creek during periods of overspill.

- **Actions** – Actions would include revising reservoir release criteria to permit more flexibility in making releases beneficial to anadromous fish.

- **Benefits** – This measure could support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by improving temperature, flow, and aquatic habitat conditions. However, without mitigating features to account for potential reductions in water supply, it could adversely impact the primary objective of water supply reliability.
- **Implementation Issues and Cost** – This measure could have undesirable effects on water supply or hydropower production. However, it would complement measures to increase the height of Shasta Dam and capacity of Shasta Reservoir, which could offset hydropower or water supply impacts. The cost for this measure would be moderate relative to other measures identified herein, depending upon the cost of features to mitigate impacts to hydropower and/or water supply reliability.

A14 – Construct Instream Fish Habitat on Tributaries to Sacramento River

There is an opportunity to improve instream aquatic habitat along the lower reaches of the tributaries to the Sacramento River using various structural techniques to trap spawning gravels in deficient areas, create pools and riffles, provide instream cover, and improve overall instream habitat conditions. Both perennial and intermittent streams are potential candidates for structural habitat improvements.

- **Actions** – Structural treatments would vary depending upon stream conditions, but include the installation of gabions, log weirs, boulder weirs, and other anchored structures. Rearing habitat can be created for juveniles by providing cover with large root wads and by the use of drop structures, boulders, or logs that cause scouring and help clean gravels. Candidates for aquatic habitat improvement include Middle, Olney, Churn, and Cow creeks. If the stream or creek reaches chosen for restoration were not in public ownership, easements could be required to implement the improvements.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations by enhancing aquatic conditions on tributaries that provide important spawning and rearing habitat.
- **Implementation Issues and Cost** – DFG is a potential non-federal sponsor for instream habitat restoration. The cost for this measure would be low to medium relative to other measures identified herein, depending upon the number of sites selected for restoration. Long-term maintenance would not be required after initial construction, though monitoring would be beneficial to determine the effectiveness of various structural treatments.

A15 – Remove Instream Sediment along Middle Creek

There is an opportunity to implement a sediment removal and control program along Middle Creek, an intermittent tributary to the Sacramento River between Keswick Dam and Redding. Lower Middle Creek supports spawning runs of rainbow trout, steelhead, and salmon. Spawning gravels have been degraded by fine granitic sediment that erodes from streambanks and adjacent land. Sediment from the creek also impacts spawning habitat in the Sacramento River around the Middle Creek confluence.

- **Actions** – Actions include dredging the Swasey sediment basin, streambank and gully protection, and small sediment capture impoundments on tributaries. If the creek reaches chosen for restoration are not already in public ownership, land easements could be required to implement the improvements and to ensure the continued benefits of the measure.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations by enhancing aquatic conditions on tributaries that provide important spawning and rearing habitat.
- **Implementation Issues and Cost** – DFG is a potential non-federal sponsor for instream habitat restoration. The cost for this measure would be low to medium relative to other measures identified herein. There appears to be local support for actions on Middle Creek. Repeated sediment removal may be required to maintain long-term benefits.

A16 – Restore Instream Gravel Mines along Stillwater Creek

There is an opportunity to rehabilitate and revegetate former instream gravel mining sites along Stillwater Creek. There are seven inactive gravel pits on Stillwater Creek that have depleted nearly all of the instream gravel resources in some reaches, leaving the channel scoured to bedrock. Stillwater Creek provides seasonal habitat for various anadromous and resident fish.

- **Actions** – Actions would include filling abandoned pits, re-contouring the channel and floodplain, and restoring aquatic, riparian, and floodplain habitat alongside the creek. If the instream sites chosen for restoration are not already in public ownership, easements or land acquisition could be required to implement the improvements and to ensure the continued benefits of the measure.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by eliminating stranding in abandoned gravel pits and restoring aquatic and riparian habitat. The measure also supports the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River through the restoration of riparian and floodplain habitat.
- **Implementation Issues and Cost** – DFG and DWR are potential non-federal sponsors for this measure. There appears to be a high degree of public agency interest in gravel pit restoration. The cost for this measure would be moderate relative to other measures identified herein. There would be initial short-term maintenance and monitoring costs associated with revegetation, but no long-term maintenance requirements are anticipated.

A17 – Modify ACID Diversion to Reduce Flow Fluctuations

There is an opportunity to modify operations at the ACID diversion dam near Anderson to reduce flow fluctuations and resulting impacts to anadromous fish. Extreme fluctuations in Sacramento River flows result in fish stranding and juvenile fish mortality.

- **Actions** – Actions would include reconstructing the dam and diversion screens to facilitate flexibility in operation and reduce significant fluctuations in flow. The facility could also be reoperated to maintain flows of 5,000 cfs to 5,500 cfs during the critical migration period from October through April.

- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by alleviating flow fluctuations that cause stranding and juvenile mortality.

- **Implementation Issues and Cost** – DFG and ACID are potential non-federal sponsors for this measure. This measure would complement the measures to enlarge the Shasta Lake cold water pool and to modify the storage and release operations at Shasta Dam (A12 and A13) by providing additional flexibility in regulating flows in the Sacramento River. The cost for this measure would be moderate to high relative to other measures identified herein.

A18 – Screen Diversions on Old Cow and Cow Creeks

There is an opportunity to screen the diversion intakes in the Cow Creek watershed to reduce fish mortality. There are over 100 diversions from the Cow Creek watershed. While many are small agricultural diversions, larger diversions can entrain juvenile salmonids and other fish that utilize the spawning habitat provided by the watershed.

- **Actions** – Actions would include installing fish screens on diversions over five feet per second that are located within the range of spawning salmonids. Alternatively, multiple diversions could be consolidated and screened or alternative water supplies could be developed, such as groundwater. Potential diversions are listed in Table V-1. Construction easements would be required at the diversions chosen for screening.

- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by reducing salmonid mortality at diversions within the Cow Creek watershed.

- **Implementation Issues and Cost** – There appears to be significant local and agency interest in screening diversions in the Cow Creek watershed. This measure was recommended in the *Cow Creek Watershed Assessment*, 2001 and by the Western Shasta RCD. The cost for this measure would be moderate relative to other measures identified herein, depending upon the number of diversions selected for screening.

TABLE V-1
DIVERSIONS GREATER THAN FIVE CFS IN THE COW CREEK WATERSHED

Tributary	Location (miles up tributary)	Diversion Name	Diversion Rate (cfs)
Old Cow Creek	24	Kilarc Powerhouse Ditch	58.0
Old Cow Creek	10	Bassett Ditch	27.6
Old Cow Creek	16	Brown Grover	14.0
Old Cow Creek	12	Parker Hufford Ditch	11.1
Glendenning	2.5	Neely Glendenning Creek Ditch	7.8
Old Cow Creek	6.5	Crowe Lower Ditch	7.8
Canyon Creek	N/A	East Canyon Creek Ditch	7.5
South Cow Creek	10.5	South Cow Creek Powerhouse Ditch	47.9
South Cow Creek	21	German Ditch	13.7
Mill creek	0	Mill Creek Ditch	13.5
South Cow Creek	6.5	Abbott Ditch	13.1
Atkins Creek	1.5	Worden Ditch	5.5
South Cow Creek	13.5	East Hufford Ditch	5.0

Source: Cow Creek Watershed Assessment, 2001
Note: Some of the diversions listed above may already be screened; specific diversions have not been selected for this measure.

A19 – Increase Instream Flows on Clear Creek by 150 to 200 cfs

There is an opportunity to increase instream flows on Clear Creek during critical periods to support anadromous fish that spawn in the creek. The removal of McCormick-Saeltzer Dam has restored access to many miles of spawning habitat on Clear Creek. However, all but about 13 percent of flows in Clear Creek are diverted to the Spring Creek Powerplant above Whiskeytown Dam, leaving insufficient flows during dry and critically dry years to support significant spawning runs.

- **Actions** – Increasing minimum flows by 150 to 200 cfs would require modifications to diversion operations at Whiskeytown Dam to allow more water to remain in Clear Creek.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by increasing the amount of suitable tributary spawning habitat available on Clear Creek during dry and critically dry years. This measure would complement recent aquatic habitat restoration programs along lower Clear Creek.
- **Implementation Issues and Cost** – This measure was recommended in the CALFED ERP. The measure would require changes to the operation of Whiskeytown Dam, which currently diverts Clear Creek flows to the Spring Creek Powerplant. There could be negative impacts associated with hydropower generation. The cost for this measure would be moderate relative to other measures identified herein, depending upon the impacts to power production at Spring Creek.

A20 – Increase Instream Flows on Cow Creek by 25 to 50 cfs

There is an opportunity to increase instream flows on Cow Creek to support anadromous fish during critical periods. Increasing flows would increase the quality of instream habitat and help reduce water temperatures, a factor limiting the use of Cow Creek by anadromous fish.

- **Actions** – Minimum flows would be increased by 25 to 50 cfs during critical spawning periods (May through October) and dry years. These increases could be achieved through voluntary agreements with local agricultural water users or by providing an alternate water supply, such as groundwater, during critical flow periods. Groundwater wells could be developed to replace the spring and summer diversions of the larger agricultural water users.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by increasing the amount of suitable tributary spawning habitat available on Cow Creek.
- **Implementation Issues and Cost** – This measure was recommended in the CALFED ERP. The measure would require agreements with numerous agricultural water diverters on Cow Creek. The cost for this measure would be low to moderate relative to the other measures identified herein, depending upon the need for and availability of alternate agricultural water sources.

A21 – Increase Instream Flows on Bear Creek by 10 to 20 cfs

There is an opportunity to increase instream flows on Bear Creek to support anadromous fish during critical periods. Increasing flows would increase the quality of spawning habitat and help reduce water temperatures.

- **Actions** – Minimum flows would be increased by 10 to 20 cfs during critical spawning periods and dry years. These increases could be achieved through voluntary agreements with local agricultural water users or by providing an alternate water supply, such as groundwater, during critical flow periods. Groundwater wells could be developed to replace the spring and summer diversions of the larger agricultural water users.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by increasing the amount of suitable tributary spawning habitat available on Bear Creek.
- **Implementation Issues and Cost** – This measure was recommended in the CALFED ERP. The measure would require agreements with agricultural water diverters on Bear Creek. The cost for this measure would be low to moderate relative to the other measures identified herein, depending upon the need for and availability of alternate agricultural water sources.

A22 – Remove or Screen Diversions on Battle Creek

There are opportunities to remove or screen diversions and other water control facilities on Battle Creek to allow full use of the watershed's high-quality, cold-water spawning habitat. Several projects have been implemented on lower Battle Creek to improve access and spawning success, but large portions of the upper Battle Creek watershed remain inaccessible to anadromous fish due to diversions.

- **Actions** – Actions identified for Battle Creek include installing fish screens and fish ladders at North Fork diversions below the North Fork Battle Creek Feeder; installing screens and ladders on all South Fork diversions; and installing additional fish screens and fish ladders above Eagle Canyon. It may also be possible to remove or consolidate some diversions. Construction easements would be required at diversions selected for screening or modification.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by providing access to high-quality spawning habitat in the upper Battle Creek watershed. Battle Creek's cool flows and gravel resources make this tributary system an important spawning and rearing resource for salmonids.
- **Implementation Issues and Cost** – There appears to be significant local and agency interest in additional anadromous fish restoration projects in the Battle Creek watershed. The cost for this measure would be moderate relative to other measures identified herein, depending upon the number of diversions selected.

A23 – Restore Instream Gravel Mines along Cottonwood Creek

There is an opportunity to rehabilitate and revegetate several inactive instream gravel mines along lower Cottonwood Creek, which provides valuable spawning and rearing habitat for anadromous fish. Cottonwood Creek is also an important source of spawning gravel to the Sacramento River.

- **Actions** – Actions would include filling abandoned pits and re-contouring the channel and floodplain, and restoring aquatic, riparian, and floodplain habitat alongside the creek. If the lands chosen for restoration are not already in public ownership, land acquisition and/or easements may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by restoring tributary spawning habitat on Cottonwood Creek. The measure also supports the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River through the restoration of riparian and floodplain habitat.
- **Implementation Issues and Cost** – DFG and DWR are potential non-federal sponsors for this measure. There appears to be a high degree of public agency interest in gravel pit restoration and growing local interest for restoration on Cottonwood Creek. The cost for this measure would be moderate relative to other measures identified herein.

A24 – Restore Streambed near ACID Siphon on Cottonwood Creek

There is an opportunity to restore the streambed near the ACID siphon on Cottonwood Creek to prevent degradation of this anadromous fish migration corridor. Erosion and channel downcutting at the siphon has altered the streambed and may prevent migration up Cottonwood Creek during low flow periods.

- **Actions** – Actions would include excavating and replacing the existing ACID siphon followed by re-contouring and armoring the streambed to prevent future erosion. Some vegetation replacement may be required. If the stream reach is not already in public ownership, easements may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by restoring tributary spawning habitat on Cottonwood Creek.
- **Implementation Issues and Cost** – DFG and the local RCD are potential non-federal sponsors for this measure. There appears to be growing local interest in fisheries restoration projects on Cottonwood Creek. This action was recommended in the recently completed *Cottonwood Creek Watershed Assessment*, 2001. The cost for this measure would be low relative to other measures identified herein.

A25 – Construct Fish Barrier at Crowley Gulch on Cottonwood Creek

There is an opportunity to construct a fish barrier at the mouth of Crowley Gulch on Cottonwood Creek to eliminate adult fall-run chinook stranding. Intermittent flows in Crowley Gulch attract spawners to the waterway but they often become trapped when flows decrease.

- **Actions** – Actions would include constructing a physical barrier within the Crowley Gulch stream channel to prevent fish from entering the stream during low flows. The barrier could be passive or active in operation, depending upon stream flow and channel conditions. A passive barrier would likely be earthen in nature and employ culverts or shallow flow weirs. An active barrier would employ flashboards or other temporary barriers that would need to be put in place annually and removed following critical spawning periods. If the area chosen to construct the barrier is not already in public ownership, land acquisition and/or easements may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by preventing stranding mortality on Cottonwood Creek.
- **Implementation Issues and Cost** – DFG and the local RCD are potential non-federal sponsors for this measure. There appears to be growing local interest in fisheries restoration projects on Cottonwood Creek. This action was recommended in the recently completed *Cottonwood Creek Watershed Assessment*, 2001. The cost for this measure would be low relative to other measures identified herein.

A26 – Construct Storage Facility on Cottonwood Creek to Augment Spring Flows

There is an opportunity to construct an onstream or offstream storage facility on upper Cottonwood Creek to support flows for spring-run chinook salmon. A storage facility would provide the means to make late-spring and summer releases to increase streamflows for spring-run chinook salmon, and improve overall seasonal aquatic conditions.

- **Actions** – Actions would include constructing an onstream or offstream dam and reservoir to capture winter flows for release in the late spring and summer. An onstream reservoir would be constructed along the existing channel of upper Cottonwood Creek or one of its tributaries; an offstream facility would be constructed adjacent to Cottonwood Creek and be filled via diversion from one or more Cottonwood tributaries. Significant land acquisition and construction easements at the proposed reservoir site would be required to implement this measure.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by supporting spring-run chinook salmon on Cottonwood Creek. This measure may also provide residual flood control benefits, supporting the secondary study objective to reduce flood damages along the Sacramento River.
- **Implementation Issues and Cost** – There would be significant environmental impacts associated with constructing a dam and reservoir in this otherwise undeveloped watershed; there is a potential to impact vernal pools and other sensitive grassland habitats. The cost for this measure would be high to very high relative to other measures identified herein. There would be moderate long-term maintenance costs associated with the dam and reservoir.

Riparian and Wetland Habitat

B5 – Restore Riparian and Floodplain Habitat on Lower Clear Creek

There is an opportunity to continue the floodplain and riparian habitat restoration work being performed on lower Clear Creek. Several additional phases of Western Shasta RCD's Clear Creek Project have not been funded to date, and present an opportunity to continue riparian habitat restoration along this important spawning corridor.

- **Actions** – Actions include channel relocation and revegetation at two historic gravel mining locations; spawning gravel injection; and erosion control at the former McCormick-Saeltzer dam site and the Sunrise Bluffs. Some work would be performed instream and some would be performed within adjacent floodplains. If the lands chosen for restoration are not already in public ownership, land acquisition and/or easements may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by improving conditions for anadromous fish that spawn and rear along lower Clear Creek. Gravel injections would eventually reach and benefit the Sacramento River. Similarly, erosion control measures on Clear Creek could also benefit sediment conditions at the confluence with the Sacramento River.
- **Implementation Issues and Cost** – This measure has been proposed by the Western Shasta RCD, indicating a high degree of local support. The cost for this measure would be low to moderate relative to other measures identified herein.

B6 – Restore Offstream Gravel Mines near Sacramento River

There are opportunities to restore inactive offstream gravel pits along the Sacramento River and its tributaries. Restoration provides the opportunity to develop a variety of valuable wetland, riparian, floodplain, and upland habitats.

- **Actions** – Actions include partial or complete filling of former pits, re-contouring and grading floodplain areas, reconnection with area drainages or streams, and revegetation. Ten inactive gravel mines were identified by DWR in *Use of Alternative Gravel Sources for Fishery Restoration*, 1994, although it is likely that not all of these sites are suitable for restoration and some may be located on private land. If the lands chosen for restoration are not already in public ownership, land acquisition and/or easements may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by restoring and/or creating wetland, riparian, floodplain, and upland habitat near the Sacramento River.
- **Implementation Issues and Cost** – The cost for this measure would be moderate relative to other measures identified herein, depending upon the number of sites selected for restoration.

B7 – Remove and Control Non-native Vegetation in Cow Creek Watershed

There is an opportunity to implement exotic vegetation abatement in the Cow Creek watershed. Noxious weeds and other non-native invasive plants threaten the limited riparian corridors and diminishing native grassland habitats in Cow Creek.

- **Actions** – Actions include removal of invasive species from riparian corridors, including arundo (giant reed), Himalayan blackberry, Scotch broom, pampas grass, and other aggressive species. Removal methods could include herbicides, physical removal, or controlled burning. Construction easements would be required to implement this measure.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by preserving native riparian habitat. Riparian habitat also contributes to the quality of instream aquatic habitat, providing shade and a source of woody debris; therefore, this measure may also support the primary study objective to increase the survival of anadromous fish that spawn and rear along Cow Creek.
- **Implementation Issues and Cost** – No non-federal sponsor has been identified for this measure. The cost for this measure would be low relative to other measures identified herein, depending upon the extent of vegetation removal and type of control methods. Periodic monitoring and reapplication of control measures would be required to maintain long-term benefits and effectiveness.

B8 – Remove and Control Non-native Vegetation along Cottonwood Creek

There are opportunities to implement exotic vegetation abatement in the Cottonwood Creek watershed. Noxious weeds and other non-native invasive plants threaten the limited riparian corridor along Cottonwood Creek.

- **Actions** – Actions include removal of invasive species from riparian corridors, including arundo, Himalayan blackberry, Scotch broom, and other aggressive species. Removal methods could include herbicides, physical removal, or controlled burning. Construction easements would be required to implement this measure.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by preserving native riparian habitat. Riparian habitat also contributes to the quality of instream aquatic habitat, providing shade and a source of woody debris; therefore, this measure may also support the primary study objective to increase the survival of anadromous fish that spawn and rear along Cottonwood Creek.
- **Implementation Issues and Cost** – This measure was recommended by the *Cottonwood Creek Watershed Analysis*, 2001, indicating growing local support for work on Cottonwood Creek. No non-federal sponsor has been identified for this measure. The cost for this measure would be low relative to other measures identified herein, depending upon the extent of vegetation removal and type of control methods. Periodic monitoring and reapplication of control measures would be required to maintain long-term benefits and effectiveness.

B9 – Promote Great Valley Cottonwood Regeneration on Sacramento River

There is an opportunity to support Great Valley Cottonwood regeneration along the Sacramento River. Cottonwood regeneration has significantly decreased over the last century due to flow and stream morphology changes, urban encroachment, gravel mining, and rock revetment. Cottonwoods add to the complexity of riparian habitat and support a more diverse ecosystem.

- **Actions** – Actions include replacing lost floodplain sediment, regrading or recontouring floodplains that have been disconnected from the river, and revegetating floodplain areas that could support Great Valley Cottonwoods. Specific areas for restoration have not yet been identified. If the sites chosen for restoration are not already in public ownership, land acquisition and/or easements may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by preserving native riparian habitat. Riparian habitat also contributes to the quality of instream aquatic habitat, providing shade and a source of woody debris; therefore, this measure may also support the primary study objective to increase the survival of anadromous fish on the Sacramento River.
- **Implementation Issues and Cost** – The low rate of Cottonwood regeneration was identified by the SRCA forum as one of the factors threatening remaining riparian habitat along the Sacramento River. There appears to be some local support for this type of restoration project

along the Sacramento River, particularly near urban areas that are beginning to place more value on natural habitats for recreation and general public enjoyment. The cost for this measure would be low to moderate relative to other measures identified herein, depending upon the extent of restoration actions taken. There would be initial short-term monitoring and maintenance associated with revegetation.

B10 – Riparian and Floodplain Restoration along Sacramento River

There is an opportunity to perform riparian and floodplain habitat restoration along the Sacramento River to promote the health and vitality of the river ecosystem. Locations near tributary confluences that are inundated by floods on a fairly frequent basis would be targeted for restoration to maximize the potential for long-term success and benefits.

- **Actions** – Actions would include replacing lost floodplain sediment, regrading or recontouring floodplains that have been disconnected from the river, removal of berms or levees (as appropriate), and revegetating floodplain and adjacent riparian areas. Locations for restoration would be in areas with a 20 percent to 50 percent chance of flooding in any year to ensure riparian habitat growth and regeneration. If the lands chosen for restoration are not already in public ownership, land acquisition and/or easements may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by restoring native riparian habitat and associated floodplain lands. Riparian habitat also contributes to the quality of instream aquatic habitat, providing shade and a source of woody debris; therefore, this measure may also support the primary study objective to increase the survival of anadromous fish on the Sacramento River.
- **Implementation Issues and Cost** – There appears to be local support for this type of restoration project along the Sacramento River, and the importance of restoring habitat at tributary confluences has been highlighted by several studies and programs. The cost for this measure would be low to moderate relative to other measures identified herein, depending upon the extent of restoration actions taken. There would be initial short-term monitoring and maintenance associated with revegetation.

B11 – Preserve Riparian Vegetation on Cow Creek

There is an opportunity to protect valuable riparian corridors in the Cow Creek watershed that are impacted by cattle grazing. Damages caused by grazing include loss of vegetation, increased erosion, and contamination of waterways with bacteria and fecal coliform. These impacts, in turn, degrade water quality by increasing turbidity and water temperature.

- **Actions** – Actions include obtaining a real estate interest, such as an environmental easement, installing exclusive fencing, developing natural vegetation barriers, and replanting streamside grasses, shrubs, and trees that have been harmed by grazing livestock. No specific sites have been identified at this time.

- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by preserving native riparian habitat along Cow Creek. Riparian habitat also contributes to the quality of instream aquatic habitat, providing shade and a source of woody debris; therefore, this measure may also support the primary study objective to increase the survival of anadromous fish that spawn and rear along Cow Creek.

- **Implementation Issues and Cost** – This measure was identified by the Western Shasta RCD in the *Cow Creek Watershed Assessment*, 2001. The cooperation of local landowners would be required, but could be facilitated through the Cow Creek Watershed Management Group and/or the Western Shasta RCD. Depending upon the magnitude of real estate interest required and the extent of restoration action taken, the cost for this measure could be low relative to other measures identified herein.

Other

C2 – Create a Parkway along Lower Clear Creek

There is an opportunity to create a public parkway and habitat corridor along the urbanizing portion of lower Clear Creek, near the confluence with the Sacramento River. Urban expansion from the nearby City of Redding threatens the quality and quantity of valuable riparian and aquatic habitat along lower Clear Creek.

- **Actions** – Actions would include establishing a parkway or other public easement that would prevent further urban encroachment on the river and preserve riparian habitat while providing for appropriate public uses and access. Land would be acquired from private owners on a willing seller basis either through fee purchase or conservation easements. Long-term management of the parkway could be placed with the City of Redding and/or a local parkway foundation.

- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by preserving native riparian habitat. Riparian habitat also contributes to the quality of instream aquatic habitat, providing shade and a source of woody debris; therefore, this measure may also support the primary study objective to increase the survival of anadromous fish that spawn and rear along lower Clear Creek.

- **Implementation Issues and Cost** – There appears to be a high degree of local interest in establishing parkways and preserving the natural values of river corridors in the Redding area; successful examples include the Sulphur Creek Greenway and Turtle Bay projects. The cooperation of local landowners would be required, but could be facilitated through existing parkway groups, the City of Redding, and/or the Western Shasta RCD. The cost for this measure would be moderate relative to other measures identified herein, depending upon the quantity of land acquired and the type of acquisition (fee or easement). A local entity would need to be identified to take responsibility for long-term management.

C3 – Create a Parkway along Sacramento River

There is an opportunity to develop a parkway and wildlife corridor along the Sacramento River around the urbanized Redding and Anderson areas. Urban encroachment in Redding, Anderson, and expanding suburban areas has significantly reduced riparian habitat, with development immediately adjacent to the river channel in some areas. Remaining habitat could be preserved and protected, and some urbanized areas could be restored to improve habitat connectivity along this important river corridor.

- **Actions** – Actions would include establishing a parkway or other public easement that would prevent further urban encroachment on the river and preserve riparian habitat while providing for appropriate public uses and access. Land would be acquired from private owners on a willing seller basis either through fee purchase or conservation easements. It may be possible to purchase developed land immediately adjacent to the river for later restoration or development of park facilities. Connections could be made with existing conservation and parks lands, such as Turtle Bay, the Redding Arboretum, and the Sulphur Creek Greenway. Long-term management of the parkway could be placed with the Cities of Redding and Anderson and/or a local parkway foundation.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by preserving native riparian habitat. Riparian habitat also contributes to the quality of instream aquatic habitat, providing shade and a source of woody debris; therefore, this measure may also support the primary study objective to increase the survival of anadromous fish in the Sacramento River.
- **Implementation Issues and Cost** – There appears to be a high degree of local interest in establishing parkways and preserving the natural values of river corridors in the Redding area; successful examples include the Sulphur Creek Greenway and Turtle Bay projects. The cooperation of local landowners would be required, but could be facilitated through existing parkway groups, the Cities of Redding and Anderson, and/or the Western Shasta RCD. Success of this measure would depend on acquiring significant amounts of private lands, which may limit Federal interest. The cost for this measure would be moderate to high relative to other measures identified herein, depending upon the quantity of land acquired and the type of acquisition (fee or easement). A local entity would need to be identified to take responsibility for long-term management.

C4 – GIS for Shasta Dam to Red Bluff Reach

There is an opportunity to develop a geographic information system (GIS) for the Sacramento River and tributaries between Shasta Dam and Red Bluff. The system would include information about the geology, topography, habitat, and other features of the reach to assist future restoration studies and projects.

- **Actions** – Actions would include developing a comprehensive GIS for the reach that could be accessed and utilized by federal, state, and local restoration groups. The system would include the following types of information: topography; hydrography; aerial photography; habitat mapping; land use; geology; extent of sensitive species; dams, diversions and other infrastructure; historic flow data; locations of instream and offstream gravel mines; and locations of past and current restoration projects.

- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by providing a resource or tool for future restoration studies and projects. Restoration programs often duplicate data collection efforts, and smaller studies may be unable to collect detailed watershed information; this system would provide a centralized data resource for future projects.
- **Implementation Issues and Cost** – A non-federal sponsor has not been identified for this measure. The cost for this measure would be low to moderate relative to other measures identified herein, depending upon the extent and nature of the data selected for inclusion in the GIS. A responsible entity would need to be identified for long-term maintenance and updating of the system.

C5 – Erosion Control in Tributary Watersheds

There is an opportunity to perform local erosion control projects in watersheds tributary to the Sacramento River to prevent loss of key floodplain and riparian habitat, and preserve the quality of aquatic habitat impaired by excessive sediment input. Much of the fine sediment in the Sacramento River is derived from smaller tributary drainages.

- **Actions** – Actions would include revegetation of eroding banks, armoring the toe of streamside landslide areas, removing or enlarging culverts under roads, outsloping roads or installing waterbars, mulching and planting bare slopes, and other land management treatments. Specific sites have not been identified at this time. If sites chosen for restoration are not already in public ownership, easements or other real estate interests may be required to implement the measure and ensure continued benefits.
- **Benefits** – This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by preserving floodplain, riparian, and aquatic habitat impacted by accelerated erosion. This measure would also support the primary study objective to increase the survival of anadromous fish by reducing siltation of spawning gravels along the lower reaches of Sacramento River tributaries.
- **Implementation Issues and Cost** – A non-federal sponsor has not been identified for this measure. The cost for this measure would be low to moderate relative to other measures identified herein, depending upon the extent and nature of erosion control projects selected.

COMPARISON AND EVALUATION

Tables V-2 and V-3 summarize the potential ecosystem restoration opportunities in the Shasta Lake and Tributaries sub-area and Shasta Dam to Red Bluff sub-area, respectively. The tables also identify potential implementation issues and present a preliminary comparison and screening of potential measures based on the following elements:

- **Objective Fulfillment** – Indicates whether the measure fulfills the primary and/or secondary study objectives.
- **Physical Implementability** – Indicates the relative likelihood of physical implementation, taking into consideration any design or construction challenges, regulatory issues, etc. A "High" rating indicates a high probability that the action can be physically performed.
- **Consistency and Reliability** – An estimate of the ability of the action to provide consistent and reliable benefits, compared against the other measures proposed. For example, a "High" rating would be given to a measure that is extremely likely to produce the anticipated benefit (such as an action that has proven highly successful in past applications). Measures are assigned a "Low" rating if there is significant uncertainty associated with the ability of the action to perform as intended or consistently produce the intended benefits.
- **Future Actions** – Indicates the degree to which future actions will be required to achieve or maintain the anticipated benefits of the measure. For example, the degree to which long-term O&M will be required to maintain functionality, or the degree to which actions will need to be taken by others to produce long-term benefits.
- **Redirected Impacts** – Indicates the potential for a measure to negatively impact an existing beneficial use (such as water supply, the environment, flood control, or hydropower) or create significant mitigation obstacles.
- **Efficiency** – A measure of the efficiency of the action based on relative cost and accomplishments, compared against the other measures proposed. For example, a measure with a high cost that produces a relatively small benefit would be assigned a "Low" rating.
- **Potential Non-Federal Sponsor(s)** – Identifies potential non-federal sponsor(s) for the measure.

The tables also list a preliminary measure status – either retained for further study or deleted from consideration at this time – based on the elements listed above. Measures retained for further study are discussed in Chapter VI.

TABLE V-2
POTENTIAL RESTORATION MEASURES IN THE SHASTA LAKE AND TRIBUTARIES SUB-AREA

A1-A6 – Cold-water and Warm-water Fisheries
B1-B4 – Riparian and Wetland Habitat
C1 - Other

ID No.	Measure	Area of Influence	Objective Fulfillment - Primary	Objective Fulfillment - Secondary	Potential Implementation Issues	Physical Implementability	Consistency and Reliability	Future Actions (Including O&M)	Redirected Impacts	Efficiency – Relative Cost	Efficiency – Cost Efficiency	Potential Non-Federal Sponsor(s)	Status	Reason
A1	Construct Shoreline Fish Habitat around Shasta Lake	Shasta Lake	No	Yes	Creation of potential submerged hazards to boaters	High	Med	Med	No	Low	Med	DFG through WCB	Retained	Would complement measures to increase pool in Shasta Lake
A2	Reduce Acid Mine Drainage Drainage Entering Shasta Lake	Shasta Lake and various tributaries	No	Yes	Some mines on privately owned lands (liability issues); long-term maintenance req.	Med	Med	High	No	High – Very High	Low	None	Deleted	Long-term monitoring and liability issues; low likelihood for non-federal sponsor
A3	Reduce Motorcraft Access to Upper Reservoir Arms	Shasta Lake	No	Yes	Negative recreation impacts	High	High	Med	No	Low	High	None	Deleted	Already under the purview of Forest Service; negative recreation impacts
A4	Increase Instream Flows and Pit River	Pit River	No	Yes	Require agreements or buyouts with PG&E due to potential negative hydropower impacts.	Low	Med – High	Low	No	High	Low	None	Deleted	Negative impacts to benefits of Shasta Dam and Reservoir project.
A5	Construct Instream Fish Habitat on Tributaries to Shasta Lake	Major and minor Shasta Lake tributaries	No	Yes	Specific sites on lands within Federal ownership have not been identified	High	Med	Low	No	Low	Med	DFG, Cantara Trust, McCloud CRMP	Retained	Would complement measures to increase pool in Shasta Lake, high likelihood for local support
A6	Construct a Migration Corridor from Sacramento River to Pit River	Pit River, Sacramento River, Cow Creek	Yes	Yes	Difficult to design & operate; limited spawning habitat available on the Pit River; conflict with primary objective.	Low – Med	Low	High	Yes	Very High	Low	None	Deleted	Uncertain potential to consistently and reliability operate over a range of flow conditions (overall low feasibility); low likelihood for non-federal sponsor; conflicts with primary objective.
B1	Enhance Forest Management to Preserve Bald Eagle Nesting Habitat	Shasta Lake, lower Pit River	No	Yes		High	Low	Low	No	Low	Med	None	Deleted	Already within purview of existing FS management programs.

ID No.	Measure	Area of Influence	Objective Fulfillment - Primary	Objective Fulfillment - Secondary	Potential Implementation Issues	Physical Implementability	Consistency and Reliability	Future Actions (Including O&M)	Redirected Impacts	Efficiency – Relative Cost	Efficiency – Cost Efficiency	Potential Non-Federal Sponsor(s)	Status	Reason
B2	Remove and Control Non-Native Plans around Shasta Lake	Shasta Lake & vicinity	No	Yes	Actions would likely need to be repeated to maintain benefits.	Med	Low – Med	Med	No	Low	Low	None	Deleted	Already within purview of existing FS management programs.
B3	Restore Wetlands along Fall River and Hat Creek	Pit River watershed	No	Yes	Limited benefits lower in the Pit River system.	High	Med	Med	No	Low	Low	Fall & Pit River RCDs	Deleted	Significantly removed from the primarily study area.
B4	Preserve Upper Pit River Riparian Areas	Upper Pit River watershed	No	Yes	Specific sites have not been identified.	High	Med – High	Med	No	Low	Med	Local RCDs	Deleted	Significantly removed from the primary study area.
C1	Control Erosion and Restore Affected Habitat in Shasta Lake Area	Shasta Lake & vicinity	No	Yes	Some lands may be privately owned.	Med	Low	High	No	Low-Med	Low – Med	Local RCDs	Deleted	Already within the purview of existing FS management programs.

TABLE V-3
POTENTIAL ECOSYSTEM RESTORATION MEASURES IN THE SHASTA DAM TO RED BLUFF SUB-AREA

A7-A26 – Cold-water and Warm-water Fisheries
B5-B11 – Riparian and Wetland Habitat
C2-C5 - Other

ID No.	Measure	Area of Influence	Objective Fulfillment – Primary	Objective Fulfillment – Secondary	Potential Implementation Issues	Physical Implementability	Consistency and Reliability	Future Actions (Including O&M)	Redirected Impacts	Efficiency – Relative Cost	Efficiency – Cost Efficiency	Potential Non-Federal Sponsor(s)	Status	Reason
A7	Restore Inactive Gravel Mines on Sacramento River	Sacramento River	Yes	Yes	Acquiring land rights	High	High	Low	No	Med	High	DFG, DWR, local groups	Retained	High potential for success and likelihood for non-federal sponsor
A8	Construct Instream Habitat Downstream from Keswick Dam	Sacramento River	Yes	Yes	Acquiring land rights and high O&M	Med	Med	High	No	Med	High	DFG, local groups	Tentatively Retained	Spawning habitat would be highly valuable in this reach
A9	Replenish Spawning Gravel in Sacramento River	Sacramento River	Yes	Yes	High O&M and concerns over downstream impacts	High	Ned	Very High	No	Med	High	DFG, DWR, local groups	Tentatively Retained	Demonstrated benefits that continue as gravel moves downstream
A10	Additional Modifications to Shasta Dam for Temperature Control	Sacramento River	Yes	No	Raising Shasta Dam may reduce benefits or need for this measure	Med	Med	Low	No	High – Very High	Low – Med	None	Retained	Potential for combination with other measures to modify Shasta Dam for other objectives
A11	Improve Fish Tray below Keswick Dam	Sacramento River	Yes	No	Likely require expansion of Coleman Fish Hatchery	High	Med	High	Yes	Med – High	Med	None	Deleted	Low potential for ancillary facilities and non-federal sponsorship
A12	Enlarge Shasta Lake Cold Water Pool	Sacramento River	Yes	Yes	Reserve rim area impacts	Med	Med	Low	No	Very High	Low	CALFED	Retained	High potential for combination with other measures and support by CALFED
A13	Modify Storage and Release Operations at Shasta Dam	Sacramento River	Yes	No	Potential impacts to hydropower or water supply	Med	Med	Low	No	Low – Med	Med	CALFED	Retained	High potential for combination with measures to modify Shasta Dam for other objectives
A14	Construct Instream Fish Habitat on Tributaries to Sacramento River	Middle, Olney, Churn, and Cow creeks	Yes	No	Acquiring land rights	High	Med	Med	No	Low – Med	Med	DFG	Deleted	Not directly related to Upper Sacramento River
A15	Remove Instream Sediment along Middle Creek	Middle Creek, Sacramento River confluence	Yes	No	Acquiring land rights	High	Med	High	No	Med	Low	DFG, local RCD	Deleted	Not directly related to a modification of Shasta Dam; repeated sediment removal would be required to maintain benefiting long-term

ID No.	Measure	Area of Influence	Objective Fulfillment – Primary	Objective Fulfillment – Secondary	Potential Implementation Issues	Physical Implementability	Consistency and Reliability	Future Actions (Including O&M)	Redirected Impacts	Efficiency – Relative Cost	Efficiency – Cost Efficiency	Potential Non-Federal Sponsor(s)	Status	Reason
A16	Restore Instream Gravel Mines along Stillwater Creek	Stillwater Creek	Yes	No	High local benefits, but diminished benefits to Sacramento River	High	High	Low	No	Med	High	DFG, DWR, local RCD	Deleted	Not directly related to a modification of Shasta Dam; diminished benefits to Sacramento River
A17	Modify ACID Diversion to Reduce Flow Fluctuations	Sacramento River	Yes	No	Would require participation of ACID; potential water supply delivery impacts	High	Med	Low	No	Med – High	Low – Med	ACID, DFG	Deleted	Potential water supply impacts
A18	Screen Diversions on Old Cow and Cow Creeks	Cow Creek watershed; anadromous fish migrating from Sacramento River	Yes	No		High	Med – High	Med	No	Med – High	Med	Local groups	Deleted	Not directly related to a modification of Shasta Dam
A19	Increase Instream Flows on Clear Creek by 150 to 200 cfs	Clear Creek; anadromous fish migrating from Sacramento River	Yes	No	Would require changes to the operation of Whiskeytown Dam; potential hydropower impacts	Low – Med	Med – High	Low	No	Med	Med	None	Deleted	Not directly related to a modification of Shasta Dam; low likelihood for non-federal sponsor
A20	Increase Instream Flows on Cow Creek by 25 to 50 cfs	Cow Creek; anadromous fish migrating from Sacramento River	Yes	No	Would require agreements with numerous agricultural users; potential water supply impacts	High	Med	Low	No	Low – Med	Low – Med	None	Deleted	Not directly related to a modification of Shasta Dam; low likelihood for non-federal sponsor
A21	Increase Instream Flows on Bear Creek by 10 to 20 cfs	Bear Creek; anadromous fish migrating from Sacramento River	Yes	No	Would require agreements with numerous agricultural users; potential water supply impacts	High	Med	Low	No	Low – Med	Low – Med	None	Deleted	Not directly related to a modification of Shasta Dam; low likelihood for non-federal sponsor
A22	Remove or Screen Diversion on Battle Creek	Battle Creek; anadromous fish migrating from Sacramento River	Yes	No	Potential hydropower impacts	Med	Med – High	Med	No	Med	Med	Local groups	Deleted	Not directly related to modification of Shasta Dam
A23	Restore Instream Gravel Mines along Cottonwood Creek	Cottonwood Creek; anadromous fish migrating	Yes	No	Some reaches of Cottonwood Creek are still actively mined; acquiring land rights	High	Med	Low	No	Med	Med	DFG, DWR, local RCD	Deleted	Not directly related to a modification of Shasta Dam

ID No.	Measure	Area of Influence	Objective Fulfillment – Primary	Objective Fulfillment – Secondary	Potential Implementation Issues	Physical Implementability	Consistency and Reliability	Future Actions (Including O&M)	Redirected Impacts	Efficiency – Relative Cost	Efficiency – Cost Efficiency	Potential Non-Federal Sponsor(s)	Status	Reason
		from Sacramento River												
A24	Restore Streambed near ACID Siphon on Cottonwood Creek	Cottonwood Creek; anadromous fish migrating from Sacramento River	Yes	No	Would required cooperation with ACID	High	Med	Med	No	Low	Med	DFG, local RCD	Deleted	Not directly related to a modification of Shasta Dam
A25	Construct Fish Barrier at Crowley Gulch on Cottonwood Creek	Cottonwood Creek; anadromous fish migrating from Sacramento River	Yes	No	Barrier may also prevent use of Crowley Gulch by resident fish; acquiring land rights/easements	High	Med	Med	No	Low	Med	DFG, local RCD	Deleted	Not directly related to a modification of Shasta Dam
A26	Construct Storage Facility on Cottonwood Creek to Augment Spring Flows	Cottonwood Creek; anadromous fish migrating from Sacramento River	Yes	No	Environmental impacts; undesirable water temperature in reservoir; land acquisition	Med	Med	High	No	High – Very High	Low	None	Deleted	Potential significant negative environmental impacts; low cost efficiency
B5	Restore Riparian and Floodplain Habitat on Lower Clear Creek	Clear Creek; anadromous fish migrating from Sacramento River	Yes	Yes	Land acquisition or easements	High	Med – High	Low	No	Low – Med	Med – High	Local RCD	Deleted	Not directly related to a modification of Shasta Dam
B6	Restore Offstream Gravel Mines near Sacramento River	Floodplain and Uplands adjacent to Sacramento River	No	Yes	Acquiring land rights (restoration sites may be located on private lands)	High	Med	Low	No	Med	Low	None	Deleted	Not directly related to a modification of Shasta Dam; low cost efficiency
B7	Remove and Control Non-native Vegetation in Cow Creek Watershed	Riparian areas along Cow Creek	No	Yes	Access to private lands	Low	Low	Med	No	Low	Low	None	Deleted	Not directly related to a modification of Shasta Dam; low potential to provide long-term benefits
B8	Remove and Control Non-native Vegetation along Cottonwood Creek	Riparian areas along Cottonwood Creek	No	Yes	Access to private lands	Low	Low	Med	No	Low	Low	None	Deleted	Not directly related to a modification of Shasta Dam; low potential to provide long-term benefits

ID No.	Measure	Area of Influence	Objective Fulfillment – Primary	Objective Fulfillment – Secondary	Potential Implementation Issues	Physical Implementability	Consistency and Reliability	Future Actions (Including O&M)	Redirected Impacts	Efficiency – Relative Cost	Efficiency – Cost Efficiency	Potential Non-Federal Sponsor(s)	Status	Reason
B9	Promote Great Velley Cottonwood Regeneration on Sacramento River	Sacramento River	No	Yes	Specific sites have not been identified; some uncertainty as to long-term success	Med	Low – Med	Med	No	Med	Med	None	Deleted	No non-federal sponsor identified; large Cottonwood stands were probably not common in this reach historically
B10	Riparian and Floodplain Restoration along Sacramento River	Sacramento River	No	Yes	Acquiring land rights (restoration sites may be located on private lands)	High	Med – High	Low	No	Med	High	DFG, DWR, local RCD	Retained	Strong potential for addressing secondary objectives and for local sponsorship
B11	Preserve Riparian Vegetation on Cow Creek	Cow Creek watershed	No	Yes	Access to private lands (easements)	High	Med	Med	No	Low	Med	None	Deleted	Not directly related to a modification of Shasta Dam
C2	Create a Parkway along Lower Clear Creek	Clear Creek	No	Yes	Would require land acquisition and/or easements; need a long-term parkway manager	Med	High	Med	No	Med – High	Med	None	Deleted	Not directly related to a modification of Shasta Dam
C3	Create a Parkway along Lower Clear Creek	Sacramento River	No	Minor	Would require high land acquisition and/or easements; need a long-term parkway manager	Med	High	Med	No	Med – High	Med – High	City of Redding; local groups	Deleted	Low potential to meet objectives and high real estate requirements
C4	GIS for Shasta Dam to Red Bluff Reach	Sacramento River & tributaries	No	Yes	Long-term maintenance and updates would be required to maintain effectiveness	High	Med – High	Low	No	Low – Med	Low	None	Deleted	Not directly related to a modification of Shasta Dam; long-term maintenance and periodic updates would be required
C5	Erosion Control in Tributary Watersheds	Sacramento River & tributaries	No	Yes	Specific sites have not been identified; land acquisition	Med	Low	Med	No	Low – Med	Low	None	Deleted	Not directly related to a modification of Shasta Dam; low cost efficiency

CHAPTER VI
POTENTIAL ECOSYSTEM RESTORATION PLAN COMPONENTS

This section provides a discussion of the ecosystem restoration measures preliminarily retained for further consideration. These restoration measures will be combined with other project measures to form alternative plans that collectively meet the goals and objectives of the SLWRI. These measures were developed specifically to address the identified environmental problems and needs consistent with the goals and objectives of the SLWRI. Although developed for ecosystem restoration, there is the potential to consider several of these measures as elements in alternative plans for the purpose of mitigating negative impacts caused by other plan components.

MEASURES RETAINED FOR FURTHER CONSIDERATION

Based on a preliminary screening of measures discussed in Chapter V, the following potential ecosystem restoration measures were retained for further evaluation and consideration:

- A1 – Construct Shoreline Fish Habitat around Shasta Lake
- A5 – Construct Instream Fish Habitat on Tributaries to Shasta Lake
- A7 – Restore Inactive Gravel Mines on Sacramento River
- A8 – Construct Instream Habitat Downstream from Keswick Dam
- A9 – Replenish Spawning Gravel in Sacramento River
- A10 – Additional Modifications to Shasta Dam for Temperature Control
- A12 – Enlarge Shasta Lake Cold Water Pool
- A13 – Modify Storage and Release Operations at Shasta Dam
- B10 – Riparian and Floodplain Restoration along Sacramento River

Each of these measures contributes to one or more of the goals and objectives of the study, although no individual measure is capable of fully meeting study goals. The extent to which each measure contributes to these goals varies significantly and, in some cases, is difficult to quantify without further study. For this reason, it was necessary to make preliminary assumptions regarding the application, extent, size, and/or cost of the measures for the purpose of this initial evaluation. In addition, measure features may have changed somewhat from those presented in Chapter V based on further evaluation and investigation.

The measures are discussed below in terms of their actions and accomplishments, compatibility with other potential measures, implementation issues, and estimated cost. The level of detail of the discussion is appropriate for initial evaluation and to determine how these ecosystem restoration components might combine with other project components to form alternative plans. However, additional investigation and refinement of these measures would be required to develop alternative plans. Preliminary, order-of-magnitude costs were developed for the purpose of comparing measures. Because initial costs and long-term costs can vary between measures, costs are presented in terms of *first cost* (the sum of initial construction, lands, planning, engineering, and design costs), and *annual cost* (including anticipated annual operation and maintenance costs, replacement costs, and other periodic costs). First cost indicates the initial investment that would be required to implement the measure. Annual cost, on the other hand, includes future costs that will be required annually to maintain benefits and provides a common platform on which measure costs can be compared. Annual costs are presented as relative comparisons to the first costs.

A1 – Construct Shoreline Fish Habitat around Shasta Lake

Shallow, warm-water areas along the shoreline of Shasta Lake provide preferred habitat for juvenile fish and other adult resident fish species. However, whereas the shorelines of most natural lakes and water bodies are lined with trees, rocks, debris, and other structures that provide cover, the shoreline of Shasta Lake is comparatively barren, increasing juvenile mortality. The lack of shoreline cover and suitable shallow-water fish habitat is due to several factors, including the steep topography, soils, wave action, and seasonal water fluctuations in the reservoir. These factors cause erosion and prevent vegetation from becoming established within the reservoir drawdown area. In addition, large woody debris entering the lake from its tributaries is removed annually due to boating concerns. This measure would improve shallow, warm-water habitat around the shoreline of Shasta Lake by planting resistant vegetation and placing large woody debris, boulders, and other aquatic 'cover' structures within the drawdown area of the lake.

Actions and Accomplishments

The measure would involve the installation of artificial fish cover including anchored complex woody structures (root wads, trunks, and other large woody structures) and boulders, and the planting of water tolerant and/or erosion resistant vegetation at prescribed locations within the reservoir drawdown area. Specific applications would be chosen as appropriate to site-specific shoreline conditions, such as bank slope, rate of erosion, proximity to tributaries, soils, and the presence of existing cover or vegetation. It is estimated that about 20 structures and approximately 400 selective plantings would be required for each acre of shoreline restored. The estimated life of the artificial cover structures is 10 to 15 years; however, additional vegetation recruitment could be encouraged that would extend the benefits beyond this preliminary estimate.

It is estimated that locations near the mouths of tributaries would be targeted for restoration because the lower reaches of many tributaries provide favorable spawning conditions, and juvenile fish leaving the tributaries would benefit from improved adjacent shoreline habitat. Although intermittent streams provide some seasonal rearing habitat, the mouths of perennial tributaries would be favored. Further, shoreline areas with gradual slopes provide a wider, shallow-habitat area and would be more appropriate than steep banks that are prone to accelerated erosion. In addition, the sites would need to be undeveloped, provide reasonable construction access, and not be subject to significant recreational disturbances (i.e. adjacent to marinas, picnic areas, campgrounds, or other areas that attract large numbers of people). There are several major and minor tributaries to Shasta Lake that appear to have a high potential for application of this measure. For the purpose of this initial evaluation, it is estimated that sites at the mouths of eight of these perennial tributaries would be selected with approximately five acres of shoreline suitable for restoration at each site. Other areas may also have a high potential and would be evaluated in future studies.

The availability of cover for juvenile fish can significantly improve survival. The establishment of vegetation could also benefit land-based species that inhabit the shoreline of Shasta Lake. This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area. Increased shallow-water fish survival would also enhance recreational sport-fishing opportunities in the lake, supporting the secondary recreation objective of the SLWRI.

Compatibility with Other Measures

Potential measures to raise Shasta Dam would increase the reservoir drawdown area during dry periods that is subject to erosion and other factors that diminish shoreline habitat. This measure would be compatible with potential measures to raise Shasta Dam because the habitat treatments could be extended, as needed, into the additional drawdown area. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects in the vicinity of Shasta Lake.

Implementation

DFG participates in fish stocking and monitoring in Shasta Lake and would be the likely non-federal sponsor for this measure, possibly through the WCB. Actions would need to be coordinated with Reclamation (the primary landowner) and the FS (the primary land manager).

A potential implementation issue concerns the creation of submerged hazards for watercraft users. Shasta Lake is a key recreational draw for the area, primarily due to the opportunities for fishing, boating, and other water-related sports and activities. Fishermen and recreational boaters favor the mouths of tributaries, which are the areas targeted for shoreline restoration. However, potential shoreline hazards would be limited to a relatively narrow area because the shoreline of Shasta Lake is generally steep. Specific restoration sites could be marked with buoys or signs, and cautionary notes could be added to the boating guidelines produced by the FS. In addition, artificial cover structures should be firmly anchored to prevent them from dislodging and becoming floating hazards. This potential issue is not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of the measure in achieving its intended accomplishments is moderate. There are numerous factors affecting the sustainability of habitat within the drawdown area of the lake. An adaptive management approach may be needed to monitor and modify the restoration elements.

Preliminary Cost

It is estimated that a total of 40 acres of shoreline restoration would be performed under this measure, consisting of about five acres of restoration at each of eight sites. This would include the placement of about 20 artificial cover structures per acre and selective plantings of 400 plants per acre. Land acquisition would not be required because the shoreline areas are already under

Federal ownership. The first cost, including planning, engineering, design, and initial implementation of this measure, is estimated to be about $1.6 million.

Some short-term monitoring and maintenance of revegetation sites would be required for up to three growing seasons following installation, and the habitat structures would need to be periodically inspected to ensure that they remain anchored. Depending upon short-term monitoring, an adaptive management approach may be necessary to ensure measure success. It is estimated that habitat structures would need to be replaced, on average, about every 12 years during the life of the project. Accordingly, the estimated annual costs would be relatively moderate to high compared to the first cost.

A5 – Construct Instream Fish Habitat on Tributaries to Shasta Lake

Tributary streams are an important environmental resource in the primary study area, supporting a variety of native and non-native fish and other aquatic organisms. However, the quality and quantity of instream aquatic habitat has decreased over the last century due to the construction of dams, modification of stream hydrology, and other human influences. This measure would improve and restore instream aquatic habitat along the lower reaches of the major tributaries to Shasta Lake using various structural techniques to trap spawning gravels in deficient areas, create pools and riffles, provide instream cover, and improve overall instream habitat conditions.

Actions and Accomplishments

Structural treatments would vary depending upon stream conditions. Generally, they would include the installation of gabions, log weirs, boulder weirs, and other anchored structures. Spawning and rearing habitat would be created by providing instream cover with large root wads and by the use of drop structures, boulders, gravel traps, and/or logs that cause scouring and help clean gravels.

Although both perennial and intermittent streams would benefit from structural habitat improvements, the lower reaches of perennial tributaries to Shasta Lake would be targeted for aquatic restoration under this measure because they provide year-round fish habitat. The measure could be applied along numerous perennial streams tributary to Shasta Lake. Although up to nearly 20 miles of stream could be considered for this measure, not all of the streams would be chosen for implementation. The initial implementation would likely be restricted to the larger tributaries, after which the potential to expand to smaller tributaries could be assessed. The estimated life of structural aquatic restoration measures is 10 to 15 years, but would be highly dependent on localized streamflow hydrology and the occurrence of large flood events.

The quality and availability of aquatic habitat can significantly improve the survival of fish that reside on the tributaries to Shasta Lake. Both native and non-native fish would benefit, including some lake fish that spawn on the lower reaches of the tributaries. It could also benefit steelhead, a native species that must be planted in the lake annually, because some natural steelhead reproduction occurs on the lower reaches of the tributaries to Shasta Lake. This measure would support the secondary objective to preserve and restore ecosystem resources in the Shasta Lake area by improving aquatic habitat conditions. Improving aquatic habitat would also enhance recreational sport-fishing opportunities in the area, supporting the secondary recreation objective of the SLWRI.

Compatibility with Other Measures

This restoration measure would complement potential measure A1 to restore shoreline fish habitat in Shasta Lake because many juveniles that utilize shoreline habitat hatch on the lower reaches of the tributaries; improving and restoring aquatic habitat on the tributaries would increase the number of juveniles entering Shasta Lake. This measure would be compatible with potential measures to raise Shasta Dam, and does not conflict with any of the other ecosystem restoration measures that were preliminarily retained. This measure does not conflict with other known programs or projects in the vicinity of Shasta Lake.

Implementation

The DFG, Cantara Trust, or McCloud River CRMP are potential non-federal sponsors for instream habitat restoration. Each of these groups has participated in similar restoration activities in Shasta County. Restoration actions should be coordinated with local restoration groups, tribes, landowners, and the DFG, as appropriate.

A potential implementation issue concerns obtaining agreements with landowners to perform restoration along tributaries located on private lands, and/or gaining access through private lands to restoration sites. This issue could be avoided by selecting stream reaches that are located exclusively on public or conservation lands, and/or restoring sites on private lands only if proposed by their respective landowners.

The estimated certainty of this measure in achieving its intended accomplishments is high. Similar activities have been accomplished with success on other, similar stream systems. In addition, most of the major tributaries to Shasta Lake are highly regulated, reducing the potential for improvements to be damaged or destroyed during extreme flow events.

Preliminary Cost

The cost of this measure would be low relative to the cost of other measures identified, depending on the number and length of stream reaches selected for restoration. It is estimated that instream aquatic restoration would be performed along 8 miles of stream, or 2 miles along the lower reaches of each of the four major tributaries to Shasta Lake. The measure would involve the construction of about 40 complex boulder/log structures per mile stream to create gravel traps, pools, and riffles. It is estimated that all restoration activities would be conducted on Federal lands. The first cost, including planning, engineering, design, and initial implementation of this measure, would be approximately $600,000.

Some long-term monitoring and maintenance would be required after construction. It is estimated that habitat structures would need to be replaced, on average, about every 12 years during the life of the project. Accordingly, the estimated annual costs would be relatively moderate to high compared to the first cost.

A 7 - Restore Inactive Gravel Mines on Sacramento River

Instream gravel mining has degraded aquatic and floodplain habitat, creating large, artificial pits along the river that disrupt natural geomorphic processes and riparian regeneration. Aquatic conditions at former gravel mining sites are typically unsuitable for spawning and rearing. High fish mortality occurs at many abandoned pits that lose their connection with the river during low flow periods, stranding fish and encouraging unnatural predation rates. Due to changes in flow regime and reductions in coarse sediment input, the river is not capable of refilling and restoring many of these pits naturally. This measure includes acquiring, restoring, and reclaiming several inactive gravel mining operations along the Sacramento River to create valuable aquatic and floodplain habitat.

Actions and Accomplishments

Gravel pit restoration would involve filling deep pits (potentially requiring the importation of suitable fill material from local sources) and re-contouring the stream channel and floodplain to mimic more natural conditions. Side channels and other features could be created to encourage spawning and rearing. Soil may need to be imported to replenish areas where gravel mining has resulted in a significant loss of fine sediments. Revegetation using native riparian plants would be performed on restored floodplain lands. Hydrologic, hydraulic, and sedimentation studies would identify optimal restoration conditions and any actions necessary to offset or minimize undesirable hydraulic conditions caused by restoration. Potential sites for gravel mine restoration along the Sacramento River between Keswick Dam and Red Bluff are listed in Table Vl-1.

TABLE VI-1
POTENTIAL GRAVEL MINE RESTORATION SITES
ALONG THE SACRAMENTO RIVER

Location	Approximate Rivermile	Bank	Approx. Size in Acres
Red Bluff near Salt Slough	247	Left	140
Upstream of Stillwater Creek	282	Right	320
Redding	287-288	Right	135
Redding	287.5-288	Left	65
Redding	288.5-290.3	Left	305
Redding	292.5-294	Left	230
		TOTAL	**1,055**

One or more of these sites would be selected for restoration under this measure, pending more detailed evaluation of site-specific conditions. Most of these sites consist of one or more deep pits surrounded by partially disturbed land, with the majority of the site consisting of disturbed lands that would require minimal restoration actions. It is estimated that gravel mine restoration would have lasting benefits for the environment because more natural physical and biological processes would be restored.

Restoring stream habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining cold-water spawning areas available to anadromous fish. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by eliminating stranding in abandoned gravel pits and restoring aquatic, riparian, and wetland habitat. The measure also supports the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River through the restoration of riparian and floodplain habitat.

Compatibility with Other Measures

This measure would combine favorably with potential measures to modify Shasta Dam because increased cold-water releases and other operational changes at the dam would further enhance the habitat restored by this measure and increase opportunities for anadromous fish to utilize the restored habitat. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained. It would combine favorably with measures involving floodplain restoration and gravel replenishment along the Sacramento River. This measure does not conflict with other known programs or projects on the upper Sacramento River.

Implementation

The DFG and DWR are potential non-federal sponsors for this measure. There appears to be a high degree of public agency and local interest for gravel pit restoration. DWR has performed several studies of instream and offstream gravel resources and stream geomorphology within the Keswick Dam to Red Bluff reach.

A potential implementation issue consists of access to and restoration of gravel pits located on or adjacent to private lands. However, there may be opportunities to work with landowners and incorporate design elements that would also benefit adjacent lands, such as constructing low berms to prevent nuisance flooding or incorporating erosion protection for hardpoints. To ensure that project benefits are lasting and sustainable, land would need to be acquired for the project if not already in public ownership.

Another potential implementation issue concerns movement of the river channel after restoration actions have been performed. One goal of gravel pit restoration is to return the river to a more natural state, including geomorphic channel forming processes that naturally support healthy aquatic and riparian habitat. Three of the potential restoration sites are located near or adjacent to urban development. Restoration actions should be designed such that nearby development is protected from potentially damaging bank erosion, floodwaters, or lateral channel movement. These potential implementation issues are not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of this measure achieving the intended accomplishments is very high. Similar restoration projects in other areas have provided favorable, sustainable results.

Preliminary Cost

The cost of this measure would be moderate to high relative to the cost of other measures identified, depending upon the number and size of the sites selected for restoration. For the purpose of this preliminary evaluation, it is estimated that one mining site totaling 150 acres would be selected for restoration, and a real estate interest would be acquired for those lands.

Intensive restoration would occur around gravel pits or extraction sites themselves, while minimal revegetation and earthwork would be performed on the remainder of the site. The first cost, including land acquisition, planning, engineering, design, and initial implementation of the measure, is estimated to be approximately $8 million.

It is anticipated that no elements of this measure would need to be replaced or reapplied during a 50-year project life. Short-term maintenance of revegetated areas would be required for up to three growing seasons following installation, and some long-term maintenance would be required; maintenance costs would not increase the total cost of this measure significantly. Estimated annual costs would be moderate compared to the first cost.

A8 – Construct Instream Habitat Downstream from Keswick Dam

Keswick Dam represents the upper-most barrier to anadromous fish migration on the Sacramento River. Immediately downstream from Keswick Dam, the Sacramento River channel is entrenched in bedrock with very little coarse gravel and vegetation. Releases from the dam have scoured the channel bottom and the dam blocks the passage of gravels, bed sediments, and woody debris that were replenished historically by upstream tributaries. As a result, aquatic habitat is poor for spawning and rearing of anadromous fish and predation can be high due to the lack of instream cover. Despite these unfavorable channel conditions, cold-water releases from Keswick Dam attract large numbers of spawners to the reach. This measure consists of constructing complex aquatic habitat in and adjacent to the Sacramento River downstream from Keswick Dam to encourage use of this reach for anadromous fish reproduction.

Actions and Accomplishments

Aquatic habitat restoration would involve acquisition of lands adjacent to the Sacramento River; earthwork along the riverbank to construct side channels for spawning; and the strategic placement of manmade instream cover structures within the river channel using large boulders, anchored root wads, and other natural materials. The structures would be designed to improve the complexity of aquatic habitat in this reach, help retain sediment and gravel, provide cover from predators, and encourage the formation of spawning beds. Side channels would be constructed immediately below the dam and gravel would be imported to the site to create spawning beds. Structures would be anchored to prevent movement during flood releases from Keswick Dam.

The potential site is located on the Sacramento River immediately downstream from Keswick Dam. Although planning, engineering and design would be needed to refine the components of this measure, it is estimated that in-channel treatments would extend approximately ¾ mile below the dam and include 20 to 35 log/boulder structures, two constructed side-channel spawning areas, and 500 tons of imported gravel. The beneficial life of the measure would be highly dependent on hydrology. Instream structures and imported gravel, in particular, are subject to movement during high flows and flood conditions. Depending upon the materials used, the estimated life of instream structures is estimated to be 5 to 10 years. The beneficial life of the side spawning beds is assumed to be significantly longer, as they would only be subject to damage during the most extreme flood events. However, replacement and/or replenishment of spawning gravel in the beds could be required on a frequent basis, depending upon hydraulic conditions and the effectiveness of gravel retention measures.

The restoration of aquatic habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining spawning corridors available to anadromous fish along the Sacramento River. Large numbers of anadromous fish are attracted to the proposed restoration site because it is situated at the upper-most end of the migration corridor and releases from Keswick Dam provide cool water temperatures. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by restoring important spawning habitat below Keswick Dam.

Compatibility with Other Measures

This measure would combine favorably with potential measures to modify Shasta Dam because increased cold-water releases and other operational changes at the dam would further enhance the habitat restored by this measure and increase opportunities for anadromous fish to utilize the restored habitat. This measure would not conflict with any of the other ecosystem restoration measures that were preliminarily retained. It would combine favorably with measures involving gravel replenishment along the upper Sacramento River. This measure would not conflict with other known programs or projects on the upper Sacramento River.

Implementation

Because of the high peak flood flows expected for fairly frequent events in this reach of river, success of this measure would depend on reconstructing primary measure elements every 5 to 10 years by a non-federal sponsor. Because of such a long-term commitment needed to credit this measure as a viable project purpose, there would likely be limited Federal interest in its inclusion in a larger project. However, there may be interest by DFG or DWR to be a non-federal sponsor for this measure. Local conservation organizations may also be interested in participating or contributing to the project. There may be a high degree of public agency interest for restoration in this reach, which is highly visible due to the presence of Keswick Dam and its related fish facilities.

A potential implementation issue concerns the ability to design instream restoration features that are capable of withstanding scouring flows from Keswick Dam. Structural elements such as boulders, root wads, and other complex features should be anchored to the channel bottom to prevent movement during floods and other periods of high dam releases. Another potential implementation issue concerns the ability to construct side channels within the bedrock present at the site; a geologic evaluation would be required to fully assess construction feasibility. It may also be difficult for construction equipment to access the channel. Mitigation would be provided for any construction-related impacts. This potential issue is not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of this measure in achieving the intended accomplishments is moderate. There are numerous factors affecting the sustainability of healthy spawning areas in the reach of river downstream from Keswick Dam. These are primarily related to the potential for high releases from the dam to damage habitat improvements. An adaptive management approach may be warranted to monitor and modify the spawning areas to achieve the desired benefits.

Preliminary Cost

The cost of this measure would be moderate relative to the cost of the other measures identified. Cost would depend on the length of stream channel selected for restoration and the extent of channel modification needed to create suitable side spawning areas. It is estimated that instream aquatic restoration would be performed along a ¾ mile reach of river immediately downstream from Keswick Dam. Restoration actions would involve placement of instream aquatic cover structures, placement of 500 tons of imported spawning gravel, and construction of two side channels along the banks of the river for spawning. It is estimated that 50 acres of land would be acquired for the side spawning channels. The total first cost, including land acquisition, planning, engineering, design, and initial implementation costs, is estimated to be approximately $800,000.

Monitoring, maintenance, and periodic gravel replacement would be required after construction. It is anticipated that major habitat structures would need to be replaced, on average, about every 10 years during the life of the project. For cost estimating purposes, gravel replacement is assumed to occur every 5 years. Annual and periodic costs would be relatively high compared to the first cost.

A9 – Replenish Spawning Gravel in Sacramento River

Historically, the tributary watersheds upstream from Keswick and Shasta Dams provided a source of gravel and other coarse sediments to the Sacramento River. Gravels were continually replenished as they moved down the river system. Gravel recruitment is of particular importance to anadromous fish, which require clean gravels for their spawning beds. Today, dams, river diversions, gravel mining, and other obstructions have blocked or reduced natural gravel sources. Suitable spawning gravel has been identified as a potential limiting factor in the recovery of anadromous fish populations on the Sacramento River. Several other programs, including CALFED and the Anadromous Fish Restoration Program (AFRP), have participated in gravel replenishment on the Sacramento River in selected locations. However, these efforts were single applications with short-term benefits, and no long-term program exists to continue and maintain gravel replenishment efforts. This measure would help replenish spawning-sized gravel in the Sacramento River between Keswick Dam and Red Bluff.

Actions and Accomplishments

This measure would involve transporting and injecting gravel into the Sacramento River downstream from Keswick Dam. Suitable spawning gravel would consist of uncrushed, natural river rock, washed and placed in the river at strategic locations. Hydraulic and geomorphic evaluations are needed to determine the most effective gravel size distribution and the most appropriate locations for the injections. The size and amount of gravel is first determined by the hydraulic characteristics of the river at the injection site and secondarily by the spawning characteristics of the targeted fish species. For the purpose of this evaluation, it is estimated that a total of 10,000 tons of gravel between 1-inch and 3 inches in diameter would be injected at three sites.

Injecting the gravel in relatively stable reaches that lack natural gravel sources, preferably those with complex structures or large woody debris to trap and retain gravel, would increase the success and longevity of the measure. The reach immediately downstream from Keswick Dam has no natural gravel sources and currently provides marginal spawning habitat. Gravel injections would be concentrated in this uppermost reach, between Anderson and Keswick Dam. Gravel is typically moved downstream from the site of injection by high flows that occur, on average, about every five years; therefore, this measure would need to be reapplied periodically to maintain site-specific benefits. However, injected spawning gravels continue to benefit the stream environment as they move through a river system, although the benefits tend to be less distinct the farther one moves downstream.

The restoration of aquatic habitat between Keswick Dam and Red Bluff is of high priority because it is one of the few remaining spawning corridors available to anadromous fish along the Sacramento River. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by contributing to the replenishment of spawning gravels used by anadromous fish.

Compatibility with Other Measures

This measure would combine favorably with measures involving aquatic habitat restoration, such as measures A7 and A8, because complex aquatic structures tend to trap and retain gravel longer. Combining these measures would increase effectiveness and longevity. This measure would also combine favorably with potential measures to modify Shasta Dam because increased cold-water releases and other operational changes at the dam would increase opportunities for anadromous fish to utilize spawning habitat created by the gravel injections. This measure would complement potential measures to raise Shasta Dam because improved cold-water release flexibility would enable anadromous fish to take greater advantage of restored spawning habitat. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects on the upper Sacramento River.

Implementation

Success of this measure would depend on the regular and recurrent injection of spawning gravels into the Sacramento River over the life of the Federal project by a non-federal sponsor. Because of such a long-term commitment needed to credit this measure as a viable project purpose, there would likely be limited Federal interest in its inclusion in a larger project. However, there may be significant interest by DFG, DWR, or the Western Shasta RCD to be a non-federal sponsor. Spawning gravel replenishment programs have been successful along the Sacramento River in the past. This would infer a high certainty that the measure will achieve the desired benefits.

Another potential implementation issue would be the perception that injected gravels could eventually contribute to deposition problems around agricultural water diversion facilities further downstream. However, due to the limited volume injected, desirable size range for spawning gravels, and careful selection of injection sites, it is likely that there would be minimal adverse impacts to facilities on the river.

Preliminary Cost

The cost of this measure depends on the size of the restoration effort. Generally, it would have a low initial cost but a moderate cumulative cost over the 50-year project life. A total of 10,000 tons of gravel would be injected at three sites along the Sacramento River. Real estate interests would likely be minor and consist of acquiring the sites for gravel injection, easements to access the sites, and potential interests in borrow areas. The first cost for planning, engineering, design, and initial gravel injection would be approximately $400,000.

As mentioned, gravel injections would need to be repeated periodically as part of project operation in order to maintain the benefits and efficacy of this measure. For cost estimating purposes, it is estimated that 10,000 tons of gravel would be re-injected, on average, about every 5 years. The estimated annual costs would be very high compared to the first cost.

A10 – Additional Modifications to Shasta Dam for Temperature Control

The TCD installed at Shasta Dam allows operators to make selective releases from various reservoir depths in order to regulate water temperatures in the Sacramento River. The TCD works well in helping regulate the release temperature through the powerhouse. However, it could be improved, as some amount of warm-water leakage occurs near the lake surface, which reduces its effectiveness. This measure would provide additional structural modifications to the outlets and existing TCD at Shasta Dam for the purpose of temperature control, allowing additional flexibility in making cold-water releases during critical spawning periods and extending the area of suitable spawning habitat in the Sacramento River.

Actions and Accomplishments

The existing temperature control device consists of a submersed multi-level intake structure that hangs from the upstream face of the dam. The shuttered structure is 250 feet wide and 300 feet high, with a low-level intake that is 125 feet wide and 170 feet high. Under this measure, the existing device would be widened to increase intake capacity and the device would be extended to a greater depth. This would involve a modification to the existing multi-level intake structure to reduce leakage. It could also involve major modifications such as the intake structure connections to the powerhouse penstocks and may require additional coring or drilling into the face of the dam.

The benefits of additional modifications to the cold-water release capabilities of the dam are not likely to be as dramatic as those achieved with construction of the existing temperature control device. Consequently, there is some uncertainty as to the cost effectiveness of this measure unless it is combined with other measures involving major modification to Shasta Dam.

Water temperature is one of the most important factors contributing to the success of anadromous fish reproduction. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River by improving the ability to provide desirable water temperatures for spawning, rearing, and out-migration. This measure may also support the secondary objective to increase hydropower generation, although the benefits to hydropower may have been fully realized with the construction of the existing temperature control device. The existing temperature control device maximizes power generation by routing cold-water releases through the powerhouse turbines, and has allowed Reclamation to produce additional hydroelectricity during its use.

Compatibility with Other Measures

This measure would complement potential measures to raise Shasta Dam because additional temperature control improvements could be incorporated into the design of a dam raise and further improve cold-water releases. It would also combine well with measures to improve aquatic spawning habitat in the Sacramento River, as better water temperature regulation could allow anadromous fish to take greater advantage of these habitat improvements. This measure does not conflict with other environmental restoration measures preliminarily retained herein or other known programs or projects on the upper Sacramento River.

Implementation

The State of California through the DFG was a funding partner for construction of the existing temperature control device. Accordingly, DFG would be a potential candidate for non-federal sponsorship of this measure.

This measure would involve significant modifications to the existing intakes at Shasta Dam. However, knowledge gained during design and construction of the existing temperature control device should help overcome any physical construction issues associated with the measure. This includes using underwater construction techniques to reduce the need to draw down the lake. More importantly, there may be limits to the degree of dam modifications allowable while maintaining the structural integrity of the dam; the existing temperature control device weighs almost 9,000 tons. For this reason, it may be more feasible to implement this measure in combination with other modifications to the dam, such as a dam raise.

The estimated certainty of this measure in achieving its intended accomplishments would be high. As mentioned, it would not provide the same degree of benefits achieved when the existing TCD was constructed. However, it would likely be much more effective if combined with other measures to increase the cold water pool in Shasta Lake.

Preliminary Cost

The cost for this measure would be high relative to the other measures identified. The existing TCD cost about $80 million to plan, design, and construct (1995 price levels). It is difficult to estimate the cost of additional modifications to the device prior to preliminary planning and design. However, it is anticipated that the cost for this measure could be fairly low for improvements to resolve the existing leakage problems to high, similar to the initial construction cost, for higher dam raises.

A12 – Enlarge Shasta Lake Cold Water Pool

Water temperature has been identified as one of the most important factors in achieving recovery goals for anadromous fish on the Sacramento River. Cold water released from Shasta Dam significantly influences water temperature conditions on the Sacramento River between Keswick Dam and Red Bluff, and can have an extended influence on river temperatures even farther downstream. This measure includes increasing the volume of the cold water pool in Shasta Lake to help maintain colder releases for anadromous fish during certain periods by raising Shasta Dam and enlarging Shasta Reservoir.

Actions and Accomplishments

This measure involves increasing the volume of the cold water pool in Shasta Lake to permit greater flexibility in making releases beneficial to anadromous fish. The increased volume of cold water would be achieved through raising Shasta Dam and enlarging Shasta Reservoir. Dam raises ranging from about 6.5 feet to about 200 feet have been considered in previous studies by Reclamation. A dam raise of about 6.5 feet creating an increase in lake storage of about 290,000 acre-feet was suggested in the CALFED ROD. Other dam raises are also being evaluated. As an example, a dam raise of about 200 feet would create an increase in lake storage of about 9.3 million acre-feet. The increased cold water pool from the dam raises could be used to target increasing cold-water discharges during the summer, which could significantly extend the downstream reach of suitable spawning habitat. Changes in the timing and magnitude of releases from the increased pool consistent with measure A13 could also be considered to improve the quality of aquatic habitat by cleaning spawning gravels, and to improve attraction flows that cue in-migration and temperatures that cue out-migration.

The primary benefits of this measure are improved water temperature control, extension of suitable spawning habitat, and improvement in overall physical aquatic habitat conditions. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River. It wold also benefit the primary objective of increasing water supply reliability.

Compatibility with Other Measures

This measure could combine favorably with other primary and secondary planning objectives. It could also complement measures to improve aquatic habitat conditions on the Sacramento River, such as rehabilitating spawning and rearing areas. This measure would not conflict with other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects on the upper Sacramento River.

Implementation

Implementation would require coordination with multiple Federal and State agencies, which may include the California Bay-Delta Authority, Corps, FWS, DFG, NOAA Fisheries, FERC, DWR, and the Reclamation Board. Raising Shasta Dam and enlarging Shasta Reservoir would result in impacts to reservoir rim natural resources and infrastructure requiring significant mitigation and relocations. Impacts associated with dam raises less than about 18 feet would be significant but likely manageable. Higher dam raises result in major impacts to reservoir area resources and infrastructure with a resulting significant reduction in likely economic justification. Very high dam raises (100 to 200 feet), besides having extreme impacts in the Shasta Lake area, might also result in major impacts to natural resources conditions downstream along the Sacramento River. Impacts would likely be so great as to eliminate serious consideration of higher dam raises. However, no mater what magnitude of dam raise is considered, careful planning would be required to identify and offset impacts to these resources and infrastructure. The estimated certainty of this measure in achieving its intended accomplishments would be high.

Preliminary Cost

Preliminary estimates of first costs for this measure range from about $210 million for raising Shasta Dam 6.5 feet to about $5 billion for raising the dam 200 feet. Annual costs would be relatively low compared to the first cost.

A13 – Modify Storage and Release Operations at Shasta Dam

As mentioned, water temperature has been identified as one of the most important factors in achieving recovery goals for anadromous fish on the Sacramento River. Cold water released from Shasta Dam significantly influences water temperature conditions on the Sacramento River between Keswick Dam and Red Bluff, and can have an extended influence on river temperatures even farther downstream. This measure would modify reservoir storage and dam release operations to benefit anadromous fisheries on the Sacramento River by providing greater flexibility in meeting water temperature targets and/or flow stability to help restore suitable spawning habitat and related channel conditions.

Actions and Accomplishments

This measure would involve revising reservoir storage and release criteria throughout the year to permit greater flexibility in making releases beneficial to anadromous fish. Operational changes could target increasing cold-water discharges during the summer, primarily during dry and critically dry years, which could significantly extend the downstream reach of suitable spawning habitat. Changes would also be made to the timing and magnitude of releases to improve the quality of aquatic habitat by cleaning spawning gravels, and to improve attraction flows that cue in-migration and temperatures that cue out-migration. Further, the measure could provide additional control and dilution of acid mine drainage from Spring Creek.

Shasta Dam already operates for multiple objectives including water supply, flood control, water temperature, hydropower, and others. As mentioned, modifying existing storage and release operations would likely impact water supply or other beneficial uses of the water stored in the reservoir, which would be contrary to SLWRI goals and objectives. Therefore, this measure would require some amount of additional water storage in Shasta Lake by raising Shasta Dam to offset any negative impacts to water storage.

The primary benefits of this measure are improved water temperature control, flow stability, extension of suitable spawning habitat, and improvement in overall physical aquatic habitat conditions. This measure would support the primary objective to increase the survival of anadromous fish populations in the Sacramento River.

Compatibility with Other Measures

This measure would combine favorably with measures to increase the capacity of Shasta Dam, which would increase opportunities to change existing storage and release operations and minimize impacts to hydropower or water supply. It would also complement measures to improve aquatic habitat conditions on the Sacramento River, such as spawning gravel injection or improvements to the complexity of aquatic habitat. This measure would not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor would it conflict with other known programs or projects on the upper Sacramento River.

Implementation

Implementation would require coordination with multiple Federal and State agencies, which may include the Corps, FWS, DFG, NOAA Fisheries, FERC, DWR, and the Reclamation Board.

As mentioned, without enlarging the cold water pool in Shasta Lake, this measure would have the potential to negatively impact water supply, hydropower production, or flood control. Careful planning would be required to identify and offset impacts to the other beneficial uses of Shasta Dam and Reservoir, possibly requiring additional water supply. This would include hydrologic and hydraulic modeling, and reservoir operation simulations. In general, the process of changing a reservoir's operation criteria is politically and institutionally difficult because it involves multiple agencies and a wide group of stakeholders. These potential issues could threaten successful implementation of this measure.

The estimated certainty of this measure in achieving its intended accomplishments would be moderate. Successful implementation would be highly dependent upon the extent of dam modifications and reoperation that could be implemented while offsetting or minimizing adverse impacts to water supply or hydropower. It would also depend on a non-federal sponsor to share in the implementation, operation, and maintenance costs. However, the likelihood of achieving the intended accomplishments would increase considerably if combined with other measures to increase the capacity of Shasta Lake.

Preliminary Cost

The potential cost of this measure would be directly linked with other actions to increase the storage space in Shasta Lake.

B10 – Riparian and Floodplain Restoration along Sacramento River

Riparian areas provide habitat for a diverse array of plant and animal communities along the Sacramento River, including numerous threatened or endangered species. Riparian areas also provide shade and woody debris that improve the complexity of aquatic habitat and its suitability for spawning and rearing. Lower floodplain areas, river terraces, and gravel bars play an important role in the health and succession of riparian habitat. These areas are seasonally flooded on a frequent basis, interacting with dynamic river processes such as erosion and deposition. Riparian and floodplain terrace habitat along the Sacramento River is limited between Keswick Dam and Red Bluff. This is partially due to the natural topography and hydrography of the region; the Sacramento River is naturally more entrenched in this reach, and floodplains are narrow compared with the broad alluvial floodplains found lower in the Sacramento River system. Over the last century, human land development and urbanization in the Redding, Anderson, and Red Bluff areas have further reduced riparian habitat along the Sacramento River. This measure would involve restoring riparian and floodplain habitat along the Sacramento River to promote the health and vitality oft he river ecosystem.

Actions and Accomplishments

This measure would involve acquiring and revegetating floodplain terraces and adjacent riparian areas with native plants. It is estimated that a limited amount ofland contouring and imported fill material would be required at several locations where the historic floodplain has been disconnected from the river or disturbed by human activity. Suitable locations for restoration would be in areas with a 20 percent to 50 percent chance offl ooding in any year (commonly referred to as 2-year to 5-year floodplains). Locations near the confluences of major tributaries with the Sacramento River have the potential to provide the maximum benefits because they interact with riparian areas on tributary streams. Continuity is also important to the health and vitality of riparian areas; small, isolated patches of riparian habitat tend to be less productive than larger, continuous stretches of habitat. Potential restoration sites are listed in Table Vl-2. These preliminary sites were identified based on flood frequency, previous human disturbances, lack of existing riparian vegetation, proximity to tributary confluences, land use, and proximity to other healthy riparian areas.

TABLE VI-2
POTENTIAL RIPARIAN AND FLOORPLAIN RESTORATION SITES
ALONG THE SACRAMENTO RIVER

General Location	Approximate Rivermile	Bank	Approx. Size in Acres
Near RBDD	242-244	Left	300
Red Bluff u/s Sand Slough	247	Left	140
Near Bend Bridge	258	Left	200
Inks Creek confluence	264-265	Right	175
South of Battle Creek confluence	271-272	Left	55
North of Battle Creek confluence	271-272	Left	100
Ash Creek confluence	277-277.5	Left	85
Cow Creek confluence	280	Left	60
Stillwater Creek confluence	281.5	Left	16
		TOTAL	1,131

For the purpose of this preliminary evaluation, it is estimated that a total of 500 acres would be restored at one or more sites. Planting mix, composition, and density would be determined by a more detailed site analysis, but could include native cottonwood, willow, boxelder, valley oak, western sycamore, elderberry, and a variety of understory brush species. Temporary irrigation would be provided on an as-needed basis. The revegetated areas are expected to develop into self-sustaining riparian habitats within one to four years of initial planting, based on the results of previous riparian restoration projects along the Sacramento River. Re-graded floodplain areas are expected to change over time depending upon hydrologic conditions. The site would be fenced to reduce the potential for access by livestock.

This measure would support the secondary objective to preserve and restore ecosystem resources along the upper Sacramento River by restoring native riparian habitat and associated floodplain lands. Riparian habitat contributes to species diversity, water quality, and the quality of instream aquatic habitat, providing shade and a source of woody debris. In this manner, this measure indirectly supports the primary study objective to increase the survival of anadromous fish on the Sacramento River.

Compatibility with Other Measures

This measure would combine favorably with potential measures to modify Shasta Dam because operational changes could benefit the natural riverine processes that drive riparian habitat regeneration. This measure does not conflict with any of the other ecosystem restoration measures that were preliminarily retained, nor does it conflict with other known programs or projects on the upper Sacramento River. Restoration would support the goals of the SRCA, CALFED, and other programs associated with riparian restoration along the Sacramento River.

Implementation

There appears to be local support for this type of restoration project along the Sacramento River. Potential non-federal sponsors include the DFG and various local agencies and organizations, including the Western Shasta RCD, TNC, and local watershed groups.

The principal implementation issue concerns ownership and access to lands selected for restoration. If sites selected for restoration were not already in public ownership, conservation easements could be purchased from landowners interested in performing restoration on their lands, or lands could be purchased in fee-title from willing sellers. For the purpose of this initial evaluation, and to ensure continued protection of restored lands, it is assumed that land would be acquired in fee-title. This potential issue is not believed to pose a significant threat to successful implementation of this measure.

The estimated certainty of this measure achieving the intended accomplishments is very high. Similar restoration projects along the Sacramento River have provided favorable, sustainable results.

Preliminary Cost

The cost of this measure would be moderate to high relative to the cost of other measures identified, depending upon the size of the site(s) selected for restoration. It is estimated that one site totaling 500 acres would be selected for restoration, and a real estate interest would be acquired for those lands. The measure would involve land acquisition, floodplain contouring and other earthwork, and revegetation. The total first cost, including land acquisition, planning, engineering, design, and initial implementation, is estimated to be approximately $9 million.

It is anticipated that no elements of this measure would need to be replaced or reapplied during the 50-year project life. Short-term maintenance of revegetated areas would be needed for up to three growing seasons following installation. Some long-term maintenance would be required, primarily to monitor plant density and maintain site security, but is not expected to involve significant cost. The annual costs for this measure would likely range from moderate to high compared to the first cost.

POTENTIAL PLAN COMPONENTS

Figures 11 and 12 illustrate the approximate locations of the potential ecosystem restoration measures in the Shasta Lake and Tributaries and Shasta Dam to Red Bluff sub-areas, respectively. The preliminarily retained ecosystem restoration plan components are summarized in Table VI-3. The summary table compares the measures and their estimated first cost, annual cost, benefits or advantages, and implementation issues or disadvantages. It also provides overall comments and conclusions that identify several of the measures as highly recommended.

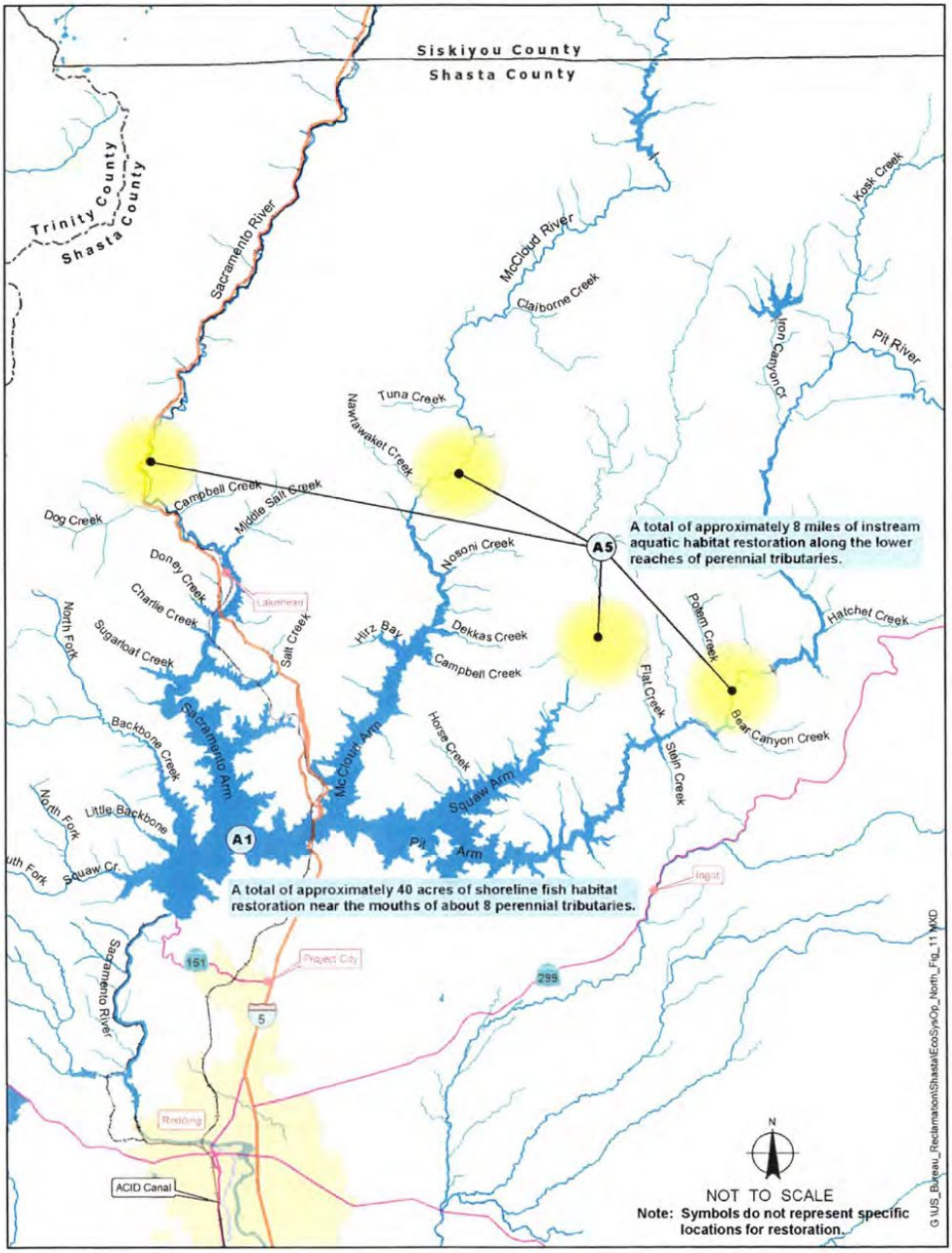


Figure 11- Preliminary Ecosystem Restoration Components, Shasta Lake and Tributaries

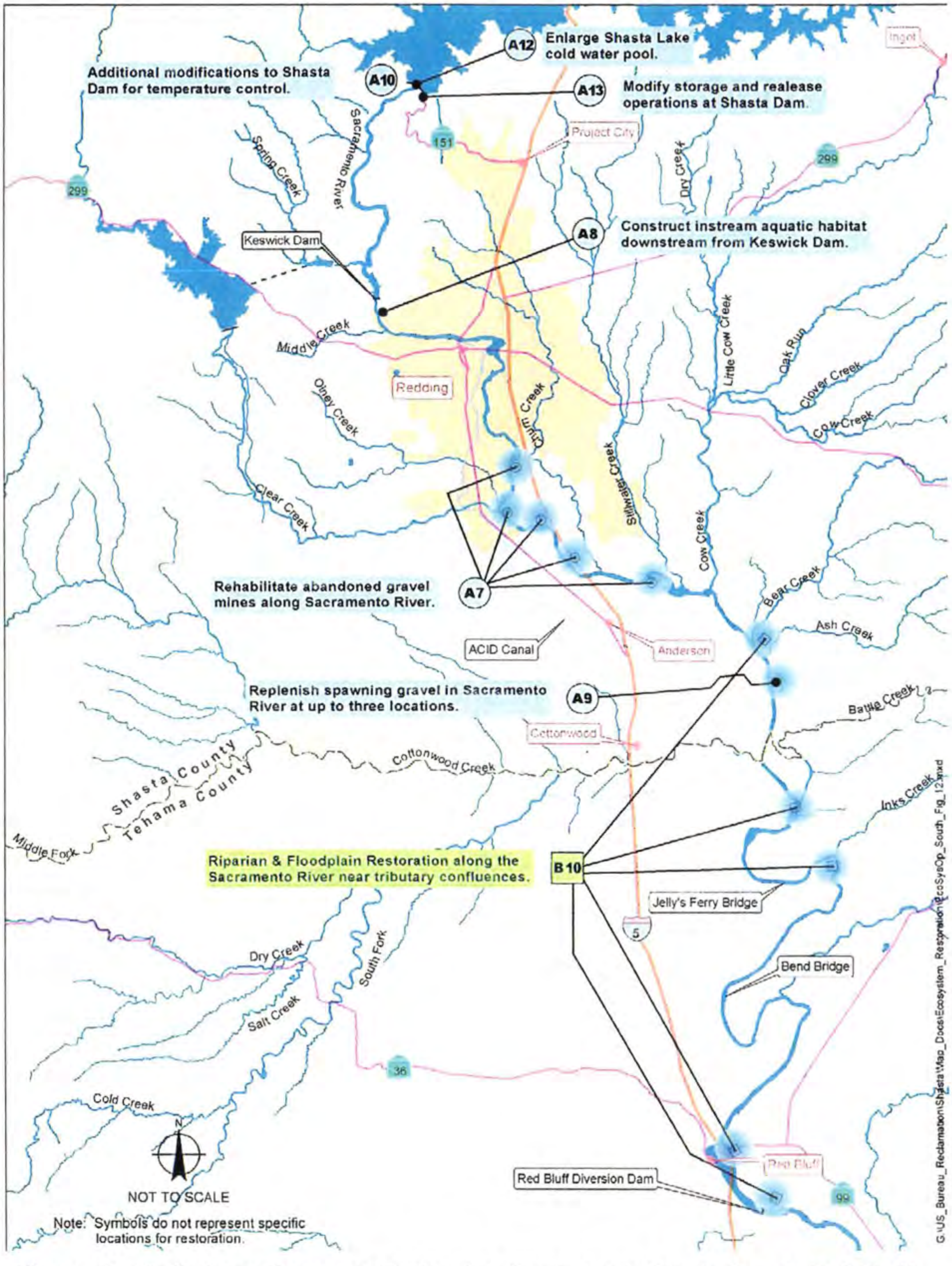


Figure 12 – Preliminary Ecosystem Restoration Components, Shasta Dam to Red Bluff

TABLE VI-3
PRELIMINARY ECOSYSTEM RESTORATION PLAN COMPONENTS

ID No.	Measure Description	First Cost[1] / Annual Cost[2]	Benefits / Advantages	Implementation Issues / Disadvantages	Comments and Conclusions
A1	**Construct Shoreline Fish Habitat around Shasta Lake** *20 acres of shallow-water habitat restoration around Shasta Lake.*	$1.6 million / Moderate – High	Improve shallow, warm-water fish habitat in drawdown area; improve juvenile rearing; increase angling opportunities.	May create submerged hazards for watercraft; likely high operation and maintenance, as structures would need to be replaced periodically.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Moderate uncertainty
A5	**Construct Instream Fish Habitat on Tributaries to Shasta Lake** *8 miles aquatic habitat restoration along lower reaches of perennial tributaries to Shasta Lake.*	$0.6 million / Moderate – High	Improved spawning and rearing habitat in Shasta tributaries.	Habitat structures would need to be replaced periodically; site access may be problematic.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Low uncertainty
A7	**Restore Inactive Gravel Mines on Sacramento River** *Restoration of 150 acres of land formerly mined for gravel.*	$8 million / Moderate	Provides benefits for both aquatic and floodplain habitats; reduced mortality at pits and improved spawning success.	Land acquisition would be required to ensure long-term benefits.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Benefits both terrestrial and aquatic habitats ▪ Low uncertainty
A8	**Construct Instream Habitat Downstream from Keswick Dam** *¾ mile of aquatic habitat restoration on the Sacramento River downstream from Keswick Dam.*	$0.8 million / Moderate – High	Improved spawning success in a reach currently unsuitable for spawning; reduced mortality below dam.	Design and construction constraints related to site conditions and dam releases; high operation and maintenance, as habitat structures would need to be replaced periodically; low potential for inclusion in Federal projects.	▪ High long-term cost for restoring a relatively small, although strategically located, reach of river ▪ Moderate uncertainty ▪ Potential for non-federal consideration
A9	**Replenish Spawning Gravel in Sacramento River** *10,000 tons spawning gravel injected at three sites between Keswick Dam and Red Bluff.*	$0.4 million / Very High	Improved aquatic habitat / spawning success; gravel may become limiting factor in fisheries restoration; benefits would continue as gravel moves through system.	Very high operation and maintenance, as gravel injections would need to be repeated at frequent intervals to maintain benefits over project life; concerns over downstream impacts to infrastructure; low potential for inclusion in Federal projects.	▪ Very low initial cost but higher long-term cost ▪ Moderate uncertainty ▪ Potential for non-federal consideration

TABLE VI-3 (CONT.)
PRELIMINARY ECOSYSTEM RESTORATION PLAN COMPONENTS

ID No.	Measure Description	First Cost[1] / Annual Cost[2]	Benefits / Advantages	Implementation Issues / Disadvantages	Comments and Conclusions
A10	**Additional Modifications to Shasta Dam for Temperature Control** *Expansion of existing temperature control device at Shasta Dam.*	Similar to existing TCD Low	Improved temperature control would support spawning success.	Potential for high initial cost depending on other modifications to Shasta Dam.	▪ **High Recommendation** ▪ High potential to combine with other measures ▪ Moderate uncertainty
A12	**Enlarge Shasta Lake Cold Water Pool** *Raise Shasta Dam between about 6.5 and 18 feet and enlarge Shasta Reservoir by between 290,000 and 630,000 acre-feet, respectively.*	$210 to $290 million Low	Increased cold water release capability from Shasta Dam would improve meeting downstream water temperature goals and spawning and rearing success and likely water supply reliability, hydropower, and lake area recreation benefits.	High initial costs; adverse impacts to reservoir rim physical and natural resources requiring significant mitigation measures.	▪ **High recommendation** ▪ Consistent with CALFED ▪ High initial costs ▪ Strong potential to combine with other measures ▪ Low uncertainty
A13	**Modify Storage and Release Operations at Shasta Dam** *Reoperate Shasta Dam to benefit anadromous fisheries.*	Low (without mitigation) Low	Greater flexibility in meeting fishery needs would improve spawning and rearing success.	Would only be feasible with measures to mitigate likely adverse impacts to water supply reliability and other resources.	▪ **High recommendation** ▪ Good potential to combine with other measures ▪ Moderate uncertainty
B10	**Riparian and Floodplain Restoration along Sacramento River** *500 acres of floodplain and riparian habitat restoration near tributary confluences.*	$9 million Moderate – High	Restores floodplain and riparian habitat, with residual benefits to aquatic habitat (source of shade and woody debris); restore natural processes.	Land acquisition would be required to ensure long-term benefits.	▪ Good potential to combine with other measures ▪ Benefits both terrestrial and aquatic habitats ▪ Low uncertainty

Notes:
1. *First Cost includes initial construction, real estate, planning, engineering, and design; represents the initial cost required to implement the measure.*
2. *Relative comparison to first cost. Annual Cost includes annual monitoring, operation, and maintenance costs, and any periodic or recurring costs associated with the measure.*

CHAPTER VII
CONCLUSIONS

Major conclusions of this office report are:

- Ecosystem resource problems and needs in the Shasta Lake and Tributaries sub-area include:
  - Reductions in warm-water and cold-water fisheries in Shasta Lake, resulting primarily from (1) acid mine drainage, (2) lack of shallow-water, shoreline habitat, and (3) human disturbances.
  - Reductions in fisheries in the tributaries to Shasta Lake, resulting primarily from (1) modification of seasonal flows, (2) loss of access to historic spawning and rearing areas, and (3) acid mine drainage.
  - Reductions in riparian and wetland habitat in the sub-area, resulting primarily from increased erosion and sediment input, and non-native species.
- Ecosystem resource problems and needs in the Shasta Dam to Red Bluff sub-area include:
  - Reductions in anadromous fish populations in the upper Sacramento River, resulting primarily from (1) water temperature, (2) physical migration barriers, (3) diversions and flow regulation, (4) reduction in suitable spawning gravels, (5) acid mine drainage, and (6) unnatural predation rates.
  - Reductions in riparian, floodplain, and wetland habitat, resulting primarily from (1) changes to natural geomorphic processes, (2) urban and agricultural encroachment and other land management changes, and (3) invasive species.
- There are numerous Federal and State agencies, local working groups, and private organizations active in implementing ecosystem restoration programs and projects in the upper Sacramento River area. However, there remains residual opportunities to implement actions to help restore ecosystem values in the study area.
- Based on the problems, needs, and opportunities identified, ecosystem restoration measures can be formulated to address (1) the primary SLWRI objective to increase the survival of anadromous fish populations in the Sacramento River, primarily upstream from the Red Bluff Diversion Dam, and (2) the secondary SLWRI objective to preserve and restore ecosystem resources in the Shasta Lake area and along the upper Sacramento River.
- Over 40 potential resources management measures were identified that addressed the identified problems and needs while contributing to the primary and/or secondary study objectives.
- Of the resources management measures identified, nine measures were identified as warranting further consideration and six of the measures were given a high recommendation for potential consideration in multi-purpose alternatives being formulated in the feasibility scope studies;

- Four of the recommended management measures address the primary planning objective by helping to increase anadromous fish populations in the upper Sacramento River: (1) rehabilitating inactive gravel mines along the Sacramento River, (2) enlarging Shasta Lake cold water pool, (3) modifying storage and release operations at Shasta Dam, and (4) additional modifications to Shasta Dam for temperature control.
- Two of the recommended management measures address the secondary planning objective and are focused on helping restore ecosystem values in the Shasta Lake area. They include: (1) creating shoreline fish habitat around Shasta Lake and (2) constructing instream fish habitat on tributaries to Shasta Lake.
- One of the remaining management measures recommended for further consideration addresses riparian and flood plain restoration on the Sacramento River.
- Two measures potentially warranting additional consideration likely by non-federal interests include: (1) constructing instream habitat downstream from Keswick Dam and (2) replenishing spawning gravels in the Sacramento River.

- It is believed that future plan formulation efforts for the SLWRI should include further consideration of the recommended management measures.

CHAPTER VIII
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