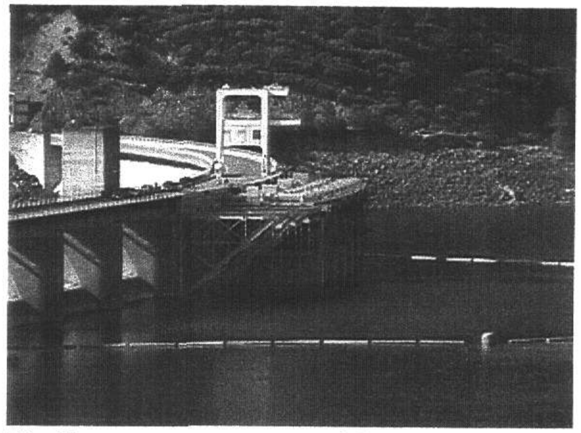
platform steel at the new dam crest elevations. The existing rigid frames will remain in place to support the shutters and low-level intakes. Sloping trashracks will be added to the top of the shutters at elevation 1067.5 to prevent debris from entering the TCD. The existing temperature monitoring equipment will be extended, if possible, or completely raised to the new hoist platform elevation. New rigid frames will be anchored to the raised dam near the crest elevation to support the new hoists, electrical equipment, miscellaneous metalwork, and hoist platform steel.

Electrical Equipment.

Main Generating Units.—Five new generators, each rated 260 MW, 0.95 power factor (pf) at 13,800 volts for the high dam raise option, and 215 MW, 0.95 pf at 13,800 volts for the intermediate dam raise option, will be required for the new powerplant. These generators are of the vertical-shaft synchronous type and will be provided with a static excitation system.

Bus and Power Circuit Breakers.—One 15-kV isolated-phase bus, rated 12,500 amps for the high dam raise option and 11,000 amps for the intermediate dam raise option, will run from each generator through its associated unit power circuit breaker out to the unit transformer.

Generator Step-Up Transformer.—Three single-phase outdoor transformers will be provided for each unit to transform the generator's 13.8 kV output voltage to 230 kV for use in the new switchyard. One



The Shasta temperature control device.

spare transformer will also be provided to minimize downtime for a single transformer failure.

Station Service.—The station service power supply will be obtained by tapping off two of the generators' 13.8-kV bus and by providing stepdown transformers to transform the voltage down to 480 volts. The plant station service needs will be provided by the 480-volt distribution equipment located inside the plant's double-ended unit substation.

Duplex Control Switchboards.—Duplex control switchboards will provide all control, protective, and monitoring (indication) features required for the main generators. Manual, automatic, and supervisory type functions will be provided to allow full flexibility in plant operations.

600-Volt Motor Control Centers.—600-volt motor control centers will be provided in the plant for operating all the auxiliary systems, such as hydraulic pumps, water cooling pumps, electrically driven valves, air compressors, and sump pumps.

Switchyards.—Prior to commencing construction for the new powerplant, the existing switchyard will be replaced with a new 230-kV switchyard at a downstream location (to be determined). The new switchyard will permit continued power generation to some degree throughout construction, using the existing powerplant and available units. Concurrent with construction for the new powerplant, a new 525-kV switchyard will be constructed to serve the new plant. Overall site dimensions for the new switchyards were developed for the 1978 studies, as follows: 1,250 by 400 feet for the 230-kV switchyard, 700 by 500 feet for the 525-kV switchyard for dam crest elevation 1270, and 350 by 500 feet for the 525-kV switchyard for dam crest elevation 1180.

Construction of a new 525-kV (and other) transmission line will be required to accommodate the new power output from both powerplants but is not included in the current appraisal-level studies.

Cofferdam Features

Construction of the new gravity wing dams on both abutments will require the construction of upstream cellular cofferdams. The left abutment cofferdam will consist of four large cloverleaf cells founded on an excavated bench at elevation 970 and three to four smaller circular cells founded on an excavated bench at elevation 1020. The right abutment cofferdam will consist of four small circular cells and connecting arcs above elevation 1050. The cells will consist of interlocking steel sheet piling, backfilled with a free-draining sand and gravel material, and extending to the existing dam crest at elevation 1077.5. Cell diameters are assumed to be equal to the cell heights to ensure stability. Concrete will be placed to provide water barriers at the contacts with the existing dam and abutments. The steel sheet piling and free-draining backfill will be removed from both locations following construction; however, the backfill and anchor concrete will remain. Details related to the constructability of these cofferdams are discussed later.

To retain tailwater levels during reservoir releases, downstream cofferdams will be required within the tailrace area for unwatering the stilling basin and for construction of the new powerplant. The *stilling basin cofferdam may be subject to* overtopping for passage of floodflows from the river outlets. Details for these cofferdams will be developed for future feasibility-level designs.

Reservoir Dikes

Four reservoir dikes are required to contain new reservoir levels up to elevation 1280, at the Centimudi, Bridge Bay, Jones Valley, and Clickapudi Creek sites. Reservoir dikes at the Jones Valley and Clickapudi Creek sites will be required to contain reservoir levels up to only elevation 1180. No reservoir dikes are assumed to be required for the low dam raise option, although the available topography suggests some minor protection may be required. Better site topography should be developed for future feasibility-level designs.

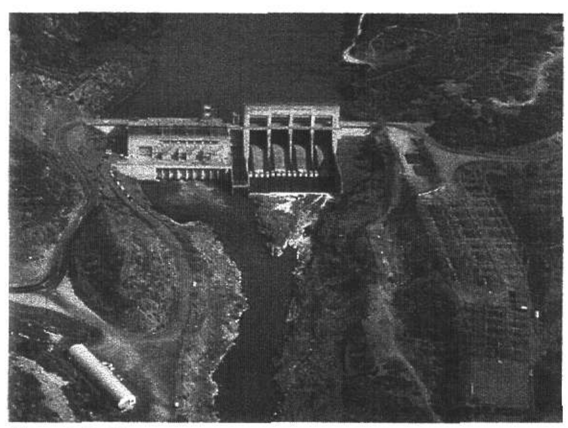
The appraisal-level design for each reservoir dike is based on a zoned earthfill structure with a 10-foot freeboard allowance. The entire foundation for each dike will be stripped to a suitable depth, and special attention will be given to the contact surface for the central impervious core. A core trench will be excavated to reduce the potential seepage through the foundation. The depth of the core trench will depend on site conditions. The removal of highly fractured rock, especially in the area of faults or shear zones, will require foundation treatment. The appraisal designs include a line of pressure grout holes to depths of 40 feet and quantities for slush grouting and dental concrete treatment.

The central impervious core (zone 1) will have a top elevation 2 feet above the maximum reservoir level. It will have a top width of 15 feet and sideslopes of 0.75 to 1. The placement and compaction requirements will be determined based on the materials to be used. A chimney drain with a 10-foot horizontal width will be provided on the downstream slope of the central core and will be connected to a 10-foot-thick blanket drain placed on the dike foundation between the core and the downstream toe. The chimney drain will act as a filter to prevent fines migration from the core. A 12-inch perforated toe drain pipe will be provided near the downstream toe to collect the seepage through the dike embankment and foundation. Because of the assumed highly fractured condition of the bedrock foundation, the depth of the toe drain should be significant (assumed 20 feet).

An outer (zone 2) shell of semipervious to pervious materials will be provided both upstream and downstream from the central core, with the more pervious materials being placed in the downstream portion. The outer slopes will be 2.5:1 on the upstream face and 2:1 on the downstream face. Compaction requirements will be determined based on the materials to be used. Riprap placed on a bedding layer will be provided to protect the upstream shell against wave action. Each reservoir dike will be completed with suitable instrumentation for future monitoring.

Keswick Dam and Powerplant Modifications

Modifications to Keswick Dam and Powerplant would be required to increase the storage capacity of Keswick Reservoir if increased releases are made from the new Shasta Powerplant for peaking power. The extent of modifications required at Keswick



Keswick Dam.

will depend on more refined studies of power and water operations and a determination of downstream storage requirements needed to maintain flow release capability and restrictions. Enlargement of the reservoir would be achieved by either increasing the height of the existing dam by up to 25 feet or by constructing a new concrete structure about 2 miles downstream. Preliminary designs and estimates for an enlarged Keswick Dam were prepared in 1982 and provide the basis for indexed costs used for this study. Preliminary designs and estimates for a new Keswick Powerplant were prepared by Bookman-Edmonston Engineering in 1996. Appraisal-level designs for an enlarged and/or new dam and powerplant should be prepared after the need for an enlarged afterbay reservoir has been determined. It should be noted that raising the existing Keswick Dam would increase tailwater levels at both Shasta Dam and Spring Creek Debris Dam, reducing power generation capacity and requiring additional structural modifications at both powerplants to prevent flooding.

Constructability

Constructability issues associated with implementation of any proposed enlargement were reviewed during this appraisal study. Issues that were assessed include material sources, reservoir operations, equipment/material transportation, sequencing/scheduling, cofferdam construction, penstock construction, and access. No issues were identified that were unsolvable.

Materials.—Several material borrow sources have been identified in previous studies. Several potential rock and earthfill sources within an area of about 6.2 miles east and 15.6 miles south of Shasta Dam have been examined in previous studies. The most promising aggregate sources were located south of Shasta Dam. Aggregate sources would likely be in off-river areas in order to avoid any spawning gravel sites. Earth materials are available in an area several miles to the southeast of Project City. Road distances to proven sources of concrete aggregate range from about 13.7 miles to 16.2 miles. Borrow areas within the reservoir have also been identified. This source will be dependent on reservoir fluctuations. Since the alternative borrow sites were identified some time ago, a new evaluation of these potential sites will be required. It is not anticipated that borrow material areas will be a major issue.

Reservoir Operations.—During construction, water releases for temperature control, water quality, and water supply will still be required. Release capabilities through the dam will need to be maintained during construction to meet these demands. Close coordination between dam operators and construction managers should address this issue.

Power generation during the construction period will have to be assessed in detail. For power generation and downstream releases, a construction sequence would be developed that would permit continued operation of four of the five existing powerplant units during modifications to the existing penstocks and TCD. The powerplant release capacity should be sufficient for passage of normal reservoir inflows during construction. Sufficient river outlet capacity must also be maintained throughout construction to provide for passage of potential diversion floods, up to the downstream channel capacity of 79,000 ft^3/s. The current studies assume no more than two river outlets would be unavailable for releases at any time, using the new bulkhead gate and the existing coaster gate to provide upstream closure for gate replacement. Replacement of the four tube valves at elevation 742 should be completed first to provide increased release capacity from the lower tier of river outlets. Flood releases from river outlets located above the concrete overlay block construction should, of course, be avoided, but may be required during construction.

Equipment/Material Transport.— Construction materials and equipment may be delivered onsite by either truck or rail transportation modes. Lake Boulevard will be severely affected during construction work on the left abutment. In addition, Shasta Dam Boulevard will need widening.

The existing rail alignments are not conducive to efficient handling of materials. Reworking of the existing railroad lines would be required if extensive use of the railroad is anticipated. Without reworking of the alignments, double handling of materials may be required. Preliminarily, it appears that trucks may provide the most efficient means of transporting material. Some materials, such as the power transformers, may not be deliverable by truck, however, and may require double handling.

Cofferdam.—Perhaps the most difficult constructability issues associated with any enlargement project involve the construction of the cofferdams. For both the Intermediate and High Options, two cofferdams on the left abutment and one on the right abutment are proposed. All cofferdams would be built to a crest elevation of 1077.5. On the left abutment, one cofferdam would be constructed on a bench established at elevation 970. The second cofferdam on the left abutment would be established on a bench at elevation 1020. On the right abutment, the cofferdam is built on a bench at about elevation 1050.

These cofferdams are constructed most efficiently and cost effectively in the dry. Table 1 shows the range of monthly Shasta reservoir elevations for the period of record from 1944 to 1997. Depending on the type of cofferdam, a drawdown period of 5 to 6 months may be required to complete all the cofferdam construction. For construction of the lower bench cofferdam on the left abutment to be done completely in the dry, a reservoir drawdown to elevation 965 is required. While table 1 shows this to be feasible in drier years, additional drawdown of the reservoir would likely be required in normal and wet years. The feasibility of making additional drawdowns in the reservoir during construction will be very difficult, given the various temperature and water quality criteria in the lower river

Table 1.—Mean monthly Shasta Reservoir elevations, 1944-97

Month	Minimum	Maximum	Average
January	700	1053	998
February	787	1045	1008
March	846	1053	1021
April	884	1063	1036
May	895	1067	1040
June	890	1066	1036
July	866	1060	1023
August	843	1049	1007
September	839	1037	995
October	849	1032	991
November	846	1036	992
December	852	1033	995
Mean annual	841	1050	1012

and delta. If reservoir drawdown is absolutely required, the water costs could be significant. Such a drawdown could result in a loss of water that would impact water deliveries, recreation, power, and, potentially, fish and wildlife.
Finding replacement water could be costly and may only partially offset the adverse effects of a drawdown for construction.

Based on average mean monthly elevations, the construction period for the higher benched cofferdam on the left abutment could easily occur during the months of August through March. Similarly, construction of the cofferdam on the right abutment could continue throughout the year. During an average year, construction of the left abutment low bench cofferdam could proceed from September through January if an additional 30 feet of drawdown were to occur. This low-level cofferdam may be constructed early if reservoir levels are expected to be low before the prime contract is awarded.

Alternatively, the low bench cofferdam could be built by working in about 30 feet of water, at additional costs. Underwater construction of the lower portions of cellular cofferdams is possible and has been performed previously on smaller cofferdams in water depths up to about 60 feet. Foundation excavation would be much slower, however, and tremie methods would be required for concrete placement. Construction costs and durations would increase significantly.

Use of RCC construction methods on the dam abutments may also shorten the drawdown period. A full assessment of the construction of this low bench cofferdam needs to be accomplished at more detailed level studies.

Access.—There are several residences on the ridge above the right side of the dam. Relocation of the powerplant road and bridge for access to the right side may be necessary to provide access to the homes.

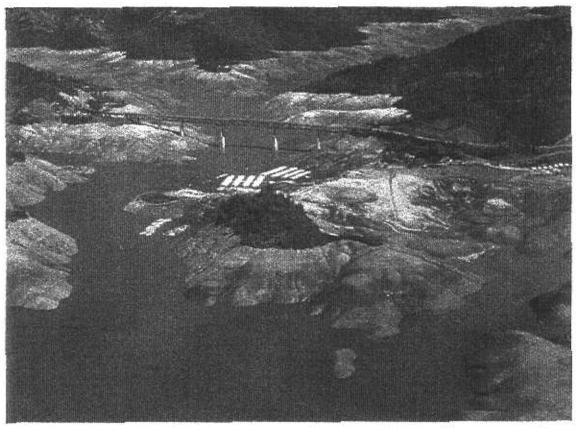
New Penstocks.—Development of a new powerplant on the left side of the dam will require developing a new hole through the dam to accommodate penstock pipes to take water from the reservoir to the powerplant turbine generators. The centerline of the new penstocks is anticipated to be at elevation 970. Drawdown conditions in the reservoir will preclude the normal water surface from being below this elevation for any appreciable time. Consequently, construction will require underwater work on the upstream face of the dam. This work would entail placing some type of temporary underwater structure that would seal off the area where the new penstock hole would be drilled through the upstream face of the dam.

Sequencing/Scheduling—Preliminary indications are that required construction activities to raise Shasta Dam may take 8 to 10 years for the maximum proposed raise to crest elevation 1280. Figure 4 shows a schematic of the potential construction period.

Project work may be divided into separate contracts for financial reasons. Dam features which may be considered for construction under separate contracts (apart from the prime contract) include the reservoir dikes, the 230-kV switchyard, the 525-kV switchyard, the new powerplant, and the upstream cellular cofferdams.

The 230-kV switchyard should be completed before construction for the new powerplant begins, while the 525-kV switchyard will not be needed until several years later, when the new powerplant is completed and operational. A separate contract for the new powerplant could extend to a penstock connection point identified in the prime contract.

The majority of the reservoir dikes are located several miles from Shasta Dam and would be easily separated, even if some construction materials are developed from required excavation under the prime contract or other contracts. Construction of the reservoir dikes can be completed later in the process because the reservoir is likely to fill slowly. Although contracts for the remaining heavy construction work on the dam raise, spillway, river outlets, power outlets, and penstock intakes could not be easily divided, the larger mechanical items could be included under separate supply contracts to reduce the cost of the prime contract.



Shasta Lake at low storage during drought period. Ideally, construction of Intermediate and High Options could occur when the reservoir level is low, minimizing underwater work. Construction of the Low Option is only minimally affected by the reservoir level.

Appendix B is a complete technical evaluation of engineering considerations related to enlarging the dam. Table 2 summarizes the features of the various options.

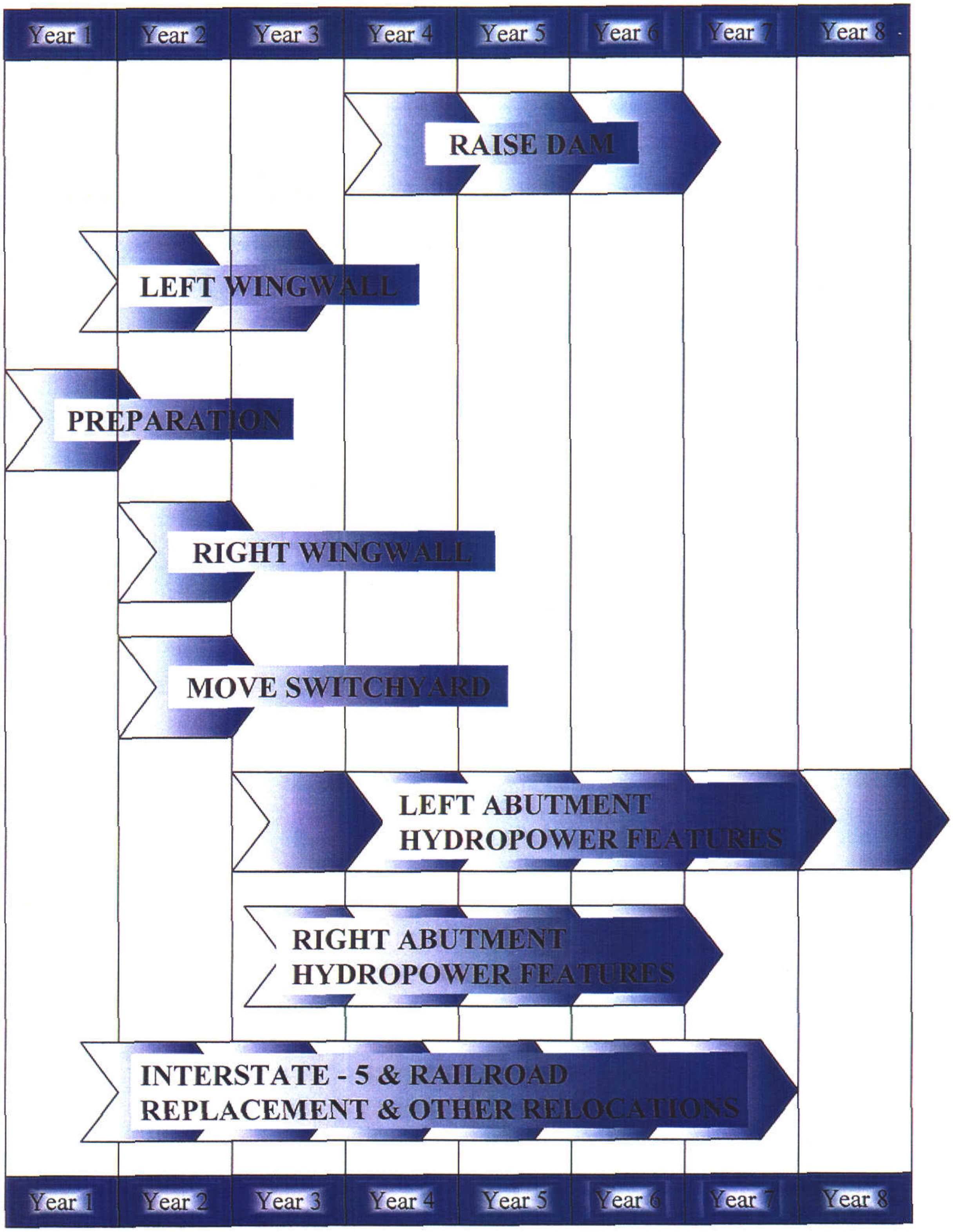
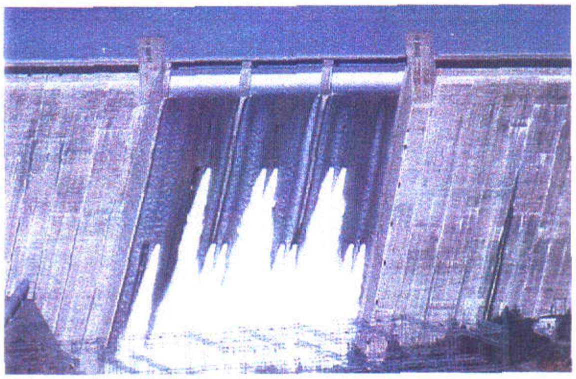


Figure 4 Eight-Year Construction Schedule

Table 2 Enlargement Option Features

FEATURE	EXISTING DAM	HIGH OPTION	INTERMEDIATE OPTION	LOW OPTION
Dam Crest Elevation (ft)	1,077.50	1,280	1,180	1,084
Dam Crest Length (ft)	3,460	4,930	4,590	3,660
Height Raise (ft)	None	202.5	102.5	6.5
Joint Use and Top of Gates Elevation (ft)	1,067	1,273.50	1,173.50	1,077.50
Total Reservoir Capacity (MAF)	4.5	14	8.5	4.9
Increase in Capacity (MAF)	None	9.5	4	0.4
Spillway Crest Elevation (ft)	1,037	1,246	1,146	1050
Spillway Gates	three 28' by 110' drum type	six 27.5- by 55-foot radial	six 27.5- by 55-foot radial	six 27.5- by 55-foot radial
Outlet Works	18 outlets in 3 tiers at elev. 950 (six 96" tubes), 850 (eight 96" tubes), and 750 (four 102" tubes)	Replace all 14 existing outlet tubes to handle increased head	Replace outlets in two lower tiers of existing dam (upper tier can accommodate increased head from raise)	Replace 4 tube valves on lower tier outlets for greater reliability and discharge capacity
Relocation/Replacement				
Interstate 5-Union Pacific Railroad Bridge- Bridge Bay	Not applicable	Yes	Yes	No
Recreation Facilities	Not applicable	Yes	Yes	Minor
Resort Facilities	Not applicable	Yes	Yes	No
Communities	Not applicable	Yes	Yes	No
Modified Features				
Temperature Control Device	250' by 300' shutter structure and 125' by 170' with operating range between elev. 840 and 1065.low level intake structure	Raise operating controls	Raise operating controls	Raise operating controls
Existing Penstocks and Penstock Intakes	Five 15' diameter steel penstocks at elev. 815	New 16' by 25' gates, Replace existing pipes with thicker walled steel pipes, strengthen exposed pipe supports	New 16' by 25' gates, Replace existing pipes with thicker walled steel pipes, strengthen exposed pipe supports	Strengthen exposed pipe supports
New Penstocks and Penstock Intakes	Not applicable	Five new 20' diameter penstocks and intakes at elev. 970 on left abutment	Five new 20' diameter penstocks and intakes at elev. 880 on left abutment	None
Existing Powerplant	Currently rated at 578 MW with ongoing uprating program to increase generation to 676 MW. Operation level between elev. 840 and 1065.	No modifications for existing powerplant to upgrade power generation.Upstream isolation valves required to protect existing spiral cases for reservoir elevations above 1186 feet.	No modifications for existing powerplant to upgrade generation. New upstream isolation valves not required.	No modifications for existing powerplant to upgrade generation. New upstream isolation valves not required.
New Powerplant	Not applicable	Five 260 MW turbine/generator units (combined capacity of 1,300 MW) for operation between elevations 980 and 1,280 feet.	Five 215 MW units (combined plant capacity of 1,075 MW) operating between elevations 890 and 1180.	None
Switchyard	Existing switchyard located at left abutment.	Replace the existing switchyard with a new 230kV switchyard (required space 1,250' by 400') at a downstream location. Develop a new 525 kV switchyard (required space 700' by 500')along left abutment.	Replace the existing switchyard with a new 230kV switchyard (required space 1,250 by 400') at a downstream location. Develop a new 525 kV switchyard (required space 350' by 500') along left abutment.	None
Reservoir Dikes				
Centimundi	No	Yes	No	No
Bridge Bay	No	Yes	No	No
Jones Valley	No	Yes	Yes	No
Clickapudi Creek	No	Yes	Yes	No
Other				
Keswick Dam and Powerplant	Not applicable	Enlargement required up to 25 feet to accommodate increased releases from new powerplant.	Enlargement required up to 25 feet to accommodate increased releases from new powerplant.	None
Scheduling/Sequencing	Not applicable	8 to 10 year construction period	8 to 10 year construction period	4 year construction period
Total Investment Cost	Not applicable	$5,810,927,000	$3,889,729,000	$122,281,000



Shasta dam during spill.

Hydrology

Flood frequency hydrographs were developed in 1985 for the winter season and are summarized in table 3, below. An updated frequency flood study is recommended for future feasibility-level studies.

Table 3.—Frequency floods for Shasta Dam

Frequency	Volume (15-day) (acre-feet)	Peak inflow (ft^3/s)
25-year	1,773,400	187,000
50-year	2,016,900	219,000
100-year	2,235,600	251,000

Mean monthly streamflow data for Shasta Dam from 1922 to 1996 were obtained from Water Supply reports and were averaged to represent normal inflow conditions. These values range from less than 4,000 ft^3/s (from July through October) to nearly 14,000 ft^3/s (in February and March), as indicated in table 4, below.

Table 4.—Mean monthly streamflow data, Shasta Reservoir

Month	Streamflow (ft^3/s)	Month	Streamflow (ft^3/s)
January	11,201	July	3,815
February	13,981	August	3,430
March	13,609	September	3,482
April	11,603	October	3,963
May	8,189	November	5,637
June	5,339	December	8,525

Determination of a probable maximum flood (PMF) is an estimation of the largest flood that is likely to occur within a basin. This flood is used as a design tool to establish spillway capacities and the size of other physical features incorporated into the dam. The current PMF for Shasta Dam has a peak inflow of 623,000 ft^3/s and a 15-day volume of 4,266,000 acre-feet. This PMF was developed in 1984 using appropriate data available at the time. A review of these data has indicated that a complete reassessment of the PMF would likely lead to a decision to reduce the size of the PMF. A rough approximation of the new PMF peak inflow indicates that it would be about 91 percent of the current value. The new 15-day volume of a revised PMF is estimated to be about 80 percent of the existing PMF volume. Formal determination of the new PMF will be performed for future feasibility-level studies. A smaller design PMF would enable a more efficient design of the spillway to allow more storage at a given height raise. This is particularly significant in the Low Option, where the amount of storage developed is limited by