

Draft

Engineering Summary Appendix

Shasta Lake Water Resources Investigation

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Bureau of Reclamation
Mid-Pacific Region**



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Bureau of Reclamation**

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1 Abbreviations and Acronyms

2	AASHTO	American Association of State Highway and Transportation
3		Officials
4	AB	aggregate base
5	AC	asphaltic concrete
6	APS	allowance for procurement strategies
7	AREMA	American Railway Engineering and Maintenance-of-Way
8		Association
9	ASTM	American Society for Testing and Materials
10	AT&T	American Telephone and Telegraph
11	AWWA	American Water Works Association
12	BIL	basic impulse level
13	Caltrans	California Department of Transportation
14	CDFW	California Department of Fish and Wildlife
15	cfs	cubic foot per second
16	CIP	cast in place
17	CMP	corrugated metal pipe
18	CP	Comprehensive Plan
19	CPUC	California Public Utilities Commission
20	CPUC-GO 95	California Public Utilities Commission General Order 95
21	CSA	County Service Area
22	CVP	Central Valley Project
23	CVPIA	Central Valley Project Improvement Act
24	DEIS	Draft Environmental Impact Statement
25	Delta	Sacramento-San Joaquin Delta
26	DWR	California Department of Water Resources
27	EHD	Environmental Health Division
28	elevation xxx	elevation in feet above mean sea level
29	EPA	Environmental Protection Agency
30	ESRD	Emergency Spillway Release Diagram
31	gpd	gallon per day
32	gpm	gallon per minute
33	HHA	hydrologic hazard analysis
34	HMR 59	Hydrometeorological Report No. 59
35	IDC	interest during construction
36	km	kilometer

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1	kV	kilovolt
2	L-G voltage	voltage between phase conductor and ground
3	LTPP	Long Term Power Procurement
4	M&I	municipal and industrial
5	MAF	million acre-feet
6	mm	millimeter
7	MSE	mechanically stabilized earth
8	msl	mean sea level
9	MW	megawatt
10	MWh	megawatt-hour
11	NAVD88	North American Vertical Datum of 1988
12	NCAO	Northern California Area Office
13	NESC	National Electrical Safety Code
14	NESHAP	National Emission Standards of Hazardous Air Pollutants
15	NGS	National Geodetic Survey
16	NGVD29	National Geodetic Vertical Datum of 1929
17	NRA	National Recreation Area
18	O&M	operations and maintenance
19	PFR	Plan Formulation Report
20	PG&E	Pacific Gas and Electric
21	PMF	probable maximum flood
22	psi	pound per square inch
23	PVC	polyvinyl chloride
24	RBPP	Red Bluff Pumping Plant
25	Reclamation	U.S. Department of the Interior, Bureau of Reclamation
26	ROW	right-of-way
27	RWS	reservoir water surface
28	SDR	standard dimension ratio
29	SLWRI	Shasta Lake Water Resources Investigation
30	SWP	State Water Project
31	TCD	temperature control device
32	UPRR	Union Pacific Railroad
33	USFS	U.S. Forest Service
34	UV	ultraviolet
35	V	volt
36		

1 **Chapter 1**
2 **Introduction**

3 **Purpose and Need for Project**

4 The primary purpose of the Shasta Lake Water Resources Investigation
5 (SLWRI) is to develop an implementable plan that primarily involves
6 modifying Shasta Dam and Reservoir to promote increased survival of
7 anadromous fish populations in the upper Sacramento River; promote increased
8 water supplies and water supply reliability; and to the greatest extent possible
9 through meeting these primary planning objectives, include features to benefit
10 other identified ecosystem, flood control, and related water resources needs.

11 **Background**

12 The following sections describe the study area location, study authorization, and
13 the scope, purpose, and organization of this Engineering Summary Appendix.

14 **Study Area Location and Description**

15 The primary study area for the SLWRI includes Shasta Dam and Reservoir,
16 lower reaches of three primary tributaries flowing into Shasta Lake
17 (Sacramento, McCloud, and Pit rivers) and all smaller tributaries flowing into
18 the lake, Trinity Lake and Lewiston Reservoir, and the Sacramento River
19 downstream to about the Red Bluff Pumping Plant (RBPP). Plate 1 is a vicinity
20 map showing the primary study area within the Sacramento River basin. The
21 RBPP is the point at which releases from Shasta Dam begin to have a negligible
22 effect on Sacramento River water temperatures, and the river landscape changes
23 to a broader, alluvial stream system.

24 Because of the potential influence of a modified Shasta Dam on other programs
25 and projects, primarily in the Central Valley, an extended study area also
26 encompasses the Sacramento River downstream from the RBPP, the
27 Sacramento-San Joaquin River Delta (Delta), parts of the lower American and
28 Feather rivers, parts of the lower San Joaquin River; and facilities and water
29 service areas of the Central Valley Project (CVP) and State Water Project
30 (SWP).

31 Shasta Dam and Reservoir are located on the upper Sacramento River in
32 Northern California about 9 miles northwest of the City of Redding (see Plate
33 1); the entire reservoir is within Shasta County. Shasta Lake has 370 miles of
34 shoreline. The reservoir controls runoff from about 6,420 square miles. The four

1 major tributaries to Shasta Lake are the Sacramento River, McCloud River, Pit
2 River, and Squaw Creek, in addition to numerous minor tributary creeks and
3 streams.

4 **Study Authorization**

5 On August 30, 1935, in the Rivers and Harbors Bill, an initial amount of
6 Federal funding was authorized for constructing Kennett (now Shasta) Dam.
7 Fundamental authorization for the SLWRI derives from the 1980 Public Law
8 96-375 and 2004 Public Law 108-361. Public Law 96-375 authorized the
9 Secretary of the Interior to engage in feasibility studies relating to (1) enlarging
10 Shasta Dam and Reservoir, or constructing a replacement dam on the
11 Sacramento River, and (2) using the Sacramento River to convey water from an
12 enlarged dam. Public Law 108-361 again directed the Secretary of the Interior
13 to conduct "...planning and feasibility studies for projects to be pursued with
14 project-specific study for enlargement of...Shasta Dam in Shasta County..."

15 **Scope and Purpose of Engineering Summary Appendix**

16 The primary purpose of this Engineering Summary Appendix is to present
17 information related to feasibility-level cost estimates and designs for the
18 measures included in the Comprehensive Plans described in the SLWRI Draft
19 Environmental Impact Statement (DEIS). The measures included in each of the
20 Comprehensive Plans can be put into three categories: dam raises, reservoir area
21 infrastructure, and ecosystem restoration. Information associated with these
22 measures will be used to compare the Comprehensive Plans. Previous SLWRI
23 milestone documents including the Draft Feasibility Report (Reclamation
24 2011b) were used as an initial basis for development of feasibility-level designs
25 and cost estimates for this Engineering Summary Appendix.

26 **Appendix Organization**

27 This Engineering Summary Appendix is organized as follows:

28 **Chapter 1** introduces the SLWRI, provides background on the study, and
29 describes the scope, purpose, and organization of this appendix.

30 **Chapter 2** provides background information on Shasta Dam and Reservoir and
31 describes the three dam raise and reservoir enlargement options included in the
32 comprehensive alternatives presented in the SLWRI DEIS. These alternatives
33 include the 6.5-foot raise, 12.5-foot raise, and 18.5-foot raise.

34 **Chapter 3** describes design considerations for the dam and appurtenances raise
35 options.

1 **Chapter 4** describes design considerations for reservoir area infrastructure
2 modifications and/or relocations for the raise options.

3 **Chapter 5** presents cost estimates developed for each of the Comprehensive
4 Plans, and information and methodology used to develop the estimates.

5 **Chapter 6** contains sources used to prepare this Engineering Summary
6 Appendix.

7 Summary and detailed cost estimate worksheets are included in the following
8 attachments to this Engineering Summary Appendix:

9 **Attachment 1** – Cost Estimates for Comprehensive Plans

10 **Attachment 2** – 6.5-Foot Raise and Reservoir Area Infrastructure Cost
11 Estimates

12 **Attachment 3** – 12.5-Foot Raise and Reservoir Area Infrastructure Cost
13 Estimates

14 **Attachment 4** – 18.5-Foot Raise and Reservoir Area Infrastructure Cost
15 Estimates

16 **Attachment 5** – Preliminary Construction Schedule and Work Packages

17 **Attachment 6** – CP4 Crystal Ball Estimate Summary

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1 Chapter 2

2 Dam and Reservoir Raise Options

3 Shasta Dam and Reservoir Background

4 Shasta Reservoir is California's largest man-made lake, with a full pool storage
5 capacity and surface area at the top of joint-use of 4,552,000 acre-feet and
6 29,600 acres, respectively. (Top of joint-use is measured at elevation 1,067 feet
7 above mean sea level (msl) (elevation 1,067) according to the National Geodetic
8 Vertical Datum of 1929 (NGVD29).) As mentioned, Shasta Reservoir has
9 approximately 370 miles of shoreline when full, and a maximum depth of 517
10 feet. The Shasta Dam and Reservoir project was constructed by the U.S.
11 Department of the Interior, Bureau of Reclamation (Reclamation), Region 2, as
12 an integral element of the CVP from 1938 to 1945, for six purposes. These
13 purposes include irrigation water supply, municipal and industrial (M&I) water
14 supply, flood control, hydropower generation, fish and wildlife conservation,
15 and navigation. The project also supports vigorous water-oriented recreation at
16 the reservoir, which is located within the Shasta Unit of the Whiskeytown-
17 Shasta-Trinity National Recreation Area (NRA). Table 2-1 presents pertinent
18 Shasta Dam and Reservoir data Plate 2 shows the reservoir and numerous
19 surrounding facilities.

20 Shasta Dam and Reservoir are located on the upper Sacramento River in
21 Northern California about 9 miles northwest of the City of Redding. The entire
22 reservoir is within Shasta County. The reservoir controls runoff from about
23 6,420 square miles from four major tributaries, including the Sacramento,
24 McCloud, and Pit rivers, Squaw Creek, and numerous minor creeks and
25 streams. Historically, essentially all outflow from Shasta Dam has traveled
26 through Northern California to the Delta southwest of Sacramento. Total
27 drainage area of the Sacramento River at the Delta is about 26,300 square miles.
28 Average annual runoff to the Delta from the Sacramento River watershed is
29 about 17.2 million acre-feet (MAF). This represents about 62 percent of total
30 inflows to the Delta.

31 Shasta Dam is a curved, gravity-type, concrete structure 487 feet high above the
32 streambed, with a total height above the foundation of 602 feet. Its crest is at
33 elevation 1,077.5 (NGVD29). Maximum seasonal flood control storage space in
34 Shasta Reservoir is 1.3 MAF. Shasta Dam has a crest width of 30 feet and
35 length of about 3,500 feet. The Shasta Powerplant consists of five main
36 generating units with a current capacity of 710 megawatts (MW), and two
37 station service units with a current capacity of 5 MW. Plan views of Shasta
38 Dam and Powerplant are shown in Plate 3. Figure 2-1 shows the area-capacity
39 curve for Shasta Reservoir.

Table 2-1. Pertinent Data – Shasta Dam and Reservoir

General			
Drainage Areas (excluding Goose Lake Basin)		Mean Annual Runoff (1908 – 2006)	
Sacramento R. at Shasta Dam	6,421 square miles	Sacramento R. at Shasta Dam	5,737,000 acre-feet
Sacramento R. at Keswick	6,468 square miles	Sacramento R. near Red Bluff	8,421,000 acre-feet
Bridge near Red Bluff	8,900 square miles	Sacramento River Maximum Flows	
Sacramento R. near Ord Ferry	12,250 square miles	At Shasta Lake 16 Jan 1974	216,000 cfs
Pit R. at Big Bend	4,710 square miles	Near Red Bluff 28 Feb 1940	291,000 cfs
McCloud R. above Shasta Lake	604 square miles	At Ord Ferry 28 Feb 1940	370,000 cfs
Sacramento R. at delta above Shasta Lake	425 square miles		
Shasta Dam and Reservoir			
Shasta Dam (concrete gravity)		Shasta Reservoir	
Crest elevation	1,077.5 feet	Full pool elevation (msl)	1,067.0 feet
Freeboard above full pool	9.5 feet	Minimum operating level	840.0 feet
Height above foundations	602 feet	Taking line	Irregular
Height above streambed	487 feet	Surface Area	
Length of crest	3,500 feet	Minimum operating level	6,700 acres
Width of crest	30 feet	Full pool	29,500 acres
Slope, upstream	Vertical	Taking line	90,000 acres
Slope, downstream	1 on 0.8	Storage capacity	
Volume	8,430,000 cubic yards	Minimum operating level	587,000 acre-feet
Normal tailwater elevation	585 feet	Full pool	4,552,000 acre-feet
Spillway (gated ogee)		Shasta Powerplant	
Crest length		Main units	
Gross	360 feet	5 turbines, Francis type	515,000 hp (total)
Net	330 feet	5 units @ 142 MW	710 MW (total)
Crest gates (drum type)		Station units	
Number and size	3 @ 110 feet x 28 feet	2 generators, 2,500 kW each	5,000 kW (total)
Top elevation when lowered	1037.0 feet	Elevation centerline turbines	586 feet
Top elevation when raised	1065.0 feet	Maximum tailwater elevation	632.5 feet
Discharge capacity at pool (1,065 feet)	186,000 cfs	Total discharge at pool (1,065 feet)	14,500 cfs

Table 2-1. Pertinent Data – Shasta Dam and Reservoir (contd.)

Shasta Dam and Reservoir (contd.)			
Drainage Areas (excluding Goose Lake Basin)		Mean Annual Runoff (1908 – 2006)	
Flashboard gates	3 @ 110 feet x 2 feet	Total discharge at pool (827.7 feet)	16,000 cfs
Top elevation when lowered	1,067.0 feet	Power outlets (15-foot steel penstocks)	
Bottom elevation when raised	1,069.5 feet	5 with invert elev. of intake	807.5 feet
Outlets 102-inch-diameter conduit with 96-inch-diameter wheel-type gate			
4 with invert elevation	737.75 feet	Capacity at elevation 1,065 feet	81,800 cfs
8 with invert elevation	837.75 feet	Capacity at elevation 827.7 feet	12,200 cfs
6 with invert elevation	937.75 feet		

Note:

Elevations given are in vertical datum NGVD29.

Key:

cfs = cubic feet per second

elevation = elevation in feet above mean sea level

hp = horsepower

kW = kilowatt

msl = mean sea level

MW = megawatt

NGVD29 = National Geodetic Vertical Datum of 1929

R = river

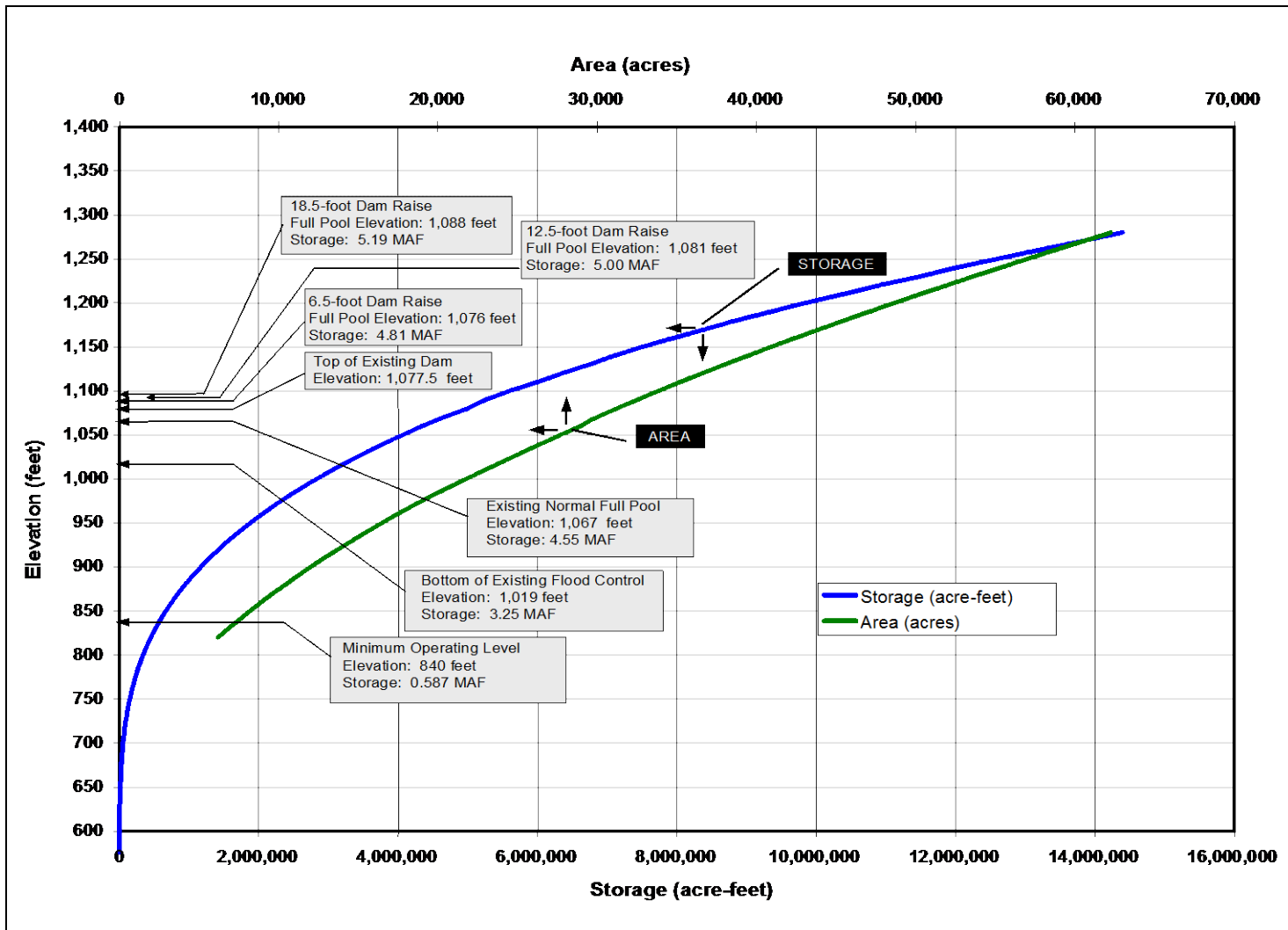


Figure 2-1. Area-Capacity Curve for Shasta Reservoir

Vertical Datum Differences

Currently, elevations listed in most reference materials related to Shasta Dam and Reservoir are in NGVD29. However, a 2001 aerial survey of the reservoir area was done using the North American Vertical Datum of 1988 (NAVD88). All current feasibility-level designs and plates for the dam and appurtenances are based on NGVD29. All current feasibility-level designs and plates for reservoir area infrastructure modifications and/or relocations are based on the 2001 aerial survey and use NAVD88, unless otherwise noted. These include the designs and plates of the protective dikes in the upstream reservoir.

According to the National Geodetic Survey (NGS) Program *VERTCON*, the difference between the vertical datums at Shasta Dam is 2.664 feet (0.812 meters). Table 2-2 lists key elevations in both vertical datums for comparison and clarification.

Table 2-2. Vertical Datum Comparison

Feature	Existing (feet)	6.5-foot Dam Raise (feet)	12.5-foot Dam Raise (feet)	18.5-foot Dam Raise (feet)
Vertical Datum: NGVD29				
Dam Crest	1,077.5	1,084.0	1,090.0	1,096.0
Full Pool/Top of Joint-Use	1,067.0	1,075.5	1,081.5	1,087.5
Spillway Crest	1,037.0	1,037.5	1,043.5	1,049.5
Vertical Datum: NAVD88				
Dam Crest	1,080.2	1,086.7	1,092.7	1,098.7
Full Pool/Top of Joint-Use	1,069.7	1,078.2	1,084.2	1,090.2
Spillway Crest	1,039.7	1,040.2	1,046.2	1,052.2

Key:
NAVD88 = North American Vertical Datum of 1988
NGVD29 = National Geodetic Vertical Datum of 1929

Dam Raise and Reservoir Enlargement Options

The proposed Comprehensive Plans (CP) can be categorized into three dam raise options: 6.5 feet, 12.5 feet, and 18.5 feet. Each Comprehensive Plan includes, to some degree, the following common measures:

- Enlarge Shasta Lake cold-water pool
- Modify temperature control device (TCD)
- Increase water conservation storage
- Reduce water demand

- 1 • Modify flood control operations
- 2 • Modify hydropower facilities
- 3 • Maintain or increase recreation opportunities
- 4 • Maintain or improve water quality

5 **6.5-Foot Raise Option (CP1)**

6 The low-level option evaluated is a 6.5-foot raise of Shasta Dam. This would
7 correspond to a raise in the top of joint-use pool elevation of about 8.5 feet, and
8 increasing water storage capacity by approximately 256,000 acre-feet and
9 reservoir surface area by 1,110 acres. This would increase water supply
10 reliability and improve anadromous fish survival, with some benefit to other
11 resources.

12 **12.5-Foot Raise Option (CP2)**

13 The 12.5-foot raise is considered in this Engineering Summary Appendix as an
14 intermediate-level option between the 6.5-foot raise and the 18.5-foot raise. The
15 12.5-foot dam raise would correspond to a raise in the top of joint-use pool
16 elevation of about 14.5 feet, increasing the water storage capacity by
17 approximately 443,000 acre-feet and reservoir surface area by 1,750 acres. This
18 would increase water supply reliability and improve anadromous fish survival,
19 with some benefit to other resources.

20 **18.5-Foot Raise Option (CP3, CP4, CP5)**

21 The 18.5-foot raise represents the largest practical dam raise that would not
22 require relocating the Pit River Bridge. This would correspond to a raise in the
23 top of joint-use pool elevation of about 20.5 feet. This option would increase
24 water storage capacity by approximately 634,000 acre-feet and reservoir area by
25 about 2,500 acres. Also, this option would increase water supply reliability and
26 improve anadromous fish survival, with some benefit to other resources. CP3,
27 CP4, and CP5 would all include the 18.5-foot dam raise. However, CP4 would
28 dedicate about 60 percent of the new storage space (378,000 acre-feet) to
29 increasing the cold-water supply for anadromous fish purposes and include
30 features for ecosystem restoration. CP5 would include features for ecosystem
31 restoration and recreation facilities around Shasta Lake, in addition to those
32 included in the other Comprehensive Plans.

33 **Other Options Considered in Previous Studies**

34 The potential enlargement of Shasta Dam has been studied since the 1970s.
35 In addition to the low-level option (6.5 feet), Reclamation also presented
36 descriptions and cost estimates for the intermediate-level option (102.5 feet),
37 and high-level option (202.5 feet) raises of Shasta Dam (Reclamation 1998,
38 1999). Estimated total first costs for the intermediate- and high-level options
39 were \$2.9 billion, and \$4.4 billion, respectively. The assessment concluded that
40 the costs of the intermediate- and high-level options posed significant

1 challenges in developing required financial packages. Results of the assessment
2 led to the following recommendation: “It is recommended that feasibility
3 studies examining a low-raise option enlargement of Shasta Dam and Reservoir
4 proceed.” In a subsequent study, Reclamation identified the 18.5-foot raise as
5 the major cost break-point. Higher raises require relocation of the Pit River
6 Bridge, which would amount to nearly 50 percent of the total project cost
7 (Reclamation 2003b).

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Chapter 3

Design Considerations for Dam and Appurtenances of Dam Enlargements

This section summarizes major features associated with enlarging Shasta Dam and Reservoir and modifying its appurtenances for all SLWRI dam raise alternatives. Total surface area that would be required for work limits and permanent features, and an estimate of materials needed to modify Shasta Dam and its appurtenances under each dam raise alternative are shown in Table 3-1. Detailed explanations of construction activities and considerations are discussed below.

Table 3-1. Physical Quantities for Proposed Modifications of Shasta Dam and Appurtenances for SLWRI Dam Raise Alternatives

Physical Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Quantity of Concrete (cy)	57,000	77,300	100,800
Quantity of Cement (tons)	128,600	170,500	213,000
Quantity of Metalwork (lbs)	19,654,400	20,435,900	21,751,200
Volume of Imported Fill Material (cy)	61,200	94,400	130,500
Volume of Excavation to Waste Material (cy)	1,600	1,600	1,600
Quantity of Demolished Material (cy)	25,400	29,200	31,600
Area of Permanent Structures (sf)	412,600	412,600	412,600
Area of Work Limits (sf)	460,900	460,900	460,900

Key:
cy = cubic yards
lbs = pounds
sf = square feet

Dam Crest Structure Removal

Before any enlargement of Shasta Dam, existing structures on the dam crest would need to be removed. These structures include the gantry crane, existing spillway drum gates and frames, spillway bridge, concrete in the spillway crest and abutments, upstream parapet walls, sidewalks, curbing, crane rails, and control equipment. The cost for this preparatory work would be the same for the 6.5-, 12.5-, or 18.5-foot dam raises.

1 Modifying the main dam would require the demolition, removal, and
2 transportation of top-of-dam materials to an approved disposal area. This would
3 include the demolition and removal of the upstream reinforced-concrete parapet
4 wall and curb. Sawcuts would be used to aid in removing the upstream
5 reinforced-concrete parapet wall and curb. In addition, sawcuts would be
6 required along the upstream face and crest of the dam before the excavation of a
7 2-foot by 2-foot end area at the upstream face of the dam to embed a 12-inch
8 polyvinyl chloride (PVC) waterstop. The existing dam crest would be prepared
9 by using a high-pressure water jet on the concrete surface. The existing roadway
10 drains would be backfilled with cement grout.

11 Equipment would be mobilized for drilling 4-inch-diameter drain holes on
12 10-foot centers from two different locations: from the existing dam crest to
13 drain the surface contact, with each hole 2.5 feet long (248 holes), and from the
14 existing dam crest for surface drainage at the downstream overhang, with one
15 hole per block and each hole 6.5 feet long (50 holes). A 3-foot-diameter vertical
16 shaft would be excavated through the concrete from the existing dam crest to
17 the hoist gallery in Block 47 for installation of electrical conduit.

18 The existing spillway drum gates and piers would require removal according to
19 a phased construction plan that would minimize impacts to reservoir operations
20 during construction. Two drum gates and one pier would be removed to
21 construct three new piers and install three new sloping fixed-wheel gates. This
22 would be followed by removal of the remaining drum gate and pier to construct
23 two new piers and install three new sloping fixed-wheel gates. This work would
24 require two construction seasons to complete.

25 The spillway bridge and dam crest access road would be out of service for an
26 extended period of time (over two years) during construction of the new
27 spillway and dam crest raise. A detour route would be provided below the dam
28 across an existing bridge.

29 Modifications to the TCD would be performed to minimize impacts to reservoir
30 operations to the extent possible, but supplemental cold water releases may be
31 required through the river outlets during a portion of the construction period.
32 Control equipment for the TCD would be removed, stored, and reinstalled for
33 the higher dam crest. The elevator tower would be out of service for about 4
34 months for construction of the dam crest raise and for replacement of the
35 elevator car and hoist equipment.

36 **Concrete Dam and Wing Dams**

37 Shasta Dam is located on the Sacramento River, approximately 9 miles
38 northwest of Redding, California, and is a major feature of the CVP. As
39 mentioned, the dam was designed and constructed by Reclamation, and was
40 completed in 1945. The concrete dam portion has a structural height of 602 feet,

1 a hydraulic height of approximately 480 feet (between reservoir water surface
2 elevation 1,067 (NGVD29) and the original streambed at the axis of the dam), a
3 crest width of 30 feet, and a crest length of 3,460 feet at crest elevation 1,077.5
4 (NGVD29). (Note that the following elevations presented in this section are
5 based on the NGVD29 datum.) The downstream face of the concrete dam is
6 vertical above elevation 1,050, with a slope of 0.8:1 below elevation 1,050, and
7 the upstream face of the dam is vertical above elevation 720, with a slope of
8 0.5:1 below elevation 720. The concrete dam is slightly curved in plan view,
9 with a large radius of 2,500 feet; however, the 375-foot-long spillway section
10 located in the central portion of the concrete dam has a straight alignment. The
11 volume of concrete in the main dam is 6,270,000 cubic yards. The dam
12 impounds a reservoir with a total volume of 4,552,000 acre-feet at the top of
13 joint-use storage, reservoir water surface (RWS) elevation 1,067. The focus of
14 the feasibility study and this document is a dam raise of 18.5 feet. However,
15 pertinent factors related to other proposed Shasta Dam raise heights of 6.5 and
16 12.5 feet have been considered for development of cost estimates.

17 Enlargement of Shasta Dam and Reservoir under SLWRI dam raise alternatives
18 raises would require raising Shasta Dam (the main gravity dam), and its left and
19 right wing dams as indicated in Table 3-2.

20 **Table 3-2. Physical Features for Proposed Modifications of Shasta Dam**
21 **and Appurtenances for SLWRI Dam Raise Alternatives**

Feature	Existing	Dam Raise Alternatives		
		6.5 feet	12.5 feet	18.5 feet
Main Gravity Dam				
Crest Raise (feet)	0	6.5	12.5	18.5
Crest Elevation	1,077.5	1,084.0	1,090.0	1,096.0
Upstream Parapet Wall Elevation	1,079.1	1,087.5	1,093.5	1,099.5
Reservoir Water Surface Elevation	1,067.0	1,075.5	1,081.5	1,087.5
Left Wing Dam				
Crest Raise (feet)	0	8.5	14.5	20.5
Crest Elevation	1,077.5	1,086.0	1,092.0	1,098.0
Upstream Parapet Wall Elevation	1,079.1	1,089.5	1,095.5	1,101.5
Right Wing Dam				
Crest Raise (feet)	0	6.5	12.5	18.5
Crest Elevation	1,077.5	1,084.0	1,090.0	1,096.0
Upstream Parapet Wall Elevation	1079.1	1,087.5	1,093.5	1,099.5

Note:

Elevations are based on the National Geodetic Vertical Datum of 1929 (NGVD29). All current feasibility-level designs and figures for Shasta Dam and appurtenant structures are based on NGVD29.

Key:

SLWRI = Shasta Lake Water Resources Investigation

22 The main dam raise would consist of mass and structural concrete placements
23 for dam Blocks 15 through 38, and 46 through 71. The new dam crest would
24

1 have the same surface area as the existing dam crest and similar features,
2 including gantry crane rails and surface drains. A new upstream parapet wall
3 would provide flood protection to elevations indicated in Table 3-2. The dam
4 raise would include a new utility gallery, and 5-inch-diameter formed drains on
5 10-foot centers. Two rows of post-tensioned anchors spaced on 10-foot centers
6 would be installed from the new dam crest to a depth of 92.5 feet within Blocks
7 30 through 38, and 46 through 50, for dynamic stability of the raised dam crest
8 during a large earthquake. The existing elevator tower in Block 46 and the
9 existing hoist tower in Block 35 would be raised to maintain their functions.
10 Plate 4 shows typical sections of the concrete dam raise.

11 The mass concrete placements would use lift heights between 5 feet and 10 feet
12 above the existing concrete surface at elevation 1,077.5, between contraction
13 joints, and to the required 30-foot width. The contraction joints in the raised
14 portion of the main dam would match the existing contraction joints, and would
15 be keyed and grouted. Artificial cooling of the mass concrete placements would
16 not be required because limits would be imposed on the placement temperature,
17 and the concrete mix would be designed to limit the heat of hydration. The mass
18 concrete would have a design compressive strength of 4,000 pounds per square
19 inch (psi) at 365 days and would have 370 pounds of cementitious material per
20 cubic yard of concrete, consisting of 50 percent pozzolan and 50 percent
21 cement. Five-inch-diameter formed drains on ten-foot centers would be located
22 in the center of the blocks from elevation 1,077.5 to the new dam crest, and
23 would have caps for future inspection and maintenance.

24 Structural concrete would be placed for the top of dam starting approximately
25 3.5 feet below the new dam crest including concrete for the roadway, the
26 upstream and downstream parapets, and the walkway. The structural concrete
27 would have a design compressive strength of 4,000 psi at 28 days, would have
28 564 pounds of cementitious material per cubic yard of concrete, and would be
29 made up of 20 percent pozzolan and 80 percent cement. Reinforcing bars would
30 be used around the utility gallery, and nominal temperature steel would be used
31 for the exposed structural concrete surfaces. Two 6-inch-diameter steel top-of-
32 dam drains would be furnished and installed in each block to drain to the
33 upstream face.

34 At each contraction joint, 12-inch PVC waterstops would be furnished and
35 installed across the dam block contraction joints and around the utility gallery to
36 provide a grout seal. Mobilization and demobilization would occur for pressure
37 grouting the contraction joints. The 1.5-inch-diameter standard pipe metal
38 tubing and fittings for the grouting system would be furnished and installed.
39 There would be a total of 144 grout hookups based on 3 hookups at each of the
40 48 joints for the main dam. The system would be water-tested before pressure
41 grouting. The final mix for the grout would use Type II cement and is assumed
42 to have a water-cement ratio of 0.9:1, which requires 0.7 bags/cubic yard.
43 Assuming six times the final volume to cover waste, the volume of grout per
44 contraction joint is assumed to be 1 cubic yard.

1 Zoned embankment wing dams were originally constructed on both abutments
2 of the main dam to protect the contact between the concrete and the excavated
3 foundation surface. The tops of the embankment wing dams slope
4 longitudinally from the main dam crest at the abutments down toward the
5 spillway, approximately parallel to the excavated surface of the dam foundation,
6 except the top of the right upstream embankment wing dam, which is
7 approximately 200 feet below the crest of the main dam. The upstream face
8 slopes at 2.5:1 and the downstream face slopes at 2.4:1 for both wing dams. The
9 left wing dam includes a 450-foot-long concrete core wall beyond the left end
10 of the concrete dam above elevation 980. The embankment wing dams contain
11 approximately 2,160,000 cubic yards of earthfill materials.

12 The left wing dam would be raised to the elevations indicated in Table 3-2 to
13 maintain the same height above the top of joint-use storage as for existing
14 conditions. This would involve extending the existing reinforced-concrete core
15 wall to the raised dam crest, and placing a thick layer of large rockfill
16 downstream from the core wall to a slope of 2.5:1. The upstream face would
17 consist of a reinforced concrete or mechanically stabilized earth (MSE) wall,
18 and a concrete parapet wall. The road from the concrete dam crest would be
19 ramped up through the left wing dam to the new embankment crest. Roadways
20 and security features on the existing dam crest would be relocated to the new
21 dam crest (see Plate 5). The existing rotunda on the left abutment of the dam
22 would be removed and reconstructed.

23 The right wing dam would be raised to the elevations indicated in Table 3-2,
24 which would involve extending the main dam raise from Block 71 to the right
25 abutment gantry crane storage area (Block 77) using mass and structural
26 concrete founded on bedrock. Concrete was selected for the right wing dam in
27 lieu of embankment to facilitate construction. The new right wing dam crest
28 would have the same surface area and similar features as for the existing right
29 wing dam crest, including gantry crane rails and surface drains. A new upstream
30 parapet wall would provide flood protection to elevations indicated in Table 3-
31 2. The right wing dam would include a new utility gallery and a foundation
32 drainage curtain (see Plate 6). The right abutment access roads would be
33 modified to match the new dam crest, as shown in Plate 7. Construction
34 quantities for the major items of work for these features are summarized in
35 Table 3-3.

Table 3-3. Concrete Dam and Wing Dams Construction Quantities for SLWRI Dam Raise Alternatives

Item	Dam Raise Alternatives								
	6.5 feet			12.5 feet			18.5 feet		
	Main Concrete Dam	Right Wing Dam	Left Wing Dam	Main Concrete Dam	Right Wing Dam	Left Wing Dam	Main Concrete Dam	Right Wing Dam	Left Wing Dam
Concrete Removal (cy)	2,100	30	600	1,400	10	600	1,400	10	600
Concrete (cy)	25,200	3,800	1,500	40,300	6,100	1,800	57,000	8,800	2,900
Reinforcing Steel (lbs)	1,098,800	109,000	248,500	1,176,700	115,600	297,000	1,188,700	115,600	435,000
Crane Rails (lbs)	249,200	With main dam	N/A	249,200	With main dam	N/A	249,200	With main dam	N/A
Misc. Metalwork (lbs)	65,400	With main dam	N/A	65,400	With main dam	N/A	65,400	With main dam	N/A
Post-Tension Anchors (lf)	11,800	N/A	N/A	12,600	N/A	N/A	13,400	N/A	N/A
MSE Wall (sf)	N/A	N/A	1,000	N/A	N/A	2,700	N/A	N/A	6,100
Embankment Core (cy)	N/A	N/A	6,600	N/A	N/A	7,900	N/A	N/A	9,100
Embankment Filter (cy)	N/A	N/A	1,400	N/A	N/A	2,000	N/A	N/A	3,900
Embankment Rockfill (cy)	N/A	N/A	30,000	N/A	N/A	57,400	N/A	N/A	85,000
Embankment Riprap (cy)	N/A	N/A	1,900	N/A	N/A	5,400	N/A	N/A	8,000

Key:

cy = cubic yard

lbs = pounds

lf = linear feet

Misc. = miscellaneous

MSE = mechanically stabilized earth

N/A = not applicable

sf = square feet

1 More details regarding the concrete dam and wing dam raise designs are
2 contained in Reclamation *Technical Memorandum No. SHA-8110-FEAS-2007-1*
3 (*2007e*), *No. SHA-86-68110-FEAS-2008-1* (2011d), *No. SHA-86-68110-CD-*
4 *2011-1* (2011a), and in Reclamation’s *Left Wing Dam Raise Feasibility –*
5 *Design Report* (2009a) and *Shasta Dam Raise Feasibility – Final Risk Analysis*
6 (2012a).

7 **Spillway**

8 Spillway releases are controlled by three 110-foot-wide by 28-foot-high steel
9 drum gates located within the concrete overflow (spillway) section of the dam.
10 The drum gates are hinged and anchored along the upstream side to a
11 reinforced-concrete cantilever wall section. Rubber seals are located on the ends
12 and downstream lip of each drum gate to form a watertight seal, allowing
13 regulation of the spillway gate heights by adjusting the water levels inside the
14 float chambers. The total discharge capacity of the existing spillway is 186,000
15 cubic feet per second (cfs) at RWS elevation 1,065 (NGVD29). (Note that the
16 following elevations presented in this section are based on the NGVD29
17 datum). Two-foot-high steel flashboards operated from a walkway beneath the
18 spillway bridge allow for reservoir storage between the top of the raised drum
19 gates at elevation 1,065 and the top of joint-use storage at elevation 1,067.

20 Structural concrete would be used to raise the existing spillway crest based on
21 the elevations indicated in Table 3-4, and to shape the raised spillway crest (see
22 Plate 8). The existing spillway bridge, the two existing spillway piers, the
23 cantilever wall sections, and the three existing drum gates and operating
24 equipment would be removed. Five new spillway piers would be constructed at
25 locations within the spillway designed to avoid existing overflow block
26 contraction joints, and a new concrete spillway crest would be constructed
27 between the piers. One row of post-tensioned anchors variably spaced (average
28 10-foot centers) would be installed from the top of each spillway pier to a depth
29 of 100 feet for dynamic stability during a large earthquake. The locations of the
30 new piers would result in different widths of spillway gates. The three existing
31 110- by 28-foot drum gates would be replaced with six sloping, fixed-wheel
32 gates (four 48- by 38-foot and two 54- by 38-foot gates). The total spillway
33 crest length would be reduced from 330 feet to 300 feet as a result. Sloping,
34 fixed-wheel gates were selected in lieu of radial gates to reduce potential
35 seismic loads on the spillway piers during a large earthquake. Cross-bracing
36 would be installed at the tops of the spillway piers to serve as gate seats in the
37 raised position, and to reduce the height of the gates. Stop log guides would be
38 placed immediately upstream from the spillway crest for gate maintenance. Two
39 sets of stop logs (48 and 54 feet long) would be provided to service the six gate
40 openings.

Table 3-4. Spillway Feature Elevations for Proposed Modifications of Shasta Dam Spillway for SLWRI Dam Raise Alternatives

Feature	Existing	Dam Raise Alternatives		
		6.5 feet	12.5 feet	18.5 feet
Crest Raise (feet)	0	0.5	6.5	12.5
Crest Elevation ¹	1037.0	1,037.5	1,043.5	1,049.5

Note:
¹ Main dam and wing dam crest elevations are based on the National Geodetic Vertical Datum of 1929 (NGVD29). All current feasibility-level designs and figures for Shasta Dam and appurtenant structures are based on NGVD29.

Key:
 SLWRI = Shasta Lake Water Resources Investigation

Additionally, an aeration system would be constructed in the spillway chute at approximately elevation 875 to mitigate potential cavitation damage during spillway releases, as shown in Plate 9. The total discharge capacity of the raised spillway is estimated to be 266,300 cfs.

A new bridge would be required to span the spillway to allow for vehicular traffic and for a gantry crane to travel from the right end of the dam to the far end of the spillway (see Plates 10 and 11). The existing spillway bridge consists of three 100-foot spans, while the new bridge would consist of six shorter spans. The spans would not be equal, because the pier locations were set to avoid the existing dam contraction joints. The spillway bridge is designed to be continuous over the pier supports; therefore, there are no deck expansion joint details except at the abutment ends of the bridge. Construction quantities for major items of work for this feature are summarized in Table 3-5. Figure 3-1 is an artist rendering of the 18.5-foot dam raise option.

Table 3-5. Spillway Construction Quantities for SLWRI Dam Raise Alternatives

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Concrete Removal (cy)	8,600	6,900	3,100
Removal of 3 Drum Gates (lbs)	3,000,000	3,000,000	3,000,000
Removal of Bridge Superstructure (lbs)	755,000	755,000	755,000
Concrete (cy)	23,900	26,600	29,500
Reinforcing Steel (lbs)	1,647,900	1,762,900	1,978,400
Post-Tension Anchors (lf)	7,400	7,900	8,400
Sloping Fixed Wheel Gates (lbs)	3,000,000	3,315,600	3,315,600
Stoplogs and Guides (lbs)	1,038,000	1,038,000	1,038,000

Key:
 cy = cubic yard
 lbs = pounds
 lf = linear feet



1
2 **Figure 3-1. Shasta Dam 18.5-Foot Raise**

3 More details regarding the spillway structural and hydraulic designs are
4 contained in Reclamation *Technical Memorandum No. SHA-8110-FEAS-2007-1*
5 *(2007e)*, *No. SHA-86-68110-FEAS-2008-1* (2011d), and *No. SHA-8130-FEAS-*
6 *2011-1* (2013b).

7 **River Outlets**

8 The outlet works consist of eighteen trash-racked, 102-inch-diameter steel-lined
9 conduits that pass through the concrete overflow (spillway) section – six at
10 elevation 942, eight at elevation 842, and four at elevation 742 (NGVD29).
11 Outlet releases are controlled by 102-inch-diameter tube valves for the four
12 lower tier outlets, and by 96-inch-diameter wheel-type outlet gates for the
13 fourteen middle tier and upper tier outlets. The river outlet works conduits,
14 upstream from the regulating tube valves and outlet gates, can be closed by
15 installing a portable coaster gate using the 125-ton gantry crane located on the
16 crest of the dam. The single portable coaster gate is 11.05 feet square, and is
17 stored within a structure at the right abutment of the dam. Total discharge
18 capacity of the outlet works is 81,800 cfs at RWS elevation 1,067 (NGVD29).

19 Because of existing operational limitations associated with the four lower tier
20 102-inch-diameter tube valves, these valves would be replaced by four 96-inch-
21 diameter jet flow gates, as shown in Plate 12. A downstream air shroud and vent
22 would be provided for each gate, which would discharge into the existing 102-

1 inch-diameter conduits. Construction quantities for the major items of work for
2 this feature are summarized in Table 3-6.

3 **Table 3-6. River Outlets Modifications Construction Quantities for all**
4 **SLWRI Dam Raise Alternatives**

Item	Quantity
Concrete Removal (cy)	350
Concrete (cy)	300
Reinforcing Steel (lbs)	30,000
Four 96-Inch Jet-Flow Gates (lbs)	375,400
Coaster Gate Guide Extensions (lbs)	178,200

5 Key:
 cy = cubic yard
 lbs = pounds

6 **Power Outlets**

7 The Shasta Powerplant contains five main generating units and two station
8 service units fed by five 15-foot-diameter penstocks that pass through the
9 concrete dam to the right of the spillway section (intake centerline at elevation
10 815 (NGVD29)). The steel penstock pipes extend over 500 feet from the
11 downstream face of the dam to the powerplant structure, and are supported by
12 concrete saddles. Each penstock pipe has a discharge capacity of 2,800 cfs and
13 an upstream 15-foot by 19.05-foot coaster gate for emergency closure. The total
14 discharge capacity of the powerplant is 14,000 cfs under a gross head of 480
15 feet. The maximum total generating capacity of the main units is 710 MW. Two
16 of the five penstock pipes were modified in 1998 to supply water to a
17 downstream fish hatchery located on the right bank of the downstream channel.

18 The existing steel penstock pipes have been determined to be adequate for the
19 higher reservoir loads. Some modifications are anticipated for the power intake
20 gate hoists to accommodate the higher dam crest. Although vulnerable to
21 seismic loads, penstock failure due to an earthquake is not considered to be a
22 dam safety issue, and modifications to the existing penstocks and concrete
23 saddle supports are not proposed at this time. However, higher reservoir levels
24 associated with the proposed dam raise alternatives would increase the normal
25 head on the penstocks and associated damage in the event of a large earthquake.
26 Construction quantities for the major items of work for this feature are
27 summarized in Table 3-7.

28

Table 3-7. Power Outlets Construction Quantities for all SLWRI Dam Raise Alternatives

Item	Quantity
Relocate Hydraulic Hoist Systems (lbs)	105,000
Gate Stem Extensions (lbs)	12,500
Coaster Gate Guide Extensions (lbs)	15,000

Key:
lbs = pounds
SLWRI = Shasta Lake Water Resources Investigation

Temperature Control Device

Construction of the Shasta TCD to allow selective withdrawal of the cooler reservoir water for discharge through the five powerplant penstocks was completed in 1996 to enhance the downstream fishery. The TCD is a steel structure consisting of a shutter structure and a low-level intake structure that are attached to the upstream face of the dam. Plate 13 shows a plan view of the TCD, with elevations and sections shown in Plates 14, 15, and 16. Conservation of the cold-water pool is achieved by forcing withdrawal from the highest elevation possible. To that end, the upper shutter gates, followed by the middle shutter gates, followed by the pressure relief gates, are operated to access the highest permissible level of withdrawal based on the RWS elevation and downstream water quality objectives. The design flow through the TCD is 19,500 cfs. Major TCD modifications necessary for the 18.5-foot dam raise include the following:

- Disassemble, reinstall, and modify gate hoists to accommodate the longer ropes required.
- Remove and reinstall motor control centers and distribution switchboards.
- Remove and reinstall hoist platforms on new rigid frame box girders to elevate the gate hoist and electrical equipment above the raised maximum RWS elevation.
- Install new dam connections for new rigid frames.
- Remove upper segments of trash racks and replace them with barrier panels on the upstream face of the TCD with cladding panels along the sides of Shutters 1 and 5 to reduce undesirable mixing of reservoir water during controlled downstream releases.
- Extend gate guides, and cladding guides, barrier panels, cladding panels, and closure panels.

- 1 • Remove and reinstall miscellaneous metalwork (e.g., grating, pipe
2 guardrails) and provide new miscellaneous metalwork (e.g., grating,
3 pipe guardrails, platforms, ladders, safety cages) to account for the dam
4 raise, modified platform member configurations, and safety
5 requirements.

- 6 • Attach a new debris boom to existing lake and dam anchorages to
7 exclude debris from the TCD and spillway (see Plate 17), and provide
8 equipment to remove and transport debris from the lake.

9 Construction quantities for the major items of work for this feature are
10 summarized in Table 3-8.

11 **Table 3-8. Temperature Control Device Modifications Construction**
12 **Quantities for SLWRI Dam Raise Alternatives**

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Steel Removal and Disposal (lbs)	253,000	253,000	253,000
Remove and Reinstall Hoist Platform Steel (lbs)	740,000	740,000	740,000
Remove and Reinstall Miscellaneous Metalwork (lbs)	150,000	150,000	150,000
Remove and Reinstall Hoists (each)	17	17	17
Rigid Frame Steel (lbs)	436,000	494,000	562,000
Hoist Platform Steel (lbs)	50,000	50,000	50,000
Miscellaneous Metalwork (lbs)	31,000	31,000	31,000
Cladding Panels and Guides (lbs)	146,000	172,000	199,000
Front Gate Guides (lbs)	249,000	289,000	329,000
Barrier Panels (lbs)	465,000	465,000	465,000
Debris Boom (each)	1	1	1

Key:
lbs = pounds
SLWRI = Shasta Lake Water Resources Investigation

13
14 More details regarding the TCD designs are contained in the Reclamation
15 *Technical Memorandum No. SHA-8120-FEAS-2007-1* (2008d) and *Underwater*
16 *Examination of Temperature Control Device* (2008b).

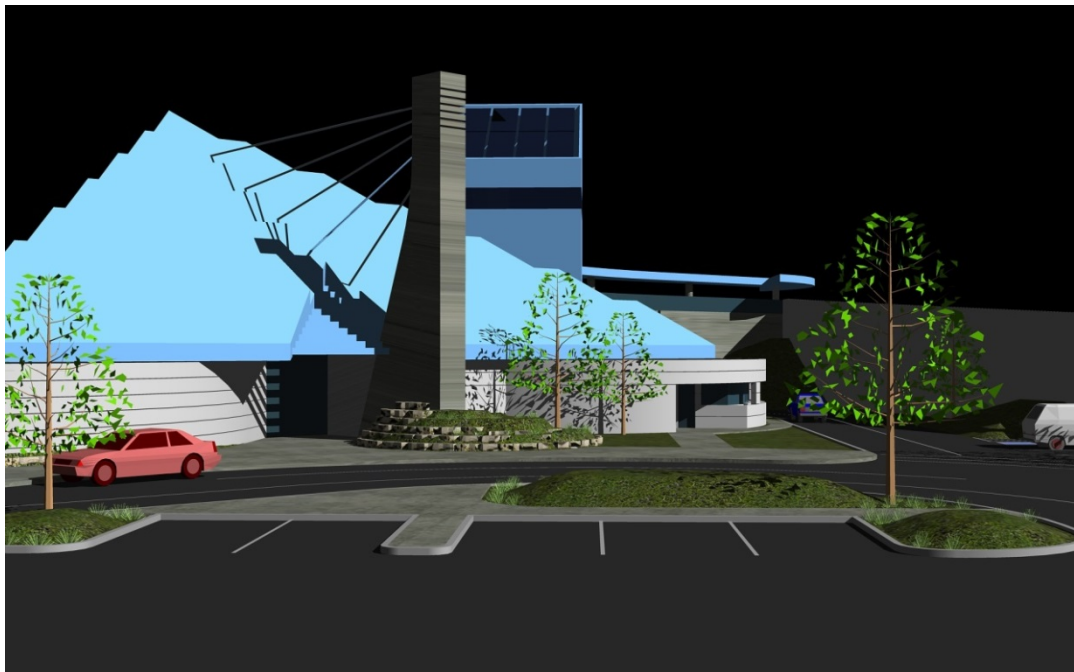
17 **Visitor Center**

18 The existing visitor center building is located on the left abutment of Shasta
19 Dam, as shown in Plate 3, and provides office space for Reclamation’s Northern
20 California Area Office (NCAO) in addition to visitor space, storage areas, and
21 visitor center staff offices. With the dam raise, visitors would have to be
22 conveyed approximately 21 vertical feet to access the new dam crest for the
23 18.5-foot dam raise option. The current access point to the parking lot would

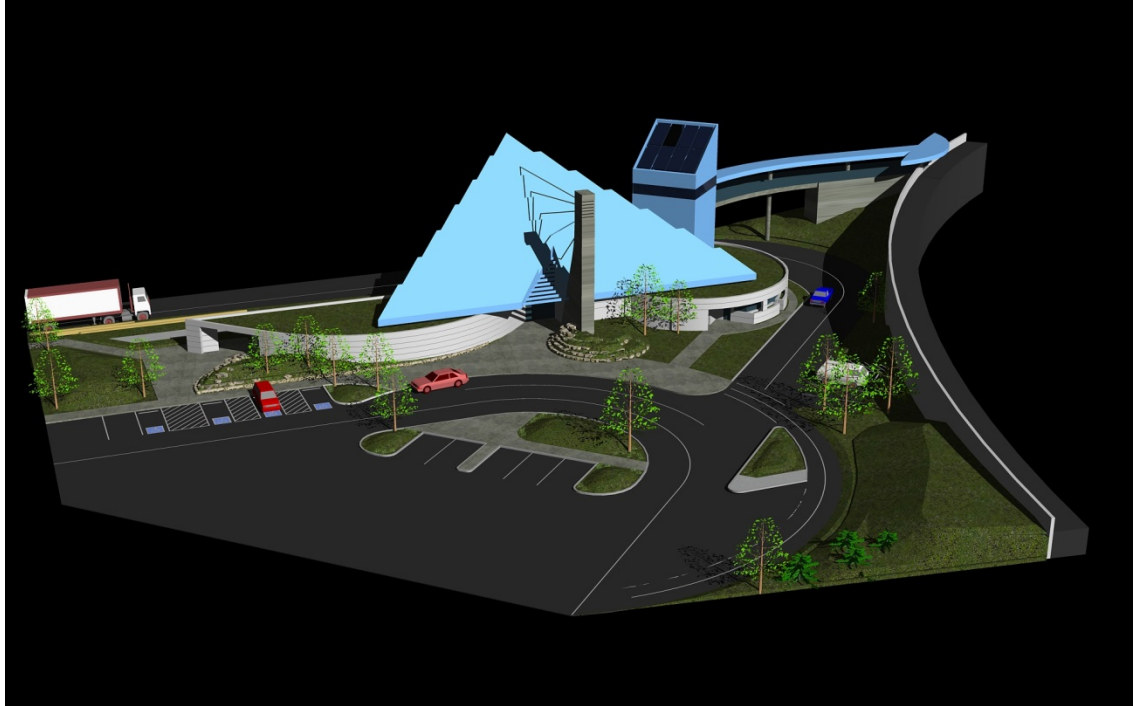
1 not be usable because of the vertical realignment of Shasta Dam Boulevard and
2 the construction of a concrete retaining wall associated with the dam raise. The
3 existing security office is housed in an adjacent building that would be too low
4 with respect to the new dam crest elevation for effective observation of the site
5 facilities.

6 As a part of the overall Shasta Dam raise feasibility-level design, preliminary
7 designs were prepared for a new visitor's facility with a security office and
8 associated site improvements. It is assumed that the existing building would be
9 remodeled for sole occupancy by the NCAO and Shasta Dam administration
10 staff. The remodel of the existing building is not currently included in the dam
11 raise project.

12 The proposed 11,000-square-foot visitor center building would provide
13 adequate space for visitors, storage, staff, and security functions, and feature a
14 panoramic view of all facilities (see Plate 18). A modern theater would have
15 state-of-the-art media equipment and a 14-foot-wide suspended screen. An
16 outdoor, terraced lawn area would be integrated into the site design for picnics
17 and viewing. A security checkpoint would be located at the beginning of the
18 powerplant access road. An elevator, stairs, and a covered pedestrian bridge
19 would provide access to the new dam crest. The new design would comply with
20 all accessibility, life safety, and seismic safety standards, and would
21 demonstrate a commitment to sustainable building design and alternative energy
22 uses. The existing parking lot would be redesigned to provide efficient, safe,
23 and secure vehicular and pedestrian circulation through the site for visitors,
24 NCAO staff, security, and maintenance operations. Figures 3-2 and 3-3 are
25 artist renderings of the proposed visitor center.



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27 **Figure 3-2. Visitor Center Entrance**



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Figure 3-3. Visitor Center and Surrounding Area

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The proposed architectural design would be visually compatible with the dam and with other outstanding regional features. A freestanding vertical, reinforced concrete pier structure with an array of tension rods would support the central beam of a triangular metal roof. The vaulted triangular roof would be stepped with north-facing vertical clear-story windows to provide an open and unimpeded view of the dam. Curved exterior concrete walls with earthen embankments would help moderate heat gain and loss. The ground floor security offices on the east side and visitor center staff offices on the west side would feature vegetated roofs of native grass species. An adjoining four-story metal building would contain a stairwell, elevator, and access to the theater, pedestrian bridge, and fourth floor security observation room. Construction quantities for the major items of work for this feature are summarized in Table 3-9.

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Table 3-9. Visitor Center Construction Quantities for all SLWRI Dam Raise Alternatives

Item	Quantity
Site Excavation (cy)	9,400
Compacted Backfill (cy)	4,250
Topsoil (cy)	670
Asphalt Pavement (cy)	1,100
Solar Panels (sf)	11,800
Glass Curtain Wall (sf)	4,000
Exterior Metal Siding (sf)	5,100
Metal Roofing (sf)	13,545
Concrete (cy)	820
Reinforcing Steel (lbs)	115,000

Key:
 cy = cubic yard
 lbs = pounds
 sf = square feet
 SLWRI = Shasta Lake Water Resources Investigation

3 Lands

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The Shasta Lake area lands valuation accounts for cost of acquiring public and private land required for the project because of new inundation, and permanent and temporary construction easements for reservoir area facility relocations. For the 6.5-foot, 12.5-foot, and 18.5-foot dam raise options, other than in the vicinity of Lakeshore, relatively few additional non-Federal acres of land would need to be acquired through easement or purchase. Table 3-10 shows the affected parcels by SLWRI Comprehensive Plans. The Real Estate Appendix provides estimated land requirements and costs.

12

Table 3-10. Parcels Affected by SLWRI Comprehensive Plans

	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3 (18.5-Foot)	CP4 (18.5-Foot)	CP5 (18.5-Foot)
Total Non-Federal Parcels Affected	79 to 81	130 to 132	178 to 180	201 to 203	201 to 203
USFS Land Cabins Affected	23 to 25	26 to 28	27 to 29	27 to 29	27 to 29

Key:
 CP = Comprehensive Plan
 SLWRI = Shasta Lake Water Resources Investigation
 USFS = U.S. Forest Service

1 Clearing of Reservoir Area

2 An increase in the height of Shasta Dam and Reservoir is expected to inundate
3 varying areas of vegetated shoreline and riparian areas, depending on the final
4 dam raise height. Inundated areas are described in Table 3-11; corresponding
5 vegetation management is discussed in a later section. Inundation levels
6 currently vary by water year and season at Shasta Lake, and this variation would
7 continue if the dam were raised. Maximum water surface occurs during late
8 spring, consistent with flood control operating guidelines. The reservoir is
9 drawn down steadily throughout the summer in response to water supply
10 demands. Based on this historic pattern, the new inundation zone would be
11 exposed during most of the year for most water year types. Treatment windows
12 and access are very limited by water levels and public use of the reservoir.
13 Thus, a thorough vegetation removal strategy would be necessary to facilitate
14 the continued safe operation of the dam and recreation area.

15 **Table 3-11. Inundated Areas and Corresponding Vegetation Prescriptions**
16 **for SLWRI Dam Raise Alternatives**

Description		Vegetation Removal Prescription		
Dam Raise (feet)	Total Inundated Area (acres)	No Treatment (acres)	Overstory Removal (acres)	Total Removal (acres)
6.5	1,110	740	220	150
12.5	1,750	1,167	347	236
18.5	2,500	1,668	495	337

Key:
SLWRI = Shasta Lake Water Resources Investigation

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18 Rationale and Need for Vegetation Management

19 The majority of the area now occupied by Shasta Lake was completely cleared
20 of vegetation during construction of the original dam but some vegetation was
21 left in place. The Pit River arm of the reservoir represents an area that was not
22 cleared because of a shortage of available workers and resources. This area is an
23 example of the effects of not clearing vegetation. Many snags are still standing
24 in the Pit River arm, providing unique wildlife habitat. If left untreated,
25 inundated upland vegetation is not expected to survive the first period of
26 sustained inundation. Riparian vegetation would survive most of the expected
27 inundation periods, although occasional mortality would be experienced over
28 the life of the project.

29 The goals of preconstruction vegetation management are as follows:

- 30 • Reduce hazards to the public using the lake for recreation.

- 1 • Provide access to the shoreline near high-use areas.
- 2 • Maximize retention of habitat components that would survive
- 3 inundation.
- 4 • Minimize impacts to operation of the dam and spillway.

5 If left in place, inundated vegetation could pose a hazard to the recreating public
6 and physically block access to the newly created shoreline. Snags or fallen trees
7 could pose a navigation hazard to boaters.

8 Brush, particularly manzanita, provides effective rearing cover for fish when
9 inundated. Manzanita would be removed in clearing areas and stockpiled to be
10 used for fish habitat structures placed in designated locations; however,
11 willows, cottonwoods, and buttonbush would not be removed in and along
12 riparian areas. Dead upland vegetation would provide some habitat during
13 periods of inundation. Snags caused by inundation would provide habitat for
14 birds and cavity nesters. During periods of reservoir drawdown, the residual
15 root systems of inundated vegetation would provide support to newly created
16 shorelines, reducing erosion. The benefits provided by dead vegetation would
17 decrease over time as roots, plant skeletons, and snags decay.

18 To minimize operational hazards from small debris loading after vegetation
19 removal, booms and other methods would be employed to capture debris, and
20 are intended to provide better protection than currently exists for the dam and
21 TCD. Plate 17 shows the plan, sections, and details for a proposed reservoir
22 boom.

23 **Proposed Vegetation Management Prescriptions**

24 Three vegetation removal prescriptions are proposed for the areas around the
25 reservoir that would be inundated, as described in the following sections.

26 ***Complete Vegetation Removal***

27 Complete vegetation removal treatment would clear all existing vegetation from
28 a designated treatment area and would generally be applied to areas along and
29 adjacent to developed recreation areas, including boat ramps, day use areas,
30 campgrounds, marinas, and resorts. Plate 19 shows the various vegetation
31 management prescriptions around the reservoir. Exceptions would be made in
32 areas with high shoreline erosion potential or in habitat for special-status
33 species.

34 Timber would be harvested and removed to landings by ground skidding
35 equipment if road access is available and slopes are less than 35 percent;
36 otherwise, trees would be yarded by helicopter, and residual vegetation and
37 activity-created slash would be piled and burned by hand. Where possible, trees
38 would be felled into the reservoir during removal to minimize damage to
39 reservoir embankments. Tree stumps would be cut to within 24 inches of the

1 ground surface and brush stumps would be cut flush to the ground. Stumps
2 would be left in place to reduce shoreline erosion. This treatment is intended to
3 maximize shoreline access and minimize the risk to visitors from snags and
4 water hazards.

5 ***Overstory Removal***

6 Overstory removal treatment would remove all trees greater than 10 inches in
7 diameter at breast height or 15 feet in height from the treatment area, and would
8 generally be applied to houseboat mooring areas or narrow arms of the reservoir
9 where snags would pose the greatest risk to boaters. Trees would be harvested
10 and removed to landings by ground skidding equipment if road access were
11 present and slopes were less than 35 percent; otherwise, trees would be yarded
12 by helicopter, and activity-created slash would be piled and burned by hand.
13 The remaining understory vegetation would be left in place. Where possible,
14 trees would be felled into the reservoir during removal to minimize damage to
15 reservoir walls. Tree stumps would be cut to within 24 inches of the ground
16 surface. Stumps would be left in place to reduce shoreline erosion. This
17 treatment is intended to minimize the risk to visitors from snags and water
18 hazards.

19 ***No Treatment***

20 Designated areas of the inundation zone would be left untreated and no
21 vegetation would be removed. This prescription would generally be applied to
22 stream inlets, the upper end of major drainages, and the shoreline of wider arms
23 of the reservoir. This prescription would also apply to special habitat areas, and
24 is intended to maximize the habitat benefits of inundated and residual
25 vegetation.

26 **Vegetation Management Areas**

27 Fifteen vegetation management areas have been delineated to facilitate the
28 efficient removal of vegetation around the reservoir perimeter. The acreages of
29 each management prescription are summarized in Table 3-12 by vegetation
30 management area.

31

Table 3-12. Vegetation Management Prescription Summary by Area for SLWRI Dam Raise Alternatives

Landing Location	Dam Raise Alternatives											
	6.5 feet				12.5 feet				18.5 feet			
	Overstory Removal (acres)	Overstory Removal Quantity (board feet)	Complete Removal (acres)	Complete Removal Quantity (board feet)	Overstory Removal (acres)	Overstory Removal Quantity (board feet)	Complete Removal (acres)	Complete Removal Quantity (board feet)	Overstory Removal (acres)	Overstory Removal Quantity (board feet)	Complete Removal (acres)	Complete Removal Quantity (board feet)
Antlers	5	33,400	8	48,600	8	52,700	12	76,600	12	75,100	17	109,300
Bailey Cove	7	40,600	17	148,400	11	64,000	26	234,000	15	91,300	37	333,700
Beehive Point	24	102,300	3	5,400	38	161,300	4	8,500	54	230,100	6	12,100
Bridge Bay	0	0	9	51,800	0	0	14	81,600	0	0	20	116,400
Digger Bay	31	92,600	8	27,700	49	146,000	13	43,700	70	208,300	19	62,400
Hirz Bay	22	169,500	22	211,200	34	267,300	35	333,000	49	381,200	49	474,900
Jones Valley	51	328,000	17	81,700	81	517,100	26	128,800	116	737,500	38	183,700
Lakeshore East	2	12,500	17	58,800	4	19,700	27	92,800	5	28,100	39	132,300
Lower Salt Creek	15	62,700	14	96,300	24	98,900	22	151,800	35	141,100	31	216,500
McCloud Arm	0	0	4	14,900	0	0	7	23,500	0	0	10	33,500
Packers Bay	22	78,800	7	29,200	35	124,200	11	46,000	50	177,100	16	65,600
Pit Arm	0	0	2	22,400	0	0	3	35,300	0	0	4	50,400
Shasta Marina	13	89,400	1	17,900	21	141,000	2	28,200	30	201,100	2	40,200
Silverthorn	18	115,100	17	117,900	29	181,400	26	185,900	41	258,800	37	265,200
Turntable	8	88,700	5	33,100	13	139,900	8	52,200	19	199,500	11	74,400
Total	220	1,213,600	150	965,300	347	1,913,500	236	1,521,900	495	2,729,200	337	2,170,600

Key:
SLWRI = Shasta Lake Water Resources Investigation

1 Vegetation management activities would need to be complete before inundation
2 of new areas created by enlarging the reservoir. A single staging area (landing)
3 would serve each vegetation management area. Access for vegetation removal
4 activities would most likely be limited to late summer and fall, when water
5 levels are low and recreation use has decreased. Removal by helicopter would
6 generally be limited to spring and fall because of the limited availability of
7 helicopters during the summer fire season. Vegetation removal would also be
8 limited during bird nesting season, typically early spring through mid-summer.
9 Breeding bird surveys in suitable habitats would be performed to determine the
10 appropriate time frame for vegetation removal activities and as an effort to
11 avoid nesting species.

12 The average distance for helicopter trips per vegetation management area is
13 described in Table 3-13. Note that because of distance and/or safety constraints,
14 helicopters would not be used in the following vegetation management areas:
15 Bridge Bay, Lakeshore East, Pit Arm, and McCloud Arm. Slash burning could
16 take place during the winter following vegetation treatment, and would comply
17 with all regulations set forth by the Shasta County Air Quality Management
18 District. Vegetation management activities would need to be complete before
19 inundation of new areas created by a dam raise.

20 **Table 3-13. Average Flight Distance**
21 **for Each Vegetation Management Area**

Landings	Average Distance per Flight (miles)
Antlers	0.8
Bailey Cove	1.3
Beehive Point	1.2
Digger Bay	2.5
Hirz Bay	1.5
Jones Valley	2.7
Lower Salt Creek	1.1
Packers Bay	1.7
Shasta Marina	1.3
Silverthorn	1.0
Turntable	1.1

22

23 Reservoir Area Dikes

24 With Shasta Dam enlargement scenarios, dikes in the Lakeshore and Bridge
25 Bay areas would be required to protect California Department of Transportation
26 (Caltrans) highways, the Union Pacific Railroad (UPRR), and other
27 infrastructure from inundation.

1 Two closure dikes and three railroad embankments in the Lakeshore area, and
 2 two closure dikes in the Bridge Bay area would be required in support of an
 3 18.5-foot dam raise. Locations of the proposed dikes are shown in Plates 20 and
 4 21. Table 3-14 summarizes the quantities of each type of material required for
 5 the proposed Lakeshore area and Bridge Bay dikes. The dikes are named to
 6 correspond with those presented in the *Plan Formulation Report* (PFR)
 7 (Reclamation 2007f). Some of the dikes originally proposed in the PFR were
 8 not required for feasibility-level analysis because of the new proposed
 9 alignments of the dikes. Doney Creek and Antlers Dikes were originally named
 10 Dikes 8 and 10, respectively, in the PFR.

11 **Table 3-14. Estimated Material Quantities Required for Proposed**
 12 **Lakeshore and Bridge Bay Dikes and Railroad Embankments**

Dike Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Lakeshore Dikes			
Doney Creek Dike			
Crest Elevation ¹ (feet)	-	1087.2	1,098.7
Volume of Fill Material (core, drain, filter) (cy)	-	12,200	75,000
Volume of Riprap (cy)	-	1,000	5,900
Volume of Excavated Material (cy)	-	3,100	10,200
Site Clearing and Grubbing Below Dike (acres)	-	1.5	7.2
Antlers Dike			
Crest Elevation ¹ (feet)	-	-	1,098.7
Volume of Fill Material (core, drain, filter) (cy)	-	-	4,900
Volume of Riprap (cy)	-	-	400
Volume of Excavated Material (cy)	-	-	300
Site Clearing and Grubbing Below Dike (acres)	-	-	0.9
North Railroad Embankment			
Crest Elevation ¹ (feet)	varies ²		
Volume of Fill Material (core, filter) (cy)	17,100	17,100	17,100
Volume of Riprap (cy)	400	400	400
Volume of Excavated Material (cy)	1,500	1,500	1,500
Site Clearing and Grubbing Below Dike (acres)	1.2	1.2	1.2
Middle Railroad Embankment			
Crest Elevation ¹ (feet)	varies ²		
Volume of Fill Material (core, filter) (cy)	13,400	13,400	13,400
Volume of Riprap (cy)	300	300	300
Volume of Excavated Material (cy)	4,000	4,000	4,000
Site Clearing and Grubbing Below Dike (acres)	2.9	2.9	2.9

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Table 3-14. Estimated Material Quantities Required for Proposed Lakeshore and Bridge Bay Dikes and Railroad Embankments (contd.)

Dike Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
South Railroad Embankment			
Crest Elevation ¹ (feet)	varies ²		
Volume of Fill Material (core, filter) (cy)	101,900	101,900	101,900
Volume of Riprap (cy)	2,500	2,500	2,500
Volume of Excavated Material (cy)	8,500	8,500	8,500
Site Clearing and Grubbing Below Dike (acres)	6.2	6.2	6.2
Bridge Bay Dikes			
West Dike			
Crest Elevation ¹ (feet)	1,081.2	1087.2	1,104.2
Volume of Fill Material (core, drain, filter) (cy)	3,000	7,700	69,000
Volume of Riprap (cy)	200	800	23,600
Volume of Excavated Material (cy)	2,100	5,000	15,300
Site Clearing and Grubbing Below Dike (acres)	0.8	1.4	2.2
East Dike			
Crest Elevation ¹ (feet)	1,081.2	1087.2	1,104.2
Volume of Fill Material (core, drain, filter) (cy)	1,000	3,000	40,100
Volume of Riprap (cy)	40	160	7,400
Volume of Excavated Material (cy)	900	2,000	16,900
Site Clearing and Grubbing Below Dike (acres)	0.4	0.6	1.1

Note:
 Volumes exclude swelling factors.
¹ Elevation based on North American Vertical Datum of 1988.
² Railroad embankment crest elevations vary by the proposed railroad alignment.
 Key:
 - = not applicable
 cy = cubic yards

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Typical cross sections for homogenous fill dikes for an 18.5-foot dam raise are shown in Plate 22. Cross sections would be similar for 6.5- and 12.5-foot raises. Plate 23 shows typical cross sections of railroad embankments. It is expected that up to 5 feet of organic-rich soil and vegetation would be excavated from the foundation of the dike, and from a shear key on the upstream side of the dike. Ground treatment and/or over-excavation may be necessary in some areas to remove and/or treat pervious material. Riprap would be placed on the upstream face of each dike to the crest of the dike to provide protection from wave run-up and erosion.

1 For the purposes of this feasibility study, *Reclamation Design of Small Dams*
2 (Reclamation 1987) guidelines were used to generate typical dike cross
3 sections. Currently, all dikes are proposed with homogenous fill, consisting of
4 relatively impervious fill with embankment slopes of 3:1 upstream and 2.5:1
5 downstream, as shown in Plate 22. A low-permeability core would extend to the
6 crest of the dike and have upstream and downstream slopes of 2:1. Subsequent
7 phases of geotechnical investigation during final design may lead to revisions of
8 these typical cross sections.

9 **Doney Creek Dike**

10 For the proposed 18.5-foot alternative, the Doney Creek Dike would extend
11 approximately 1,800 feet along the southeastern side of the UPRR embankment
12 to the north of the Doney Creek Bridge, turning to the west underneath the
13 Doney Creek Bridge along the shoreline of Doney Creek, as shown in Plate 20.
14 The purpose of the Doney Creek Dike would be to protect the UPRR
15 embankment to the north of the Doney Creek Bridge from partial inundation
16 when water reached ordinary high water levels as a result of the 18.5- and 12.5-
17 foot dam raise alternatives.

18 Dike construction would consist primarily of homogenous fill in the flat areas to
19 the south of the existing UPRR embankment. The use of homogenous earth
20 dikes in this area is intended to limit construction costs. A combination of flood
21 walls and zone embankments would be required in areas where construction
22 access would be limited or where natural slopes exceeded the slopes of the
23 embankments. The limited overhead construction space below the Doney Creek
24 Bridge would make constructing an earthen dike infeasible, since the upper lifts
25 of the dike would not be accessible with a compactor. Accordingly, a flood wall
26 would be required at this location. Similarly, the natural slopes of the ravine
27 located north of the Doney Creek Bridge are steeper than the anticipated slopes
28 of the homogenous dikes. A rock fill dike or a dike supporting a floodwall
29 would be required at this location.

30 **Antlers Dike**

31 For the proposed 18.5-foot alternative, the Antlers Dike would extend
32 approximately 200 feet in a northeasterly direction away from Interstate 5. The
33 purpose of the Antlers Dike would be to protect Interstate 5 from partial
34 inundation when water reached ordinary high water levels for the 18.5-foot dam
35 raise. Dike construction would consist of a homogenous fill embankment, which
36 would be the most cost-effective and appropriate for this small dike.

37 **Railroad Embankments**

38 Three railroad embankments, labeled North, South, and Central (see Plate 24),
39 are proposed along the railroad alignment in the Lakeshore area, located
40 between the Doney and Charlie creek arms of Shasta Lake. The purpose of
41 these embankments would be to support the railroad for the adjusted alignment.
42 The North Embankment would extend approximately 1,700 feet from the north
43 shore of Charlie Creek in a northern direction. The South Embankment would

1 be to the north of the first embankment and would extend approximately 1,100
2 feet along the proposed railroad alignment. The Central Embankment would
3 extend approximately 340 feet along the proposed railroad alignment,
4 terminating at the south shore of Doney Creek.

5 **Bridge Bay West and East Dikes**

6 At the Bridge Bay Marina, a 700-foot long section of UPRR tracks stretches
7 between two railroad tunnels, located downslope from Interstate 5. This section
8 of railroad tracks would be inundated as a result of ordinary high water for all of
9 the dam raise alternatives. Dikes are proposed on either side of the tracks to
10 protect the railroad from inundation both by Shasta Lake and impounded
11 stormwater runoff from the hillside directly east of the tracks, as shown in Plate
12 25.

13 Geotechnical analysis of the existing foundation material for the Bridge Bay
14 dikes determined that significant excavation would be required for the west
15 Bridge Bay Dike. To minimize the dike footprint and limit excavation, jet
16 grouting was proposed. The existing unsuitable foundation material for the east
17 Bridge Bay Dike was determined to extend to a maximum depth of 15 feet.

18 **Borrow Material for Dikes**

19 The Lakeshore and Bridge Bay dikes would be constructed as homogenous
20 embankments. Homogenous dikes would consist primarily of low-permeability
21 fill with a small granular drain and filter at the toe of the embankment. Dike
22 slopes retaining water would be armored with riprap. An overview of the
23 borrow material needed for construction of the proposed dikes and description
24 of potential borrow sources is provided in the following paragraphs.

25 ***Borrow Material Classification***

26 Dike designs consider embankment fill materials, including homogenous fill,
27 core, riprap, filter, and drain materials. Brief descriptions of these materials are
28 given below.

29 **Core and Homogenous Fill Material** Feasibility-level designs of dikes
30 constructed as homogenous embankments would be constructed almost entirely
31 of low-permeability soil. Typically, core fill materials consist of impervious
32 fine-grain materials, such as silts and clays, or coarse-grain materials, such as
33 gravels or sands with significant components of clay or silt.

34 **Riprap** Riprap is used to protect embankment slopes subjected to wave
35 erosion. Properly graded riprap is commonly used to provide slope protection.
36 Riprap needs to be placed in a manner to provide a well-integrated mass with
37 minimum void spaces. Generally, riprap consists of a uniform distribution of
38 angular and durable gravel- to boulder-sized rock.

39 **Filter Material** Granular filters will be required for each of the proposed
40 embankments in the Lakeshore and Bridge Bay areas. Granular filters are used

1 to minimize the risk of internal erosion at the boundaries of dissimilar fill
2 materials. The filters consist of uniformly graded, free-draining materials with
3 less than 5 percent fines by weight. Granular filters are restricted to a maximum
4 particle size of 3 inches to avoid segregation and bridging of large particles
5 during construction.

6 **Drain Material** The proposed homogenous fill embankments would be
7 constructed with toe drains to minimize pore pressures within the embankments.
8 Toe drains can be used in concert with blanket drains to further reduce uplift
9 pressures along embankment foundations. Toe drains must be strong, durable,
10 and free draining. Typically, drain materials consist of sands and gravels with
11 less than 5 percent fine-grained soil.

12 **Borrow Requirements for Dikes**

13 Estimates of the borrow materials needed to construct the proposed dikes are
14 presented in Table 3-14. Proposed dike geometries were developed for
15 feasibility evaluations. Accordingly, volumes of core and homogenous fill,
16 riprap, filter, and drain materials are estimates, and may be refined during
17 subsequent phases of design. Borrow sources for proposed dikes are discussed
18 in a later section under “Other Considerations.” The required fill volumes are
19 presented in greater detail in the SLWRI *Reservoir Area Dikes and Related*
20 *Facilities Report* (Reclamation 2012b).

21 **Other Considerations**

22 The following sections discuss other dam raise options considerations relating
23 to Pit 7 Dam, Keswick Dam, probable maximum flood (PMF), borrow sources,
24 and geological and geotechnical information.

25 **Pit 7 Dam and Powerhouse**

26 This section presents design and construction information to support the
27 assessment of the Pit 7 Dam, Powerhouse, and related facilities associated with
28 the proposed raise of Shasta Dam. The Pit 7 Dam and Powerhouse, which is
29 owned and operated by Pacific Gas and Electric (PG&E), is located on the
30 upper Pit River at the northeast end of Shasta Lake. The complex consists of
31 three main features: a main dam with integral spillway, a two-unit hydroelectric
32 powerhouse immediately downstream from the main dam, and an afterbay dam
33 (see Plate 24). Each main feature, and the impacts of the three Shasta Dam and
34 Reservoir raise options on each feature, are discussed below. Costs are included
35 in the estimates for potential physical impacts to the Pit 7 Powerhouse. No
36 modifications are identified or included for the main dam or afterbay facilities.

37 The main Pit 7 gravity dam was evaluated to determine the impact of the
38 increased tailwater level caused by a Shasta Dam raise on the uplift pressures
39 under the base of the dam. Normal operating conditions for the three Shasta
40 Dam raise alternatives (6.5, 12.5, and 18.5 feet) were considered in the stability

1 analysis. An extreme loading combination, including seismic loads, was also
2 considered in the analyses. For this evaluation, the computer program CADAM
3 2000 (Version 1.4.11) was used to calculate factors of safety against sliding and
4 overturning of the dam. Compressive and tensile stresses were also investigated
5 at the heel and toe of the dam. Stability analysis results can be found in the
6 *SLWRI Pit 7 Dam and Powerhouse Facilities Report* (Reclamation 2008).

7 ***Pit 7 Spillway***

8 The spillway was evaluated to determine if a potential modification or raising of
9 the Pit 7 Dam spillway flip bucket would be required because of higher
10 tailwater levels caused by a Shasta Lake raise and concurrent Pit 7 Dam
11 spillway flows. Tailwater levels above the lip of the spillway combined with
12 substantial spillway flows could potentially affect spillway performance and
13 have adverse effects on the dam and adjacent powerhouse.

14 Backwater conditions above the lip of the spillway could potentially interfere
15 with spillway performance. If the spillway discharge was small enough or if the
16 tailwater was high enough, sweep-out of the flip bucket would not occur and the
17 roughly 85-foot-long flip bucket would function in a manner similar to a stilling
18 basin. If the spillway flows were great enough to cause sweep-out of the flip
19 bucket, a high tailwater level could interfere with the intended trajectory of the
20 spill and cause energy dissipation and potential scour to occur near the terminus
21 of the spillway. This is a condition that should be avoided. At all tailwater levels
22 below the lip of the flip bucket, the flip bucket would either function as a
23 stilling basin for low flows, or when the spillway flow was high enough, the
24 spill would be thrown a distance downstream and energy dissipation would
25 occur at an acceptable distance away from the dam.

26 Conditions that could cause potential energy dissipation problems would require
27 tailwater caused by backwater above elevation 1,075.5 (NGVD29) coincident
28 with high spillway flows.

29 The 50-year historical and simulated record does not indicate any spillway
30 discharge events that would likely be damaging because of the potential Shasta
31 Dam raises. Thus, it can be projected that the Pit 7 Dam should not be subjected
32 to damaging flows for the potential dam raise alternatives up to the 1 percent
33 chance of occurrence each year. This is not an indication that damaging
34 conditions at the spillway would not occur for all flood events up to the PMF,
35 but the damage potential from overtopping of the Pit 7 Dam would probably
36 exceed that which could be attributed to spillway performance alone. Therefore,
37 it is recommended that there should be no requirement to raise the Pit 7 Dam
38 spillway as a direct result of the Shasta Dam raise options that are under
39 consideration.

40 ***Pit 7 Powerhouse***

41 The powerhouse is a semi-outdoor type powerhouse, with two generating units
42 each rated at 56 MW output under approximately 204 feet of net head. The

1 main powerhouse yard/deck, where the generators and generator step-up
2 transformer are located, is at elevation 1,104.25 feet (NGVD29). (Note that the
3 following elevations presented in this section are based on the NGVD29
4 datum). A training wall with top at elevation 1,094 feet separates the dam
5 spillway from the powerhouse. The normal tailwater level under existing
6 conditions is elevation 1,067 feet. A raise of Shasta Dam by 18.5 feet would
7 raise the normal tailwater to elevation 1,087.5 feet. This would still provide 6.5
8 feet of freeboard to the top of the training wall and 16.75 feet of freeboard to the
9 powerhouse yard/deck. The overall powerhouse would not be inundated, but
10 other effects need to be considered/addressed.

11 The Pit 7 Powerhouse is sometimes operated in synchronous or “motoring”
12 mode to balance the power grid if demand drops below available generation. In
13 this condition, the water in the draft tube is lowered to an elevation below the
14 runner while the unit is at synchronous speed. A set of breakers is closed and
15 surplus power from the grid is used to turn the generator similar to a motor
16 without water flowing through the turbine. At the Pit 7 Powerhouse, the normal
17 tailwater is below the bottom of the runners. This enables the Pit 7 Powerhouse
18 to switch to synchronous mode by simply closing the wicket gates and allowing
19 the tailwater to equalize in the draft tubes at the current stream elevation, then
20 closing the breakers to switch to “motoring” mode. With an increased tailwater
21 elevation, it would be necessary to install a tailwater depression system to lower
22 the water level in the draft tubes before the units could be switched to
23 synchronous mode. The tailwater depression system would be sized with
24 enough storage tank capacity to complete the initial blowdown in a few
25 seconds, and a smaller compressor could be used to maintain the draft tube
26 pressure and water elevation over long periods of time.

27 Another consideration is the static pressure on the turbine head covers and main
28 shaft seals due to the increased tailwater elevation. At the current normal
29 tailwater elevation, the turbine head covers are only under pressure with the
30 wicket gates open and the turbine units running. When the wicket gates are
31 closed, the water in the turbine and draft tube equalizes with the tailwater and
32 relieves the pressure on the head cover. If the tailwater elevation were higher
33 than the turbine head covers, the head covers and associated seals would
34 experience static internal pressures when the wicket gates were closed with the
35 draft tube gates open. A tailwater depression system would maintain the same
36 static pressure under the head covers while the units operated in synchronous
37 mode. The unit centerlines are at elevation 1,073.0, which is 14.5 feet below the
38 new maximum tailwater elevation of 1,087.5 feet for the proposed 18.5 foot
39 dam raise option. The 14.5 feet of static head is much less than the 204 feet of
40 head that the turbines currently operate under. Therefore, the existing seals in
41 the turbines should be capable of withstanding the static head at any of the
42 proposed maximum tailwater elevations. Aside from the decrease in generation
43 due to the reduced net head, the existing turbines should function properly with
44 the new maximum tailwater elevation.

Reduction in Generation Capacity

Initial estimates of reduced generation at the Pit 7 Powerhouse used the maximum proposed pool elevations for Shasta Lake, but more recent models recognize that the maximum pool would not be maintained for extended periods, and may not even be achieved most years. The most recent estimates of reductions in energy generation at the Pit 7 Powerhouse due to the proposed SLWRI dam raises are indicated in Table 3-15.

Table 3-15. Simulated Average Annual Decrease in Pit 7 Powerhouse Generation for SLWRI Comprehensive Plans

Item	CP 1 (6.5-Foot)	CP 2 (12.5-Foot)	CP 3 (18.5-Foot)	CP 4 (18.5-Foot)	CP 4 (18.5-Foot)
Change in Generation (GWh)	-4	-7	-15	-10	-15
Percent Change (percent)	-1%	-1%	-3%	-2%	-3%

Key:
 GWh = gigawatt-hour
 SLWRI = Shasta Lake Water Resources Investigation

Analysis of the sump and dewatering pumps, cooling water systems, air intake systems, and wall penetrations can be found in the SLWRI *Pit 7 Dam and Powerhouse Facilities Report* (Reclamation 2008e).

Existing Powerhouse Structure

The existing Pit 7 Powerhouse has 4 foot-thick concrete walls. These walls span vertically between the concrete floor slabs to resist lateral soil and hydrostatic loads. A review of the structure’s capacity indicates that the existing powerhouse wall would perform satisfactorily when subjected to loading from the maximum proposed tailwater elevation. The existing powerhouse structure would not require modifications to accommodate any of the proposed tailwater elevations.

The existing draft tube gates are fabricated from steel wide-flange beams and steel plate. A review of the gate elements indicates that under the new maximum tailwater elevation, the 11/16-inch-thick skin plate and the 24-inch-deep wide flange beams spanning horizontally that comprise the draft tube gates would perform adequately under the proposed tailwater elevations associated with the three Shasta Dam raise options. Therefore, the existing draft tube gates are considered adequate for continued service under the maximum proposed tailwater elevation. Further detailed review and/or analysis of specific elements or locations may be required at a later date, when a final tailwater elevation is determined.

1 **Pit 7 Afterbay Dam**

2 The Pit 7 Afterbay Dam consists of two main sections: a rockfill dam with a
3 550-foot-long crest with elevation 1,060 feet (NGVD29) (note that the
4 following elevations presented in this section are based on the NGVD29
5 datum), and a concrete uncontrolled spillway section 145 feet in length, with a
6 crest elevation that varies between elevation 1,026 feet and elevation 1,058 feet.

7 Slope stability analyses results for the Pit 7 Afterbay Dam, as modeled under
8 the higher water levels cause by a raised Shasta Dam and Reservoir, show that
9 the factors of safety against slope failures of the rockfill dam are above 2.0 for
10 all the loading cases considered. Although the analyses show that complete
11 failure of the rockfill dam would not occur under seismic loading, local surficial
12 deformations would likely occur on the upstream side and less likely on the
13 downstream reinforced face.

14 At the time of year when Shasta Lake is at the maximum normal pool, elevation
15 1,087.5, the rockfill dam is under 27.5 feet of water. The dam would be
16 subjected to both hydrostatic and hydrodynamic forces that are not expected to
17 have any significant impacts to the structural stability of the dam. The weight of
18 water on top of the dam acts against slope failures and would increase the factor
19 of safety. Flow velocities through the dam are not expected to be high enough to
20 cause erosion of the dam. If high velocities were to occur, the steel
21 reinforcement in the dam and on the downstream slope would act against
22 erosion of the dam. Based on this feasibility-level assessment, it is not
23 recommended that any modifications be made to the Pit 7 Afterbay Dam.
24 However, the steel reinforcement should be inspected regularly.

25 **Keswick Dam**

26 Keswick Dam is a concrete, gravity-type structure with a spillway over the
27 center of the dam, and is located downstream from Shasta Dam. The spillway
28 has four 50-foot by 50-foot fixed-wheel gates with a combined discharge
29 capacity of 248,000 cfs at full pool elevation (587). It is estimated that no
30 modifications to Keswick Dam would be required for the 6.5-, 12.5-, or 18.5-
31 foot Shasta Dam raise options.

32 **Probable Maximum Flood**

33 An appraisal-level PMF was originally developed by Reclamation for the Shasta
34 Dam Enlargement Studies in April 2001 (Reclamation 2008a), using current
35 Hydrometeorological Report No. 59 (HMR 59) procedures. The 2001 PMF
36 was a general storm with a peak inflow of 633,400 cfs and a 15-day volume
37 of 3,961,700 acre-feet, and was used to develop an appraisal-level hydrologic
38 hazard analysis (HHA). The HHA provided frequency floods with return
39 periods ranging from 100 to 20,000 years. Of note, the 20,000-year
40 frequency flood was the same size (by peak and 15-day volume) as the
41 appraisal-level PMF (Reclamation 2002).

1 A feasibility-level PMF hydrograph was developed by Reclamation for the dam
 2 raise feasibility-level design in January 2008 (Reclamation 2008a), with a peak
 3 inflow of 631,806 cfs and a 30-day volume of 6,245,905 acre-feet for a general
 4 storm on snow. The peak 15-day volume for the revised PMF was estimated to
 5 be 4,970,100 acre-feet. This corresponds closely with the appraisal-level PMF
 6 peak inflow, but is significantly greater in 15-day flood volume because of
 7 increased contributions from the Pit River Arm of the Shasta Lake drainage
 8 basin, and because of a generally larger (and longer duration) 100-year rain-on-
 9 snow antecedent flood. The Sacramento, McCloud, and lower Pit river
 10 subbasins would contribute the majority of the flow and would be responsible
 11 for the PMF peak inflow. The upper Pit River subbasins, with a total area of
 12 3,310 square miles, were shown to contribute only about 2 percent to the peak
 13 inflow and 7 percent to the flood volume.

14 A revised HHA was prepared for the 2008 *Comprehensive Facility Review of*
 15 *Shasta Dam* by scaling the frequency flood hydrographs from the revised PMF
 16 (Reclamation 2008c). Table 3-16 summarizes peak discharge and volume
 17 estimates for return periods between 100 and 20,000 years. The revised 20,000-
 18 year frequency flood has about the same inflow peak and 15-day volume as the
 19 revised (feasibility-level) PMF.

20 **Table 3-16. Revised Frequency Flood Peaks and Volumes, Shasta Dam**

Return Period (years)	Peak Discharge (cfs)	Flood Volume (acre-feet)				
		1-Day	3-Day	5-Day	7-Day	15-Day
100	259,134	471,474	1,051,291	1,382,661	2,091,844	3,344,938
200	300,152	546,344	1,181,525	1,479,017	2,232,652	3,529,297
500	358,657	653,186	1,399,982	1,720,821	2,442,971	3,789,612
1,000	406,375	740,373	1,577,562	1,921,799	2,619,760	3,999,925
2,000	457,260	833,383	1,766,161	2,140,084	2,811,839	4,222,543
5,000	529,664	965,787	2,033,887	2,448,206	3,088,838	4,536,346
10,000	588,534	1,073,488	2,250,234	2,696,538	3,314,482	4,789,570
20,000	631,800	1,152,666	2,409,440	2,878,272	3,479,689	4,974,552

Key:
 cfs = cubic feet per second

21 Flood routings were performed for both the existing and raised conditions, using
 22 an Excel spreadsheet to simulate the Emergency Spillway Release Diagram
 23 (ESRD) to properly limit discharges when the RWS is below the top of joint-
 24 use storage.
 25

26 **Borrow Areas/Sources**

27 Construction at Shasta Dam for the main concrete dam, right wing dam, left
 28 wing dam, spillway, river outlets, power outlets, TCD, and visitor center will
 29 require nearly 100,000 cubic yards of concrete, or between 150,000 and
 30 180,000 tons of sand and gravel, and between 20,000 and 25,000 tons of
 31 cementitious material (cement and pozzolan). Construction for the UPRR

1 railroad bridges and Pit River Bridge modification will require nearly 23,000
 2 cubic yards of concrete, or approximately 35,000 tons of sand and gravel, and
 3 approximately 6,000 tons of cementitious material. Construction for Lakeshore
 4 and Bridge Bay area embankments would need more than 300,000 cubic yards
 5 of core and homogenous fill, shell fill, riprap, filter, and drain materials.

6 **Potential Borrow Sources**

7 Multiple borrow sources are available to meet project needs for core and
 8 homogenous fill, shell fill, riprap, filter, and drain materials of the reservoir area
 9 embankments. Potential borrow sources were examined at a preliminary level
 10 and would need further sampling and testing to determine suitability and to
 11 refine quantity estimates. These borrow sources could include areas of the dike
 12 construction sites, areas located below the reservoir’s inundation zone, and
 13 commercial sources. Material availability would vary with market demand and
 14 production restrictions, but it is expected that sufficient concrete sand and
 15 gravel materials will be available when needed for construction. More details
 16 regarding potential local sand and gravel aggregate sources are contained in
 17 Reclamation’s *Shasta Dam Enlargement – Sand and Gravel Aggregate Sources*
 18 (2007d). For projects involving more than 100,000 cubic yards, Reclamation
 19 recommends locating five times the material required for construction when
 20 evaluating this project to ensure adequate fill materials (Reclamation 1987).

21 Potential borrow sources and fill materials available at these borrow sources are
 22 summarized in Table 3-17. Commercial sources are located within
 23 approximately 2 to 30 miles of the Bridge Bay site, and within approximately
 24 15 to 43 miles of the Lakeshore sites. Locations of potential reservoir area and
 25 commercial borrow sources are identified in Plate 25.

26 **Table 3-17. Summary of Potential Borrow Resources**

Borrow Sources	Core (cy)¹	Shell (cy)¹	Drain & Filter (cy)¹	Riprap (cy)¹
Shasta Dam Area	0	500,000	N/A	N/A
Lakeshore Drive Area	642,000	553,000	N/A	230,000
Bridge Bay Marina Area	N/A	674,000	N/A	200,000
Material Total	642,000	1,727,000	N/A	430,000

Note:

¹ Some of these volume estimates have not been field-verified by subsurface investigations.

Key:

cy = cubic yards

N/A = not available

27 The top 3 feet of material in all borrow areas are likely to contain organic
 28 matter, and be unsuitable for construction purposes. This surface material
 29

1 should be stockpiled and used to restore the sites after borrow activities are
2 completed. A 3-foot increment was subtracted from the estimated depths of
3 borrow materials to estimate volumes for all borrow areas.

4 Riprap material developed from moderately to slightly weathered basalt can be
5 quarried below a thin soil cover in most locations along the Lakeshore Drive
6 area. It is assumed that if a borrow area is selected for soil materials, this area
7 could also be quarried for the required riprap.

8 Clean sand required for the proposed filters and drains was not found in any of
9 the borrow locations investigated. Sand may possibly be produced from
10 crushing and processing the basalt. Further study is recommended to evaluate
11 the feasibility of crushing basalt into sand and gravel to construct drainage and
12 filter elements.

13 For additional details on potential borrow sources, please refer to Reclamation's
14 *Geology Report 2, Phase 1 Feasibility Geologic Report for Shasta Dam*
15 *Enlargement Project* (2009b).

16 ***Borrow Recommendations***

17 The borrow source evaluation was conducted as part of feasibility-level
18 analyses for the Shasta Dam and Reservoir enlargement project for the purpose
19 of feasibility-level design and planning. Note that the statements provided
20 herein are based on available information and not on field explorations or
21 laboratory testing.

22 Based on anticipated borrow requirements, and the initial assessment of
23 potential borrow sources, construction of the proposed Lakeshore and Bridge
24 Bay dikes is generally feasible with respect to the availability of construction
25 materials. Note, however, that the findings in this section are based on
26 feasibility-level analyses that may change as the project is developed. Design
27 changes and field investigations may encounter conditions that would modify
28 the evaluations and statements presented in this Engineering Summary
29 Appendix.

30 It is recommended that geotechnical investigations be conducted to evaluate
31 actual conditions present at the proposed borrow sites before final design of the
32 proposed project. Laboratory testing would be required during subsequent
33 phases of design to determine the actual physical and strength characteristics of
34 borrow materials.

35 **Geology/Geotechnical**

36 The following sections discuss the regional geology and seismicity of the
37 SLWRI study area.

1 **Regional Geology**

2 The regional geology of the area surrounding Shasta Dam is influenced by the
3 intersection of three tectonic plates, defined as a triple junction (Reclamation
4 2004b, 2007a). The Mendocino Triple Junction, composed of the Gorda, North
5 American, and Pacific plates, is one of the most seismically active regions of
6 the San Andreas transform system. Since 1983, the region has generated about
7 80 earthquakes with a magnitude of greater than or equal to 3.0 each year, and
8 historically the region has experienced major quakes. This activity is generated
9 in response to ongoing plate motions among the three plates of the Mendocino
10 Triple Junction, which lies approximately 100 miles east of Shasta Dam (USGS
11 2013). Three active fault zones make up the tectonic interaction. These faults
12 are the San Andreas Fault Zone, Cascadia Subduction Zone, and Mendocino
13 Fault Zone. Both the San Andreas and Mendocino faults are classified as
14 transform faults, or faults whose motion is normal along the fault trace. The
15 Cascadia Subduction Zone is the result of the Pacific plate being subducted
16 under the North American plate.

17 The interaction of the three plates of the Mendocino Triple Junction has created
18 varied surface geomorphology, resulting in five major geomorphic provinces in
19 the area of Northern California: the Klamath Mountain Range, Cascade
20 Mountain Range, Great Valley Sequence, Modoc Plateau, and Coastal
21 Mountain Range (Reclamation 2007a). Shasta Dam and Reservoir are located at
22 the southeastern edge of the Klamath Mountains geomorphic province.

23 The Klamath Mountains geomorphic province is formed from the
24 compressional and uplift forces of the volcanic arc and continental margin
25 sequence (Reclamation 2007a). Surface topography is rugged, with prominent
26 peaks and ridges reaching elevations 6,000 to 8,000. Throughout this
27 mountainous region are thrust faults; structure relates to low-grade
28 metamorphism. Rocks of the Klamath Mountains range in age from Ordovician
29 to late Jurassic, and consist of greywacke sandstones, greenstones, cherts,
30 limestone, and metamorphic equivalents of (the foregoing) rock types, and
31 abundant granitic intrusive and ultramafic sheets.

32 Geology and subsurface foundation conditions for proposed structure
33 modifications and new construction have been observed by Reclamation. A
34 subsurface investigation performed in 2009 by Reclamation included fifteen
35 boreholes 50 feet to 100 feet deep and fifteen test pits. These boreholes and test
36 pits were located in the Shasta Dam, Lakeshore Drive, and Bridge Bay Marina
37 areas to characterize subsurface foundation conditions within designated areas,
38 document geologic investigations, and identify and characterize borrow sources
39 (Reclamation 2009b). Known foundation conditions have been summarized on
40 a dike-by-dike basis in Chapter 4.

41 **Seismicity**

42 The closest active fault to Shasta Dam is the Battle Creek Fault, located
43 approximately 25 miles to the south. The Battle Creek Fault is a normal fault

1 with a length of 29 kilometers (km), a dip of 75 degrees, and a width of 11 km
2 (USGS 2002). The characteristic magnitude is 6.5, with a recurrence rate of 7.6
3 E-04/year and a slip rate of 0.5 millimeters (mm) per year.

4 Since 1973, 1,548 recorded earthquakes greater than magnitude 3.0 have
5 occurred within 200 km of Shasta Dam. This radius includes earthquakes
6 generated by activity in the Mendocino Triple Junction. When the search radius
7 is reduced to 100 km (excluding the Triple Junction), only 224 earthquakes
8 greater than magnitude 3.0 are found. The majority of earthquakes in this region
9 are magnitude 3.0 to 4.0. The largest earthquake near Shasta Dam occurred on
10 November 26, 1998, and was magnitude 5.4 (USGS 2013). This earthquake was
11 not located on the Battle Creek Fault.

12

1 Chapter 4
2 **Design Consideration for Reservoir Area**
3 **Infrastructure Modifications and/or**
4 **Relocations**

5 **Road Relocations**

6 As a result of the proposed Shasta Dam raise, existing reservoir area roads
7 inundated by the increase in full pool elevation would need to be removed
8 and/or relocated. The following sections discuss road relocation construction
9 activities, design criteria and estimated material quantities for each dam raise
10 alternative.

11 **Construction Activities**

12 Roadway construction activities would involve, but not be limited to,
13 demolition of existing roadways as required; clearing, grubbing, and site
14 preparation of work areas, as required; grading road alignments to meet finished
15 grades; placing road subgrade; paving operations; installing storm drain
16 culverts; constructing retaining wall systems; installing road appurtenances such
17 as guardrails; and performing construction-related traffic control.

18 Replacement roadways would be constructed by excavating the existing up-
19 grade slope to provide fill material for the embankment fill portion of road
20 construction; bench-excavating into the up-grade slope above the existing
21 roadway to establish the new road finished grade; building the new road on an
22 engineered fill embankment from imported borrow material; or building the
23 new road directly above the existing road on an engineered fill embankment
24 from imported borrow material. A road alignment may use either use a single
25 method of construction for the entire alignment, or use all four methods at
26 different locations along an alignment. A graphical representation of the typical
27 road replacement sections can be found in Plate 26.

28 Estimated work limits depend on the surrounding terrain, and vary from a
29 minimum of 5 feet to 30 feet wide, measured from the extent of earthwork.
30 Where the road would be constructed as an embankment fill against an existing
31 steep hillside, a 5-foot-wide minimum work area would be used. Where the
32 terrain beyond the limit of earthwork was flat enough to be used as work areas
33 for construction equipment, the work limits would range from 15 feet to 30 feet
34 wide.

1 **Design Criteria Basis**

2 Feasibility-level road replacement design criteria were established based on the
3 following documents:

- 4 • *A Policy on Geometric Design of Highways and Streets, American*
5 *Association of State Highway and Transportation Officials (AASHTO)*
6 *(1990).*
- 7 • *Shasta County Development Standards, Shasta County (1997).*

8 Research was conducted into the road design standards used by the U.S. Forest
9 Service (USFS). Some information was provided by USFS from Chapter 4 of
10 the USFS Road Preconstruction Handbook; however, no specific USFS
11 requirements pertaining to road materials, widths, and construction were
12 obtained. For this level of analysis, the criteria established below, based on
13 AASHTO and Shasta County standards, are sufficient. Further research into
14 USFS road requirements should be conducted before final design of roadways.
15 For additional design and specification information, see the *SLWRI Road*
16 *Relocations Technical Memorandum (Reclamation 2007g).*

17 **Road Design Criteria**

18 Criteria were established for four typical road replacement scenarios. (Table 4-1
19 presents the feasibility-level road design criteria. Graphical representation of the
20 typical road replacement sections can be found in Plate 26.)

21 Nearly all paved roadways to be replaced have a paved width of approximately
22 18 feet, 20 feet, or 24 feet; therefore, typical paved sections of those dimensions
23 were established. The design intent was to match road replacement widths with
24 those of the existing paved roads to be replaced. The thicknesses used for
25 asphaltic concrete (AC) and aggregate base (AB) are based on Shasta County
26 typical requirements. During final design of the road relocations, geotechnical
27 recommendations should be provided regarding actual AC and AB thicknesses
28 to be used for construction.

29

1

Table 4-1. Typical Road Replacement Scenarios

Criteria	24-foot-wide Paved Road	20-foot-wide Paved Road	18-foot-wide Paved Road	Unpaved Road (AB)
Paved Width	24 feet	20 feet	18 feet	Varies
Shoulder Width	4 feet	4 feet	2 feet	2 feet
Roadside V-Ditch	As required	As required	As required	As required
Cross Slope	3%	3%	3%	3%
AC Thickness	4 inches	3 inches	3 inches	N/A
AB Thickness	8 inches	8 inches	8 inches	8 inches
Traffic Index	6.0	5.0	4.5	N/A
Rolling Terrain Minimum Design Speed	40 mph	30 mph	20 mph	20 mph
Mountainous Terrain Minimum Design Speed	30 mph	20 mph	20 mph	20 mph
Maximum Grade	8%	8%	10%	10%
Minimum Horizontal Curve Radius	50 feet	50 feet	50 feet	50 feet
Minimum Right-of-Way	60 feet	50 feet	50 feet	50 feet
Minimum Freeboard (above elevation 1,090.20 (NAVD88))	3 feet	3 feet	3 feet	3 feet

Key:
 AB = aggregate base
 AC = asphaltic concrete
 mph = miles per hour
 NAVD88 = North American Vertical Datum of 1988
 N/A = not applicable

2

Unpaved roads requiring replacement vary in road width and in road material. Some unpaved roads have a gravel finished surface and others are earth with no finish material. For this analysis, it was assumed that all unpaved roads would be replaced with an 8-inch-thick AB section meeting the width of the existing road.

7

Guardrail would be placed in areas where the existing road has guardrail or in areas where conditions have a higher potential for vehicles to run off the road.

9

Culverts would be placed at low points, as required, based on the road relocation grading designs. In areas where feasible, low points would be filled with embankment fill rather than providing a culvert. The majority of existing culverts in the Shasta Lake area appear to be corrugated metal pipe (CMP); thus, this was the pipe material assumed for the analysis. Minimal analysis was conducted to establish the culvert diameters shown. Acreages of the upstream stormwater sheds were estimated, and a culvert diameter was assumed based on these areas. These culvert sizes should be used for feasibility-level cost estimating only. During final design of the road relocations, a complete hydrological analysis should be conducted to size all culverts for the established design storm.

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1 Properly graded riprap is commonly used to provide slope protection. Riprap
 2 would be placed on new embankment slopes that would be subject to wave
 3 erosion. Riprap would need to be placed in a manner that would provide a well-
 4 integrated mass with minimum void spaces. Generally, riprap consists of a
 5 uniform distribution of angular and durable gravel- to boulder-sized rock.

6 In areas where it would not be feasible to make steep hillside excavations or use
 7 embankment fill to establish the finished road grades, cast-in-place (CIP)
 8 concrete retaining walls, with spread footings, would be used. Wall dimensions
 9 are based on previous retaining wall designs. This detail should be used for
 10 feasibility-level cost estimating only. During final design, the need for retaining
 11 walls should be revisited and designed accordingly for construction.

12 The existing terrain around Shasta Lake varies from rolling to mountainous,
 13 depending on the specific area. Slopes of the existing hillside embankments
 14 typically range from as steep as 0.25:1 to as flat as 3:1. Slopes of the existing
 15 terrain were assessed at each road relocation area during the analysis. For this
 16 analysis, it was assumed that the steepest cut slope allowed would be 1:1 and
 17 the ideal cut slope would be 2:1. If an existing roadway cut slope appeared to be
 18 in good condition, it was assumed that the new road cut slopes in the same
 19 vicinity could safely match the existing conditions. The steepest fill slope
 20 permitted would be 1.5:1 and the ideal fill slope would be 2:1. Borrow material
 21 for road embankment construction would be derived from sources identified in
 22 Chapter 3.

23 **Estimated Quantities**

24 Feasibility-level quantities, based on the feasibility-level designs, have been
 25 generated for each road segment. It is estimated that approximately 4.1 miles of
 26 paved roadway and 2.3 miles of unpaved roadway would need to be constructed
 27 as a result of the new full pool water surface elevation for the 18.5-foot raise.
 28 Table 4-2 summarizes the estimated road relocation quantities and Table 4-3
 29 details the quantities by major road focus areas. Imported fill borrow areas
 30 would be similar to those outlined for dikes and embankments in Chapter 3.

31 **Table 4-2. Summary of Approximate Road Relocation Quantities for**
 32 **SLWRI Dam Raise Alternatives**

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Road Segments Affected	10	21	30
Length (lf)	17,400	29,000	33,800
Paved Area (sf)	322,900	542,600	630,300
Embankment Fill (cy)	259,400	396,500	424,100
Excavation (cy)	65,100	78,300	82,100

Key:
 lf = linear feet
 sf = square feet
 cy = cubic yards
 SLWRI = Shasta Lake Water Resources Investigation

Table 4-3. Approximate Road Relocation Quantities by Major Road Focus Area for SLWRI Dam Raise Alternatives

Road Relocation Features	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Lakeshore Drive			
Number of Road Segments Affected	4	6	8
Length (lf)	8,100	13,100	13,700
Clearing and Grubbing (acres)	4	7	7
Excavation to Embankment (cy)	46,100	55,100	55,500
Embankment Fill (cy)	95,900	145,900	149,300
Closure Expected	No	No	No
Turntable Bay Area			
Number of Road Segments Affected	3	3	3
Length (lf)	6,200	6,200	6,200
Clearing and Grubbing (acres)	2	2	2
Excavation to Embankment (cy)	19,000	19,100	19,000
Embankment Fill (cy)	71,500	71,500	71,500
Closure Expected	Yes	Yes	Yes
Gillman Road			
Number of Road Segments Affected	-	3	3
Length (lf)	-	1,200	1,200
Clearing and Grubbing (acres)	-	1	1
Excavation to Embankment (cy)	-	0	0
Embankment Fill (cy)	-	28,500	28,500
Closure Expected	-	Yes	Yes
Jones Valley and Silverthorn Area			
Number of Road Segments Affected	1	1	4
Length (lf)	2,000	2,000	3,600
Clearing and Grubbing (acres)	1	1	2
Excavation to Embankment (cy)	0	0	1,500
Embankment Fill (cy)	41,300	41,300	54,500
Closure Expected	Yes	Yes	Yes
Salt Creek Road			
Number of Road Segments Affected	-	4	5
Length (lf)	-	4,300	5,100
Clearing and Grubbing (acres)	-	1	1
Excavation to Embankment (cy)	-	4,100	5,500
Embankment Fill (cy)	-	34,600	34,600
Closure Expected	-	Yes	Yes
Remaining Road Relocations			
Number of Road Segments Affected	2	4	7
Length (lf)	230	2,300	3,900
Clearing and Grubbing (acres)	0.4	1	2
Excavation to Embankment (cy)	15	120	600
Embankment Fill (cy)	34,200	76,100	89,300
Closure Expected	No	No	No

Key:
 - = not applicable
 cy = cubic yards

lf = linear feet
 SLWRI = Shasta Lake Water Resources
 Investigation

Relocations for 6.5-foot and 12.5-foot Dam Raises

The analyses presented in this document were performed to support evaluations of the 18.5-foot dam raise. However, 6.5- and 12.5-foot dam raise scenarios are also under consideration. As a result of a 6.5- and 12.5-foot Shasta Dam raise, the new reservoir full pool elevations would be 1,078.2 (NAVD88) and 1,084.2 (NAVD88), respectively. Table 4-4 summarizes the road segments that would be inundated by the 18.5-foot dam raise, and continue to be inundated by 6.5- and 12.5-foot dam raises. It is estimated that approximately 1.5 miles of paved roadway and 0.8 miles of unpaved roadway would have to be constructed as a result of a 6.5-foot dam raise; 2.5 miles of paved roadway and 1.5 miles of unpaved roadway would have to be constructed as a result of a 12.5-foot dam raise.

Table 4-4. Impacts from 6.5-Foot and 12.5-Foot Dam Raises

Road Segment ID No.	Description	6.5-Foot Dam Raise Impact (Y or N)	12.5-Foot Dam Raise Impact (Y or N)
32	Unpaved road to waterfront	Y	Y
71	USFS Road 35N17–Conflict Point	N	N
76A	USFS Road 35N08–Lakeshore Drive	Y	Y
76B1	USFS Road 35N08–Lakeshore Drive	N	N
76B2	USFS Road 35N0–Lakeshore Drive	Y	Y
76C	USFS Road 35N08–Lakeshore Drive	N	N
77	USFS Road 35N17–Conflict Point	N	Y
81	USFS Road 35N08–Lakeshore Drive	Y	Y
93	Shasta County Road–Lakeshore Drive	Y	Y
99	Shasta County Road–Lakeshore Drive	N	Y
110	Shasta County Road–Lakeshore Drive	N	Y
109	USFS Road 35N14E–Antlers Road	N	N
34	USFS Road 34N09B–Lower Deck	Y	Y
39	USFS Road 34N09A–Shasta Yacht Club Road	Y	Y
96	USFS Road 35N60D–Hirz Road	N	Y
135	Shasta County Road 7H009–Gillman Road	N	Y
140	Shasta County Road 7H009–Gillman Road (McCloud River Bridge)	N	Y
141	Shasta County Road 7H009–Gillman Road (McCloud River Bridge)	N	Y
144	USFS Road 36N54–Bollibokka Club Road	N	N
174	USFS Road 34N09–Turntable Road	Y	Y
7	USFS Road 33N13–Jones Bay	Y	Y
9	USFS Road 33N86–Jones Valley	N	N
20	Shasta County Road 5J050–Silverthorn Road	N	N

1 **Table 4-4. Impacts from 6.5-Foot and 12.5-Foot Dam Raises (contd.)**

Road Segment ID No.	Description	6.5-Foot Dam Raise Impact (Y or N)	12.5-Foot Dam Raise Impact (Y or N)
21	Shasta County Road 5J050–Silverthorn Road	N	N
156	South Access Road–Pit River Bridge	Y	Y
41	USFS Road 35N03–Salt Creek Road	N	N
47A	USFS Road 35N03–Salt Creek Road	N	Y
47B	USFS Road 35N03–Salt Creek Road	N	Y
61	USFS Road 35N03–Salt Creek Road (Didallas Creek Bridge)	N	Y
62	USFS Road 35N03–Salt Creek Road (Didallas Creek Bridge)	N	Y

2
Key:
ID = identification
N = no
USFS = U.S. Forest Service
Y = yes

3 **Conclusions**

4 The major road and road segment feasibility-level designs presented in this
5 Engineering Summary Appendix are potential solutions to the inundation of
6 existing roads as a result of an 18.5-foot dam raise. As work continues toward a
7 more detailed design phase of these road modifications, it is recommended that
8 the following be considered and data be obtained:

- 9 • Further coordination must be conducted with USFS and Shasta County.
10 Consideration should be given to the need for some of the road
11 segments to be above the new full pool elevation.
- 12 • Further coordination must be conducted with UPRR regarding the
13 Lakeshore Drive relocation impacts on the existing and relocated
14 UPRR tracks in the Lakeshore area.
- 15 • A current topographical survey for each road segment area would need
16 to be conducted before final design.
- 17 • Geotechnical data and recommendations would need to be obtained
18 specific to each road segment area, including, but not limited to
19 clearing and site preparation, slope stability, excavation and shoring,
20 subgrade preparation, embankment fill materials, compaction criteria,
21 retaining wall earth pressures, and pavement sections.
- 22 • Additional design refinements and cost reduction ideas would need to
23 be evaluated and integrated, as appropriate.

1 **Bridge Relocations**

2 Raising Shasta Dam would affect nine bridges around the reservoir to varying
3 degrees. Some bridges would require complete removal and replacement, while
4 others would require protection of the piers from inundation. The bridges
5 affected by a dam raise were identified as vehicle bridges or railroad bridges.
6 Feasibility-level designs and costs were developed based on initial analyses
7 performed in previous SLWRI milestone reports.

8 **Vehicle Bridge Replacements**

9 As a result of raising Shasta Dam, the following local vehicle bridges would be
10 replaced:

- 11 • Charlie Creek Bridge
- 12 • Doney Creek Bridge
- 13 • McCloud River Bridge
- 14 • Didallas Creek Bridge

15 Advance planning studies were prepared for the four bridges listed above (refer
16 to Plates 27 through 30). The Second Creek Bridge, which was addressed in the
17 PFR, is not included in the above list because the relocated replacement
18 structure is anticipated to consist of a small culvert. Relocation costs for this
19 bridge are included in the road relocations cost estimates.

20 ***Design Criteria and Assumptions***

21 Criteria and assumptions considered in determining structure type and length for
22 the replacement structures included the following:

- 23 1. Structure type based on cost and constructability.
- 24 2. Superstructure depth based on depth-to-span ratios of 0.04 for CIP
25 prestressed concrete box girder structures, and .055 and 0.06 for
26 multispan and single-span CIP reinforced-concrete box girder
27 structures, respectively.
- 28 3. Four-foot minimum freeboard above full pool elevation 1,087.50 (18.5-
29 foot dam raise, NGVD29).
- 30 4. Approach fill height into the river/creek channel limited to
31 approximately 10 feet to minimize reduction of hydraulic opening.
- 32 5. Total bridge width of 31 feet, 6 inches, based on two 12-foot lanes with
33 2-foot shoulders (low volume road) and 1-foot, 9-inch barrier railing
34 widths.

- 1 6. Use of driven steel piles and sheet piling for foundations/falsework and
2 cofferdams, respectively.

3 **Bridge Replacement Summary**

4 Based on the above noted design criteria and assumptions, and considering
5 horizontal alignments and profile grades developed for the relocated roadways,
6 Table 4-5 summarizes proposed bridge characteristics for the four vehicle
7 bridges requiring replacement.

8 **Table 4-5. Vehicle Bridge Replacement Summary Table**

Bridge Name	Bridge Type	Bridge Length (feet)	Structure Depth (feet-inches)	Bridge Deck Profile Grade Elevation (feet)	Vertical Clearance (freeboard) Above Full Pool (feet)
Charlie Creek Bridge	CIP Prestressed Concrete Box Girder	782	10-0	1,102.0	4.5
Doney Creek Bridge	CIP Prestressed Concrete Box Girder	760	10-0	1,102.0	4.5
McCloud River Bridge	CIP Reinforced-Concrete Box Girder	490	8-3	1,100.25	4.5
Didallas Creek Bridge	CIP Reinforced-Concrete Box Girder	115	7-0	1,099.0	4.5

9 Key:
CIP = cast in place

10 **Construction Quantities**

11 Construction quantities for major items of work are summarized in Table 4-6.
12 Demolition of the four bridges would produce about 9,900 cubic yards of waste
13 material.

1

Table 4-6. Construction Quantities for Vehicle Bridge Construction

Item Description	Charlie Creek Bridge	Doney Creek Bridge	McCloud River Bridge	Didallas Creek Bridge
Demolished Material (cy)	3,500	3,300	2,300	800
Excavation (cy)	1,200	550	820	440
Backfill (cy)	480	400	530	180
Number of Piers	4	4	4	0
Pier Diameter (lf)	14	14	6	N/A
CIP Structural Concrete (cy)	3,530	3,320	2,320	760
Bar Reinforcing Steel (lbs)	1,124,000	1,006,000	757,000	208,000
Prestressing Steel (lbs)	26,000	25,000	N/A	N/A
Class 140 Piles (each)	24	24	24	24
Class 140 Piles (lf)	1,080	1,080	1,080	1,080
24-inch Cast-In-Steel-Shell Piles (each)	72	72	32	N/A
24-inch Cast-In-Steel-Shell Piles (lf)	3,600	3,600	1,600	N/A

Key:
 CIP = cast in place
 cy = cubic yard
 lbs = pounds
 lf = linear feet
 N/A = not applicable

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Construction Activities

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Most of construction would take place during the low-water season, and is expected to last about 12 months. The waterway would remain clear for navigation during construction. Bridge construction would begin with piers and abutments. To allow underwater construction of pier foundations, steel pile shells would be driven into the lake bed to create a temporary cofferdam. It may be necessary to dewater the shells during drilling if water seeps in. A hole would then be drilled to the specified foundation depth. Reinforcing steel would be installed within the shells before concrete was poured. After completion of the piers and abutments, construction of the superstructure and bridge deck would begin via the balanced cantilever method. This process entails forming and constructing the horizontal structure outward from the piers in each direction, in equal (balanced) proportions, until the superstructure/deck segments meet at midspan.

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Traffic would continue on the existing bridges during construction. It is likely that barges would be used extensively for bridge foundation construction, bridge assembly, transport of materials, workers, and equipment, and demolition of the existing bridges. Concrete would be poured from barges. A staging area would be required on the lakeshore, from which barges could be loaded and unloaded.

Fender's Ferry Bridge Modifications

The Fender's Ferry Bridge is a three-span structure comprising a steel plate girder superstructure supported on riveted steel tower bents and reinforced-concrete piers with spread footings. As a result of differences in West River and East River bank topography, the Pier 3 steel tower is supported at a much lower elevation than the Pier 2 tower. Thus, considering a full pool elevation of 1,087.50 (NGVD29), the Pier 3 steel tower would be inundated.

Proposed Modifications

A preliminary modification concept previously proposed consisted of constructing a concrete box extension to protect the existing steel tower (Reclamation 2004a). However, considering the narrow geometry of the concrete pier and steel tower, construction of a concrete box around the existing steel tower would preclude adequate future inspections and likely result in maintenance problems. Thus, it was recommended that the existing reinforced-concrete pier and footing be enlarged and extended, and the existing steel tower be modified to prevent inundation as a result of the higher joint-use pool level. Proposed modifications would include the following:

- Enlargement of the existing reinforced-concrete footing
- Enlargement and extension of the existing reinforced-concrete columns and pier wall to elevation 1,096.16 (NGVD29)
- Removal of approximately 24 feet of the lower portion of the Pier 3 steel tower (based on location of existing cross bracing)
- Reuse of the existing steel bearing assemblies

Construction activities would likely be completed from the existing embankment without the need to construct cofferdams around the pier because the average water surface elevations are below the existing Pier 3 bottom of footing elevation for all months, with the exception of April and May. Construction of temporary bents to support the superstructure would be necessary to facilitate construction of the pier modifications. During construction activities, temporary traffic controls may be needed to facilitate delivery of materials and construction of temporary support bents. Refer to Plate 31 for the Advance Planning Study illustrating the proposed modifications.

Construction Quantities

Construction quantities for major items of work are summarized in Table 4-7.

1

Table 4-7. Fender’s Ferry Bridge Construction Quantities

Item Description	Quantity
Excavation (cy)	75
Temporary Superstructure Support (lump sum)	1
Concrete Surface Preparation (sf)	2,150
Drill and Bond Dowels (each)	540
Structural Concrete (cy)	230
Bar Reinforcing Steel (lbs)	66,400
Removal of Portion of Existing Steel Tower (lump sum)	1
Structural Steel (lbs)	130
Lead Paint Containment (lump sum)	1

Key:
 cy = cubic yard
 lbs = pounds
 sf = square feet

2 **Union Pacific Railroad Bridge Replacements**

3 As a result of the raising of Shasta Dam, the following UPRR bridges would
 4 need modification or replacement:

- 5 • Pit River Bridge
- 6 • Sacramento River 2nd Crossing Bridge
- 7 • Doney Creek Railroad Bridge

8 ***Pit River Bridge Pier Modification***

9 The existing bridge was designed and built by Reclamation in 1938 as part of
 10 the relocated highway and railroad facilities required for the construction of
 11 Shasta Dam. The bridge is still owned by Reclamation. Plate 32 is a copy of the
 12 original design drawing showing the bridge plan, elevation, and sections. The
 13 bridge is a multipurpose structure, carrying both UPRR and Interstate 5 traffic.
 14 The bridge is both a steel-through truss and a deck truss. UPRR and Caltrans
 15 have joint operation and maintenance responsibility. The bridge main structure
 16 is approximately 2,754 feet long; including the approach spans, it is
 17 approximately 3,588 feet long. The new top of full pool elevation was set based
 18 on providing a minimum 4-foot freeboard below the existing Abutment
 19 2 bearing seat elevation.

20 The elevation at the top of existing Pier 3 concrete is 1,069.67 (NAVD88).
 21 (Note that the following elevations presented in this section are based on the
 22 NGVD29 datum). This elevation matches the existing top of joint-use (full
 23 pool) elevation of 1,069.67. The elevation at the top of existing Pier 4 concrete
 24 is 1,072.19, which is 2.52 feet above the existing top of joint-use (full pool)
 25 elevation. A new full pool elevation above the concrete on Pier 4 would
 26 inundate the existing bridge bearings and low-chord steel truss members.
 27 Elevations for the top of the bearing protection structure and major construction
 28 quantities for Pit River Bridge modifications under each proposed dam raise are

1 shown in Table 4-8. The remainder of the Pit River Bridge structure would not
 2 be affected by the proposed dam raise. To keep the existing steel bearings and
 3 lower portions of the steel truss members from being submerged, a watertight
 4 concrete tub structure would be required. This reinforced-concrete structure
 5 would be attached to the top of the existing concrete Piers 3 and 4, as shown in
 6 Plate 33. The structure footprint is rectangular and is approximately 151 feet
 7 long by 52.5 feet wide. From the edge of the existing pier, the interior base of
 8 the tub extends 8 feet and the side slopes approximately match the slope of the
 9 existing steel truss members. Structure thickness varies from 2 feet to 8 feet.
 10 The top of the concrete structure is set to be 4 feet above the new full pool
 11 elevation. Four-inch-diameter holes would be drilled through the existing
 12 concrete for installation of bundled No. 11 bars to anchor the structure to the
 13 existing pier.

14 **Table 4-8. Bearing Protection Structure Physical Features for SLWRI Dam**
 15 **Raise Alternatives**

Item	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Top of Bearing Protection Structure Elevation (feet) ¹	1082.2	1088.2	1094.2
Concrete (cy)	2,100	2,900	4,000
Reinforcing Steel (lbs)	618,000	876,000	1,200,000
Core Drilling (lf)	2,200	2,200	2,200

Notes:

¹ Bearing protection structure elevations are based on the North American Vertical Datum of 1988

Key:

cy = cubic yard

lbs = pounds

lf = linear feet

SLWRI = Shasta Lake Water Resources Investigation

16 **Piers 3 and 4 Protection Sump Pumps** Since the existing bridge
 17 superstructure and top of pier are exposed to the elements, a structure cover
 18 would not be required; however, sump pumps would be installed that would
 19 keep any water away from the bearings. The following assumptions have been
 20 made:
 21

- 22 • Existing highway drains would be redirected away from the sump
- 23 • 120-volt (V) alternating current would be available
- 24 • Telephone line would be available for the requested alarm system
- 25 • Railroad tracks would be built on open style supports that would allow
- 26 passage of water
- 27 • Two 2.5-by-2.5-foot sumps in the concrete would be provided

1 Two submersible sump pumps would be used to keep the water level in the new
2 concrete protective structure from rising near the bearings. Each pump would
3 discharge into 2-inch-diameter copper tubing, and the two lines would tee into a
4 2.5-inch-diameter line that would follow the slope upward to the discharge
5 point. Check valves and ball valves would prevent pumped water from draining
6 out of the line back into the sump, and would isolate the sump. Protective grates
7 would prevent large objects from entering the sump area. A high-water alarm
8 would be used to alert personnel someone if the pumps did not function
9 properly. An electrical engineer would provide power and alarm designs. Brief
10 research showed a 2006 peak rainfall in Redding, California, of 5 inches per
11 hour. The pumps were sized for this peak level even though the tub structure
12 would be partially covered because winds and other drainage problems could
13 cause larger amounts of water to enter the sump. It was assumed that the current
14 bridge drains would be redirected to discharge outside the protective structure.
15 If the bridge drains cannot be redirected, larger pumps may be needed.

16 More details regarding Pit River Bridge modification designs are contained in
17 Reclamation *Technical Memorandum No. SHA-8140-FEAS-2007-1* (2007j).

18 ***Union Pacific Railroad Bridges***

19 The existing Sacramento River 2nd Crossing and Doney Creek railroad bridges
20 were designed and built by Reclamation, and are operated and maintained by
21 UPRR. The bridge superstructures consist of deck truss bridges with a single
22 track, and the piers and abutments were designed to accommodate a future
23 parallel single-track superstructure. Portions of both bridges would be
24 submerged for any reservoir raise and would need to be replaced with new
25 higher superstructures. Structural analyses of the existing bridge piers under
26 design earthquake loads indicated that new bridge piers would be required.
27 Minimal changes would be required for the railroad vertical alignment. The
28 feasibility-level designs would permit uninterrupted rail service during
29 construction.

30 For this feasibility study, the bridge superstructures and substructures were
31 designed to accommodate a single track according to the American Railway
32 Engineering and Maintenance of Way (AREMA) code (2007). The UPRR
33 office in Omaha, Nebraska, indicated a preference for a deck girder
34 superstructure rather than a through-truss or girder for both replacement
35 bridges. The proposed new bridge superstructure would be a composite
36 superstructure consisting of steel plate girders and a reinforced concrete deck. In
37 general, the bridge superstructures would be designed to be continuous over the
38 piers. However, with a requirement for 16 feet of vertical clearance underneath
39 Span 2 for the Sacramento River 2nd Crossing Bridge, with a minimum width of
40 30 feet, to allow for the passage of houseboats, Span 2 is a simply supported
41 span. No minimum clearance for houseboat traffic would be required for the
42 Doney Creek railroad bridge. Large-diameter concrete columns with drilled
43 shafts would support the superstructure and be founded on bedrock. The
44 Sacramento River 2nd Crossing railroad bridge would require nine spans with a

1 total length of 982 feet between concrete abutments (see Plates 34 and 35). The
 2 Doney Creek railroad bridge would require five spans with a total length of
 3 537.5 feet between concrete abutments (see Plates 36 and 37). Construction
 4 quantities for major items of work for these features are summarized in Table
 5 4-9.

6 **Table 4-9. Railroad Bridge Construction Quantities**

Item	Sacramento River 2 nd Crossing Bridge Quantities	Doney Creek Bridge Quantities
Steel Truss Bridge Removal (lbs)	3,300,000	2,000,000
Concrete Removal (cy)	15,310	4,570
Excavation (cy)	2,100	630
Backfill (cy)	1,900	2,200
Concrete , including Shafts (cy)	11,700	7,080
Reinforcing Steel (lbs)	3,420,000	1,760,000
Drilled Shafts, 6-foot diameter (lf)	130	230
Drilled Shafts, 8-foot diameter (lf)	110	N/A
Drilled Shafts, 12-foot diameter (lf)	120	N/A
Drilled Shafts, 14-foot diameter (lf)	N/A	416
Drilled Shafts, 16-foot diameter (lf)	280	N/A
Structural Steel in Girders (lbs)	4,750,000	2,250,000

Key:

cy = cubic yard

lbs = pounds

lf = linear feet

N/A = not applicable

7 More details regarding the Union Pacific Railroad Bridge designs are contained
 8 in Reclamation *Technical Memorandum No. SHA-8140-FEAS-2007-1* (2007j).

9 The proposed relocation of the railroad bridges would require realigning the
 10 railroad tracks between the two bridges. This realignment would parallel the
 11 existing tracks with a 25-foot offset to the east. Proposed horizontal and vertical
 12 alignments for the new railroad tracks between the two new railroad bridges are
 13 shown in Plate 38. Construction quantities for major items of work for the
 14 railroad realignment between the UPRR bridges are summarized in Table 4-10.
 15

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Table 4-10. Railroad Realignment Construction Quantities

Item	Railroad Realignment Between Bridges
Length of Track Realignment (lf)	8,400
Removal of Existing Railroad Track (tons)	370
Ballast Removal (tons)	6,400
Excavation (cy)	35,000
Compacted Backfill (cy)	7,500
Railroad Track (tons)	390
Concrete Railroad Ties (each)	4,200
Ballast (tons)	26,500

Key:
cy = cubic yard
lf = linear feet

2 Utilities and Miscellaneous Minor Infrastructure

3 As a result of the proposed Shasta Dam raise, existing infrastructure inundated
4 by the increase in full pool elevation would need to be removed and/or
5 relocated. The following sections discuss existing reservoir area utilities, design
6 criteria, and relocations approach.

7 Existing Utilities and Minor Infrastructure Description

8 As previously stated, infrastructure was inventoried around the perimeter of the
9 reservoir that would be impacted by the proposed 18.5-foot dam raise
10 (Reclamation 2003a, 2007i). This 18.5-foot dam raise corresponds to a 20.5-
11 foot raise in the full pool because of associated modifications in operation of the
12 dam (new full pool elevation 1,090.2, NAVD88). The identified inventory items
13 included bridges, buildings, dams, gas/petroleum facilities, hazardous materials,
14 miscellaneous objects, parking areas, power towers, railroads, and roads. Also
15 on the inventory are potable water, power distribution, telecommunication, and
16 wastewater facilities.

17 A majority of the infrastructure adjacent to Shasta Reservoir is located along the
18 Interstate 5 corridor (see Plates 1 and 2). The largest potentially impacted
19 residential developments near the reservoir are in the Lakeshore and Sugarloaf
20 areas in the northern part of the Sacramento River arm (see Plate 2). The main
21 facilities in the Pit River arm are at Bridge Bay Marina and in the Jones Valley
22 and Silverthorn areas. The upper Pit River arm is very remote; the only
23 significant infrastructure is the Fender Ferry Bridge and Pit 7 Dam at the
24 upstream end. Main development along the McCloud River arm includes
25 several USFS campgrounds and a marina, the Bollibokka Club, and some
26 summer-use cabins. The Squaw Creek Arm has the least infrastructure, with the
27 old Bully Hill Mine and a few cabins.

1 Only impacts to gas/petroleum, potable water, power distribution,
2 telecommunications, and wastewater facilities will be discussed in this
3 Engineering Summary Appendix; other types of facilities may be listed in the
4 tables for completeness but are not discussed in detail. Following is a
5 description of existing facilities and a discussion of their distribution around the
6 perimeter of the lake.

7 ***Gas/Petroleum Facilities***

8 The inventory concluded that no natural gas facilities are present in the
9 inventory area (Reclamation 2007i). Home heating and cooking gas used in the
10 area are exclusively propane. Propane tanks for homes and businesses were not
11 included in the inventory because they are portable and also may be leased. The
12 gas/petroleum facilities that were identified were primarily gasoline and diesel
13 fuel storage tanks. The majority of the tanks were used to store fuel for boats.
14 The tanks varied in size from approximately 1,000 gallons to 4,000 gallons.

15 ***Potable Water Facilities***

16 Potable water is provided in one of three ways in the inventory area: (1) water
17 may be provided by Shasta County through county service areas (CSA); (2) by
18 mutual water companies; (3) by individual residence or group wells. The two
19 CSAs in the inventory area are CSA 2, which operates in the Sugarloaf
20 community, and CSA 6, which provides water to the Silverthorn summer
21 homes. Mutual water companies are cooperative or mutual associations that
22 furnish water to a resort or development. Fifteen mutual water companies were
23 identified in the inventory area. Wells serving groups of homes or resorts were
24 also identified in the inventory (Reclamation 2007h). Individual homes or
25 businesses that were not confirmed to be associated with CSAs, mutual water
26 companies, or group wells were assumed to have an individual well.

27 ***Power Distribution Facilities***

28 All electric power service in the inventory area is provided by PG&E. Power
29 lines are typically routed overhead on poles or towers, although a portion of the
30 lines serving individual businesses, homes, and cabins is routed underground.
31 Power lines are also frequently attached to bridges when routed over rivers and
32 lake inlets. Voltage of local distribution lines is typically 12 kilovolts (kV)
33 while the voltage of high-voltage transmission lines is typically 60 kV to 230
34 kV. Service to individual homes and businesses is typically 120 to 480V.

35 ***Telecommunications Facilities***

36 Telecommunication services in the inventory area are primarily provided by
37 American Telephone and Telegraph (AT&T). Qwest Communications was
38 listed with AT&T on one line but the continued ownership was not confirmed.
39 One cable television operator, DCA Cable, was reported to have facilities in the
40 inventory area but this was not confirmed and these facilities were not located.
41 Telecommunication lines in the area are either copper wire or fiber optic cable,
42 which, similar to power lines, may be overhead, underground, or attached to
43 bridges. It should be noted that no cell phone towers were identified in the

1 inventory area (Reclamation 2007h). Also, AT&T confirmed that there were no
2 transcontinental fiber-optic lines in the inventory area.

3 **Wastewater Facilities**

4 No large wastewater collection or treatment systems are located in the inventory
5 area. Wastewater treatment is accomplished using septic tank/leach field
6 systems or vault/pit toilets. At several larger resorts, three to five cabins or
7 buildings were routed to a single septic system. In all other cases, individual
8 homes, cabins, or businesses were routed to individual septic systems.
9 Campgrounds and public restrooms were either septic tank/leach field systems
10 or vault/pit toilets (Reclamation 2007h).

11 **Design Criteria**

12 The following sections discuss the demolition and design criteria for relocated
13 utilities and minor infrastructure within the SLWRI study area.

14 **Demolition Criteria for Existing Utilities and Minor Infrastructure**

15 A set of criteria was established for each category of utilities to determine
16 whether or not the utilities would need to be demolished.

17 **Buildings**

18 Knowledge of the relocation status of all potentially impacted buildings is
19 critical to accurately assessing the extents of utilities and minor infrastructure
20 that would require removal or relocation. In addition, an accurate accounting of
21 the extent of relocated utilities and minor infrastructure cannot be determined
22 unless the ultimate location of the relocated buildings is known.

23 *Demolition Criteria*

24 Nonrecreation Structures Under all proposed dam raise alternatives,
25 nonrecreational residential and commercial structures affected by inundation
26 would require demolition. Any structure that is inundated or within 3 vertical
27 feet of the inundation line would be demolished along with its associated
28 utilities unless otherwise specified. Demolished residences would not be
29 relocated. Table 4-11 shows the total volume of demolished material for
30 nonrecreational structures by each dam raise alternative.

31 **Table 4-11. Nonrecreation Structures Demolition Quantities for SLWRI**
32 **Dam Raise Alternatives**

Demolition	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Structure Demolition (square feet)	8,700	21,500	27,000
Total Volume of Material (cubic yards)	1,300	3,200	4,000

Key:

SLWRI = Shasta Lake Water Resources Investigation

1 *Recreation Structures* Any recreation building that is inundated or within
2 3 vertical feet of the inundation line would be demolished along with its
3 associated utilities. All demolished recreation buildings and their associated
4 facilities would be relocated, with the exception of recreation facilities that
5 would be abandoned. More detail on these requirements is discussed in a later
6 section, “Recreation Facilities.”

7 *Demolition Practices* If buildings are inundated, structures would be
8 demolished by appropriately licensed contractors. All utilities would be
9 disconnected, capped, and/or removed per permit requirements and governing
10 utility standards. The structure and foundation would then be demolished.
11 Asbestos material, if discovered, would be removed and taken to an approved
12 landfill for disposal per permit requirements. General demolition waste would
13 also be removed and trucked to an approved landfill.

14 A typical structure demolition crew would include an excavator with operator, a
15 50- to 70-yard end-dump truck with operator, a bobcat or similar small front-
16 loader with operator, and two laborers. A typical house would reduce to about 3
17 to 4 feet high (5 to 6 feet for two-story houses) of fluffed material within the
18 foundation footprint. Typical foundation construction is assumed to be a
19 concrete stem wall around the perimeter of a structure with an overall height of
20 5 feet and thickness of 1 foot. Costs associated with nonrecreation structures
21 demolition are included as part of the utilities and miscellaneous minor
22 infrastructure cost estimate discussed in Chapter 5. Costs associated with
23 recreation structures demolition are included as part of recreation facilities cost
24 estimate also discussed in Chapter 5.

25 All structures subject to demolition must file a Demolition Declaration with the
26 Shasta County Department of Resource Management’s Building Division,
27 pursuant to Section 19827.5 of the State Health and Safety code. Structure
28 demolitions associated with this public project would require filing an Asbestos
29 National Emission Standards for Hazardous Air Pollutants (NESHAP)
30 Notification of Demolition and Renovation. An asbestos survey must be
31 completed by a licensed and appropriately registered contractor, and the
32 completed Asbestos NESHAP Notification must be sent to the U.S.
33 Environmental Protection Agency (EPA). Any asbestos abatement would be as
34 required by the agency. A copy of the Asbestos NESHAP Notification must be
35 attached to the Demolition Declaration filed with Shasta County.

36 Grading or excavating activities associated with the structure demolitions for
37 public works projects are typically exempt from the Shasta County Department
38 of Resource Management’s Environmental Health Division (EHD) Grading
39 Permit under Shasta County Code 12.12.050. An Application for Grading
40 Permit, however, must be filed with EHD to indicate the exemption.

1 **Septic Systems**

2 *Demolition Criteria* The Shasta County Development Standards state the
3 following (Shasta County 1997):

4 *Disposal area shall not include:*

5 *Land closer than 200 feet to a lake or reservoir, measured from*
6 *the high water line or 100 feet if down slope from the lake or*
7 *reservoir.*

8 These criteria would be applied to the septic system demolition criteria,
9 indicating that septic systems within 200 feet of the new full pool waterline or
10 100 feet downslope of the new full pool waterline would be demolished.

11 *Demolition Practices*

12 *Wastewater Pipes* Abandon in place wastewater pipes 6 inches in
13 diameter and smaller. Fill pipes larger than 6 inches with sand and abandon in
14 place per Shasta County Public Works Department requirements (Shasta
15 County 1997).

16 *Septic System and Vaults/Pits* Pump out septic tank, fill with sand, and
17 abandon in place per Shasta County Environmental Health Division
18 requirements (Shasta County 1997). Pump out vaults/pits, fill with sand, and
19 abandon in place. Abandon leach fields in place. Demolish associated restroom
20 building and contents and take to an approved landfill. A Shasta County permit
21 is required.

22 **Water System**

23 *Demolition Criteria* The water systems affected by the inundation line consist
24 of either wells or waterlines.

25 *Wells* Several wells do not fall within the inundation line but are close to
26 the shoreline at the new full pool. If these wells appear to be associated with
27 buildings that would be demolished, they would also be demolished. If these
28 wells are associated with a water system or with buildings that would not be
29 demolished, they would remain in place.

30 *Waterlines* Waterlines that would be relocated would be moved to a
31 minimum of 20 feet from the shoreline at the new full pool. Several waterlines
32 do not fall within the inundation line but are close to the shoreline at the new
33 full pool and are located at a depth below the water level. These water lines
34 would remain in place.

35 *Demolition Practices*

36 *Water Pipes* Abandon in place water pipes 6 inches in diameter and
37 smaller. Fill pipes larger than 6 inches with sand and abandon in place per
38 Shasta County Public Works Department requirements (Shasta County 1997).

1 *Wells* Fill wells with sand and abandon in place per Shasta County
2 Environmental Health Division requirements (Shasta County 1997). A Shasta
3 County permit is required.

4 *Pump/Lift Station* Demolish building and contents and take to an
5 approved landfill. Abandon associated underground piping in place. Reseed
6 area.

7 **Power and Telecommunication Facilities**

8 *Demolition Criteria* Most power lines and telecommunication lines are along
9 the same alignment because they typically use the same power pole. The
10 majority of the power lines and telecommunication lines are overhead with a
11 few underground lines.

12 Any low-voltage power lines, telecommunication lines, or power poles that are
13 inundated or within 50 feet from the new full pool elevation would be relocated
14 a minimum of 50 feet from the new full pool elevation.

15 Any high-voltage power lines or power towers that are inundated or within 100
16 feet from the new full pool elevation would be relocated a minimum of 100 feet
17 from the new full pool elevation.

18 *Demolition Practices*

19 *Power and Telecommunication Lines* Demolish power and
20 telecommunication lines in accordance with the National Electrical Safety Code
21 (NESC) and California Public Utilities Commission General Order 95
22 (CPUC-GO 95) requirements. Remove all poles and wires and dispose of at an
23 approved landfill. Excavate and remove connection point to underground wires
24 to 30 inches below grade and abandon remaining underground wires in place.

25 **Gas/Petroleum Facilities and Miscellaneous Objects**

26 *Demolition Criteria* Demolish and relocate any gas/petroleum facilities and/or
27 miscellaneous objects that are inundated.

28 *Demolition Practices*

29 *Fuel Tanks* Excavate and remove existing underground tanks and all
30 associated piping. Perform hazardous material testing and removal, as required,
31 in accordance with Title 23 of the California Code of Regulations, Division 3,
32 Chapter 16, Underground Tank Regulations (State of California 2005), and in
33 accordance with Shasta County Environmental Health Division requirements
34 (Shasta County 1997). A Shasta County permit is required.

35 **Design Criteria and Assumptions for Relocated Utilities and Minor 36 Infrastructure**

37 Facilities to be relocated would be designed and constructed in accordance with
38 all applicable Federal, State, and local codes and requirements. Demolished
39 facilities would not be reused to construct relocated facilities. Relocated

1 facilities would be of the same types, sizes, and materials as the existing
2 facilities to be replaced, where in compliance with applicable codes and
3 requirements. Additional criteria for specific facilities are discussed in the
4 following sections.

5 **Gas/Petroleum Facilities** Relocated fuel storage tanks would be designed and
6 constructed in accordance with Title 23 of the California Code of Regulations,
7 Division 3, Chapter 16, Underground Tank Regulations (State of California
8 2005); the Uniform Fire Code (NFPA 2006); California Air Resources Board,
9 Shasta County Development Standards, Section 6.7, and Shasta County
10 Environmental Health Division requirements (Shasta County 1997).

11 **Potable Water Facilities** Relocated potable water facilities would be designed
12 and constructed in accordance with Shasta County Development Standards,
13 Chapter 7, and the following:

- 14 • Relocated wells would acquire and would meet conditions of a Shasta
15 County Environmental Health Division Well permit.
- 16 • For cost estimating purposes, wells would be assumed to be 200 feet
17 deep and produce 15 gallons per minute (gpm).
- 18 • Water main piping smaller than 4 inches in diameter would be
19 American Society for Testing and Materials (ASTM) 1785 Schedule 40
20 PVC. Water main piping 4 inches in diameter and larger would be PVC
21 – American Water Works Association (AWWA) C900, Class 150,
22 standard dimension ratio (SDR) 18, or Ductile Iron – AWWA C151,
23 Class 51 or 50.
- 24 • Water main piping serving fire hydrants would be a minimum of 6
25 inches in diameter, or as required.
- 26 • Water main piping serving only service connections would be a
27 minimum of 2 inches in diameter, or as required.
- 28 • Individual service connections are assumed to be 0.75-inch- or 1-inch-
29 diameter pipe.
- 30 • Blowoffs would be provided at all low points and on any main with
31 dead-ends more than 10 feet past a fire hydrant.
- 32 • Combination air valves would be installed on all high points. Valves
33 would be a minimum of 1 inch in diameter or as required.
- 34 • Minimum depth of cover would be 3 feet for water mains.

1 **Power Distribution Facilities** All safety and operational requirements for
2 relocated power lines would comply with NESC and CPUC-GO 95 regulations.
3 Underground lines would have a minimum of 30 inches of cover.

4 **Telecommunications Facilities** All safety and operational requirements for
5 relocated telecommunication lines would comply with NESC and CPUC-GO 95
6 regulations. Underground lines would have a minimum of 30 inches of cover.

7 **Wastewater Facilities** Relocated wastewater facilities would be designed and
8 constructed in accordance with Shasta County Development Standards, Chapter
9 5 (Shasta County 1997), and the following:

- 10 • Relocated septic systems would acquire and meet conditions of a
11 Shasta County Environmental Health Division Sewage Disposal
12 System Permit.
- 13 • For cost estimating purposes, septic tanks would be assumed to have an
14 1,100-gallon capacity, and leach fields would be assumed to be 100 feet
15 long and 3 feet deep by 3 feet wide. Septic tanks would have a
16 minimum of two compartments.
- 17 • Pipe would be PVC ASTM 3034, SDR 35 with Ring-Tite or Fluid-Tite
18 joints, and would be a minimum of 6 inches in diameter, or as required.

19 **General Facility Relocations Approach**

20 The following sections discuss the general facility demolition and design
21 criteria for relocated utilities and minor infrastructure within the SLWRI study
22 area. Relocation quantities of utilities and minor infrastructure are shown for
23 each proposed dam raise in Table 4-12.

1
 2

Table 4-12. Utilities and Minor Infrastructure Relocation Quantities for SLWRI Dam Raise Alternatives

Utility Type	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Potable Water Facilities			
Length of Waterlines Relocated (lf)	7,200	8,500	11,000
Wells/Tanks Relocated (number)	12	13	10
Pump Stations Relocated (number)	2	2	3
Length of Waterline Demolished (lf)	8,900	11,200	14,800
Wells/Tanks Demolished (number)	16	28	25
Pump Stations Demolished (number)	2	2	3
Gas/Petroleum Facilities			
Tanks Relocated (number)	7	10	10
Tanks Demolished (number)	7	10	10

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Table 4-12. Utilities and Minor Infrastructure Relocation Quantities for SLWRI Dam Raise Alternatives (contd.)

Utility Type	Dam Raise Alternatives		
	6.5 feet	12.5 feet	18.5 feet
Wastewater Facilities			
Septic Systems Relocated ¹ (number)	14	19	19
Vault/Pit Toilets Relocated (number)	2	2	2
Pump Stations Relocated (number)	1	1	1
Length of Wastewater Pipe Relocated (lf)	400	400	430
Septic Systems Demolished ² (number)	211	239	266
Vault/Pit Toilets Demolished (number)	2	2	2
Pump Stations Demolished (number)	2	2	2
Length of Wastewater Pipe Demolished (lf)	2,300	2,300	2,400
Package Wastewater Treatment Plants ³ (number)	Up to 6	Up to 6	Up to 6
Power Distribution Facilities			
Power Lines Relocated (lf)	30,300	36,300	37,800
Power Towers Relocated (number)	6	6	6
Power Lines Demolished (lf)	26,400	33,700	36,200
Power Towers Demolished (number)	6	6	6
Telecommunications			
Copper Wire Relocated (lf)	27,900	30,200	33,400
Fiber-Optic Cable Relocated (lf)	4,300	5,800	5,800
Copper Wire Demolished (lf)	23,600	27,800	31,200
Fiber-Optic Cable Demolished (lf)	3,600	5,200	5,200

Note:

¹ Does not include septic systems replaced with new sewer connections.

² Includes demolition of septic systems to be relocated, replaced with new sewer connections, and removed without relocation or replacement.

³ Includes additional lift stations, force main, laterals, and holding tank pumps/valves not shown.

Key:

lf = linear feet

SLWRI = Shasta Lake Water Resources Investigation

3

Fuel Storage Tanks

4
5
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Relocated fuel tanks would be designed and constructed in accordance with Title 23 of the California Code of Regulations, Division 3, Chapter 16, Underground Tank Regulations (State of California 2005); Uniform Fire Code (NFPA 2006); California Air Resources Board; Shasta County Development Standards, Section 6.7; and Shasta County Environmental Health Division

1 requirements, as noted in Section C (Shasta County 1997). The tanks would be
2 located in cleared areas with code-mandated clearances from other facilities.
3 For reference, 4,000-gallon capacity tanks may be assumed to be approximately
4 8 feet in diameter and 15 feet long.

5 **Potable Water and Wastewater Piping**

6 Relocated piping for potable water and wastewater facilities would follow the
7 design criteria previously described and would typically be located within
8 established roadways consistent with Shasta County Development Standards
9 (Shasta County 1997). Pipe trench sections would meet Shasta County
10 Development Standards (Shasta County 1997). Typical construction
11 characteristics for potable water and wastewater piping are also described in the
12 *SLWRI Utilities and Miscellaneous Minor Infrastructure Technical*
13 *Memorandum* (Reclamation 2007h).

14 **Potable Water Wells**

15 Potable water wells would be designed and constructed per Shasta County
16 Environmental Health Division requirements (Shasta County 1997). Wells
17 would be sited with the required separation from septic systems, would be
18 drilled to an approximate depth of 200 feet, and would have a capacity of
19 approximately 15 gpm. The actual depth and capacities of specific wells would
20 depend on groundwater table elevation and soil permeability characteristics at
21 the particular site. Residential wells would typically include a bladder tank and
22 a small well pump.

23 **Wastewater Treatment Facilities**

24 An expanded discussion of the approach and methodology for relocation of
25 wastewater treatment facilities is presented below.

26 **General Considerations** With the proposed full pool water surface raised
27 approximately 20.5 feet to elevation 1,090.2 (NAVD88), a number of
28 wastewater facilities, primarily septic systems, would be directly inundated. In
29 addition, some existing septic systems would no longer meet Shasta County
30 Environmental Health Division requirements for separation from the lake
31 (Shasta County 1997). This is significant because homes and businesses without
32 permitted septic systems cannot be occupied and would require abandonment
33 and demolition.

34 The approach to relocation of wastewater treatment facilities in the project area
35 is to either construct new septic systems on the property of an impacted home,
36 where feasible, or to define a possible wastewater treatment plant alternative to
37 abandoning homes that do not meet Shasta County requirements for septic
38 system separation from the lake. New septic systems would be constructed per
39 Shasta County Development Standards (Shasta County 1997). Tanks would
40 have two compartments and would be approximately 11 feet long, 5 feet high,
41 and 5 feet wide, and buried with about 3 feet of cover. Leach fields would
42 typically be 100 feet long and 3 feet wide by 3 feet deep. The actual size of

1 specific septic tanks and leach field systems would depend on the size of the
2 homes or businesses and the percolation characteristics of soils in the leach field
3 area.

4 The locations where the possible wastewater treatment plant approach would be
5 implemented are described in Section E of the *SLWRI Utilities and*
6 *Miscellaneous Minor Infrastructure Technical Memorandum* (Reclamation
7 2007h). The general wastewater treatment plant concept includes a pressurized
8 sewer collection system to transport wastewater flows to a number of
9 centralized package wastewater treatment plants.

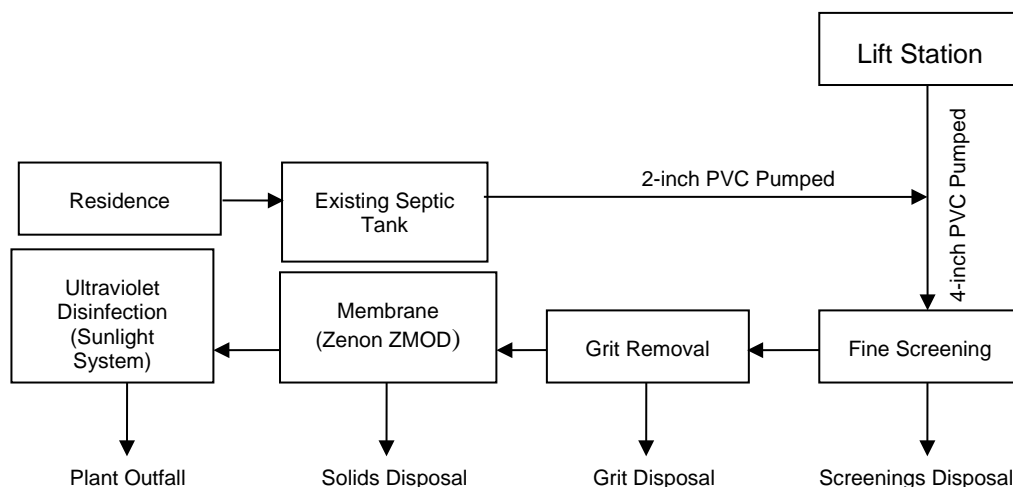
10 **Plant Siting Considerations** The following discussion defines wastewater
11 treatment plant siting considerations, one package wastewater treatment plant
12 alternative, other possible alternatives, and various assumptions that were made.
13 Treatment plant siting is generally based on the following factors:

- 14 • Distance from the effluent discharge location. Locations as close to the
15 effluent discharge location as possible are desirable.
- 16 • Treatment plant equipment layout (size of lot needed).
- 17 • Method of wastewater collection (gravity versus pumped). Maximizing
18 gravity flows to minimize the pumping requirements is desirable.
- 19 • Environmental impacts to the potential site. Environmental impacts to
20 the receiving water body, especially how the water quality management
21 plan of the area is affected.
- 22 • Availability of power and other utilities.
- 23 • Accessibility to roads.
- 24 • Flooding potential and earthquake fault locations.
- 25 • Construction costs of building at a particular site.
- 26 • Site maintenance, including parking.
- 27 • Operator safety and neighborhood safety.

28 Specific plant siting issues applicable to the proposed project are described in
29 this paragraph. It is generally assumed that most of the wastewater collection
30 system (including individual laterals to homes) would need to be pumped
31 because of the mountainous terrain and the likelihood that few sites suitable for
32 pump stations or wastewater treatment facilities are located near Shasta
33 Reservoir. If suitable sites are available near Shasta Reservoir, this would
34 decrease pumping costs. No attempt has been made to evaluate the water quality
35 impacts of wastewater treatment effluent discharge to Shasta Reservoir.

1 Odor control is another important factor to consider for plant siting. Odors from
2 the wastewater facilities have the potential to affect nearby residents. Buffer
3 zones are often used to deal with this problem. A buffer zone is a defined
4 distance from wastewater facilities to the closest neighbor. This distance is
5 determined by performing odor studies that take into account an odor source
6 and strength, meteorological/dispersion conditions, and type of surrounding
7 development. Buffer zones can be as large as 1,500 feet. Physical/mechanical
8 methods may also be used to control odors. These methods would typically
9 include carbon air filters combined with air blowers. If no physical/mechanical
10 odor control is included in wastewater treatment design, this will increase the
11 land area required. The approximate amount of land area required for each of
12 the assumed treatment plants is about 0.25 acres. If a 1,500-foot-wide buffer
13 zone were required, this area would increase to about 40 acres.

14 **Wastewater Treatment Process** The wastewater treatment process assumed
15 in the current analysis is shown in Figure 4-1.



16
17 **Figure 4-1. Wastewater Treatment Process Flow Schematic**

18 The wastewater treatment process shown in Figure 4-1 is described in this
19 paragraph. It is assumed in the proposed plan that the existing septic tanks at
20 each residence can be reused. The tank discharge pipe to the disposal field
21 would be capped off and the disposal field would become inactive. Sewage
22 ejector pumps would be installed in each septic tank and the contents of the
23 septic tank would be pumped via a 2-inch PVC line into a 4-inch PVC force
24 main (pressurized sewer line). The 4-inch PVC force main for each system is
25 assumed to be a common collection force main that would be installed in the
26 existing roadways. It is assumed that lift stations would be required to pump all
27 wastewater because of the mountainous terrain. Each lift station would consist
28 of a 4-foot-diameter manhole with two grinder pumps. The footprint area
29 required for each lift station would be approximately 15 feet by 15 feet. Two

1 pumps would be required to provide redundancy in case one of the pumped
2 stops operating. The 4-inch PVC force main contents would be pumped to the
3 wastewater treatment plant. The wastewater treatment plant would require a fine
4 screen (2 mm openings) to screen out all large solids to prevent damage to the
5 proposed membrane system. Grit removal would follow the fine screens to
6 remove small abrasive materials (e.g., sand) that can also damage the membrane
7 system. Flow after these two preliminary treatment processes would then be
8 directed to the secondary treatment process, which is an ultrafiltration
9 membrane. This is basically a biological filter that removes smaller particles
10 and organics. The last step in the treatment process would be ultraviolet (UV)
11 disinfection, which is used to destroy disease-causing organisms before
12 discharge. Treated water from this treatment train would then be discharged to
13 Shasta Reservoir (pending permit approval). It has been assumed that this would
14 be accomplished via gravity, although the mountainous terrain may require
15 effluent to be pumped to Shasta Reservoir.

16 It is assumed that the system described above would be used at several locations
17 around the lake.

18 Various issues should be understood when considering a small package
19 treatment plant, as described above. Wastewater treatment in small communities
20 is relatively expensive because the same level of treatment is usually required
21 for small communities, without the financial advantage of the economy of scale
22 of a larger community. Smaller communities are generally more spread out,
23 which also increases the wastewater collection system cost. In the case of
24 Shasta Reservoir, the mountainous terrain would increase the per capita cost
25 even more. In addition, operation and maintenance costs that currently are not
26 incurred would be required for the wastewater treatment system shown in
27 Figure 4-1, further increasing the overall cost. Another issue is odor control. As
28 discussed previously, buffer zones are often used to mitigate odor problems, and
29 this has been assumed in the wastewater treatment process described above. If
30 physical/mechanical odor control facilities would be required, this would
31 increase a wastewater treatment facility's capital cost and operation and
32 maintenance costs.

33 **Other Wastewater Treatment Alternatives** It should be noted that other
34 alternatives could be considered during final design, as described below.

35 *Centralized Septic System* This type of system would use existing septic tanks
36 for solids separation, and then all septic tanks would pump septic tank effluent
37 to a centralized septic field. The size of the septic field would be based on many
38 different factors, including soil type and trench capacity. Trench capacity can
39 include sidewalls or just the trench bottom. A rough calculation with no site-
40 specific data, and the assumption of a wastewater flow capacity of 25,000
41 gallons per day (gpd), yields a septic field size of about 30 acres. If sidewalls
42 are included in the calculation, the required area may be reduced to about 25
43 percent of the trench-bottom-only area.

1 *Recirculating Granular-Medium Filter* In these systems, septic tank effluent is
2 pumped to a sand filter multiple times before being discharged to a plant outfall
3 or septic field. Disinfection is required if discharging to surface waters directly
4 from the sand filter.

5 *Other Package Treatment Plant Alternatives* Many other package wastewater
6 treatment plant alternatives could be suitable.

7 **Power Distribution Facilities**

8 An expanded discussion of the approach and methodology for relocating power
9 distribution facilities is provided below.

10 **General Considerations** With a dam raise of 18.5 feet, several transmission
11 and distribution lines would either be inundated or in close proximity to the
12 reservoir. All transmission towers, power poles, and underground power lines
13 that would be inundated would be relocated. There are no regulations pertaining
14 to how far power lines need to be located from the inundation line.
15 Underground power lines, transmission towers, and power poles merely need to
16 be located in dry areas. It is assumed that areas 100 feet inland from the
17 inundation line would be dry enough for the transmission towers, while areas 50
18 feet inland from the inundation line would be suitable for underground power
19 lines and power poles. If a transmission line is within 100 feet of the inundation
20 line, it would be relocated. If a distribution line is generally within 50 feet of the
21 inundation line, it would be relocated. If a home is within 50 feet of the
22 inundation line, and is not demolished because of other criteria, the local
23 distribution line to the house would be retained.

24 **Inventory of Existing Transmission and Distribution Lines in Project Area**

25 An initial inventory of and data collection for the existing transmission and
26 distribution lines near the reservoir, or subject to be inundated, was carried out
27 to identify the volume of work that would be generated by the project.

28 Two 230 kV power towers (186, 187) and two 115 kV (3497, 3498),
29 respectively, would be inundated. Approximately 3,000 feet of 230 kV and
30 5,900 feet of 115 kV transmission line would be demolished and relocated.

31 For the main distribution lines, about 23,300 feet would be demolished and
32 relocated. An average distance of 75 feet was assumed for the distance between
33 a home and main distribution line. Approximately 8,000 feet of local
34 distribution lines would be demolished and relocated.

35 **Selection of New Power Line Routes** Route selection is a critical step in the
36 design process for a transmission line. Any route selected would have some
37 impact on the land and its uses. Therefore, it is important to analyze all possible
38 alternatives and choose a route that would minimize those impacts, and allow
39 construction, and facilitate utility personnel in easily building or accessing the
40 routes.

1 From an engineering perspective, several factors associated with relocating
 2 power lines are typically addressed in a route selection study. These factors are
 3 economics, reliability, and environmental impacts. The power towers preferably
 4 would be located in dry areas where foundations are above the water table level
 5 and soils are capable of sustaining the foundations. If wetlands or severe
 6 terrains cannot be avoided, costly foundations and/or special construction
 7 equipment or techniques would be required. Also, crossing heavily forested
 8 areas that would require extensive clearing would be avoided, as well as hunting
 9 grounds with a high probability of gunshot damage to insulators. These are a
 10 few aspects to be considered when planning a new route.

11 **Clearances** Clearances for transmission lines are those required to provide
 12 safety to the public and those required to provide reliable operations. Clearances
 13 required for safety and, to some extent, for operations, are stated in the NESC.
 14 These include clearances above the ground, streets, railroads, etc. For
 15 transmission lines of 230 kV and below, NESC clearances would generally
 16 provide for reliable operations as well as safety. These clearances are based on
 17 the voltage between the phase conductor and ground (L-G voltage). When
 18 considering phase voltage, a multiplier of 1.05 should be applied to the nominal
 19 voltage to determine maximum L-G voltage. Structure clearances are concerned
 20 with the air gap clearance between an energized conductor and the supports to
 21 prevent lightning and switching surge flashovers. Table 4-13 shows clearances
 22 between a restrained conductor and supporting structure. If conductor support is
 23 not restrained, clearance would be adjusted according to the maximum design
 24 range of swing of the insulator string. Any additional clearance to allow
 25 workers movement during live-line maintenance work should be added to
 26 determine the minimum tower-to-conductor clearance.

27 **Table 4-13. Restrained Conductor Clearances**

Voltage (L – L)	Phase to Ground Voltage	Minimum Structure Clearance (feet)
69 kV and below	41 kV	1.3
138 kV and below	84 kV	2.5
230 kV and below	140 kV	4

Key:
 kV = kilovolt
 L – L = line to line

28 Clearances not covered by the NESC that should be considered are phase-phase
 29 clearance, for very long spans, galloping, and leakage current limitation.
 30

31 At the start of the design of a line, it is important to develop a table of
 32 clearances as part of the design criteria to be used throughout the design. The
 33 table would include not only phase-to-ground and phase-to-phase structure
 34 clearances, but also phase-to-ground or crossing, or to the edge of right-of-way
 35 (ROW) clearances.

1 Also, various clearance requirements would need to be implemented from
2 CPUC-GO 95. Since PG&E owns the power lines and ROW, PG&E criteria
3 would also need to be met.

4 **Rights-of-Way** When considering a new line, it is always necessary to
5 determine ROW width. It is known that transmission lines generate electric and
6 magnetic fields, but no clear evidence has been found of any significant
7 environmental and health effects resulting from the operation of these lines.
8 However, some states have established regulatory limits on the strength of
9 electric and/or magnetic fields from power lines. Therefore, a ROW easement
10 obtained for transmission lines generally prohibits the installation of any
11 buildings or facilities within the ROW, but would allow buildings or structures
12 at the edge of a ROW. Therefore, the first condition for ROW width is to
13 provide NESC horizontal clearances to buildings for the longest span in the
14 transmission line, remembering that the clearance must be maintained with a 6-
15 pound wind on the conductor and structure. Therefore, conductor swing and
16 structure deflection must be considered when calculating the clearance. The
17 minimum clearance under these conditions can be based on the basic impulse
18 level (BIL) flashover distance rather than the NESC safety distance.

19 Table 4-14 presents typical minimum ROW widths for transmission lines with
20 voltages (phase to phase) of up to 230 kV. However, ROW widths would need
21 to be calculated based on site-specific data for any particular line.

22 **Table 4-14. Minimum Right-of-Way Widths**

Voltage (L – L)	BIL Flashover	Minimum Right-of-Way Width (feet)
68 kV and below	350 kV	40
138 kV and below	550 kV	60
230 kV and below	750 kV	75

Key:
BIL = basic impulse level
kV = kilovolt
L – L = line to line

23 **Plan and Profile, Structure Spotting** Plan and profile information is essential
24 to determine structure locations. These drawings generally consist of a plan on
25 half of a drawing and an elevation of a transmission centerline on the other half
26 of the drawing. Such information is obtained by performing a survey along a
27 transmission line corridor. This survey may consist of a ground survey or an
28 aerial survey. Generally, short lines (such as the lines to be relocated by this
29 project) use a ground survey, while long lines use aerial surveys.
30

31 When plan and profile information is prepared, it would include plan
32 information and centerline elevations, as well as the following information:

- 1 • Section line locations
- 2 • Property line locations
- 3 • Property owners
- 4 • Road and street ROW
- 5 • Railroad ROW
- 6 • Wire crossings (e.g., transmission lines, telephone)
- 7 • Elevation of wire crossing
- 8 • Underground facilities (e.g., pipelines, cables)

9 **Poles and Structures** Poles can be of wood or steel, and used as a single
 10 support, or as a framed structure, such as an H-frame steel pole, unlike wood
 11 poles can be fabricated to almost any required strength and are therefore more
 12 versatile for longer span applications.

13 Regarding structures, even though some can be of wood, steel is the most
 14 common material, particularly for structures subjected to high mechanical loads.
 15 Lattice steel structures have been used since the earliest transmission lines, but
 16 more recently tubular steel poles have become common.

17 **Foundations** Wood pole or steel pole foundations can be directly embedded in
 18 the ground with crushed rock or concrete backfill, or installed using reinforced-
 19 concrete caissons and anchor bolts. The direct-embedment type foundation is
 20 acceptable for tangent and small-angle structures, but concrete caisson
 21 foundations would be required for large angle and dead-end structures.

22 Foundations for lattice steel structures are typically concrete caissons or earth
 23 grillages.

24 **Permits**

25 A series of permits would need to be obtained from Federal and State agencies,
 26 and also from local governments for relocating power lines. As a minimum, the
 27 following agencies would be contacted and/or permits would be required:

28 *State*

- 29 • California Public Utility Commission (CPUC)
- 30 • California Department of Fish and Wildlife (CDFW)
- 31 • Caltrans
- 32 • Road crossing permit

- 1 • Railroad crossing permit

2 *Municipal*

- 3 • Neighborhood plan review from each town or community where a
- 4 power line would cross a roadway
- 5 • Local permits for construction
- 6 • Local zoning permits or conditional use permits

7 Please see Draft Environmental Impact Statement, Chapter 26, for additional
8 information on compliance with applicable laws, policies, and plans.

9 **Telecommunication Facilities**

10 Relocation of telecommunication lines would comply with all NESC and
11 CPUC-GO 95 requirements. Telecommunications lines would typically be
12 attached to power poles at a height lower than the power lines, typically 18 feet
13 off the ground. Buried lines would typically be routed along roadway shoulders
14 and direct-buried with a minimum of 30 inches of cover.

15 **Recreation Facilities**

16 The Whiskeytown-Shasta-Trinity NRA was established November 8, 1965, by
17 Congress to provide for public outdoor recreation use and enjoyment, and
18 conserve scenic, scientific, historic and other values contributing to public
19 enjoyment of such lands and waters. The NRA offers a variety of outdoor
20 activities, including boating, water-skiing, swimming, fishing, camping,
21 picnicking, hiking, and hunting.

22 Shasta Dam and Reservoir are located in the Shasta Unit of the NRA. Shasta
23 Reservoir and is the largest man-made reservoir in California, with 370 miles of
24 shoreline, and a surface area of 29,600 acres, making the lake ideal for
25 recreation.

26 Any raise of Shasta Dam would have some effect on the many recreation
27 features found along the reservoir shoreline. These features include
28 marinas/boat ramps, resorts, campgrounds/day use areas, trails, and USFS
29 facilities. Reclamation would protect such facilities from inundation, modify
30 existing facilities to replace affected areas (i.e., relocate facilities on site) or
31 abandon existing facilities and replace them at other suitable sites (i.e., relocate
32 facilities off site).

33 Although USFS has not approved relocation sites or recreation site plans,
34 preliminary plans for effects of a dam raise on Shasta Lake recreation facilities
35 have been developed with the cooperation of USFS. Plate 39 details the location
36 of existing and potential recreation areas (referred to as windows) with
37 proposed site modification, expansion, or relocation associated with an 18.5-

1 foot dam raise; and proposed new recreation sites. (Preliminary recreation plans
2 have not been developed for lower dam raise heights, but would likely require
3 fewer relocation areas.) After authorization of the project, further detailed
4 designs would need to be developed. The primary goal of the relocation plans is
5 to verify that with any dam raise, the existing recreation capacity could be
6 maintained. Reclamation and USFS would continue to work together to revise a
7 recreation plan that is suitable for the NRA.

8 Decisions about whether individual affected facilities would be modified or
9 relocated would be addressed in conjunction with USFS, based on overall
10 effects on the features of individual facilities as well as operational needs. Some
11 relocated facilities may be consolidated within other existing facilities, rather
12 than being relocated at a currently undeveloped area. All plans for replacing of
13 facilities would be evaluated and approved by USFS.

14 Where feasible, Reclamation would protect recreation facilities from seasonal
15 high-water levels by installing retaining walls or similar structures to prevent
16 inundation. The surface level of affected paved and unpaved areas (most used
17 for parking) would be raised if that would prevent inundation. In areas where
18 this would not be feasible or would be impractical, new facilities to replace lost
19 parking areas would be constructed in adjacent unaffected areas.

20 All capacity of recreation facilities (e.g., boat launching, campsites, picnic sites,
21 marina moorage and related services, resort lodging) lost as a result of
22 inundation would be replaced. Reclamation would seek to maintain the quality
23 of visitor experiences by replacing affected recreation facility capacity with
24 facilities providing equivalent visual resource quality, amenities, and access to
25 Shasta Lake and terrestrial natural resources.

26 Inundated recreation facilities and associated utilities would be relocated before
27 demolition, with the exception of facilities identified for abandonment.
28 Proposed dam raise alternatives would, at minimum, maintain the existing
29 recreation capacity at Shasta Lake. Recreation facilities to be modified or
30 relocated under SLWRI proposed Comprehensive Plans are summarized in
31 Table 4-15. Construction-specific information regarding relocation and
32 demolition of recreation facilities is under development and will be completed
33 after the SLWRI is authorized. Estimated quantities of demolition and
34 construction materials associated with modification and relocation of recreation
35 facilities are listed in Table 4-16.

36

1
2

Table 4-15. Recreation Facilities to be Modified or Relocated under SLWRI Comprehensive Plans

Recreation Facilities	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3 and CP4 (18.5-Foot)	CP5 (18.5-Foot)
Marinas/Public Boat Ramps				
Number of Affected Facilities (marinas/boat ramps)	9/6	9/6	9/6	9/6
Relocation Needed ¹ (acres)	8.5	8.5	8.5	8.5
Replacement Structures (sf)	49,900	49,900	49,900	49,900
Campsites and Day-Use Sites				
Number of Affected Facilities (campsites and day-use sites)	202	261	328	328
Relocation Needed ¹ (acres)	32	34	39	39
Replacement Structures (sf)	6,200	6,200	6,200	6,200
Resorts				
Number of Affected Facilities (resorts)	6	6	6	6
Relocation Needed ¹ (acres)	14	14	14	14
Replacement Structures (sf)	27,100	38,900	55,000	55,000
USFS Facilities				
Number of Affected Facilities (USFS facilities)	2	2	2	2
Relocation Needed ¹ (acres)	5	5	5	5
Replacement Structures (sf)	13,900	13,900	13,900	13,900
Trailheads/Trails				
Number of Affected Facilities (trailheads/trails)	2/9	2/9	2/9	2/9
Relocation Needed ¹ (miles)	8.1	9.9	11.6	11.6
Recreation Enhancement ² (trailheads/trails[miles])	-	-	-	6/18

Note:

¹ Does not include on-site modification of facilities.

² Additional recreation facilities for Alternative CP5 only.

Key:

- = not applicable

CP = Comprehensive Plan

sf = square feet

SLWRI = Shasta Lake Water Resources Investigation

USFS = U.S. Department of Agriculture, Forest Service

3
4

Table 4-16. Recreation Demolition and Construction Material Quantities for SLWRI Comprehensive Plans

Material	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3, CP4, and CP5 (18.5-Foot)
Recreation Facilities			
Imported Fill (cy)	236,200	384,200	552,800
Excavation to Waste (cy)	592,300	430,600	315,400
Structure Demolition (sf)	130,700	146,700	164,200
Demolition Waste (cy)	99,200	102,100	105,200

Key:
 CP = Comprehensive Plan
 cy = cubic yard
 sf = square feet
 SLWRI = Shasta Lake Water Resources Investigation

Marinas/Public Boat Ramps

Several marinas around Shasta Lake would be affected by raising Shasta Dam. Typically, marinas consist of a parking area, a boat ramp, various structures (e.g., retail, restrooms, maintenance facilities, storage, administration), and utilities (power, water, and septic). Most of the effects of the dam raise would result from the inundation of boat ramps, parking lots, structures, and utilities. Boat ramps would be modified in place on fill, where possible. Modifications to parking areas would include replacing them on fill, or relocating them above the new reservoir elevation. Existing structures that would be inundated would be demolished, and either replaced above the reservoir elevation (upslope or on placed fill), or moved to a floating structure on the water to provide better access for recreational users. Any access roads would be relocated above the new full pool to continue to provide access around the marinas. Existing septic systems that would be inundated would be demolished and removed from the area or relocated. New facilities could also be connected to new localized wastewater treatment facilities. Power lines would be installed to accommodate new structures.

Marinas and public boat ramps that could not be modified in place would be relocated to adjacent areas that are capable of providing the necessary grade and access for ramps, or facility capacity would be replaced at other facilities identified to have potential for expansion. To maintain current recreation capacity, as much as 8.5 acres of expanded, or new, boat ramp and/or marina land use would be needed. The following potential areas could be used to meet this need:

- Antlers Boat Ramp and adjacent marina area

- 1 • Silverthorn Marina Area
- 2 • Turntable Bay Area
- 3 • Holiday Harbor

4 See Plate 39 for locations of these potential recreation areas.

5 **Campgrounds/Day Use Areas**

6 Several undeveloped areas have been identified as potential campgrounds to
7 replace capacity lost because of inundation. While some inundated
8 campgrounds would be relocated on fill at their existing location, others would
9 be moved around the reservoir to new locations identified as potential
10 campground sites. As much as 39 acres of expanded, or new, campground area
11 would be needed for the 18.5-foot dam raise to maintain current recreation
12 capacity of campgrounds, boat-in campgrounds, and day-use areas. The
13 following areas could be used to meet the need for campgrounds:

- 14 • Antlers Campground
- 15 • Oak Grove Campground
- 16 • Hirz Bay Campground
- 17 • McCloud Bridge Area

18 The following areas could be used to meet this need for boat-in campgrounds:

- 19 • Lakeview Marina Area
- 20 • Monday Flat Boat-In Camp

21 The following areas could be used to meet this need for day-use areas:

- 22 • Ellery Creek Campground
- 23 • Gregory Creek Campground
- 24 • McCloud Bridge Area

25 See Plate 39 for locations of these potential relocation areas.

26 **Resorts**

27 Raising Shasta Dam would affect approximately six resorts around the reservoir
28 to some degree. Inundated structures, and those within 3 feet of the new full
29 pool, would be demolished. Associated septic systems would also be
30 demolished, and the remaining structures would either connect to new localized
31 wastewater treatment facilities or be relocated to other septic systems. As much
32 as 14 acres of expanded, or new, resort land use would be needed to maintain

1 current recreation capacity. The Antlers Concession Area is a potential area that
2 could be used to meet this need.

3 **USFS**

4 Recreation within the NRA is managed by USFS, which has several facilities
5 located throughout the reservoir area. USFS facilities consist of various storage
6 and maintenance buildings and equipment, fire protection equipment, customer
7 service facilities, office space, and employee living facilities. Two USFS
8 facilities would be inundated at all dam raise heights, and require relocation or
9 replacement: Lakeshore Fire Station and Turntable Bay Station. Lakeshore Fire
10 Station would be relocated to an area above the new full pool just west of the
11 Antlers Campground expansion area, providing necessary access to Interstate 5
12 and minimizing potential conflicts with adjacent recreation, residential, and
13 commercial areas. The new facility would contain all of the features that exist at
14 the current facility. The inundated facility would be demolished, and hauled to
15 waste. Additional space at Turntable Bay Station would allow this facility to be
16 relocated on fill in its current location.

17 **Recreation Trails**

18 Portions of most Shasta Lake trails would be affected by any dam raise.
19 Affected segments of hiking and biking trails would be relocated upslope to
20 restore the continuity of affected trails. In addition, CP5 includes construction
21 and/or modification of existing facilities at various locations to provide for 18
22 new miles of trails and 6 trailheads to enhance recreation opportunities at Shasta
23 Lake.

24 **Access Roads**

25 Reclamation's modification and/or relocation plans for recreation facilities
26 include project effects on roads and bridges (as described in the preceding
27 discussion of roadway relocations), many of which are used to access recreation
28 facilities. Facility access roads may be relocated, raised, or abandoned. If
29 abandoned roads serve a substantial recreation-access purpose, relocation may
30 take the form of upgrading alternative access routes that serve the same areas.

31 **Ecosystem Restoration**

32 CP4 and CP5 include ecosystem restoration measures around Shasta Lake and
33 along its tributaries, as well as downstream from Shasta Dam along the upper
34 Sacramento River.

35 **Reservoir Area**

36 Shoreline enhancement and tributary aquatic habitat enhancement are only
37 considered reservoir area ecosystem restoration measures for CP5.

1 **Shoreline Enhancement**

2 The ecosystem enhancement goal for the shoreline environment of Shasta Lake
3 is to improve the warm-water fish habitat associated with the transition between
4 the reservoir’s aquatic and terrestrial habitats. Shoreline enhancement entails the
5 range of enhancement opportunities along the Shasta Lake shoreline below the
6 full-pool elevation of 1,090.2 (NAVD88) that would occur with an 18.5-foot
7 dam raise. This area is typically between 0.1 and 1.5 miles upslope from the
8 current full-pool elevation of 1,069.7 (NAVD88). The shoreline is defined as
9 the area encompassing nearshore aquatic habitat within the reservoir itself and
10 vegetation and other habitat components adjacent to the reservoir.

11 Two categories of potential nearshore warm-water fish habitat enhancement
12 activities are discussed below: (1) *structural enhancements*, which entail
13 construction and placement of artificial structures in Shasta Lake’s littoral zone;
14 and (2) *vegetative enhancements*, which entail planting and seeding to provide
15 submerged and partly submerged vegetative cover when the reservoir is at full-
16 pool capacity during the winter/spring months.

17 Structural enhancements associated with CP5 include placement of brush
18 structures constructed from whiteleaf manzanita (*Arctostaphylos manzanita*) in
19 Shasta Lake’s littoral zone. Because of manzanita’s density, installation does
20 not require using anchor or cabling techniques that could result in ancillary
21 negative impacts (e.g., maintenance, hazards to boaters). The brush structures
22 would be assembled in the drawdown zone of the reservoir in an area that would
23 be inundated as the reservoir surface elevation rises in fall. The brush structures
24 are expected to be about 1,800 cubic feet in size. The establishment period
25 would be the first year after construction; life span of the brush structures is
26 projected to be 10 years.

27 Table 4-17 identifies the general area, number, and size of proposed structural
28 enhancement locations for the main body of Shasta Lake, and the Pit,
29 Sacramento, McCloud, Big Backbone, and Squaw arms. Selection of specific
30 locations has been deferred so that enhancement locations would be consistent
31 with other objectives of the SLWRI. The level of proposed treatment is based
32 on the proportion of available manzanita surrounding Shasta Lake. In general
33 terms, these locations would incorporate available material at locations with
34 preferred topographic features; preferred locations are coves that offer steep
35 drawdown areas during the primary use period (spring, early summer).

36

Table 4-17. Proposed Structural Enhancement of Lake and by Arm Under Comprehensive Plan 5

Area	Area Treated (acres)	Number of Locations
Lake Main Body	17	595
Pit Arm	12	420
Sacramento Arm	43	1,505
McCloud Arm	8	280
Big Backbone Arm	3	105
Squaw Arm	17	595
Total	100	3,500

Vegetative enhancements associated with CP5 include planting willows (*Salix*) to enhance nearshore fish habitat, and aerial and hand seeding of annual cereal grains to treat shoreline areas at Shasta Lake. More than 30 acres could be available to enhance willow recruitment adjacent to Shasta Lake. Rooted willows would be planted in draws and other moist sites, such as springs, to provide long-term live cover. The establishment period for willows would be the first year after construction; life span is projected to be 5 to 50 years. The establishment period for cereal grains would also be the first year of construction, with the life span projected to be 1 to 3 years. This approach requires native seed and nursery stock; several years of advanced preparation would be needed before planting could take place. Table 4-18 identifies the general area, number, and size of proposed vegetation enhancement locations for the main body of Shasta Lake, and the Pit, Sacramento, McCloud, Big Backbone, and Squaw arms.

Table 4-18. Proposed Vegetation Enhancement of Lake and by Arm Under Comprehensive Plan 5

Area	Willow Planting (acres)	Native Grass Seeding (acres)
Lake Main Body	1	2
Pit Arm	1	4
Sacramento Arm	7	4
McCloud Arm	1	2
Big Backbone Arm	3	2
Squaw Arm	1	2
Total	14	16

Tributary Aquatic Habitat Enhancement

The quantity and quality of aquatic habitat in the tributaries of Shasta Lake are influenced primarily by the presence of road crossings and culverts, although in some cases, other structures or grade controls (e.g., transitional deltaic deposits) may constitute barriers to aquatic connectivity, including fish passage.

Barriers to fish passage in the watersheds above Shasta Lake are primarily associated with culverts or other types of stream crossings. Typical passage problems created by culverts and other road crossings include the following:

- Excessive drop at the downstream end of a crossing (perched outlet)
- Water velocities within a crossing that are too fast to allow fish to swim upstream
- Constriction of flow as it enters a crossing, causing excessive water velocities and turbulence at an inlet
- Lack of sufficient water depth in a culvert for the fish to swim
- Debris accumulation across an inlet or within a culvert

Surveys have identified opportunities to restore and/or enhance 14 perennial and intermittent stream crossings to improve fish passage. Based on information obtained in the surveys, these crossings meet one or more of the criteria for impaired fish passage. Table 4-19 identifies the sites by road section, the watershed in which they occur (arm of Shasta Lake), and the type and size of crossing, and characterizes problems identified at these sites.

Table 4-19. Culvert Replacement on Perennial and Intermittent Streams Under Comprehensive Plan 5

Road/Site No.	Watershed	Type/Size of Crossing	Problems
FS 35N08 Sugarloaf Creek (Site 1)	Sugarloaf Creek	Culvert / 13.5-foot- diameter	Undersized, misaligned culvert, velocity/gradient barrier, eroding fill slope
FS 35N60 (Site 3)	McCloud	Culvert / 48-inch- diameter	Undersized culvert, velocity/gradient barrier, plunge pool, fill slope erosion
FS 35N60 (Site 4)	McCloud (Ellery Creek)	Culverts / 3 culverts 5-foot-diameter	Multiple culverts, velocity/gradient barrier, plunge pool, fill slope erosion
FS 35N60 (Site 5)	McCloud (Moore Creek)	Culvert / 72-inch- diameter	Culvert damaged, undersized, fill slope erosion
FS 35N17 (Site 6)	Salt Creek	Culvert / 36-inch- diameter	Undersized, shotgun outlet, velocity/gradient barrier, eroding fill slope
FS 35N17 (Site 7)	Salt Creek	Culvert / 24-inch- diameter	Undersized, shotgun outlet, velocity/gradient barrier, eroding fill slope
FS 35N08 (Site 11)	Sugarloaf Creek	Culvert / 48-inch- diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion

Table 4-19. Culvert Replacement on Perennial and Intermittent Streams Under Comprehensive Plan 5 (contd.)

Road/Site No.	Watershed	Type/Size of Crossing	Problems
FS 35N60 (Site 12)	McCloud Arm	Culvert / 24-inch- diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 13)	McCloud Arm	Culvert / 24-inch- diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 14)	McCloud Arm	Culvert / 18-inch- diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 15)	McCloud Arm	Culvert / 18-inch- diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 16)	McCloud Arm	Culvert / 18-inch- diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 17)	McCloud Arm	Culvert / 36-inch- diameter	Undersized culvert, velocity/gradient barrier, fill slope erosion
FS 35N60 (Site 18)	McCloud Arm	Culvert / 24-inch- diameter	Damaged culvert, velocity/gradient barrier, fill slope erosion

Key:

FS = U.S. Forest
Service road

Downstream from Shasta Dam

Gravel augmentation and side channel restoration are two proposed ecosystem restoration measures for CP4 and CP5 downstream from Shasta Dam.

Gravel Augmentation

Gravel suitable for spawning has been identified as a significant influencing factor in the recovery of anadromous fish populations in the Sacramento River. As part of CP4 and CP5, spawning-sized gravel would be placed at multiple locations along the Sacramento River between Keswick Dam and the RBPP.

Gravel augmentation would occur at one to three locations every year, for a period of 10 years, unless unusual conditions or agency requests precluded placement during a single year. This program, in combination with the ongoing Central Valley Project Improvement Act (CVPIA) gravel augmentation program, would help address the gravel debt in the upper Sacramento River, but the reach may continue to be gravel-starved into the future. Therefore, the gravel augmentation program proposed herein would be reevaluated after the 10-year period to assess the need for continued spawning gravel augmentation, and to identify opportunities for future actions or programs to do so.

1 Fifteen preliminary locations for spawning gravel augmentation were identified
2 in the Sacramento River between Keswick Dam and Shea Island, and were
3 selected based on potential benefits to anadromous fish and site accessibility.
4 Each location would be eligible for gravel placement one or more times during
5 the 10-year program. Gravel placement would provide either immediate
6 spawning habitat or long-term recruitment.

7 Although preliminary sites have been identified, specific gravel augmentation
8 site(s) and volume(s) would be selected each year in spring or early summer
9 through discussions among Reclamation, the U.S. Fish and Wildlife Service,
10 CDFW, and the National Marine Fisheries Service. The discussions would
11 include topics such as avoiding redundancy with planned CVPIA gravel
12 augmentation activities in a given year; identifying hydrology or morphology
13 issues that could impact the potential benefit of placing gravel at any particular
14 site; identifying changes in spawning trends due to previous years' gravel
15 augmentation activities; evaluating potential new sites; and are appropriately
16 distributing selected gravel sites along the river reach(es).

17 **Construction Activities** On average, 5,000 to 10,000 tons of gravel would be
18 placed each year, although the specific quantity of gravel placed in a given year
19 may vary from that range. Gravel would be obtained as uncrushed, rounded
20 river rock, free of debris and organic material, from local, commercial sources.
21 To maximize the benefit to anadromous fish, gravel would be washed and
22 sorted to meet specific size criteria. To minimize impacts to salmonid spawning
23 activity, gravel applied to active river channels would be placed between
24 August and September each year, consistent with the time frame for the ongoing
25 CVPIA gravel augmentation program.

26 Construction activities would vary significantly by location, but generally
27 would include clearing, grubbing, and some grading of new access routes to
28 allow construction vehicles to access the river. At several locations, clearing
29 and grubbing of the riverbank would be required to allow gravel to be placed on
30 the bank for recruitment. Gravel would be delivered to the locations by dump
31 trucks. In most cases, gravel would be stockpiled in a staging area and moved
32 with bulldozers, loaders, and/or excavators. Dust control trucks would be
33 present during all construction activities.

34 Several locations would require in-water construction work. Generally, this
35 involves building gravel out into the river channel "step-wise," meaning that
36 gravel is dumped and leveled, and the leveled area serves as a working platform
37 for the next step of construction. This practice is common for spawning gravel
38 placement, and minimizes the extent to which construction vehicles drive
39 directly through an active river channel. One or two locations, however, would
40 require construction activity in the active river channel, where construction
41 vehicles would deposit gravel and raise the grade of the river near existing
42 riffles.

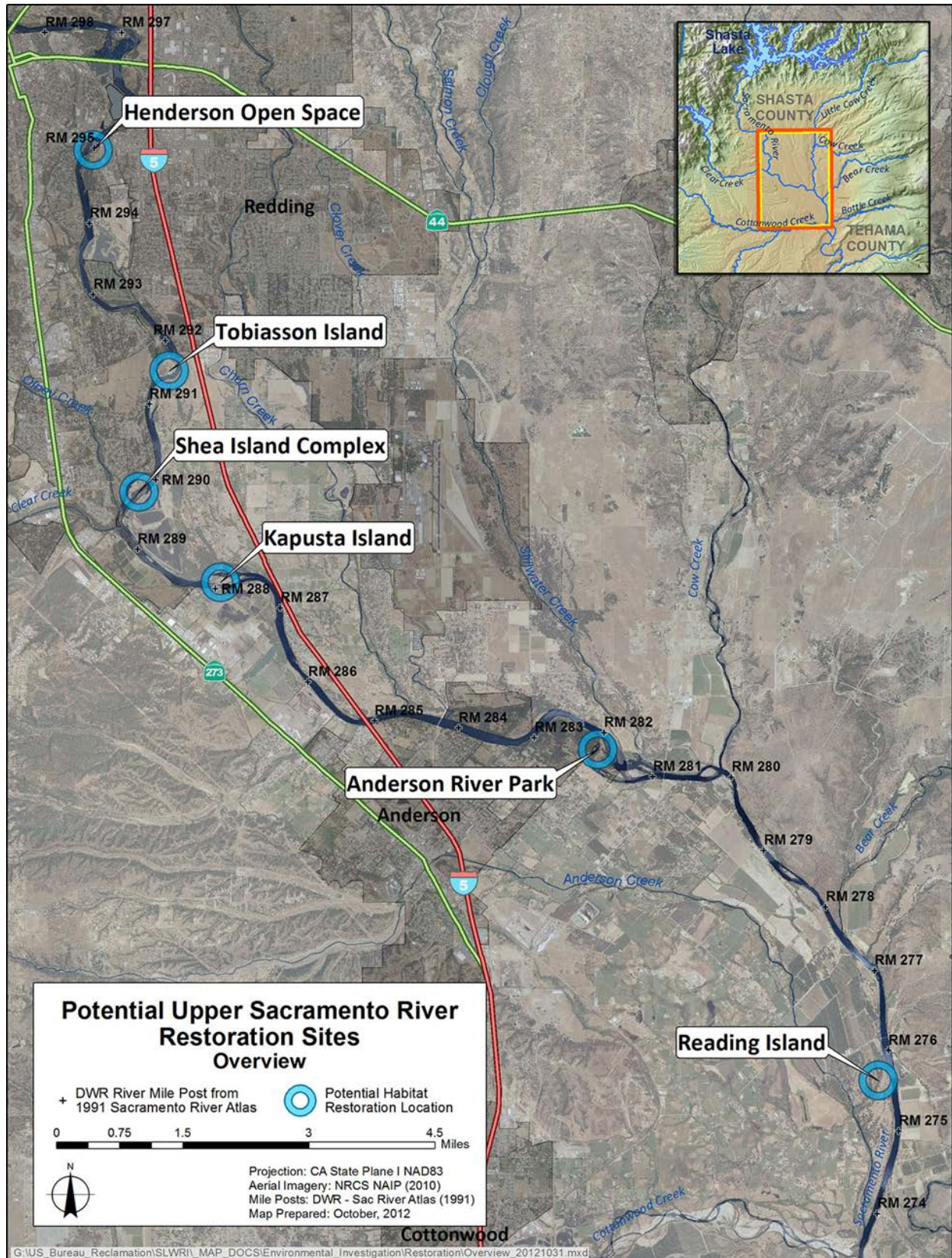
Restore Riparian, Floodplain, and Side Channel Habitat

Under CP4 and CP5, riparian and floodplain habitat restoration would be constructed at a suitable location along the Sacramento River. Several potential sites exist along the upper Sacramento River between Keswick Dam and RBPP that would be fit for restoration measures to benefit anadromous fish. Table 4-20 lists the potential restoration site and type of habitat enhancement. Figure 4-2 is an overview map of the potential restoration sites along the upper Sacramento River. These sites were evaluated for possible inclusion in CP4 and CP5 based on their geologic, hydrologic, and ecologic restoration potential through floodplain, side channel, and riparian habitat enhancement. Additional considerations included site accessibility and immediate availability for restoration activities. The sites described in this section are described in the order that they are located along the Sacramento River from upstream to downstream. Additional detail on the evaluation of potential riparian, side channel, and floodplain restoration site can be found in the *SLWRI Upper Sacramento River Potential Restoration Sites Technical Memorandum* (Reclamation 2012c).

Currently, the exact size, scope, and location of a desired and suitable restoration site is still under development. Not all of these sites will be included in the final alternatives so the following should be considered as examples of construction measures proposed for restoration of riparian, floodplain, and side channel habitat. However, for this stage in the planning process restoration activities anticipated under CP4 and CP5 are expected to be similar in size and scope of restoration at Reading Island (described below), and of which is used as a proxy for anticipated costs.

Table 4-20. SLWRI Potential Restoration Sites in the Upper Sacramento River by Type of Habitat Enhancement

Site Name	Spawning Habitat Enhancement	Rearing Habitat Enhancement
Henderson Open Space	x	
Tobiasson Island	x	
Shea Island Complex	x	
Kapusta Island	x	
Anderson River Park		x
Reading Island	x	x



1
 2 **Figure 4-2. Overview of Locations of Potential Restoration Sites Along Upper**
 3 **Sacramento River as Part of the SLWRI**

1 The HEC-RAS hydraulic model developed by the California Department of
2 Water Resources (DWR), Division of Planning and Local Assistance, Northern
3 District was used to estimate river stages at different flow rates for the potential
4 restoration sites. Steady flow data for a 50 year flood event was scaled down
5 uniformly to generate 15 different flow profiles ranging from an average flow of
6 4,000 cfs to 20,000 cfs in the Sacramento River. Critical depth for each flow
7 profile was set equal to the downstream boundary condition for the hydraulic
8 model.

9 **General Construction Activities** Construction activities for riparian,
10 floodplain, and side channel habitat restoration would vary depending on the
11 location or locations and type of restoration measure to be implemented at the
12 site. Table 4-21 summarizes the estimated construction quantities for each the
13 potential sites. In general, construction activities would include earth moving
14 activities with bulldozers, loaders, excavators, and/or compactors. Sites
15 proposing channel excavation would typically follow a trapezoidal 3:1 cut with
16 a 25-30' wide base. Excavated materials would either be reused on site, or be
17 taken off site to commercially available, approved locations for safe storage,
18 use, and/or disposal. Access to some sites may be achieved through public and
19 private access and include construction of temporary bridges to allow
20 construction vehicles to cross existing side channels. Embankment bridges
21 would be constructed with appropriately sized spawning gravels which could
22 then be used for gravel augmentation purposes. Vegetation removal may be
23 necessary at some sites, either for channel deepening/widening, or where water
24 with aquatic vegetation is present in a channel pending modification.
25 Revegetated areas are expected to develop into self-sustaining riparian habitats
26 within 1 to 4 years of initial planting, based on results of previous riparian
27 restoration projects along the Sacramento River.

28 Special precautions for restoration at these sites will primarily involve:

- 29 • maintaining the active spawning areas in proximity to the site
- 30 • avoiding the creation of habitat for predacious fish
- 31 • minimal disruptions to navigability of the river
- 32 • prevent the spread of invasive, non-native plant species
- 33 • insuring the safety of homes located on the Sacramento River
- 34 • downstream of the sites

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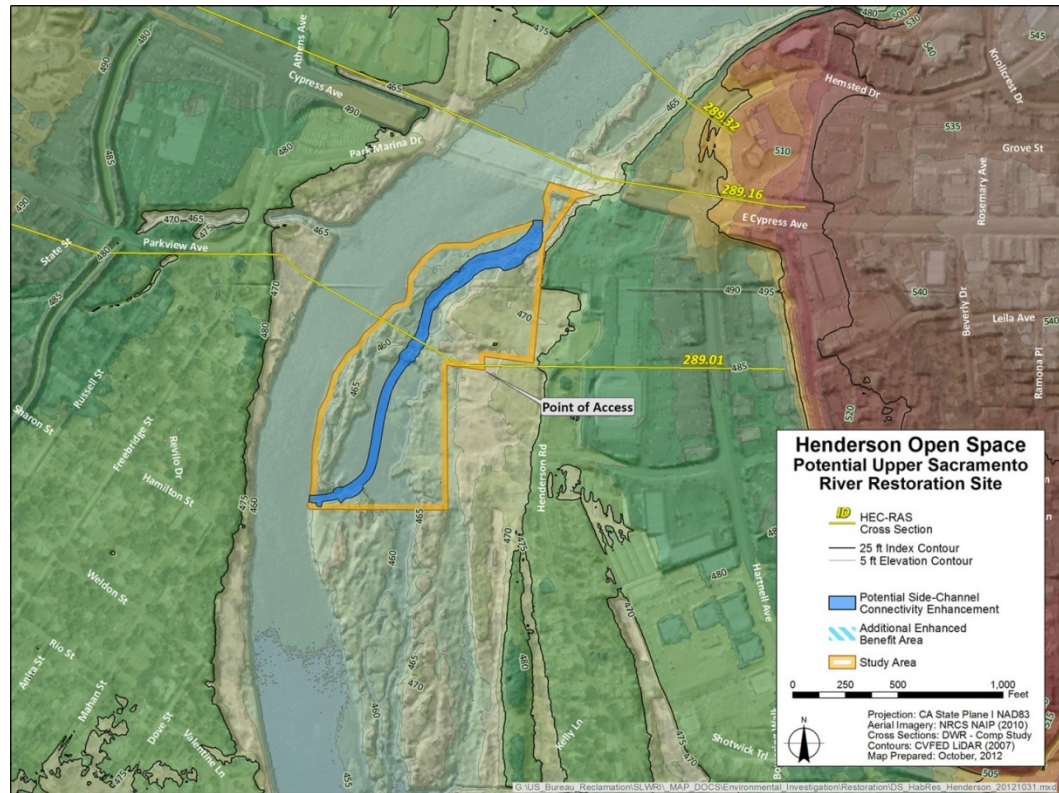
Table 4-21. Construction Quantities for Potential Restoration Sites Along the Upper Sacramento River

Item	Henderson Open Space	Tobiasson Island	Shea Island Complex	Kapusta Island	Reading Island
Modified Channel Length (lf)	1,900	1,300	700	1,600	4,300
Vegetation Removal (acres)	2.6	3.2	0.9	3.1	2.9
In-River Gravel Placement (cy)	-	3,100	4,700	3,100	-
Excavation (cy)	14,700	37,300	3,400	25,900	23,500
Riparian Vegetation Planting (acres)	1.2	1.4	0.4	1.4	2.3
Temporary Irrigation and Site Fencing	Yes	No	No	No	Yes
Relocation of Power Lines (lf)	1,100	-	-	-	-

Key:
 cy = cubic yard
 lf = linear feet

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Henderson Open Space The City of Redding Henderson Open Space area is located south of Cypress Bridge on the east side of the Sacramento River at River Mile 295. Riparian and side channel restoration at the Henderson Open Space site as shown in Figure 4-3 could consist of the enhancement of an existing side channel to activate the frequency and duration of flows for Chinook salmon spawning habitat throughout the side channel. This potential modification would create up to 2,000 more linear feet of spawning habitat in close proximity to areas of the Sacramento River that are actively used by anadromous fish for spawning.



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Figure 4-3. Henderson Open Space Potential Restoration Site

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The enhancement of an existing side channel to activate the frequency and duration of flows for Chinook salmon spawning habitat throughout a portion Henderson Open Space Park would involve modifying the northern opening to the existing side channel from the main stem of the Sacramento River and restore connectivity with the Sacramento River at flows greater than 8,000 cfs. Additionally, minor grading and channel slope modification of the existing (sometimes inundated) channel to a point at which flows may be activated for spawning habitat would be necessary. The existing power poles and low frequency power lines on the site would potentially need to be relocated and replaced. Access to Henderson Open Space for habitat restoration would be achieved via public road.

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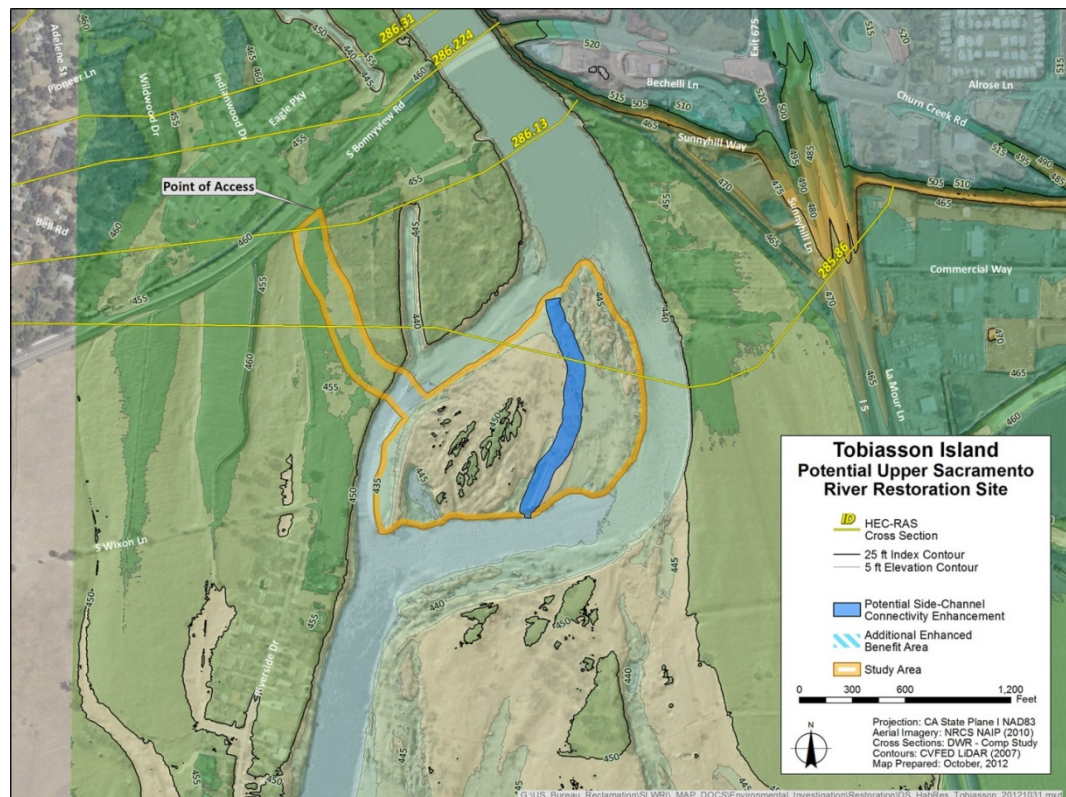
Currently, the existing Henderson Open Space side channel is heavily vegetated. Floodplain terraces and adjacent riparian areas would be replanted with native vegetation following the completion of earth moving activities. Native riparian vegetation planting mix, composition, and density would be determined by a more detailed site analysis. To varying degrees, temporary fencing and irrigation would be necessary to protect and sustain newly established riparian vegetation.

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Tobiasson Island Tobiasson Island is located downstream of South Bonnyview Bridge in the center of the Sacramento River at River Mile 292.

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Riparian, floodplain and side channel habitat enhancement at this site would include the enhancement of the island to allow for a regularly flowing side channel to increase spawning habitat for all runs of Chinook salmon as shown in Figure 4-4. This would include excavation of a trapezoidal shaped channel to allow flows to enter the side channel and hydraulically connect the side channel to the Sacramento River at flows of 5,000 cfs or greater. If created, this new side channel would add approximately 1,300 linear feet of spawning habitat to this section of the Sacramento River. This process would also include the establishment of new floodplain habitat and riparian vegetation along the course of the side channel.



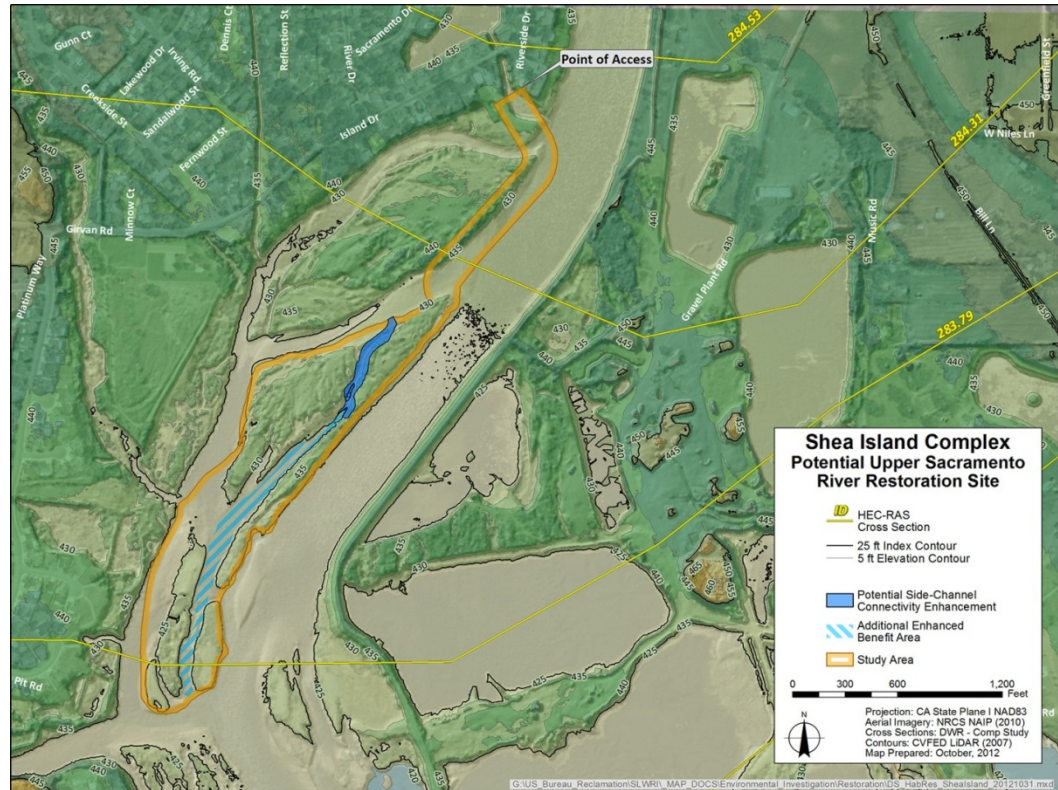
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Figure 4-4. Tobaiasson Island Potential Restoration Site

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The earth material on site consists of optimally sized salmonid spawning gravel, and could be disposed of on site or reused for gravel augmentation projects in the upper Sacramento River. Upon completion of earth moving activities, it would be necessary to establish native vegetation throughout the side channel on the newly created floodplain terraces. Riparian vegetation planting mix, composition, and density would be determined by a more detailed site analysis. Temporary irrigation and fencing for vegetation planting at this site is not feasible due to a lack of electricity at the site. Access to Tobaiasson Island could be accomplished by accessing the site at low flows or via a temporary constructed gravel bridge from adjacent private property.

1 **Shea Island Complex** The Shea Island Complex is located on the west side of
 2 the Sacramento River upstream of the river's confluence with Clear Creek at
 3 River Mile 291. Restoration at the Shea Island Complex to improve side
 4 channel, riparian, and floodplain habitat would include enhancing a major side
 5 channel through the site to keep the side channel hydraulically connected with
 6 the main stem of the Sacramento River at a broader range of flows as shown in
 7 Figure 4-5.



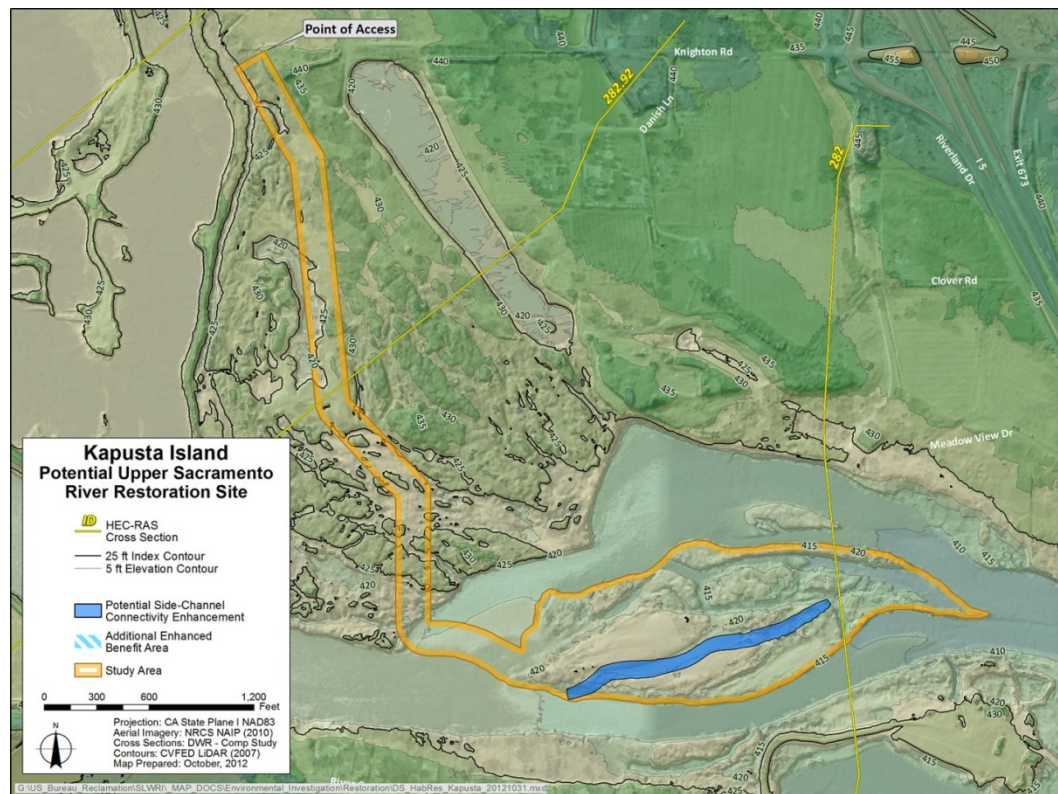
8 **Figure 4-5. Shea Island Complex Potential Restoration Site**

10 Restoration would include lowering a section of the upstream end of the major
 11 side channel to keep water more continuously moving through the channel at
 12 Sacramento River flows of 10,000 cfs to enhance salmonid spawning habitat.
 13 This potential modification would not only create up to 700 more linear feet of
 14 spawning habitat in close proximity to areas of the Sacramento River that are
 15 actively used by anadromous fish for spawning, but would also add channel
 16 complexity and enhance spawning habitat up to an additional 1,900 linear feet
 17 because of the connectivity with an existing side channel south of the modified
 18 channel. Additionally, vegetation and debris removal would be necessary in the
 19 excavated portion of the channel, as well as other portions of the channel to
 20 insure connectivity of flows. Minor grading activity would increase channel
 21 complexity along the length of the corridor. Upon completion of earth moving
 22 activities, it would be necessary to establish native vegetation throughout the
 23 side channel on the newly created floodplain terraces. Riparian vegetation

1 planting mix, composition, and density would be determined by a more detailed
2 site analysis. Temporary irrigation and fencing for vegetation planting at this
3 site is not feasible due to a lack of electricity at the site.

4 Access to the site would be achieved through private property at the north end
5 of the complex, potentially via a constructed gravel travelway, if needed. As the
6 substrate of the Shea Island Complex appears to consist of optimally sized
7 spawning gravels, earthen materials could be disposed of on or off of site, and
8 are potentially available for use as gravel augmentation substrate.

9 **Kapusta Island** Kapusta Island is located adjacent to the Kapusta Open Space
10 area upstream of the I-5 crossing of the Sacramento River at River Mile 288.
11 Restoration of riparian, side channel and floodplain habitat at Kapusta Island
12 would include the enhancement an existing side channel by allowing it to carry
13 water at a greater spectrum of flows specifically to increase winter-run and
14 spring-run Chinook salmon spawning habitat as shown in Figure 4-6.



15 **Figure 4-6. Kapusta Island Potential Restoration Site**

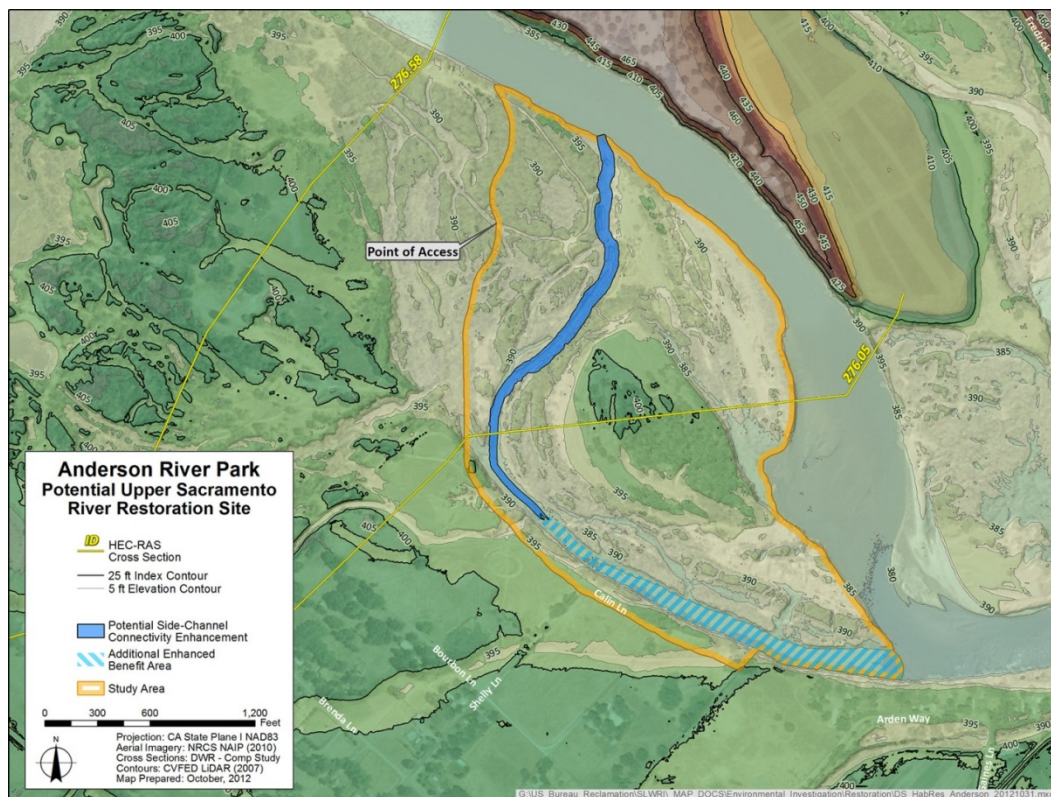
17 The enhancement of an existing side channel on Kapusta Island to increase
18 spawning habitat for winter-run and spring-run Chinook salmon in the
19 Sacramento River would involve lowering the channel bed so that the channel
20 may be hydraulically connected to the Sacramento River when it is flowing in
21 excess of 10,000 cfs. Allowing flow through the island, and increasing

1 floodplain habitat would increase spawning habitat potential in his area of the
2 river by about 1,600 linear feet.

3 Excavated material would need to be disposed of onsite due to difficulty of
4 access at this point in the river. Vegetation and debris would also need to be
5 removed from the infrequently inundated side channel. Upon completion of
6 earth moving activities, revegetating floodplain terraces and adjacent riparian
7 areas with native plants would be necessary. Riparian vegetation planting mix,
8 composition, and density would be determined by a more detailed site analysis.
9 Temporary fencing or irrigation at this site for newly established riparian
10 vegetation is highly infeasible and a planting mix with this limitation in mind
11 will need to be selected.

12 Access to the site could be achieved from several publically owned access
13 points as Kapusta Island is located to the south of U.S. Department of the
14 Interior, Bureau of Land Management's Riverland Drive property and north of
15 the Kapusta Open Space Park. Access across the river could be accomplished in
16 any of several ways, including gravel bridge, pontoon, or helicopter with
17 consideration for deep pools and high flows in the river at this site. Special
18 precautions for restoration at this island site primarily involve access to the site
19 at a point in the Sacramento River with high, fast moving flows.

20 **Anderson River Park** Anderson River Park is an open space area on the south
21 bank of the Sacramento River downstream from Churn Creek, and upstream of
22 the Deschutes Road crossing at River Mile 283. Restoration at this site would be
23 to hydraulically reconnect a remnant Sacramento River side channel with the
24 Sacramento River as shown in Figure 4-7. Regularly flowing water throughout
25 the length of this side channel would increase anadromous fish rearing habitat in
26 this section of the river.



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Figure 4-7. Anderson River Park Potential Restoration Site

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Floodplain, riparian, and side channel habitat restoration at Anderson River Park would involve altering a relic Sacramento River side channel located in the southeastern portion of the park to function at Sacramento River flows of, or above 8,000 cfs. This type of side channel alteration would create rearing habitat for anadromous fish along 4,800 feet of side channel (including the unmodified portion). Excavated materials would either be reused on site, or be taken off site to commercially available, approved locations for safe storage, use, and/or disposal. Riparian vegetation and appurtenant biota are well established at this site, therefore removal of vegetation to lower the channel bed would be necessary, followed by replanting of native riparian vegetation post-excavation.

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Access to Anderson River Park would be achieved via public roads and trail corridors throughout the park. Special precautions at this site to consider are to insure human safety in the park and temporary fencing around the construction and revegetated areas as a safety precaution in this highly recreated area.

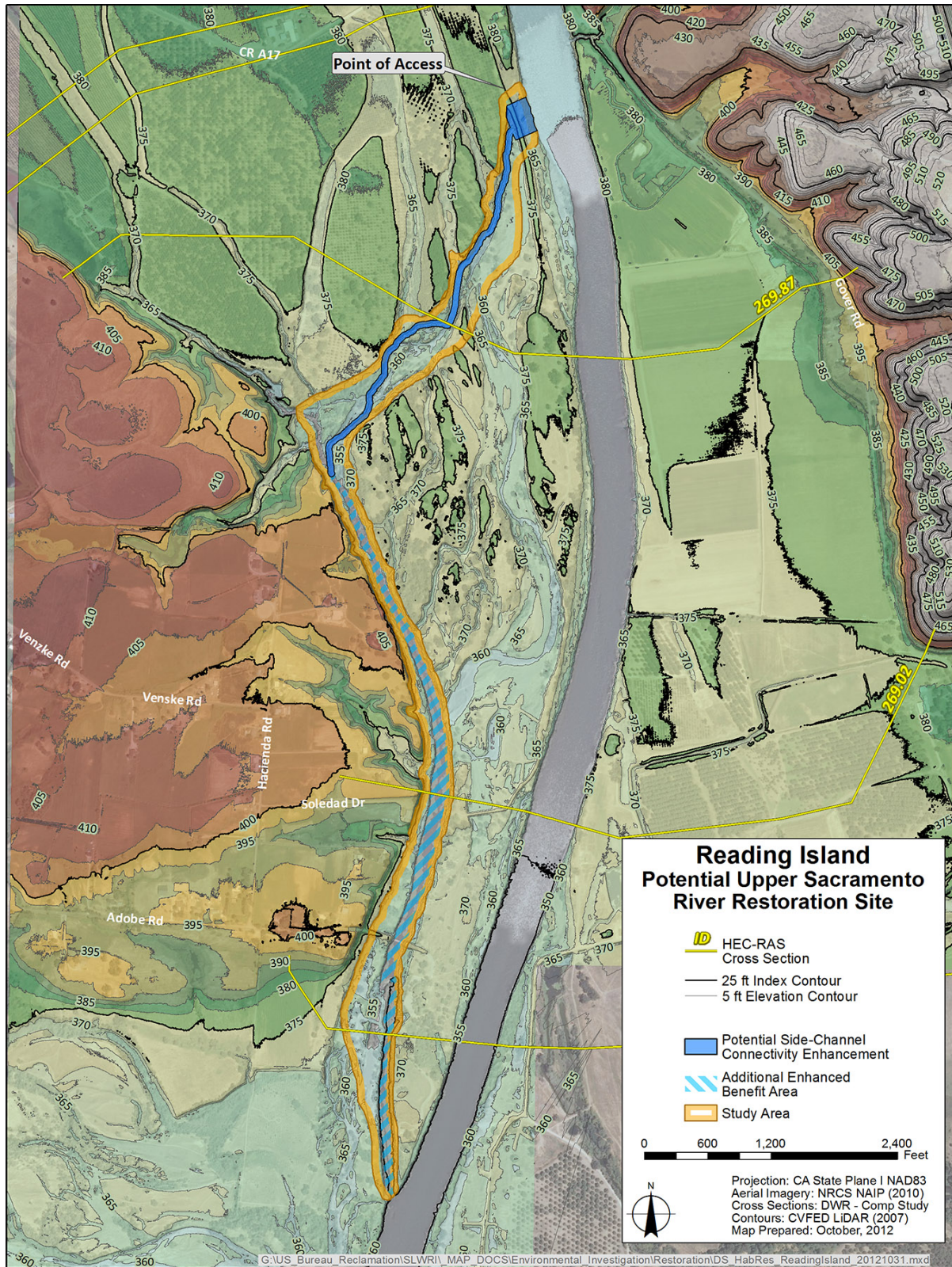
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Reading Island Reading Island lies along the Sacramento River just north of Cottonwood Creek at River Mile 274 (Figure 4-8). At the Reading Island site, a historic Sacramento River side channel drains into the present-day Anderson Creek, a remnant Sacramento River side channel. The Anderson Creek Slough, into which Anderson Creek empties, was blocked at the upstream end in the

1 early 1970s by construction of a levee on the adjoining private property. Before
2 levee construction, the Anderson Creek Slough captured a portion of the
3 Sacramento River flow and functioned as side channel habitat, supporting
4 rearing habitat for winter-run Chinook and spawning habitat for Central Valley
5 steelhead. Riparian, floodplain, and side channel restoration on Reading Island
6 would be to restore flows in Anderson Creek and through Anderson Slough by
7 removing the levee on Reading Island and lowering the channel bed.

8 Preliminary analysis indicates that breaching the levee, and channel clearing
9 and excavation would be necessary to restore connectivity with the Sacramento
10 River at flows ranging between 4,000 to 6,000 cfs. This would include
11 vegetation and debris removal and deepening of the existing channel. These
12 activities, alongside invasive aquatic vegetation removal in the channel and
13 reestablishing riparian vegetation would aid in restoring the juvenile salmonid
14 spawning and rearing habitat that once existed in Anderson Creek, potentially
15 increasing spawning habitat along 7,100 feet (including the unmodified portion)
16 of channel in this area of the river.

17 Excavated materials would be taken off site to commercially available,
18 approved locations for safe storage, use, and/or disposal. Post-excavation,
19 revegetating floodplain terraces and adjacent riparian areas with native plants
20 would be necessary. This would require temporary irrigation and fencing to
21 sustain plantings and keep livestock off site. Planting mix, composition, and
22 density would be determined by a more detailed site analysis. Reading Island is
23 both privately and publically owned, the potential restoration area is accessible
24 by public road (Adobe Road) via a U.S. Department of the Interior, Bureau of
25 Land Management day-use area.



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 2 **Figure 4-8. Reading Island Conceptual Study Area**

Chapter 5

Opinion of Probable Construction Cost

Feasibility-level most-probable construction cost estimates for the Shasta Dam and Reservoir raise include 3 dam raise alternatives, resulting in 5 Comprehensive Plans with 19 to 23 separate features. The three dam raise alternatives considered raises of 6.5 feet, 12.5 feet, and 18.5 feet, respectively. Significant features were included separately related to the dam and reservoir raise. The cost estimates were intended to capture the most current pricing for materials, wages and salaries; accepted productivity standards; and typical construction practices, procurement methods, current construction economic conditions, and site conditions for the current level of design. The cost estimates were prepared with less than complete designs and have inherent levels of risk and uncertainties. The cost estimates are intended to be a basis for budget authorization, appropriation, and funding.

Feasibility-Level Cost Estimates

Feasibility-level cost estimates are based on information and data obtained during design investigations. These investigations provide sufficient information to permit the preparation of preliminary layouts and designs from which approximate quantities for each kind, type, or class of material, equipment, or labor may be obtained. These estimates will be used to assist in the selection of a preliminary proposed plan to determine the economic feasibility of a project and to support seeking construction authorization from Congress.

Unit prices were developed using a semi-detailed method. Specific construction activities were identified for major cost drivers. Costs for labor, equipment, materials, and other resources were developed. Production rates, overhead, and taxes were applied to develop applicable unit prices. Vendor quotations were obtained for major equipment, supplies, and other items. Minor cost items were developed using historical bid and industry standard reference cost data.

Major Cost Estimate Components and Assumptions

The assumptions listed for direct cost line items, and specifically factors used to determine indirect costs, are critically important to the overall accuracy of the estimate, and should be reviewed and understood by all parties.

Competitive Market Conditions at Time of Bid Tender

Estimates assume that Builder's Risk Insurance would be available to the contractor. If Builder's Risk Insurance is not available to the contractor because

1 of the scope, security implications, or magnitude of the project, increased bid
2 margins can be expected because the contractor would need to assume
3 additional risks.

4 **Price Level**

5 Feasibility-level cost estimates were developed at April 2010 price levels for the
6 SLWRI Preliminary DEIS (2011c). For this DEIS, costs were indexed to April
7 2012 price levels using Reclamation's Construction Cost Trends (Reclamation
8 2013a). For subsequent drafts, or as part of the Final Feasibility Report, cost
9 estimates may be repriced to the current price level.

10 **Cost Estimate Components and Allowances**

11 Depending on the level of study, it is often impractical to identify all items
12 associated with a project. Accordingly, appraisal, feasibility, and partial design
13 estimates should contain a percentage allowance shown as a separate line item
14 for unlisted items. This unlisted items allowance represents the amount required
15 to achieve comparability between preliminary estimates and prevalidation
16 estimates. In general, the less refined the estimate, the higher the percentages
17 used. As more details are developed to refine a specific cost estimate, the
18 number of direct cost line items increases, the accuracy of the quantity takeoffs
19 increases, and the allowance for unlisted items decreases.

20 Field cost is an estimate of capital costs of a feature or project from award to
21 construction closeout. Allowances for mobilization, design contingencies,
22 allowance for procurement strategies (APS), and construction contingencies are
23 included in field costs.

24 ***Mobilization***

25 Mobilization costs include contractor bonds, and mobilizing contractor
26 personnel and equipment to the project site during initial project setup. A value
27 of 5-10 +/- percent was used for mobilization. This is based on past experience
28 of similar projects.

29 ***Design Contingency***

30 Design contingencies are intended to account for three types of uncertainties
31 inherent as a project advances from the planning stage through final design,
32 which directly affects the estimated cost of the project. These include (1) minor
33 unlisted items, (2) minor design and scope changes, and (3) minor cost
34 estimating refinements. Based on the completeness of the listed items that the
35 detail provided, the design contingency was set at 10-20 +/- percent of the listed
36 items for this project, depending on the feature.

37 ***Allowance for Procurement Strategies***

38 A line item for APS may be included in feasibility-level cost estimates to
39 account for additional costs when solicitations will be advertised and awarded
40 under other than full and open competition. These include solicitations that will
41 be set aside under socioeconomic programs, along with solicitations that may

1 limit competition or allow award to other than the lowest bid or proposal. For
2 SLWRI, APS was set at 2 percent. SLWRI estimates assume full and open
3 competition, receipt of sealed bids, with award to the lowest responsive and
4 responsible bidder.

5 **Construction Contingency**

6 Feasibility-level estimates include a percentage allowance for construction
7 contingencies as a separate item to cover minor differences in actual and
8 estimated quantities, unforeseeable difficulties at the site, changed site
9 conditions, possible minor changes in plans, and other uncertainties during the
10 construction period. A value of 10-20 +/- percent was used for construction
11 contingencies for the majority of the features. The bridge features used a
12 slightly higher value of 25 +/- percent. The allowance is based on engineering
13 judgment of the major pay items in the estimate, reliability of the data,
14 adequacy of the projected quantities, and general knowledge of site conditions.

15 **Non-Contract Costs**

16 Construction cost is the sum of the feature field costs plus non-contract costs.
17 Non-contract costs refer to costs of work or service provided in support of the
18 feature construction, and other work that can be attributed to the feature as a
19 whole, known as distributed costs, which include facilitating services,
20 investigations, design and specifications, construction management,
21 environmental compliance, and archeological considerations.

22 Non-contract costs were estimated to be $32 \pm$ percent of the total field costs
23 based on typical non-contract cost percentage ranges from past large
24 Reclamation projects. Land acquisition or relocation of property by others is not
25 included in this percentage.

26 Non-contract costs were divided into five categories for SLWRI and are as
27 follows (this list is not all-inclusive):

- 28 • **Planning, Engineering, Design, and Construction Management** –
29 This includes collection, assembly, analysis of data, and preparation
30 and review of additional planning studies. This also includes
31 construction designs and specifications, construction engineering and
32 management, other costs such as general office salaries, supplies and
33 expenses, general transportation expenses, security, environmental
34 oversight, and legal services. The planning, engineering design, and
35 construction management non-contract cost was estimated at 20 percent
36 of the total field cost.
- 37 • **Land Acquisition** – This includes lands to be acquired in fee for
38 inundated lands; in fee and by permanent easement for reservoir area
39 facility relocations such as roads, recreation facilities, dikes, utilities,
40 and bridges; and by temporary use agreement for staging and

1 construction activities. See the Real Estate Appendix for detailed
2 analysis on land acquisition non-contract cost.

- 3 • **Environmental Mitigation** – This includes additional development or
4 requirements of environmental impact reports, and implementation of
5 environmental mitigation. The environmental mitigation non-contract
6 cost was estimated at 10 percent of total field cost excluding
7 environmental restoration.
- 8 • **Cultural Resources Mitigation** – This includes coordination with
9 California State Historic Preservation Office, compliance
10 documentation, and mitigation. Cultural resources mitigation non-
11 contract cost was estimated at 2 percent of the total field cost.
- 12 • **Water Use Efficiency Actions** – This includes funding for an
13 additional water conservation program for new water supplies created
14 by the project, to augment current water use efficiency practices (see
15 Draft Environmental Impact Statement, Chapter 2, for more detail on
16 the program). The program is estimated to be included over 10 years at
17 a cost of \$5 per year per acre-foot of new average annual yield.

18 ***Total Capital Costs***

19 Total capital cost is the sum of the construction costs and interest during
20 construction (IDC). IDC is interest that accrues on a loan that finances the
21 construction of an alternative. It is applied over the construction period and/or
22 until the debt is begun to be served. For this Study, IDC was applied over the
23 time until the debt is begun to be served, which was estimated at 4 years for all
24 of the Comprehensive Plans, at the current Federal discount rate of 4 percent. 4
25 years is the period from the Notice to Proceed milestone to when the reservoir
26 can start filling and claim benefits.

27 ***Total Annual Costs***

28 Total annual costs for each alternative were estimated by interest and
29 amortization of the capital cost over 100 years and at the current Federal
30 discount rate of 4 percent. Annual operations and maintenance (O&M) costs
31 were also estimated at 0.2 percent of the field cost plus the costs associated with
32 the increase in CVP/SWP system pumping energy use. Increase or decrease in
33 CVP/SWP system generation is not included in this cost, but instead as part of
34 the benefits analysis (not discussed in this appendix). Chapter 23 of the DEIS
35 details the impacts associated with the CVP/SWP system pumping energy use
36 for each Comprehensive Plan, which is summarized in the Table 5-1.

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Table 5-1. Simulated Average Annual Increase in CVP/SWP Pumping Energy Use for SLWRI Comprehensive Plans

Item	CP1 (6.5-Foot)	CP2 (12.5-Foot)	CP3 (18.5-Foot)	CP4 (18.5-Foot)	CP5 (18.5-Foot)
Increase in CVP System Pumping Energy Use (GWh)	11	17	35	11	28
Increase in SWP System Pumping Energy Use (GWh)	46	72	-16	46	85
Total Increase in Pumping Energy Use (GWh)	57	89	19	57	113
Total Increase in Annual Pumping Energy Cost (\$ million)	\$3.6	\$5.6	\$1.2	\$3.6	\$7.2

Key:
 \$ Million = Million Dollars
 CP = Comprehensive Plan
 CVP = Central Valley Project
 Gwh = Gigawatt-Hour
 SLWRI = Shasta Lake Water Resources Investigation
 SWP = State Water Project

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Annual costs associated with the increase in CVP/SWP pumping energy use were estimated using average annual market prices developed under the Upper San Joaquin River Basin Storage Investigation, which included modeling in PLEXOS[®], a power market simulation model (Pinnacle Consulting 2012), with input from CPUC Long Term Power Procurement (LTPP) proceedings (CPUC 2012). The value of energy is estimated by its market value in the year 2020 and then indexed to a 2010 price level. The market value is determined by the shadow price (i.e., marginal value) on an hourly basis for NP15 (the CAISO Northern California area). Since the shadow prices are initially based on the incremental cost of the marginal generating units, the “market price” represents a conservative estimate of the energy value, as no bid mark-ups or market power is assumed. For SLWRI, Consumer Price Indices were used to index the market price to an April 2012 price level (BLS 2013). This method does not account for variances in daily pumping and prices (i.e., peak and off-peak), and may be updated for the Final EIS. Based on the methodology described above, the average annual market price was estimated to be \$63.34 per megawatt-hour (MWh). Table 5-1 summarizes the total increase in average annual pumping energy costs by Comprehensive Plan.

Major Cost Estimate Exclusions

The feasibility-level cost estimates do not include costs associated with the following:

- 1 • Loss of water and power due to construction requirements affecting
2 dam and powerplant operation
- 3 • Impacts to downstream water intakes
- 4 • General access road maintenance
- 5 • Impacts due to multiple construction contracts, market conditions, and
6 number of bidders

7 **Contractor Risks**

8 Several risk items have been identified below in an effort to alert decision-
9 makers to important issues that could impact contractor operations and costs:

- 10 • Wing dam and spillway modifications relative to fluctuating lake levels
- 11 • Schedule slippage due to security concerns
- 12 • Schedule delays for bird nesting restrictions
- 13 • Blasting operations at or near dam facilities
- 14 • Stringent classification of materials to meet specification requirements
- 15 • Material transport restrictions and safety concerns
- 16 • Processing areas that are identified as not sufficient to meet required
17 production goals
- 18 • Insurance issues in relation to dam significance
- 19 • Seasonal work restrictions imposed by phased spillway gate and lower
20 tier outlet gate replacement schedule
- 21 • Long contract periods that expose liabilities
- 22 • Contractual risk transfer
- 23 • Minority business enterprise and miscellaneous flow-down provisions

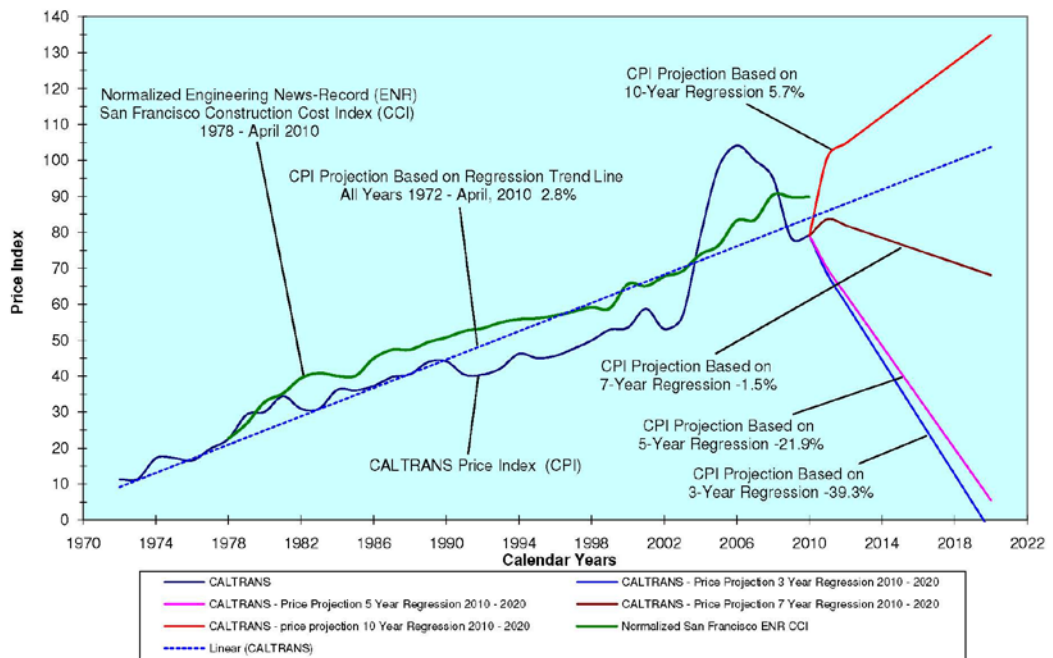
24 **Escalation**

25 An allowance for escalation from the April 2012 price level to the Notice to
26 Proceed milestone was not included in the estimate. For projects that are to be
27 developed over an extended period of time, or at some distant time in the future,
28 it is prudent to consider the time value of money. Two distinct periods of time
29 must be considered with escalation: (1) the period from the published price level
30 until Notice to Proceed, and (2) the duration of the construction contract. The
31 cost estimates only include escalation during construction, which is
32 incorporated into the unit prices.

1 Since escalation through Notice to Proceed was not included, the legislation
2 authorizing the construction of this project should contain appropriate language
3 to provide Reclamation the authority to adjust the appropriation ceiling by
4 indexing to reflect future changes in costs.

5 As mentioned, this estimate includes only first costs (without escalation from
6 published price level to Notice to Proceed); however, escalation would be a
7 very significant cost driver for the project. For economic analysis and future
8 project budgeting, a preliminary escalation rate of 3 percent per year is
9 recommended to be used.

10 The preliminary escalation rate is based on reliance of recent cost escalation
11 data supplied by the Caltrans Price Index (Caltrans 2010). The Caltrans Price
12 Index demonstrates that California recently experienced a significant downturn
13 in prices for highway and heavy civil construction infrastructure work. Figure
14 5-1 shows Caltrans highway construction price trends from 1972 through April
15 2010, San Francisco City Cost Index trends from 1978 to April 2010
16 (Engineering News-Record 2011), and Caltrans highway construction price
17 trends from 1972 through the present. From Caltrans Price Index data, expected
18 long-term price trends have been projected through 2020.



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Figure 5-1. California Construction Price Trends

21 The construction market has experienced extreme price volatility in the last
22 several years. A significant market anomaly occurring from 2002 through 2009
23 skews the calculation of forward cost trends using short-term linear regression
24 techniques. Of note, the Caltrans Price Index decreased over 17 percent for the
25 calendar year of 2008, and the Caltrans Price Index projection based on the

1 3-year regression indicates a negative average growth rate of almost 40 percent
2 per year. Although the recent economic downturn has resulted in price
3 decreases, it is expected that prices will continue to escalate over the long-term.
4 While future inflation trends are difficult to predict, new market forces (e.g.,
5 higher material commodity pricing, energy costs, lack of competition) will
6 likely continue to have significant impacts on heavy civil infrastructure
7 construction costs for the foreseeable future. Because of uncertainty and
8 variability among the short-term regressions, a longer view of the market is
9 preferred. Consequently, while forward cost trends are always difficult to
10 predict, there is some basis to believe that cost escalation is normalizing back to
11 historical levels at approximately 3 percent per year. Future studies and
12 coordination should be undertaken to determine the appropriate escalation
13 factor to be used for budgetary approval.

14 **Program Cost Drivers**

15 Although not included in the estimates of first costs, escalation is a significant
16 cost factor for the program and should be included for economic studies and
17 future project budgeting. Total contingency is another significant cost driver. As
18 explained previously, contingency consists of three separate components:
19 estimating contingency, risk provision supported by probability theory, and
20 unlisted items allowance.

21 **Risk and Uncertainty**

22 With each aspect of this report, certain assumptions were made based on
23 engineering and scientific judgment. Careful consideration was given to the
24 methodologies and evaluations for hydrology and system operations, cost
25 estimates, and biological analyses. Analyses were developed with advanced
26 modeling and estimating tools using historical data and trends. While this is an
27 effective way to help predict outcomes for future operations, biological
28 conditions, and costs, many uncertainties could affect the findings of this
29 Engineering Summary Appendix. Various uncertainties and risks associated
30 with the SLWRI are discussed in the Plan Formulation Appendix.

31 All cost estimates, even at a feasibility-level, have inherent risks and
32 uncertainties. In development of cost estimates for the alternatives, the Study
33 team has no control over the costs of labor, materials, competitive bidding
34 environments, unidentified field conditions, financial and/or commodity market
35 conditions, or any other factors likely to affect the cost estimates of the Study
36 alternatives, all of which are and will unavoidably remain in a state of change,
37 especially in light of high market volatility attributable to Acts of God and other
38 market forces or events beyond the control of the parties. As such, these
39 feasibility-level estimates are based on normal market conditions, defined by
40 stable resource supply/demand relationships, and do not account for extreme
41 inflationary or deflationary market cycles. These estimates are a "snapshot in
42 time" and their reliability will degrade over time. No warranty, promise,
43 guarantee or representation, either expressed or implied, is given that proposals,

1 bids, project construction costs, or cost of O&M functions will not vary
2 significantly from these cost estimates.

3 **Feasibility-Level Cost Estimates for Alternatives**

4 Estimated total construction costs for each of the Comprehensive Plans are
5 summarized in Table 5-2. Total capital and annual costs and more detailed cost
6 estimate worksheets are included in the following attachments to this appendix:

- 7 • **Attachment 1** – Cost Estimates for Comprehensive Plans
- 8 • **Attachment 2** – 6.5-Foot Raise and Reservoir Area Infrastructure Cost
9 Estimates
- 10 • **Attachment 3** – 12.5-Foot Raise and Reservoir Area Infrastructure
11 Cost Estimates
- 12 • **Attachment 4** – 18.5-Foot Raise and Reservoir Area Infrastructure
13 Cost Estimates
- 14 • **Attachment 5** – Preliminary Construction Schedule and Work
15 Packages
- 16 • **Attachment 6** – CP4 Crystal Ball Estimate

17 The estimates of construction costs shown, and any resulting conclusions on the
18 project's financial requirements, economic feasibility, or funding requirements,
19 have been prepared from the best information available at the time the estimate
20 was performed. Final project costs and resulting feasibility would depend on
21 actual labor and material costs, competitive market conditions, and other
22 variable factors, and should include escalation from the published price level to
23 Notice to Proceed. Accordingly, the final project cost would vary from the
24 estimate. Therefore, project feasibility, benefit/cost analysis, risk, and funding
25 would need to be carefully reviewed before making specific funding decisions
26 and/or establishing the project budget.

27

1 **Table 5-2. Estimated Total Construction Costs for Comprehensive Plans**

Item	CP1 6.5 Feet (\$ million)	CP2 12.5 Feet (\$ million)	CP3 18.5 Feet (\$ million)	CP4 18.5 Feet (\$ million)	CP5 18.5 Feet (\$ million)
Field Costs					
Relocations					
Vehicular Bridges	\$34	\$34	\$52	\$52	\$52
Doney Creek Railroad Bridge	\$55	\$55	\$55	\$55	\$55
Sacramento River Railroad Bridge, Second Crossing	\$113	\$113	\$113	\$113	\$113
Pit River Bridge Modifications	\$16	\$23	\$30	\$30	\$30
Railroad Realignment	\$8.1	\$8.1	\$8.1	\$8.1	\$8.1
Roads	\$17	\$25	\$37	\$37	\$37
Utilities	\$25	\$26	\$31	\$31	\$31
Buildings/Facilities - Recreation	\$131	\$147	\$166	\$166	\$166
Dams and Reservoirs					
Main Dam	\$52	\$62	\$74	\$74	\$74
Outlet Works	\$27	\$27	\$27	\$27	\$27
Spillway	\$101	\$105	\$107	\$107	\$107
Temperature Control Device	\$28	\$29	\$30	\$30	\$30
Powerhouse and Penstocks	\$1.2	\$1.2	\$1.2	\$1.2	\$1.2
Right Wing Dam	\$4.5	\$5.6	\$6.7	\$6.7	\$6.7
Left Wing Dam	\$13	\$18	\$25	\$25	\$25
Visitor Center	\$8.3	\$8.6	\$8.9	\$8.9	\$8.9
Dikes	\$14	\$16	\$26	\$26	\$26
Reservoir Clearing	\$4.5	\$7.1	\$20	\$20	\$20
Pit 7 Dam and Powerhouse Modifications	\$0.2	\$0.2	\$0.2	\$0.2	\$0.2
Environmental Restoration	-	-	-	\$6.1	\$18.1
Recreation Enhancement	-	-	-	-	\$1.3
Total Field Costs	\$653	\$711	\$818	\$824	\$838
Planning, Engineering, Design and Construction Management	\$131	\$142	\$164	\$165	\$168
Lands	\$28	\$43	\$64	\$65	\$65
Environmental Mitigation	\$65	\$71	\$82	\$82	\$84
Cultural Resource Mitigation	\$13	\$14	\$16	\$16	\$17
Water Use Efficiency Actions	\$1.6	\$2.6	\$3.1	\$1.6	\$3.8
Total Construction Cost	\$891	\$913	\$1,147	\$1,154	\$1,174

Note:

Cost estimate is feasibility-level in April 2012 dollars, and subject to change in the future. Escalation from published price level to notice to proceed is excluded. Estimates may include discrepancies due to rounding. For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03 (2007c).

Key:

\$ million = million dollars

- = not applicable

CP = Comprehensive Plan

2
3

Chapter 6

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