CHAPTER IX
SPECIAL TOPICS

This chapter summarizes various topics and analyses that, in addition to information in the appendices and reference documents, supported development of the concept plans and initial alternatives. Special topics included in this chapter are (1) scenarios for enlarging Shasta Dam and Reservoir, (2) designs and costs, (3) CALSIM II modeling, (4) fish survival assessment, (5) hydropower benefits and (6) sensitivity of Banks Pumping Plant expansion.

SHASTA DAM AND RESERVOIR ENLARGEMENT SCENARIOS

In the 1999 Reclamation report titled Appraisal Assessment of the Potential for Enlarging Shasta Dam and Reservoir, 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 significantly change due to the need for relocations or modifications of major project features. 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-gross-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-gross-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 coffer dams 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, and also to help focus the number of concept plans.

Information is presented below on 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 to identify potential sizes recommended for further development into concept plans.

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 million acre-feet, which is an increase of 290,000 acre-feet above the existing available storage. At gross 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 IX-1** lists major features associated with this dam raise scenario.

TABLE IX-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 (ft)	NA	6.50	18.50	30.00	102.50	202.50
Dam Crest Elevation (ft)	1,077.50	1,084.00	1,096.00	1,107.50	1,180.00	1,280.00
Gross Pool Raise (ft)	NA	8.50	20.50	32.00	104.50	204.50
Gross Pool Elevation (ft)	1,067.00	1,075.50	1,087.50	1,099.00	1,171.50	1,271.50
Reservoir Capacity (MAF)	4.55	4.84	5.19	5.57	8.47	13.89
Surface Area @ Gross Pool Elevation (acres)	29,600	30,700	32,100	33,700	44,200	60,800
Capacity Increase (MAF)	NA	0.29	0.64	1.02	3.92	9.34

Key:
ft – feet MAF - million acre-feet NA - not applicable

The dam raise would be limited to the existing dam crest only, with mass concrete placed in blocks on the existing concrete gravity section and precast concrete panels used to retain compacted earthfill placed on wingdam 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 gross 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 gross pool elevation of 1,075.5, about 7 existing bridges would need to be either significantly modified or relocated. **Table IX-2** lists estimated infrastructure impacts associated with various increases in gross pool. Minor modifications to the Pit River Bridge, which carries I-5 and the UPRR near Bridge Bay, would be required with this scenario.

The expanded gross pool would impact about 45 structures that would need to be removed or relocated (see **Figure IX-1**). However, few impacts would occur to reservoir rim ecosystem resources or reservoir-area developed properties.

TABLE IX-2
RESERVOIR INFRASTRUCTURE IMPACTS AND ACTIONS FOR ELEVATIONS 1,070 - 1,280[1]

New Top of Joint-Use	Impact Remediation Actions
1,071	Relocate Charlie Creek Bridge, Doney Creek Bridge, and Antlers Bridge, relocate impacted portion of Lakeshore Drive north of Sugarloaf
1,072	Relocate UPRR Doney Creek Bridge, UPRR Sacramento River Bridge (2nd Crossing), relocate segment of Bully Hill Rd 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 gross 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 town of Pollock (population 1,165 to ~1,220)
1,170	Begin to remediate impacts 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 gross pool at crest of Pit 7 Dam[2]
Key: I-5 - Interstate 5	UPRR - Union Pacific Railroad

Notes:
[1]This table does not include impacts to specific buildings. Impacted portions of roads, communities, and other infrastructure will 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 feet (powerhouse yard floor) and elevation 1,278 feet (crest of dam).

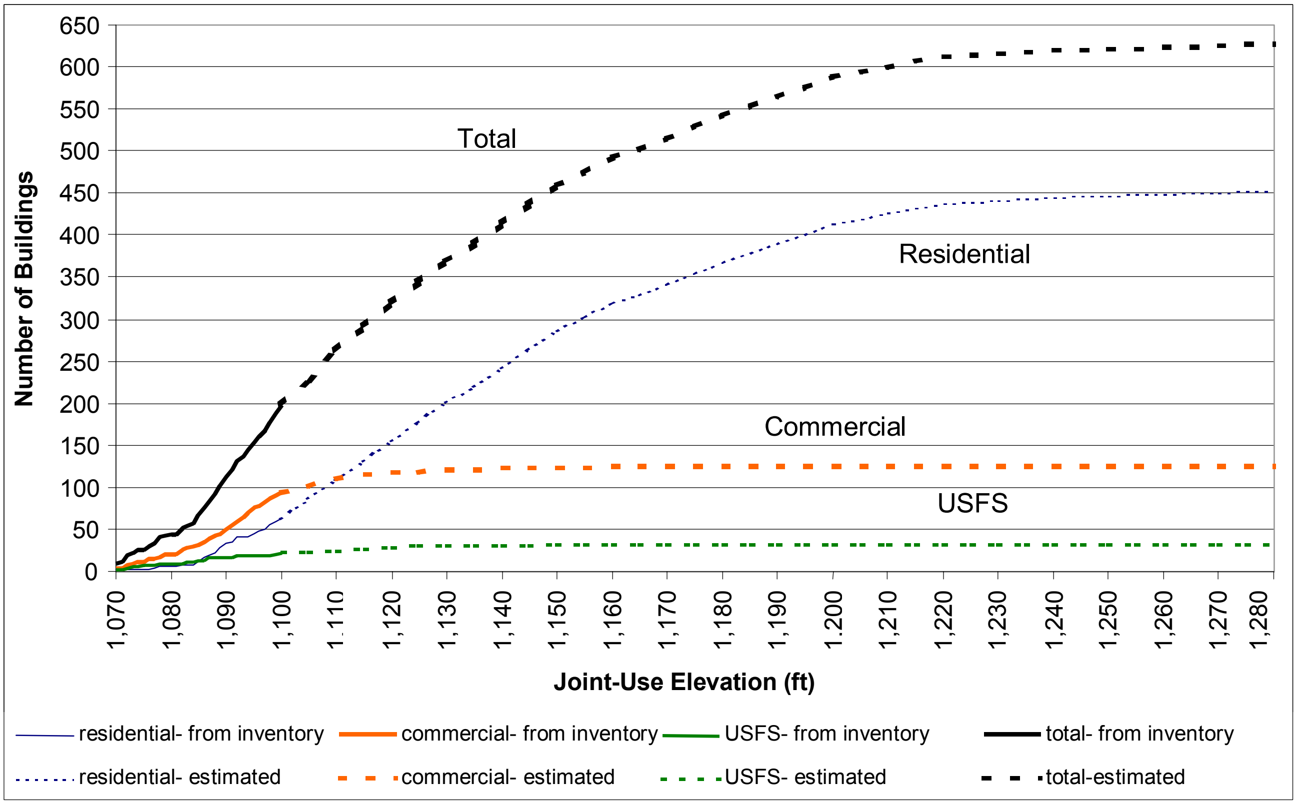

Figure IX-1 – Estimated number of structures affected by increasing the height of Shasta Dam and Reservoir.

Accomplishments and Costs

Although not to the extent of higher-larger reservoir sizes, this scenario would have the potential to contribute to both primary study objectives if also consistent with the CALFED ROD. It could support each of the secondary study 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, and increase hydropower generation, and slightly increase potential reservoir area recreation opportunities. Also, it would have minor impacts on the McCloud River and associated issues relating to the State of California special designation of that waterway.

System Yield

As mentioned previously and described in **Appendix A**, 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 IX-3** shows a comparison of the annual yield for simulated CVP and SWP deliveries for average year and drought year conditions with Banks Pumping Plant capacity at 6,680 cfs, and 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 significantly higher potential to meet future demands.

TABLE IX-3
CVP/SWP SYSTEM YIELD INCREASE
(1,000 acre-feet per year)

Dam Raise	Average Year Conditions	Drought Year Conditions
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
Key: CVP – Central Valley Project	SWP – State Water Project	

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 IX-4**. **Figure IX-2** 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 estimate 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. As shown in **Table IX-4,** the estimated first cost for the Low-Level Raise Scenario is $282 million; the resulting estimated average annual cost is $19 million.

TABLE IX-4
FIRST AND ANNUAL COSTS FOR DAM RAISE OPTIONS

Dam Raise Options	First Cost ($millions)[1]	Annual Costs ($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 Bureau of 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.

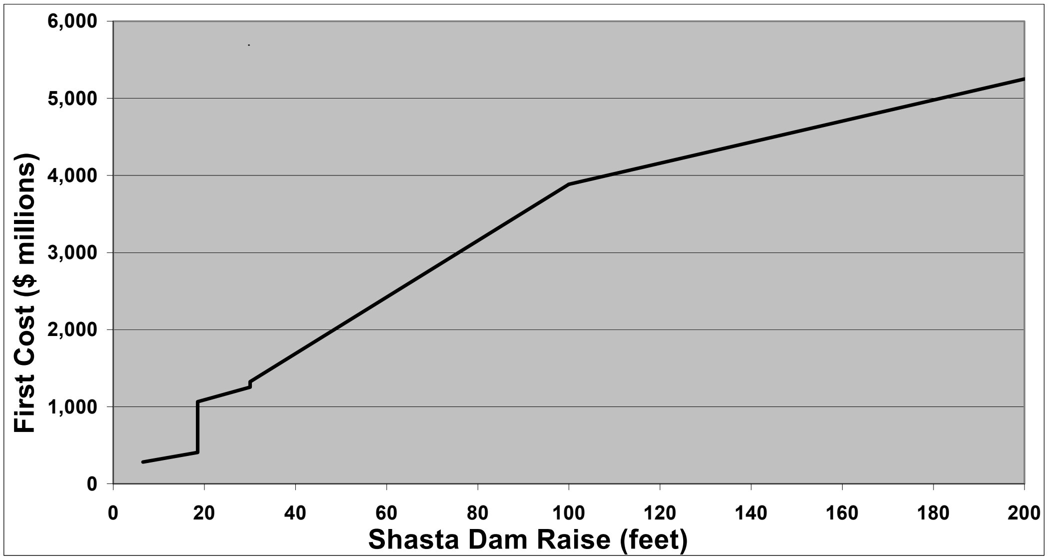

Figure IX-2 – Estimated first cost for various Shasta Dam raises.

Unit Costs

Table IX-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 IX-5** as a function of new dam crest elevation was used to create the plot in **Figure IX-3**. 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 significantly smaller influence. As shown in **Table IX-5** and **Figure IX-3**, the estimated total unit storage cost for the Low-Level Raise scenario is about $970 per acre-foot. The estimated unit cost for average annual and drought year yield would be about $410 and $270 per acre-foot, respectively.

TABLE IX-5
WATER SUPPLY UNIT COST SUMMARY

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)	290	636	636	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)							
- Total Storage[1]	970	640	1,670	1,230	1,300	990	560
- Yield – Avg Annual[2]	410	400	1,050	810	850	1,320	1,160
- Yield – Drought Year[3]	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.

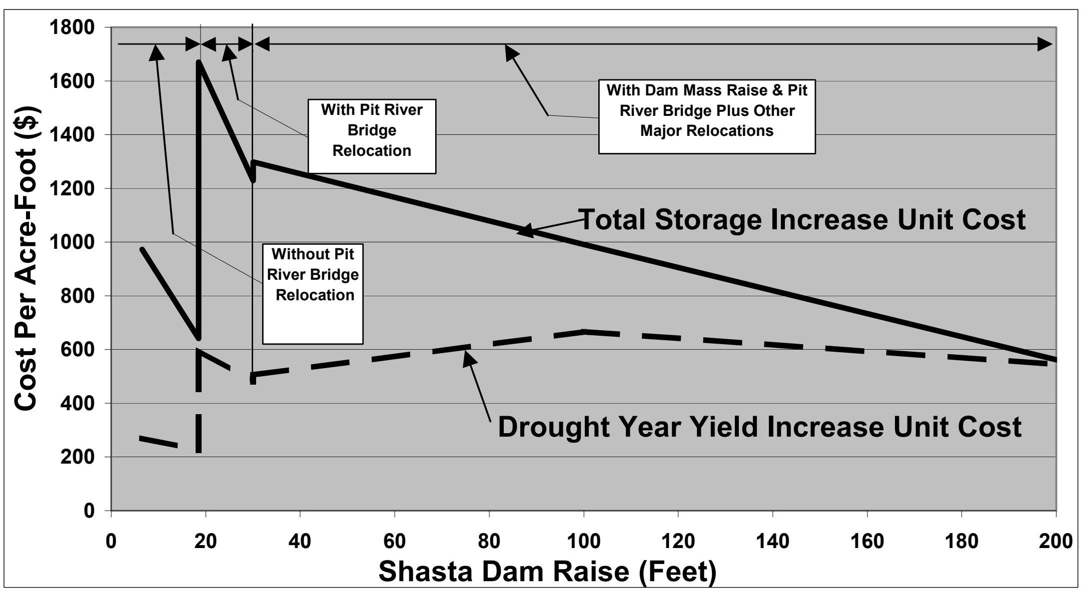

Figure IX-3– Plot of total storage and water supply reliability yield unit cost for various increases of Shasta Dam Raise.

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 636,000 acre-feet above the existing available storage. At gross 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 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 gross 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 IX-2**, with the increased gross pool at elevation 1,087.5, an estimated 7 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 gross 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 gross pool raise would be limited to about 14 feet. However, it is believed that because of the infrequent occurrences of the water surface reaching gross pool during high recreation periods, appropriate mitigation features can be included for this scenario.

The expanded gross pool area requires about 130 structures to be removed or relocated (see **Figure IX-1)**. 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 significantly contribute to both primary study objectives. It also could support each secondary study objective. Increasing the gross pool storage at Shasta Reservoir by about 636,000 acre-feet by raising the dam 18.5 feet would increase the average annual and annual drought year yield by about 71,000 and 125,000 acre-feet, respectively (see **Table IX-5**).

It also 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 slightly increase potential reservoir area recreation opportunities. This scenario is generally consistent with the goals and objectives in the CALFED ROD. It would have minor and manageable impacts on the McCloud River and issues relating to the State of California special designation of that waterway.

As shown in **Table IX-4**, to accomplish this magnitude of dam raise without major reservoir area relocations, the estimated first cost for this scenario would be about $410 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 of about $640 per acre-foot (**Table IX-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 IX-3**).

Tables IX-4 and **IX-5** and **Figures IX- 2** and **IX-3** also show the estimated impact on the first, annual, and unit costs for an 18.5-foot dam raise, including relocating I-5 and the UPRR Pit River Bridge at Bridge Bay. (It is believed for a dam raise greater than about 18.5 feet, this relocation would be needed.) 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 IX-1**). This scenario would have a new top of joint-use (gross 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 gross 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 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 gross pool elevation.

The 30-foot Expanded Low-Level Raise 30 foot 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 gross pool area would require about 200 structures to be removed or relocated (see **Figure IX-1**). This scenario also would 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. Significant impacts to reservoir rim and tributary stream ecosystem resources would occur.

Accomplishments and Costs

This scenario also would significantly contribute to both primary study objectives and also support each of the secondary study objectives. Increasing the gross 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 IX-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 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 IX-4** and **Figure IX-2**, the estimated first cost 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 of about $1,230 per acre-foot **(Table IX-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 IX-4** and **IX-5** and **Figures IX- 2** and **IX-3** also show the estimated impact on first, annual, and unit costs for a 30-foot dam raise, including this change in construction method. 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 IX-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 gross pool storage, the reservoir would cover about 44,200 acres, which is an increase of about 14,600 acres over existing conditions (49 percent). **Plate 15** includes the aerial extent of the Intermediate-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 main section of the dam with roller-compacted concrete (RCC) 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 gross pool area would require about 520 structures to be removed or relocated (see **Figure IX-1**). 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, primarily including improvements to the existing penstocks. In addition, most recreational facilities would require relocation. Significant 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 PG&E Pit 7 Dam and Powerhouse on the upper Pit River just upstream of Lake Shasta.

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 Reservoir or one of its tributaries. A significant 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 significantly contribute to both primary study objectives and also support each of the secondary study objectives. Increasing the gross 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 IX-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 significant increase in potential reservoir area recreation opportunities. However, it would have major impacts on the McCloud River and issues relating to the State of California special designation of that waterway.

Because of the significant 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, significant disruption would occur to local and interstate roadway and railroad transportation, recreation, and related facilities in the Shasta Lake region.

As shown in **Table IX-4** and **Figure IX-2**, the estimated first cost 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 IX-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 IX-1**). The new top of joint-use storage space would be 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 million acre-feet, an increase of 9.34 million acre-feet above the existing available storage. This dam raises represents the highest practical raise of Shasta Dam. Enlargements beyond this point would begin to experience significant 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 gross pool storage, the reservoir would cover about 60,800 acres, which is an increase of about 31,200 acres over existing conditions (105 percent). **Plate 15** 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 gross 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.

Significant 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 of California special designation of that waterway.

Accomplishments and Costs

This High-Level Raise scenario would significantly contribute to both primary study objectives and support each of the secondary study objectives. Increasing the gross 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 IX-5**). It would significantly increase anadromous fish survival by creating a very large increased cold water pool. In addition, because of the significant increase in total space in Shasta Reservoir capable of capturing significantly 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 gross pool elevation.

Because of the significant 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, significant 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 is about $5.2 billion with the estimated average annual cost of about $383 million (see **Table IX-4**). The estimated unit cost for new storage space in Shasta Lake would be about $560 per acre-foot **(Table IX-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 IX-5)**.

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 IX-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-Raise scenario, Expanded Low Level Raise – 18.5-Foot scenario, and High-Raise 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 IX-6
SUMMARY COMPARISON OF SHASTA DAM RAISE SCENARIOS

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
Gross Pool Raise (feet)	8.5	20.5	32	104.5	204.5
Capacity Increase (million AF)	0.29	0.64	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					
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 CALFED ROD. • Can contribute to both primary 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 CALFED ROD. • Can contribute to both primary 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 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 objectives. • Can contribute significantly 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 significantly contribute to both primary objectives. • Can contribute significantly 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 future water supply shortages.
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 – significant 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 future water shortages.

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

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

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 the CALFED program, 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 CALFED program,

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 significantly high 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 significantly high 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 significantly 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 being considered by CALFED, this scenario was carried forward for inclusion in a concept plan.

DESIGNS AND COSTS

Appraisal-level designs and cost estimates were developed for the concept plans described in **Chapter VII**. A description of these designs and costs are contained in **Appendix E (Basis of Design)** and referenced in the Shasta Dam and Reservoir Enlargement Initial Assessment Study. Following is a summary of these efforts.

Designs

Most of the design information for various dam raise elements and options in the SLWRI is based on previous evaluations preformed as part of the initial feasibility study and for the 1999 Appraisal Report, and contained in reference documents provided with this report. For the 202.5-foot raise, no additional designs were developed beyond the 1999 Appraisal Report. Additional work was conducted on designs for the 6.5-foot and 18.5-foot dam raise scenarios primarily related to main dam features, spillways, wing dams, major relocations, and appurtenant features.

Dam and Appurtenances

Following is a highlight of main dam and appurtenances features for the 6.5-foot and 18.5-foot dam raises.

Main Dam

Raises for Shasta Dam of 6.5 or 18.5 feet could be accomplished by adding blocks of mass concrete to the existing dam crest (concrete gravity section and spillway crest section). It is estimated that the mass concrete block method of raising the dam would be adequate for a raise in height about equal to its crest width (approximately 30 feet).

Wing Dams

As the height of Shasta Dam increases, wing dams would be required to extend the dam crest beyond its existing length. For a 6.5-foot dam raise, wing dams would be composed of reinforced earth embankments. For an 18.5-foot dam raise, the wing dams are estimated to be concrete to elevation 1089.5 with a similar reinforced earth panel construction on top of the concrete.

Spillway

For any raise of Shasta Dam, the three existing drum gates would be removed due to a seismic loading deficiency and their inability to handle increased reservoir loads. The drum gates would be replaced with six radial gates, each of which would be operated using a gate hoist located on an operating deck above the gate. The new top of joint-use storage (gross pool) would be at the top of the radial gates when lowered. The spillway crest and dam crest would be raised, and the training walls would be extended. The existing spillway crest length of 330 feet would be retained and the proper ogee spillway shape would be maintained.

River Outlets

Shasta Dam has 18 river outlets in 3 tiers. A dam raise of 6.5 or 18.5 feet would require replacement of the lower tier tube valves on the 102-inch outlet valves due to problems with vibration during certain operating conditions. New gates on the lower tier outlets would also provide increased operating reliability and improved discharge capacity. Current estimates indicate that the middle tier of gates is adequate for the Low-Level and Expanded Low-Level raises. River outlet modification work is estimated to be the same for the 6.5-foot and 18.5-foot dam raises.

Power Outlets

Facilities associated with the power outlets at Shasta Dam include the TCD and penstocks.

Temperature Control Device

Modifications to the TCD would be needed for dam and top of joint-use elevation raises above about 2 to 3 feet. For both 6.5-foot and 18.5-foot dam raises, modifications would primarily include extending the main steel structure to the new gross pool elevation; raising the TCD operating equipment, including gate hoists, electrical equipment, miscellaneous metalwork, and hoist platform above the new top of joint-use elevation; and lengthening the shutter operating cables.

Penstock Intake and Penstock Modifications

It is estimated that the centerline of the existing penstock intakes would remain at the current level, but the gate hoists would require relocation with a higher dam crest. The existing penstocks are estimated to be adequate for increased hydrostatic pressures resulting from a dam raise of 6.5 or 18.5 feet. Additional penstock foundations (earthquake supports) would be provided on the exposed portion of the penstocks downstream of the dam.

Reservoir Area Dikes

Small reservoir dikes would be required in the areas of Antlers/Lakeshore (for a dam raise of 18.5 feet) and the UPRR between Tunnels 1 and 2 at the south end of Bridge Bay (for dam raises of 6.5 and 18.5 feet) for protection of major existing infrastructure from increased gross pool elevations. A typical section, estimated for both of these dike locations, would have a top width of 15 feet and side slopes of 3:1, with the crest elevation estimated to be the same as the dam crest.

Major Relocations

Major structures that would need to be modified or relocated include the Pit River Bridge, railroad bridges, vehicle bridges, major roads and road segments and buildings.

Pit River Bridge

The Pit River Bridge carries the UPRR on the lower deck and I-5 on the upper deck. With either of the two low-level raises being considered, some type of protection for the bearings and steel members on the piers in the deepest part of the old Pit River channel (Piers 3 and 4) would be necessary. A scenario to protect the bearings and the steel members at Piers 3 and 4 was developed that considers using reinforced concrete box type structures to keep reservoir water off the bearings and the structure. The reinforced concrete structures would be attached to the existing piers and extend out as cantilevers parallel to the tracks with a closure wall around the perimeter. The length of the box is defined to protect the bridge lower chord steel for a distance of 4 feet above the gross pool. The top of the box would have a roof-type structure, which would provide access for inspection and maintenance activities.

Railroad Bridges

Two UPRR bridges would need to be relocated due to the increased reservoir levels with a 6.5-foot or 18.5-foot dam raise: Doney Creek Bridge and Sacramento River Bridge, Second Crossing.

It is estimated that these bridges, which were designed in the late 1930s, could be replaced with structures that would allow the current railroad elevations and grades to remain unchanged. The grades would be maintained so as not to affect railroad operations expenses, which, if changed could result in a substantial perpetual cost. Elevations would remain unchanged to minimize the amount of railroad that would need to be relocated. The railroad has a maximum allowable grade of 1 percent, so if bridge elevations were changed, the corresponding distance of railroad line modifications would be significant.

The scenario for replacing both bridges includes constructing a new replacement bridge immediately adjacent to the existing bridge on top of existing piers that would need to be completed. This would permit the new bridges to be constructed without impact to the railroad except for the short period of time needed to rework tracks on either end to connect new track to existing track. Replacement of railroad bridges is based on potential use of existing pier construction to eliminate the need for deep water construction of new piers. This consideration would result in a significant cost savings for bridge relocations if existing piers are found to be adequate for current design standards.

Vehicle Bridges

Five vehicle bridges would need to be relocated due to the increased reservoir levels with a 6.5-foot or 18.5-foot dam raise. The bridges to be relocated would include Charlie Creek, Doney Creek, McCloud River, Didallas Creek, and Second Creek bridges. No detailed designs, cost estimates, or alternative alignment analyses have been performed for these bridges, except when previous design work was performed by other agencies. Appraisal-level costs have been developed on a per square foot basis. Future study would be needed to address detailed design and cost estimates for these bridges.

Major Roads and Road Segments

Main roads that would be impacted for dam raises of 6.5 or 18.5 feet include Lakeshore Drive, Fenders Ferry, Gilman, and Silverthorn roads. Lakeshore Drive connects residences, resorts, and recreation facilities in the Lakeshore and Sugarloaf areas. Fenders Ferry Road is one of the main forest roads in the northern area of Shasta Reservoir. Gilman Road provides access to recreation facilities along the McCloud River Arm from I-5. The low segments of these roads would either need to be relocated outside of a raised gross pool or abandoned.

Buildings – Resort/Marina, Residential, USFS Facilities

On the basis of the 2003 infrastructure inventory of Shasta Reservoir, it is estimated that raising Shasta Dam by 6.5 or 18.5 feet would result in about 45 or 130 structures (see **Figure IX-1**) requiring disposition, respectively. The estimated average square feet per structure in the inventory is about 1,800. Some of the structures are located around Shasta Lake by permit and may not require acquisition/relocation. However, for this cost estimate assessment, it was estimated that all structures would be acquired. Communities located in close proximity to Shasta Lake include Sugarloaf, Lakeshore, Silverthorn, Delta, Pollock, Lakehead, and Riverview. Bridge Bay Resort and Marina also is located on Shasta Lake. This resort and marina complex is the largest on Shasta Lake and one of the largest inland marinas in the western United States.

Environmental Restoration

Environmental restoration components include restoring abandoned gravel mines, riparian habitat, floodplain terraces and instream and shoreline fish habitat.

Abandoned Mine Restoration Along the Sacramento River

This component of some of the concept plans 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 to mimic more natural conditions.

For cost-estimating purposes, a total of 150 acres is estimated for restoration. Cost estimates include a per-acre cost for restoration and for land acquisition. Estimated per-acre costs were developed from available information from other recently completed upper Sacramento River and various tributary restoration projects.

Riparian and Floodplain Restoration Along the Sacramento River

This component of some of the concept plans would involve acquiring, recontouring, and revegetating floodplain terraces and adjacent riparian areas with native plants, and performing other earth work. 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). For the purpose of this preliminary evaluation, it is estimated that a total of 500 acres would be restored at one or more sites. Planting mix, composition, and density would be determined by a more detailed site analysis, but could include native cottonwood, willow, boxelder , valley oak, western sycamore, elderberry, and a variety of understory brush species. Temporary irrigation would be provided on an as-needed basis.

Cost estimates assume a per-acre cost for restoration. Estimated per-acre costs were developed from available information from other recently completed upper Sacramento River and various tributary restoration projects.

Instream Fish Habitat on Tributaries to Shasta Lake

This component of some of the concept plans primarily would include various structural techniques to trap spawning gravels in deficient areas, create pools and riffles, provide instream cover, and improve overall instream habitat conditions. Structural treatments would vary depending on stream conditions but generally would include installing gabions, log weirs, boulder weirs, and other anchored structures. Spawning and rearing habitat would be created by providing instream cover with large root wads and by using drop structures, boulders, gravel traps, and/or logs that cause scouring and help clean gravels. This component also would involve construction of about 40 complex boulder/log structures per mile of stream to create gravel traps, pools, and riffles. For cost-estimating purposes, 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. A 100-foot wide corridor for the 8 miles of restoration was estimated for land acquisition.

Shoreline Fish Habitat Around Shasta Lake

This component of some of the concept plans would involve installing artificial fish cover, including anchored complex woody structures (root wads, trunks, and other large woody structures) and boulders; planting water-tolerant and/or erosion-resistant vegetation at prescribed locations within the reservoir drawdown area; and selective reservoir rim clearing. Specific applications would be chosen as appropriate to site-specific shoreline conditions, taking into consideration bank slope, rate of erosion, proximity to tributaries, soils, and the presence of existing cover or vegetation. For cost-estimating purposes, a total of 40 acres is estimated for shoreline restoration. Cost estimates include a cost-per-complex-structure plus per-acre costs for plantings. It is estimated that about 20 structures and approximately 400 selective plantings would be required for each acre of shoreline restored.

Conjunctive Water Management

This component consists largely of contract agreements between Reclamation and certain Sacramento River Basin water users. Contract agreements would focus on exchanging additional surface supplies in normal water years with participating CVP users for reducing deliveries (reliance on groundwater supplies) in dry and critically dry years. Possible additional infrastructure needs may include any additional river diversions, increase in current diversion capacity, increase in additional pumping capacity and/or transmission facilities to facilitate the exchange. For cost-estimating purposes, it was assumed that existing river diversion and conveyance facilities would be in place to receive surface water during normal years. However, increased groundwater pumping capacity was estimated to be required during dry and critically dry years. Based on modeling simulations for preliminary work, the peak increase in peak monthly groundwater requirement is approximately 7,700 acre-feet. To pump this additional amount of groundwater, new wells and conveyance facilities likely would be required. For cost-estimating purposes, sixty 1,500-gallon-per-minute wells would be needed. In addition, 1 acre of land for each well and allowance for conveyance facilities were included in the cost estimates.

Costs

Table IX-7 shows a breakdown of costs for items in the concept plans, total estimated first costs, and average annual costs for each of the concept plans considered. First costs in the table are based primarily on information contained in the Reclamation 1999 Appraisal Report. Adjustments, and additions were made for feature additions and deletions from the Appraisal Report. Annual costs in the table are based on a project life of 100 years and a Federal discount rate of 5-5/8 percent.

TABLE IX-7
ESTIMATED FIRST AND ANNUAL COSTS FOR CONCEPT PLANS
($millions)[1]

DESCRIPTION	AFS-1	AFS-2	AFS-3	WSR-1	WSR-2	WSR-3	WSR-4	CO-1	CO-2	CO-3	CO-4	CO-5
Lands and Damages	3.8	3.8	5.6	3.8	9.4	117.0	9.8	5.6	11.3	11.3	13.0	18.7
Relocations	126.0	126.0	126.0	126.0	173.6	1,809.0	173.6	126.0	173.6	173.6	126.0	173.6
Dams and Reservoirs[2]	82.9	82.9	82.9	82.9	125.8	2,046.0	125.8	82.9	125.8	125.8	82.9	125.8
Environmental Restoration	-	-	6.6	-	-	-	-	6.6	6.6	6.6	12.5	12.5
Conjunctive Water Management	-	-	-	-	-	-	37.5	-	-	-	37.5	37.5
Cultural Resources Preservation and Environmental Mitigation[3]	23.0	23.0	23.0	23.0	32.9	424.0	37.1	23.0	33.0	33.0	27.2	37.2
TOTAL FIELD COST	235.7	235.7	244.2	235.7	341.7	4,395.9	383.7	244.2	350.2	350.2	299.2	405.2
Planning, Engineering, and Design[4]	27.8	27.8	28.6	27.8	39.9	513.5	44.9	28.6	40.7	40.7	34.3	46.4
Construction Management[5]	18.6	18.6	19.1	18.6	26.6	347.3	29.9	19.1	27.1	27.1	22.9	30.9
TOTAL FIRST COST	282.0	282.0	291.9	282.0	408.2	5,251.7	458.5	291.9	418.0	418.0	356.4	482.5
Investment Cost												
Interest During Construction	51.7	51.7	53.8	51.7	75.0	1,339.0	84.4	53.8	76.9	76.9	65.6	88.8
TOTAL INVESTMENT COST	333.7	333.7	345.7	333.7	483.2	6,590.7	542.9	345.7	494.9	494.9	422.0	571.3
Annual Cost[6]												
Interest & Amortization	18.8	18.8	19.5	18.8	27.3	372.5	30.7	19.5	28.0	28.0	23.8	32.2
Major Replacement[7]	-	-	-	-	-	-	-	-	-	-	0.2	0.2
O&M	0.6	0.6	0.6	0.6	0.8	10.5	1.6	0.6	0.8	0.8	1.4	1.6
TOTAL ANNUAL COST	**19.4**	**19.4**	**20.1**	**19.4**	**28.1**	**383.0**	**32.3**	**20.1**	**28.8**	**28.8**	**25.4**	**34.0**
Key: AFS - anadromous fish survival CO – combined objective O&M – operations and maintenance WSR – water supply reliability												

Notes:
[1]October 2003 price levels.
[2]Includes pertinent dam crest structure removal, concrete dam, wing dams, spillway, outlet works, and reservoir dikes.
[3]Includes 1 percent of relocations, dams and reservoirs, environmental restoration, and conjunctive water management for cultural resources preservation and 10 percent of relocations, dams and reservoirs, and conjunctive water management for environmental mitigation.
[4]Includes 12 percent of relocations, dams and reservoirs, environmental restoration, and conjunctive water management.
[5]Includes 8 percent of relocations, dams and reservoirs, environmental restoration, environmental mitigation, and conjunctive water management.
[6]Based on 5-5/8 interest rate and 100-year period of analysis.
[7]Includes replacement of habitat features on a 16-year recurrence interval.

First costs in **Table IX-7** include eight major categories: (1) lands and damages; (2) relocations; (3) dams and reservoirs; (4) environmental restoration; (5) conjunctive water management; (6) cultural resources preservation and environmental mitigation; (7) planning, engineering, design, supervision, and administration; and (8) construction management. Estimated annual costs also are included in **Table IX-7**. Annual costs include amortizing the total investment cost over the life of the proposed plan, estimated O&M costs, and any major replacements. The investment cost includes the first cost and interest during construction (IDC). IDC was based primarily on uniform distribution of the first cost over the construction period, which would range from 6 to 8 years.

Lands and Damages

This cost item is intended to cover the estimated value of lands required for the concept plans. It includes land categories for four primary features – Shasta Lake area land rights, anadromous fish restoration, ecosystem restoration, and conjunctive water management.

For the 6.5-and 18.5-foot dam raise scenarios, other than in the vicinity of Lakeshore, few additional lands would need to be acquired through easement or purchase. However, additional lands (mostly Federal) would be inundated by the higher water surface elevation, and these lands have value.

Environmental restoration land requirements include lands for both anadromous fish restoration and ecosystem restoration. Lands required for anadromous fish restoration features include an estimated 150 acres for abandoned gravel mine restoration along the Sacramento River. Lands for ecosystem restoration include 100 acres for instream habitat restoration on tributaries to Shasta Lake, 40 acres for shoreline habitat restoration around Shasta Lake, and 500 acres for riparian and floodplain restoration along the Sacramento River. Land requirements for conjunctive water management facilities were estimated at 60 acres.

Relocations

Cost estimates include relocations and/or modifications to existing infrastructure within the Shasta Reservoir area that would be impacted by raising Shasta Dam. Likely significant relocations related to raising Shasta Dam include major roadways and bridges, UPRR tracks, bridges and appurtenances, area recreation facilities, minor roads, and related surface facilities. Potential modifications to the Pit River Bridge and railroad bridges for the 6.5- and 18.5-foot dam raises are described above. Cost estimates for impacts to I-5, railroad facilities, and other facilities for the high dam raise scenario were obtained from the 1999 Appraisal Report. Potential removal of the Pit 7 Dam for the high dam raise scenario is not included in the cost estimate.

Dams and Reservoirs

Costs for dams and reservoirs include estimated costs for modifications to the main dam at Shasta, wing dams, reservoir dikes, spillway modifications, outlet works, powerplant modifications (for the higher dam raise), and potential changes to or replacements of the TCD.

Environmental Restoration

Environmental restoration costs were developed for abandoned gravel mine restoration along the Sacramento River, riparian and floodplain restoration along the Sacramento River, instream habitat restoration on tributaries to Shasta Lake, and Shasta Lake shoreline habitat restoration.

Conjunctive Water Management

Conjunctive water management includes estimated costs for groundwater pumping facilities and associated infrastructure.

Cultural Resources

A value equal to 1 percent of the first cost for each of the concept plans (less lands) was developed to account for future cultural surveys and limited recovery and restoration. Additional recovery and restoration efforts could be required depending on results of the surveys and future project definition.

Environmental Mitigation

One of the plan formulation criteria is to minimize the need for environmental mitigation. However, at this level of study, to ensure that estimated total project costs are sufficient to cover costs of possible environmental mitigation, or changes in project designs to avoid mitigation, a value of 10 percent of the first cost for each of the concept plans (less lands) was developed. Resources baseline inventories and studies are underway in the primary study area. These inventories and studies will be used in the development of each of the alternative plans to better define the mitigation features, if required, and develop consistent scope cost estimates.

CALSIM II MODELING

As described in **Chapter VII**, three categories of concept plans were developed that focus on (1) increasing anadromous fish survival, (2) increasing water supply reliability or (3) combined objectives. CALSIM II, a statewide water resources planning model, was used in the SLWRI to evaluate hydrologic impacts from Shasta Lake enlargement and/or changes in system operation in the California water supply system. In the hydrologic analyses, a benchmark was established and concept plans were simulated by modifying benchmark facilities or operational rules. Hydrologic impacts are defined as CALSIM II result differences between the concept plans and benchmark conditions. CALSIM II hydrologic features of each SLWRI initial concept plan are summarized in **Table IX-8**. (See **Appendix A** for more detail.)

Concept Plans Focused on Anadromous Fish Survival

The primary objective of the AFS concept plans is to increase anadromous fish survival through a Shasta Lake enlargement of 290,000 acre-feet. Although there were three AFS concept plans, only AFS-2 was simulated in CALSIM II. A primary purpose of AFS-1 would be to increase the cool water pool in Shasta Lake and maintain cooler releases to the Sacramento River. This would be achieved through increasing the Shasta Lake minimum pool from 550,000 to 840,000 acre-feet with no change in Shasta active storage, and no hydrologic impacts (such as downstream operations and downstream flow rate) from a larger Shasta inactive storage. Therefore, a CALSIM II simulation was not necessary for AFS-1. The CALSIM II hydrologic features for AFS-3 are the same as for AFS-2, except spawning habitat restoration cannot be modeled in CALSIM II.

With a 290,000 acre-feet enlargement of Shasta Reservoir, a new minimum Keswick Dam release schedule for October through April (**Table IX-9**) was used to increase minimum Sacramento River flow from 3,250 cfs. The new monthly flow target, developed from the Final Restoration Plan of the Anadromous Fish Restoration Program (January 2001), varies with the previous end-of-September storage in the enlarged Shasta Lake; also, the flow increment is subject to a release increase ceiling of up to 500 cfs.

TABLE IX-8
CALSIM II HYDROLOGIC FEATURES OF SLWRI CONCEPT PLANS

	Shasta Dam Raise / Enlarged Active Storage			Operational Change		
	6.5 feet / 290,000 AF	18.5 feet / 636,000 AF	200 feet / 9,338,000 AF	Increase Fishery Flow Below Keswick Dam	Conjunctive Water Management	Remarks
Concepts Focused on Anadromous Fish Survival						
AFS-1						Not modeled in CALSIM II
AFS-2	X			X		
AFS-3	X			X		Same as AFS-2
Concepts Focused on Water Supply Reliability						
WSR-1	X					
WSR-2		X				
WSR-3			X			
WSR-4		X			X	
Concepts Focused on Combined Objectives						
CO-1	X					Same as WSR-1
CO-2		X				Same as WSR-2
CO-3		X		X		
CO-4	X				X	
CO-5		X			X	Same as WSR-4
Key: AFS – anadromous fish survival WSR – water supply reliability CO – combined objective AF – acre-feet						

Notes:
1. CVP agricultural contractors along Tehama-Colusa Canal (CALSIM II delivery is D112a) are a surrogate for north-of-Delta conjunctive water management. D112a cutback schedule for Tier 1/Tier 2/Tier 3/Tier 4 is 0.0/0.25/0.25/0.5.
2. New Keswick Dam release schedule for higher fishery flows from October through April is shown in Table IX-9.

Concept Plans Focused on Water Supply Reliability

The primary objective of the WRS concept plans is to increase water supply and water supply reliability through enlarging Shasta Lake. Of the four WRS plans, the first three simulated Shasta Dam raises of 6.5, 18.5, and 202.5 feet, and the fourth, WSR-4, modeled a Shasta Dam raise of 18.5 feet with conjunctive water management among CVP north-of-Delta agricultural contractors. The purpose of conjunctive water management is to exchange additional surface water supplies in normal water years for reducing deliveries (reliance on groundwater supplies) during dry years. In the CALSIM II modeling, the delivery schedule to the CVP agricultural contractors along Tehama-Colusa Canal was used as a surrogate for conjunctive water management participants. Various delivery schedules were modeled to assess the viability of adding conjunctive water management as a potential component to the concept plans.

Concept Plans Focused on Combined Objectives

The primary objectives of CO concept plans are to increase anadromous fish survival and water supply reliability. Of five concepts, only two were simulated in CALSIM II: CO-3 and CO-4. For CO-1, CO-2, and CO-5, because their CALSIM II hydrologic features are the same as for WSR-1, WSR-2, and WSR-4, respectively, their hydrologic impacts are assumed to be equivalent. CO concept simulation combines modeling methodology for the AFS and WSR concepts.

TABLE IX-9
SLWRI MINIMUM KESWICK DAM RELEASE TARGETS AND FLOW INCREASE CEILING FOR OCTOBER THROUGH APRIL

Carryover Storage[1] (MAF)	Minimum Keswick Dam Release (cfs)	Keswick Dam Release Increase Ceiling[2] (cfs)
1.9 to 2.1	3,250	0
2.2	3,500	250
2.3	3,750	500
2.4	4,000	500
2.5	4,250	500
2.6	4,500	500
2.7	4,750	500
2.8	5,000	500
2.9	5,250	500
3.0	5,500	500
Key:	cfs – cubic feet per second	MAF – million acre-feet

Notes:
[1]Carryover storage is the end-of-September storage for Shasta Lake.
[2]"Keswick Dam release increase ceiling" limits the differences between the "minimum Keswick Dam release target" under the new release schedule and the benchmark.

CALSIM II Results

CALSIM II modeling results for the SLWRI concept plans are summarized in **Table IX-10** and **Figures IX-4** and **IX-5**.

Table IX-10 shows the annual average increase in project deliveries compared to the SLWRI Benchmark; **Figure IX-5** shows a breakdown of the increase in CVP deliveries. Most of increase in the CVP total deliveries went to south-of-Delta agricultural deliveries, followed by north-of-Delta agricultural deliveries and Cross Valley Canal deliveries. All concept plans had higher CVP total deliveries but some SWP total deliveries were reduced by a small degree. The greater the enlargement, the more CVP total increase deliveries. For the same enlargement, the concept plan with conjunctive water management had a greater increase. During wet years, conjunctive water management created additional underground storage for floodwater through in-lieu banking; in dry years, groundwater was pumped to provide extra water supply. However, for the same enlargement, the concept plan with a new Keswick Dam release target had a smaller increase; higher release requirements for Shasta Dam from October through April reduced storage for summer water consumption.

TABLE IX-10
SUMMARY OF MODELING RESULTS FOR CONCEPT PLANS

Concept Plan	Increase in Annual Average Delivery Compared to the Benchmark (1,000 acre-feet)			
	CVP		SWP	
	All Year Types	Dry and Critical Years	All Year Types	Dry and Critical Years
AFS-1	0	0	0	0
AFS-2	-16	0	18	20
AFS-3	-16	0	18	20
WSR-1	51	83	-3	-11
WSR-2	79	138	-8	-13
WSR-3	348	768	-17	-65
WSR-4	89	162	-9	-16
CO-1	51	83	-3	-11
CO-2	79	138	-8	-13
CO-3	25	70	12	20
CO-4	57	107	-7	-18
CO-5	89	162	-9	-16

Key:
AFS – anadromous fish survival
CO – combined objective
CVP – Central Valley Project
SWP – State Water Project
WSR – water supply reliability

Notes:
1. Year-types are based on the Sacramento Valley Water Year Hydrologic Classification Index.
2. Banks Pumping Plant capacity is 6,680 cfs for the benchmark.

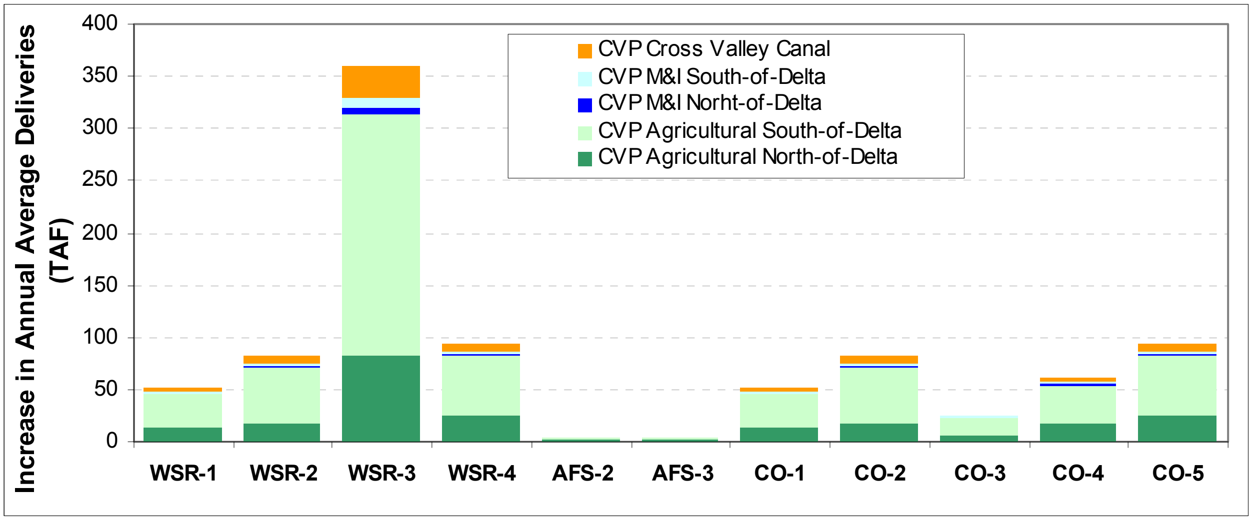

Figure IX-4. Simulated annual average increase in CVP deliveries compared to the benchmark (agricultural, M&I, and Cross Valley Canal).

Figure IX-5 shows the monthly average increase in Keswick Dam releases from the benchmark. For the concept plans, except WSR-3, patterns are similar; for concept with the same enlargement, patterns are even more alike. A larger Shasta Lake captured more flood flow during December through February, and increased releases for high summer consumption from June through September. As noted previously, AFS-1 was not simulated because active storage in Shasta would not change (all additional storage would be dedicated to increasing flows) and there would be no resulting hydrologic impacts.

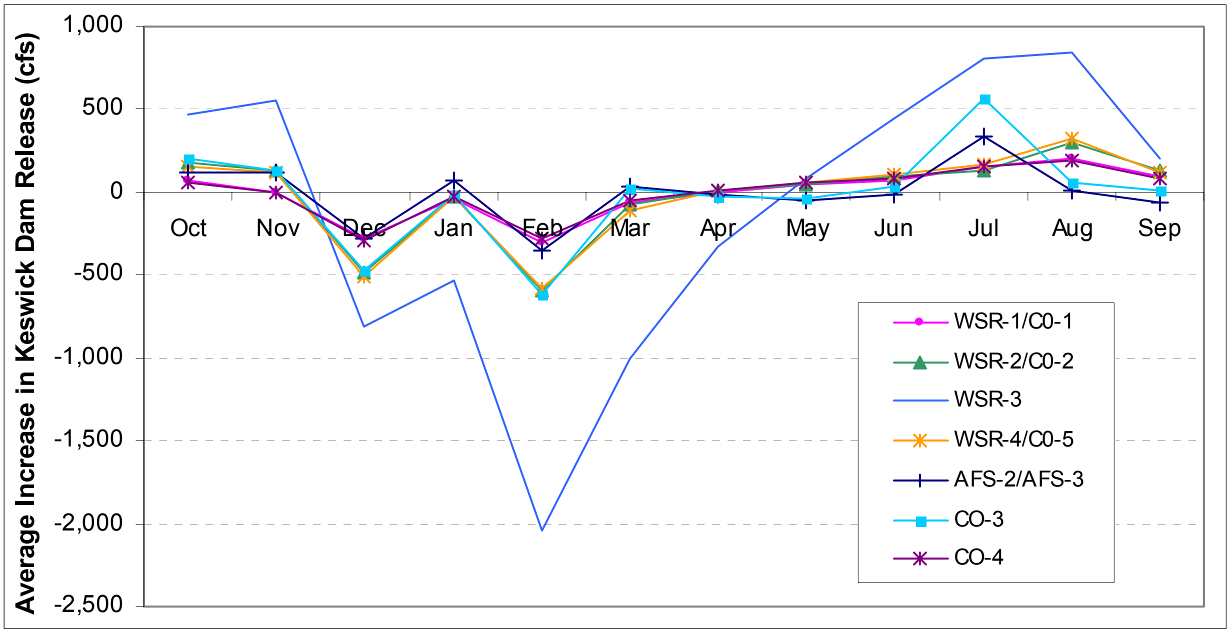

Figure IX-5. Simulated monthly average increase in Keswick Dam releases compared to the benchmark.

FISH SURVIVAL ASSESSMENT

The health and survival of anadromous fish depend on numerous environmental factors, including water temperature, available habitat, river flows, seasonal hydrologic conditions, spawning substrate, ocean conditions, and many more. This complex interaction makes it difficult to predict how changes to one or more environmental conditions will affect the survival of anadromous fish. This section discusses preliminary analyses conducted to assess the potential effects on anadromous fish survival of two important factors: cold water storage in Shasta Lake and minimum flows on the upper Sacramento River.

Currently, no tools exist that take into account all of the major influences on anadromous fish survival in the upper Sacramento River. Consequently, preliminary analyses were performed that evaluated cold water storage and minimum stream flows separately. The effects of additional cold water storage were assessed using procedures and models developed previously by Reclamation and USFWS to evaluate fish mortality related to the TCD. Potential benefits of increases in minimum stream flows were assessed using a hydraulic model of the upper Sacramento River developed previously by DWR. While these preliminary assessments do not take into consideration every factor affecting anadromous fish survival, they provide a means of comparing potential actions to address this primary objective of the SLWRI.

Effect of Additional Cold Water Storage in Shasta Reservoir on Anadromous Fish Survival

An assessment was performed of estimated relative impacts to the chinook salmon population along the upper Sacramento River associated with enlarging the cold water pool in Shasta Reservoir. The assessment followed a process used by Reclamation and USFWS to examine the impacts on water temperature and fish mortality related to the TCD.

Modeling

Three basic modeling tools were used to derive the estimated impacts of various increases and operations of Shasta Dam on the salmon fish populations primarily in the Sacramento River. Modeling tools included CALSIM II, the Sacramento River Water Temperature Model, and the Salmon Mortality Model. The CALSIM II model was described previously in this chapter; the temperature and salmon mortality models are described briefly below.

Sacramento River Water Temperature Model - The Reclamation temperature model consists of reservoir and river modeling components. The reservoir component was developed by the Corps. It simulates one-dimensional, vertical distribution of reservoir water temperature using monthly input data on initial storage and temperature conditions, inflow, outflow, evaporation, radiation, and average air temperature. The river temperature component receives output from the reservoir component and calculates temperature changes in the four reregulating reservoirs (Lewiston, Keswick, Thermalito, and Natoma). The river model also computes temperatures at various selected locations in each river. It is a one-dimensional model, in the longitudinal direction, and assumes fully mixed river cross sections. The effect of tributary inflow on river temperature is computed by mass balance. The models simulate TCD operations by making upper-level releases in the winter and spring, mid-level releases in the late spring and summer, and low-level releases in the late summer and fall. River temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data. Monthly mean historical air temperatures for the 73-year period and other long-term average climatic data were obtained from Weather Bureau records.

Salmon Mortality Model - The Reclamation Salmon Mortality Model evaluates temperature-exposure mortality criteria for three salmon life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry), spawning distribution data, and output from the river temperature models to compute salmon spawning losses. Temperature units (TU), defined as the difference between river temperatures and 32° F, are calculated daily by the mortality model and used to track early life-stage development.

The Salmon Mortality Model was run for seven different reservoir raise scenarios using information from the CALSIM and temperature model, and 2020-level hydrologic conditions. Primary output of the mortality model is the estimated percent mortality for each of the four runs of salmon in the upper Sacramento River as a function of water-year conditions. These conditions are defined as wet, above normal, below normal, dry, and critically dry conditions. The increase in salmon populations was estimated for the various dam raise scenarios over baseline conditions, as shown in **Table IX-11**.

TABLE IX-11
PREDICTED UPPER SACRAMENTO RIVER CHINOOK SALMON POPULATION OVER 50-YEAR PERIOD

Concept Plan	Population Over 50 Years[1]				
	Fall-Run	Late Fall-Run	Winter-Run	Spring-Run	Total
Initial Returning Population [2]	49,000	10,000	2,800	800	62,600
6.5-ft Raise - Minimum Pool (AFS-1)					
Incremental Population In 50 Years [3]	88,176	10,246	3,802	3,481	105,706
Increase over Without-Project[4]	39,176	246	1,002	2,681	43,106
Percent Increase	80	2	36	335	69
Average Annual Increase	784	5	20	54	862
6.5-ft Raise - AFRP Flows (AFS-2)					
Incremental Population In 50 Years [3]	66,832	10,200	2,733	1,499	81,265
Increase over Without-Project[4]	17,832	200	-67	699	18,665
Percent Increase	36	2	-2	87	30
Average Annual Increase	357	4	-1	14	373
6.5-ft Raise (WSR-1)					
Incremental Population In 50 Years [3]	68,522	10,199	2,595	1,575	82,891
Increase over Without-Project [4]	19,522	199	-205	775	20,291
Percent Increase	40	2	-7	97	32
Average Annual Increase	390	4	-4	16	406
18.5-ft Raise (WSR-2)					
Incremental Population In 50 Years [3]	101,526	10,427	2,912	3,085	117,949
Increase over Without-Project [4]	52,526	427	112	2,285	55,349
Percent Increase	107	4	4	286	88
Average Annual Increase	1,051	9	2	46	1,107
200-ft Raise (WSR-3)					
Incremental Population In 50 Years [3]	537,760	12,017	9,177	34,870	593,824
Increase over Without-Project [4]	488,760	2,017	6,377	34,070	531,224
Percent Increase	997	20	228	4,259	849
Average Annual Increase	9,775	40	128	681	10,624
18.5-ft Raise with Conjunctive Water Management (WSR-4)					
Incremental Population in 50 Years	97,939	10,408	2,825	2,622	113,795
Increase over Without-Project [4]	48,939	408	25	1,822	51,195
Percent Increase	100	4	1	228	82
Average Annual Increase	979	8	1	36	1,024

Key: AFRP – Anadromous Fish Restoration Program; TCD – temperature control device; WSR – water supply reliability

Notes:
[1]Population increases over baseline conditions.
[2]Based on average annual returning population for years 1996 through 2001.
[3]Based on population increase for each return cycle over 50 years (17 occurrences).
[4]Net increase over conditions including increases due to TCD.

Findings

Evaluation indicates a general correspondence between increases in storage space in Shasta Reservoir and increases in the population of chinook salmon in the upper Sacramento River. Raising Shasta Dam 200 feet provides the greatest quantity of cold water and, therefore, has the greatest potential to benefit the salmon population throughout the primary and secondary study areas. For each dam raise scenario evaluated, the largest increase in salmon population is projected to occur to the fall-run salmon, with the smallest increases to the late-fall- and winter-runs. Further, increasing storage in Shasta Reservoir also tends to reduce salmon mortality in other tributaries to the Sacramento River, including the Trinity, Feather, and American rivers.

It should be noted that limitations exist in the use of the CALSIM, temperature, and mortality models. The main limitation is the monthly simulation time-step, which does not distinguish daily variations that could occur in the rivers. The temperature models also are unable to accurately simulate certain aspects of the actual operations strategies used when attempting to meet temperature objectives. Similarly, uncertainty exists regarding actual performance characteristics of the Shasta Dam TCD (due to leakage, overflow, and performance of the side intakes); a more conservative approach is taken in real-time operations that are not fully represented by the models. The Salmon Mortality Model is limited to temperature effects on early life stages of chinook salmon, and does not evaluate potential impacts on later life stages (emergent fry, smolts, juvenile out-migrants, or adults). Also, it does not consider other factors that may affect salmon mortality, such as instream flows, gravel sedimentation, diversion structures, predation, ocean harvest, etc. Furthermore, the salmon model requires daily temperatures, which it computes based on linear interpolation between the monthly output from the temperature models. Despite these limitations, it is believed the above tools and approach provide a valid approximation of the relative influences that increasing the storage space in Shasta Reservoir will have on the salmon population in the upper Sacramento River.

Effect of Minimum Flow Increases on Anadromous Fish Habitat and Survival

A preliminary assessment was performed to evaluate potential aquatic habitat improvements resulting from increasing minimum instream flows on the upper Sacramento River. Water storage to support these instream flow increases would be derived from the various dam raises under consideration by the SLWRI.

Existing Flow Requirements

The 1993 winter-run chinook salmon BO issued by NMFS (now NOAA Fisheries) requires minimum releases from Keswick Dam of 3,250 cfs between October 1 and March 31. These minimum flows are intended to promote successful rearing and safe downstream passage for winter-run chinook salmon. However, flows between 5,000 cfs and 5,500 cfs during this same period produce conditions that are more ideal for anadromous fish. Higher instream flows would provide access to additional spawning and rearing habitat sites, extend the area of suitable habitat farther downstream, avoid dewatering higher spawning beds, and generally improve aquatic and riparian habitat conditions along the river.

Average daily outflow from Keswick Dam between 1998 and the present is illustrated in **Figure IX-6**. The figure provides insight into the success of operators in maintaining healthy flows for anadromous fish in the upper Sacramento River.

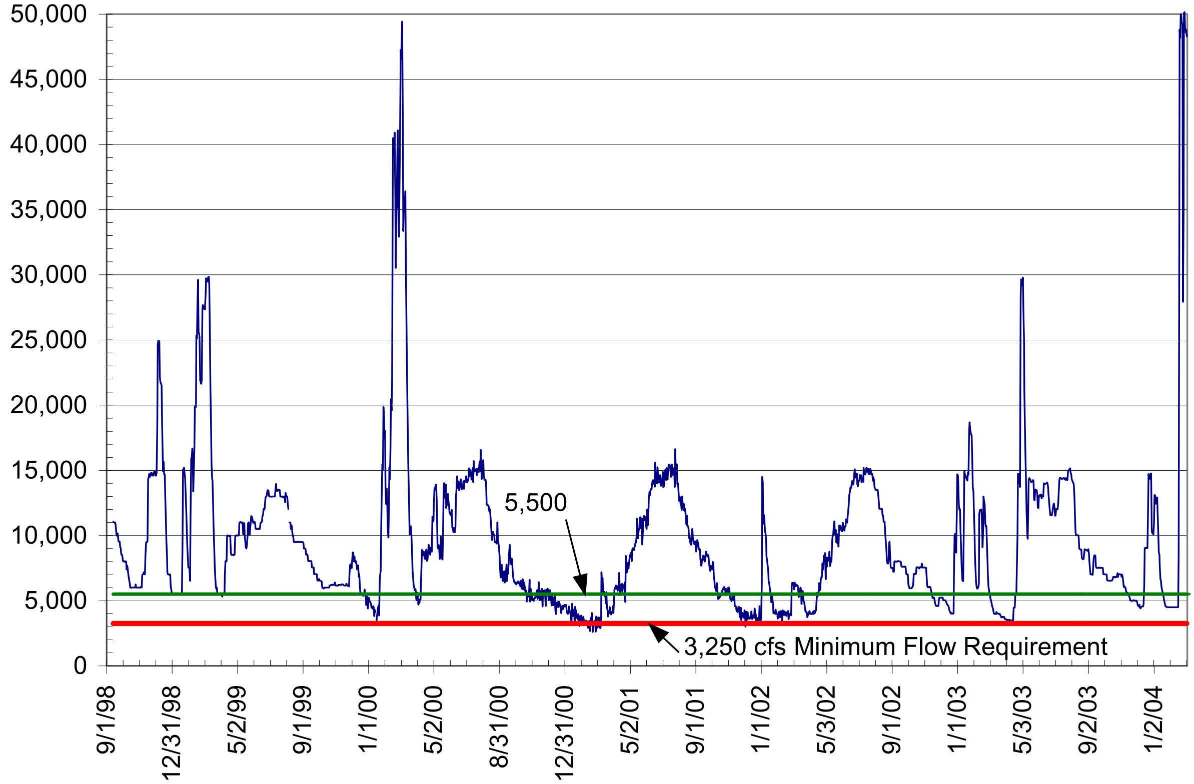

Figure IX-6 – Historic outflow from Keswick, 1998 to the present.

Existing Distribution of Spawning Within the Study Reach

Table IX-12 presents the estimated redd (underwater gravel nest where eggs are deposited) distribution for winter-run salmon within the study reach for 2000 through 2003, as reported by CDFG. This survey confirms that the majority of winter-run salmon are spawning in the uppermost portion of the study reach, with the greatest numbers of redds reported in the subreach between the Highway 44 Bridge and Airport Road Bridge. The distribution of redds within the study reach varies with each salmon run. With the exception of the fall run, the majority of spawning for each of the other runs occurs in the uppermost reaches of the river.

The HEC-RAS model calculates various types of information about hydraulic conditions in the channel at each cross section. Wetted perimeter at each cross section was multiplied by the distance between cross-sections to develop an approximation of the area of aquatic habitat for each simulated flow. These areas were summed for various reaches of the river to estimate the number of acres of aquatic habitat available. Similarly, hydraulic depth is calculated by dividing the cross sectional flow area by the width of flow at each cross section. These values do not represent the maximum or minimum depth of flow, but indicate the geometry of the channel within the reach. It should be noted that this method only provides a rough estimate of aquatic habitat, and is highly dependent on the (1) detail of the channel geometry, (2) spacing between the cross sections, and (3) uniformity of the channel between cross sections.

TABLE IX-12
ESTIMATED REDD DISTRIBUTION, WINTER-RUN CHINOOK SALMON

Reach	2000 Count	2000 % Total	2001 Count	2001 % Total	2002 Count	2002 % Total	2003 Count	2003 % Total
Keswick to ACID Dam	34	6	484	35	297	49	578	66
ACID Dam to Hwy 44 Bridge	157	27	215	15	134	22	151	17
Hwy 44 Bridge to Airport Road Bridge	274	47	624	45	168	28	143	16
Airport Rd Bridge to Balls Ferry Bridge	32	5	55	4	7	1	3	0
Balls Ferry Bridge to Battle Creek	35	6	2	0	3	0	0	0
Battle Creek to Jelly’s Ferry	10	2	2	0	0	0	0	0
Jelly’s Ferry to Bend Bridge	46	8	8	1	0	0	0	0
Bend Bridge to RBDD	0	0	0	0	0	0	0	0
TOTAL Upstream From RBDD	**588**		**1,390**		**609**		**875**	

Key: ACID – Anderson Cottonwood Irrigation District Hwy – Highway RBDD – Red Bluff Diversion Dam

Source: California Department of Fish and Game aerial surveys.
Note:
Percent of total represents the percentage of all redds surveyed upstream from the RBDD occurring within a given reach. Does not include redds surveyed downstream from the RBDD

Further, this initial assessment does not provide a means of evaluating the quality of the new aquatic habitat, or whether the new habitat was suitable for spawning, rearing, or other life stages of anadromous fish. While this assessment can not quantify the benefits to anadromous fish in terms of fish mortality or long-term survival, the assessment does provide an initial means of comparing the relative benefits of potential flow increases on the upper Sacramento River. Future studies will be required to better quantify the benefits of flow increases to chinook salmon and other anadromous fish on the upper Sacramento River.

Findings

Modeling results indicate that increasing the minimum flow target from 3,250 cfs to 5,500 cfs (identified as the ideal flow for winter-run) could potentially increase aquatic habitat in the study area by between 14 percent and 19 percent, corresponding to a potential increase of about 3,000 acres of aquatic habitat. As shown in **Table IX-13**, the area that showed the greatest potential increases in aquatic habitat was the subreach from Airport Road Bridge to Balls Ferry Bridge. Subreaches between Battle Creek and Bend Bridge also showed notable increases. The subreach between Balls Ferry and Battle Creek showed the greatest increase in hydraulic depth; this could be significant because this subreach is comparatively shallow and has fewer deep pools. Hence, increases in depth could potentially improve aquatic habitat conditions within the subreach.

TABLE IX-13
HEC-RAS MINIMUM FLOW SIMULATION RESULTS BY SUBREACH

Flow (cfs)	Hydraulic Depth (feet) (Avg / Max / Min)[1]			Average Wetted Perimeter (feet)	Total Wetted Area[2] (acres)	% Change in Aquatic Habitat over 3,250 cfs
	Avg	Max	Min			
Keswick to ACID Dam (RM 295.92-292.428) 3.5 miles						
3,250	5.22	15.66	1.52	347	123	-
4,000	5.58	16.23	1.65	360	128	4
5,000	6.01	16.91	1.78	373	133	8
6,000	6.38	17.52	1.97	383	138	13
ACID Dam to Hwy 44 Bridge (RM 292.428-290.45) 2.0 miles						
3,250	3.80	8.21	1.75	367	77	-
4,000	3.99	8.60	1.73	398	80	5
5,000	4.14	8.66	2.08	442	85	11
6,000	4.32	8.70	2.41	476	93	21
Hwy 44 Bridge to Airport Road Bridge (RM 290.45-278.49) 12.0 miles						
3,250	4.04	12.03	1.17	423	697	-
4,000	4.33	12.23	1.33	442	725	4
5,000	4.70	12.66	1.53	459	757	9
6,000	5.03	13.09	1.71	478	790	13
Airport Road Bridge to Balls Ferry Bridge (RM 278.49-270.64) 7.8 miles						
3,250	4.38	15.22	1.31	361	352	-
4,000	4.64	15.39	1.29	390	385	9
5,000	4.78	15.60	1.32	481	466	32
6,000	5.09	15.81	1.38	505	488	39
Balls Ferry Bridge to Battle Creek (RM 270.64-268.6) 2.0 miles						
3,250	3.19	4.09	1.98	381	138	-
4,000	3.59	4.49	2.22	390	141	2
5,000	4.06	4.97	2.47	402	146	5
6,000	4.47	5.26	2.83	413	151	9
Battle Creek to Jelly's Ferry (RM 268.6-261.5) 7.1 miles						
3,250	3.81	5.42	1.72	355	266	-
4,000	4.14	5.85	1.82	378	285	7
5,000	4.49	6.38	1.96	405	305	15
6,000	4.83	6.82	2.09	423	320	20
Jelly's Ferry to Bend Bridge (RM 261.54-252.24) 9.3 miles						
3,250	5.75	11.45	1.95	246	257	-
4,000	6.00	11.60	2.12	262	276	7
5,000	6.27	11.52	2.29	284	302	18
6,000	6.51	11.85	2.48	305	326	27
Bend Bridge to RBDD (RM 252.24-237.54) 14.7 miles						
3,250	5.19	13.65	1.88	367	694	-
4,000	5.57	14.05	2.12	381	717	3
5,000	5.94	14.54	2.39	398	749	8
6,000	6.28	15.01	3.02	415	781	13
Key: ACID – Anderson Cottonwood Irrigation District cfs – cubic feet per second RM – river mile Hwy – Highway						

Notes:

[1]Hydraulic depth is calculated by dividing the cross-sectional flow area by the width of flow. Average hydraulic depth is calculated by averaging the hydraulic depth at each cross section within the reach.

[2]Wetted area is estimated by multiplying the wetted perimeter by the reach length (distance between cross sections) at each cross section.

Various potential dam raises are under consideration in the SLWRI. All or a portion of the additional water storage afforded by these raises could be used to increase minimum flow requirements on the upper Sacramento River. **Table IX-14** provides estimates of potential increases in aquatic habitat area under two scenarios being considered: a 6.5-foot raise with an increase in minimum flow to 3,575 cfs, and an 18.5-foot raise with an increase in minimum flow to 5,194 cfs.

TABLE IX-14
POTENTIAL INCREASES IN AQUATIC HABITAT WITH
6.5-FOOT AND 18.5-FOOT DAM RAISE SCENARIOS

		Estimated Increase in Aquatic Area (acres)	
Reach	**Reach Length (miles)**	**6.5-Foot Raise Flow Target: 3,575 cfs**	**18.5-Foot Raise Flow Target: 5,194 cfs**
Keswick to ACID Dam	3.5	2.1	11.2
ACID Dam to Hwy 44 Bridge	2.0	1.8	16.1
Hwy 44 Bridge to Airport Road Bridge	12.0	11.7	62.9
Airport Rd Bridge to Balls Ferry Bridge	7.9	13.4	129.3
Balls Ferry Bridge to Battle Creek	2.0	1.3	8.0
Battle Creek to Jelly's Ferry	7.1	7.9	42.3
Jelly's Ferry to Bend Bridge	9.3	8.1	50.2
Bend Bridge to RBDD	14.7	11.3	62.0
Total	**52.9**	**57.8 acres**	**382.0 acres**

Key:
ACID – Anderson Cottonwood Irrigation District cfs – cubic feet per second Hwy – Highway
RBDD – Red Bluff Diversion Dam

Note:
Estimated increases in aquatic area are interpolated based on the target flow of the scenario and the flows simulated in the HEC-RAS analysis.

Based on HEC-RAS simulation results, aquatic habitat within the study area could potentially be increased by about 56 acres if the minimum flow were increased to 3,575 cfs in conjunction with a 6.5-foot dam raise. Similarly, 382 acres of additional aquatic habitat could potentially be created if the minimum flow were increased to 5,194 cfs in conjunction with an 18.5-foot raise. However, equating the estimated increases in aquatic habitat to increases in anadromous fish survival is not possible at this time. This is largely because anadromous fish survival depends on numerous factors in addition to flow: water temperature, climatic variability, the number of fish migrating upstream, age of the returning fish, etc.

HYDROPOWER BENEFITS

Benefits of additional storage in Shasta Reservoir for hydropower can occur when more electricity is generated as a result of both higher hydrologic head and more water available for release through the powerhouse during high demand periods when energy is more valuable. For each initial concept plan considered, an estimate was made of the average annual increase, or change from the without-project condition, in power generation and revenues to the CVP system.

Table IX-15 shows the estimated changes in power generation in GWh per year for Shasta Dam and for the CVP system as a whole. The estimate was made using results first from CALSIM II modeling runs (level-2020 hydrology) for each concept and then a separate power model designed to identify energy generation changes at system facilities. Also shown is a system adjustment, which is the difference between the energy generated at Shasta and for the CVP system for each concept plan. This difference is due primarily to increased pumping in the Delta because of the increase in water supply reliability. It also accounts for the summation of other system-wide operational changes.

TABLE IX-15
ESTIMATED INCREASE IN HYDROPPOWER GENERATION AND REVENUE FOR CONCEPT PLANS

Concept Plan	Net Generation (GWh/year)			Net System Revenue ($Millions)
	At Shasta Dam	System Adjustments[1]	CVP System	
AFS-1	50.9	0	50.9	2.4
AFS-2	30.0	2.3	32.3	1.5
AFS-3	30.0	2.3	32.3	1.5
WSR-1	32.1	-17.4	14.7	0.6
WSR-2	71.8	-27.8	44.0	2.0
WSR-3[2]	2,383.7	-129.8	2,253.9	107.8
WSR-4	71.8	-27.8	44.0	2.0
CO-1	32.1	-17.4	14.7	0.6
CO-2	71.8	-27.8	44.0	2.0
CO-3	66.5	-5.3	61.2	2.9
CO-4	30.0	-18.3	11.7	0.5
CO-5	71.8	-27.8	44.0	2.0

Key:
AFS – anadromous fish survival
CO – combined objective
CVP – Central Valley Project
GWh – gigawatt-hour
WSR – water supply reliability

Notes:
[1]Accounts for increased pumping.
[2]Does not include loss in energy and revenue due to removal of the Pit 7 Dam.

Table IX-15 also shows the estimated average annual net revenue for each concept plan. Revenue estimates were derived using projected monthly power generation over the period of analysis in the CALSIM model multiplied by the California Independent System Operators 2003 monthly rates. As can be seen in **Table IX-15**, potential net revenues range from about $0.5 million a year for WSR-1, CO-1, and CO-4 to over $100 million for WSR-3. The estimated increase in generation and revenue for WSR-3 does not include the reduction in energy due to the removal of the Pit 7 Dam.

SENSITIVITY OF BANKS PUMPING PLANT EXPANSION

The current allowable pumping capacity at the Banks Pumping Plant is 6,680 cfs, and actions are underway by DWR and Reclamation to increase the allowable pumping capacity to 8,500 cfs during certain seasonal periods. This increase in pumping capacity at Banks is critical to the SDIP and helping improve the reliability of future water supplies in California. Because this potential CALFED action is still in the planning phase and not yet approved, significant uncertainty exists about whether it will be implemented and therefore it is not included as a without-project condition in the SLWRI. However, expanding pumping capacity at Banks and other planned improvements of the SDIP possess broad State and Federal agency support. In addition, efforts are ongoing by DWR and Reclamation to develop a set of common assumptions (see **Chapter II**) for use in planning CALFED storage projects. A Common Assumptions work group has been formed that is developing recommendations relative to without-project conditions, common analytical tools, and other study procedures and processes. A major assumption related to defining a common without-project condition for the studies includes expansion of the Banks Pumping Plant. Following is a brief description of the estimated differences in the without-project condition assumption regarding expanding the pumping capacity at Banks and potential impacts of that assumption on conclusions in this report.

Included in **Appendix A** (CALSIM II System Operation Simulation) is information on the sensitivity of storage and delivery changes for concept plans WSR-1 (6.5-foot Shasta Dam raise and 290,000 acre-feet of additional storage) and WSR-2 (18.5-foot Shasta Dam raise and 640,000 acre-feet of additional storage) under a Banks pumping capacity of 6,680 and 8,500 cfs. Pertinent information from **Appendix A** regarding the changes in storages and deliveries is included in **Table IX-16**. Also included in the table is information on the first, annual, and unit cost differences between the two plans under the two pumping capacities.

As shown in **Table IX-16** and based on current assumptions within the CALSIM model, it is estimated that increasing the pumping capacity at Banks, without any modification at Shasta Dam and Reservoir, would result in an average decrease in end-of-September storage in Shasta and on average the other north-of-Delta reservoirs. It would also result in an increase in storage at San Luis Reservoir. Most important, however, is that increasing Banks pumping would result in an increase in SWP and CVP water supply deliveries. As in the table, it is estimated that in drought and average years, without any modification of Shasta Dam and Reservoir, this increase could be on the order of 109,000 and 162,000 acre-feet, respectively. This increase in water supply reliability is the primary reason for increasing the pumping capacity at Banks.

At a Banks pumping capacity of 6,680 cfs, adding an increment of storage to the CVP under concept plan WSR-1 would result in an increase in drought and average annual deliveries of 72,000 and 48,000 acre-feet, respectively. Increasing the pumping capacity to 8,500 cfs would result in WSR-1 yielding an estimated 84,000 and 59,000 acre-feet during drought and average annual deliveries, respectively. Accordingly, increasing the pumping capacity would improve the effectiveness of WSR-1 during drought years by about 12,000 acre-feet, or 17 percent, and in average years of about 11,000 acre-feet, or 23 percent. As shown in the table, a similar increase in yield would occur with WSR-2 when drought and average year yields between the two pumping capacities were 22,000 acre feet (18 percent) and 30,000 acre-feet (42 percent), respectively.

Table IX-16 also shows that for WSR-1, the estimated cost for each additional acre-foot of drought period yield would be reduced by almost $40 from about $270 to $230. Similarly, for WSR-2, the estimated cost for each additional acre-foot of drought period yield would be reduced by $32 from $225 to $193 per acre-foot.

It is expected that similar results in estimated increases in water supply yields and unit cost reductions would occur for all the concept plans described in **Chapter VII**. Therefore, it is believed that changes in the without-project conditions from a Banks pumping capacity of 6,680 to 8,500 cfs would result in slight increases in the estimated water supply reliability shown in **Table VIII-2** and reductions in the relative unit cost for water for all the concept plans in the table (except AFS-1). However, it is also believed that none of these differences would result in changing how the concept plans would rank against each other (**Table VIII-1)**. Accordingly, the without-project assumption regarding pumping capacity at Banks would make no difference in the concept plans identified in **Chapter VIII** for further development in the SLWRI.

TABLE IX-16
DIFFERENCE BETWEEN WITHOUT AND WITH-PROJECT CONDITIONS FOR BANKS PUMPING CAPACITY OF 6,680 AND 8,500 CFS

Metric	Difference Between Without & With-Project Conditions				Difference Between Banks at 8,500 & 6,680 cfs		
	Banks @ 6,680 cfs		Banks @ 8,500 cfs		Without-Project Conditions	6.5 Feet (WSR-1)	18.5 Feet (WSR-2)
	6.5 Feet (WSR-1)	18.5 Feet (WSR-2)	6.5 Feet (WSR-1)	18.5 Feet (WSR-2)			
Storage – End-of-September (1,000 AF)							
Shasta	315	370	157	369	-63	12	-1
Trinity	15	25	-19	-15	54	-34	-40
Folsom	3	7	-9	-5	-29	-12	-12
Oroville	-6	-12	-20	-12	-46	-14	0
San Luis	-5	-3	-3	-18	142	2	-15
Deliveries (AF/year)							
CVP							
Total Drought Years	83	138	92	146	48	9	8
Total Average	53	79	57	96	67	4	17
SWP							
Total Drought Years	-11	-13	-8	1	51	3	14
Total Average	-5	-8	2	5	95	7	13
Total CVP & SWP							
Drought Years	72	125	84	147	109	12	22
Average	48	71	59	101	162	11	30
Economics							
First Cost ($ millions)	282	408	282	408	NA	0	0
Annual Cost ($ millions/year)	19.4	28.1	19.4	28.1	NA	0	0
Unit Cost (drought years) $/AF	269	225	231	193	NA	-38	-32

Key:
AF – acre-feet cfs – cubic-feet per second NA – not applicable WSR – water supply reliability