Draft

Plan Formulation Appendix

Shasta Lake Water Resources Investigation, California

Prepared by:

United States Department of the Interior
Bureau of Reclamation
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Abbreviations and Acronyms

2004 OCAP	*2004 Long-Term CVP Operations Criteria and Plan*
2004 OCAP BA	*2004 Long-Term CVP and SWP OCAP Biological Assessment*
AFS	anadromous fish survival
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta
BDCP	Bay-Delta Conservation Plan
BLM	Bureau of Land Management
BO	Biological Opinion
CA	California Aqueduct
CALFED	CALFED Bay-Delta Program
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CO	combined objectives
CP	Comprehensive Plan
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Production Model
Delta	Sacramento-San Joaquin Delta
DEIS	Draft Environmental Impact Statement
DHCCP	Delta Habitat Conservation and Conveyance Plan
DMC	Delta-Mendota Canal
DMC/CA	Delta Mendota Canal/California Aqueduct
DWR	California Department of Water Resources
EIS	Environmental Impact Statement
elevation xxx	elevation in feet above mean sea level
EQ	Environmental Quality
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
GIS	geographic information system
GWh	gigawatt-hour
I-5	Interstate 5
IDC	interest during construction
IMPLAN	IMpact analysis for PLANning
M&I	municipal and industrial

MAF	million acre-feet
MW	megawatt
NED	National Economic Development
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NODOS	North-of-the-Delta Offstream Storage
NRA	National Recreation Area
O&M	operations and maintenance
OCAP	Operations Criteria and Plan
P&G	Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
PG&E	Pacific Gas and Electric Company
PMF	Probable Maximum Flood
RBPP	Red Bluff Pumping Plant
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RED	Regional Economic Development
ROD	Record of Decision
RPA	reasonable and prudent alternative
SCRB	separable costs-remaining benefits
SLWRI	Shasta Lake Water Resources Investigation
SRTTG	Sacramento River Temperature Task Group
STNF	Shasta-Trinity National Forest
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TCD	temperature control device
UPRR	Union Pacific Railroad
USACE	U.S. Army Corps of Engineers
USFS	U.S. Department of Agriculture, Forest Service
USFWS	U.S. Department of the Interior, Fish and Wildlife Service
WSR	water supply reliability

Chapter 1 Introduction

This appendix describes the iterative plan formulation and evaluation process for the Shasta Lake Water Resources Investigation (SLWRI) by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), Mid-Pacific Region. This chapter defines planning objectives, constraints, and criteria. Subsequent chapters describe management measures, representative sets of concept plans, and development of comprehensive plans. Information presented in this appendix is used to support discussions in the Draft Environmental Impact Statement (DEIS).

Plan Formulation Process

Consistent with the National Environmental Policy Act (NEPA), the plan formulation process for Federal water resources studies is identified in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) (WRC 1983) and consists of the following deliberate and iterative steps:

- Identifying existing and projected future resources conditions likely to occur in a study area.
- Defining water resources problems, needs, and opportunities to be addressed, and developing planning objectives, constraints, and criteria.
- Identifying potential management measures and formulating potential alternative plans to meet planning objectives within planning constraints.
- Comparing and evaluating alternative plans.
- Selecting a plan for recommendation to decision makers for implementation or no action.

For the SLWRI, this iterative process was separated into multiple phases as illustrated in Figure 1-1 and described below:

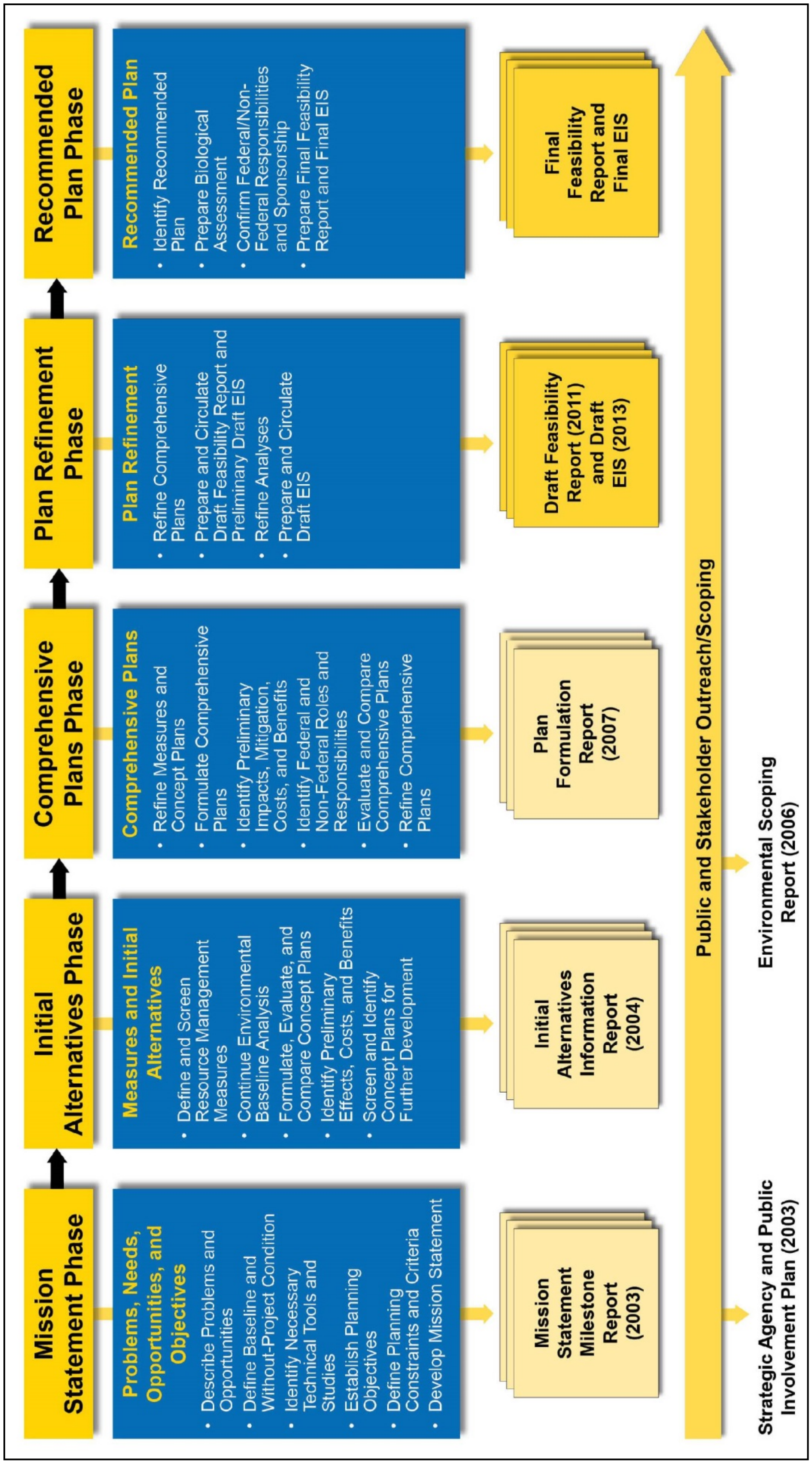


Figure 1-1. Plan Formulation Phases

- **Mission Statement Phase –** This study phase consisted of projecting without-project future conditions, defining resulting resource problems and needs, defining a specific set of planning objectives, and identifying constraints and criteria for addressing the planning objectives. The results of this phase of study were included in the 2003 *SLWRI Mission Statement Milestone Report* (Reclamation 2003a).

- **Initial Alternatives Phase –** This phase included developing a number of potential management measures, or project actions or features designed to address planning objectives. These measures were then used to formulate a set of plans that were conceptual in scope (concept plans). These initial plans were evaluated and compared to the planning objectives to identify the most suitable plans for further development. The results of this phase of study were included in the 2004 *SLWRI Initial Alternatives Information Report* (Reclamation 2004a).

- **Comprehensive Plans Phase –** The measures and concept plans carried forward were further refined and developed with more specificity to formulate comprehensive plans to address the planning objectives. These plans were then evaluated and compared. The results of this phase of the study were included in the 2007 *SLWRI Plan Formulation Report* (Reclamation 2007).

- **Plan Refinement Phase –** This phase focuses on further refinement of the comprehensive plans to identify a plan suitable to be recommended for implementation. This phase includes preparing and circulating a Draft Feasibility Report, which was completed in November 2011 and released to the public in February 2012, and DEIS.

- **Recommended Plan Phase –** The next phase of the SLWRI planning process will focus on identifying a recommended plan, preparing a Biological Assessment, and confirming Federal and non-Federal responsibilities. This phase will conclude with the preparation and processing of a Final Feasibility Report, to support a Federal decision, and a Final Environmental Impact Statement (EIS).

Public and stakeholder outreach was performed concurrently with the above phases, as shown in Figure 1-1. Major reports include the *SLWRI Strategic Agency Public Involvement Plan*, published in 2003 (Reclamation), and the *SLWRI Environmental Scoping Report*, published in 2006 (Reclamation).

The first three phases have been completed. As shown in Figure 1-1, emphasis in these planning phases changes as the Feasibility Study proceeds. In the beginning, the emphasis is on defining problems, needs, and opportunities, and inventorying and forecasting conditions in the study area to help define a specific set of planning objectives. In time, however, emphasis shifts to defining water management measures and ways of combining the most appropriate of these measures into concept plans. Later, emphasis shifts to formulating, evaluating, and comparing complete and comprehensive alternatives. Still later in the study, emphasis is on defining and describing a recommended plan and preparing a Feasibility Report. During each study phase, it is important to review and revise, if necessary, previous decisions and future study planning objectives.

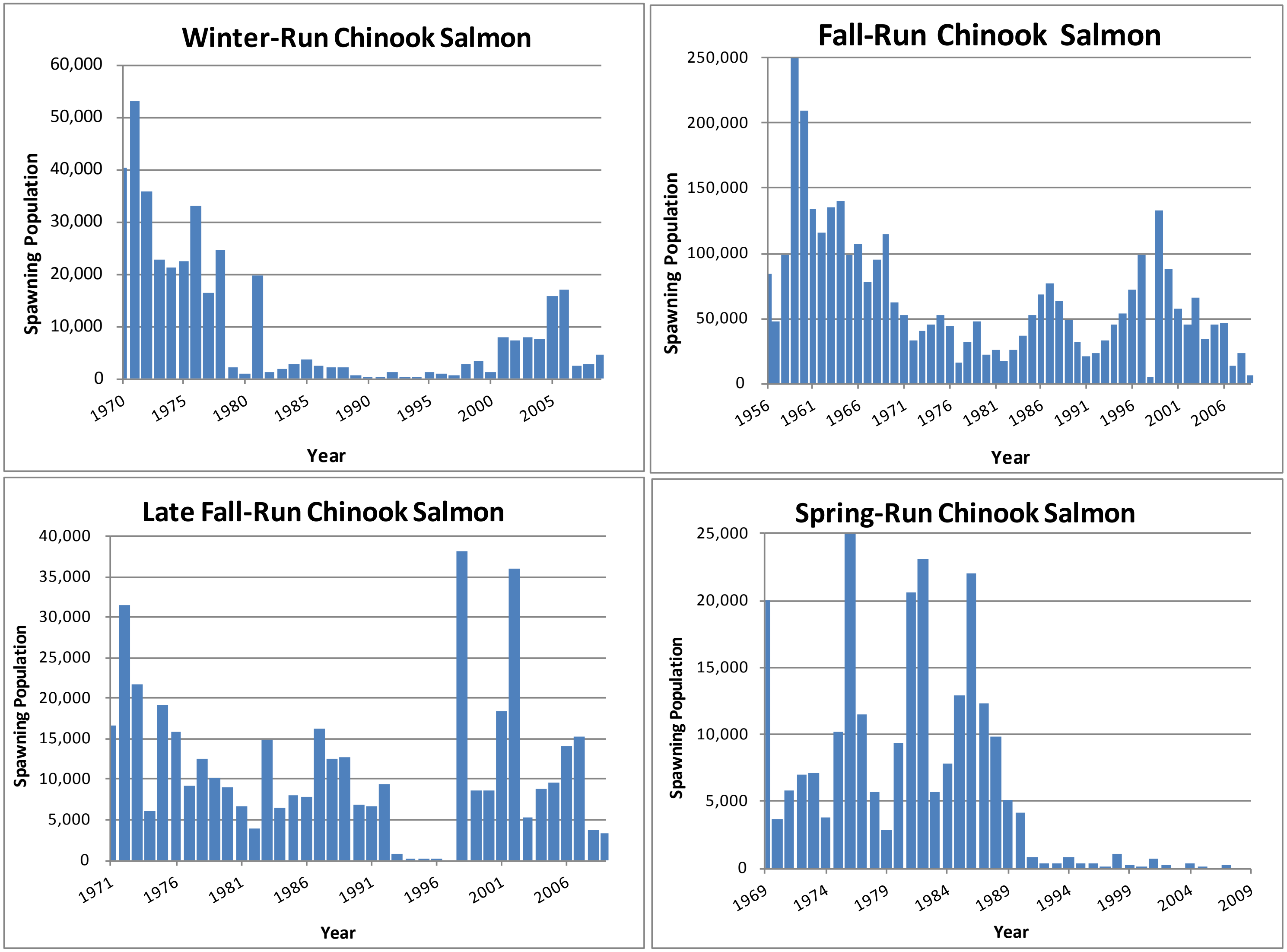
Water and Related Resources Problems, Needs, and Opportunities

Based on the overall feasibility study authority, and concerns expressed about existing and likely future water and related resources issues, following is a description of identified major water resources problems, needs, and opportunities in the primary SLWRI study area.

Anadromous Fish Survival

The Sacramento River system supports four separate runs of Chinook salmon: fall-, late fall-, winter-, and spring-run. The adult populations of the four runs of salmon and other important fish species that spawn in the upper Sacramento River have declined considerably over the last 40 years (Figure 1-2) (CDFW 2010). Several fish species in the upper Sacramento River have been listed as endangered or threatened, as defined by the Federal Endangered Species Act (ESA): Sacramento River winter-run Chinook salmon (endangered), Central Valley spring-run Chinook salmon (threatened), Central Valley steelhead (threatened), and the Southern Distinct Population Segment of North American green sturgeon (threatened). Two of these species also are listed as endangered or threatened, as defined by the California Endangered Species Act (CESA): Sacramento River winter-run Chinook salmon (endangered) and Central Valley spring-run Chinook salmon (threatened).

Numerous factors have contributed to these declines, including unstable water temperature, loss of historic spawning areas and suitable rearing habitat, water diversions from the Sacramento River, drought conditions, reduction in suitable spawning gravels, fluctuations in river flows, toxic acid mine drainage, high rates of predation, unsustainable fish harvests, and unsuitable ocean conditions. One of the most significant environmental factors affecting Chinook salmon is unsuitable water temperature in the Sacramento River (NMFS 2009b). Water temperatures that are too high or, less commonly, too low, can be detrimental to the various life stages of Chinook salmon. Elevated water temperatures can negatively impact holding and spawning adults, egg viability and incubation, preemergent fry, and rearing juveniles and smolts, significantly diminishing the next generation of returning spawners. Stress caused by high water temperatures also may reduce the resistance of fish to parasites, disease, and pollutants.



Source: CDFW, 2010

Figure 1-2. Chinook Salmon Historic Spawning Populations in the Sacramento River

Releases of cold water stored behind Shasta Dam can significantly improve seasonal water temperatures in the Sacramento River for anadromous fish during critical periods. The 2009 National Marine Fisheries Service (NMFS) Public Draft Recovery Plan states that prolonged droughts depleting the cold-water stored in Shasta Reservoir, or some related failure to manage cold-water storage, could put populations of anadromous fish at risk of severe population decline or extirpation in the long-term (NMFS 2009b). The risk associated with a prolonged drought is especially high in the Sacramento River, as Shasta Reservoir is intended to maintain only one year of carryover storage. The recovery plan emphasizes that, under current conditions, even two consecutive years of drought could reduce Shasta Reservoir storage to levels insufficient to support the Sacramento River winter-run Chinook salmon spawning and incubation season.

Conversely, water that is too cold is detrimental to the rapid growth of rearing juveniles. Following construction of Shasta Dam, water released in the spring was unusually cold and prevented the characteristic rapid growth of fall-run and late fall-run juvenile Chinook salmon. Reduced growth rates result in increased risk for predation and entrainment at unscreened and inadequately screened diversions.

Various Federal, State, and local projects are addressing each of the aforementioned factors contributing to anadromous fish population declines. Recovery actions range from changing the timing and magnitude of reservoir releases to changing the temperature of released water. In May 1990, State Water Resources Control Board (SWRCB) issued Order 90-5, which included temperature objectives for the Sacramento River to protect winter-run Chinook salmon. This order was reinforced by the 1993, 2004, and 2009 NMFS biological opinions (BO) for winter-run Chinook salmon, which established certain operating parameters for Shasta Reservoir. The State Water Resources Control Board action and the NMFS BOs set minimum flows in the river downstream from Keswick Dam and minimum Shasta Reservoir carryover storage targets primarily to affect water temperatures during key periods.

In addition to flow requirements, structural changes were made at Shasta Dam to change the temperature of released water, such as construction of a temperature control device (TCD), completed in 1997. The TCD can be used to selectively draw water from different depths within the lake, including the deepest, to help maintain river water temperatures beneficial to salmon. The TCD is effective in helping to reduce winter-run Chinook salmon mortality in some critical years,[1] and for fall- and spring-run Chinook salmon in below-normal water years.

However, implementing requirements in the Trinity River Record of Decision (ROD) (Reclamation 2000), as amended, may reduce water temperature

[1] Throughout this document, water year types are defined according to the Sacramento Valley Index Water Year Hydrologic Classification unless specified otherwise.

improvements provided by the TCD at Shasta Dam. One of the major elements of the Trinity River ROD is reducing the average annual export of Trinity River water from 74 percent to 52 percent of the flow (Reclamation 2000). This reduces flow from the Trinity River basin into Keswick Reservoir, and then into the Sacramento River. Because water diverted from the Trinity River is generally cooler than flows released from Shasta Dam, implementing the Trinity River ROD offsets some of the benefits derived from the TCD.

The overall trend for the past 10 years has shown increases in Sacramento River Chinook salmon populations (CDFG 2010). This increasing trend in salmon populations is likely due primarily to minimum release requirements at Shasta Dam, the TCD, and changes in operating the Red Bluff Diversion Dam. In addition, the Red Bluff Pumping Plant (RBPP) is expected to benefit Chinook salmon populations in the Sacramento River. However, there is a residual need for generally cooler water in the Sacramento River, especially in dry and critical water years.

In the future, effects of climate change on operations at Shasta Lake could potentially result in changes to water temperature, flow, and ultimately, fish survival. As described in the Climate Change Projection Appendix, climate change could result in increased inflows to Shasta Lake and higher reservoir releases because of an increase in winter and early spring inflow into the lake from high intensity storm events. The change in reservoir releases could be necessary to manage flood events resulting from these potentially larger storms. Climate change could also result in reduced end-of-September carryover storage volumes, resulting in lower lake levels for a portion of the year, and a smaller cold-water pool, resulting in warmer water temperature and reduced water quality within Shasta Reservoir. Most importantly, it is expected that climate change may result in increased water temperatures downstream from Shasta Dam, particularly in summer months, and more frequent wet and drought (particularly extended drought) years. Increased water temperatures and extended drought periods may compound the threats to anadromous fish in the Sacramento River.

Water Supply Reliability

California's water supply system faces critical challenges with demands exceeding supplies for urban, agricultural, and environmental water uses across the State. The 2009 *California Water Plan Update* (DWR 2009) concludes that California is facing one of the most significant water crises in its history; drought impacts are growing, ecosystems are declining, water quality is diminishing, and climate change is affecting statewide hydrology. Compounding these issues, Reclamation's *Water Supply and Yield Study* (Reclamation 2008) describes dramatic increases in population, land use changes, regulatory requirements, and limitations on storage and conveyance facilities, further straining available water supplies and infrastructure to meet water demands. Resulting unmet water demands have led to increases in competition for water supplies among urban, agricultural, and environmental uses.

The following subsections discuss identified key issues related to water supply reliability in California, including current and estimated water shortages, anticipated effects of population growth and climate change on water supply and demand, and limitations on system flexibility. The final subsection discusses strategies for meeting future statewide water supply needs.

Estimated Water Supply Shortages

Projecting accurate and quantified water supply and shortages in California is complex; numerous variables exist and, just as important, numerous opinions have been expressed regarding these variables. Table 1-1 displays estimated water demands, available supplies, and shortages for the Central Valley and the State under existing conditions (Reclamation 2008). Current water supply shortages for the State are estimated at 2.3 and 4.2 million acre-feet (MAF) for average and dry years, respectively. As shown in Table 1-2, without further investment in water management and infrastructure, future shortages are expected to increase to approximately 4.9 and 6.1 MAF in average and dry years, respectively, by 2030. Representative demands for dry and average years were based on water use data from the 2005 *California Water Plan Update* (DWR), adjusted for population growth, increasing urban water use, and reductions in irrigated acreage and environmental flow due to insufficient water supplies. Shortages were determined on a regional basis, assuming that limitations on conveyance and storage would prevent surpluses from one region or use category from filling shortages in another.

Table 1-1. Estimated Water Demands, Supplies, and Shortages Under Existing Conditions[1]

Item	Hydrologic Basin						State of California	
	Sacramento		San Joaquin		Two-Basin Total			
	Average Year[2]	Dry Year[2]	Average Year[2]	Dry Year[2]	Average Year[2]	Dry Year[2]	Average Year[2]	Dry Year[2]
Population (million)[3]	2.9		2.0		4.9		36.9	
Water Demand (MAF)								
Urban	0.9	0.9	0.6	0.6	1.5	1.5	8.9	9.0
Agricultural	8.7	8.7	7.0	7.0	15.7	15.7	34.2	34.2
Environmental	11.9	9.4	3.1	2.3	15.0	11.7	17.5	13.9
Total	***21.5***	***19.0***	***10.7***	***9.9***	***32.2***	***28.9***	***60.6***	***57.1***
Water Supply (MAF)								
Urban	0.9	0.9	0.6	0.6	1.5	1.5	8.8	8.4
Agricultural	8.7	8.6	6.9	7.0	15.6	15.6	33.2	32.0
Environmental	11.5	8.7	2.5	1.8	14.0	10.5	16.3	12.6
Total	***21.1***	***18.2***	***10.0***	***9.4***	***31.1***	***27.6***	***58.3***	***53.0***
Total Shortage (MAF)[4]	**0.4**	**0.8**	**0.7**	**0.5**	**1.1**	**1.3**	**2.3**	**4.1**

Notes:
[1] Water demands, supplies, and shortages are from the 2008 Reclamation Water Supply and Yield Study
[2] Representative dry and average year supplies and demands were based on adjusted water use and supply data from the 2005 California Water Plan Update (DWR 2005).
[3] Population estimates are from the California Department of Finance (2010)
[4] Total shortages are calculated as the sum of shortages for each category by region and, therefore, may not equal the difference between total demands and supplies. For categories where supply is greater than demand, the shortage is equal to zero.
Key:
MAF = million acre-feet

Table 1-2. Estimated Water Demands, Supplies, and Shortages for 2030[1]

Item	Sacramento and San Joaquin Hydrologic Basins – Two-Basin Total		State of California	
	Average Year[2]	Dry Year[2]	Average Year[2]	Dry Year[2]
Population (million)[3]	10.5		49.2	
Water Demand (MAF)				
Urban	2.4	2.5	11.9	12.0
Agricultural	15.0	15.0	31.4	31.4
Environmental	14.9	11.7	17.5	14.0
Total	***32.3***	***29.2***	***60.8***	***57.4***
Water Supply (MAF)				
Urban	1.5	1.5	8.4	8.0
Agricultural	15.6	15.6	32.8	31.5
Environmental	14.0	10.5	16.3	12.6
Total	***31.1***	***27.6***	***57.5***	***52.1***
Total Shortage (MAF)[4]	**1.8**	**2.2**	**4.9**	**6.1**

Notes:
[1] Water demands, supplies, and shortages are from the 2008 Reclamation *Water Supply and Yield Study*
[2] Representative dry and average year supplies and demands were based on water use and supply data from the 2005 *California Water Plan Update* (DWR 2005) adjusted for population growth, increasing urban water use, and reductions in irrigated acreage and environmental flow due to insufficient water supplies.
[3] Population estimates are from the California Department of Finance (2010)
[4] Total shortages are calculated as the sum of shortages for each category by region and, therefore, may not equal the difference between demands and supplies. For categories where supply is greater than demand, the shortage is equal to zero.

Key:
MAF = million acre-feet

Potential Effects of Population Growth on Water Demands

A major factor in California's future water picture is population growth. California's population is expected to increase by just over 60 percent by 2050 (California Department of Finance 2010) and could force some of the existing water supplies currently identified for agricultural uses to be redirected to urban uses. Some portion of increased population in the Central Valley would occur on lands currently used for irrigated agriculture. Water that would have been needed for these lands for irrigation would instead be used to serve replaced urban demands. However, this would only partially offset the required agricultural-to-urban water conversion needed to sustain projected urban water demands, since much of the growth would occur on nonirrigated agricultural lands.

The 2009 *California Water Plan Update* (DWR) estimates changes in future water demands by 2050 considering three different population growth scenarios as well as climate change. Table 1-3 shows results of this study for an average water year (DWR 2009). The first scenario (Current Trends) assumes that recent population growth trends will continue until 2050. The second scenario (Slow and Strategic Growth) assumes that population growth will be slower than currently projected. The third scenario (Expansive Growth) assumes that population growth will be faster than currently projected, with nearly 70 million people living in California in 2050. Estimated reductions in agricultural water demands in Table 1-3 represent decreases in future agricultural water demands due to conversion from agricultural to urban land uses. Under the Current Trends and Expansive Growth scenarios, as much as 3 and 8 MAF, respectively, of increased demand is projected, adding to the current water shortages estimated in Table 1-1.

Table 1-3. Estimated Annual Change in Water Demand in California for 2050 Considering Different Population Growth Scenarios

Item	Current Trends	Slow and Strategic Growth	Expansive Growth
Population (million)	59.5	44.2	69.8
Irrigated Crop Acreage (million)	8.6	9	8.3
Water Demand Change[1] (MAF)			
Urban	7	2	11
Agricultural	-4.5	-5.5	-4
Environmental	1	2	1
Total	***3***	***-1.5***	***8***

Source: DWR 2009
Note:
[1] Water demand change is the difference between the average demands for 2043—2050 and 1998—2005.
Key:
MAF = million acre-feet

Potential Effects of Climate Change

Another potentially significant factor affecting water supply reliability is climate change. Potential effects of climate change are many and complex (DWR 2006), varying through time and geographic location across the State (Reclamation 2011). Changes in geographic distribution, timing, and intensity of precipitation are projected for the Central Valley (Reclamation 2011), which could broadly impact rainfall runoff relationships important for flood management as well as water supply. Additionally, when climate change is considered in projections of future water demand, annual water demand is higher than under a repeat of historical climate (DWR 2009). Other possible impacts range from potential sea level rise, which could impact coastal areas and water quality, to impacts to overall system storage for water supply.

A reduction in total system storage is widely predicted to occur with climate change. Precipitation held in snowpacks makes up a significant quantity of total annual supplies needed for urban, agricultural, and many environmental uses. It is expected that in the future, climate change may significantly reduce water held in snowpacks in the Sierra Nevada (Reclamation 2011, DWR 2009). Further potential for reductions in water conservation space in existing reservoirs in the Central Valley is anticipated because of increasing needs for additional space for flood management purposes. These potential reductions could significantly impact available water supplies, especially for reservoirs immediately upstream from large urban areas such as Folsom Lake on the American River, upstream from the greater Sacramento metropolitan area. During drought periods, supplies could be further reduced, and expected shortages would be substantially greater.

System Flexibility

In addition to concerns about future water supply and demand, California's Federal and State water systems lack flexibility in timing, location, and capacity to meet the multiple objectives of the projects. Central Valley Project (CVP) and State Water Project (SWP) flexibility has diminished with population growth and increased environmental and ecosystem commitments and requirements (Reclamation 2008). Complicating this issue is the variability associated with water resources in California. Precipitation in California is seasonably, temporally, and spatially variable, and urban, agricultural, and environmental water users have variable needs for quantity, quality, timing, and place of use.

California's water systems face the threat of too much water during floods, and too little water to meet demands during dry and critical water years. Chronic water shortages have led to increases in groundwater usage, which has led to groundwater overdraft in many regions across the State. Groundwater overdraft can cause permanent declines in groundwater levels, long-term reductions in groundwater supplies, land subsidence, decreases in water quality, a greater potential for salt water intrusion, and lasting environmental impacts. Challenges are greatest during drought years, when water supplies are less available (DWR 2009).

Increasing CVP/SWP operational constraints have led to growing competition for limited system resources between various users and uses. Urban and required environmental water uses have each increased, resulting in increased competition and conflicting demands for limited water supplies. For example, the Central Valley Project Improvement Act (CVPIA), implemented in 1993, dedicated 800 thousand acre-feet (TAF) of CVP water supplies to the environment as well as additional water supplies for the Trinity River and wildlife refuges. Table 1-4 illustrates the impacts of the CVPIA, modeled using CalSim-II, on urban and agricultural water deliveries to the north and south of the Sacramento-San Joaquin Delta (Delta). Dry year agricultural water deliveries were particularly impacted with deliveries to agricultural users, both north and south of the Delta, reduced by about 50 percent. Current BOs by NMFS and U.S. Department of Interior, Fish and Wildlife Service (USFWS), resulting in increased Delta pumping constraints and other operational restrictions, coupled with drought conditions, have even further decreased CVP deliveries. As competition for limited resources between various uses grows, water management flexibility and adaptability will be even more necessary in the future.

Table 1-4. Impact of CVPIA on CVP Deliveries

CVP Contract Deliveries	All Years			Driest Years		
	Pre-CVPIA Implementation (TAF)	Post-CVPIA Implementation (TAF)	Percent Change	Pre-CVPIA Implementation (TAF)	Post-CVPIA Implementation (TAF)	Percent Change
NOD Urban	176	167	-5%	166	145	-13%
NOD Agriculture	279	234	-16%	169	84	-50%
SOD Urban	134	122	-9%	114	96	-16%
SOD Agriculture	1,588	1,137	-28%	931	471	-49%
Total	**2,176**	**1,660**	**-24%**	**1,381**	**796**	**-42%**

Source: Reclamation 2008
Notes:
[1] Deliveries were modeled using CalSim-II.
Key:
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
NOD = north of Delta
SOD = south of Delta
TAF= thousand acre-feet

Potential Approaches to Address Water Supply Needs

As noted by Reclamation's *Water Supply and Yield Study* (Reclamation 2008), the *California Water Plan Update* (DWR 2009), and CALFED Bay-Delta Program (CALFED) ROD (2000), an integrated portfolio of solutions, regional and statewide, is needed to meet future water supply needs. The *Water Supply and Yield Study* stated that a "variety of storage and conveyance projects and water management actions have the potential to help fill [the] gap" between water supply and demand in California. The 2009 *California Water Plan Update* concluded that California must invest in reliable, high quality, and affordable water conservation; efficient water management; and development of water supplies to protect public health, and improve California's economy, environment, and standard of living. However, even with major efforts by multiple agencies to address the complex water resources issues in the State, demands are expected to continue to exceed supplies in the future.

To avoid major impacts to the economy, overall environment, and standard of living in California, actions to conserve existing supplies and optimize the use of existing facilities will be needed. Additionally, development of additional water sources and increased storage and delivery capability are critical for providing reliable water supplies for expanding municipal and industrial (M&I) uses and to maintain adequate supplies for agricultural and environmental purposes.

Ecosystem Resources

The health of the Sacramento River ecosystem, as elsewhere in the Central Valley, has been impacted in the last century by conflicts over the use of limited natural resources, particularly water resources. Many of California's rivers and streams have been harnessed for beneficial uses such as hydropower, flood damage reduction, and water supply, contributing to a decline in habitat and native species populations, and a resulting increase in endangered or threatened species listings under the ESA and CESA.

Construction of Shasta Dam has had both negative and positive effects on environmental resources in the region. While construction of the dam displaced valuable riverine and upland habitat, it also created shoreline and shallow water habitat for aquatic, terrestrial, and avian species in the reservoir area. For example, Shasta Lake is home to the largest concentration of nesting bald eagles in California, with 18 pairs nesting within 0.5 miles of the shoreline in any given year.

Shasta Lake Area

Various activities have impacted natural resources upstream from Shasta Dam, within the lake, on adjacent lands, and in and near tributary streams. Historical mining, ore processing practices and resulting acid mine drainage, and fire suppression are among the activities causing the greatest challenges to ecosystem resources in this area. Although mines in this area are no longer operational and are currently undergoing remediation, they continue to remain a documented source of metals, acidity, and sediments in the reservoir area. In addition, fire suppression activities have resulted in an accumulation of vegetation cover in the watershed and a decrease in the return intervals of natural fires, both of which potentially affect erosion processes and sediment delivery to tributaries and increase the likelihood of higher intensity fires (USFS 2010). To guide management of the Shasta-Trinity National Forest (STNF), the U.S. Department of Agriculture, Forest Service (USFS) has prepared the *Shasta-Trinity National Forest Land and Resource Management Plan* (USFS 1995). Primary goals of the *Shasta-Trinity National Forest Land and Resource Management Plan*, which was implemented in 1995, are to integrate a mix of management activities that allows use and protection of forest resources; meets the needs of guiding legislation; and addresses local, regional, and national issues. The *Shasta-Trinity National Forest Land and Resource Management Plan* is intended to guide implementation of the *Aquatic Conservation Strategy of the Northwest Forest Plan* (USFS 1994) for protection and management of riparian and aquatic habitats adjacent to Shasta Lake.

Opportunities exist to further support ongoing USFS programs. These opportunities include improving and restoring environmental conditions by developing self-sustaining natural habitat in the area of Shasta Lake and its tributaries to benefit fish and wildlife resources.

Downstream from Shasta Dam

Land and water resources development has caused major resource problems and challenges in the Sacramento River basin, including decreases in anadromous fish and wildlife populations and losses of riparian, wetland, floodplain, and shaded riverine habitat. These decreases and losses have resulted in reduced populations of many plant and animal species.

The quantity, quality, diversity, and connectivity of riparian, wetland, floodplain, and shaded riverine habitat along the Sacramento River have been severely limited through confinement of the river system by levees, reclamation of adjacent lands for farming, bank protection, channel stabilization, and land development. Modification of seasonal flow patterns by dams and water diversions also has inhibited the natural channel-forming processes that drive riparian habitat succession. It is estimated that less than 5 percent of the historical acreage of riparian habitat within the Sacramento River basin remains today (Huber-Lee et al. 2003).

Decreases in quality and quantity of habitat have resulted in reduced populations of various fish and wildlife species. The low populations and questionable sustainability of these species have led to an increase in listings under the ESA and CESA in recent years. Introduction of nonnative species has also contributed to the decline in native animal and plant species. In addition, lack of linear continuity of riparian habitat has impacted the movement of wildlife species among habitat areas, adversely affecting dispersal, migration, emigration, and immigration. For many species, this has resulted in reduced wildlife numbers and population viability.

Ecosystem restoration along the Sacramento River has been the focus of several ongoing programs, including the Senate Bill 1086 Program, CVPIA, CALFED, and Central Valley Habitat Joint Venture. These and numerous local programs have been established to address ongoing conflicts over the use of limited resources within the Central Valley. Much effort has been directed in the upper Sacramento River region above the RBPP toward restoring or improving anadromous fisheries, which provide recreational and commercial values in addition to their environmental value. Despite these efforts, a significant need remains to conserve and restore ecosystem resources along the Sacramento River.

Endangered and threatened fish and wildlife populations, critical habitat, and sensitive Delta ecosystems are also declining. The decline is especially pronounced in the case of pelagic fish species in the Delta, including delta smelt, striped bass, threadfin shad, and longfin smelt. Recent monitoring results indicate that the threatened delta smelt population continues to remain at or near all-time lows and, as a result, delta smelt have been recommended for relisting as endangered. Observations of sharp declines in fish population have resulted in restrictions on Delta water operations to protect fish populations during environmentally sensitive periods. Legal actions concerning the impacts of CVP and SWP operations on fish populations, such as the December 2007 *Natural Resources Defense Council v. Kempthorne* (delta smelt), court decision and the May 2008 *Pacific Coast Federation of Fishermen's Associations vs. Gutierrez* (anadromous fish species) court decision, continue to shape water management in the Sacramento River basin and Delta.

In recognition of the challenges facing water management in California, and the need to develop new strategies for a sustainable Delta ecosystem that would continue to support its economic functions, various planning efforts are underway. Current planning efforts, such as the Bay Delta Conservation Plan/ Delta Habitat Conservation and Conveyance Program are focused on developing ecological solutions to protect Delta fisheries while providing a sustainable and reliable water conveyance system for the CVP and SWP. Greater operational flexibility within the CVP/SWP system is needed to address ecosystem concerns in the Sacramento River and Delta.

Flood Management

Large and small communities and agricultural lands in the Central Valley are subject to flooding along the Sacramento River. U.S. Army Corps of Engineers (USACE), in partnership with DWR, has worked to assess basin-wide flood management issues and identify options in the Sacramento River basin to address these issues. Measures to reduce high flows in the Sacramento River include spilling floodwater into bypass areas through historical overflow areas, streams, conveyance canals, and weirs. The comprehensive flood control system in the Sacramento River basin includes river, canal, and stream channels, levees, flood relief bypasses, weirs, flood relief structures, a natural overflow area, outfall gates, and drainage pumping plants. USACE and DWR continue to develop improvements associated with the Sacramento River Bank Protection Project and to assist in local flood damage reduction projects along the Sacramento River. DWR is currently working on the implementation of the Central Valley Flood Protection Plan, which was adopted in 2012 to address flood issues throughout the Sacramento and San Joaquin valleys and the Delta.

Flooding poses risks to human life, health, and safety. Threats to the public from flooding are caused by many factors, including overtopping or sudden failures of levees, which can cause deep and rapid flooding with little warning, threatening lives and public safety. In addition, urban development in flood-prone areas has exposed the public to the risk of flooding.

Physical impacts from flooding occur to residential, agricultural, commercial, industrial, institutional, and public property. Damages occur to buildings, contents, automobiles, and outside property, including agricultural crops, equipment, and landscaping. Physical damages include cleanup costs and costs to repair roads, bridges, sewers, power lines, and other infrastructure components. Nonphysical flood losses include income losses and the cost of emergency services, such as flood fighting and disaster relief.

Even though a project to enlarge Shasta Dam and Reservoir has the potential to significantly reduce flood flows in the upper Sacramento River, influencing factors exist that can conflict with flood operation. Flood management operations at Shasta Dam, even with explicit rules provided in the Shasta Dam and Lake Flood Control Diagram (USACE 1977), are difficult to manage during a flood event. This is primarily due to the extreme inflow volumes to Shasta

Reservoir that can occur over long periods, numerous points of inflow along the river downstream from Shasta Dam, and multiple points of operational interest downstream. The primary downstream control point along the Sacramento River that determines reservoir releases under real-time operations is Bend Bridge.

Other unofficial factors enter into flood management decisions, such as peak flows at Hamilton City or other rural communities that are at risk of flooding. These factors, combined with the uncertainty of storm forecasting, could lead to a reduction in flood operation flexibility at Shasta Dam. Should this occur, it could cause a cascading impact on effective flood management downstream to the Delta. Accordingly, there is a need to review flood control operations at Shasta Dam.

Hydropower

Were California a nation, it would be the twelfth largest consumer of electricity worldwide (California Energy Commission 2002). Among the 50 States, California is the second largest consumer of electricity. Although California has 12 percent of the Nation’s population, it uses only 7 percent of the Nation’s electricity. This makes California the most energy-efficient State per capita in the Nation. Even so, demands for electricity are growing at a rapid pace.

As an example, over the next 10 years, California’s peak demand for electricity is expected to increase 30 percent, from about 50,000 megawatts (MW) to about 65,000 MW. There are, and will continue to be, increasing demands for new electrical energy supplies, including clean energy sources, such as hydropower. Executive Orders S-14-08 and S-21-09, issued in 2008 and 2009 respectively, established a goal of using renewable energy sources, including hydropower, for 33 percent of the State’s energy consumption by 2020 (California Public Utilities Commission 2011). Adding to the need for additional energy sources, existing nuclear power plants are nearing the end of their design lives and some may be offline within the next 10 to 20 years.

Recreation

As the population of the State of California continues to grow, demands will increase significantly for water-oriented recreation at and near the lakes, reservoirs, streams, and rivers of the Central Valley. According to the 2009 California Water Plan Update (DWR 2009), the Central Valley is experiencing dramatic population growth, but currently has insufficient access to water-dependent recreation opportunities. Further increases in demand, accompanied by relatively static recreation resources, will cause additional issues at existing recreation areas. These challenges will be especially pronounced at Shasta Lake, which is one of the most visited recreation destinations in the state and in the region. Even under current levels of demand, USFS, which manages recreation at Shasta Lake, has expressed concern about seasonal capacity problems at existing marinas and USFS facilities. A significant and increasing need exists to improve recreation-related facilities and conditions at Shasta Lake.

Water Quality

The Sacramento River and the Delta support fish and wildlife while providing water supplies for urban, agricultural, and environmental uses across the state. The Sacramento River downstream from Keswick Dam is critical habitat for the migration and reproduction of Chinook salmon (NMFS 2009b) and the Delta is one of the largest ecosystems for fish and wildlife habitat and production in the United States (Cal Water Boards, SWRCB, and CalEPA 2006). However, saltwater intrusion, municipal discharges, agricultural drainage, and water project flows and diversions have led to water quality issues within the Delta, particularly related to salinity, that have resulted in significant declines in pelagic populations (Cal Water Boards, SWRCB, and CalEPA 2006). In the Sacramento River and its tributaries, water temperatures, which are vital for anadromous fish survival, are affected by variations in climate and rainfall as well as operating conditions of various Federal, State, and local water supply systems. Additionally, urban and agricultural runoff, and runoff and seepage from abandoned mining operations, have resulted in elevated levels of pesticides, phosphorous, mercury, and other metals in the Sacramento River.

Several environmental flow goals and objectives in the Central Valley, including the Delta, have been established through legal mandates to address the impacts of water operations and water quality deterioration on the Sacramento River basin and Delta ecosystems and on endangered and threatened fish populations. Planning efforts, such as the Bay Delta Conservation Plan, are intended to allow implementation of projects that restore and protect water supply and reliability, water quality, and ecosystem health in the Delta to proceed within a stable regulatory framework. Additional operational flexibility is needed to provide further opportunities to improve Sacramento River and Delta water quality conditions. Increasing storage in Shasta Reservoir could provide increased CVP operational flexibility to meet water quality goals in the Delta, as well as provide more cold-water storage in critical years to improve Sacramento River water temperatures.

Existing and Future Resources Conditions in Study Area

Shasta Dam and Reservoir are located on the upper Sacramento River in Northern California about 9 miles northwest of the City of Redding, within Shasta County. The SLWRI includes both a primary and extended study area because of the potential influence of the proposed modification of Shasta Dam and Reservoir, and subsequent water deliveries on resources over a rather large geographic area. The primary study area for the SLWRI encompasses Shasta Dam and Lake; lower reaches of three primary tributaries flowing into Shasta Lake (Sacramento River, McCloud River, and Pit River) and all smaller tributaries flowing into the lake; Trinity Lake and Lewiston Reservoir; and the

Sacramento River downstream to about the RBPP, including tributaries at their confluence. Figure 1-3 shows the geographic extent of the primary study area.

The extended study area includes other areas of California with resource programs or projects that could potentially be indirectly influenced by modifying Shasta Dam and Reservoir. The extended study area encompasses the Sacramento River downstream from the RBPP, the Delta, portions of major tributaries, namely the lower Feather and American Rivers, parts of the lower San Joaquin River, and facilities and water service areas of the CVP and SWP. Detailed descriptions of the study area and existing conditions for physical, biological, cultural, and socioeconomic resources within the SLWRI study area is included in the accompanying DEIS and the Physical Resources Appendix, Biological Resources Appendix, Cultural Resources Appendix, and Socioeconomics Appendix. Following is a brief description of the likely future resources conditions in the study area.

Likely Future Conditions

Identification of the magnitude of potential water resources and related problems, needs, and opportunities in the study area is based not only on the existing conditions, but also on an estimate of how these conditions may change in the future. Predicting future changes to the physical, biological, cultural, and socioeconomic environments in the primary and extended study areas is complicated by ongoing programs and projects and potential changes in regulatory requirements. Several ecosystem restoration, water quality, water supply, and levee improvement projects are likely to be implemented in the future. Collectively, these efforts may improve ecosystem resources, Delta water quality, water supply, and levees. Much of this improvement would be based on separate opportunities that are not integrated in a single plan or part of an approved and funded program.

The following sections summarize likely future conditions for physical, biological, cultural, and socioeconomic resources within the SLWRI study area, as described in the accompanying DEIS.

Physical Resources Environment

Basic physical conditions in the primary and extended study areas are expected to remain relatively unchanged in the future. Continued development in urban and suburban areas is expected. Ongoing restoration efforts along rivers are expected to marginally improve natural riverine processes. Without major physical changes to the river systems, hydrologic conditions may remain unchanged. However, the region’s hydrology could be altered should there be significant changes in global climatic conditions; scientific work in this field of study is continuing. Without major changes in hydrology, topography, or geology, sedimentation and erosion are also likely to remain unchanged.

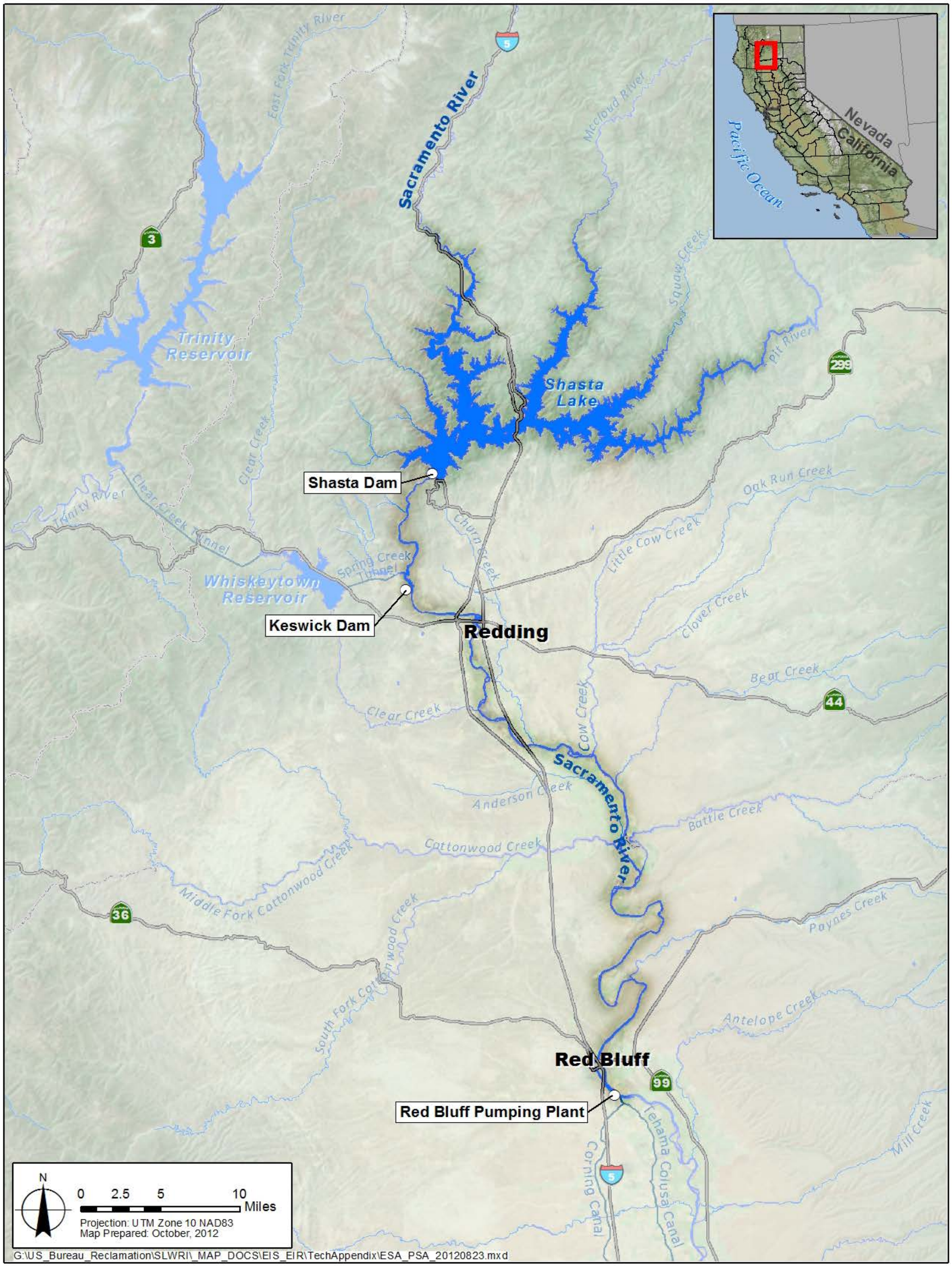


Figure 1-3. Shasta Lake Water Resources Investigation Primary Study Area – Shasta Lake Area and Sacramento River from Shasta Dam to Red Bluff Pumping Plant

Much effort has been expended to control the levels and types of herbicides, fungicides, and pesticides that can be used in the environment. Further, efforts are underway to better manage the quality of runoff from urban environments to the major stream systems. However, water quality conditions are expected to remain unchanged and similar to existing conditions.

It is unclear to what extent potential changes to the region's climate could occur in association with global climate change. As the population continues to grow and agricultural lands are converted to urban and industrial uses, a general degradation of air quality conditions could occur. However, because of technological innovation and stringent regulations, air quality could improve over time. While similar types and sources of hazardous materials and waste are likely to be present in the future, increasing population will likely increase the potential for hazardous waste issues. Similarly, increasing population will likely affect increases in environmental noise and vibration.

Biological Resources Environment

Efforts are underway by numerous agencies and groups to restore various biological conditions throughout the primary and extended study areas. Accordingly, major areas of wildlife habitat, including wetlands and riparian vegetation areas, are expected to be protected and restored. However, as population and urban growth continues, and land uses are converted to urban centers, many wildlife and plant species especially dependent on woodland, oak woodland, and grassland habitats may be adversely affected.

Through the significant efforts of Federal and State wildlife agencies, populations of special-status species in the riverine and nearby areas are estimated to generally remain as under existing conditions. Although increases in anadromous and resident fish populations in the Sacramento River could continue through implementation of projects such as the Battle Creek Salmon and Steelhead Restoration Project, some degradation will likely occur through actions that reduce Sacramento River flows or elevate water temperatures such as implementation of the Trinity River ROD. Accordingly, populations of anadromous fish are expected to remain generally similar to existing conditions.

No rivers or streams in the primary study area are expected to be added to the list of Federal and/or State wild and scenic resources. The wild and scenic status of the McCloud River is expected to remain as under existing conditions.

Cultural Resources Environment

In the vicinity of Shasta Lake, any archaeological, historic, or ethnographic resources currently affected by erosion due to reservoir fluctuations would continue to be impacted. Artifacts located around the perimeter of the existing reservoir will continue to be subject to collection by recreationalists. Similarly, conditions related to the cultural environment downstream from Shasta Dam are unlikely to change significantly.

Socioeconomic Resources Environment

The State's population is estimated to increase from approximately 37 million in 2005 to about 44 million by 2020, and to approximately 60 million by 2050. Between now and 2050, Shasta and Tehama counties are expected to continue their historic growth trends. According to the California Department of Finance (2007, 2010), Shasta County's population is expected to increase by approximately 86 percent by 2050 to a total of approximately 332,000 residents (2005 population was 179,000). This represents an expected increase in population that is almost 20 percent greater than for the State as a whole. The population of Tehama County is expected to more than double by 2050, with population increasing from approximately 60,000 (in 2005) to 124,000 (California Department of Finance 2007, 2010).

To support these expected increases in population, some conversion of agricultural and other rural land to urban uses is anticipated. More transportation routes are likely to be constructed to connect the anticipated population increase in the Central Valley to transportation infrastructure. Anticipated increases in population growth will also impact visual resources as areas of open space on the valley floor are converted to urban uses.

Increases in population will increase demands for electric, natural gas, and wastewater utilities; public services such as fire, police protection, and emergency services; and water-related and communication infrastructure. The increase in population and aging "baby boomer" generation will increase the need for health services. The region's superior outdoor recreational opportunities and moderate housing cost opportunities are expected to attract increasing numbers of retirees from outside the region and State. An increasing population will produce employment gains, particularly in retail sales, personal services, finance, insurance, and real estate. Recreation is expected to remain an important element of the community and economy in the region.

Anticipated increases in population growth in the Central Valley will also significantly increase demands on water resources systems for additional and reliable Central Valley water supplies, energy supplies, water-related facilities, recreational facilities, and flood management facilities.

Planning Objectives

This section discusses the national planning objectives and objectives, constraints, and other considerations specific to the SLWRI.

National Planning Objectives

The Federal objective is defined in the P&G (WRC 1983) as follows:

> *The Federal objective of water and related resources project planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant*

to national environmental statutes, applicable executive orders, and other Federal planning requirements.

Contributions to national economic development (NED) are further defined as "increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are direct net benefits that accrue in the planning area and the rest of the Nation" (WRC 1983).

The National Water Resources Policy specified in the Water Resources Development Act of 2007 (Public Law 110-114, Section 2031), is that Federal water resources investments should reflect national priorities, encourage economic development, and protect the environment by doing the following:

- Seek to maximize sustainable economic development
- Seek to avoid the unwise use of floodplains and flood-prone areas and minimize adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used
- Protect and restore the functions of natural systems and mitigate any unavoidable damage to natural systems

In consideration of the many complex water management challenges and competing demands for limited Federal resources, Federal agencies investing in water resources should strive to maximize public benefits, particularly compared to costs. Public benefits encompass environmental, economic, and social goals, including monetary and nonmonetary benefits, and allow for the inclusion of quantified and unquantified benefits. Stakeholders and decision makers expect the formulation and evaluation of a diverse range of alternative solutions. Such solutions may produce varying degrees of benefits and/or impacts relative to the three goals specified above. As a result, trade-offs among potential solutions will need to be assessed and properly communicated during the decision making process.

SLWRI-Specific Planning Objectives

On the basis of the problems, needs, and opportunities identified and defined previously, study authorities and other pertinent direction, including information contained in the August 2000 CALFED ROD, primary and secondary planning objectives were developed. Primary planning objectives are those which specific alternatives are formulated to address. The primary objectives are considered to have equal priority, with each pursued to the maximum practicable extent without adversely affecting the other. Secondary planning objectives are considered to the extent possible through pursuit of the primary planning objectives.

- **Primary Planning Objective**s:
  - Increase the survival of anadromous fish populations in the Sacramento River, primarily upstream from RBPP.
  - Increase water supply and water supply reliability for agricultural, M&I, and environmental purposes to help meet current and future water demands, with a focus on enlarging Shasta Dam and Reservoir.
- **Secondary Planning Objectives**:
  - Conserve, restore, and enhance ecosystem resources in the Shasta Lake area and along the upper Sacramento River.
  - Reduce flood damage along the Sacramento River.
  - Develop additional hydropower generation capabilities at Shasta Dam.
  - Maintain and increase recreation opportunities at Shasta Lake.
  - Maintain or improve water quality conditions in the Sacramento River downstream from Shasta Dam and in the Delta.

Planning Constraints and Other Considerations

The P&G provide fundamental guidance for the formulation of Federal water resources projects. In addition, basic constraints and other considerations specific to this investigation must be developed and identified. Following is a summary of the constraints and considerations being used for the SLWRI.

Planning Constraints

Fundamental to the plan formulation process is identifying and developing basic constraints specific to this investigation. Some planning constraints are more rigid than others. Examples of more rigid constraints include congressional direction in study authorizations; other current applicable laws, regulations, and policies; and physical conditions (e.g., topography, hydrology). Other planning constraints are less restrictive but are still influential in guiding the process. Examples include water resource planning efforts such as the CALFED ROD. Several key constraints identified for the SLWRI are as follows:

- **Study Authorizations –** On August 30, 1935, in the Rivers and Harbors Bill, an initial amount of Federal funds was authorized for constructing Kennett (now Shasta) Dam. Initial authorization for the SLWRI derives from Public Law 96-375 of 1980. This law authorized the Secretary of the Interior to engage in feasibility studies relating to

(1) enlarging Shasta Dam and Reservoir, or constructing a replacement dam on the Sacramento River and (2) using the Sacramento River to convey water from an enlarged dam. Additional guidance is contained in Public Law 108-361 of 2004, which authorized the Secretary of the Interior to carry out "…planning and feasibility studies for projects to be pursued with project-specific study for enlargement of the Shasta Dam in Shasta County…" The CVPIA of 1992 (Public Law 102-575) is pertinent because of its influence on water supply deliveries, river flows, and related environmental conditions in the primary and extended study areas.

- **CALFED Record of Decision –** CALFED was established to "develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) system." The 2000 CALFED ROD (CALFED 2000) includes program goals, objectives, and projects primarily to benefit the Bay-Delta system. The objectives for the SLWRI are consistent with the CALFED ROD (CALFED 2000) for Shasta enlargement, as follows:

  > *Expand CVP storage in Shasta Lake by approximately 300 TAF. Such an expansion will increase the pool of cold water available to maintain lower Sacramento River temperatures needed by certain fish and provide other water management benefits, such as water supply reliability.*

  The ROD has been adopted by various Federal and State agencies as a framework for further consideration. In addition to objectives for potential enlargement of Shasta Dam and Reservoir, the Preferred Program Alternative in the CALFED ROD includes four other potential surface water and various groundwater storage projects to help reduce the gap between water supplies and projected demands. Expanding water storage capacity is critical to the successful implementation of all aspects of the program. Water supply reliability rests on capturing peak flows, especially during wet years. New storage must be strategically located to provide the needed flexibility in the current water system to improve water quality, support fish restoration goals, and meet the needs of a growing population. CALFED ROD also includes numerous other projects to help improve the ecosystem functions of the Bay-Delta system. Developed plans should address the goals, objectives, and programs and projects of the CALFED ROD (CALFED 2000).

- **Laws, Regulations, and Policies –** Numerous laws, regulations, executive orders, and policies need to be considered, among them: the P&G, NEPA, Fish and Wildlife Coordination Act, Clean Air Act, Clean Water Act, National Historic Preservation Act, California Public Resources Code, Federal and State ESA, California Environmental Quality Act, and CVPIA. Table 1-5 summarizes many of the applicable laws, policies, plans, and permits potentially affecting the project.

Table 1-5. Summary of Applicable Laws, Policies, Plans, and Permits Potentially Affecting Project

Level	Laws, Policies, Plans, and Permits
Federal	Federal Endangered Species Act
	Section 404 of the Clean Water Act
	Rivers and Harbors Act Section 10
	National Historic Preservation Act, Section 106 (1966)
	Migratory Bird Treaty Act
	Fish and Wildlife Coordination Act
	Executive Orders 11990 (Wetlands Policy), 11988 (Flood Hazard Policy), and 12898 (Environmental Justice Policy)
	Indian Trust Assets
	Americans with Disabilities Act
	Rehabilitation Act
	Farmland Protection Policy
	Federal Transit Administration Activities and Programs
	Essential Fish Habitat
	Architectural Barriers Act
	Federal Cave Resources Protection Act (1988)
	Executive Order 11312 (National Invasive Species Management Plan)
	Magnuson-Stevens Fishery Conservation and Management Act
	National Wild and Scenic Rivers System
	Federal Land Use Policies
	Federal Water Project Recreation Act
	Whiskeytown-Shasta-Trinity National Recreation Area Management Guide
	Whiskeytown-Shasta-Trinity National Recreation Act
	Shasta-Trinity National Forest Management Plan
	Federal Energy Regulatory Commission Permitting Requirements
	U.S. Army Corps of Engineers – Shasta Dam and Reservoir Regulation Requirements
	U.S. Coast Guard Activities and Programs
	Uniform Relocations Assistance and Real Properties Acquisition Act of 1970, as amended (Public Law 91-646 and Public Law 100-17)

Table 1-5. Summary of Applicable Laws, Policies, Plans, and Permits Potentially Affecting Project (contd.)

Level	Laws, Policies, Plans, and Permits
State	California Public Resources Code
	Clean Water Act Section 401
	California Endangered Species Act
	California Fish and Game Code – Fully Protected Species
	California Fish and Game Code Section 1600 – Streambed Alteration
	Porter-Cologne Water Quality Control Act
	California Native Plant Society Species Designations
	Reclamation Board Encroachment Permit
	California Water Rights
	State Lands Commission Land Use Lease
	State of California General Plan Guidelines
	California Department of Transportation Encroachment Permit and Activities, Programs
	California Land Conservation Act of 1965 (Williamson Act)
	California Native Plant Protection Act
	California Department of Boating Activities and Programs
	California Scenic Highway Program
	California Wild and Scenic Rivers Act
Local	Shasta County Air Quality Management District Authority to Construct and Permit to Operate
	Shasta County Building Division Grading Permit
	Shasta County Zone Plan
	Shasta County Department of Public Works Encroachment Permit
	Shasta County General Plan
	Other Local Permits and Requirements

Statewide Water Operation Considerations

Reclamation and DWR use CalSim-II, a specific application of the Water Resources Integrated Modeling System (WRIMS) to Central Valley water operations, to study operations, benefits, and effects of new facilities and operational parameters for the CVP and SWP. Operational assumptions for refinement, modeling, and evaluation of potential effects of the No-Action Alternative and action alternatives included in the DEIS were derived from the following:

- The Reclamation 2008 *Biological Assessment on the Continued Long-Term Operations of the CVP and SWP* (2008 OCAP BA)
- The USFWS 2008 *Formal ESA Consultation on the Proposed Coordinated Operations of the CVP and SWP* (2008 USFWS BO)
- The NMFS 2009 *BO and Conference Opinion on the Long-Term Operations of the CVP and SWP* (2009 NMFS BO)
- The Coordinated Operations Agreement between Reclamation and DWR for the CVP and SWP, as ratified by Congress

Ongoing reconsultation processes for the 2008 USFWS and 2009 NMFS BOs have resulted in some uncertainty in future CVP and SWP operational constraints. In response to lawsuits challenging the 2008 and 2009 BOs, the District Court for the Eastern District of California (District Court) remanded the BOs to USFWS and NMFS in 2010 and 2011, respectively, and subsequently ordered reconsultation and preparation of new BOs. These legal challenges may result in changes to CVP and SWP operational constraints if the revised USFWS and NMFS BOs contain new or amended reasonable and prudent alternatives (RPA).

Despite this uncertainty, the 2008 and 2009 BOs issued by the fishery agencies contain the most recent estimate of potential changes in water operations that could occur in the near future. Furthermore, it is anticipated that the final BOs issued by the resource agencies will contain similar RPAs. However, if ongoing reconsultation results in operational conditions that deviate substantially from the 2008 OCAP BA and the 2008 and 2009 BOs, these changes may be considered in future SLWRI documents.

Other Planning Considerations

In addition to the planning constraints, a series of other planning considerations helps guide plan formulation, not only in formulating the initial set of concept plans, but also in determining which alternatives best address the planning objectives. Planning considerations relate to economic justification, environmental compliance, technical standards, etc., and may result from local policies, practices, and conditions. Examples of these planning considerations, used in the SLWRI for formulating, evaluating, and comparing concept plans, and later, detailed comprehensive alternatives, include the following:

- Alternative plans should incorporate results of coordination with other Federal and State agencies such as the USFWS, NMFS, USFS, Bureau of Indian Affairs, U.S. Department of the Interior, Bureau of Land Management (BLM), DWR, and California Department of Fish and Wildlife (CDFW).
- A direct and significant geographical, operational, and/or physical dependency must exist between major components of alternatives.
- Alternative plans should address, at a minimum, each of the identified primary planning objectives and, to the extent possible, the secondary planning objectives.
- Measures to address secondary planning objectives should be either directly or indirectly related to the primary planning objectives (i.e., plan features should not be independent increments).
- Alternatives should strive to first avoid potential adverse effects to environmental resources, or then should include features to mitigate for

unavoidable adverse effects through enhanced designs, construction methods, and/or facilities operations.

- Alternatives should avoid any increases in flood damage or other significant, adverse hydraulic effects to areas downstream along the Sacramento River.

- Alternatives should strive to first avoid potential adverse effects to present or historical cultural resources, or then include features to mitigate unavoidable adverse effects.

- Alternatives should not result in significant adverse effects to existing and future water supplies, hydropower generation, or related water resources conditions.

- Alternatives should strive to balance increased water supply reliability between agricultural and M&I uses.

- Alternatives should not result in a reduction in existing recreation capacity at Shasta Lake.

- Alternatives are to consider the purposes, operations, and limitations of existing projects and programs and be formulated to not adversely impact those projects and programs.

- Alternatives are to be formulated and evaluated based on a 100-year period of analysis.

- Construction costs for alternatives are to reflect current prices and price levels, and annual costs are to include the current Federal discount rate and an allowance for interest during construction (IDC).

- Alternatives are to be formulated to neither preclude nor enhance development and implementation of other elements included in the CALFED ROD or other water resources programs and projects in the Central Valley.

- Alternatives should have a high certainty for achieving intended benefits and not significantly depend on long-term actions (past the initial construction period) for success. Alternatives that require future and ongoing action specific for success have a higher uncertainty than other plans.

Criteria

The Federal planning process in the P&G also includes four specific criteria for consideration in formulating and evaluating alternatives: completeness, effectiveness, efficiency, and acceptability (WRC 1983).

- Completeness is a determination of whether a plan includes all elements necessary to realize planned effects, and the degree that intended benefits of the plan depend on the actions of others.

- Effectiveness is the extent to which an alternative alleviates problems and achieves objectives.

- Efficiency is the measure of how efficiently an alternative alleviates identified problems while realizing specified objectives consistent with protecting the Nation's environment.

- Acceptability is the workability and viability of a plan with respect to its potential acceptance by other Federal agencies, State and local governments, and public interest groups and individuals.

These criteria were used for comparison and evaluation of concept plans (Chapter 4) during the Initial Alternatives Phase, and will be used for comparison and evaluation of comprehensive plans as the SLWRI progresses.

Chapter 2
Management Measures

After development of the planning objectives, constraints, and criteria, the next major step in formulating concept plans was to identify and evaluate potential management measures. A management measure is any structural or nonstructural project action or feature that could address the planning objectives and satisfies the other applicable planning considerations. Concept plans are formulated (see Chapter 4) by combining retained management measures that address the primary planning objectives.

More than 60 potential management measures were identified as part of the SLWRI plan formulation process to address the primary and secondary planning objectives and satisfy the other applicable planning constraints, considerations, and criteria. These measures were developed through study team meetings, field inspections, public outreach, and environmental scoping for the SLWRI and EIS. Management measures were reviewed by SLWRI study team and stakeholders for their ability to address the primary and secondary planning objectives. Following is a general description of the measures considered, reasons for retaining or deleting the measures from further development, and information on how retained measures could fit into potential concept plans.

In the discussion of SLWRI management measures, the term “enhancement” specifically refers to restoration actions that improve environmental conditions above the baseline (without-project condition). Correspondingly, the term “mitigation” refers to restoration actions that improve environmental conditions toward the baseline to compensate for project impacts. The relationship between enhancement and mitigation is illustrated in Figure 2-1.

Identified management measures were analyzed in the *Mission Statement Milestone Report* (Reclamation 2003a), and summarized herein, to determine whether they would be retained for further consideration. One important factor was the potential for a measure to directly address a planning objective without adversely impacting other objectives. Measures were rated on a scale of high to low based on their relative ability to address the planning objectives. In most cases, measures that were rated as moderately addressing a planning objective, or less than moderately, were deleted from further consideration, while measures rating higher were retained. This is primarily because measures that could only marginally address an objective were generally found inconsistent with study constraints or other principles and criteria. Other major factors and rationale in retaining or deleting a measure are included in the following descriptions of the individual management measures.

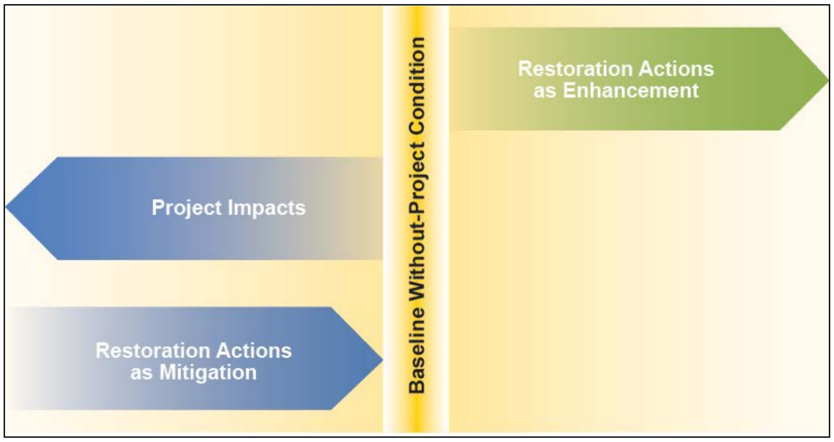


Figure 2-1. Conceptual Schematic of Restoration Actions as Enhancement Versus Restoration Actions as Mitigation

It should be noted that measures that did not directly address the planning objectives, or were otherwise dropped from consideration and further development as alternative plan components under certain circumstances, may be incorporated into alternative plans as mitigation measures. This is primarily because some measures may be found potentially effective in mitigating adverse impacts.

Measures to Address Primary Planning Objectives

Various management measures were identified to address the primary planning objectives of increasing anadromous fish survival and increasing water supply reliably. For each planning objective, measures were identified and separated into categories. In the following sections, rationale is discussed for retaining or deleting each measure.

Increase Anadromous Fish Survival

A number of potential management measures to address increasing anadromous fish restoration opportunities were identified. Most are listed in the November 2003 *Ecosystem Restoration Office Report* (Reclamation 2003b). Of more than 20 measures identified specifically to address the primary objective of increasing anadromous fish survival on the Sacramento River (see Table 2-1), six were retained for possible inclusion in concept plans during the initial plans phase.

Measures Considered

Following is a brief discussion of the array of measures considered, which are separated into three broad categories: (1) improve fish habitat, (2) improve water flows and quality, and (3) improve fish migration. This section summarizes rationale for deleting measures or retaining measures for further consideration, as presented in Table 2-1.

Table 2-1. Management Measures Addressing the Primary Planning Objective of Increasing Anadromous Fish Survival

Management Measure	Potential to Address Planning Objective	Status/Rationale
Improve Fish Habitat		
Restore abandoned gravel mines along the Sacramento River	**Moderate** – Addresses primary planning objective.	**Deleted –** Consistent with other anadromous fish programs and with secondary planning objectives and constraints. This measure was initially retained, then deleted from further consideration during the comprehensive plans phase due to subsequent modeling results indicating marginal benefits to anadromous fish and a general lack of interest from the public and stakeholders.
Construct instream aquatic habitat downstream from Keswick Dam	**Moderate –** Addresses primary planning objective.	**Retained –** This measure was retained for potential further development due to its potential to successfully address the first primary planning objective, potential to combine favorably with other potential measures, and a high interest from fisheries agencies
Replenish spawning gravel in the Sacramento River	**Moderate –** Addresses primary planning objective.	**Retained –** High potential for combining with other measures. Demonstrated benefits that continue as gravel moves downstream. Low initial cost. Concerns over induced downstream impacts to agricultural facilities. Consistent with Federal planning objectives and principles.
Construct instream fish habitat on tributaries to the Sacramento River	**Low to Moderate** – Indirectly benefits planning objective.	**Deleted –** Considerable benefit to tributaries. Independent of hydraulic/hydrologic conditions in upper Sacramento River and would not directly contribute to improved ecological conditions along mainstem Sacramento River.
Remove instream sediment along Middle Creek	**Low** – Indirectly benefits planning objective.	**Deleted –** Considerable benefit to spawning conditions in tributaries. Independent of hydraulic/hydrologic conditions in upper Sacramento River and would not directly contribute to improved ecological conditions along mainstem Sacramento River. High uncertainty due to increased need for long-term remediation.
Rehabilitate inactive instream gravel mines along Stillwater and Cottonwood creeks	**Low** – Indirectly benefits planning objective.	**Deleted –** Considerable benefit to spawning conditions in tributaries. Independent of hydraulic/hydrologic conditions in upper Sacramento River and would not directly contribute to improved ecological conditions along mainstem Sacramento River.
Improve Water Flows and Quality		
Make additional modifications to Shasta Dam for temperature control	**Moderate to High** – Potential to contribute to planning objective by improving temperatures for anadromous fish.	**Retained –** High likelihood of combining with measures involving increasing Shasta storage. Although existing TCD at Shasta effectively meets objectives, potential may exist to further modify the device to benefit anadromous fish with increased storage at Shasta.
Enlarge Shasta Lake cold-water pool	**Moderate to High** – Directly contributes to planning objective by improving water temperature conditions for anadromous fish.	**Retained –** High potential for combining with other measures. Consistent with other primary planning objective and secondary planning objectives. Consistent with goals of CALFED.
Modify storage and release operations at Shasta Dam	**Moderate to High** – Directly contributes to planning objective by improving flow conditions for anadromous fish.	**Retained –** This measure was retained because it is consistent with goals of CALFED and other programs/projects to benefit anadromous fish and has potential to combine with other measures, including raising Shasta Dam and Shasta Reservoir.
Modify Anderson-Cottonwood Irrigation District diversions to reduce flow fluctuations	**Moderate** – Reduced flow fluctuations would benefit anadromous fish, directly contributing to the planning objective.	**Deleted –** Conflicts with other primary planning objective of water supply reliability.
Increase instream flows on Clear, Cow, and Bear creeks	**Low** – Indirectly benefits planning objective on the Sacramento River.	**Deleted –** Independent of hydraulic/hydrologic conditions in upper Sacramento River.
Construct a storage facility on Cottonwood Creek to augment spring instream flows	**Very Low** – Indirectly benefits planning objective on the Sacramento River.	**Deleted –** Independent of hydraulic/hydrologic conditions in upper Sacramento River. Adverse environmental impacts expected to exceed benefits.

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Table 2-1. Management Measures Addressing the Primary Planning Objective of Increasing Anadromous Fish Survival (contd.)

Management Measure	Potential to Address Planning Objective	Status/Rationale
Improve Water Flows and Quality (contd.)		
Transfer existing Shasta Reservoir storage from water supply to cold-water releases	**Low** – Potential to benefit anadromous fish but at a considerable disbenefit to water supply reliability.	**Deleted** – Violates basic plan formulation criteria – causes considerable reduction in water supply reliability without development of a replacement supply.
Remove Shasta Dam and Reservoir	**Very Low** – Relatively low potential benefit to anadromous fish with major adverse impacts to all other planning objectives.	**Deleted** – Violates basic plan formulation criteria and no known project or projects could replace the lost benefits provided by Shasta and Keswick dams, reservoirs, and appurtenant facilities, at any price.
Improve Fish Migration		
Improve fish trap below Keswick Dam	**Low to Moderate –** Directly contributes to planning objective by reducing mortality and supplying more fish to hatcheries.	**Deleted –** Although helps fish populations, would not contribute to favorable conditions for sustained spawning and rearing of anadromous fish along mainstem Sacramento River.
Screen diversions on Old Cow and South Cow creeks	**Moderate –** Indirectly benefits planning objective on the Sacramento River.	**Deleted –** Considerable benefit to spawning conditions in tributaries. Independent of hydraulic/hydrologic conditions in upper Sacramento River and would not contribute to improved ecological conditions along mainstem Sacramento River.
Remove or screen diversions on Battle Creek	**Moderate –** Indirectly benefits planning objective on the Sacramento River.	**Deleted –** Considerable benefit to spawning conditions in tributaries. Independent of hydraulic/hydrologic conditions in upper Sacramento River and would not contribute to improved ecological conditions along mainstem Sacramento River.
Construct a migration corridor from the Sacramento River to the Pit River	**Low –** High uncertainty as to the potential to successfully benefit area resources.	**Deleted –** Extremely high cost. Multiple physical obstructions of effective fish passage even after implementation. Very low certainty of success.
Cease operating or remove the Red Bluff Diversion Dam	**Moderate –** Potential to improve fish migration along upper Sacramento River.	**Deleted –** As the result of another Federal investigation, the Red Bluff Diversion Dam Fish Passage Improvement Project, Reclamation has subsequently ceased operation of Red Bluff Diversion Dam.
Reoperate the CVP to improve overall fish management	**Low –** Limited potential to improve anadromous fish survival along the upper Sacramento River.	**Deleted –** See above measure regarding the Red Bluff Diversion Dam. Issues regarding reoperating facilities on the Trinity River were addressed in the Trinity River Record of Decision in 2000. Any further modification within that system would violate planning criteria for SLWRI.
Construct a fish ladder on Shasta Dam	**Very Low –** Very low potential for marginal benefit to anadromous fish on the upper Sacramento River.	**Deleted –** Extremely high cost, relatively small benefit on limited stream system, and very low potential for physically implementing a workable ladder.
Reintroduce anadromous fish to areas upstream from Shasta Dam	**Low –** Low potential for marginal benefit to anadromous fish on the upper Sacramento River.	**Deleted –** Fish passage above Shasta Dam is being studied under a separate Federal program as the result of the 2009 NMFS biological opinion.

Key:
CALFED = CALFED Bay-Delta Program
cfs = cubic feet per second
CVP = Central Valley Project
TCD = temperature control device

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Improve Fish Habitat The six measures described below were identified to improve fish habitat.

- **Restore abandoned gravel mines along the Sacramento River –** Instream gravel mining has resulted, in many instances, in the degradation of aquatic and floodplain habitat. This is primarily because these activities have often created large artificial pits at various locations in the primary study area 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 due to stranding and unnatural predation occurs in many abandoned pits that either lose their connections with the river during low-flow periods or otherwise discourage effective transmission of fish passage between the river and mine area. The river cannot refill and restore many of these pits naturally because of changes in flow regime and reductions in coarse sediment input. This measure consists of acquiring, restoring, and reclaiming several inactive gravel mining operations along the Sacramento River to create valuable aquatic and floodplain habitat. Gravel pit restoration would involve filling deep depressions and recontouring the stream channel and floodplain within the gravel mine area, if possible and practical, to mimic more natural conditions. Side channels and other features could be created to encourage spawning and rearing and prevent stranding. Soil may need to be imported to replenish areas where gravel mining has resulted in a considerable loss of fine sediments. Revegetation using native riparian plants would be performed on restored floodplain lands.

  This measure was retained for potential further development as part of the SLWRI because it may have potential to successfully address the first primary planning objective. Furthermore, it may combine favorably with other potential measures related to Shasta Dam and Lake and their operation. This measure would not be expected to conflict with other known programs or projects on the upper Sacramento River.

  Construct instream aquatic habitat downstream from Keswick Dam – Keswick Dam is the uppermost barrier to anadromous fish migration on the Sacramento River. Releases from the dam have scoured the channel, and the dam blocks 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 because of the lack of instream cover. Despite these unfavorable channel conditions, cold-water releases from Keswick Dam attract large numbers of spawners to this reach. This measure consists of constructing aquatic habitat in and adjacent to the Sacramento River downstream from Keswick Dam to encourage use of this reach by anadromous fish for reproduction. Habitat restoration would involve acquiring lands adjacent to the Sacramento River; earthwork along the riverbank to construct side channels for spawning; and strategic placement of instream cover structures within the river channel, including large boulders, anchored root wads, and other natural materials. Side channels and other features could also be created to encourage spawning and rearing. Restored floodplain lands could be revegetated with native riparian plants.

This measure was retained for potential further development as part of the SLWRI, because it may have potential to successfully address the first primary planning objective and due to high interest from fisheries agencies. Furthermore, this measure will likely combine favorably with other potential measures related to Shasta Dam and Reservoir and their operation. This measure would not be expected to conflict with other known programs or projects on the upper Sacramento River.

- **Replenish spawning gravel in the Sacramento River –** Historically, tributary watersheds upstream from Keswick and Shasta Dams provided a continuous source of high-quality gravel and other coarse sediments to the Sacramento River. Dams, river diversions, gravel mining, and other obstructions have blocked or reduced natural gravel sources. Gravel suitable for spawning has been identified as a considerable influencing factor in the recovery of anadromous fish populations in the Sacramento River. Several programs, including CALFED and the Anadromous Fish Restoration Program, have provided gravel replenishment in selected locations. With the exception of the CVPIA(b)(13) program, these programs represent single applications at discrete locations. Similarly, this measure consists of a single application of spawning-sized gravel at a discrete location in the Sacramento River between Keswick and RBPP. Gravel would be transported and placed into the Sacramento River downstream from Keswick Dam. This measure was retained for potential further development as part of the SLWRI because it may have potential to successfully address the first primary planning objective. Furthermore, it may combine favorably with other potential measures related to Shasta Dam and Reservoir and their operation.

- **Construct instream fish habitat on tributaries to the Sacramento River –** This measure consists of improving instream aquatic habitat along the lower reaches of tributaries to the Sacramento River. Various structural techniques would be employed 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 would be potential candidates for structural habitat improvements. Candidates for aquatic habitat improvement include Middle, Olney, Churn, and Cow creeks. However, this measure would not directly contribute to improved ecological conditions or fish habitat along the mainstem Sacramento River. Although this measure would have considerable benefits for tributaries, it was deleted from further development as part of the SLWRI primarily because it is a separate and independent action. It would not directly contribute to increasing anadromous fish survival within the primary Sacramento River study area.

- **Remove instream sediment along Middle Creek –** This measure consists of implementing 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 eroding from streambanks and adjacent land. Sediment from the creek also negatively impacts spawning habitat in the Sacramento River around the Middle Creek confluence. This measure was deleted from further development primarily because it is a separate and independent action. It would not considerably contribute to increasing anadromous fish survival within the primary Sacramento River study area.

- **Rehabilitate inactive instream gravel mines along Stillwater and Cottonwood creeks –** This measure consists of rehabilitating ecological conditions in former instream gravel mining sites along Stillwater Creek. Seven inactive gravel pits on Stillwater and/or Cottonwood creeks historically contributed to depletion of nearly all instream gravel resources along various reaches, leaving the channel scoured to bedrock. Restoring these gravel mines could help Stillwater Creek provide additional seasonal habitat for various anadromous and resident fish. This measure was deleted from further development primarily because it is a separate and independent action. It would not contribute directly to increasing anadromous fish survival within the primary Sacramento River study area.

Improve Water Flows and Quality The following section describes the measures considered for improving water flows and quality.

- **Make additional modifications to Shasta Dam for temperature control –** The TCD installed at Shasta Dam allows operators to make selective releases from various reservoir depths to regulate water temperatures to benefit anadromous fish in the upper Sacramento River. This measure consists of determining if making additional structural modifications to the outlets and existing TCD for temperature control is possible and feasible and, if so, implementing those modifications.

This measure was retained for further development primarily because it could (1) improve the performance of the existing facility, (2) complement other measures under consideration to raise Shasta Dam, and (3) complement measures to improve aquatic spawning habitat in the Sacramento River. This measure would not conflict with other ecosystem restoration measures preliminarily retained herein, or other known programs or projects on the upper Sacramento River.

- **Enlarge Shasta Lake cold-water pool –** Cold water released from Shasta Dam considerably influences water temperature conditions on the Sacramento River between Keswick Dam and the RBPP. This measure consists of enlarging the cold-water pool by either raising Shasta Dam and enlarging the minimum operating pool, or increasing the seasonal carryover storage in Shasta Lake. Each action would help provide greater flexibility in meeting water temperature targets throughout the year and extending suitable spawning habitat downstream. This measure also would be consistent with the goals of CALFED.

  This measure was retained for further development primarily because it would (1) directly contribute to both primary planning objectives for the SLWRI, (2) combine favorably with other measures, and (3) have a high certainty of providing the intended benefits once implemented. This measure would not conflict with any other ecosystem restoration measures that were preliminarily retained, nor would it conflict with other known programs or projects on the upper Sacramento River.

- **Modify storage and release operations at Shasta Dam –** In addition to water temperature, flow conditions in the upper Sacramento River are also important in addressing anadromous fish needs. This measure consists of enlarging Shasta Dam and modifying seasonal storage and releases to benefit anadromous fisheries. Although this measure could help provide greater flexibility in meeting water temperature targets, it would be aimed primarily at improving flows and influencing physical channel conditions for anadromous fish. Changes would be made to the timing and magnitude of releases performed to maintain target flows in spawning areas and to improve the quality of aquatic habitat. The quality of aquatic habitat could be further improved by cleaning spawning gravels. These changes would be at the discretion of Reclamation based on recommendations by the Sacramento River Temperature Task Group (SRTTG). This measure would contribute to the goals of the Anadromous Fish Restoration Program included as part of the CVPIA. This measure also could include release changes during the flood season to permit “pulse flows” and other releases that could improve aquatic habitat conditions. Further, this measure could provide additional control and dilution of acid mine drainage from Spring Creek.

This measure was initially deleted from consideration because analyses indicated a decreased fisheries benefit with increasing Sacramento River flows compared to increasing the cold-water pool. However, this measure was retained for further development when combined with additional storage space in Shasta Reservoir, as part of an adaptive management plan, primarily because it could directly contribute to both primary objectives of the SLWRI and combine favorably with other measures.

- **Modify Anderson-Cottonwood Irrigation District diversions to reduce flow fluctuations –** This measure consists of modifying operations at the Anderson-Cottonwood Irrigation District diversion dam near Anderson to reduce extreme flow fluctuations and their resulting impacts on anadromous fish. Extreme fluctuations in Sacramento River flows result in fish stranding and juvenile fish mortality. This measure was deleted from further development, however, primarily because of potential impacts to water supply reliability. Negative impacts on water deliveries from the Anderson-Cottonwood Irrigation District diversion dam would conflict with the second primary planning objective of increasing water supply reliability.

- **Increase instream flows on Clear, Cow, and Bear creeks –** This measure consists of increasing instream flows on Clear, Cow, and Bear Creeks during critical periods to support anadromous fish that spawn in the creek. Increasing flows would improve the quality of spawning habitat and help reduce water temperatures, thereby increasing the amount of suitable tributary spawning habitat available in the creeks. This measure was deleted from further development primarily because it would not contribute directly to increasing anadromous fish survival within the primary Sacramento River study area. In addition, this measure could impact hydropower production.

- **Construct a storage facility on Cottonwood Creek to augment spring instream flows –** This measure consists of constructing a dry dam or offstream storage facility on upper Cottonwood Creek to support flows for spring-run Chinook salmon. A storage facility would allow late-spring and summer releases for spring-run Chinook salmon, and improve overall seasonal aquatic conditions. This measure was deleted from further development primarily because it is an independent action. It would not considerably or directly contribute to increasing anadromous fish survival within the primary Sacramento River study area. In addition, it is highly likely that this measure would have considerable and overriding adverse environmental impacts in the Cottonwood Creek watershed.

- **Transfer existing Shasta Reservoir storage from water supply to cold-water releases –** This measure consists of reoperating the existing Shasta Dam and Reservoir for anadromous fishery resources. This measure was requested as part of the environmental scoping process. For this measure, it was assumed that storage space in Shasta could be reoperated to provide flows similar to those identified in the January 2001 *Final Restoration Plan* for the Anadromous Fish Restoration Program. This would require an optimal minimum flow along the upper Sacramento River of about 5,500 cubic feet per second (cfs) during certain periods of time. Operational considerations of the increased flows would be given to managing the existing cold-water pool in Shasta Reservoir. A cursory estimate was made of the potential water supply yield reduction through increasing the minimum flows from the existing 3,250 cfs to 5,500 cfs. It showed that the loss in drought period yield would amount to about 50,000 acre-feet per year. Additional fishery modeling studies and water supply related analysis would be necessary to both confirm the magnitude of yield loss and potential benefit to the anadromous fishery. A potential least-cost replacement water source for the yield reduction would likely be in excess of $250 million. This measure was deleted from further consideration primarily because it violates at least one of the planning criteria concerning the potential to adversely impact existing project purposes. In addition, it is believed that existing CVP water contractors would not be willing to pay for the water loss, and no other entities willing to pay have been identified.

- **Remove Shasta Dam and Reservoir –** This measure consists of removing the existing Shasta Dam and Reservoir to benefit anadromous fishery resources. This measure was requested as part of the environmental scoping process. It is believed that this measure would also include removing Keswick Dam and Reservoir to allow anadromous fish to access upstream river areas. Removing Keswick and Shasta Dams and Reservoirs would allow anadromous fish access to spawning areas that are now within the lake areas and passage to the headwaters of the upper Sacramento River, several smaller streams, and about 24 miles of river area along the lower McCloud River. A number of additional dams and reservoirs on the Pit and upper McCloud rivers would block access along those water courses.

  The Shasta Division of the CVP provides supplemental irrigation service to nearly 1 half-million acres of land in the Central Valley of California. It also provides water for M&I purposes and power generation amounting to about 680,000 kilowatts. In addition, Shasta Dam helps reduce flooding over a large area along the Sacramento River. Estimates of flood damages prevented by Shasta Dam and Reservoir during the major storms of 1995 and 1997 were about $3.5 billion and 4.3 billion, respectively. Much of the economy of the

Central Valley, and the entire State, has greatly benefited from Shasta Dam and Reservoir. It is believed that the cost of Shasta Dam and Reservoir and its associated facilities have been paid multiple times over since they were constructed in the early 1940s. Although the potential benefit to anadromous fish resources along the upper Sacramento River may be sizeable (substantial studies would be required to define potential benefits and disadvantages to the fisheries), these benefits by no means begin to approach the monetary benefit associated with the existing project. No known project or projects could replace the benefits provided by Shasta and Keswick dams, reservoirs, and appurtenant facilities at any price. This measure was deleted from further consideration primarily because it violates at least one of the planning criteria concerning the potential to adversely impact existing project purposes.

Improve Fish Migration The measures identified to improve migration are described in the subsequent section.

- **Improve fish trap below Keswick Dam –** Keswick Dam is an upstream barrier to fish migration on the Sacramento River. As part of mitigation actions associated with the construction of Shasta and Keswick dams, a fish trap facility was constructed at Keswick Dam to capture anadromous fish for transport to the Coleman National Fish Hatchery on Battle Creek. This measure consists of improving the efficiency and performance of the fish trap below Keswick Dam to increase survival of anadromous fish captured at the facility, thereby providing additional adults and increased egg production for fish hatchery operations. Although this measure has potential to contribute to the primary planning objective of increasing anadromous fish populations in the upper Sacramento River, it would not necessarily contribute to increasing survival of anadromous fish in the upper Sacramento River. This measure was deleted from further development primarily because it would not improve spawning and rearing conditions necessary for natural and sustainable reproduction of anadromous fish in the upper Sacramento River.

- **Screen diversions on Old Cow and South Cow creeks –** This measure consists of screening diversion intakes in the Cow Creek watershed to reduce fish mortality. Over 100 agricultural diversions exist from the Cow Creek watershed; while many are small, larger diversions can entrain juvenile salmonids and other fish that use spawning habitat provided by the watershed. This measure would potentially reduce salmonid mortality at diversions within the Cow Creek watershed. This measure would not contribute directly to improved fish migration in the upper Sacramento River. Some of the largest diversions identified as part of this measure, such as Kilarch Powerhouse Ditch, South Cow Creek Powerhouse Ditch, and Bassett

Ditch, are between 10 and 25 miles upstream from the confluence with the Sacramento River. In addition, several programs, including the CVPIA (b)(21) are already proceeding with installation of fish screens within the Sacramento River system. This measure was deleted from further development primarily because it is an independent action and would not directly contribute to anadromous fish survival within the primary Sacramento River study area.

- **Remove or screen diversions on Battle Creek –** This measure consists of removing or screening 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 either have been, or are being implemented, on Battle Creek to improve access to habitat and spawning success, including the Battle Creek Salmon and Steelhead Restoration project and the Orwick Diversion Fish Screen Improvement Project. However, additional large portions of the upper Battle Creek watershed remain inaccessible to anadromous fish because of diversions. This measure would provide access to high-quality spawning habitat in the upper Battle Creek watershed. However, several programs, including the CVPIA (b)(21) are already proceeding with installing fish screens within the Sacramento River system. Furthermore, this measure would not contribute directly to improved fish migration in the upper Sacramento River. This measure was deleted from further development primarily because it is an independent action and would not contribute directly to increasing anadromous fish survival within the primary Sacramento River study area.

- **Construct a migration corridor from the Sacramento River to the Pit River –** This measure consists of providing passage to spawning areas upstream from Shasta Dam for anadromous fish from the Sacramento River. One concept includes connecting the upper Pit River to the Sacramento River, which would consist of (1) constructing a fish channel between the Cow Creek basin and the Pit River Arm of Shasta Lake, (2) constructing a fish barrier to prevent fish from entering Shasta Lake, and (3) installing fish screens and flow control structures at various locations along the natural and man-made migration route to prevent straying. This and similar measures were deleted from further consideration primarily because of the (1) high cost for complex infrastructure, (2) major impacts to other facilities and extensive long-term operation and maintenance requirements, and (3) high uncertainty for the potential to achieve and maintain successful fish passage and spawning.

- **Cease operating or remove the Red Bluff Diversion Dam –** This measure involved either ceasing the operation of Red Bluff Diversion Dam or removing the facility completely. This measure was requested as part of the environmental scoping process. The two primary fish passage issues associated with the Red Bluff Diversion Dam were (1) delay and blockage of adults migrating upstream, and (2) the impedance and losses of juveniles emigrating downstream. Fish ladders located on each abutment of the dam were ineffective, limiting access to remaining spawning habitat between Keswick Dam and Red Bluff. Predation was also problematic in Lake Red Bluff. Potential solutions to these problems were considered as part of the Red Bluff Diversion Dam Fish Passage Improvement Project, a cooperative effort led by Reclamation and the Tehama-Colusa Canal Authority. The project developed a long-term solution to relieve conflicts between fish passage and agricultural diversion needs. A number of alternatives were considered, including removing the barrier to fish by removing the gates completely and constructing pumps to divert water into the Tehama-Colusa Canal, improvements to the existing fish ladders, and construction of a bypass channel. This measure was deleted from further consideration in the SLWRI because, as the result of the Red Bluff Diversion Dam Fish Passage Improvement Project, Reclamation has subsequently ceased operation of Red Bluff Diversion Dam.

- **Reoperate the CVP to improve overall fish management –** This measure primarily includes reoperating all of the CVP facilities in the upper Sacramento River system to improve anadromous fish resources. This measure was requested as part of the environmental scoping process. Major CVP facilities in the Sacramento River watershed that could influence the primary planning objective besides Shasta Dam and Reservoir includes Keswick Dam and Reservoir and features of the Trinity and Sacramento River Divisions. Major facilities in the Trinity River Division include Trinity Dam and Trinity Lake on the Trinity River, Lewiston Dam and Lake on the Trinity River, and Whiskeytown Dam and Lake on Clear Creek. Major facilities in the Sacramento River Division include the RBPP and various facilities within the Corning and Tehama-Colusa Canal service areas.

  Efforts by the U.S. Department of the Interior in the Trinity River ROD (Reclamation 2000) primarily resulted in reoperating facilities within the Trinity River Division to improve fishery conditions on the Trinity River. Any further reoperation of the facilities within the Trinity River Division not adversely impacting other project purposes would likely not be allowed under the existing decision because reoperations likely could be accomplished only at the expense of fish on the Trinity River. In addition, as a result of the Red Bluff Fish Passage Improvement Project, Reclamation ceased operating Red Bluff Diversion Dam to improve fish passage conditions in the Sacramento River. Construction of a screened pumping plant, the RBPP, was completed in 2012 to provide for continued water deliveries within the Corning and Tehama-Colusa Canal CVP service areas.

This measure was deleted from further consideration in the SLWRI primarily because no opportunity appears to exist to effectively further reoperate the CVP facilities capable of affecting the Sacramento River that would not result in adversely impacting other project purposes.

- **Construct a fish ladder on Shasta Dam** – This measure primarily includes constructing a fish ladder on Shasta Dam to allow anadromous fish to access Shasta Lake and approximately 40 miles of the upper Sacramento River, about 24 miles of the lower McCloud River, and various small creeks and streams tributary to Shasta Reservoir. This measure was requested as part of the environmental scoping process. A fish ladder at Shasta Dam would need to be approximately 476 feet high. A number of high-head dams have been studied for fish ladders, many of which would have allowed fish passage to much more historical spawning areas than would be available upstream from Shasta Lake. All of these high-head dam fish ladders have been rejected mainly for cost reasons (fish trapping and hauling is much cheaper under these circumstances). In addition, a high ladder concept was attempted at the Pelton project on the Deschutes River in Oregon. At this location, the fish were not able to travel the entire distance safely because of the extreme length of the ladder, and the water temperature increased considerably at higher elevations. This measure was deleted from further consideration in the SLWRI primarily because of the estimated high cost to construct and operate the fish ladder, the low likelihood for success in getting the fish to successfully ascend the ladder, and the likely major impacts to existing warm- and cold-water species in the upper river reaches.

- **Reintroduce anadromous fish to areas upstream from Shasta Dam** – This measure primarily includes trapping anadromous fish along the Sacramento River likely just downstream from Keswick Dam, transporting the fish by tanker truck, and releasing the fish in the upper Sacramento River or the McCloud River to spawn. It would also include some method of trapping potential out-migrating fish and transporting them to the Sacramento River near Keswick for release into the lower river. This measure was requested as part of the environmental scoping process. Numerous dams would preclude this measure on the upper Pit River. This measure was deleted from further consideration in the SLWRI primarily because fish passage above Shasta Dam to the upper Sacramento and McCloud rivers is being studied under a separate Federal program as the result of the 2009 NMFS BO.

Measures Retained for Further Consideration

Each of the six management measures retained to address the primary planning objective of increasing anadromous fish survival was considered in greater detail to determine how they might become components of potential concept plans. Of the six measures initially retained, five were chosen for further development and inclusion in comprehensive plans. Measures are shown in Figure 2-2, and their major components, accomplishments are described below.

- **Restore abandoned gravel mines along the Sacramento River –** Protecting and restoring spawning and rearing habitat have been identified by National Oceanic and Atmospheric Administration Fisheries as a primary goal in the recovery of Sacramento River winter-run Chinook salmon. It is estimated that over 80 percent of the winter Chinook spawning population migrates to the upper Sacramento River when passage at the Red Bluff Diversion Dam is unobstructed. Therefore, restoring suitable spawning habitat in the upstream reach of the river has potential to benefit a large portion of the salmonid population.

  One method of increasing anadromous fish survival is rehabilitating lands formerly mined for gravel along the Sacramento River. Instream gravel mining degrades aquatic and floodplain habitat by (1) creating large artificial pits along the river that disrupt natural geomorphic processes and riparian regeneration, (2) stranding fish and encouraging predation, and (3) removing valuable gravel sources. Aquatic conditions at former gravel mining sites are typically unsuitable for spawning and rearing. High fish mortality occurs at many abandoned pits that effectively lose their connection with the river during low flow periods, stranding fish and encouraging unnatural predation rates. Because of changes in flow regime and reductions in coarse sediment input, the river is not capable of refilling and restoring many of these pits naturally. In addition, removing fine sediments during the gravel extraction process inhibits establishment of riparian vegetation that provides protective cover and shade for spawning and rearing.

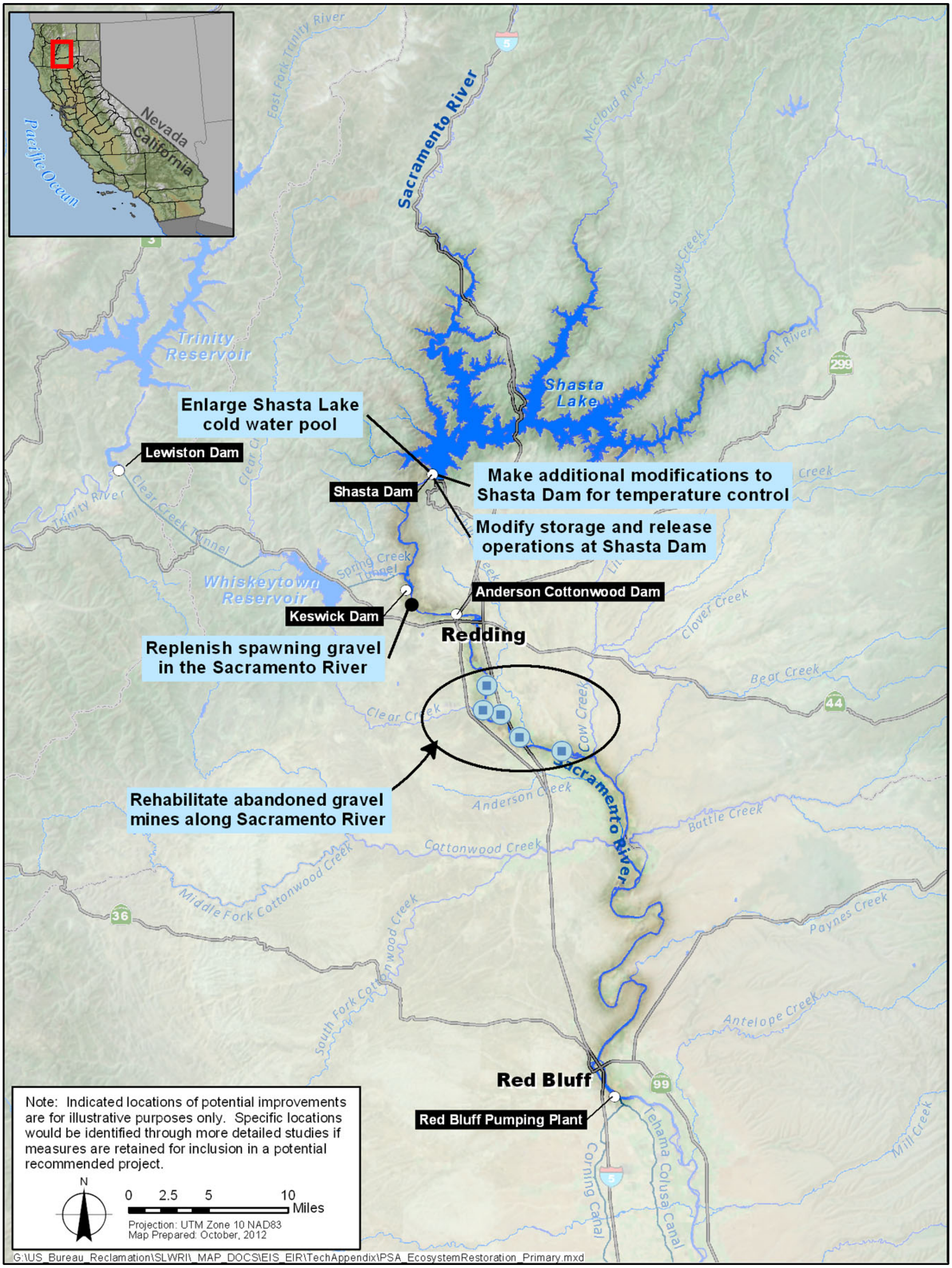

Figure 2-2. Measures Retained to Address Primary Planning Objective – Anadromous Fish Survival

Actions associated with this measure would help restore the natural complexity required for a healthy, self-sustaining river ecosystem. Actions would include filling deep pits (potentially requiring suitable fill material to be imported from local sources), recontouring the stream channel and floodplain to mimic natural conditions, and reconnecting the reclaimed area to the Sacramento River. Side channels and other features could be created to encourage spawning and rearing, and restored floodplain lands could be revegetated using native plants. Soil might need to be imported to replenish areas where gravel mining has resulted in a considerable loss of fine sediments. Hydrologic, hydraulic, and sedimentation studies would identify optimal restoration conditions and any actions necessary to offset or minimize undesirable hydraulic conditions caused by restoration.

This measure consists of acquiring, restoring, and reclaiming one or more inactive gravel mining operations along the Sacramento River to create valuable aquatic and floodplain habitat. Several potential sites for gravel mine restoration along the Sacramento River between Keswick and the RBPP listed in Table 2-2. Figure 2-3 shows an example area for implementing this measure. Most of these sites consist of one or more deep pits surrounded by partially disturbed land, with the majority of sites consisting of disturbed lands that would require minimal restoration actions. For this assessment, however, a potential restoration area of 150 acres was considered. The exact size and location(s) would be determined in further studies.

Table 2-2. Potential Gravel Mine Restoration Sites Along the Sacramento River

Location	Approximate River Mile	Bank	Area acres
Red Bluff near Salt Slough	247	Left	140
Upstream from 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

Source: M. Kondolf, 1989

Figure 2-3. Example of Abandoned Gravel Mine with Isolated Pits (left side of photo)

Primary accomplishments of gravel mine site restoration along the upper Sacramento River would be to (1) improve spawning success by increasing the amount of suitable spawning habitat along the Sacramento River for anadromous fish and (2) improve the health and vitality of self-sustaining riverside riparian ecosystems by restoring their connection with natural geomorphologic processes.

This measure would support the primary planning objective of increasing the survival of anadromous fish populations in the Sacramento River by eliminating stranding and restoring spawning and rearing habitat at one or more abandoned gravel pits. The measure also would support the secondary planning objective of conserving and restoring ecosystem resources along the upper Sacramento River through restoring riparian and floodplain habitat.

Although this measure was initially retained and considerably developed for inclusion in concept plans, as discussed above, it was later deleted from further development during the comprehensive plans phase. Subsequent evaluations related to the use of the SALMOD model have indicated that restoring these areas may not result in a significant benefit to anadromous fish. Concerns were also expressed that ranged from a low likelihood that these areas could be effectively used to increase spawning and rearing habitats to the likelihood for increased predation. Further, during public and stakeholder outreach meetings in late 2005 held primarily for environmental scoping purposes, there was little to no interest expressed for acquisitioning and restoring these areas. At this time, restoration of abandoned gravel mines is not included in further plan formulation activities for the SLWRI.

- **Construct instream aquatic habitat downstream from Keswick Dam –** This measure consists of constructing aquatic habitat in and adjacent to the Sacramento River downstream from Keswick Dam to encourage use of this reach by anadromous fish for spawning and rearing. Habitat enhancements in this measure included floodplain, riparian, and side channel habitats.

Side channels can support important habitat for anadromous salmonids, including rearing and spawning habitat. Side channel habitats provide refuge from predators and productive foraging habitat for juvenile anadromous salmonids. Salmonids also seem to prefer the hydraulic and channel bed conditions provided in side channels for spawning.

Riparian vegetation, including shaded riverine aquatic cover, provides juvenile salmonids cover from predators, habitat complexity, a source of insect prey, and shade for maintaining water temperatures within suitable ranges for all life stages. Juvenile salmonids prefer riverine habitat with abundant instream and overhead cover (e.g., undercut banks, submerged and emergent vegetation, logs, roots, other woody debris, and dense overhead vegetation) to provide refuge from predators, and a sustained, abundant supply of invertebrate and larval fish prey.

There is an opportunity to perform riparian and floodplain habitat restoration along the Sacramento River downstream from Keswick Dam 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. Restoration would include replacing lost floodplain sediment, regrading or recontouring floodplains that have been disconnected from the river, removing berms or levees (as appropriate), and revegetating floodplain and adjacent riparian areas. Locations for restoration would be in areas with a 20 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.

This measure would support the secondary objective to conserve and restore ecosystem resources along the upper Sacramento River by restoring native riparian habitat, side channels, 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 in the Sacramento River.

- **Replenish spawning gravel in the Sacramento River** – The restoration of aquatic habitat between Keswick Dam and the RBPP is of high priority because this stretch is one of the few remaining spawning corridors available to anadromous fish along the Sacramento River. This measure would support the primary objective of increasing the survival of anadromous fish populations in the Sacramento River by contributing to replenishing spawning gravels used by anadromous fish.

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. 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, have provided gravel replenishment on the Sacramento River in selected locations.

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. These gravel sources could be artificially augmented by gravel injections.

This measure would involve transporting and placing gravel into the Sacramento River downstream from Keswick Dam. Actions would include placing suitable gravels into the Sacramento River immediately below Keswick Dam. Structural treatments may be required below Keswick Dam to prevent the gravel from being washed downstream. Temporary construction easements could be required. 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 gravel placement. 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 one site.

Replenishing 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 placement would be concentrated in this uppermost reach, between Anderson and Keswick Dam. Gravel is typically moved downstream from the site of placement by high flows that occur, on average, about every 5 years. However, added spawning gravels continue to benefit the stream environment as they move through a river system, although the benefits tend to be less distinct farther downstream.

This measure would support the primary planning objective of increasing 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.

- **Make additional modifications to Shasta Dam for temperature control –** Adverse water temperature conditions in the upper Sacramento River have been identified as a critical factor leading to decline of anadromous fish species. As demand for CVP water has increased over time, the ability to maintain suitable water temperatures downstream from Keswick Dam for salmonids has become increasingly difficult. The NMFS 1993 BO for CVP and SWP operations (NMFS 1993) established water temperature criteria for the Sacramento River between Keswick Dam and Bend Bridge, or points upstream from Bend Bridge depending on climatic and water storage conditions. These water temperature requirements were reinforced by the subsequent 2004 and 2009 NMFS BOs for CVP and SWP operations. The existing TCD at Shasta Dam, shown in Figures 2-4 and 2-5, was constructed from 1996 to 1998 to help meet requirements of the 1993 BO.

Figure 2-4. TCD Located on Upstream Face of Shasta Dam

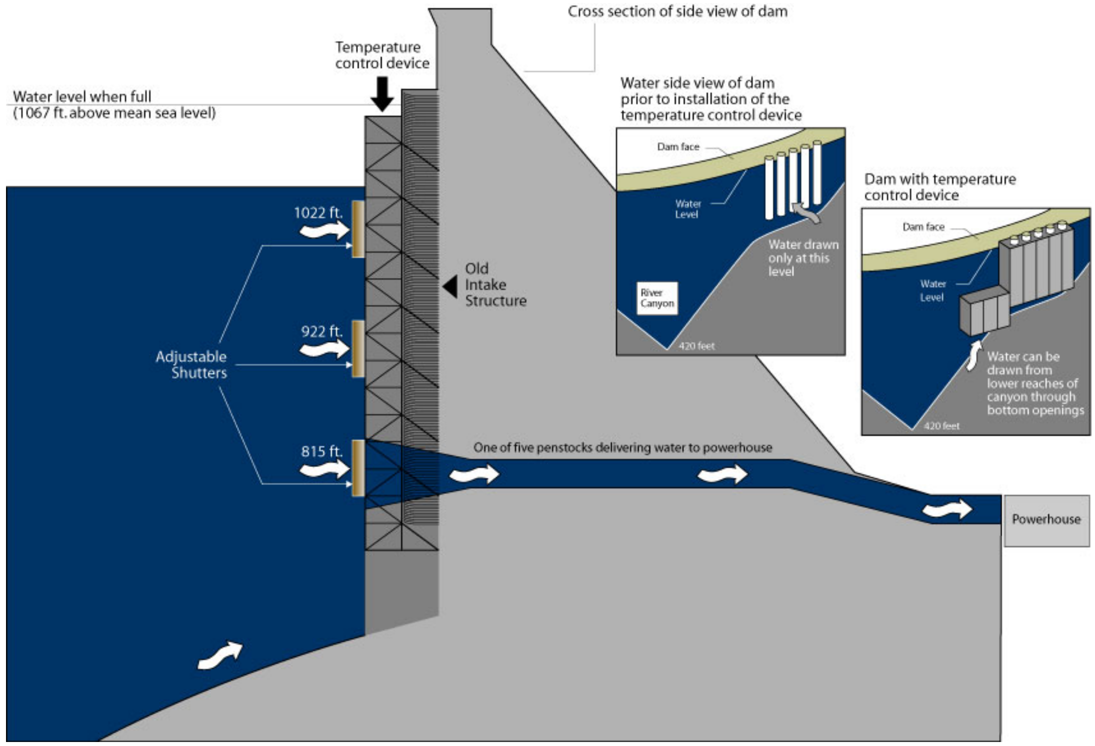

Figure 2-5. Shasta Dam Temperature Control Device

This measure consists of first assessing if modifications to the TCD are possible and feasible and, if so, implementing those modifications. This measure could be highly effective when combined with measures to increase storage space in Shasta Reservoir. For relatively small raises of Shasta Dam, the existing TCD structure would be retrofitted to account for additional dam height and to reduce leakage of warm water into the structure, but no new structure would be needed. However, modifications to the existing structure are more likely to become necessary for increasingly higher dam raises. For dam raises higher than about 50 feet, it is believed that major modifications to the TCD would be needed to manage the increasing depth and volume of water. Accordingly, modifications under this measure for higher dam raises would include widening the existing structure to increase intake capacity, and extending the device to a greater depth. In addition, this measure would provide for added structural modifications to the outlets at Shasta Dam for the purpose of temperature control.

Accomplishments of this measure would be to increase survival of anadromous fish populations in the Sacramento River by (1) increasing the ability of operators at Shasta Dam to meet downstream temperature requirements for anadromous fish, (2) providing more flexibility in achieving desirable water temperatures during critical spawning, rearing, and out-migration, and (3) extending the area of suitable spawning habitat farther downstream in the Sacramento River.

This measure would support the primary planning objective of increasing survival of anadromous fish populations in the Sacramento River. Also, it 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. This measure would combine well with measures to improve aquatic spawning habitat in the Sacramento River because better water temperature regulation could allow anadromous fish to take greater advantage of these habitat improvements. This measure would not conflict with other environmental restoration measures or other known programs or projects on the upper Sacramento River.

- **Enlarge Shasta Lake cold-water pool –** Cold water released from Shasta Dam considerably influences water temperature conditions on the Sacramento River between Keswick Dam and the RBPP. This measure includes increasing the volume of the cold-water pool in Shasta Lake by raising Shasta Dam and enlarging Shasta Lake primarily to help maintain colder releases for anadromous fish during certain periods. Increased storage volume could also help increase seasonal flows during dry and critical years in the upper Sacramento River that are important to fish populations.

  Possible operational changes to the timing and magnitude of releases from Shasta Dam, primarily to improve the quality of aquatic habitat, could be applied under an adaptive management plan. Changes in operating the cold-water pool could include increasing minimum flows, timing releases out of Shasta Dam to mimic more natural seasonal flows, meeting flow targets for side channels, or retaining the additional water in storage to meet temperature requirements. Reclamation would manage the cold-water pool each year based on recommendations from the SRTTG.

  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, as suggested in the CALFED ROD, would increase storage by about 256,000 acre-feet. A dam raise of about 200 feet would increase storage by about 9.3 MAF. The increased cold-water pool could be used to meet existing or proposed temperature targets or provide additional cold-water discharges during the summer, which could considerably extend the downstream reach of suitable spawning habitat. Increased volume could also help meet minimum flows in late fall in the upper Sacramento River.

  Raising Shasta Dam and enlarging Shasta Lake would result in impacts to natural resources and infrastructure around the reservoir rim, potentially requiring considerable mitigation and relocations. Impacts associated with dam raises of less than about 18 feet would be significant but likely manageable. Higher dam raises would result in major impacts to reservoir area resources and infrastructure, reducing the likelihood of economic justification. In addition to extreme impacts in the Shasta Lake area, very high dam raises (100 to 200 feet) might also result in major impacts to natural resources along the Sacramento River downstream from the dam. These impacts would likely eliminate serious consideration of high dam raises.

This measure would support the primary planning objective of increasing survival of anadromous fish populations by (1) improving water temperature control, (2) extending suitable spawning habitat, and (3) improving overall physical aquatic habitat conditions in the Sacramento River. It also would support the primary planning objective of increasing water supply reliability. The estimated certainty of this measure in achieving its intended accomplishments would be high.

This measure would complement the other primary and secondary planning objectives. Also, it would combine favorably with measures aimed at changing the timing and magnitude of releases from the increased pool, which would improve the quality of spawning and rearing habitat, increase attraction flows that cue in-migration, and improve water temperatures that cue out-migration. 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.

- **Modify storage and release operations at Shasta Dam –** In addition to water temperature, flow conditions in the upper Sacramento River are important in addressing anadromous fish needs. Timing and magnitude of river flows are important to successful spawning and rearing of anadromous fish populations. This measure consists of enlarging Shasta Dam and modifying seasonal storage and releases to benefit anadromous fisheries in the Sacramento River by providing greater flexibility in achieving desirable river flows that would improve and expand suitable spawning and rearing habitat.

  Changes would be made to the timing and magnitude of releases performed to maintain target flows in spawning areas, and to improve the quality and quantity of aquatic habitat. Nearly all winter-run, and by far the majority of the spring-run and late-fall-run salmon in the Sacramento River, spawn in the reach upstream from the confluence with Battle and Cottonwood Creeks. It is within this reach of river that the measure would be most effective by reducing the frequency and magnitude of habitat dewatering. The quality of aquatic habitat could be further improved by cleaning spawning gravels. This measure could also include release changes during the flood season to permit “pulse flows” and other releases that could improve aquatic habitat conditions. Further, the measure could help provide additional control and dilution of acid mine drainage from Spring Creek.

Shasta Dam operates for multiple objectives, including water supply, flood control, water temperature, hydropower, and others. Modifying existing storage and release operations could adversely impact water supply reliability to agricultural and M&I uses or other beneficial uses of the water stored in the reservoir, which would be contrary to SLWRI goals and objectives. Therefore, this measure would need to include enlarging the storage space in Shasta Reservoir to mitigate potential adverse impacts to water supply reliability. This measure would not conflict with any ecosystem restoration measures that were preliminarily retained, nor would it conflict with other known programs or projects on the upper Sacramento River.

The estimated certainty of this measure in achieving its intended accomplishments would be moderate. The relationship between minimum river flows and increased survivability of salmon is not clear because many factors affect anadromous fish populations. Further, successful implementation would be highly dependent on the extent of dam modifications and reoperation that could be implemented while offsetting or minimizing adverse impacts to water supply or hydropower.

This measure was initially deleted from consideration because analyses indicated a decreased fisheries benefit with increasing Sacramento River flows compared to increasing the cold-water pool. However, this measure was subsequently retained as part of an adaptive management strategy for operation of the cold-water pool in Shasta Reservoir. Changes in operating the cold-water pool could include increasing minimum flows, timing releases out of Shasta Dam to mimic more natural seasonal flows, meeting flow targets for side channels, or retaining the additional water in storage to meet temperature objectives.

Increase Water Supply Reliability

Various potential water management measures were identified to address the primary objective of increasing water supply reliability for M&I, agricultural, and environmental purposes to help meet current and future water demands. Of 22 measures considered to help increase water supply reliability (see Table 2-3), four were retained for possible inclusion in concept plans. Rationale is discussed for retaining or deleting measures in this section.

Measures Considered

Following is a brief discussion of the measures considered, which are separated into eight categories: (1) increased surface water storage, (2) reservoir reoperation, (3) improved conjunctive water management, (4) coordinated operation and precipitation enhancement, (5) demand reduction, (6) improved water purchases and transfers, (7) improved Delta export and conveyance, and (8) improved surface water treatment. Also included are additional descriptions of the three measures retained for further consideration.

Increase Surface Water Storage Measures identified to increase surface water storages are described below.

- **Increase conservation storage space in Shasta Reservoir by raising Shasta Dam –** This measure consists of increasing the amount of available space for conservation storage in Shasta Reservoir through raising Shasta Dam. A range of potential dam raises has been considered in previous studies, including raises of more than 200 feet. A raise of 6.5 feet is included in the Preferred Program Alternative for the CALFED ROD (2000). Raising Shasta Dam would contribute directly to the primary planning objectives, and previous studies have indicated that raising the dam would be technically feasible. Raising Shasta Dam also could contribute to the secondary planning objectives. In addition, there is likely strong Federal and non-Federal interest in this measure. Therefore, this measure was retained for further development.

Table 2-3. Management Measures Addressing the Primary Planning Objective of Increasing Water Supply Reliability

Management Measure	Potential to Address Planning Objective	Status/Rationale
Increase Surface Water Storage		
Increase conservation storage space in Shasta Reservoir by raising Shasta Dam	**Very High** – Raising dam directly contributes to increased water supply reliability.	**Retained** – Consistent with primary planning objective and directly contributes to secondary planning objectives.
Construct new conservation storage reservoir(s) upstream from Shasta Reservoir	**Very Low** – Limited potential to effectively contribute to increased system water supply reliability or other planning objectives.	**Deleted** – Upstream storage sites capable of CVP system-wide benefits would be very costly, result in environmental impacts difficult to mitigate, and would be inconsistent with the CALFED ROD.
Construct new conservation storage on tributaries to the Sacramento River downstream from Shasta Dam	**Low** – Several sites/projects, including Auburn Dam Project, have demonstrated an ability to contribute to system water supply reliability.	**Deleted** – Although potentially feasible sites/projects exist that could increase water supply reliability, considerable overriding environmental and socioeconomic issues restrict implementation at this time.
Construct new conservation offstream surface storage near the Sacramento River downstream from Shasta Dam	**Moderate to High** – Although not as effective as additional storage at Shasta, there is potential for offstream storage projects (NODOS) to contribute to increasing water supply reliability.	**Deleted** – Not as efficient as developing additional storage in Shasta Dam. NODOS being pursued as added increment to system through a separate feasibility-scope study initiated under Public Law 108-361.
Construct new conservation surface water storage south of the Sacramento-San Joaquin Delta	**Moderate** – Potential for surface water storage projects (upper San Joaquin River) to contribute to increasing water supply reliability to CVP primarily in the San Joaquin Valley and Tulare Lake basin area.	**Deleted** – Not an effective alternative to additional storage at Shasta. Does not contribute to other planning objectives. Upper San Joaquin River being pursued as added increment to system through feasibility-scope study initiated under Public Law 108-361.
Increase total or seasonal conservation storage at other CVP facilities	**Moderate** – Would require several projects to contribute to water supply reliability (e.g., raise Folsom and Berryessa).	**Deleted** – Not an efficient alternative to increasing storage in Shasta Reservoir; considerably higher unit cost for increased water supply. Known efforts to increase space in other Northern California CVP (or SWP) reservoirs rejected by CALFED.
Dredge bottom of Shasta Reservoir	**Very Low** – Limited potential to effectively contribute to increases in system water supply reliability or any other planning objective**.**	**Deleted** – Extremely high cost for very small potential benefit and severe environmental impacts.
Reoperate Reservoir		
Increase the effective conservation storage space in Shasta Reservoir by increasing the efficiency of reservoir operation for water supply reliability	**Moderate to High** – Potential for increment of increased water supply reliability at Shasta Reservoir.	**Retained** – Although potential for increased water supply reliability is limited, added opportunities exist for increased flood control and other management elements.
Increase the conservation pool in Shasta Reservoir by encroaching on dam freeboard	**Very Low** – Very small space increase possible.	**Deleted** – Very limited potential to encroach on existing freeboard above full pool, which is only 9.5 feet. High relative cost to resolve uncertainty issues related to encroachment.
Increase conservation storage space in Shasta Reservoir by reallocating space from flood control	**Low** – Space reallocated to water supply could contribute to increased water supply reliability.	**Deleted** – Very low potential for implementation due to considerable adverse impacts on flood control.
Improve Conjunctive Water Management		
Develop conservation offstream surface storage near the Sacramento River downstream from Shasta Dam	**Moderate** – Potential to enhance system yield when combined with new storage and reoperation of Shasta.	**Deleted** – Implementing additional surface water storage project increment for Shasta would not be as efficient as new storage in Shasta Reservoir. Potential for shared storage in NODOS project is being considered in separate feasibility study initiated under Public Law 108-7.
Develop conservation groundwater storage near the Sacramento River downstream from Shasta Dam	**Moderate to High** – Considerable potential to enhance system yield when combined with new storage and reoperation of Shasta.	**Deleted** –This measure was initially retained for inclusion in concept plans, then eliminated in the comprehensive plans phase due to subsequent operations modeling indicating trade-offs between conjunctive use water supply benefits and critical gains in fisheries accomplishments.
Develop additional conservation groundwater storage south of the Sacramento-San Joaquin Delta	**Moderate** – Potential to enhance system yield when combined with new storage and reoperation of Shasta.	**Deleted** – Not as effective as storage north of the Delta and would not contribute to other study objectives.
Coordinate Operation and Precipitation Enhancement		
Improve Delta export and conveyance capability through coordinated CVP and SWP operations	**Moderate** – Potential to enhance system yield when combined with new storage and reoperation of Shasta.	**Deleted** – Joint point of diversion is being actively pursued in other programs. A likely without-project condition.
Implement additional precipitation enhancement	**Low** – Low potential to provide improvements to drought period water supply reliability.	**Deleted** – Not an effective alternative to new storage. Very limited potential to benefit drought period water supply reliability. Being actively pursued under without-project condition.

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Table 2-3. Management Measures Addressing the Primary Planning Objective of Increasing Water Supply Reliability (contd.)

Management Measure	Potential to Address Planning Objective	Status/Rationale
Reduce Demand		
Implement water use efficiency methods	**Moderate** – Potential to benefit overall State water supply issues.	**Retained** – Although water use efficiency does not add to increased supplies, conservation is being actively pursued through other programs. Conservation needs to be considered as an element of any plan considered in addressing California's future water picture.
Retire agricultural lands	**Moderate** – Would reduce water demand rather than increase ability to meet projected future demands.	**Deleted** – Not an alternative to new storage. Does not address planning objectives and constraints/criteria. Land retirement test programs being performed by Reclamation. On a large scale, could have considerable negative impacts on agricultural industry.
Improve Water Transfers and Purchases		
Transfer water between users	**Very Low** – Does not generate an increase in water supply reliability.	**Deleted** – Not an alternative to new water sources or reliable substitute for new storage at Shasta Reservoir. Will likely be accomplished with or without additional efforts to develop new sources.
Expand Delta Export and Conveyance Facilities		
Expand Banks Pumping Plant	**Moderate** – Potential to help increase water supply reliability south of the Delta.	**Deleted** – Not an alternative to new storage north of the Delta. Does not address planning objectives or constraints/principles/criteria. Will likely be accomplished with or without additional efforts to develop new sources.
Construct DMC/CA intertie	**Moderate** – Potential to help increase water supply reliability south of the Delta.	**Deleted** – Not an alternative to new storage north of the Delta. Does not address planning objectives or constraints/principles/criteria. Will likely be accomplished with or without additional efforts to develop new sources.
Improve Surface Water Treatment		
Implement treatment/supply of agricultural drainage water	**Very Low** – Very low potential to improve water supply reliability for agricultural uses.	**Deleted** – Not a viable alternative to new water storage. Very high unit water cost.
Construct desalination facility	**Low** – Although growing new source for urban water supplies in State, low potential to address SLWRI planning objectives.	**Deleted** – Not an alternative measure for drought period supplies. Not an alternative to new storage at Shasta. Very high unit water cost.

Key:
CALFED = CALFED Bay-Delta Program
CVP = Central Valley Project
Delta = Sacramento-San Joaquin Delta
DMC/CA = Delta-Mendota Canal/California Aqueduct
NODOS = North-of-the-Delta Offstream Storage
Reclamation = U.S. Department of the Interior, Bureau of Reclamation
ROD = Record of Decision
SLWRI = Shasta Lake Water Resources Investigation
State = State of California
SWP = State Water Project

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- **Construct new conservation storage reservoir(s) upstream from Shasta Reservoir –** This measure consists of constructing dams and reservoirs at one or more locations upstream from Shasta Lake, primarily for increased water conservation storage and operational flexibility. Numerous reservoir storage projects have been considered and many constructed in the watershed upstream from Shasta Lake. Three of the most promising remaining sites include Allen Camp Reservoir (180,000 acre-feet on the Pit River in Modoc County), Kosk Reservoir (800,000 acre-feet on the Pit River in Shasta County), and Squaw Valley Reservoir (400,000 acre-feet on Squaw Valley Creek in Shasta County). These three potential project sites were deleted from further consideration because they (1) would only be capable of marginally improving water supply reliability to the CVP, (2) would not be consistent with screening criteria established in the CALFED Integrated Storage Investigations, (3) would likely not be supported in the local area because the water would need to be developed for CVP system reliability (not retained for local use), and (4) would result in a relatively high unit water cost to implement. In addition to the above three potential projects, an additional offstream storage site at Goose Valley near Burney was suggested to the SLWRI Product Delivery Team during a stakeholder meeting in Redding. A cursory evaluation indicated, however, that at a potential full pool storage of about 230,000 acre-feet, and with a generous estimate of available river flows available for diversion from the Pit River to the site, likely costs to develop the project would exceed water supply benefits by at least 2 to 1. Further, although larger sizes of a project at the Goose Valley site are physically feasible, there is little potential for water to fill the facility. Accordingly, this site was not considered further and this measure was deleted from further consideration in the SLWRI.

- **Construct new conservation storage on tributaries to the Sacramento River downstream from Shasta Dam –** Numerous onstream surface water storage projects along tributaries to the Sacramento River downstream from Shasta Dam have been investigated in past studies. Several projects have potential to contribute considerably to increasing water supply reliability, including the Cottonwood Creek Project (1.6 MAF on Cottonwood Creek north of Red Bluff), the Auburn Dam Project (up to about 2.3 MAF on the Middle Fork American River near Sacramento), and the Marysville Lake Project (920,000 acre-feet on the Yuba River near Marysville). Although each of these potential projects could considerably contribute to increasing the water supply reliability of the CVP and SWP systems, they have been rejected by State and local interests as potential candidates for new water sources. Each was eliminated from further consideration in the SLWRI primarily because they would not contribute to the primary planning objectives or because they would have significant overriding environmental issues and opposition. This measure was deleted from further consideration in the SLWRI.

- **Construct new conservation offstream surface storage near the Sacramento River downstream from Shasta Dam –** Various offstream reservoir storage projects have been evaluated in previous studies. All but one of the offstream reservoir storage projects were eliminated from further consideration in the CALFED ROD, primarily because of project cost considerations, potential environmental impacts, and lands and relocation issues. The one project retained for further consideration in the ROD is Sites Reservoir, with a storage capacity of up to 1.8 MAF. DWR is studying Sites Reservoir and alternatives under the North-of-the-Delta Offstream Storage (NODOS) Project. Sites Reservoir would be filled primarily by water diverted from the Sacramento River and tributaries during periods of excess flows through the Tehama-Colusa Canal, Glenn-Colusa Irrigation District Canal, and/or a new pipeline near Maxwell. Another potential source of water for filling the reservoir is moving (predelivery) Tehama-Colusa Canal Authority and Glenn-Colusa Irrigation District water from Shasta Reservoir during the spring and storing it at Sites Reservoir for delivery during the irrigation season. Reclamation received Federal feasibility study authority for NODOS under Section 215 of PL 108-7 in September 2003. NODOS has the potential to increase the water supply reliability of Sacramento Valley users, the CVP, and SWP; improve Delta water quality; contribute to ecosystem restoration; and provide water to support the Environmental Water Account. The emphasis of the objectives of the NODOS project are different than those of Shasta enlargement; NODOS would not be a substitute for enlarging Shasta Dam and Reservoir and was eliminated from further consideration in the SLWRI.

- **Construct new conservation surface water storage south of the Sacramento-San Joaquin Delta –** A relatively large portion of the CVP's future water needs is located in service areas in the San Joaquin River basin, south of the Delta. In addition, large demands will continue to be made, primarily on the SWP, to provide water for M&I purposes farther south via the California Aqueduct and for increased water supply reliability to the South Bay areas. A portion of these demands could be provided by onstream and/or offstream surface water storage within the San Joaquin River basin. Numerous surface water storage sites have been identified in the past along the east and west sides of the San Joaquin Valley and in areas to the west of the Delta near Stockton.

  Potential onstream storage sites are exclusively located on the east side of the valley due to the lack of substantial annual runoff from the Coast Range. Several potential onstream storage sites could include enlarging

Pardee Reservoir on the Mokelumne River, enlarging and modifying Farmington Dam on Littlejohns Creek, and additional storage on the upper San Joaquin River. Numerous potential offstream storage sites also have been considered in the San Joaquin Valley. Several potential sites have been identified on the east side of the valley and would receive diverted flows from nearby rivers, but most sites are on the west side of the valley and designed to receive pumped water primarily from the California Aqueduct during periods of excess flows. Potential sites would include Los Vaqueros enlargement, Ingram Canyon Reservoir, Quinto Creek Reservoir, and Panoche Reservoir.

All of the potential onstream or offstream storage projects south of the Delta were deleted from further consideration primarily because they would not (1) contribute to the objectives of the SLWRI or (2) be as efficient or effective as additional storage in an enlarged Shasta Reservoir. In addition, feasibility-scope investigations for both Los Vaqueros Reservoir and upper San Joaquin River storage were authorized in Section 215 of Public Law 108-7. Both studies are addressing specific planning objectives that are unique to their geographic areas, but differ from those of the SLWRI.

- **Increase total or seasonal conservation storage at other CVP facilities –** This measure primarily consists of providing additional conservation storage space in other major CVP (and/or SWP) reservoirs in the Sacramento River watershed through enlarging existing dams and reservoirs. Besides Shasta Dam and Lake, projects primarily would include additional storage in facilities such as Lake Berryessa on Putah Creek, Folsom Lake on the American River, Trinity Lake on the Trinity River, and Lake Oroville on the Feather River. It is believed that, of the existing reservoirs in the CVP/SWP systems, increasing water supply reliability through modifying Shasta Dam and Lake would be the most cost-effective. Further, all known efforts to increase storage space in other Northern California CVP (or SWP) reservoirs were rejected by CALFED and local interest groups. For these reasons, and because this measure would not address all SLWRI planning objectives, constraints, principles, and criteria, this measure was deleted from further consideration in the SLWRI.

- **Dredge bottom of Shasta Reservoir –** This measure consists of increasing the total storage space in Shasta Reservoir by excavating either deposited or native materials below full pool elevation. In general, this measure is not practical for large impoundments due to cost; however, it is included here for completeness and because it was a specific request in the environmental scoping process. For comparison purposes, an estimate was made that considered removing 100,000 acre-feet of dredged material from Shasta Reservoir. This volume in Shasta Reservoir would result in approximately 22,000 acre-feet per year of additional drought period yield to the CVP. An increased volume of 100,000 acre-feet is about 160 million cubic yards, or the equivalent volume of the area of a football field over 14 miles high. Excavation costs vary widely depending on the type of material and location of excavation. Soil that is movable by scraper machines can be excavated and dumped locally for about $3 per yard while dredged soil costs much more, over $10 per yard, and rock excavates are about $10 per yard. Assuming that Shasta Reservoir is drawn down and half of the volume is removed by scraper and half by excavation, and then assuming transport and disposal of the material locally at an additional cost of approximately $3 yard, this measure would have a total cost of about $1.5 billion. This cost does not include any real estate costs or expenditures to mitigate for drawing down Shasta Lake or for the disposal of the materials. In addition, the soil and rock could not be sold because no need exists for this quantity of fill, and local fill sources are usually available. The resulting equivalent cost of increasing water supply reliability would be nearly $5,000 per acre-foot. This unit cost is multiple times greater than that of other sources. Accordingly, this measure was deleted from further consideration.

Reoperate Reservoir The three measures described below involve increasing the conservation storage space by altering the operations of Shasta Dam and Reservoir.

- **Increase the effective conservation storage space in Shasta Reservoir by increasing the efficiency of reservoir operations for water supply reliability –** This measure consists of changing the flood control operations of Shasta Dam and Reservoir (without reducing the maximum flood pool) with a goal of increasing water supply reliability. This measure would focus on revising the operation rules for flood control such that the facility could potentially be managed more efficiently for flood control, thereby freeing some seasonal storage space for water supply. A primary constraint would be to ensure no adverse impacts to the existing level of flood protection provided by the Shasta Dam project. It is believed that some degree of operational efficiency could be gained through a critical assessment of reservoir operations using more current analytical and weather forecasting tools. Although the potential for increased water supply reliability through reoperation efficiencies for flood control is believed to be limited, this measure was retained for further detailed consideration for possible inclusion in concept plans.

- **Increase conservation pool in Shasta Reservoir by encroaching on dam freeboard –** This measure consists of increasing the conservation storage space in Shasta Reservoir by raising the full pool elevation without raising Shasta Dam. The current full pool elevation at Shasta Dam is 1,067 feet above mean sea level (elevation 1,067) and the top-of-dam elevation is approximately elevation 1,076.5. Accordingly, the design freeboard above maximum water surface elevation is 9.5 feet. It is estimated that major modifications would be required to the dam and appurtenances to allow operational encroachments on the design freeboard of the dam, only to gain a small potential increase in reservoir storage. This measure was deleted from further consideration primarily because it would have low potential to effectively address the planning objective.

- **Increase the conservation storage space in Shasta Reservoir by reallocating space from flood control –** This measure consists of decreasing the maximum seasonal flood control storage space in Shasta Reservoir and dedicating that space to water supply reliability in the CVP. It also includes constructing flood protection features along the Sacramento River to mitigate for potential induced flood damages. The maximum seasonal flood control storage space in Shasta is 1.3 MAF from December 1 through March 20, depending on accumulated seasonal inflow volumes. Reducing seasonal flood control storage space would reduce the ability of the reservoir to control peak flood flow releases. This would result in an increase in the frequency of flooding and flood damages along the Sacramento River downstream from Shasta Dam. This measure was deleted from further consideration in the SLWRI primarily because of its likely adverse impacts on flood controls.

Improve Conjunctive Water Management The following three measures were identified to improve conjunctive water management.

- **Develop conservation offstream surface storage near the Sacramento River downstream from Shasta Dam –** This measure consists of developing surface water transfer storage capabilities near the Sacramento River downstream from Shasta Dam to use in conjunction with storage in Shasta Reservoir. This storage would be an extension of storage space in Shasta Reservoir. Water temporarily stored or “parked” in the transfer storage facility would be delivered to local CVP contractors in substitution for their current diversions via either the Anderson-Cottonwood Irrigation District facilities or Tehama-Colusa Canal water users facilities. Water not diverted from the water users would remain in the Sacramento River to benefit anadromous fish, for delivery to downstream water users, and/or for Delta water quality. One possibility identified would be to consider some of the space in the Sites Reservoir project, or NODOS, which was previously described as conjunctive use storage for Shasta. This possibility is being considered in studies by DWR. However, development of a separate surface water storage project or space in the Sites Project expressly as part of the SLWRI is believed to be inconsistent with the planning objectives and constraints for the

SLWRI. Accordingly, this measure was deleted from further consideration in the SLWRI. It continues to be considered, however, as part of the NODOS project.

- **Develop conservation groundwater storage near the Sacramento River downstream from Shasta Dam –** This measure consists of developing groundwater storage near the Sacramento River. Similar to the surface storage measure described above, releases from Shasta Dam would be diverted from the Sacramento River and used to recharge local groundwater rather than be stored in a surface water facility. During drought periods, stored groundwater would be pumped for local uses. This pumped water would be substituted for surface water that would have otherwise been diverted from the Sacramento River during the irrigation season. Several options have been identified. One option would be similar to surface water conjunctive use storage except diverted water would be stored in groundwater basins adjacent to the Sacramento River. However, this option would be very costly because of the amount of land or land rights required. Another option would be to work with existing water contractors in the Sacramento River valley to exchange surface water for in-lieu pumped groundwater, depending on the water year.

  The in-lieu option of this measure was retained primarily because it would have potential to increase water supply reliability and would be consistent with the identified plan formulation constraints and criteria. Also, it would be consistent with CALFED goals for the water storage component of the August 2000 ROD and would not conflict with other planning objectives.

- **Develop additional conservation groundwater storage south of the Sacramento-San Joaquin Delta –** This measure consists of either developing new groundwater recharge projects south of the Delta or contributing to existing recharge projects. It would include diverting flows during periods of excess from the San Joaquin River, Delta-Mendota Canal (DMC), or California Aqueduct and helping recharge depleted groundwater basins. It is believed that this measure would have limited potential to allow storage from modifying Shasta to be temporally stored south of the Delta for later use during critical dry periods. Conjunctively using water in the DMC or California Aqueduct has been pursued in other CALFED programs. These conjunctive use scenarios would not be considerably influenced by added system storage north of the Delta. This measure would not be as effective or efficient as increased storage space in Shasta Reservoir and would not contribute to the other primary planning objective. Accordingly, this measure was deleted from further consideration in the SLWRI because it would not effectively address primary planning objectives of the SLWRI.

Coordinate Operation and Precipitation Enhancement The two measures discussed below involve coordinating operations and precipitation enhancement.

- **Improve Delta export and conveyance capability through coordinated CVP and SWP operations –** This measure primarily consists of improving Delta export and conveyance capability through a more effective coordinated management of surplus flows in the Delta. A specific application of the measure would be the joint point of diversion. Joint point of diversion operations would allow Federal and State water managers to use excess or available capacity in their respective south Delta diversion facilities at the Jones and Banks pumping plants. Currently, little excess capacity exists in the Federal pumps at Jones, but some additional capacity is available in the SWP pumps at Banks. The potential added benefit to CVP through joint point of diversion operations during average and critical years would be about 61,000 and 32,000 acre-feet, respectively. This measure is being actively pursued by Reclamation and DWR and it is highly likely that some form of the joint point of diversion will be implemented in the future. This measure was deleted from further consideration in the SLWRI because it would not effectively address the primary planning objectives, and is likely to be implemented, in some form, independent of the SLWRI.

- **Implement additional precipitation enhancement –** Precipitation enhancement is a process by which clouds are stimulated to produce more rainfall or snowfall than they would naturally. This process is accomplished by seeding a cloud with a substance such as silver iodide, an ice-like structure, that encourages water to form ice particles heavy enough to fall out as rain or snow. Precipitation enhancement has been practiced continuously in California since the 1950s for water supply and hydroelectric power purposes. It is estimated that about a 2 to 15 percent increase in annual precipitation or runoff can be achieved by this process. Indications are that precipitation enhancement is highly cost-effective in increased average annual rainfall. It has been determined that this technology likely does not decrease downwind precipitation. However, environmental concerns exist about weather modification.

  It is important to understand that precipitation enhancement is not a short-term remedy for droughts because supply increases can only be achieved during years when it would otherwise rain or snow naturally, meaning in above-average precipitation years. Accordingly, precipitation enhancement is not an alternative to new system storage, which focuses on conserving water in wetter years for use in drier years. In addition, this technology is being pursued under the without-project condition. This measure was deleted from further consideration in the SLWRI primarily because it would not address the planning objectives and is not an alternative to new storage in Shasta Reservoir.

Reduce Demand Measures identified to reduce demand and thus increase water supply reliability are described below.

- **Implement water use efficiency methods –** Water use efficiency methods can help reduce current and future water shortages by allowing a more effective use of existing supplies. As population and resulting water demands continue to grow and available supplies remain relatively static, effective use of supplies can reduce potential critical impacts to urban and agricultural resources resulting from water shortages.

  Reclamation is an implementing agency for the CALFED Water Use Efficiency program (CALFED 2000). The Water Use Efficiency Program was developed to support efficient use of water supplies developed by CALFED. The program is comprised of a combination of technical assistance, grants and loans, and directed studies in program areas including: agricultural water conservation, urban water conservation, water recycling, and desalination. The program coordinates with, builds on, and supplements the work of the Agricultural Water Management Council and the California Urban Water Conservation Council. Supporting information for the program is contained in a *2006 Water Use Efficiency Comprehensive Evaluation* for the CALFED Water Use Efficiency Element (CALFED 2006) and the *California Water Plan 2009 Update* (DWR 2009).

  The 2009 *California Water Plan Update* (DWR) also identified a host of agricultural and urban water conservation measures. It is important to note that water "saved" by conservation practices is often water that, without conservation, would return to the hydrologic system and become a supply for other users. Accordingly, conservation does not simply mean reducing consumptive uses for crops in agricultural areas or for dwelling units in urban areas. Truly effective conservation applies when it consists of reducing irrecoverable water, or reducing water use that otherwise would be lost to the hydrologic system. For agricultural uses, examples of irrecoverable water would be (1) water used to leach salts from the soil and subsequently lost to the system through collection and evaporation (2) water lost to excessive evaporation or transpiration, or (3) channel evaporation losses. For urban uses, examples of genuine water conservation would be reducing (1) residential landscape water lost to evaporation or transpiration; (2) commercial, industrial, and institutional losses that are not recoverable; and (3) water distribution system losses or leakage in areas where water would not be recoverable.

The 2006 CALFED document indicated that the potential for recovering currently irrecoverable agricultural losses in the Sacramento and San Joaquin River Basins could be about 142,000 acre-feet on an average annual basis - with resulting unit costs of about $200 per acre-foot. Larger recoveries of currently irrecoverable agricultural losses are technically feasible; however, the costs to achieve these amounts increase considerably. The report also identified various urban water use efficiency programs with the potential of reducing average annual urban water use up to about 1.1 MAF per year by 2030 through a series of best management practices. These practices ranged from potentially cost-efficient regional opportunities likely to be implemented in the future to those requiring grant funding and cost-sharing before they could be implemented. It is estimated that implementation costs (using approaches somewhat similar to those being considered for the surface water storage projects) would exceed about $300 per acre-foot for these reductions. Note that either recovery of irrecoverable agricultural losses, or reductions in urban water use during drought years would be considerably less than in average years. Accordingly, the unit cost for achieving drought period reductions in water use would be considerably greater than the average unit cost above.

Many actions planned under the CALFED Water Use Efficiency program will be accomplished with or without implementation of other projects to address water supply reliability. “Projection Level One” includes continued implementation of best management practices for urban and agricultural conservation equivalent to those observed during the first 13 years of CALFED. The CALFED Common Assumptions for Water Storage Projects estimated that Level One has a potential to reduce future agricultural losses by about 49,000 acre-feet per year and urban demands in the State by about 1.2 MAF per year. Additional water conservation measures will likely play a major role in California’s future water picture. The California Water Plan as well as numerous State and Federal agencies endorse and actively engage in water use efficiency actions. Water use efficiency will constitute a significant element in helping to reduce demands to help offset future shortages in water supplies. Accordingly, water use efficiency was retained as a potential project element to be considered to the extent possible in the implementation of a potential plan of action for the SLWRI.

- **Retire agricultural lands** – Recent studies indicate that by retiring about 150,000 acres from irrigated croplands in the San Joaquin Valley, the demand for irrigation water could be reduced by about 260,000 acre-feet per year under average conditions. It is estimated that in dry and critical years, potential savings through this measure could be much reduced from the average annual value because it is during these water-short years that marginal lands are normally allowed to go fallow. Some estimates have placed the drought period demand reduction at between 100,000 and 150,000 acre-feet per year. The estimated construction cost to acquire land rights to permanently retire lands from irrigated agriculture uses amounts to about $500 million, resulting in an equivalent dry-period unit water cost of about $300 per acre-foot. Although the equivalent unit cost of water for this measure may be found competitive with other potential water sources, this measure was deleted from further consideration. This is primarily because of the likely limited ability of this measure to actually address helping meet future water demands in the Central Valley. First, as mentioned, marginal lands are already often allowed to fallow during drought periods. Further, there would be a high degree of uncertainty regarding the institutional ability to acquire sufficient additional land rights necessary to preclude future irrigated agriculture on lands identified for inclusion in a project/program. This especially would be the case if efforts were made to acquire and retire higher productivity lands that may actually lead to water savings during drought periods. Further, there is believed to be a limited ability to successfully apply this measure to lands in the Central Valley at costs similar to those above for less productive lands. Lastly, this measure would not address other planning objectives of the SLWRI.

Improve Water Transfers and Purchases In order to improve water transfers and purchases, the following measure was identified.

- **Transfer water between users –** Water purchases and transfers do not generate new water for the CVP. They simply consist of transferring water between a seller willing to forgo a water use for a time and a willing buyer within the Central Valley. The availability and price of a supply for purchase and used for transfer depends on several factors such as year type, other available supplies, storage capabilities, and transmission capacity. Temporary and long-term (greater than 1 year, as defined by DWR) transfers between water districts have increased from about 80,000 acre-feet in 1985 to over 1.2 MAF in 2001. This trend is expected to continue as the demand for available supplies continues. Only about 20 percent of the transfers are based on agreements greater than 1 year. Most depend on the water spot market. Both Reclamation and DWR also have active water transfer programs and a significant number of water transfers will continue to occur in the future under without-project conditions as available supplies become scarce. Further, the future of the Environmental Water Account depends on the ability to acquire and transfer water through the Delta to mitigate impacts of south Delta pumping curtailment to benefit at-risk fish. Because of these and other projects and actions, and ongoing infrastructure limitations on conveying water from north of the Delta south, it is believed that as water supply demands continue to grow and exceed developed supplies, especially during dry years, and as market conditions change, the cost of water is expected to increase considerably. It is likely that the most feasible and reliable water transfers will be implemented under without-project conditions. Any remaining opportunities for transfers likely would be small, include high uncertainties, be difficult to implement, and be more costly. In addition, water transfers are unlikely to contribute to improving water quality (particularly during dry periods) or provide a less-costly Environmental Water Account replacement supply (transfers are a water acquisition tool already used by the Environmental Water Account). Consequently, this measure was deleted from further consideration primarily because it would not be a long-term reliable substitute for new storage in Shasta Reservoir.

- **Expand Delta Export and Conveyance Facilities –** The two measures in this category would divert surplus water when safe for fish, then bank, store, transfer, and release the surplus water as needed to protect fish and to compensate water users. This could be accomplished by increasing the capacity of conveyance facilities of the CVP and SWP at several locations, as follows:

  – **Expand Banks Pumping Plant –** The current allowable pumping capacity at the SWP Banks Pumping Plant is 6,680 cfs. Efforts are underway by Reclamation and DWR to construct fish protection features under the South Delta Improvements Program to allow increasing the allowable pumping capacity to 8,500 cfs during certain seasonal periods. The maximum installed pumping capacity at Banks is about 10,300 cfs. This measure primarily includes implementing additional physical features and operational improvements aimed at benefiting the overall water quality of the Delta to further increase the allowable pumping capacity at Banks from 8,500 cfs to 10,300 cfs during certain seasonal periods, and splitting the increased pumping capacity equally between the CVP and SWP. This increased capacity would allow more water that otherwise would flow to the Pacific Ocean to be conveyed south of the Delta. It is estimated that the average annual increase in supplies south of the Delta allocated to the CVP could amount to over 100,000 acre-feet. The estimated unit cost for the increase in water supply reliability would be highly efficient when compared with other potential sources of new water supplies. However, because this measure would not contribute to the SLWRI planning objectives or identified plan formulation constraints, principles, and criteria, it was not viewed as a potential alternative to new storage in Shasta Reservoir. Accordingly, it was deleted from further consideration in the SLWRI.

  – **Construct Delta Mendota Canal/California Aqueduct (DMC/CA) intertie –** The pumping capacity of the CVP Jones

Pumping Plant into the DMC in the south Delta is 4,600 cfs. However, because of land subsidence in the southern reaches of the DMC, the effective capacity is limited to 4,200 cfs. Studies have considered modifying the subsided reach of canal and constructing a new canal parallel to the existing DMC. However, it appears that a more cost-effective measure would be to connect the DMC to the California Aqueduct. In some locations, the two canals are about 400 feet apart horizontally and 50 feet apart vertically. A potential intertie would consist of constructing pumps and a 400 cfs capacity conveyance canal between the two facilities several miles south of the Jones Pumping Plant. It is estimated that this measure would result in an average annual increase in supplies south of the Delta of about 55,000 acre-feet. It is believed that the unit cost for the increase in water supply reliability for this measure would be comparable to other potential sources of new water supplies. However, because this measure would not contribute to the planning objectives of the SLWRI or identified plan formulation constraints, principles, and criteria, it was not viewed as a potential alternative to new storage in Shasta Reservoir. Accordingly, it was deleted from further consideration in the SLWRI.

Improve Source Water Treatment The following two measures were identified to improve source water treatment.

- **Implement treatment/supply of agricultural drainage water –** This measure consists of collecting agricultural drainage from farms along the Sacramento and San Joaquin Rivers and treating the drainage water for reuse. Major elements of this measure likely include an agricultural drainage collection system, pretreatment of drainage water, desalination facilities, ancillary facilities associated with desalination and brine disposal, and conveyance of treated water to end users. In addition, removing total organic carbon and pesticides plus supplementary disinfection may also be required before municipal agencies would consider using the treated agricultural runoff as a potable supply. While this measure may have potential to provide some water supply reliability to urban users, it is far too costly for agricultural users. It would be costly to initially implement and operate, problems would exist relating to brine disposal, and it would likely be unacceptable to stakeholders and the public. Accordingly, this measure was deleted from further consideration.

- **Construct desalination facility –** This measure consists of constructing seawater or brackish surface or groundwater desalination plants to supplement existing water supplies and help offset future demands. There are 23 desalination facilities with a total capacity of about 80,000 acre-feet per year currently operating in California to provide water for municipal purposes. It is estimated that by 2030, a total of 49 desalination facilities with a cumulative capacity of nearly 600,000 acre-feet per year will be in operation in California. Primary elements of any of the facilities include a water intake, pretreatment, desalination, brine disposal, and ancillary facilities for the desalination treatment plant. In addition, a conveyance system is needed to transport the desalinated water to the customer or to the water agency distribution systems. Although technological advances have substantially decreased treatment costs, desalination remains costly compared with most other water sources. Even with continual improvement in membrane technology, energy costs can account for as much as one-half the total cost of desalination.

Desalination is most efficient when used as a base supply because the plants can be better and more cost-effectively maintained if continuously operated, rather than if they are only operated during drought periods. Alternately, if desalination were operated as a base supply in all years, reserving contract water for use during drought periods, less expensive average and wet-year contract water would be forgone in most years. Consequently, desalination by itself would be a highly inefficient option for agencies that rely on multiple water sources or only intend to use desalination as a drought or emergency supply.

Depending greatly on the quality of the source water and the cost of power, desalination today can range from about $700 to several thousand dollars per acre-foot. As mentioned, desalination is energy intensive and, with rising power costs, it is expected to continue to be relatively expensive. Even if the unit cost for a base supply plant were measurably reduced, desalination by itself would likely not be superior to other potential water sources to address the primary planning objective of agricultural water supply reliability in the SLWRI. Accordingly, this measure was deleted from further consideration primarily because it would not be an alternative to new storage in Shasta Reservoir and if it were, its unit costs would be far greater than new supplies from Shasta or other sources.

Measures Retained for Further Consideration

Four of the above management measures to increase water supply reliability were retained for further consideration and possible inclusion in concept plans. Of these four, three were carried forward for inclusion in comprehensive plans. Their major components and accomplishments are described below.

- **Increase conservation storage space in Shasta Reservoir by raising Shasta Dam –** This measure consists of structural raises of Shasta Dam ranging from about 6.5 feet to approximately 200 feet. Chapter 3 includes descriptions of features, accomplishments, major impacts, and costs for various dam raises within this range. Also included in the chapter is a comparison of various dam raise options.

- **Increase effective conservation storage space in Shasta Reservoir by increasing efficiency of reservoir operation for water supply reliability** – This measure consists of modifying the operation of Shasta Dam to improve water supply reliability. It can also assist in improving flood control. Potential methods to improve water supply reliability include modifying rainflood parameters – those which address space for flows from winter rainfall – in the operation rules for Shasta Reservoir and modifying the Shasta Dam release schedule. The goal of the operation changes would be to minimize the required evacuation of the reservoir during the period from about late November through March, and to possibly allow the reservoir to be filled more rapidly in the spring. As mentioned, a primary criterion would be to prevent adversely affecting existing flood protection provided by Shasta Dam and possibly improve it. These possible reoperation opportunities are described in the reference report *Assessment of Potential of Shasta Dam Reoperation for Flood Control and Water Supply Improvement* (Reclamation 2004b).

  Although this measure was retained for inclusion in concept plans, its specific features and their influence on water supply reliability and flood damage reduction would not be developed until detailed operations modeling could be accomplished in further investigations as part of comprehensive alternative plan formulation in the SLWRI.

- **Develop conservation groundwater storage near the Sacramento River downstream from Shasta Dam** – This in-lieu conjunctive water management measure primarily consists of using the incremental increase in stored water in Shasta Reservoir to support a shift in the timing of water diversion from the Sacramento River to help increase water supply reliability to other CVP and possibly SWP water users in dry periods. Under this measure, for agricultural interests willing to participate in an in lieu program, during average and wetter years, more surface water from an increased storage space in Shasta Reservoir would be diverted from the Sacramento River and used in-lieu of groundwater pumping. Accordingly, during drought years, less surface water would be delivered to agricultural users, who would depend more on groundwater supplies, allowing more of the normally diverted surface water to be delivered to other users. The in lieu conjunctive water management program would need to include incentives to agricultural users to warrant their participation.

  Although this plan was initially retained due to significant water supply benefits, it was eliminated from further development during the comprehensive plan phase. Subsequent operations modeling indicated tradeoffs between conjunctive use water supply benefits and critical gains in fisheries accomplishments. The resulting reduction in benefits to fisheries operations in dry and critical years was deemed unacceptable in terms of meeting primary project objectives.

- **Implement water use efficiency methods** – Water use efficiency methods can help reduce current and future water shortages by allowing a more effective use of existing supplies. As population and resulting water demands continue to grow, and available supplies remain relatively static, more effective use of supplies can reduce potential critical impacts to urban and agricultural resources resulting from water shortages. The California Water Plan Updates 2005 and 2009 (DWR 2005, DWR 2009) identified a host of urban and agricultural water use efficiency measures. The 2009 plan indicates that water use efficiency measures, although costly and difficult to implement, will play a major role in California's water future. Water use efficiency will constitute a significant element in helping to reduce demands to help offset future shortages in water supplies. Accordingly, water use efficiency was retained for consideration as a potential project element for any plan to be considered for the SLWRI.

Measures to Address Secondary Planning Objectives

Various management measures were identified to address the five secondary planning objectives. For each secondary planning objective, measures were identified and separated into categories. In the following sections, the rationale is discussed for retaining or deleting each measure.

Conserve, Restore, and Enhance Ecosystem Resources

Identifying potential ecosystem restoration opportunities included water management measures to address the secondary planning objective of ecosystem restoration in the Shasta Lake vicinity and along the Sacramento River downstream from Shasta Dam. Of the 19 management measures identified to address the secondary planning objective of ecosystem restoration, three were retained for possible inclusion in concept plans (see Table 2-4).

It should be mentioned that some of the measures deleted from further consideration in this appendix for the purpose of ecosystem restoration might be determined in further studies to be suitable for helping mitigate potential adverse impacts of comprehensive alternative plans. Further, some measures or expansions of measures retained for further consideration also could be considered for mitigating adverse environmental and related impacts.

Measures Considered

Following is a brief discussion of the measures considered, which are separated into three categories: (1) improving cold-water and warm-water fisheries, (2) restoring and conserving riparian and wetland habitat, and (3) improving other fish and wildlife habitat. Rationale is included in this section for retaining or deleting measures. Also included are additional descriptions of the three measures retained for further consideration.

Table 2-4. Management Measures Addressing the Secondary Planning Objective of Conserving, Restoring, and Enhancing Ecosystem Resources

Management Measure	Potential to Address Planning Objective	Status/Rationale
Enhance Cold-Water and Warm-Water Fishery Habitat		
Construct shoreline fish habitat around Shasta Lake	**Moderate to High** – Contributes to ecosystem restoration goals within watershed.	**Retained** – Would complement measures to increase storage in Shasta Lake.
Construct instream fish habitat on tributaries to Shasta Lake	**Moderate to High** – Contributes to ecosystem restoration goals within watershed.	**Retained** – Would complement measures to increase storage in Shasta Lake. High local interest.
Increase instream flows on the lower McCloud River	**Moderate** – Potential to benefit aquatic resources on lower McCloud River.	**Deleted** – Considerable impacts to hydropower.
Reduce acid mine drainage entering Shasta Lake	**Moderate** – Considerable benefit under certain hydrologic conditions.	**Deleted** – Considerable implementation, O&M, and liability issues.
Reduce motorcraft access to upper reservoir arms	**Moderate** – Potential to benefit fisheries in Shasta Lake.	**Deleted** – Motorcraft management is under the purview of USFS.
Increase instream flows on the Pit River	**Moderate** – Potential to benefit aquatic resources in upper Pit River.	**Deleted** – Considerable impacts to hydropower.
Restore and Conserve Riparian and Wetland Habitat		
Restore riparian and floodplain habitat along the Sacramento River	**High** – Directly contributes to ecosystem restoration along mainstem Sacramento River.	**Retained** – Would be compatible with other primary study objectives. Consistent with other restoration programs and projects in the primary study area.
Restore wetlands along the Fall River and Hat Creek	**Low** – Very low potential to contribute to ecosystem restoration in the Shasta Lake area.	**Deleted** – Considerably removed from primary study area. Independent action with low potential to contribute to other primary or secondary planning objectives.
Conserve upper Pit River riparian areas	**Low** – Very low potential to contribute to planning objective.	**Deleted** – Significantly removed from primary study area. Independent action with low potential to contribute to other primary or secondary planning objectives.
Restore riparian and floodplain habitat along lower Clear Creek	**Moderate** – Indirectly supports planning objective.	**Deleted** – Considerable benefit to tributaries. Independent action and would not directly contribute to improved ecological conditions along mainstem Sacramento River.
Promote Great Valley cottonwood regeneration on Sacramento River	**Moderate –** Potential to contribute to planning objective.	**Deleted** – High uncertainty for Federal participation and low potential to contribute to primary and other secondary planning objectives.
Conserve riparian corridor along Cow Creek	**Moderate** – Indirectly supports planning objective.	**Deleted** – Considerable benefit to tributaries. Independent action and would not directly contribute to improved ecological conditions along mainstem Sacramento River.
Remove and control nonnative vegetation in the Cow Creek and Cottonwood Creek watersheds	**Moderate** – Indirectly supports planning objective.	**Deleted** – Considerable benefit to tributaries. Independent action and would not contribute to primary or secondary planning objective conditions along mainstem Sacramento River.
Improve Other Fish and Wildlife Habitat		
Create a parkway along the Sacramento River	**Moderate** – Can contribute to ecosystem restoration in the study area.	**Deleted** – Primarily focuses on land acquisition and conversion to public uses. As a project element, it would be a non-Federal responsibility with little direct Federal interest. Elements are a likely without-project condition.
Enhance forest management practices to conserve bald eagle nesting habitat	**Low to Moderate** – Can contribute to ecosystem restoration in study area.	**Deleted** – Likely a without-project condition; is an element of forest recovery plans by USFS.
Remove and control nonnative plants around Shasta Lake	**Low to Moderate** – Can contribute to ecosystem restoration in study area.	**Deleted** – Likely a without-project condition; is an element of forest recovery plans by USFS.
Control erosion and restore affected habitat in the Shasta Lake area	**Low to Moderate** – Can contribute to ecosystem restoration in study area.	**Deleted** – Likely a without-project condition; is an element of forest recovery plans by USFS.
Develop geographic information system for Shasta to Red Bluff reach	**Low to Moderate** – Can contribute to ecosystem restoration in study area.	**Deleted –** Would not directly contribute to other primary or secondary planning objectives. GIS mapping likely a without-project condition as part of other ongoing studies and projects.
Implement erosion control in tributary watersheds	**Moderate** – Indirectly supports planning objective.	**Deleted** – Considerable benefit to tributaries. Independent action and would not directly contribute to improved ecological conditions near Shasta Lake or along mainstem Sacramento River.

Key:
GIS = geographic information system
O&M = operations and maintenance
USFS = U.S. Forest Service

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Improve Cold-Water and Warm-Water Fishery Habitat The following measures were identified to improve cold-water and warm-water fishery habitat.

- **Construct shoreline fish habitat around Shasta Lake –** Many of the shallow, warm-water areas along the shoreline of Shasta Lake are capable of providing preferred habitat for juvenile fish and other adult resident fish species. The shorelines of most natural lakes and water bodies are lined with trees, rocks, debris, and other structures that provide cover. However, the shoreline of Shasta Lake is comparatively barren, which increases juvenile mortality. The lack of shoreline cover and suitable shallow-water fish habitat is due to several factors, including steep topography, soils, wave action, and seasonal water fluctuations in the lake. These factors cause erosion and prevent vegetation from becoming established within the lake drawdown area. This measure consists of improving 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. This measure would not be universally applicable. It would be considered only at locations where the physical parameters (soils, slopes, existing vegetation, etc.) would allow. This measure would support the secondary planning objective of conserving and restoring ecosystem resources in the Shasta Lake area. It would not conflict with any other ecosystem restoration measures that were preliminarily retained, nor would it conflict with other known programs or projects in the vicinity of Shasta Lake. This measure was retained for potential inclusion in concept plans primarily because it would be compatible with potential measures to raise Shasta Dam; habitat treatments could be extended, as needed, into the additional drawdown area.

- **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 nonnative fish and other aquatic organisms. However, the quality and quantity of instream aquatic habitat has decreased over the last century because of the construction of dams, modification of stream hydrology, and other human influences. This measure consists of improving and restoring instream aquatic habitat on the lower reaches of key tributaries to Shasta Lake using various structural techniques to enhance fish passage and improve overall aquatic connectivity. It would not conflict with other known programs or projects in the vicinity of Shasta Lake. This restoration measure was retained for further consideration primarily because it would be compatible with potential measures to raise Shasta Dam and with other potential ecosystem restoration measures.

- **Increase instream flows on the lower McCloud River –** This measure consists of increasing releases from McCloud Dam for the purpose of increasing flows on the lower McCloud River. This measure would benefit fisheries on the lower McCloud River. Currently, McCloud Dam operations are part of the Pit-McCloud Hydroelectric Project. Water is exported from the McCloud River watershed through a tunnel to Iron Canyon Reservoir and from there to a powerhouse on the Pit River. Dam operations maintain minimum flows between 40 and 50 cfs on the lower McCloud River. This measure was deleted from further consideration for addressing the objective of ecosystem restoration primarily because of the considerable adverse impact on hydropower generation. However, it is a good example of a measure that may be reconsidered in the future to help mitigate adverse impacts.

- **Reduce acid mine drainage entering Shasta Lake –** This measure consists of remediating the residual adverse environmental impacts of abandoned former mining operations on aquatic conditions in Shasta Lake and its tributaries. This measure was deleted from further consideration because of numerous implementation issues, including high operations and maintenance (O&M) requirements necessary for success and liability issues. This measure may be reconsidered in the future to help mitigate adverse impacts.

- **Reduce motorcraft access to upper reservoir arms –** This measure consists of imposing additional boating and personal watercraft restrictions on portions of Shasta Lake. This measure was eliminated from further consideration primarily because motorcraft activity on Shasta Lake is already regulated by Federal and State boating laws, Shasta County, and USFS; additional regulations (if applicable) would be more appropriate as part of these existing programs.

- **Increase instream flows on the Pit River –** This measure consists of increasing instream flows on the lower Pit River to benefit native fish and aquatic habitat through performing power buy-outs, altering power generation operations, or removing selected water diversions or diversion facilities. This measure was eliminated from further consideration primarily because of the considerable adverse impact on hydropower generation from these existing facilities.

Restore and Conserve Riparian and Wetland Habitat Seven measures were identified to restore and conserve riparian and wetland habitat. Each measure is described below.

- **Restore riparian and floodplain habitat along the 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 is limited between Keswick Dam and the RBPP. This is partially due to the natural topography and hydrology 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. This measure consists of restoring riparian and floodplain habitat at specific locations along the Sacramento River to promote the health and vitality of the river ecosystem. It would not conflict with other ecosystem restoration measures that were preliminarily retained or with other known programs or projects on the upper Sacramento River. The restoration would support the goals of the Sacramento River Conservation Area Forum, CALFED, and other programs associated with riparian restoration along the Sacramento River. This measure was retained for further consideration primarily because it would have a high likelihood of success in accomplishing effective restoration and would indirectly benefit aquatic habitat conditions for anadromous fish.

- **Restore wetlands along the Fall River and Hat Creek –** This measure consists of restoring marshlands and wetlands along the Fall River and Hat Creek in the Pit River watershed. This measure was deleted from further consideration primarily because it is an independent action and would not directly contribute to accomplishing the primary or other secondary planning objectives.

- **Conserve upper Pit River riparian areas –** This measure primarily consists of conserving high-value existing stands of riparian vegetation along the upper Pit River through acquiring environmental easements, and installing fencing and natural vegetation barriers around riparian corridors affected by grazing animals. This measure was deleted from further consideration primarily because it is an independent action and would not directly contribute to accomplishing the primary or other secondary planning objectives.

- **Restore riparian and floodplain habitat along lower Clear Creek –** This measure includes restoring floodplain and riparian habitat along lower Clear Creek. This measure was deleted from further consideration primarily because it would not directly contribute to accomplishing the primary or other secondary planning objectives.

- **Promote Great Valley cottonwood regeneration on the Sacramento River –** This measure consists of actively supporting the Great Valley cottonwood regeneration concept along the Sacramento River. This includes working to replace lost floodplain sediment, recontouring floodplains that have disconnected from the river, and revegetating floodplain areas that could support Great Valley cottonwoods. This measure was deleted from further consideration primarily because (1) there would be major complexities associated with continuing Federal participation in an ongoing broad-scope program in the Sacramento Valley, and (2) it would not directly contribute to accomplishing the primary or other secondary planning objectives.

- **Conserve riparian corridor along Cow Creek –** This measure consists of protecting and conserving the riparian corridor along Cow Creek. It primarily includes acquiring environmental easements, installing livestock fencing, developing natural vegetation barriers, and replanting streamside grasses, shrubs, and trees. This measure would not directly contribute to improved ecological conditions along the upper Sacramento River. This measure was deleted from further consideration primarily because it would not directly contribute to accomplishing the primary or other secondary planning objectives.

- **Remove and control nonnative vegetation in the Cow Creek and Cottonwood Creek watersheds –** This measure consists of abating exotic vegetation in the Cow Creek and Cottonwood Creek watersheds through removing invasive species from riparian corridors. Periodic monitoring and reapplication of control measures would be required to maintain long-term benefits and effectiveness. In addition, this measure would likely have a limited ability to provide consistent and reliable benefits, compared with the other measures proposed. This measure was deleted from further consideration primarily because it would not directly contribute to accomplishing the primary or other secondary planning objectives.

Improve Other Fish and Wildlife Habitat The following measures were identified to improve other fish and wildlife habitat.

- **Create a parkway along the Sacramento River –** Interest is growing in conserving public access to area rivers, lakes, streams, and other natural resources, and protecting their recreational, environmental, and aesthetic values. For instance, local groups have successfully established public parks and other ecosystem-focused conservation areas around Redding. This measure consists of establishing a natural, riverfront parkway along the Sacramento River near the Redding and Anderson urban areas to conserve riparian and floodplain habitat and promote habitat continuity along the river corridor. While this restoration would support the goals of the Sacramento River Conservation Area Forum, CALFED, and other programs, it is primarily focused on acquisition of lands and land rights, and converting existing uses to those supporting public uses. Because of the high focus on land acquisition, there would be little known Federal interest and small potential to contribute to the primary or other secondary planning objectives of the SLWRI. In addition, elements of this measure are being implemented as part of other programs, and this measure is likely a without-project condition. Accordingly, this measure was deleted from further consideration in the SLWRI.

- **Enhance forest management practices to conserve bald eagle nesting habitat –** This measure consists of enhancing bald eagle nesting habitat at various locations around Shasta Lake through forest management practices, including thinning, applying insecticides to reduce mortality from bark beetles and other pests, control stocking in conifer stands to encourage growth of large trees, and managing underbrush to protect important stands from wildfires. This measure was deleted from further consideration primarily because it is a likely without-project condition.

- **Remove and control nonnative plants around Shasta Lake –** This measure consists of removing and controlling nonnative species at various locations around Shasta Lake primarily through herbicides, physical removal, or controlled burning. This measure was deleted from further consideration primarily because it is a likely without-project condition. Also, it is similar to programs being implemented in the study area by USFS.

- **Control erosion and restore affected habitat in the Shasta Lake area –** This measure consists of restoring highly erodible lands in the Sacramento River and Pit River watershed near Shasta Lake that have been impacted by timber harvest, historic smelter blight, and other human activities. This measure was deleted from further consideration primarily because it is a likely without-project condition. Also, it is similar to programs being implemented in the study area by USFS.

- **Develop geographic information system for Shasta to Red Bluff reach –** This measure consists of developing a geographic information system (GIS) for the Sacramento River and tributaries between Shasta Dam and the RBPP. This measure was deleted from further consideration primarily because (1) it would not directly contribute to accomplishing the primary planning objectives and (2) GIS-based mapping is being developed by numerous regional studies and local entities.

- **Implement erosion control in tributary watersheds –** This measure consists of implementing local erosion control projects in watersheds tributary to the Sacramento River to prevent loss of key floodplain and riparian habitat, and to conserve the quality of aquatic habitat impaired by excessive sediment input. This measure was deleted from further consideration as a potential restoration element primarily because it would not contribute to improved ecological conditions near Shasta Lake or along the upper Sacramento River and would not directly contribute to accomplishing the primary or other secondary planning objectives.

Measures Retained for Further Consideration

Each of the three management measures retained to address the secondary objective of ecosystem restoration in the Shasta Lake vicinity and along the Sacramento River downstream from Shasta Dam were considered in greater detail to determine how they might become components of concept plans. The locations of the retained measures are shown in Figure 2-6 and described below in terms of their major components, and accomplishments.

- **Construct shoreline fish habitat around Shasta Lake –** The shorelines of most natural lakes and water bodies are lined with trees, rocks, debris, and other structures that provide aquatic cover. But the shoreline of Shasta Lake and other reservoirs is comparatively barren, increasing juvenile fish 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. Shallow, warm-water areas along the shoreline of Shasta Lake provide preferred habitat for juvenile fish and other adult resident fish species. This measure would improve shallow, warm-water fish habitat at specific locations around the shoreline of Shasta Lake using resilient vegetation and aquatic "cover" structures within the upper drawdown area of the lake.

  This measure would involve (1) installing artificial fish cover, including complex woody structures, (2) planting water-tolerant and/or erosion-resistant vegetation at prescribed locations within the reservoir drawdown area, and (3) performing selective reservoir rim clearing of specific trees and vegetation. Applications would be chosen, as appropriate, for site-specific shoreline conditions, taking into consideration 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 could depend on the type of structure.

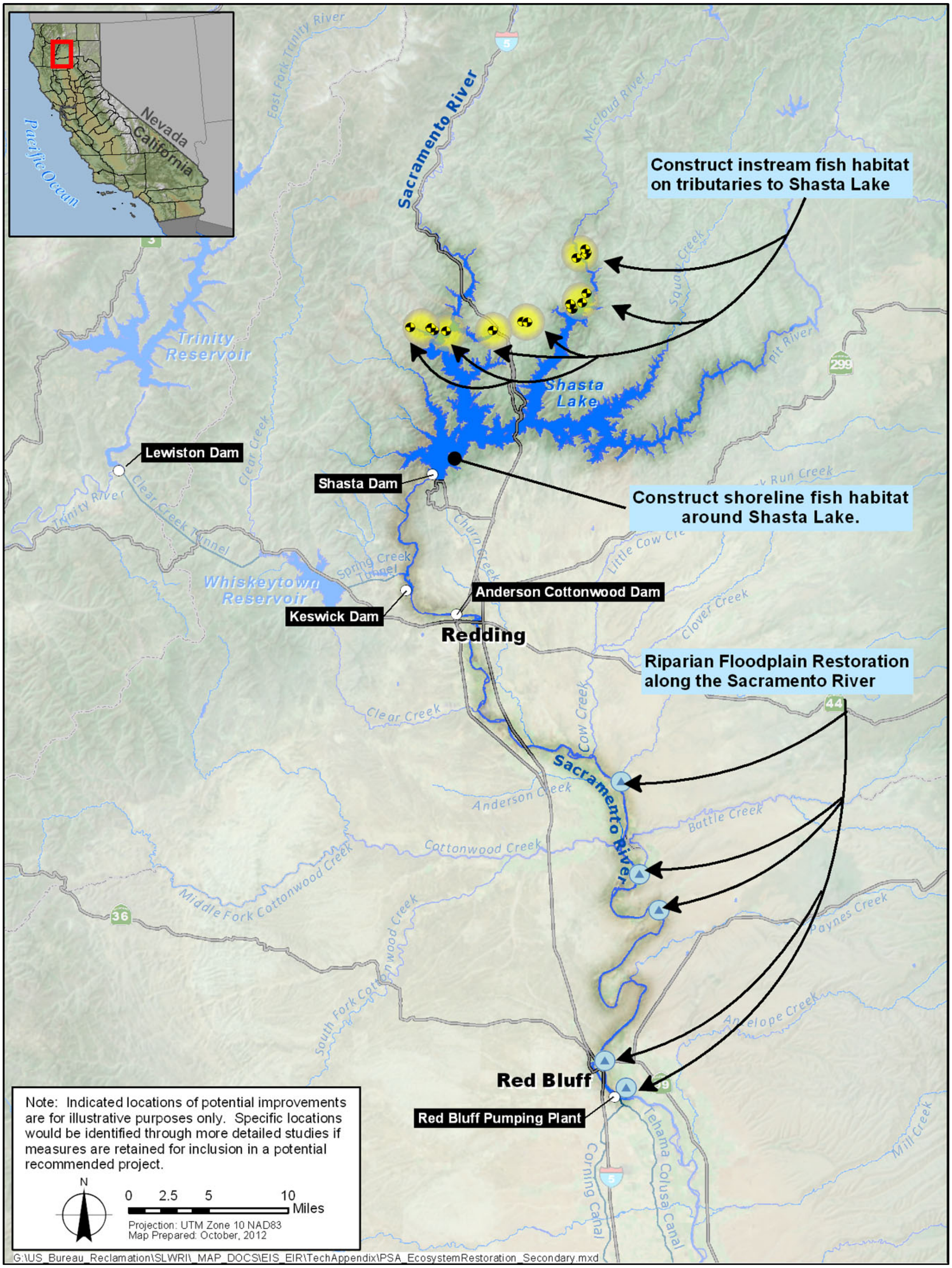

Figure 2-6. Measures Retained to Address Secondary Planning Objective – Ecosystem Restoration

It is estimated that locations near the mouths of tributaries would be targeted for restoration because their lower reaches provide favorable spawning conditions, and juvenile fish leaving the tributaries would benefit from improved adjacent shoreline habitat. Further, fishermen and other recreational users favor the mouths of tributaries. 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 considerable recreational disturbances (i.e., adjacent to marinas, picnic areas, campgrounds, or other areas that attract large numbers of people). Several major and minor tributaries to Shasta Lake 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 perennial tributaries would be selected with approximately 5 acres of shoreline suitable for restoration at each site. Other areas also may have a high potential and would be evaluated in future studies.

Major accomplishments of this measure would be to (1) increase the survival of juvenile fish by improving the quantity of available cover and overall quality of shallow-water habitat, and (2) benefit land-based species that inhabit the shoreline of Shasta Lake through establishing resilient vegetation. This measure would support the secondary planning objective of conserving and restoring ecosystem resources in the Shasta Lake area. Increased shallow-water fish survival also would enhance recreational sportfishing opportunities in the lake.

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

The estimated certainty of the measure in achieving its intended accomplishments is moderate, primarily because numerous factors affect the sustainability of habitat within the drawdown area of the lake. An adaptive management approach that would monitor and modify restoration elements would improve the likelihood of success.

- **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 nonnative fish and other aquatic organisms. However, the quality and quantity of instream aquatic habitat has decreased over the last century because of construction of dams, modification of stream hydrology, and other human influences. The quantity and quality of aquatic habitat in the tributaries of Shasta Lake are influenced primarily by the presence of road crossings and culverts, although in some cases other structures or grade controls (e.g., transitional deltaic deposits) may constitute barriers to aquatic connectivity, including fish passage. Barriers may also be created by adverse water quality conditions, particularly high water temperature or toxic materials. This measure would conserve and/or restore instream aquatic habitat on the lower reaches of key tributaries to Shasta Lake (see Figure 2-6).

Two categories of potential aquatic habitat enhancement in tributaries are discussed below: (1) identifying and correcting barriers to fish passage that are critical to various life stages for native fish species, particularly at culverts and other human-made barriers, and (2) identifying and implementing feasible aquatic habitat improvements intended to conserve or restore degraded aquatic and riparian habitat in tributaries to Shasta Lake.

Fish passage improvements include restoring and/or enhancing a minimum of five perennial stream crossings to help enable upstream and downstream passage for all life stages of native fish in Shasta Lake. Barriers to fish passage in the watersheds above Shasta Lake are primarily associated with culverts or other types of stream crossings. Typical passage problems created by culverts and other road crossings are as follows:

- Excessive drop at the downstream end of a crossing (perched outlet)

- Water velocities within the crossing that are too fast for fish to swim upstream

- Constriction of flow as it enters a crossing, causing excessive water velocities and turbulence at the inlet

- Lack of sufficient water depth in a culvert for fish to swim

- Debris accumulation across an inlet or within a culvert

Aquatic habitat restoration includes efforts to reestablish or enhance aquatic connectivity, and reestablish or conserve riparian vegetation needed to provide shade, cover, and organic material. Additionally, aquatic habitat restoration includes reducing sediment and other pollutants associated with roads and other human-made disturbances from discharging into streams flowing into Shasta Lake. These opportunities are consistent with recommendations developed in watershed assessments prepared by the Shasta-Trinity National Forest for lands in close proximity to Shasta Lake. The watershed assessments identify roads, specifically stream crossings, as opportunities for enhancing aquatic connectivity and reducing the impacts of road-related sediment on aquatic habitat. As with other elements of the aquatic enhancement program, it is anticipated that additional site evaluations would be conducted to prioritize opportunities based on available funding.

The lower reaches of intermittent and perennial streams tributary to Shasta Lake that support aquatic organisms native to the upper Sacramento River would be targeted for aquatic restoration under this measure because they provide year-round fish habitat. Although up to nearly 20 miles of stream could be considered for this measure, initial implementation would likely be restricted to larger tributaries, after which the potential to expand to smaller tributaries could be assessed. For this measure, it is estimated that instream aquatic restoration would be performed along a total of 8 miles of stream, or about 2 miles along the lower reaches of each of the four major tributaries to Shasta Lake. It is estimated that many of the restoration activities would be conducted on Federal lands.

Major accomplishment of this measure would be to improve the quality and availability of aquatic habitat on tributary streams. This measure would support the secondary planning objective of conserving and restoring ecosystem resources in Shasta Lake. Both native and nonnative 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, as some natural reproduction occurs on the lower reaches of the tributaries to Shasta Lake. Improving aquatic habitat also would enhance recreational sportfishing opportunities in the area.

This restoration measure would complement potential efforts to restore shoreline fish habitat in Shasta Lake because many juveniles that use shoreline habitat hatch on the lower reaches of the tributaries. Thus, 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 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.

The estimated certainty of this measure in achieving its intended accomplishments is high. 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. Similar activities have been accomplished with success on other similar stream systems. CDFW, the Cantara Trust, and the Coordinated Resource Management Plan group have participated in similar restoration activities in Shasta County. Restoration actions should be coordinated with local restoration groups, tribes, landowners, and CDFW, as appropriate.

- **Restore riparian and floodplain habitat along the 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 the RBPP. This measure consists of restoring riparian and floodplain habitat at specific locations along the Sacramento River to promote the health and vitality of the river ecosystem (see Figure 2-6).

  This measure would involve acquiring and revegetating floodplain terraces and adjacent riparian areas with native plants. Suitable locations for restoration would be in areas with a 20 percent to 50 percent chance of flooding in any year (commonly referred to as 2-year to 5-year floodplains). Locations near the confluences of perennial creeks and streams tributary to the Sacramento River would have potential to provide maximum benefits. 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. It is estimated that a limited amount of land 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.

  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, box elder, 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 1 to 4 years of initial planting, based on results of previous riparian restoration projects along the Sacramento River. Regraded floodplain areas are expected to change over time depending on hydrologic conditions, but it is anticipated that no elements of this measure would need to be replaced or reapplied during the 50-year project life. The site would be fenced to reduce the potential for access by livestock.

This measure would involve land acquisition, floodplain contouring and other earthwork, and revegetation. There appears to be local support for this type of restoration project along the Sacramento River. The primary accomplishment of this measure would be to restore native riparian habitat and associated floodplain lands. This measure would support the secondary planning objective of conserving and restoring ecosystem resources along the upper Sacramento River. 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 planning objective of increasing the survival of anadromous fish on the Sacramento River. 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.

This measure would combine favorably with potential measures to modify Shasta Dam because operational changes could benefit the natural riverine processes that drive sustainable riparian habitat regeneration. This measure would not conflict with other ecosystem restoration measures preliminarily retained, or other known programs or projects on the upper Sacramento River. Restoration would support the goals of the Sacramento River Conservation Area Forum, CALFED, and other restoration programs.

Reduce Flood Damage

Of five management measures identified to help reduce flood damages and contribute to public safety along the Sacramento River, two were initially retained for further development and possible inclusion in concept plans (Table 2-5). Of those two initially retained measures, one was carried forward for incorporation in comprehensive plans. Following is a brief description of the measures and rationale for retaining or deleting measures.

Table 2-5. Management Measures Addressing the Secondary Planning Objectives of Reducing Flood Damage, Developing Additional Hydropower Generation, Maintaining and Increasing Recreation, and Maintaining or Improving Water Quality

Management Measure	Potential to Address Planning Objective	Status/Rationale
Reduce Flood Damage		
Update Shasta Dam and Reservoir flood management operations	**Moderate to High** – Directly contributes to planning objective.	**Retained** – Compatible with any potential modification of Shasta Dam and Reservoir. Potential to realize an increase in flood control with increasing size of Shasta Reservoir for primary planning objectives. Would not conflict with other secondary planning objectives or planning constraints/criteria.
Increase flood management storage space in Shasta Reservoir	**Moderate** – Considerable potential to further reduce peak flows on upper Sacramento River; however, low potential to reduce flood damages due to the relatively high level of protection from existing facilities.	**Deleted** – Would conflict with the primary planning objectives. Estimated low potential for economic justification (costs are expected to exceed benefits). For increased space via raising Shasta Dam, it is expected that dam raise construction costs would considerably exceed flood control benefits. For space increase through reoperation, expected costs to replace reduction in water reliability would also considerably exceed flood control benefits.
Implement nonstructural flood damage reduction measures	**Moderate** – Partially contributes to planning objective.	**Deleted** – Independent action and not directly related to accomplishing the primary or other secondary planning objectives.
Implement traditional flood damage reduction measures	**Moderate** – Partially contributes to planning objective.	**Deleted** – Independent action and not directly related to accomplishing the primary or other secondary planning objectives.
Route PMF from top of conservation pool	**Moderate to High** – Directly contributes to public safety issues at Shasta Dam.	**Deleted** – This measure already is consistent with existing reservoir conditions and operations, making further changes unnecessary.
Develop Additional Hydropower Generation		
Modify existing/construct new generation facilities at Shasta Dam to take advantage of increased hydraulic head	**Moderate to High** – Directly contributes to planning objective.	**Retained** – Potential to realize an increase in hydropower output from Shasta with increasing size of Shasta Reservoir for primary planning objectives. Would not conflict with other secondary planning objectives or planning constraints/criteria.
Construct new hydropower generation facilities	**Moderate** – Directly contributes to planning objective.	**Deleted** – This measure would directly contribute to the secondary planning objective but it is an independent action and not directly related to accomplishing the primary planning objectives. Although potential to realize additional hydropower benefits with increased/replaced hydropower facilities, could be pursued regardless of primary planning objectives.

Table 2-5. Management Measures Addressing the Secondary Planning Objectives of Reducing Flood Damage, Increasing Hydropower, Maintaining and Increasing Recreation, and Maintaining or Improving Water Quality (contd.)

Management Measure	Potential to Address Planning Objective	Status/Rationale
Maintain and Increase Recreation Opportunities		
Maintain and enhance recreation capacity, facilities, and opportunities	**High** – Would directly contribute to planning objective.	**Retained** – Considerable potential to be added to alternatives to directly benefit recreation.
Develop new NRA recreation plan	**Low to Moderate** – Although contribute to planning objective, likely scope would be much greater.	**Deleted** – Developing a new NRA recreation plan is a completely separate process and should be pursued under that process. Scope is far beyond recreation being added as an increment to a water resources plan with the identified primary planning objectives for SLWRI.
Reoperate reservoir for recreation	**High** – Would directly contribute to planning objective.	**Retained** – Considerable potential to be added to alternatives to directly benefit recreation.
Maintain or Improve Water Quality		
Improve operational flexibility for Sacramento-San Joaquin Delta water quality by increasing storage in Shasta Reservoir.	**Moderate** – Would contribute to secondary planning objective	**Retained** – Potential to contribute to the secondary planning objective of maintaining or improving water quality conditions in the Sacramento River downstream from Shasta Dam and the Delta.

Key:
NRA = National Recreation Area
PMF = probable maximum flood
SLWRI = Shasta Lake Water Resources Investigation

- **Update Shasta Dam and Reservoir flood management operations –** This measure consists of revising the established rules for operating Shasta Dam and Reservoir for flood management. This measure would include reassessing existing seasonal flood control storage space needs at Shasta using updated information on regional hydrologic and meteorological conditions and rainfall/runoff characteristics in the drainage basin. Potential methods to improve flood control would include improved long-range weather forecasting, implementing additional forecast-based reservoir drawdown to provide additional space for anticipated high-flow events, changing criteria regarding the rate of outflows from Shasta Dam for flood control, and modifying target peak flows at Bend Bridge. This measure was retained for further consideration primarily because it would be compatible with any potential modification of Shasta Dam and Reservoir. It would not conflict with other secondary planning objectives, planning constraints, or criteria. As with reoperation for water supply reliability, although the concept of this measure is being retained for further development, its specific features and their influence on water supply reliability and flood damage reduction would not be developed until detailed operational modeling can be accomplished in further investigations as part of detailed alternative plan formulation in the SLWRI.

- **Increase flood management storage space in Shasta –** This measure consists of increasing the flood control storage space in Shasta Reservoir primarily through raising the dam or reducing water conservation storage space. A variation would be to substitute water conservation storage space in Shasta with storage in another reservoir, such as the NODOS project, and use vacant seasonal space in Shasta for increased flood control. However, it is estimated that potential flood damage reduction benefits to be gained from either action would be far less than the costs to create increased storage space, either in Shasta Reservoir or other facilities. For increased space resulting from raising Shasta Dam, it is estimated that the cost to raise the dam would considerably exceed potential flood control benefits. For space increase through reoperation, the expected costs to replace reduction in water reliability would also considerably exceed flood control benefits. This measure was deleted from further consideration primarily because it would likely conflict with the primary planning objectives. In addition, it would not be economically feasible (costs are expected to exceed benefits).

- **Implement nonstructural flood damage reduction measures –** Typical nonstructural (or nontraditional) flood damage reduction measures can include (1) flood-proofing (temporary or permanently closing structures, raising existing structures, and constructing small walls or levees around structures), (2) floodplain evacuation (moving structures and their contents to safer sites), (3) development of restrictions (restricting future building in flood-prone areas), and (4) flood warning (flood forecasting, warning, evacuation, and post-flood reoccupation and recovery). This measure was deleted from further consideration primarily because it is an independent action and would not be directly related to accomplishing the primary or other secondary planning objectives. Also, programs are already in place through Federal and State agencies to address flood hazard mitigation.

- **Implement traditional flood damage reduction measures –** Various structural methods to reduce flood damages include constructing levees or modifying the flood-carrying capacity of a river system. This measure was deleted from further consideration primarily because it is an independent action and would not be directly related to accomplishing the primary or other secondary planning objectives. Also, programs are already in place through Federal and State agencies to address flood hazard mitigation.

- **Route Probable Maximum Flood from top of conservation pool –** Shasta Dam can safely pass the computed Probable Maximum Flood (PMF). However, routing the PMF from the top of the conservation pool (4.5 MAF) would provide an additional margin of public safety in the event of an extremely rare flood event approaching or equaling the PMF. This measure was initially retained for development in concept plans, then deleted from further consideration during the comprehensive plan phase. Subsequent evaluation showed that existing reservoir operations and conditions already were consistent with this measure, making it unnecessary.

Develop Additional Hydropower Generation

Two measures were considered to increase hydropower potential in the study area (see Table 2-5). Following is a brief description of each measure:

- **Modify existing/construct new generation facilities at Shasta Dam to take advantage of increased hydraulic head –** This measure consists of modifying the hydropower generation facilities at Shasta Dam to take advantage of any increases in water surface elevations resulting from enlarging the dam, if applicable. Nearly all releases from Shasta and Keswick Dams are made through their generating facilities. On occasion, however, outflows during flood operations are made through the flood control outlets and over the spillway. During these instances, the existing powerplant is bypassed for much of the flood control (space evacuation) release. Power generated during these brief and infrequent periods generally has a lower value due to usually abundant supplies during winter periods. Raising Shasta Dam would allow the potential to reduce these flood releases in winter and allow water to pass through the generators later in the year when the water is usually more valuable. Further, with higher water surface elevation, greater energy levels (head) would be available for operating the turbines. With the greater total head, the existing power facilities, including turbines and penstocks, may need to be replaced, especially with large dam raises (e.g., 100- or 200-foot raises). This measure was retained for consideration as part of concept plans that include modifying Shasta Dam.

- **Construct new hydropower generation facilities –** This measure consists of constructing new hydropower facilities at Shasta Dam to increase the electrical generation capabilities from the project. This measure was deleted from further consideration primarily because it would not contribute either directly or indirectly to addressing the primary planning objectives and because it can be accomplished independently of modifying Shasta Dam and Reservoir.

Maintain and Increase Recreation Opportunities

Recreation is not a specific purpose to the Shasta Division of the CVP. No formal recreation facilities were developed as part of the original project. However, in Public Law 89-336 (8 November 1965), Congress established the Whiskeytown-Shasta-Trinity National Recreation Area (NRA). Resulting from that act and subsequent direction, nearly all lands surrounding Shasta Lake that were acquired for the construction and operation and maintenance of Shasta Dam and Reservoir are now within the NRA. Recreation-related activities on these lands and on Shasta Lake are administered by USFS under its responsibility to manage the NRA.

Increasing the storage in Shasta Lake would provide a larger water surface for recreation than exists today. Conversely, the larger lake area would also adversely impact some of the existing facilities and activities. It is believed that Reclamation has the authority to increase the size of Shasta Dam and Reservoir without the requirement to mitigate for adverse impacts to the existing Federal recreation-related facilities. However, doing so would be counterproductive to the planning objectives of maintaining and increasing recreation opportunities at Shasta Lake. In addition, raising Shasta Dam and Reservoir would also provide opportunities to improve recreation resources in the area.

Accordingly, the following general measures were identified to help maintain and increase recreation opportunities at Shasta Lake:

Maintain and Enhance Recreation Capacity, Facilities, and Opportunities

Major recreation activities at Shasta Lake include the following:

- Water skiing/wakeboarding
- Using personal watercraft
- Fishing

- Houseboating
- Canoeing/kayaking
- Swimming

Water-related land activities include the following:

- Camping
- Hiking and backpacking
- Wildlife viewing
- Picnicking
- Interpretive program

Recreation is not a specific purpose of the Shasta Division of the CVP, and no formal recreation facilities were developed as part of the original project. However, in 1965, Congress established the Whiskeytown-Shasta-Trinity NRA. As a result of that act and subsequent direction, USFS manages recreation within the NRA, which includes managing numerous water resources and related recreation activities at Shasta Lake. Increasing the storage in Shasta Lake would provide a larger water surface for recreation.

This measure would focus on maintaining existing recreation capacity at Shasta Dam and Lake through relocating and modernizing recreation facilities adversely affected by a higher lake level. It also includes enhancing opportunities related to the larger lake surface and modernized recreation facilities. This measure was retained for further development in the SLWRI.

- **Develop New NRA Recreation Plan –** USFS has indicated a desire to update the existing plan for the Whiskeytown-Shasta-Trinity NRA. USFS would like to use the opportunity created by raising Shasta Dam and Reservoir for that purpose. It is believed, however, that developing, coordinating, and implementing a new NRA plan is a separate Federal action and far outside the scope of the SLWRI. Accordingly, this measure was deleted from further consideration in the SLWRI.

- **Reoperate Reservoir for Recreation –** This measure consists of changing the established rules for operating Shasta Dam and Reservoir for flood management to benefit recreation resources on Shasta Lake. A claim by many of the recreation interests around Shasta Lake is that often the lake is forced to draw down in early spring for flood control and then, because of limited inflows the remainder of the season, the lake cannot recover, which adversely impacts recreation (as well as water supply). Locals cite 2004 as an example. They also claim that the existing reservoir operation rules for flood control are outdated (based on a USACE report dated 1977, nearly 30 years ago) and that by using more recent data and current technologies, the drawdown would not be required in some years, or would not be as significant. There is limited potential for changes in flood management rules to allow for more operational flexibility in reservoir drawdown requirements in response to storms with improved advanced forecasting. Additionally, with an increase in reservoir depth due to raising Shasta Dam, reservoir reoperation would likely include raising the bottom of flood control pool elevation, allowing for higher winter and spring water levels. This measure was retained for further consideration primarily because it may be compatible with any potential modification of Shasta Dam and Reservoir. In addition, it would likely be compatible with other primary and secondary planning objectives.

Maintain or Improve Water Quality

One management measure was considered to maintain or improve water quality in the study area (see Table 2-5). Following is a brief description of the measure, which was retained for further consideration:

- **Improve operational flexibility for Delta water quality by increasing storage in Shasta Reservoir –** This measure consists of providing improved operational flexibility for Delta water releases by providing additional storage in Shasta Reservoir. Shasta Dam has the ability to provide increased releases, as well as high flow releases, to reestablish Delta water quality. Improved Delta water quality conditions could provide benefits for both water supply reliability and ecosystem restoration by potentially increasing Delta outflow during drought years, and reducing salinity during critical periods. This measure was added to the comprehensive plans and was retained primarily because it had the potential to meet the secondary planning objective of maintaining or improving water quality conditions in the Sacramento River downstream from Shasta Dam and the Delta.

Measures Summary

Tables 2-6 and 2-7 summarize the water management measures that were carried forward for potential inclusion in concept plans to address the primary and secondary planning objectives, respectively. Those carried forward are believed to best address the objectives of the SLWRI, with consideration of planning constraints and criteria. It should be noted that measures that have been dropped from consideration at this stage might be reconsidered in the future as mitigation measures or other plan features. Similarly, additional measures not considered herein may be added to alternative plans as they are formulated.

Table 2-6. Measures Retained to Address the Primary Planning Objectives

Primary Planning Objective	Management Measure	
Increase Anadromous Fish Survival	Restore Spawning Habitat (Abandoned Gravel Mines)[1]	Restore abandoned gravel mines along the Sacramento River.
	Construct Instream Aquatic Habitat	Construct instream aquatic habitat downstream from Keswick Dam
	Replenish Spawning Gravel	Replenish spawning gravel in the Sacramento River.
	Modify TCD	Make additional modifications to Shasta Dam for temperature control.
	Enlarge Shasta Lake Cold-Water Pool	Enlarge Shasta Dam and Reservoir to increase the cold-water pool in the lake to benefit anadromous fish.
	Modify Storage and Release Operations at Shasta Dam	Modify storage and release operations at Shasta Dam to benefit anadromous fish
Increase Water Supply Reliability	Increase Conservation Storage	Increase conservation storage space in Shasta Reservoir by raising Shasta Dam.
	Conjunctive Water Management[1]	Develop conservation groundwater storage near the Sacramento River downstream from Shasta Dam.
	Reoperate Shasta Dam	Increase the effective conservation storage space in Shasta Reservoir by increasing the efficiency of reservoir operation for water supply reliability.
	Reduce Demand	Identify and implement, to the extent possible, water use efficiency methods.

Notes:
[1] These measures were retained for development in concept plans in the initial alternatives phase, but were later eliminated from further consideration during the comprehensive plans phase.
Key:
TCD = temperature control device

Table 2-7. Measures Retained to Address the Secondary Planning Objectives

Secondary Planning Objective	Management Measure	
Conserve, Restore, and Enhance Ecosystem Resources	Restore Shoreline Aquatic Habitat	Construct shoreline fish habitat around Shasta Lake.
	Restore Tributary Aquatic Habitat	Construct instream fish habitat on tributaries to Shasta Lake.
	Restore Riparian Habitat	Restore riparian and floodplain habitat along the upper Sacramento River.
Reduce Flood Damage	Modify Flood Operations Guidelines	Update Shasta Dam and Reservoir flood management operations.
	Route PMF From Top of Conservation Pool[1]	Route the Probable Maximum Flood from the top of the conservation pool in Shasta Reservoir.
Develop Additional Hydropower Generation	Modify Hydropower Facilities	Modify existing/construct new generation facilities at Shasta Dam to take advantage of increased head.
Maintain and Increase Recreation	Maintain and Enhance Recreation Facilities	Maintain and enhance recreation capacity, facilities, and opportunities.
	Reoperate Reservoir	Increase recreation use by stabilizing early season filling in Shasta Lake.
Maintain or Improve Water Quality	Increase Operational Flexibility	Improve operational flexibility for Delta water quality by increasing storage in Shasta Reservoir.

Notes:
[1] These measures were retained for development in concept plans in the initial alternatives phase, but were later eliminated from further consideration during the comprehensive plans phase.
Key:
PMF = Probable Maximum Flood

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Chapter 3 Shasta Dam and Reservoir Enlargement Scenarios

This chapter summarizes information developed on enlargement scenarios for Shasta Dam and Reservoir and identifies potential sizes recommended for further development into concept plans.

In the 1999 Reclamation report titled *Appraisal Assessment of the Potential for Enlarging Shasta Dam and Reservoir* (Reclamation 1999), an evaluation was made of the major features, issues, and costs associated with three potential raise scenarios for Shasta Dam and Reservoir: Low-Raise Option (6.5-foot raise), Intermediate-Raise Option (102.5-foot raise), and High-Raise Option (202.5-foot raise). Information from the report was reviewed and is summarized in this appraisal-level assessment.

A breakpoint analysis was conducted in early 2003 to identify the elevations of Shasta Dam raises for which implementation costs would considerably change due to the need for relocations or modifications of major project features (Reclamation 2004a). The analysis identified two fundamental cost components associated with raising Shasta Dam and enlarging Shasta Reservoir: (1) modifying the main dam and appurtenances and (2) modifying reservoir infrastructure and facilities. It was concluded in the analysis that the first major breakpoint in costs for increasing the size of Shasta Reservoir would occur with a top-of-full-pool raise from elevation 1,067 to about elevation 1,087.5 (20.5-foot raise), which would correspond to a dam raise of about 18.5 feet. This is primarily due to the need to relocate the Pit River Bridge with dam raises greater than about 18.5 feet. The second major breakpoint would occur with a top-of-full-pool raise to about elevation 1,100, which would correspond to a dam raise of about 30 feet. Raises of up to about 30 feet could likely be accomplished by raising the existing dam crest while higher dam raises would require increasing the dam mass, and constructing cofferdams and other facilities. Accordingly, two additional dam raise scenarios (approximately 18.5 and 30 feet) were developed in an effort to assess the relationship between the height of a dam raise and resulting cost of new water supplies.

Information is presented below on (1) rationale for establishing a dam raise of 18.5 feet and (2) the three scenarios included in the 1999 report and two expanded low-level dam raise scenarios. Also included is a comparison of the various dam raise scenarios.

Rationale for 18.5-Foot Dam Raise

As mentioned, it is estimated that the Pit River Bridge would need to be relocated for Shasta Dam raises greater than about 18.5 feet. A dam raise of 18.5 feet would allow for an increase in the full pool by about 20.5 feet or from elevation 1,067 to about elevation 1,087.5. Even with dam raises up to 18.5 feet, considerable modifications would need to be made to two piers of the bridge. These modifications are described in the Engineering Summary Appendix.

Figure 3-1 shows an elevation view of the Pit River Bridge south Abutment Number 2. Correspondence from the Union Pacific Railroad Company (UPRR) identified a minimum clearance between the low cord of the bridge and an increased water surface of 4 feet. The lowest point of the Pit River Bridge is at the south end of the structure. For this project, a minimum clearance of 1 foot below the south abutment bearing attachment to the main bridge structure was selected. This would allow a minimum clearance of 4.5 feet between the new full pool elevation and the main bridge structural elements.

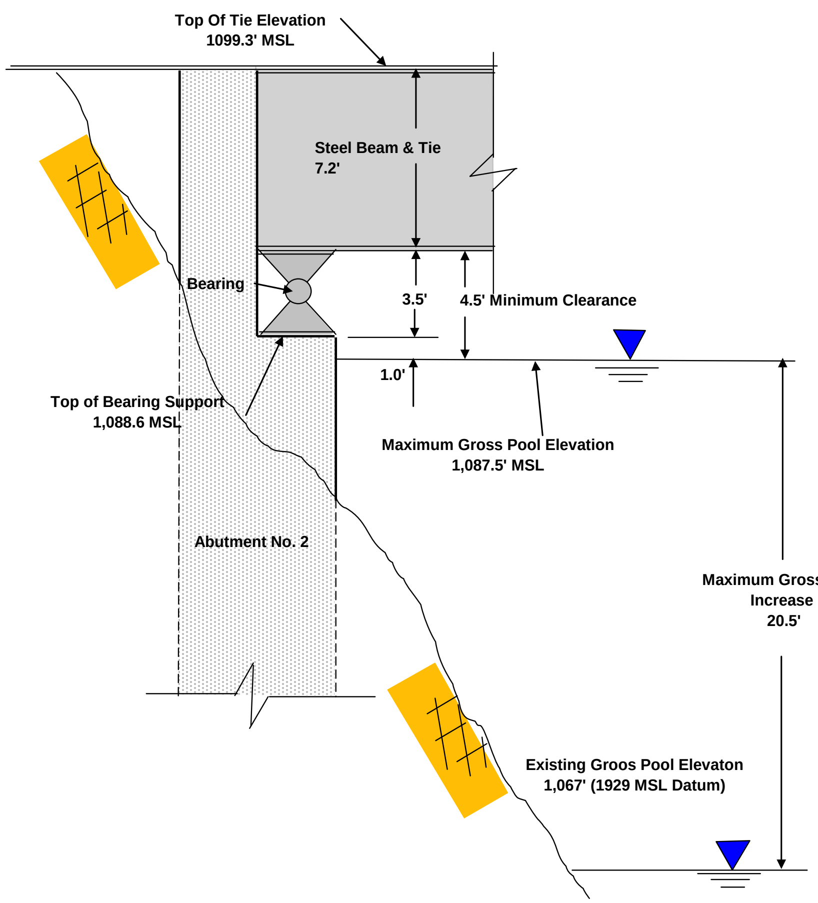

Figure 3-1. Elevation Sketch Showing the South End of the Pit River Bridge with Respect to the Existing and Increased Full Pool Elevation at Shasta Lake

It should be mentioned that storage in Shasta Reservoir, with or without raising the dam, is expected to reach full pool elevation in the future about as often it has in the past. This occurs to about once every 3 to 4 years, after the flood season, usually in May and/or early June. Durations would be only several days at the maximum elevation, but the high water condition could last several weeks. The south end of the Pit River Bridge is about 11 feet lower than the north end of the structure. Accordingly, the likely minimum clearance between the bridge and full pool elevation available for boat traffic during high water periods would be about 15 feet.

Dam Raise Scenarios

Following is a description of the three dam raise scenarios included in the 1999 appraisal report (Reclamation 1999) and two expanded low-level scenarios.

Low-Level Raise – 6.5 Feet

Major components, accomplishments and costs, system yield, implementation costs, and unit costs for the low-level raise (6.5 feet) are described in this section.

Major Components

The 6.5-foot Low-Level Raise scenario consists of a structural dam raise of 6.5 feet with a new enlarged crest elevation at 1,084 feet. This scenario would have a new top of joint-use storage space at elevation 1,075.5, and result in an additional 8.5 feet of water in the reservoir. The total capacity of this new reservoir would be 4.84 MAF, which is an increase of 256,000 acre-feet above the existing available storage. At full pool storage, the reservoir would cover about 30,700 acres, which is an increase of about 1,100 acres over existing conditions (4 percent increase). Table 3-1 lists major features associated with this dam raise scenario.

Table 3-1. Shasta Dam and Reservoir Enlargement Features

Item	Baseline	Low-Level Raise – 6.5 Feet	Expanded Low-Level Raise – 18.5 Feet	Expanded Low-Level Raise – 30 Feet	Inter-mediate-Level Raise – 102.5 Feet	High-Level Raise – 202.5 Feet
Dam Crest Raise (feet)	NA	6.50	18.50	30.00	102.50	202.50
Dam Crest Elevation (feet)	1,077.50	1,084.00	1,096.00	1,107.50	1,180.00	1,280.00
Full Pool Raise (feet)	NA	8.50	20.50	32.00	104.50	204.50
Full Pool Elevation (feet)	1,067.00	1,075.50	1,087.50	1,099.00	1,171.50	1,271.50
Reservoir Capacity (MAF)	4.55	4.81	5.19	5.57	8.47	13.89
Surface Area @ Full Pool Elevation (acres)	29,600	30,700	32,100	33,700	44,200	60,800
Capacity Increase (MAF)	NA	0.26	0.63	1.02	3.92	9.34

Key:
MAF = million acre-feet
NA = not applicable

The dam raise would be limited to the existing dam crest and appurtenant structures only, with mass concrete placed in blocks on the existing concrete gravity section and precast concrete panels used to retain compacted earthfill placed on wing dam embankment sections. A new spillway crest section would be developed within the raised structure. Control features of the existing TCD would be extended up to the new crest elevation and the main TCD enclosure would be extended to the new full pool elevation.

Although the raised dam crest construction would remain above the new top of joint-use storage, and provide for flood surcharge only, waterstops and other seepage control measures would be provided. However, with a new full pool elevation of 1,075.5, about seven existing vehicle and railroad bridges would need to be either considerably modified or relocated. Table 3-2 lists estimated infrastructure impacts associated with various increases in full pool. Minor modifications to the Pit River Bridge, which carries Interstate 5 (I-5) and the Water Use Efficiency near Bridge Bay, would be required with this scenario.

The expanded full pool would impact about 45 structures, which would need to be removed or relocated (see Figure 3-2). However, few impacts would occur to reservoir rim ecosystem resources or reservoir-area developed properties.

1 **Table 3-2. Reservoir Infrastructure Impacts and Actions for Elevations 1,070 – 1,280[1]**

New Top of Joint-Use Elevation	Impact Remediation Actions
1,072	Relocate UPRR Doney Creek Bridge, UPRR Sacramento River Bridge (2nd Crossing), relocate segment of Bully Hill Road impacted on Squaw Creek Arm
1,073	Relocate portion of Lakeshore Drive impacted by Charlie Creek Bridge
1,074	Relocate McCloud River Bridge and Didallas Creek Bridge; relocate portion of Silverthorn Road impacted on Pit River Arm
1,075	Relocate Second Creek Bridge
1,076	Relocate portion of Lakeshore Drive impacted by Doney Creek Bridge
1,077	Relocate portion of impacted Conflict Point Road (on north side of Salt Creek)
1,078	Build embankment for UPRR at Bridge Bay
1,080	Build embankment for I-5 at Lakeshore; relocate portion of Gilman Road impacted near McCloud Bridge, and portion of Fender Ferry Road impacted near McCloud Bridge
1,090	Relocate UPRR Lakeshore Drive Overcrossing by Charlie Creek
1,091	Relocate Pit River Bridge; relocate UPRR Sacramento River Bridge (2nd Crossing); relocate portion of I-5 impacted by Lakeshore (not necessary with protective dike)
1,094	Relocate UPRR Lakeshore Drive Overcrossing by Doney Creek
1,096	Relocate Wittawaket Creek Bridge and UPRR Sacramento River Bridge, 3rd Crossing
1,097	Relocate UPRR I-5 overpass
1,099	Relocate Squaw Creek Bridge
1,100	Begin to remediate impacts to Silverthorn community (population 1,100 to 1,250)
1,105	Relocate portion of West Side Road impacted at Squaw Creek Bridge
1,106	Reservoir full pool at top of powerhouse at Pit 7 Dam[2]
1,109	Relocate UPRR Sacramento River Bridge, 4th Crossing
1,110	Relocate UPRR Dog Creek Bridge
1,111	Relocate UPRR Salt Creek Bridge
1,114	Relocate Fender Ferry Bridge (Sacramento River near Delta)
1,134	Jones Valley Dike becomes necessary
1,135	Relocate Fender Ferry Bridge (upper Pit River)
1,143	Relocate Tunnel Gulch Viaduct on I-5; relocate UPRR O'Brien Creek Bridge
1,150	Begin to remediate impacts to town of Delta (population 1,150 to 1,190)
1,165	Begin to remediate impacts to town of Pollock (population 1,165 to ~1,220)
1,170	Begin to remediate impacts to town of Lakehead (population 1,170 to ~1,220)
1,172	Relocate UPRR O'Brien Creek Bridge
1,180	Clickapudi Cove Dike becomes necessary
1,230	Bridge Bay and Centimundi dikes become necessary
1,278	Reservoir full pool at crest of Pit 7 Dam[2]

Notes:
[1] This table does not include impacts to specific buildings. Impacted portions of roads, communities, and other infrastructure would be relocated where possible. In cases where relocation is not feasible, facilities may need to be abandoned.
[2] Specific remediation actions at the Pit 7 Dam have not yet been determined. The elevation at which the dam would likely need to be abandoned is between elevation 1,106 (powerhouse yard floor) and elevation 1,278 (crest of dam).
Key:
Delta = Sacramento-San Joaquin Delta
I-5 = Interstate 5
UPRR = Union Pacific Railroad

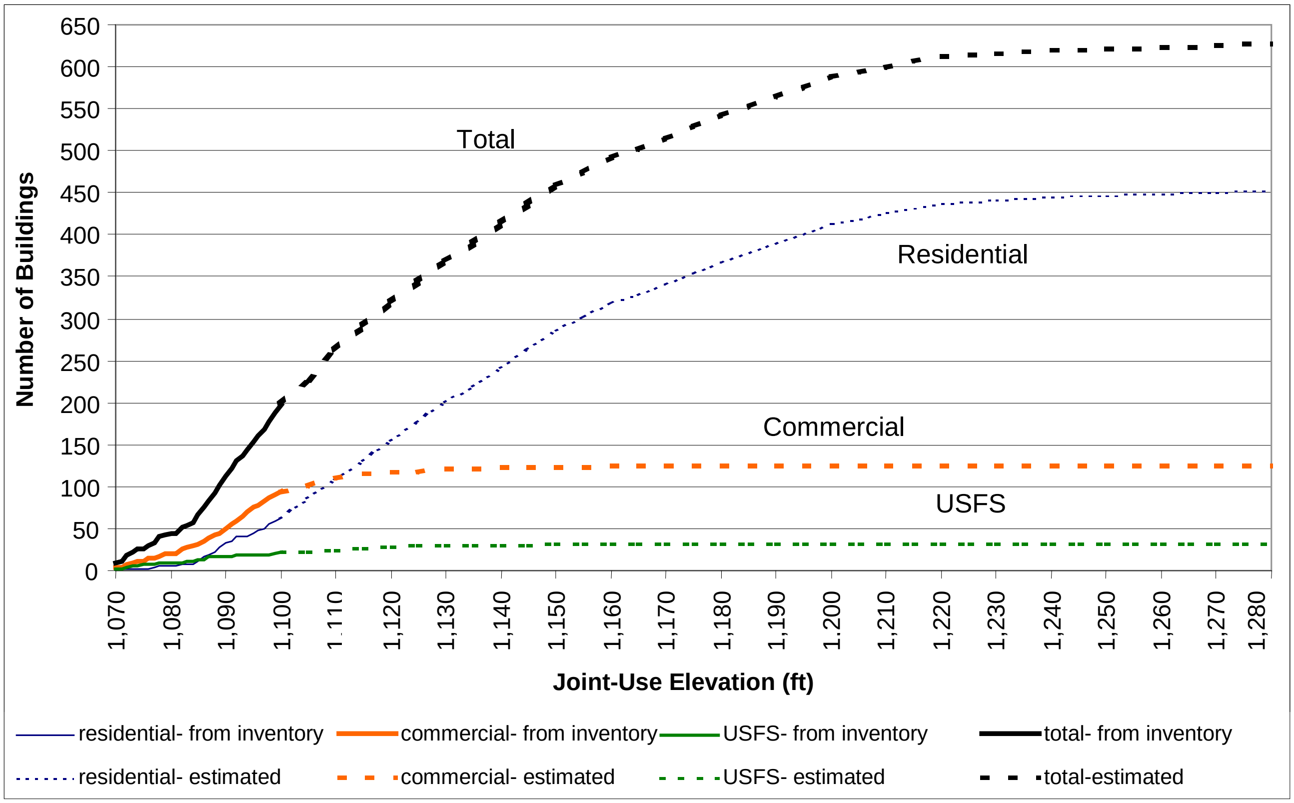

Figure 3-2. Estimated Number of Structures Affected by Increasing the Height of Shasta Dam and Reservoir

Accomplishments and Costs

Although not to the extent of higher raises and associated larger reservoir sizes, this scenario would have the potential to contribute to both primary planning objectives and is also consistent with the goals in the CALFED ROD (CALFED 2000). It could support each of the secondary planning objectives and help increase anadromous fish survival by creation of a small increased cold-water pool. In addition, it could help reduce flood damage along the upper Sacramento River, increase hydropower generation, and slightly increase potential reservoir area recreation opportunities. It would also have minor impacts on the McCloud River and associated issues relating to the State special designation of that waterway.

System Yield

Water system operation studies for the CVP and SWP were made using the CalSim-II mathematical model for the five dam raise scenarios described in this section. Table 3-3 compares annual yield for simulated CVP and SWP deliveries for average year and drought year, conditions with Banks Pumping Plant capacity at 6,680 cfs, for various Shasta Dam raise scenarios. The table shows the relative increase in reliability of each dam raise scenario to meet future demands. As expected, higher dam raise scenarios have a considerably higher potential to meet future demands.

It should be mentioned that the estimated system yield shown in Table 3-3, which was estimated in 2003, differs from that shown in other sections of this appendix and in the main report. This is due to continuing updates in the CalSim-II model. It is important to understand that these differences in system yields would not change the fundamental conclusions reached concerning cost efficiencies associated with relative increases of Shasta Dam and Reservoir.

Table 3-3. CVP/SWP System Yield Increase (2003 Estimates)

Dam Raise	Average Year Conditions[1] (TAF per year)	Drought Year Conditions[1] (TAF per year)
Low-Level Raise – 6.5 Feet	48	72
Expanded Low-Level Raise – 18 Feet	71	125
Expanded Low-Level Raise – 30 Feet	110	185
Intermediate-Level Raise – 102.5 Feet	214	425
High-Level Raise – 202.5 Feet	331	703

Note:
[1] Yields differ from other sections of appendix and main report due to update of CalSim-II model used. Differences are relative and do not change the overall conclusions reached.
Key:
CVP = Central Valley Project
SWP = State Water Project
TAF = thousand acre-feet

Preliminary Implementation Costs Preliminary estimates of total first and annual costs for Shasta Dam raise scenarios were developed for relative comparison purposes. Costs were based primarily on updating information contained in Reclamation’s 1999 appraisal report to October 2003 price levels, a 5-5/8 percent interest rate, and a 100-year analysis period. Estimated costs are summarized in Table 3-4.

It should be mentioned that, as with system yield above, the costs shown here will differ from those shown elsewhere in this appendix and in the main report. This is primarily due to updates in cost estimates and price level changes. However, it is important to note that these changes would not change the fundamental conclusions reached concerning cost efficiencies associated with relative increases of Shasta Dam and Reservoir.

Table 3-4. First and Annual Costs for Dam Raise Options

Dam Raise Options	First Cost @ 2003 Price Levels ($millions)1	Annual Costs @ 2003 Price Levels ($millions)2
Low-Level Raise	282	19
Expanded Low-Level Raise – 18.5 Feet (without major relocations)	408	28
Expanded Low-Level Raise – 18.5 Feet (with major relocations)	1,060	75
Expanded Low-Level Raise – 30 Feet (block raise)	1,250	89
Expanded Low-Level Raise – 30 Feet (mass raise)	1,330	94
Intermediate-Level Raise – 102.5 Feet	3,890	283
High-Level Raise – 202.5 Feet	5,250	383

Notes:
[1] Most information updated by price levels and interest rates from May 1999 Shasta Dam and Reservoir Enlargement, Appraisal Assessment, by Reclamation. October 2003 price levels.
[2] Construction period of 6 years for lower raise scenarios, and 8 to 10 years for higher raise scenarios. Average annual costs based on 5-5/8 percent over a 100-year project life.

Figure 3-3 shows the estimated first cost for each scenario; two cost estimates were developed for each Expanded Low-Level Raise scenario. The intent of the two estimates was to determine the influence of major cost breaks or jumps resulting from implementing major relocations for the 18.5-foot raise scenario, and additional dam construction costs for the 30-foot raise scenario. Cost estimates for each Expanded Low-Level Raise scenario in the table are based primarily on interpolating costs between the Low-Level and Intermediate-Level raises.

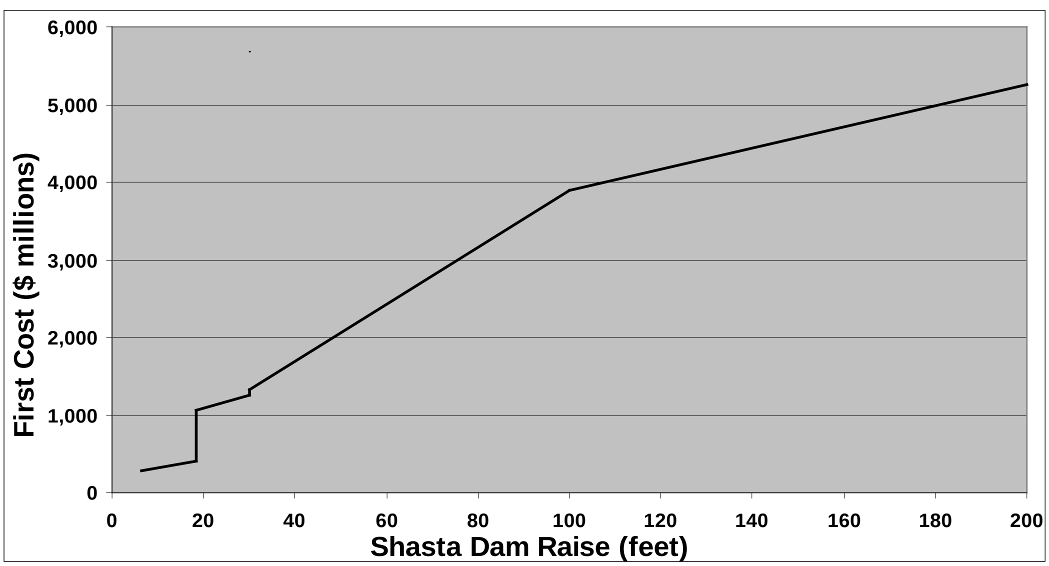

Figure 3-3. Estimated First Cost for Various Shasta Dam Raises at 2003 Price Levels

Unit Costs Table 3-5 summarizes the estimated total storage, water supply yield, and first and annual costs for each scenario considered. The table also shows the estimated unit cost of water for the various dam raise scenarios, and estimates of unit costs for the two Expanded Low-Level scenarios, including major relocations and dam construction costs at estimated major breakpoints. The total storage unit cost in the table is the estimated cost to develop an acre-foot of new storage. Total storage unit cost is the total first cost divided by the additional storage created by the scenario. The unit cost for new water supply yield is computed using estimates of both average annual and drought yield. Unit cost information from Table 3-5 as a function of new dam crest elevation was used to create the plot in Figure 3-4. The need for major relocations (primarily for I-5 and UPRR facilities) for a dam raise of about 18.5 feet (elevation 1,095) has a dramatic effect on the estimated unit cost for new storage and new water supplies at Shasta. The need to change construction methods for a dam raise of about 30 feet (elevation 1,107.5) has a considerably smaller influence.

Table 3-5. Water Supply Unit Cost Summary (2003 conditions)

Description	Low-Level Raise – 6.5 Feet	Expanded Low-Level Raise – 18.5 Feet		Expanded Low-Level Raise – 30 Feet		Inter-mediate-Level Raise	High-Level Raise
		Without Bridges	With Bridges	Block Raise	Mass Raise		
Added Storage (1,000 acre-feet)	256	634	634	1,020	1,020	3,920	9,340
Yield (1,000 acre-feet per year)							
- Average Annual	48	71	71	110	110	214	331
- Drought Year	72	125	125	185	185	425	703
Unit Cost ($/acre-foot) [1]							
- Total Storage[2]	970	640	1,670	1,230	1,300	990	560
- Yield – Average Annual[3]	410	400	1,050	810	850	1,320	1,160
- Yield – Drought Year[4]	270	225	600	480	510	670	550

Notes:
[1] First cost divided by increase in total storage.
[2] Annual cost divided by average annual yield.
[3] Annual cost divided by drought year yield.

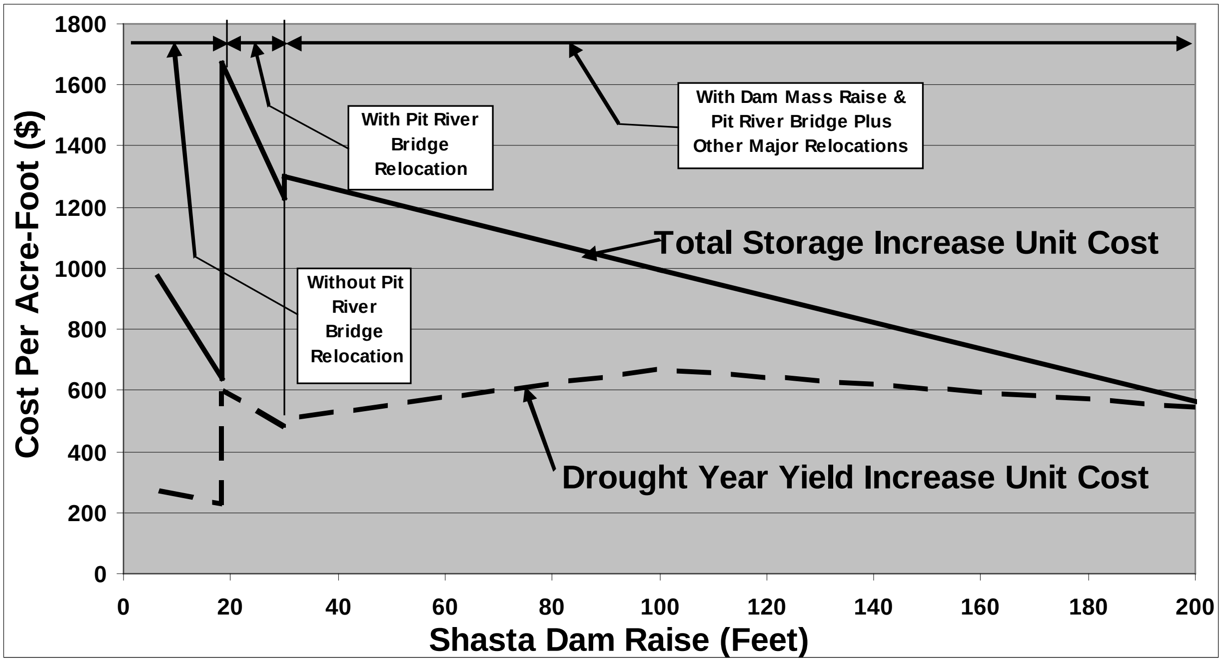

Figure 3-4. Plot of Total Storage and Water Supply Reliability Yield Unit Cost (2003 price levels) for Various Increases of Shasta Dam Raise

Expanded Low-Level Raise – 18.5 Feet

Major components, accomplishments, and costs for the Expanded Low-Level Raise (18.5 feet) are described in this section.

Major Components

This scenario consists of a structural dam raise of 18.5 feet with a new crest at elevation 1,096. The total capacity of this new reservoir would be 5.19 MAF, which is an increase of 634,000 acre-feet above the existing available storage. At full pool storage, the reservoir would cover about 32,100 acres, which is an increase of about 2,500 acres over existing conditions (9 percent).

The dam raise would be limited to the existing dam crest and appurtenant structures only, with mass concrete placed in blocks on the existing concrete gravity section and concrete wing dams constructed on both abutments. A new spillway crest section would be developed within the raised structure. Control features of the existing TCD would be raised up to the new crest elevation and the main TCD enclosure would be extended to the new full pool elevation.

The 18.5-foot Expanded Low-Level Raise scenario would require a new crest roadway, spillway bridge, elevators, gantry crane, and associated mechanical equipment required for operating the various outlet gates, TCD, and other features. Although the raised dam crest construction would remain above the new top of joint-use storage, and provide for flood surcharge only; waterstops and other seepage control measures would be provided.

As can be determined from Table 3-2, with the increased full pool at elevation 1,087.5, an estimated seven bridges in the reservoir area would need to be modified and/or relocated. Pending the results of additional analysis, it appears that this scenario represents the likely greatest dam raise without full relocation of I-5 and the UPRR Pit River Bridge at Bridge Bay. Even at a full pool elevation increase of 20.5 feet, the water surface would encroach to within 4 feet of the low cord of the bridge, which is believed to be the minimum freeboard allowable before full relocation for railroad bridges. To prevent adverse impacts to two bridge piers (Piers 3 and 4) resulting from periodic inundation, the project would include constructing a skirting system around the upper portions of the piers. For clearance for houseboats, a maximum full pool raise would be limited to about 14 feet. However, it is believed that because of the infrequent occurrences of the water surface reaching full pool during high recreation periods, appropriate mitigation features can be included for this scenario.

The expanded full pool area would require about 130 structures (2003 estimate) to be removed or relocated (see Figure 3-2). Relatively minor impacts would occur to reservoir rim ecosystem resources. However, this scenario also includes relocating many reservoir area recreation facilities.

Accomplishments and Costs

This scenario would contribute considerably to both primary planning objectives. It also could support each secondary planning objective. Increasing the full pool storage at Shasta Reservoir by about 634,000 acre-feet by raising the dam 18.5 feet would increase the average annual and annual drought year yield based on 2003 CalSim-II modeling assumptions by about 71,000 and 125,000 acre-feet (67,000 and 133,000 acre-feet in 2006 evaluations), respectively (see Table 3-5). It could also help increase anadromous fish survival by increasing the cold-water pool. In addition, it could help reduce flood damages along the upper Sacramento River, and increase hydropower generation. It would slightly increase potential reservoir area recreation opportunities. This scenario is generally consistent with the goals and objectives in the 2000 CALFED ROD. It would have minor and manageable impacts on the McCloud River and issues relating to the State special designation of that waterway.

As shown in Table 3-4, to accomplish this magnitude of dam raise without major reservoir area relocations, the estimated first cost based on 2003 price levels for this scenario would be about $408 million. The estimated average annual cost would be about $28 million. This would result in a unit cost for the new storage space in Shasta Reservoir of about $640 per acre-foot (Table 3-5). The resulting estimated unit costs for average annual and drought year yield would be about $400 and $225 per acre-foot, respectively (see Figure 3-4).

Tables 3-4 and 3-5 and Figures 3-3 and 3-4 also show the estimated impact on the first, annual, and unit costs for an 18.5-foot dam raise, including the possible relocation of I-5 and the UPRR Pit River Bridge at Bridge Bay. It is believed that this relocation would be needed for a dam raise greater than about 18.5 feet. With these additional relocations, the first cost would increase to an estimated $1.06 billion. The estimated total unit storage cost would increase to about $1,670 per acre-foot. The estimated unit cost for average annual and drought year yield would be about $1,050 and $600 per acre-foot, respectively.

Expanded Low-Level Raise – 30 Feet

Major components and accomplishments and costs for the Expanded Low-Level Raise (30 feet) are described in this section.

Major Components

This scenario consists of a structural dam raise of 30 feet with a new crest at elevation 1,107.5 (see Table 3-1). This scenario would have a new top of joint-use (full pool) storage space at elevation 1,099, resulting in an additional 32 feet of water in the reservoir. The total capacity of this new reservoir would be 5.57 MAF, an increase of 1.02 MAF above the existing available storage. At full pool storage, the reservoir would cover about 33,700 acres, which is an increase of about 4,100 acres over existing conditions (14 percent).

This scenario represents the likely greatest dam raise without major modification of the dam mass (concrete overlay on downstream face) and replacement of wing dams, river outlets, and penstocks. The dam raise would be limited to the existing dam crest and appurtenant structures only, with mass concrete placed in blocks on the existing concrete gravity section and concrete wing dams constructed on both abutments. A new spillway crest section would be developed within the raised structure. Control features of the existing TCD would be raised up to the new crest elevation and the main TCD enclosure would be extended to the new full pool elevation.

The 30-foot Expanded Low-Level Raise scenario would require a new crest roadway, spillway bridge, elevators and gantry crane, and associated mechanical equipment required for operating the various outlet gates, TCD, and other features. Although the raised dam crest construction would remain above the new top of joint-use storage, and provide for flood surcharge only, waterstops and other seepage control measures would be provided.

The expanded full pool area would require about 200 structures to be removed or relocated (see Figure 3-2). This scenario would also result in impacts to various major and minor transportation, recreation, hydropower, and other reservoir area facilities. In addition, it would require replacement of the Pit River Bridge at Bridge Bay and 12 other major and minor reservoir area bridges and roadway segments. Also, most recreational facilities would require relocation. Considerable impacts to reservoir rim and tributary stream ecosystem resources would occur.

Accomplishments and Costs

This scenario also would contribute considerably to both primary planning objectives and support each of the secondary planning objectives. Increasing the full pool storage at Shasta Reservoir by over 1 MAF through raising the dam 30 feet would increase the average annual and annual drought year yield to the CVP by an estimated 110,000 and 185,000 acre-feet, respectively (see Table 3-5). It could help increase anadromous fish survival by creating an increased cold-water pool. In addition, it could help reduce flood damages along the upper Sacramento River, and increase hydropower generation. It would increase potential reservoir area recreation opportunities. This scenario is generally consistent with the goals and objectives in the 2000 CALFED ROD. It would, however, have impacts on the lower McCloud River and issues relating to the State of California Species of Special Concern designation in that watershed.

As shown in Table 3-4 and Figure 3-3, the estimated first cost based on 2003 price levels for this scenario would be about $1.25 billion. The estimated average annual cost is $89 million. This would result in a unit cost for the new storage space in Shasta Reservoir of about $1,230 per acre-foot (Table 3-5). Estimated unit costs for average annual and drought year yield would be about $810 and $480 per acre-foot, respectively.

It is believed that for dam raises greater than about 30 to 50 feet, the existing concrete gravity dam section would need to be raised using a mass concrete overlay as opposed to raising the dam using concrete blocks. Tables 3-4 and 3-5 and Figures 3-3 and 3-4 also show the estimated impact on first, annual, and unit costs for a 30-foot dam raise, including this change in construction method. With the mass concrete overlay raise, the first cost would increase to an estimated $1.33 billion and the estimated total unit storage cost would increase to about $1,300 per acre-foot. The estimated unit cost for average annual and drought year yield would be about $850 and $510 per acre-foot, respectively.

Intermediate-Level Raise – 102.5 Feet

Major components and accomplishments and costs for the Intermediate-Level Raise (102.5 feet) are described in this section.

Major Components

The Intermediate-Level Raise scenario consists of a structural dam raise of 102.5 feet to a new crest at elevation 1,180 (see Table 3-1). The new top of joint-use storage space would be at elevation 1,171.5. This would allow for storage of an additional 104.5 feet of water in the reservoir above the existing joint-use storage pool elevation. Total capacity of this new reservoir would be 8.47 MAF, or an increase of 3.92 MAF above the existing available storage. At full pool storage, the reservoir would cover about 44,200 acres, which is an increase of about 14,600 acres over existing conditions (49 percent). Figure 3-5 includes the aerial extent of the Intermediate-Level Raise scenario in relationship to other dam raise scenarios being considered.

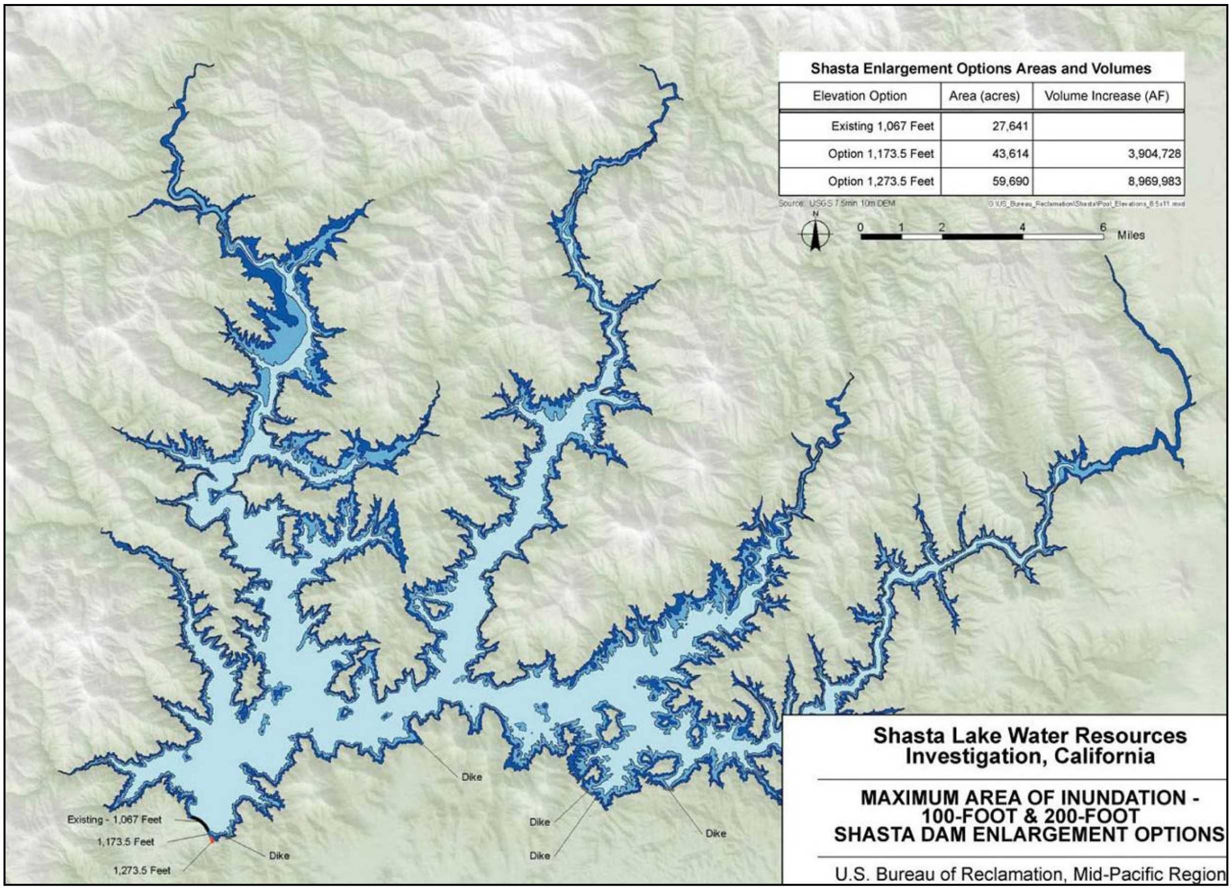

Figure 3-5. Shasta Lake Maximum Area of Inundation for 100-foot and 200-foot Dam Raise Options

The existing concrete gravity dam section would be raised using a mass concrete overlay on the main section of the dam with roller-compacted concrete wing dams constructed on both abutments. The left wing dam would extend approximately 1,380 feet, and the right wing dam would extend approximately 420 feet. The mass concrete overlay on the downstream face of the existing dam in the main section would extend from elevation 1,180 down to the foundation contact at the downstream toe on a 0.7:1 slope. The spillway section would be made thicker to accommodate the gated spillway crest.

This dam raise scenario would require a new crest roadway, spillway bridge, elevators, and a gantry crane, and associated mechanical equipment required for operating the various outlet gates, TCD, and other features. It would also involve constructing two new saddle dikes at Jones Valley and Clickapudi Creek.

The expanded full pool area would require about 520 structures to be removed or relocated (see Figure 3-2). This scenario also would result in impacts to numerous major and minor transportation, recreation, hydropower, and other reservoir area facilities. New power facilities would likely be needed at Shasta

Dam, primarily including improvements to the existing penstocks. In addition, most recreational facilities would require relocation. Considerable impacts would occur to historical and cultural resources in the Shasta Lake area. Major impacts would occur to reservoir area and tributary stream ecosystem resources. The Intermediate-Level Raise would also require relocation or abandonment of the Pacific Gas and Electric Company (PG&E) Pit 7 Dam and Powerhouse on the upper Pit River just upstream from Shasta Lake.

It is important to note that in addition to the Pit River Bridge, which would be the single most costly relocation item associated with a dam raise, 20 other bridges cross Shasta Lake or one of its tributaries. A considerable number of bridge relocations would be required with minor increases in the top of joint-use elevation, and all of the main reservoir bridges would need to be relocated with a top of joint-use raise of about 73 feet. However, with greater increases in top of joint-use elevations, major railroad and/or roadway system relocation (UPRR and I-5) also would be required.

Accomplishments and Costs

This scenario would considerably contribute to both primary planning objectives and also support each of the secondary planning objectives. Increasing the full pool storage at Shasta Reservoir by 3.9 MAF by raising Shasta Dam 102.5 feet would increase the estimated average annual and critical dry period yield to the CVP by an estimated 214,000 and 425,000 acre-feet, respectively (see Table 3-5). It could help increase anadromous fish survival by creating a small increased cold-water pool. In addition, it could help reduce flood damages along the upper Sacramento River, and increase hydropower generation. It would result in a considerable increase in potential reservoir area recreation opportunities. However, it would have major impacts on the McCloud River and issues relating to the State special designation of that waterway.

Because of the considerable increase in storage in Shasta Reservoir for this scenario, and resulting influence on residual available water resources in the upper watershed, planning for other potential water resources projects would be likely influenced measurably. Also, because this scenario requires most of the infrastructure within the reservoir area to be relocated, considerable disruption would occur to local and interstate roadway and railroad transportation, recreation, and related facilities in the Shasta Lake region.

As shown in Table 3-4 and Figure 3-3, the estimated first cost (2003 price levels) for this scenario is about $3.9 billion with an estimated average annual cost of about $283 million. The estimated unit cost for the new storage space in Shasta Lake would be about $990 per acre-foot. The resulting unit cost for the average annual and drought year water supply yield would be about $1,320 and $670 per acre-foot, respectively (Table 3-5).

High-Level Raise – 202.5 Feet

Major components and accomplishments and costs for the High-Level Raise (202.5 feet) are described in this section.

Major Components

The High-Level Raise scenario consists of a structural dam raise of 202.5 feet to a new crest at elevation 1,280 (see Table 3-1). The new top of joint-use storage space would be at elevation 1,271.5. This would allow storage of an additional 204.5 feet of water in the reservoir. The total capacity of this new reservoir would be 13.89 MAF, an increase of 9.34 MAF above the existing available storage. This dam raise represents the highest practical raise of Shasta Dam. Enlargements beyond this point would begin to experience considerable geological foundation problems. At least one upstream PG&E dam and powerhouse would be relocated with the high level raise – Pit 7 Dam and powerhouse on the upper Pit River. At full pool storage, the reservoir would cover about 60,800 acres, which is an increase of about 31,200 acres over existing conditions (105 percent). Figure 3-5 shows the aerial extent of the High-Level Raise scenario in relationship to other dam raise scenarios being considered.

The existing concrete gravity dam section would be raised using a mass concrete overlay on the existing dam crest and downstream face. The upstream face within the curved nonoverflow sections would extend vertically to the new dam crest at elevation 1,280, and the downstream face would have a 0.7:1 slope to the downstream toe. The dam crest would be completed with a crest cantilever for the roadway surface, sidewalks, and parapet walls. Existing elevator shafts would be extended to the new dam crest, and new elevator towers would be provided. The spillway section would require a thicker section to accommodate the gated spillway crest.

The new dam crest would include a crest roadway and spillway bridge, passenger and freight elevators, and three gantry cranes. This option would require constructing four saddle dikes to close off the gaps between mountain peaks in the upper watershed. A new powerplant and associated switchyard facilities would be included on the left abutment. The existing powerplant would continue to be operated within its operation range. The existing penstocks on the right abutment would be upgraded.

The expanded full pool area would require nearly 630 structures to be removed or relocated. As with the Intermediate-Level Raise scenario, this scenario would require replacement of major infrastructure associated with Shasta Dam and Reservoir.

Considerable impacts would occur to historical and cultural resources in the Shasta Lake area. Major impacts would occur to reservoir area and tributary stream ecosystem resources. This scenario would have major and likely irreversible impacts to the McCloud River and issues relating to the State special designation of that waterway.

Accomplishments and Costs

This High-Level Raise scenario would contribute considerably to both primary planning objectives and support each of the secondary planning objectives. Increasing the full pool storage at Shasta Reservoir by 9.1 MAF by raising Shasta Dam 202.5 feet would increase the estimated average annual and critical dry period yield to the CVP by an estimated 330,000 and over 700,000 acre-feet, respectively (see Table 3-5). It would considerably increase anadromous fish survival by creating a very large increased cold-water pool. In addition, because of the considerable increase in total space in Shasta Reservoir capable of capturing considerably more peak flood flows, this scenario could help resolve many existing flood problems along the upper Sacramento River. It would result in major increases in hydropower generation. It also would result in a substantial increase in water-oriented recreation in Shasta Lake by more than doubling the lake surface area at full pool elevation.

Because of the considerable increase in storage in Shasta Reservoir for this scenario, and resulting influence on residual available water runoff from the upper Sacramento River watershed, planning for other potential water resources projects in the Central Valley very likely would be influenced measurably. Also, because the scenario would require most of the infrastructure within the reservoir area to be relocated, considerable disruption would occur to local and interstate roadway and railroad transportation, recreation, and related actions in the Shasta Lake region.

The estimated first cost for this scenario (2003 price levels) is about $5.2 billion with an estimated average annual cost of about $383 million (see Table 3-4). The estimated unit cost for new storage space in Shasta Lake would be about $560 per acre-foot (Table 3-5). The resulting unit cost for the average annual and drought year water supply yield would be about $1,160 and $550 per acre-foot, respectively (Table 3-5).

Initial Screening

The five dam raise scenarios were compared to identify the scenarios that should be considered in more detail and included in concept plans. Table 3-6 is a summary comparison and screening of each scenario. As shown in the table, three Shasta Dam enlargement scenarios were identified for development into concept plans: the Low-Level Raise – 6.5-foot scenario, Expanded Low-Level Raise – 18.5-Foot scenario, and High-Level Raise – 202.5-foot scenario. The Expanded Low-Level Raise – 30-foot, Intermediate-Raise, and all other Shasta Dam and Reservoir enlargement scenarios were eliminated from further consideration. Following is a summary of each scenario.

Table 3-6. Summary Comparison of Shasta Dam Raise Scenarios (2003 Analysis)

Description	Low-Level Raise (6.5 feet)	Expanded Low-Level Raise (18.5 feet)	Expanded Low-Level Raise (30 feet)	Intermediate-Level Raise (102.5 feet)	High-Level Raise (202.5 feet)
Major Features					
Dam Crest Raise (feet)	6.5	18.5	30	102.5	202.5
Full Pool Raise (feet)	8.5	20.5	32	104.5	204.5
Capacity Increase (million AF)	0.26	0.63	1.02	3.92	9.34
Surface Area Increase (%)	4	8	14	49	105
Water Reliability Accomplishments					
Drought Year Yield (AF/year)	72	125	185	425	703
CVP Yield Replacement (%)[1]	13	20	31	77	100
Cost (2003 Price Levels)					
First Cost ($ millions)	282	408	1,250	3,890	5,250
Annual Cost ($ millions)	19	28	89	283	383
Unit Cost ($/AF)[2]	270	225	480	670	550
Major Advantages	• Low unit cost. • No major relocations. • Consistent with 2000 CALFED ROD. • Can contribute to both primary planning objectives. • Potential to provide about 5 and 14 percent of projected 2020 drought and average year shortages, respectively, in the Sacramento and San Joaquin River basins. • Low impacts in reservoir rim area.	• Low unit cost. • No major relocations. • Consistent with goals of 2000 CALFED ROD. • Can contribute to both primary planning objectives. • Potential to provide up to about 7 and 20 percent of projected 2020 drought and average year shortages, respectively, in the Sacramento and San Joaquin River basins.	• Can contribute to both primary planning objectives. • Potential to provide up to about 11 and 31 percent of projected 2020 drought and average year shortages, respectively, in the Sacramento and San Joaquin River basins.	• Can contribute to both primary planning objectives. • Can contribute considerably to increased recreation, hydropower, and flood control secondary objectives. • Potential to provide about 27 and 77 percent of projected 2020 drought and average year shortages, respectively, in the Sacramento and San Joaquin River basins.	• Can considerably contribute to both primary planning objectives. • Can contribute considerably to increased recreation, hydropower, and flood control secondary objectives. • Potential to provide about 45 and 100 percent of projected 2020 drought and average year shortages, respectively, in the Sacramento and San Joaquin River basins. • Likely lowest-cost project capable of resolving current and future water supply shortages.

Table 3-6. Summary Comparison of Shasta Dam Raise Scenarios (2003 Analysis) (contd.)

Description	Low-Level Raise (6.5 feet)	Expanded Low-Level Raise (18.5 feet)	Expanded Low-Level Raise (30 feet)	Intermediate-Level Raise (102.5 feet)	High-Level Raise (202.5 feet)
Major Disadvantages	• Relatively low potential to meet primary objectives.	• Marginal potential to meet primary objectives. • Moderate reservoir rim impacts.	• Very high unit cost. • Requires major reservoir area relocations.	• High unit water cost. • Requires major reservoir area relocations. • High reservoir area impacts.	• High unit water cost. • Requires major reservoir area relocations. • Very high reservoir area impacts.
Status	• **Retained** for further development – low unit water cost.	• **Retained** for further development – considerable accomplishments for planning objectives and low unit water cost.	• **Deleted** from further consideration – major relocations and high unit water cost.	• **Deleted** from further consideration – major reservoir impacts and high unit water cost.	• **Retained** for further consideration – high potential to meet current and future water shortages.

Notes:
[1] Percent replacement of CVPIA water reallocation.
[2] Unit cost for drought year yield.

Key:
AF = acre-feet
CVP = Central Valley Project
ROD = Record of Decision

- **Low-Level Raise – 6.5 Feet** – On the basis of an estimated unit cost per an increase in drought year yield of $270 per acre-foot, this scenario would be one of the most efficient of the five considered. Primarily due to (1) the relatively low cost for additional dry period yield, (2) high reliability of accomplishing its identified benefits, (3) low overall impact to ecosystem and related resources, (4) ability to combine with other measures, and (5) consistency with goals in the 2000 CALFED ROD, this scenario was retained for more detailed analysis as part of the concept plans.

- **Expanded Low-Level Raise – 18.5 Feet** – On the basis of an estimated unit cost per increase in drought year yield as low as $225 per acre-foot, this scenario also would be one of the most efficient of the five considered. This option was retained for more detailed analysis, primarily due to (1) the potential for additional dry period yield and high potential to influence average year water supply reliability, (2) low implementation cost and water supply reliability cost, (3) relatively low overall impact to ecosystem and related resources, and (4) consistency with the goals of the 2000 CALFED ROD.

- **Expanded Low-Level Raise – 30 Feet** – On the basis of an estimated high unit cost per new system yield, this scenario would result in relatively low economic efficiency compared with the 6.5-foot and 18.5-foot scenarios. Primarily due to considerably higher implementation costs relative to accomplishments, this scenario was deleted from further consideration.

- **Intermediate-Level Raise – 102.5 Feet** – On the basis of an estimated high unit cost per new system yield, this scenario also would result in low economic efficiency compared with the other dam raise scenarios. Primarily due to considerably higher implementation costs and unit costs for water supply reliability relative to overall accomplishments, this scenario was deleted from further consideration.

- **High-Level Raise – 202.5 Feet** – On the basis of an estimated high unit cost per new system yield, this scenario would result in relatively low economic efficiency. However, no other known single surface water storage project or combination of surface water projects in the Central Valley of California is as capable of considerably addressing the projected future water shortages with comparable unit water costs as the High-Level Raise scenario. This scenario could provide nearly half the total expected 2020 water shortages of the CVP and SWP. Also, it could almost completely fulfill the water supply replacement objectives of the CVPIA. It would, however, result in major resources impacts in the reservoir area. Primarily because unit costs for new water storage and for average annual yield reliability would be highly competitive at the magnitude of potential developed supplies compared to other surface water storage projects considered by CALFED, this scenario was carried forward for inclusion in a concept plan.

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Chapter 4
Concept Plans

During the Initial Alternatives Phase, a set of plans that were conceptual in scope (concept plans) was formulated from the retained management measures presented in Chapter 2. Because there is a vast array of potential measure combinations and sizes, the strategy was not to develop an exhaustive list of concept plans or to optimize outputs. Rather, the purpose of this phase of the formulation process was to (1) explore an array of different strategies to address the primary planning objectives, constraints, considerations, and criteria, and (2) identify concepts that warranted further development in the comprehensive plans phase.

The formulation strategy was to develop an array of concept plans representative of the range of potential actions to address objectives of the SLWRI. First, two sets of plans were developed that focused on either anadromous fish survival (AFS) or water supply reliability (WSR) as the single primary planning objective. Three AFS plans and four WSR plans were developed. Although the AFS and WSR plans focused on single planning objectives, each generally contributes to both primary planning objectives. In the three AFS concept plans, for example, emphasis was placed on the combinations of measures that could best address the fish survival goals while considering incidental benefits to WSR, if possible. Second, five concept plans were developed that included measures to address both primary and, to a lesser degree, secondary planning objectives. These are termed combined objective (CO) plans.

This chapter is organized into three sections, beginning with a discussion of the measures contained in the concept plans, including a discussion of features that are common to some or all of the plans. The AFS, WSR, and CO concept plans then are discussed individually. Last, the concept plans are compared to determine the relative scope of comprehensive alternative plans.

Overview of Concept Plan Features

Table 4-1 summarizes how the retained measures were combined to form concept plans that focus on anadromous fish, water supply reliability, or COs. The concept plans and their unique features are discussed individually in the remaining sections of this chapter. Calculated values referenced in this chapter are from the June 2004 *Initial Alternatives Information Report* (Reclamation 2004a). Raises of 6.5 feet and 18.5 feet were evaluated based on enlarged storage capacities of 290,000 acre-feet and 636,000 acre-feet, respectively.

Subsequent evaluations determined that the increases in capacity for these raises are 256,000 acre-feet and 634,000 acre-feet, respectively. The current comprehensive plans discussed in Chapter 5 reflect these changes.

Table 4-1. Summary of Concept Plan Features

Concept Plan	Features												
	Dam Raise	Primary Planning Objective Focus							Secondary Planning Objectives Addressed [4]				
		Water Supply Reliability [2]			Anadromous Fish Survival				Environmental Restoration			Flood Control and Hydropower	
	Raise Shasta Dam[1] (feet)	Increase Conservation Storage	Perform Conjunctive Water Management[3]	Reoperate Shasta Dam	Modify TCD	Replenish Spawning Gravel	Enlarge Shasta Lake Cold-Water Pool	Increase Minimum Flows[3]	Restore Shoreline Aquatic Habitat	Restore Tributary Aquatic Habitat	Restore Riparian Habitat	Modify Flood Control Operations and Implement Shasta Public Safety,[3] Features	Modify Hydropower Facilities
AFS-1	6.5	*		Changes to water supply operations and modification of the TCD would likely be included, to some extent, in any alternative that includes raising Shasta Dam.			X					Changes to flood control operations at Shasta Dam, Public Safety,[3] and hydropower facilities would likely be part of any alternative that includes physically modifying Shasta Dam; the degree and details of these changes will be included in feasibility level alternative plans.	
AFS-2	6.5	*					*	X					
AFS-3	6.5	*				X	*	X					
WSR-1	6.5	X					*						
WSR-2	18.5	X					*						
WSR-3	202.5	X					*						
WSR-4	18.5	X	X				*						
CO-1	6.5	X				X	X						
CO-2	18.5	X				X	X						
CO-3	18.5	X				X	X	X					
CO-4	6.5	X	X			X	X		X	X	X		
CO-5	18.5	X	X			X	X		X	X	X		

Notes:

[1] Raising Shasta Dam provides both water supply and temperature benefits, regardless of how the additional storage is exercised. While the AFS measures focus on use of the additional space for anadromous fish survival, they also provide significant water supply benefits. Similarly, the WSR measures focus on water supply reliability but the reservoir enlargements also provide coincidental benefits to anadromous fish.

[2] All concept plans will include attention to water demand reduction.

[3] These measures were used for evaluation because they were retained at the time of plan formulation. However, they have since been removed from consideration.

[4] Water quality was not used as an evaluation feature because it was not retained as a secondary objective at the time concept plans were formulated.

Key:
* Coincidental benefit, although not a primary focus of the concept plan
AFS= anadromous fish survival
CO = combined objectives
TCD = temperature control device
WSR = water supply reliability
X = Primary focus of concept plan

Many of the concept plans share common physical features related to raising Shasta Dam. These include the physical or construction features of dam enlargement, and reservoir area relocations and other impacts.

Each of the concept plans includes enlarging Shasta Dam and Reservoir by 6.5 feet, 18.5 feet, or 202.5 feet. Table 4-2 summarizes various changes in Shasta Dam and Lake for the three dam raises.

Table 4-2. Shasta Dam and Lake Changes – Dam Raise Scenarios

Item	Existing	6.5-Foot Raise	18.5-Foot Raise	202.5-Foot Raise
Shasta Dam				
Type	Concrete Gravity	Concrete Gravity	Concrete Gravity	Concrete Gravity
Construction Means	-	Block Raise (crest)	Block Raise (crest)	Mass Raise (overlay)
Crest Elevation[4]	1,077.5	1,084.0	1,096.0	1,280.0
Dam Crest Length[4]	3,460	3,660	3,770	4,930
Dam Crest Width[4]	30	30	30	30
Shasta Lake				
Elevation Change				
Increase in Full Pool[4]	-	8.5	20.5	204.5
Elevation of Full Pool[4]	1,067.0	1,075.5	1,087.5	1,271.5
Elevation Minimum Operating Pool[4]	840	840	840	840
Capacity (1,000 acre-feet)				
Capacity Increase	-	290[1]	636[1]	9,338
Total at Full Pool[2]	4,552	4,842[1]	5,188	13,890
Minimum Operating Pool	590	590 / 880[3]	590	590
Surface Area Increase (acres)	-	1,100	2,500	31,200

Notes:

[1] Subsequent evaluations refined the storage capacity increase with a 6.5-foot raise and with an 18.5-foot raise to 256,000 acre-feet and 634,000 acre-feet, respectively. Total capacity for an 18.5-foot raise has been refined to 5,190,000 acre-feet.

[2] Increase in full pool elevation is greater than the magnitude of the dam raise, largely due to the increased efficiency of the steel radial spillway gates that would replace the existing drum gates.

[3] Concept Plan AFS-1 includes increasing the minimum operating pool to 880,000 acre-feet. All other plans assume an existing minimum operating pool of 590,000 acre-feet.

[4] All elevations are in feet above mean sea level.

Plans Focused on Anadromous Fish Survival

Three concept plans were formulated from the management measures retained to address the primary planning objective of anadromous fish survival. The main focus of these concept plans is on anadromous fish survival in the upper Sacramento River, but each contributes somewhat to water supply reliability. While numerous possible combinations of the type and size of the measures make up these concept plans, those shown in Table 4-1 and described below are believed to be reasonably representative of the range of potential actions.

Each of the three AFS concept plans includes raising Shasta Dam 6.5 feet, which would raise the full pool level by 8.5 feet and enlarge the reservoir by 290,000 acre-feet. Although larger dam raises could produce greater benefits to fisheries, the goal at this stage in plan formulation was to provide a common baseline from which the relative performance of the three AFS concept plans could be compared. The primary difference between the three AFS concept plans is in how the additional storage gained by the raise would be used to benefit anadromous fish. AFS-1 focuses the additional storage on regulating water temperature in the upper Sacramento River, while AFS-2 and AFS-3 focus the additional storage on regulating flows in the upper Sacramento River. AFS-3 also adds an additional increment, fish habitat restoration on the upper Sacramento River.

AFS-1– Increase Cold-Water Assets with Shasta Operating Pool Raise (6.5 Feet)

AFS-1 focuses on the primary planning objective of anadromous fish survival by raising Shasta Dam 6.5 feet to enlarge the pool of cold water in Shasta Lake. Major plan components include (1) raising Shasta Dam by 6.5 feet for the primary purpose of enlarging the cold-water pool and regulating water temperature in the upper Sacramento River and (2) increasing the size of the minimum operating pool to 880,000 acre-feet.

Both of the major plan components focus on increasing the volume of cold water in Shasta Lake available for regulating water temperature on the upper Sacramento River. AFS-1 would increase the capacity of the reservoir by 290,000 acre-feet to a total of 4.84 MAF. The existing TCD would be extended and potentially modified. In addition, the minimum end-of-October carryover storage target would be increased from 1.9 MAF to about 2.2 MAF, increasing the minimum operating pool to 880,000 acre-feet. This would allow additional cold water to be stored for use the following year. No changes would be made to the existing seasonal temperature targets for anadromous fish on the upper Sacramento River, but the ability to meet these targets would be improved.

For this plan, major relocations include modifying the Pit River Bridge, replacing 7 other bridges, relocating 45 structures, and inundating numerous small segments of existing paved and nonpaved roads. About 20 buildings associated with marinas or resorts would be affected directly, and about 25 other buildings associated with ancillary facilities could be affected indirectly because of their proximity to the new water surface at full pool.

Major benefits of AFS-1 include the following:

- **Anadromous Fish Survival –** Water temperature is one of the most important factors in achieving recovery goals for anadromous fish in the Sacramento River. AFS-1 would increase the ability of Shasta Dam to make cold-water releases and regulate water temperature in the upper Sacramento River, primarily in dry and critical years. This would be accomplished by raising Shasta Dam by 6.5 feet, thus increasing the depth of the cold-water pool in Shasta Reservoir and resulting in an increase in seasonal cold-water volume below the thermocline (layer of greatest water temperature and density change). Cold water released from Shasta Dam significantly influences water temperature conditions in the Sacramento River between Keswick Dam and the RBDD, and can have an extended influence on river temperatures farther downstream. Hence, the most significant benefits to anadromous fish would occur upstream from Red Bluff, but some degree of benefit could be realized as far downstream as the Delta.

  Relationships between anadromous fish mortality and environmental conditions (including water temperature) are very complex. Recent significant strides have been made, however, to try and assess these relationships and resulting influences on increases or decreases in fish populations. For this study, the SALMOD computer model was used to simulate the dynamics of freshwater salmonid populations in the upper Sacramento River. The model's premise is that egg and fish mortality are directly related to spatially and temporally variable micro- and macrohabitat limitations, which themselves are related to the timing and amount of streamflow and other meteorological variables. Information on this model and its application to the SLWRI is presented in the Modeling Appendix. On the basis of this model assessment, it is estimated that AFS-1 could significantly contribute to an average annual increase (reduction in mortality) of salmon. For higher dam raise scenarios with corresponding increases in the minimum operating pool, the benefit to salmon would be proportionally greater.

- **Water Supply Reliability –** AFS-1 would only incidentally contribute to increasing the water supply reliability of the CVP and SWP systems.

- **Other Benefits –** Although the focus of this concept plan was on benefiting anadromous fish in the upper Sacramento River by increasing the cold-water pool in Shasta Lake, minor secondary benefits would occur. The higher water surface in the reservoir would result in a net increase in power generation. The ability to manage floods would not increase significantly. AFS-1 does not include any specific measures to address the secondary planning objective of environmental restoration. Water-oriented recreation at Shasta Lake, and the services it supports, are very important to the economic health and well-being of the community of Redding and surrounding area. AFS-1 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area. The maximum surface area of the lake would increase by about 1,100 acres (3 percent), from 29,600 to about 30,700 acres.

The most significant benefit of AFS-1 is the significant increase in anadromous fish population. The plan would not provide significant benefits to water supply reliability, although it would provide incidental increases in hydropower. Consequently, all initial costs for this plan would be allocated to anadromous fish survival.

AFS-2 – Increase Minimum Anadromous Fish Flow with Shasta Enlargement (6.5 Feet)

AFS-2 focuses on the primary planning objective of anadromous fish survival by increasing minimum seasonal flows in the upper Sacramento River from the current 3,250 cfs to about 4,200 cfs. The primary component of AFS-2 includes raising Shasta Dam by 6.5 feet for the primary purpose of enlarging the volume of water available to meet minimum flows for winter-run salmon on the upper Sacramento River.

Additional storage created by raising the dam would be focused on increasing the minimum flow target for winter-run Chinook salmon on the upper Sacramento River, consistent with the goals of the January 2001 *Final Restoration Plan* for the Anadromous Fish Restoration Program. Similar to AFS-1, this concept plan would increase the capacity of the reservoir by 290,000 acre-feet to a total of 4.84 MAF, and extend the existing TCD to achieve efficient use of the expanded reservoir. AFS-2 differs from AFS-1 in that the additional storage would be used to increase minimum flows, rather than temperature, and no changes would be made to the carryover target volume or minimum operating pool.

For this concept plan, the additional storage would allow the minimum flow target in the upper Sacramento River to be increased from 3,250 cfs to 4,200 cfs, without adversely impacting water supply deliveries to the CVP. Although 4,200 cfs does not represent flows that produce optimal spawning conditions in the river (closer to 5,000 cfs), it is believed to represent a possible balance between the various beneficial uses of the reservoir.

The benefits of AFS-2 are as follows:

- **Anadromous Fish Survival –** In addition to temperature, river flow is an important factor influencing anadromous fish survival. Flows in the upper Sacramento River are highly influenced by releases from Shasta Dam, particularly during dry years. Higher instream flows would provide access to additional spawning and rearing habitat sites, extend the area of suitable habitat farther downstream, and generally improve aquatic and riparian habitat conditions along the river. Further, over 80 percent of the total (combined) population of spring-run, late-fall-run, and endangered winter-run Chinook salmon spawn between Keswick Dam and Battle Creek. AFS-2 would use the additional 290,000 acre-feet of storage in Shasta to increase minimum flows in this reach of the upper Sacramento River between October 1 and April 30. Benefits would occur primarily during drier years, when flows often fall to the current minimum flow of 3,250 cfs. For example, the average daily outflow from Keswick fell below 4,200 cfs on about 175 days between 1998 and 2004 (period of current operating rules). It should be noted that this figure represents flows averaged over 24-hour periods, and does not reflect hourly fluctuations or every day that flows fell below 4,200 cfs (or the duration of these occurrences).

  A preliminary assessment was conducted, using an existing hydraulic model of the upper Sacramento River, to estimate the increase in available spawning habitat that would occur if flows increased from 3,250 cfs to 4,200 cfs. Although the preliminary assessment has limitations, it provides a means for comparing the relative performance of the concept plans. On the basis of this assessment, it is estimated that AFS-2 could decrease the amount of spawning area between Keswick and Battle Creek that normally becomes dewatered during low flow years by about 170 acres.

  Although the focus of AFS-2 is on increasing minimum flows, raising Shasta Dam also increases the available cold-water pool and allows operators greater flexibility in regulating water temperature in the upper Sacramento River. Based on preliminary analyses, improved temperature conditions under AFS-2 would result in an estimated average annual increase of the salmon population.

- **Water Supply Reliability** – As mentioned previously, using the additional storage to increase minimum flows would result in little or no increase in water supply reliability to the CVP. However, AFS-2 would incidentally contribute to increasing average and dry period water supply reliability to the SWP system. This increase corresponds to about 20,000 acre-feet during critical years.

- **Other Benefits –** A preliminary assessment indicated that the higher water surface in the reservoir would result in a net increase in power generation. Flood control operations at Shasta Dam and Reservoir would continue as under existing conditions. AFS-2 does not include any specific measures to address the secondary planning objective of environmental restoration. However, increasing minimum flows would provide incidental benefits to riparian habitat along the upper Sacramento River. AFS-2 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area, similar to that described for AFS-1. The maximum surface area of the lake would increase by about 1,100 acres (3 percent), from 29,600 to about 30,700 acres.

AFS-3 – Increase Minimum Anadromous Fish Flow and Restore Aquatic Habitat with Shasta Enlargement (6.5 Feet)

AFS-3 addresses the primary planning objective of anadromous fish survival through a dual focus on (1) instream habitat restoration and (2) increasing minimum seasonal flows on the upper Sacramento River by enlarging Shasta Dam and Reservoir, similar to AFS-2. Major plan components include (1) raising Shasta Dam by 6.5 feet for the primary purpose of enlarging the volume of water available to meet minimum flows for winter-run Chinook salmon on the upper Sacramento River and (2) acquiring, restoring, and reclaiming one or more inactive gravel mining operations along the upper Sacramento River to restore about 150 acres of aquatic and floodplain habitat.

These components are focused on increasing the quality and quantity of spawning habitat on the upper Sacramento River. Similar to AFS-2, minimum spring flows for winter-run Chinook salmon would increase from 3,250 cfs to 4,200 cfs; the capacity of the reservoir would increase by 290,000 acre-feet to a total of 4.84 MAF; and the existing TCD would be extended to achieve efficient use of the expanded reservoir.

AFS-3 differs from AFS-2 in that an additional increment of instream habitat would be provided by gravel mine restoration along the upper Sacramento River. For the purpose of this initial evaluation, suitable areas totaling 150 acres would be chosen from one or more abandoned gravel mines (see potential sites in Figure 4-1).

Restoration would involve filling deep pits, recontouring the stream channel and floodplain to mimic more natural topography, and reconnecting the reclaimed area to the Sacramento River. Side channels and other features would be created to encourage spawning and rearing, and restored floodplain lands would be revegetated using native riparian plants.

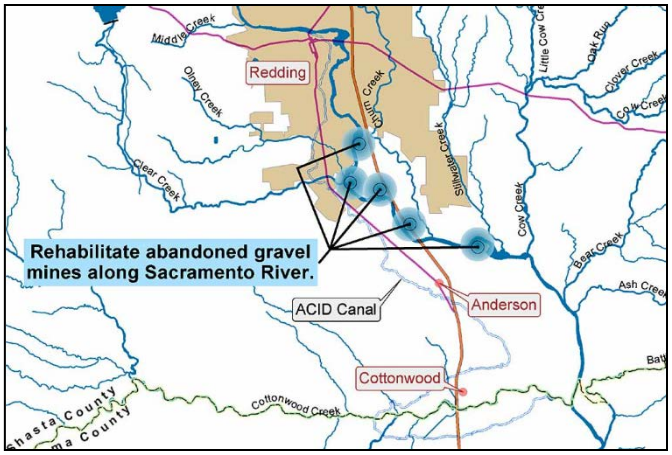

Figure 4-1. Potential Locations Along Sacramento River Where Abandoned Gravel Mines Could Be Considered for Restoration

The primary benefits of AFS-3 include the following:

- **Anadromous Fish Survival –** As described previously, instream flows and the availability of suitable aquatic habitat in the reach between Keswick Dam and Battle Creek are particularly influential on the survival of anadromous fish. AFS-3 would support the primary planning objective of anadromous fish survival by increasing minimum flows from October 1 through April 30 and restoring 150 acres of aquatic and floodplain habitat at one or more inactive gravel mines on the upper Sacramento River. Together, it is estimated that the minimum flow increase and habitat restoration would add approximately 320 acres (restored gravel mines at 150 acres and increased flows at 170 acres) of potential spawning habitat to the upper Sacramento River between Keswick and Battle Creek.

- **Water Supply Reliability –** AFS-3 would incidentally contribute to increasing average and dry period water supply reliability to the SWP system. This increase corresponds to about 20,000 acre-feet during critical years.

- **Other Benefits –** The higher water surface elevations in the reservoir would result in a net increase in power generation of about 32 gigawatt-hours (GWh) per year. Flood control operations at Shasta Dam and Reservoir would continue similar to under existing conditions. AFS-3 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area, similar to that of AFS-1 and AFS-2. The maximum surface area of the lake would increase by about 1,100 acres (3 percent), from 29,600 to about 30,700 acres.

Plans Focused on Water Supply Reliability

Four concept plans were formulated from the management measures retained to address the primary planning objective of increasing water supply reliability. Although each WSR concept plan contributes somewhat to both primary planning objectives, these four plans focus on the objective of increased water supply reliability. As with the previous set of plans that focus on anadromous fish survival, numerous potential measure combinations and sizes exist. The magnitude of enlarging Shasta Dam was important when developing the WSR concept plans because storage capacity is the most influential factor in determining benefits to water supply reliability for this study. Hence, three dam raises were considered in the WSR concept plans: 6.5 feet, 18.5 feet, and 202.5 feet. The concept plans summarized in Table 4-1 and described below are believed to be reasonably representative of the range of potential actions to address the primary planning objective of water supply reliability.

The majority of water supply reliability benefits for all water supply reliability plans consist of increases in south-of-Delta agricultural water deliveries. The remaining benefits are seen in increased water deliveries for south-of-Delta M&I and north-of-Delta agricultural and M&I uses.

WSR-1 – Increase Water Supply Reliability with Shasta Enlargement (6.5 Feet)

WSR-1 focuses on the primary planning objective of water supply reliability by increasing the volume of water stored in Shasta Lake with a 6.5-foot dam raise. Major components of this concept plan include (1) raising Shasta Dam by 6.5 feet for the primary purpose of creating 290,000 acre-feet of additional storage available for water supply and (2) revising flood control operations to benefit water supply reliability by managing floods more efficiently.

Each of these components focuses on increasing water supply reliability to the CVP and SWP. This plan is similar to AFS-1, but the additional storage would be operated for water supply reliability as under existing operational guidelines. Similar to AFS-1, this concept plan would increase the capacity of the reservoir by 290,000 acre-feet to a total of 4.84 MAF and extend the existing TCD for efficient use of the expanded cold-water pool.

In addition, WSR-1 includes revisions to the operational rules for flood control such that the facility could potentially be managed more efficiently for flood control, thereby freeing some additional seasonal storage space for water supply. This would be accomplished using advanced weather forecasting tools. A primary constraint of this component of WSR-1 is that the existing level of flood protection provided by Shasta Dam would not be adversely impacted.

Major benefits of WSR-1 include the following:

- **Anadromous Fish Survival –** Although the focus of WSR-1 is on improving water supply reliability, raising Shasta Dam also would increase the cold-water pool and benefit seasonal water temperatures along the upper Sacramento River. It is estimated that improved water temperature conditions could result in an average increase in the salmon population of about half that for AFS-1.

- **Water Supply Reliability –** WSR-1 would increase water supply reliability by increasing critical and dry year yield of the CVP and SWP. This would help reduce estimated future shortages by increasing critical and dry period supplies by at least 72,000 acre-feet per year. This increase in reliability also could help reduce supplies redirected by the CVPIA during drought years by about 13 percent.

- **Other Benefits –** The higher water surface elevation in the reservoir would result in a net increase in power generation. Flood control operations at Shasta Dam and Reservoir would continue similar to under existing conditions. WSR-1 does not include any specific measures to address the secondary planning objective of environmental restoration. Similar to the AFS plans, WSR-1 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area. The maximum surface area of the lake would increase by about 1,100 acres (3 percent), from 29,600 to about 30,700 acres.

WSR-2 – Increase Water Supply Reliability with Shasta Enlargement (18.5 Feet)

WSR-2 focuses on the primary planning objective of water supply reliability by raising Shasta Dam 18.5 feet. The major components of this plan include (1) raising Shasta Dam by 18.5 feet for the primary purpose of creating 634,000 acre-feet of additional storage available for water supply and (2) revising flood control operations to benefit water supply reliability by managing floods more efficiently.

Each of these components focuses on increasing water supply reliability to the CVP and SWP. Although higher dam raises are technically and physically feasible, 18.5 feet is the largest practical dam raise that does not require relocating the Pit River Bridge. The 18.5-foot raise would increase the capacity of the reservoir by 634,000 acre-feet to a total of 5.19 MAF (see Table 4-2). Operations for the added storage in the reservoir would be similar to existing operations. The existing TCD would be extended for efficient use of the expanded cold-water pool. As described for WSR-1, this concept plan would include modifying flood control operation rules to manage the reservoir more efficiently for flood control, thereby freeing some additional seasonal storage space for water supply.

The plan includes constructing a protection dike for I-5 at Lakeshore Drive and the UPRR at Bridge Bay. To offset potential impacts to lake area infrastructure, the plan would include modifications to the Pit River Bridge, replacement of 7 other bridges, acquisition and/or relocation of 130 structures, and relocation of small segments of existing paved and nonpaved roads. In addition, two power transmission lines, several water storage tanks, and three USFS fire stations and ancillary facilities also would be relocated. Portions of Lakeshore Drive, Fenders Ferry Road, Gilman Road, and Silverthorn Road would be relocated. To offset potential impacts to seasonal boat traffic under the Pit River Bridge, the plan would need to include features such as boat scheduling assistance and/or financial compensation.

The primary benefits of WSR-2 include the following:

- **Anadromous Fish Survival –** Although the focus of WSR-2 is on improving water supply reliability, raising Shasta Dam by 18.5 feet would increase the cold-water pool and benefit seasonal water temperatures along the upper Sacramento River. It is estimated that improved water temperature conditions could result in an average increase in the salmon population of about 30 percent over AFS-1.

- **Water Supply Reliability** – WSR-2 would increase water supply reliability by increasing the critical and dry year yield of the CVP and SWP. This would help reduce estimated future shortages by increasing critical and dry period supplies by at least 125,000 acre-feet per year. This increase in reliability could also help reduce CVPIA-redirected supplies during drought years by about 20 percent.

- **Other Benefits –** The higher water surface elevation in the reservoir would result in a net increase in power generation of about 44 GWh per year. Flood control operations at Shasta Dam and Reservoir would continue similar to under existing conditions. WSR-2 does not include any specific measures to address the secondary planning objective of environmental restoration. The water-oriented recreation experience at Shasta Lake would generally increase due to the increase in lake surface area. The maximum surface area of the lake would increase by about 2,500 acres (8 percent), from 29,600 to about 32,100 acres.

WSR-3 – Increase Water Supply Reliability with Shasta Enlargement (High Level)

WSR-3 focuses on the primary planning objective of water supply reliability by raising Shasta Dam by 202.5 feet. Major components of this plan include (1) raising Shasta Dam by about 202.5 feet for the primary purpose of creating 9.3 MAF of additional storage available for water supply and (2) major modifications to or replacing dam appurtenances, including hydropower facilities and the TCD.

Raising Shasta Dam by about 202.5 feet is considered to be the largest technically feasible raise without completely reconstructing the existing dam. The 202.5-foot raise would increase the capacity of the reservoir by 9.3 MAF to a total of 13.9 MAF. The magnitude of this raise would require significant modifications or replacement of most facilities associated with the dam (see Table 4-2). The existing TCD would be replaced, and modifications to hydropower facilities would include replacing gates and structural supports for the penstocks, adding generator units to the powerplant, replacing the switchyard, and modifying Keswick Dam and its powerplant. The additional storage in the reservoir would be operated primarily for water supply, but the magnitude of the raise also would significantly increase the cold-water pool and the ability of dam operators to meet both temperature and minimum flow requirements on the upper Sacramento River.

Because of the extensive area impacts associated with WSR-3, the plan would need to include major facilities aimed at offsetting these impacts. At minimum, they would include relocating the Pit River Bridge, replacing 20 other bridges, removing Pit 7 Dam, relocating about 630 structures, and inundating numerous large segments of existing paved and nonpaved roads. About 35 miles of the UPRR, 19 miles of I-5, and numerous associated tunnels, embankments, and other facilities would be relocated. The plan would need to include significant facilities to mitigate for impacts to reservoir area recreation facilities. The plan would include extensive facilities to mitigate impacts to environmental, historical, and other cultural resources around Shasta Lake.

The Pit 7 Dam is located at the existing headwater of Shasta Lake (see Figure 4-2). The dam is 200 feet high and was constructed for hydropower purposes in the mid-1960s by PG&E. The full pool elevation for WSR-3 would be similar to the existing top of the Pit 7 Dam, inundating all facilities at the dam. Electric generation lost at Pit 7 would be replaced from the facilities added at the enlarged Shasta Dam.

Figure 4-2. Pit 7 Dam, Located on the Pit River Upstream from Shasta Lake, is 200 Feet High

Major benefits of WSR-3 include the following:

- **Anadromous Fish Survival –** Raising Shasta Dam by 202.5 feet would substantially increase the cold-water pool and benefit seasonal water temperatures along the upper Sacramento River. Preliminary analyses indicate that improved water temperature conditions could result in a major average increase in salmon population. The additional storage also would provide operators with greater flexibility in meeting minimum flow requirements on the upper Sacramento River. Detailed studies are required to more accurately quantify the increase in anadromous fish populations resulting from such a large increase in the capacity of Shasta Dam and Reservoir.

- **Water Supply Reliability –** WSR-3 would significantly increase water supply reliability for the CVP and SWP systems. This would help reduce estimated future shortages, increasing critical and dry period supplies by over 700,000 acre-feet per year. This increase in reliability would likely offset CVPIA-redirected supplies during drought years.

- **Other Benefits –** The higher water surface elevation in the reservoir would result in a significant net increase in power generation, amounting to almost 2.3 million GWh per year. Much of this increase would be offset, however, by the loss of generation from the Pit 7 Dam, which would be removed. A potential would also exist to significantly increase the ability to control larger flood events in the Sacramento River near Redding. WSR-3 does not include any specific measures to address the secondary planning objective of environmental restoration. The water-oriented recreation experience at Shasta Lake would generally increase because of the increase in lake surface area. The maximum surface area of the lake would increase by about 31,200 acres (roughly twice that of existing conditions), from 29,600 to about 60,800 acres.

WSR-4 – Increase Water Supply Reliability with Shasta Enlargement (18.5 Feet) and Conjunctive Water Management

WSR-4 focuses on the primary planning objective of water supply reliability by raising Shasta Dam 18.5 feet in combination with conjunctive water management. Major components of this plan include (1) raising Shasta Dam by 18.5 feet for the primary purpose of creating 634,000 acre-feet of additional storage available for water supply and (2) implementing a conjunctive water management program.

Each of these components focuses on increasing water supply reliability to the CVP and SWP. The 18.5-foot raise would increase the capacity of the reservoir by 636,000 acre-feet to a total of 5.19 MAF (see Table 4-2). Operations for the added storage in the reservoir would be similar to existing operations. The existing TCD would be extended for efficient use of the expanded cold-water pool. As described for WSR-1, this concept plan would include modifying flood control operation rules to manage the reservoir more efficiently for flood control, thereby freeing some additional seasonal storage space for water supply.

The conjunctive water management component would consist largely of contract agreements between Reclamation and certain Sacramento River basin water users. It also would include any additional river diversions, increase in current diversion capacity, and/or transmission facilities to facilitate the exchange.

Major benefits of WSR-4 include the following:

- **Anadromous Fish Survival** – Raising Shasta Dam by 18.5 feet would increase the cold-water pool and benefit seasonal water temperatures along the upper Sacramento River. It is estimated that improved water temperature conditions could result in an average increase in the salmon population similar to AFS-1.
- **Water Supply Reliability** – WSR-4 would increase water supply reliability by increasing the critical and dry year yield of the CVP and SWP. The combination of increased storage space in Shasta Reservoir and exchanged surface water for participating Sacramento River water users would result in an increase in water supply reliability of about 146,000 acre-feet per year. This increase in reliability could also help reduce CVPIA-redirected supplies during drought years.
- **Other Benefits**– The higher water surface elevation in the reservoir would result in a net increase in power generation. Flood control operations at Shasta Dam and Reservoir would continue similar to under existing conditions. WSR-4 does not include any specific measures to address the secondary planning objective of environmental restoration. The water-oriented recreation experience at Shasta Lake would generally increase because of the increase in lake surface area. The maximum surface area of the lake would increase by about 2,500 acres (8 percent), from 29,600 to about 32,100 acres.

Plans Focused on Combined Objectives

Various concept plans were formulated from the retained management measures to represent a reasonable balance between the two primary planning objectives. Five of the plans are shown in Table 4-1. The CO concept plans shown in the table and described below include measures to actively address the secondary planning objectives, as appropriate. As with previous concept plans, numerous potential sizes and combinations of components are possible. However, for comparison purposes, three CO concept plans described below include raising

Shasta Dam by 18.5 feet and two involve raising Shasta Dam by 6.5 feet. It is believed that they are reasonably representative, although not exhaustively, of the range of potential and applicable actions.

CO-1 – Increase Anadromous Fish Habitat and Water Supply Reliability with Shasta Enlargement (6.5 feet)

CO-1 addresses both primary planning objectives by restoring anadromous fish habitat and raising Shasta Dam by 6.5 feet.

CO-1 includes the following major components:

- Raising Shasta Dam by 6.5 feet for the purposes of expanding the cold-water pool and creating 290,000 acre-feet of additional storage available for water supply.
- Acquiring, restoring, and reclaiming one or more inactive gravel mining operations along the upper Sacramento River to create about 150 acres of aquatic and floodplain habitat.
- Revising flood control operations to benefit water supply reliability by managing floods more efficiently.

CO-1 would use the additional storage created by the 6.5-foot raise to increase water supply reliability, while also improving the ability to meet water temperature objectives for winter-run salmon. The capacity of the reservoir would increase by 290,000 acre-feet to a total of 4.84 MAF, and the existing TCD would be extended to achieve efficient use of the expanded reservoir. This concept also would include revisions to the operational rules for flood control, such that Shasta Dam and Reservoir could be managed more efficiently for water supply reliability (see previous discussion of WSR-1). Suitable areas totaling 150 acres would be chosen for aquatic and floodplain restoration from one or more abandoned gravel mines on the upper Sacramento River (see previous discussion of AFS-3).

Benefits of CO-1 are described below:

- **Anadromous Fish Survival –** CO-1 would increase the ability of Shasta Dam to make cold-water releases to regulate water temperature in the upper Sacramento River, primarily in dry and critical years. Preliminary analyses estimate that improved water temperature conditions could result in an average annual increase of 410 salmon. Habitat restoration would add an additional 150 acres of aquatic and floodplain habitat to the Sacramento River between Keswick and Battle Creek, a critical spawning reach.

- **Water Supply Reliability –** CO-1 would increase average and dry period water supply reliability to the CVP and SWP systems. This increase corresponds to about 72,000 acre-feet during critical years.

- **Environmental Restoration, Flood Control, and Hydropower –** Higher water surface elevations in the reservoir would result in a small net increase in power generation of about 15 GWh per year.

- **Other Benefits –** CO-1 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area, similar to that described previously for concepts incorporating a 6.5-foot raise. The maximum surface area of the lake would increase by about 1,060 acres (3 percent), from 29,600 to about 30,700 acres.

CO-2 – Increase Anadromous Fish Habitat and Water Supply Reliability with Shasta Enlargement (18.5 feet)

CO-2 addresses both primary planning objectives by raising Shasta Dam by 18.5 feet and restoration of anadromous fish habitat.

CO-2 includes the following major components:

- Raising Shasta Dam by 18.5 feet for the purposes of expanding the cold-water pool and creating 636,000 acre-feet of additional storage available for water supply.

- Acquiring, restoring, and reclaiming one or more inactive gravel mining operations along the upper Sacramento River to create about 150 acres of aquatic and floodplain habitat.

- Revising flood control operations to benefit water supply reliability by managing floods more efficiently.

CO-2 is similar to CO-1, except Shasta Dam would be raised 18.5 feet instead of 6.5 feet. The additional storage created by the 18.5-foot dam raise would be used to increase water supply reliability, while also improving the ability to meet water temperature objectives for winter-run salmon. The capacity of the reservoir would increase by 636,000 acre-feet to a total of 5.19 MAF, and the existing TCD would be extended to achieve efficient use of the expanded reservoir. This concept also would include revisions to the operational rules for flood control, such that Shasta Dam and Reservoir could be managed more efficiently for water supply reliability (see previous discussion of WSR-1). Suitable areas totaling 150 acres would be chosen for aquatic and floodplain restoration from one or more abandoned gravel mines (see previous discussion of AFS-3).

Benefits of CO-2 are described below:

- **Anadromous Fish Survival –** CO-2 would increase the ability of Shasta Dam to make cold-water releases to regulate water temperature in the upper Sacramento River, primarily in dry and critical years. Preliminary analyses estimate that improved water temperature conditions could result in an average annual increase of 1,110 salmon. Habitat restoration would add an additional 150 acres of aquatic and floodplain habitat to the Sacramento River between Keswick and Battle Creek, a critical spawning reach.

- **Water Supply Reliability –** CO-2 would increase average and dry period water supply reliability to the CVP and SWP systems. This increase corresponds to about 125,000 acre-feet during critical years.

- **Environmental Restoration, Flood Control, and Hydropower –** The higher water surface elevations in the reservoir would result in a net increase in power generation of about 44 GWh per year. The ability to control floods may increase by a small degree.

- **Other Benefits –** CO-2 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area, similar to that described previously for concepts incorporating an 18.5-foot raise. The maximum surface area of the lake would increase by about 2,500 acres (8 percent), from 29,600 to about 32,100 acres.

CO-3 – Increase Anadromous Fish Flow/Habitat and Water Supply Reliability with Shasta Enlargement (18.5 feet)

CO-3 addresses both primary planning objectives by raising Shasta Dam by 18.5 feet, restoring anadromous fish habitat, and improving flow conditions on the upper Sacramento River.

CO-3 includes the following major components:

- Raising Shasta Dam by 18.5 feet, expanding the cold-water pool, and creating 636,000 acre-feet of additional storage available for both water supply and flow regulation.

- Acquiring, restoring, and reclaiming one or more inactive gravel mining operations along the upper Sacramento River to create about 150 acres of aquatic and floodplain habitat.

- Revising flood control operations to benefit water supply reliability by managing floods more efficiently.

CO-3 is similar to CO-2, except a portion of the additional storage created by the 18.5-foot dam raise would be dedicated to managing flows for winter-run salmon on the upper Sacramento River. The additional storage space could be allocated to fisheries and water supply reliability in many different ways; additional investigation would be needed to assess combinations that could best address the two major objectives. For the purpose of this initial analysis, dedicating about 320,000 acre-feet to increasing minimum flows is believed to be a good estimation of the potential benefits of this concept.

Minimum flows on the upper Sacramento River would be increased from 3,250 cfs to about 4,200 cfs between October 1 and April 30 (see previous discussion of AFS-2), consistent with the Anadromous Fish Restoration Program. Suitable areas totaling 150 acres would be chosen for restoration from one or more abandoned gravel mines (see previous discussion of AFS-3). Temperature benefits also would be gained by increasing the size of the cold-water pool.

The existing TCD would be extended to achieve efficient use of the expanded reservoir. This concept also would include revisions to the operational rules for flood control, such that Shasta Dam and Reservoir could be managed more efficiently for water supply reliability (see previous discussion of WSR-1).

Benefits of concept CO-3 are described below:

- **Anadromous Fish Survival –** CO-3 would benefit anadromous fish by increasing seasonal minimum flows and improving water temperature conditions in the upper Sacramento River, primarily in dry and critical years. Significant additional effort is needed to reliably quantify potential benefits to the anadromous fish population from this concept. However, preliminary analyses estimate that improved water temperature conditions could result in an average annual increase of 980 salmon. Habitat restoration and minimum flow increases would add an additional 320 acres of aquatic and floodplain habitat to the Sacramento River between Keswick and Battle Creek, a critical spawning reach.

- **Water Supply Reliability –** CO-3 would increase average and dry period water supply reliability to the CVP and SWP systems. This increase corresponds to about 90,000 acre-feet during critical years.

- **Environmental Restoration, Flood Control, and Hydropower –** Higher water surface elevations in the reservoir would result in a net increase in power generation of about 61 GWh per year. The ability to control floods may increase to a small degree.

- **Other Benefits –** CO-3 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area, similar to that described previously for concepts incorporating an 18.5-foot raise.

CO-4 – Multipurpose with Shasta Enlargement (6.5 feet)

CO-4 addresses the primary and secondary planning objectives through raising Shasta Dam 6.5 feet in combination with conjunctive use, habitat restoration, and environmental restoration in the Shasta Lake area and upper Sacramento River.

CO-4 includes the following major components:

- Raising Shasta Dam by 6.5 feet, expanding the cold-water pool, and creating 290,000 acre-feet of additional storage available for water supply reliability.
- Acquiring, restoring, and reclaiming one or more inactive gravel mining operations along the upper Sacramento River to create about 150 acres of aquatic and floodplain habitat.
- Implementing a conjunctive water management program.
- Revising flood control operations to benefit water supply reliability by managing floods more efficiently.
- Constructing additional resident fish habitat in Shasta Lake and along the lower reaches of the Sacramento River, McCloud River, and Squaw Creek.
- Restoring 500 acres of wetland and riparian habitat along the Sacramento River at one or more sites between Redding and Red Bluff.

CO-4 addresses both primary and secondary objectives of the SLWRI through a combination of measures. It would improve anadromous fish survival by increasing the cold water pool in Shasta Reservoir and restoring 150 acres of valuable aquatic and floodplain habitat on the upper Sacramento River. The concept would improve water supply reliability through increasing the storage space in Shasta Reservoir by 290,000 acre-feet, implementing conjunctive water management, and re-operating the reservoir more efficiently for flood control. The secondary objective of environmental restoration also would be addressed through shoreline and tributary habitat improvements around Shasta Lake, and riparian restoration along the upper Sacramento River.

CO-4 includes restoring (1) resident fish habitat in Shasta Lake and (2) riparian habitat at four locations along the lower arms of the Sacramento River, McCloud River, and Squaw Creek (see Figure 4-3).

This component includes improving shallow, warm-water habitat by installing artificial fish cover, such as anchored complex woody structures and boulders, and planting water-tolerant and/or erosion-resistant vegetation near the mouths of tributaries. These improvements would help provide favorable spawning conditions; juvenile fish leaving the tributaries would benefit from improved adjacent shoreline habitat. Establishing vegetation also could benefit terrestrial species that inhabit the shoreline of Shasta Lake.

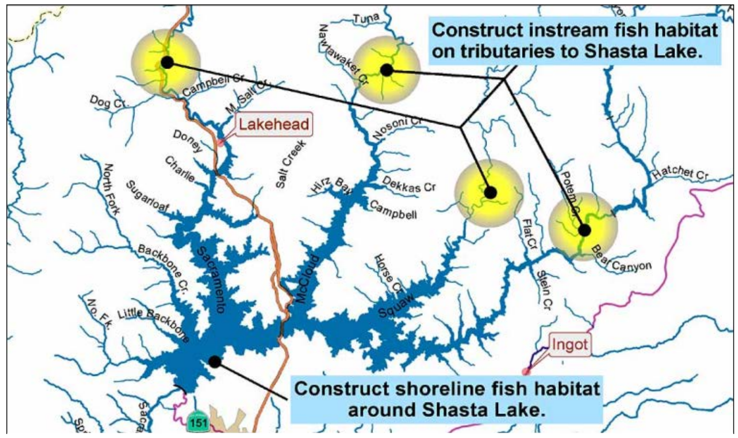

Figure 4-3. Potential Ecosystem Restoration Features in the Shasta Lake Area

This concept also includes improving and restoring instream aquatic habitat along the lower reaches of major tributaries to Shasta Lake using various structural techniques to trap spawning gravel in deficient areas, create pools and riffles, provide instream cover, and improve overall instream habitat conditions. Treatments could include installing gabions, log weirs, boulder weirs, and other anchored structures. Spawning and rearing habitat would be created by installing instream cover, such as large root wads, and drop structures, boulders, gravel traps, and/or logs that cause scouring and help clean gravel. The lower reaches of perennial tributaries to Shasta Lake would be targeted for aquatic restoration because they provide year-round fish habitat.

Also included in CO-4 is acquisition and restoration of wetland and riparian areas along the upper Sacramento River. The location and total area of potential restoration will be the subject of future studies. However, for initial planning purposes, restoration of 500 acres along the Sacramento River between Keswick and Red Bluff is included in this concept.

Major benefits of CO-4 are described below:

- **Anadromous Fish Survival –** CO-4 would benefit anadromous fish by improving water temperature conditions in the upper Sacramento River, primarily in dry and critical years, and increasing the quality and quantity of aquatic habitat. Significant additional effort is needed to reliably quantify potential benefits to the anadromous fish population from this concept. However, preliminary analyses estimate that improved water temperature conditions could result in an average annual increase of 410 salmon. Habitat restoration would add an additional 150 acres of aquatic and floodplain habitat to the Sacramento River between Keswick and Battle Creek, a critical spawning reach.

- **Water Supply Reliability –** CO-4 would increase average and dry period water supply reliability to the CVP and SWP systems through reservoir expansion and conjunctive water management. This increase corresponds to about 89,000 acre-feet during critical years.

- **Environmental Restoration, Flood Control, and Hydropower –** CO-4 includes restoring resident fish habitat in Shasta Lake and riparian habitat at four locations along the lower arms of the Sacramento River, McCloud River, and Squaw Creek. An additional 548 acres of riparian and wetland habitat would be acquired and restored along the upper Sacramento River. The location and total area of restoration in the Shasta Lake and upper Sacramento River areas will be the subject of future studies. Minor increases in hydropower production and flood protection would occur.

- **Other Benefits –** CO-4 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area, similar to that described previously for concepts incorporating a 6.5-foot raise.

CO-5 – Multipurpose with Shasta Enlargement (18.5 feet)

CO-5 addresses both primary planning objectives by raising Shasta Dam 18.5 feet in combination with conjunctive water management and anadromous fish habitat restoration.

Major plan components of CO-5 include the following:

- Raising Shasta Dam by 18.5 feet, expanding the cold-water pool, and creating 636,000 acre-feet of additional storage available for water supply.

- Implementing a conjunctive water management program.

- Acquiring, restoring, and reclaiming one or more inactive gravel mining operations along the upper Sacramento River to create about 150 acres of aquatic and floodplain habitat.

- Revising flood control operations to benefit water supply reliability by managing floods more efficiently.

- Constructing additional resident fish habitat in Shasta Lake and along the lower reaches of the Sacramento River, McCloud River, and Squaw Creek.

- Restoring 500 acres of wetland and riparian habitat at one or more sites between Redding and Red Bluff on the Sacramento River.

CO-5 is similar to CO-4, except Shasta Dam would be raised 18.5 feet instead of 6.5 feet. The additional storage created by the 18.5-foot dam raise would be used primarily to increase water supply reliability, while also improving the ability to meet water temperature objectives for winter-run salmon during drought years. The capacity of the reservoir would increase by 636,000 acre-feet to a total of 5.19 MAF and the existing TCD would be extended to achieve efficient use of the expanded reservoir. This concept also would include revising the operational rules for flood control, such that Shasta Dam and Reservoir could be managed more efficiently for water supply reliability (see previous discussion of WSR-1). Suitable areas totaling 150 acres would be chosen for restoration from one or more abandoned gravel mines (see previous discussion of AFS-3). As with CO-4, the secondary objectives of environmental restoration would be addressed through shoreline and tributary habitat improvements around Shasta Lake, and 500 acres of riparian restoration along the upper Sacramento River.

Major benefits of CO-5 include the following:

- **Anadromous Fish Survival –** CO-5 would increase the ability of Shasta Dam to make cold-water releases to regulate water temperature in the upper Sacramento River, primarily in dry and critical years. Preliminary analyses estimate that improved temperature conditions could result in an average annual increase of 1,110 salmon. Habitat restoration would add an additional 150 acres of aquatic and floodplain habitat to the Sacramento River between Keswick and Battle Creek, a critical spawning reach.

- **Water Supply Reliability –** CO-5 would increase average and dry period water supply reliability to the CVP and SWP systems through increasing the capacity of Shasta Lake in combination with conjunctive water management. This increase corresponds to about 146,000 acre-feet during critical years.

- **Environmental Restoration, Flood Control, and Hydropower –** Higher water surface elevations in the reservoir would result in a net increase in power generation of about 44 GWh per year. The ability to control floods may increase by a small degree. An additional 500 acres of riparian and wetland habitat would be acquired and restored along the upper Sacramento River between Red Bluff and Redding. The location and total area of restoration in the Shasta Lake and upper Sacramento River areas will be the subject of future studies.

- **Other Benefits –** CO-5 would provide a small benefit to the water-oriented recreation experience at Shasta Lake due to the increase in lake surface area, similar to that described previously for concepts incorporating an 18.5-foot raise. The maximum surface area of the lake would increase by about 2,500 acres (8 percent), from 29,600 to about 32,100 acres.

Summary Comparison of Concept Plans

To help focus the plan formulation process and select the most appropriate plans to be carried forward for further development, the concept plans were compared considering two basic planning criteria: effectiveness and efficiency. These are two of four criteria identified in the P&G for water resources planning, in addition to completeness, and acceptability. Below is a description of the two criteria and their application. Table 4-3 shows the resulting comparison of the concept plans based on their relative ability to address each of the criteria. As can be seen in the table and described below, each plan was assigned a relative ranking ranging from very low to very high for each criterion. Each comparison criterion for the concept plans in the table received the same weighting and resulted in an overall relative ranking. This overall ranking was used, along with other information, to determine if a concept plan should be considered further in the plan formulation process in the SLWRI.

Effectiveness

Effectiveness is the extent to which a plan alleviates problems and achieves objectives. For the primary planning objective of anadromous fish survival, two major relative ranking factors were considered: (1) increasing salmon survival (decreased salmon mortality) and (2) increasing habitat for spawning. For water supply reliability, ranking was based on the relative amount of new drought period yield that could be derived from each concept plan. For the secondary planning objectives, three relative ranking factors were considered: (1) whether a plan included ecosystem restoration, (2) potential to affect flood peaks downstream from Keswick Dam, and (3) potential to increase net electric energy. Primary planning objectives received 80 percent of the weight and secondary planning objectives received 20 percent of the weight for this criterion.

As indicated in Table 4-3, concept plans with the greatest effectiveness in meeting planning objectives are WSR-3, CO-2, and CO-5. This is primarily because, of the 12 concept plans, these three would generally result in the greatest combined contribution to both primary planning objectives. Each AFS-focused plan, when compared to other concept plans, ranks low primarily because the AFS plans would provide limited benefits to other planning objectives. The same conclusions apply to the larger sizes of raising Shasta Dam.

Table 4-3. Summary Comparison of Concept Plans

Concept Plans	**Comparison Criteria**		**Identified Status and Relative Ranking**
	Effectiveness	**Efficiency**	
AFS-1 – Increase Cold-Water Assets with Shasta Operating Pool Raise (6.5 feet)	Significantly effective in helping benefit anadromous fish survival. Does not significantly contribute to water supply reliability if all storage is dedicated to fisheries purposes. Incidental contribution to flood control and hydropower objectives.	Because contributes to only one primary planning objective (anadromous fish survival), results in greatest cost for that purpose.	Enlarging Shasta only for increasing the cold-water pool is **identified** for further consideration as a stand-alone plan. Although this plan addressed only one primary planning objective, if considered in a larger plan (allocation of space), this plan might be found feasible.
Relative Rank	*Moderate*	*Low*	*Moderate*
AFS-2 – Increase Minimum Anadromous Fish Flow with Shasta Enlargement (6.5 feet)	Relatively low increase in fish habitat with uncertain benefit to increased survival. Major trade-off in water supply reliability for relatively minor increased minimum flows. Incidental contribution to flood control and hydropower objectives.	Very high unit costs for increased fish habitat. Also, very high unit cost for water supply reliability. High costs due to dedicating storage space to increasing minimum winter/spring flows with little contribution to water supply.	Enlarging Shasta primarily to increase winter/spring river flows for anadromous fish is **not identified** for further consideration as a stand-alone plan. Very high costs for marginal increases in meeting objectives. Same conclusion for any sized project with similar component measures. However, potential operational changes to increase fish survival are **identified** for further study as part of any plan considered.
Relative Rank	*Low*	*Low*	*Low*
AFS-3 – Increase Minimum Anadromous Fish Flow and Restore Aquatic Habitat with Shasta Enlargement (6.5 feet)	Similar to AFS-2. Increased effectiveness in anadromous fish habitat through gravel mine restoration.	Similar to AFS-2. Very high unit costs to meet primary planning objective.	Similar to AFS-2, **not identified** for further consideration as a stand-alone plan. High costs for marginal increases in meeting objectives.
Relative Rank	*Low*	*Low*	*Low*
WSR-1 – Increase Water Supply Reliability with Shasta Enlargement (6.5 feet)	Relatively low potential to effectively increase water supply reliability and improve fish survival. Incidental contribution to flood control and hydropower objectives.	High cost-efficiency. Unit cost for water supply reliability highly competitive with other new sources, including potential surface water storage projects.	Enlarging Shasta primarily for water supply reliability from sizes 6.5 feet to about 18.5 feet is **identified** for further development primarily because (1) consistent with goals of the 2000 CALFED ROD, (2) high cost-efficiency compared to other new sources, and (3) provides significant incidental benefits to anadromous fish and secondary study objectives.
Relative Rank	*Low*	*Moderate*	*Moderate*

Table 4-3. Summary Comparison of Concept Plans (contd.)

Concept Plans	Comparison Criteria		Identified Status and Relative Ranking
	Effectiveness	**Efficiency**	
WSR-2 – Increase Water Supply Reliability with Shasta Enlargement (18.5 feet)	Moderate potential to effectively address primary planning objectives. Significant contribution to water supply reliability. Incidental contribution to flood control and hydropower objectives.	Very high cost-efficiency. Superior to all other known new sources, including potential surface water storage projects.	**Identified** for further development for reasons similar to WSR-1. Also, enlarging Shasta to maximum extent possible without major relocations can maximize cost-efficiency.
Relative Rank	*Moderate*	*Very High*	*High to Very High*
WSR-3 – Increase Water Supply Reliability with Shasta Enlargement (High Level)	High potential to significantly address primary planning objectives. Significantly addresses water supply reliability. Can contribute significantly to cold-water salmon resources. Provides major opportunities to address secondary planning objectives.	Very high implementation cost. Relatively high unit cost for new water supplies.	**Not Identified** for further consideration at this time. High social and environmental impacts in Shasta Lake area. Very high implementation cost.
Relative Rank	*High*	*Low*	*Low*
WSR-4 – Increase Water Supply Reliability with Shasta Enlargement (18.5 feet) and Conjunctive Water Management	Similar to WSR-2 with increased contribution to water supply reliability through conjunctive use management. However, significantly diminishes potential increased fish survival benefits.	High cost-efficiency for water supply reliability. Estimated to result in the lowest unit cost of all plans considered and of all other known potential water supply reliability projects.	Enlarging Shasta to maximum extent possible without major relocations and including conjunctive water management component is **not identified** for further development. Although cost-efficient, it diminishes fish survival benefits to achieve additional water supply reliability. No known active support for a conjunctive use component.
Relative Rank	*Low*	*Very High*	*Moderate to High*
CO-1 – Increase Anadromous Fish Habitat and Water Supply Reliability with Shasta Enlargement (6.5 feet)	Potential to address primary planning objectives with emphasis on spawning habitat restoration. Contributes to cold-water salmon resources and reduced mortality. Includes features to increase reservoir reoperation for flood control and water supply.	Unit cost for water supply reliability competitive with other new sources, including potential surface water storage projects. High potential for efficient salmon habitat restoration along the upper river.	**Not identified** for further consideration as a stand-alone plan. Major components are redundant with WSR-1 and CO-2, which are recommended for further development.
Relative Rank	*Moderate*	*Moderate*	*Moderate*

Table 4-3. Summary Comparison of Concept Plans (contd.)

Concept Plans	Comparison Criteria		Identified Status and Relative Ranking
	Effectiveness	**Efficiency**	
CO-2 – Increase Anadromous Fish Habitat and Water Supply Reliability with Shasta Enlargement (18.5 feet)	Similar to CO-1, but with increased potential to address primary and several secondary planning objectives due to increased storage space.	High cost-efficiency. Unit cost for water supply reliability highly competitive with other new sources, including potential surface water storage projects. High potential for efficient salmon habitat restoration along the upper river.	Enlarging Shasta to the maximum extent possible (without major relocations), and including features to increase anadromous fish habitat is **identified** for further development. Recommended primarily because this plan is (1) consistent with goals of the CALFED ROD, (2) highly cost efficient, and (3) addresses most of the planning objectives.
Relative Rank	*High*	*High*	*High*
CO-3 – Increase Anadromous Fish Flow/Habitat and Water Supply Reliability with Shasta Enlargement (18.5 feet)	Low to moderate potential to effectively address primary objectives. Potential to significantly benefit salmon resources through restoring fish habitat. Provides major opportunities to address secondary objectives.	Reduced cost-efficiency for water supply reliability due to dedicated increased minimum flows.	For reasons similar to AFS-2 and AFS-3, enlarging Shasta with significant storage space dedicated to increased winter/spring flows for anadromous fish is **not identified** for further consideration as a stand-alone plan at this time. Very high costs for marginal increases in meeting objectives. However, potential operational changes to increase fish survival are recommended for further study as part of any plan considered.
Relative Rank	*Moderate*	*Moderate*	*Moderate*
CO-4 – Multipurpose with Shasta Enlargement (6.5 feet)	Moderate potential to address primary planning objectives, with emphasis on spawning habitat restoration. Contributes to cold-water salmon resources and reduced mortality. Includes features to increase reservoir reoperation for flood control and water supply. Includes features to help restore ecosystem resources along the upper Sacramento River and near Shasta Lake.	Most cost-efficient plan for a 6.5-foot dam raise. Moderate potential for efficient salmon habitat restoration along upper river. High potential for helping restore ecosystem resources along the upper Sacramento River and near Shasta Lake.	**Not identified** for further consideration as a stand-alone plan with a 6.5-foot raise, primarily due to reduced effectiveness and efficiency. Major components are redundant with WSR-1 and CO-5, which are recommended for further development.
Relative Rank	*Moderate*	*Moderate*	*Moderate*

Table 4-3. Summary Comparison of Concept Plans (contd.)

Concept Plans	Comparison Criteria		Identified Status and Relative Ranking
	Effectiveness	Efficiency	
CO-5 – Multipurpose with Shasta Enlargement (18. 5 feet)	High potential to address primary planning objectives with emphasis on spawning habitat restoration. Significantly contributes to cold-water salmon resources and reduced mortality. Includes features to increase reservoir reoperation for flood control and water supply. Includes features to help restore ecosystem resources along the upper Sacramento River and near Shasta Lake.	High cost-efficiency for water supply reliability. High potential for efficient salmon habitat restoration along upper river. High potential for helping restore ecosystem resources along the upper Sacramento River and near Shasta Lake.	Enlarging Shasta to the maximum extent possible (without major relocations), and including features for conjunctive water management, anadromous fish habitat, and ecosystem restoration is **identified** for further development. Recommended primarily because this plan is (1) consistent with goals of the 2000 CALFED ROD, (2) highly cost-efficient, and (3) addresses all planning objectives.
Relative Rank	*High*	*High*	*High*

Key:
AFS = Anadromous Fish Survival
CALFED = CALFED Bay-Delta Program
CO = Combined Objective
ROD = Record of Decision
WSR = Water Supply Reliability

Anadromous Fish Survival This subcriterion is the relative ability of a plan to help increase the survival of anadromous fish populations in the Sacramento River primarily upstream from the Red Bluff. Included in Table 4-4 is a preliminary estimate of the average annual increase in Chinook salmon populations upstream from the Red Bluff only, resulting from the increase in the cold-water pool in Shasta Reservoir for three dam enlargements and reservoir operations.

For dam raises of 6.5 feet, the greatest benefit to fish survival would occur with AFS-1 because all additional space would be dedicated to the goal of increasing the cold-water pool. However, AFS-1 would not significantly contribute to the other planning objectives. The next greatest increase in fish survival with a dam raise of 6.5 feet would occur equally with WSR-1, CO-1, and CO-4. The least apparent benefit in increased salmon survival would occur with AFS-2 and AFS-3. This is because increasing minimum flows on the upper Sacramento River would deplete the cold-water pool, which may be needed later in the year for temperature regulation during the warm summer months. Also for these two concept plans, the potential to benefit other objectives would be low. It is expected that similar relationships would occur for larger dam raises but with increasing effectiveness for anadromous fish survival.

As mentioned, AFS-3, CO-1, CO-2, CO-3, CO-4, and CO-5 all included restoration of one or more abandoned gravel mines along the upper Sacramento River downstream from Keswick Dam for anadromous fish survival benefits. Recent evaluations related to the use of the SALMOD model have indicated that restoring these areas may not result in a significant benefit to anadromous fish. Concerns have been expressed ranging from a low likelihood that these areas could be effectively used to increase spawning and rearing habitats to the likelihood for increased predation. Further, during public and stakeholder outreach meetings in late 2005 held primarily for environmental scoping purposes, there was little to no interest expressed for acquisitioning and restoring these areas. At this time, restoration of abandoned gravel mines is not included in further plan formulation activities for the SLWRI.

The estimated difference in increased fish survival benefits between WSR-2 or CO-2 and WSR-4 or CO-5 (dam raises of 18.5 feet) is because including a conjunctive management component in the concept plans would lessen the amount of cold-water available during critical periods compared to operations without the conjunctive management component. Although the relative increase in water supply yield is sizeable, so are the benefits forgone for anadromous fish survival when a conjunctive use component is included. The greatest benefit to anadromous fish from an increase in the cold-water pool would be with WSR-3 (dam raise of 202.5 feet). It is believed, however, that this plan could have adverse impacts not yet defined that would discount the apparent increase in salmon survival.

Table 4-4. Summary of Estimated Costs and Benefits for Concept Plans

Item	Concept Plans											
	Anadromous Fish Survival Focus			Water Supply Reliability Focus				Combined Objective Focus				
	AFS-1	AFS-2	AFS-3	WSR-1	WSR-2	WSR-3	WSR-4	CO-1	CO-2	CO-3	CO-4	CO-5
Raise Shasta Dam (feet)	**6.5**	**6.5**	**6.5**	**6.5**	**18.5**	**202.5**	**18.5**	**6.5**	**18.5**	**18.5**	**6.5**	**18.5**
Total Increased Storage (1,000 acre-feet)[1]	290	290	290	290	636	9340	636	290	636	636	290	636
Accomplishments												
Anadromous Fish												
- Spawning Habitat - Restore Gravel Mines (acres)	-	-	150	-	-	-	-	150	150	150	150	150
- Minimum Flows (acres)	-	170	170	-	-	-	-	-	-	170	-	-
- Average Annual Salmon Increase (1,000 fish)[2]	860	370	370	410	1,110	10,620	1,020	410	1,110	980	410	1,020
Water Supply Reliability (1,000 acre-feet/year)[3]	0	20	20	72	125	703	146	72	125	90	89	146
Ecosystem Restoration (acres)	-	-	-	-	-	-	-	-	-	-	548	548
Hydropower Generation (GWh/yr)[4]	51	32	32	15	44	2,254	44	15	44	61	12	44
Flood Damage Reduction	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Construction Cost ($millions)[5]	282	282	292	282	408	5,250	459	292	418	418	356	483

Notes:

[1] Early evaluations estimated the storage capacity increase with a 6.5-foot raise at 290,000 acre-feet as indicated in Table 4-2

[2] Average Annual Salmon Increase numbers are from Initial Alternatives Information Report (simulated using SALMOD), June 2004. Updated modeling results can be found in the Modeling Appendix.

[3] Approximate increased water supply yield from the 2004 Initial Alternatives Information Report simulated with CalSim-II based on drought year conditions with Banks Pumping capacity at 6,680 cfs. At 8,500 cfs pumping capacity, yield is about 18 percent greater.

[4] Preliminary estimate based on 2003 conditions.

[5] Based on preliminary designs and cost estimates at 2003 price levels.

Key:
AFS = anadromous fish survival
CO = combined objective
GWh/yr = gigawatt hours per year
WSR = water supply reliability

Water Supply Reliability This subcriterion is the relative potential of a plan to help increase water supplies and water supply reliability to the CVP and SWP to help meet current and future water demands, with a primary focus on modifying Shasta Dam and Reservoir. Included in Table 4-4 is an estimate of the increase in drought period water supply reliability for the concept plans. As can be seen, the increase in water supply reliability ranges from about 20,000 acre-feet per year for dam raise of 6.5 feet (including dedication of increased storage to increasing spring fish flows) to over 700,000 acre-feet per year for a dam raise of 202.5 feet. The exception is concept plan AFS-1, which would provide only an incidental amount of water supply yield.

Ecosystem Restoration This subcriterion is a measure of the ability of a plan to address the secondary planning objective of ecosystem restoration. Through pursuit of the primary planning objectives, significant potential is created to implement features to help conserve and restore ecosystem resources, especially in the Shasta Lake area.

Flood Control This subcriterion includes a measure of the ability of a plan to reduce flood damages along the upper Sacramento River near Redding. Each of the concept plans has the potential to incidentally provide increased flood control opportunities. However, for any of the plans other than WSR-3, this possibility is very small, unless the projects were operated (at least in part) specifically for that purpose. However, there does not appear to be sufficient residual need for an additional flood control increment in Shasta Reservoir.

This subcriterion also addresses increases in public safety at Shasta Dam. All of the concept plans include routing the PMF from the top of conservation space in Shasta Reservoir. As mentioned, this results in additional features at Shasta Dam and around Shasta Reservoir to more safely accommodate extremely rare and large flood events such as the PMF.

Hydropower This subcriterion is a measure of the ability of a plan, through pursuit of the primary planning objectives, to help increase hydropower capabilities at Shasta Dam. Each of the plans incidentally provides increased opportunities for hydropower generation. From Table 4-4, based on 2003 conditions, it is estimated that increases in hydropower generation would range from about 15 GWh/year for WSR-1 to over 2,200 GWh/year for WSR-3 (not including loss of generation at the Pit 7 Dam).

Efficiency

Efficiency is the measure of how efficiently a plan alleviates identified problems while realizing specified objectives consistent with protecting the Nation’s environment. Concept plans ranking highest for this criterion are WSR-2, WSR-4, CO-2, and CO-5. This is primarily because each of these plans provides a significant increase in water supply reliability at a relatively low unit cost while significantly contributing to other planning objectives. Each of the AFS-focused concept plans and WSR-3 rank low. For the AFS-focused plans, this is primarily because the increased storage space would be dedicated to either increasing the cold-water pool or instream flows. These plans would provide very little economic benefit to the other planning objectives. However, plans could be simulated to dedicate some of the storage space to water supply and some to anadromous fish, which would result in lowered traditional economic benefits but increased fisheries benefits.

Anadromous Fish Survival Under the efficiency criterion, this is the measure of the potential for a plan to increase the long-term survivability of anadromous fish in the upper Sacramento River at the lowest incremental cost. Through use of SALMOD and by assessment of other features, it is estimated that the most efficient way to significantly and effectively increase the survivability of anadromous fish in the upper Sacramento River is through increases in the cold-water pool in Shasta Lake that would result in cooler water releases during critical periods of the year. Other ways of helping improve the fishery are included in several concept plans such as increased winter/spring minimum flows and habitat restoration. These measures were found to be less effective and had a higher uncertainty for success than increasing the cold-water pool in the lake.

Water Reliability Unit Cost

This is a measure of the potential for a plan to increase the reliability of the CVP and SWP by developing a reliable additional increment of water at the lowest unit cost (dollars per acre-foot of drought period yield). It is estimated that concept plans WSR-2, WSR-4, CO-2, and CO-5 would result in the lowest unit water costs compared to the other plans considered. Excluding AFS-1, concept plans that would result in the highest unit cost for increased water supply reliability are AFS-2, AFS-3, WSR-1, and WSR-3.

Secondary Planning Objective Costs

This is a measure of the potential for a plan to also include benefits for ecosystem restoration, flood control, public safety, and hydropower with the lowest incidental and economically justified additional cost. All dam raise scenarios provide some amount of increased seasonal storage space that can contribute to increased efficiency in flood operations and a higher head for power generation. For public safety, all plans would include added features to increase the certainty of Shasta Dam and Reservoir safely passing the PMF. The relative efficiency of providing flood control and hydropower increases with larger reservoirs and higher dam raises. The efficiency of a plan in providing ecosystem restoration relative to enlarging Shasta Dam and Reservoir will require additional evaluation.

Likelihood for Federal Interest

Potential for Federal interest exists for each of the concept plans, providing the plans are economically feasible and a non-Federal sponsor(s) is capable and willing to share in implementing the cost for a potential project. For those plans with high costs for a specific unit of benefit to the anadromous fishery, ecosystem, or water supply reliability, potential for Federal interest is greatly diminished because of the likely lack of economic feasibility. This is believed to be especially true for concept plans similar to AFS-1, AFS-2, AFS-3, WSR-3, and CO-3.

CALFED Consistency

This is a measure of the relationship of the plan to the overall goals and objectives of the CALFED ROD, or other ongoing projects and programs. To rank high, a plan must neither preclude nor enhance the potential for development of other projects and programs. All of the concept plans, with the exception of AFS-1 and WSR-3, are believed to be fundamentally consistent with the CALFED ROD.

Concept Alternatives Carried Forward

After comparing each concept plan to the planning criteria above, five plans initially appeared superior in Table 4-3 and in supporting analyses. Accordingly, these five plans and the required No-Action plan were recommended for further development in the comprehensive plans phase of the SLWRI. However, although WSR-4 was initially carried forward as an alternative, subsequent analysis of the conjunctive use component indicated tradeoffs between conjunctive use water supply benefits and critical gains in fisheries benefits. The resulting reduction in benefits to fisheries operations in dry and critical years was deemed unacceptable in terms of meeting primary project planning objectives. Thus, WSR-4 and the conjunctive use component of CO-5 were eliminated from further consideration. CO-2 was also initially carried forward, but was subsequently eliminated from further consideration because continued evaluation concluded that restoration of existing gravel mines would have a low likelihood of successfully benefiting salmon resources. Concept plans recommended for further development include the following:

- No-Action
- **WSR-1** –Increase Water Supply Reliability with Shasta Enlargement (6.5 feet)
- **WSR-2** – Increase Water Supply Reliability with Shasta Enlargement (18.5 feet)
- **CO-5** – Multipurpose with Shasta Enlargement (18.5 feet)

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