CHAPTER 6. RESOURCES MANAGEMENT MEASURES

Following development of the planning objectives, constraints, and criteria for the Investigation, the next major step in formulating initial alternatives is to identify and evaluate potential resources management measures. A resources management measure is any structural or non-structural action that could address the planning objectives.

Numerous potential resources management measures have been identified as part of previous studies, projects, and programs to address water resources and related problems and needs in the study area. These measures were developed and reviewed during study team meetings, field inspections, and outreach for the Investigation for their ability to address the planning objectives listed in **Chapter 5**. This chapter generally describes the measures considered, and presents summary information related to their potential new water supplies, construction costs, environmental considerations, hydropower generation effects, and reasons for either retaining or eliminating measures from further development in the Investigation. Surface water storage measures that appear to contribute the least to the planning objectives are dropped from further consideration in this chapter. Several measures are carried forward for further evaluation, comparison, and screening in **Chapter 7**.

The measures discussed in this chapter include surface water and groundwater storage measures to address the primary study objectives and hydropower replacement and flood damage reduction measures to address secondary study objectives. As explained in **Chapter 2**, the study of potential storage measures in the upper San Joaquin River basin is part of a larger CALFED program to address multiple objectives for managing water resources in California involving several subprograms that include a wide array measure types, including water efficiency, water transfers, water quality, conveyance, levee improvements, and other structural and nonstructural measures.

CHAPTER ORGANIZATION

This chapter is organized into the following major sections:

Storage Measures Background. This section presents background on the need for storage to address the primary planning objectives and how surface water and groundwater storage measures are being approached.

Initial Surface Water Storage Measures. This section summarizes the surface water storage measures retained and dropped in Phase 1 of the Investigation, and additional surface water storage measures that were proposed during the scoping process.

Evaluation of Surface Water Storage Measures Retained from Phase 1. This section presents more detailed information related to the surface water storage measures retained from Phase 1 of the Investigation, including their potential new water supply, hydropower generation effects, estimated costs, environmental considerations, and reasons for either retaining or eliminating measures from further development in the Investigation. Many of the surface water storage measures include optional approaches for developing hydropower generation capacity to replace hydropower generation adversely affected by the storage measure. The surface water storage measures address the primary planning objectives.

Surface Water Storage Measures Suggested During Scoping. This section describes components and preliminary evaluations of the upstream surface water storage measures suggested during scoping.

Groundwater Storage and Conjunctive Management Measures. This section summarizes work done during Phase 1 of the Investigation to determine the potential for conjunctive management opportunities. It also describes work performed since Phase 1 in identifying potential conjunctive management projects.

Flood Damage Reduction Measures. This section describes potential changes in flood management that could address one of the secondary planning objectives. Flood management measures included increasing dedicated flood management storage and reducing objective releases from Friant Dam.

STORAGE MEASURES BACKGROUND

As noted in **Chapter 4**, the primary problems in the study area related to the San Joaquin River ecosystem, San Joaquin River water quality, and water supply reliability, require development and management of additional water supplies in the upper San Joaquin River basin. Development and management of new water supplies, consistent with the constraints described in **Chapter 5**, could be accomplished only with additional storage and resulting changes in project operation. In addition, Federal authorization for the Investigation specifically requested a FR for storage.

All of the storage measures presented could support multiple objectives. New water supply developed by increasing storage of San Joaquin River water could be used for any or all of the primary objectives. Because specific restoration, water quality, and water supply reliability objectives have not been established for the Investigation, the quantitative degree to which the storage measures could contribute to any of the objectives is not yet known. Therefore, measures will be evaluated on the basis that they could develop and manage water supplies to contribute to San Joaquin River restoration, improve San Joaquin River water quality, and facilitate additional conjunctive water management in the eastern San Joaquin Valley to reduce groundwater overdraft and support exchanges that improve the quality of water delivered to urban areas.

In general terms, San Joaquin River water could be stored either in surface water reservoirs or in groundwater basins, and a variety of approaches is available for either of these two methods. Surface water storage of San Joaquin River water could be accomplished through enlarging existing reservoirs or developing new reservoirs that could directly receive water from the upper San Joaquin River basin. Examples include raising Friant Dam, potential offstream reservoirs in the upper San Joaquin River basin, or potential off-canal reservoirs served by the Madera or Friant-Kern canals, which receive water diverted at Friant Dam.

Storage of San Joaquin River water also could be achieved through exchanges that involve increasing the storage of water from other watersheds. This approach would require that water from another watershed be captured and held so that water from Millerton Lake could be released earlier for delivery to areas otherwise served by other watersheds, thereby lowering storage levels and allowing the capture of more San Joaquin River water. Water captured in the other watersheds then would be used for later delivery. Implementation of water storage exchange options would require participation by water rights holders in other watersheds and participation by water users who would be affected by changes in delivery sources and patterns.

Groundwater storage could be accomplished by several methods, including increasing deliveries to existing water users in the Friant Division in lieu of groundwater pumping; increasing the rate of groundwater recharge; and developing groundwater banks that would accept water during wet periods and make it available during dry periods. Implementation of groundwater storage measures would require participation by water users who would be affected by changes in the sources and patterns of supplies, and landowners in the vicinity of groundwater storage and extraction facilities.

INITIAL SURFACE WATER STORAGE MEASURES

During Phase 1 of the Investigation, a review of previous regional water resources studies identified 17 potential surface water storage sites for initial consideration (see **Figure 6-1**). Information considered was obtained from multiple sources, including previous studies, field observations by study team members, and from stakeholders. In some cases, the configuration of a surface water storage measure was modified from the project described in previous studies, and information was updated as appropriate. Most sites could be configured at various storage sizes, with each configuration identified as a measure.

The initial list of surface water storage measures included enlarging two existing reservoirs, Lake Kaweah and Lake Success. These measures were dropped from further consideration because they have been authorized for construction. The remaining measures included enlarging existing reservoirs and constructing new reservoirs. Some measures are located in the upper San Joaquin River basin; others are located in watersheds that are served by the Friant Division or would be operated as off-canal storage.

A technical memorandum (TM) was prepared for each surface water storage site considered during Phase 1. Although cost was not a criterion for initial screening, cost information was provided in all of the TMs, which were included as TAs to the October 2003 Phase 1 Investigation Report. Initial review focused on potential construction-related issues that could preclude constructing required facilities, create environmental impacts that could not be mitigated, or create conditions under which permits issued by regulatory agencies or approved by decision-makers would be unlikely. Six surface water storage measures were retained for further analysis and one measure, enlarging Mammoth Pool, is under study by others.

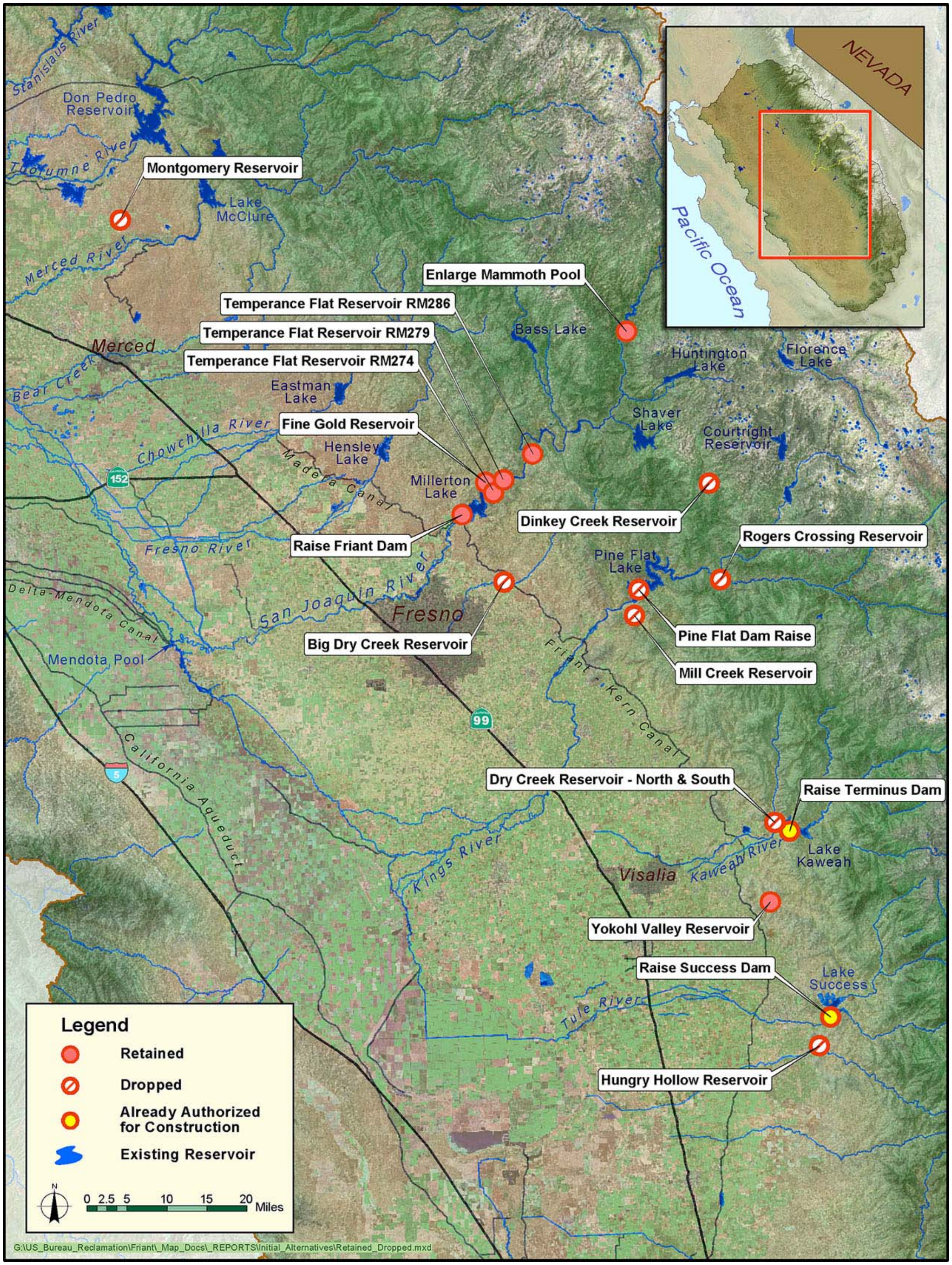

FIGURE 6-1.
SURFACE WATER STORAGE SITES CONSIDERED IN PHASE 1

Surface Water Storage Measures Dropped in Phase 1

This section briefly describes the eight surface storage sites dropped from further consideration during Phase 1. Additional details regarding these measures are provided in the Phase 1 Investigation Report and TAs.

Merced River Watershed - Montgomery Reservoir

Montgomery Reservoir would be an offstream reservoir on Dry Creek, a northern tributary to the Merced River, with a storage capacity of about 240 TAF. It would store flood flows released or spilled from Lake McClure at New Exchequer Dam and diverted from the Merced River at Merced Falls. Water stored in Montgomery Reservoir would be used to meet water needs in Merced Irrigation District (MID), allowing water stored in Lake McClure to be used in exchange for other purposes. Initial review of this measure suggested that the stored water would likely be subject to algal growth and relatively high evaporative losses. This measure was dropped from further consideration because MID expressed concern regarding the quality of the water and indicated it would not be interested in pursuing this measure.

San Joaquin River Dry Creek Watershed - Big Dry Creek Reservoir

Big Dry Creek Reservoir, an existing flood detention basin near Clovis, is operated by the Fresno Metropolitan Flood Control District. The zoned earthfill embankment dam could create a reservoir with approximately 30 TAF of storage; however, due to seepage concerns and insufficient inflow, the total storage capacity has not yet been tested. Consequently, uncertainty remains regarding the existing dam’s ability to store more than a few thousand acre-feet of water. Modifications to enable long-term storage may require extensive reconstruction. Based on these concerns, enlarging the Big Dry Creek Flood Control Basin for long-term water storage was dropped from further consideration.

Kings River Watershed - Raise Pine Flat Dam

Raising the gross pool elevation of Pine Flat Reservoir by 20 feet would provide 124 TAF of additional storage. Additional water developed from an enlarged Pine Flat Reservoir would be exchanged for Friant Division water. Early in the year, water from Millerton Lake would be delivered to Pine Flat water users, thereby creating additional storage space in Millerton Lake to capture San Joaquin River flows. Kings River water that otherwise would have been delivered would be retained in the enlarged Pine Flat Reservoir. Later in the year, water from Pine Flat would be delivered to the Friant-Kern Canal in lieu of releases from Millerton Lake. Implementation of this measure would require collaboration with the Corps and the Kings River Conservation District (KRCD), which represents the users of water stored in Pine Flat Reservoir. This measure was dropped from further consideration because it was not supported by KRCD.

Kings River Watershed - Mill Creek Reservoir

Measures at this site would involve construction of a 250-foot-high dam on Mill Creek, which joins the Kings River approximately 1.7 miles downstream of Pine Flat Dam, to create a reservoir with a storage capacity of up to 200 TAF. Excess flows in the Kings River would be diverted by gravity into Mill Creek Reservoir by means of a 5,000-foot-long, 10-foot-diameter, unlined tunnel. This measure would require participation by KCRD to facilitate water exchanges similar to the approach described for the Raise Pine Flat Dam measure. KCRD is not interested in this measure. In addition, an extensive sycamore alluvial woodland is located in the lower reaches of Mill Creek near its confluence with the Kings River (Corps, 1994). This is a rare and sensitive habitat type that hosts a diverse assemblage of wildlife, particularly birds. It is anticipated that creation of Mill Creek Reservoir would result in unmitigable negative impacts to the sycamore alluvial woodland habitat. This measure was dropped from further consideration.

Kings River Watershed - Rodgers Crossing Reservoir

A dam at Rodgers Crossing would be located on the main stem of the Kings River, above Pine Flat Reservoir, approximately one-half mile upstream of the confluence with the North Fork. Reservoir sizes of 295 TAF and 950 TAF were considered. Stored water would be exchanged with Millerton Lake water, similar to the approach described for the Raise Pine Flat Dam measure. The Kings River is one of the least disturbed large rivers in California and its wild trout population is considered one of the best in the state. Upstream of Pine Flat Reservoir, the Kings River also supports whitewater recreation. Both measures would inundate a portion of the Kings River Special Management Area, and the larger measure would inundate a portion of the river that has been Federally designated as a Wild and Scenic River, which would violate expressed Congressional intent. A reservoir at Rodgers Crossing also would affect a Wild Trout Fishery, as designated by DFG. This measure was dropped from further consideration.

Kings River Watershed - Dinkey Creek Reservoir

A dam and reservoir on Dinkey Creek, in the upper watershed of the North Fork of the Kings River, would be located within the SNF at over elevation 5,400. It would create a 90 TAF reservoir that would be operated to exchange with Millerton Lake water, similar to the approach described for the Raise Pine Flat Dam measure. Dinkey Creek is a popular recreation area and trout fishing destination; developing this measure would fundamentally alter the existing recreation-based community in the region. A flow reduction also could reduce available habitat, particularly during spring and summer when rainbow trout are spawning and rearing. Changes in water temperature below the dam could adversely affect trout, and the dam would impede migration. This measure was dropped from further consideration.

Kaweah River Watershed - Dry Creek Reservoir

Measures at this site would include a new dam and reservoir on Dry Creek, which is a tributary to the Kaweah River, just downstream and northwest of Lake Kaweah at Terminus Dam. A 70 TAF reservoir would store local inflow and water diverted from Lake Kaweah through a 7,600-foot-long gravity tunnel. Because stored water would be exchanged with Millerton Lake water, this measure would require participation by Kaweah River water users. A sycamore alluvial woodland exists near the confluence of Dry Creek and the Kaweah River. As with the Mill Creek Reservoir measure, it is anticipated that adverse effects to the sycamore alluvial woodland could not be mitigated. Consequently, this measure was dropped from further consideration.

Tule River Watershed - Hungry Hollow Reservoir

Measures at this site would involve construction of a dam and reservoir on Deer Creek, a tributary to the Tule River about 3 miles south and downstream of Lake Success and 6 miles east of Porterville. The reservoir would have a storage capacity of up to 800 TAF and could store water from Friant-Kern Canal or water diverted from Lake Success. This would involve exchanging water with Millerton Lake water and would require participation by Lake Success water users. Phase 1 studies found that construction of a dam at this site could be costly because extensive young alluvial deposits, over 300 feet thick that lie beneath the potential dam axis could be subject to liquefaction during an earthquake. The reservoir also would inundate up to 8 miles of Deer Creek, which supports well-developed sycamore alluvial woodland, a rare and regionally important wildlife habitat for which mitigation may not be possible. This measure was dropped from further consideration because of likely cost and environmental considerations.

Surface Water Storage Measures Retained from Phase 1

This section briefly describes the six surface water storage sites retained from Phase 1. The locations of surface water storage sites retained from Phase 1 studies are shown in **Figure 6-2**. Each site could be configured at various storage sizes, with each configuration identified as a measure. Detailed evaluation of these measures is presented later in this chapter. In addition, the potential enlargement of Mammoth Pool was retained from Phase 1. Because this site is under study by others, it is not addressed in this report.

Raise Friant Dam

Measures at this site would involve raising the height of Friant Dam and constructing necessary saddle dams to enlarge Millerton Lake. Three reservoir enlargement measures considered include a 25-foot, 60-foot, or 140-foot raise of Friant Dam. For each measure, Friant Dam would be raised by adding conventional mass concrete or overlays of roller-compacted concrete (RCC) to the dam crest and the dam’s downstream face, and constructing a saddle dam to contain the reservoir at a low point on the southwestern rim. These raise sizes would increase reservoir storage capacity by between 125 TAF and 920 TAF.

Temperance Flat Reservoir

Measures at this site would involve constructing a new dam and reservoir at one of three potential dam sites on the San Joaquin River mainstem, between the existing Friant and Kerckhoff dams, at RM 274, RM 279, or RM 286. The RM 274 and RM 279 sites are situated in a narrow portion of upper Millerton Lake, above the confluence with Fine Gold Creek and below Temperance Flat proper. RM 286 is about 5 miles upstream from Temperance Flat itself, in a narrow portion of the San Joaquin River canyon. Potential reservoir sizes range from 460 TAF to over 2.7 MAF.

Fine Gold Reservoir

Measures at this site would involve constructing a dam and reservoir on Fine Gold Creek, which flows into Millerton Lake about 5 miles upstream of Friant Dam. Water would be pumped from Millerton Lake and supplemented by local inflow from Fine Gold Creek. Reservoir sizes range from approximately 130 TAF to 800 TAF.

Yokohl Valley Reservoir

Measures at this site would involve constructing a dam and reservoir with a capacity of up to 800 TAF in Yokohl Valley. The reservoir would store water pumped from the Friant-Kern Canal and a minor amount of local runoff from Yokohl Creek.

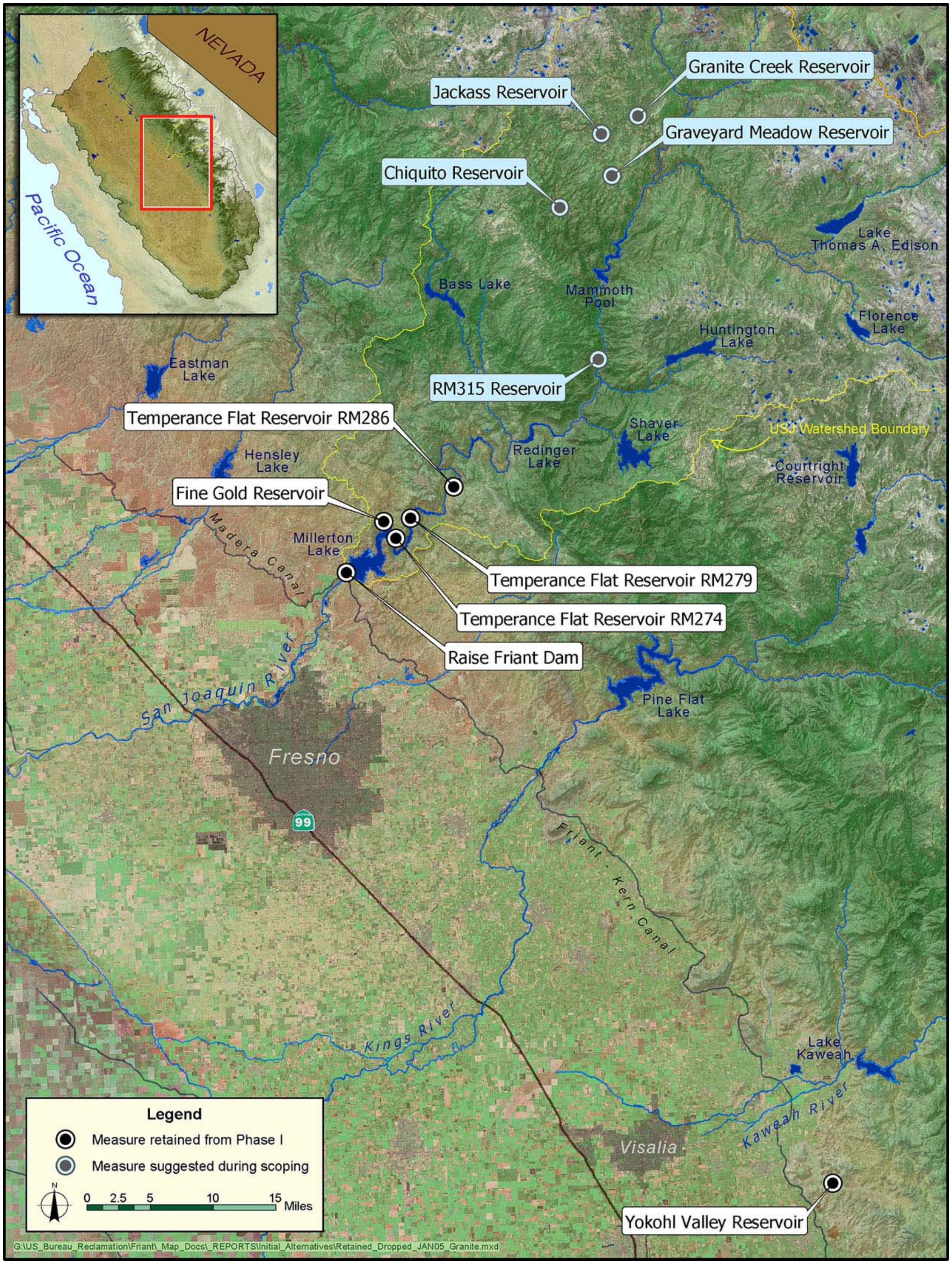

FIGURE 6-2.
SURFACE WATER STORAGE SITES RETAINED FROM PHASE 1 AND SUGGESTED DURING SCOPING

Surface Water Storage Measures Suggested During Scoping

As noted in the October 2003 Phase 1 Investigation Report, most of the surface water storage measures retained from Phase 1 would result in a net loss in power generation. In March 2004, Reclamation and DWR held a series of scoping meetings to initiate development of an EIS and EIR. During scoping, power utilities that own and operate hydropower projects in the upper San Joaquin River basin raised concerns about impacts of lost power generation and the ability of retained measures to develop adequate replacement power. These hydropower stakeholders suggested additional potential reservoir sites that could store water supplies from the upper San Joaquin River without adversely affecting existing hydropower facility operations.

Four of the suggested reservoir sites were considered in previous studies of the Granite and Jackass-Chiquito hydroelectric projects by the Upper San Joaquin River Water and Power Authority (USJRWPA) in the late 1970s and early 1980s. These projects have not been constructed. Granite Creek and Graveyard Meadow reservoirs are storage components of the Granite Project and Jackass and Chiquito reservoirs are storage components of the Jackass-Chiquito Project. These reservoir sites are located upstream of Mammoth Pool and would store water diverted from the North Fork San Joaquin River and other tributaries to Mammoth Pool reservoir. A fifth reservoir site, located on the San Joaquin River at RM 315 downstream of Mammoth Pool Reservoir, was suggested based on a conceptual understanding of historical flood spills over Mammoth Dam. All of these suggested sites are located upstream of Redinger Lake, as shown in **Figure 6-2**.

The reservoir sites suggested during scoping were evaluated as three surface water storage measures: the Granite Project, Jackass-Chiquito Project, and RM 315 Reservoir. Total storage capacities for these suggested measures range from 9 to approximately 200 TAF. The scoping comments also suggested combining these upstream storage measures with a gravity diversion tunnel from Kerckhoff Lake to a Fine Gold Reservoir.

EVALUATION OF SURFACE WATER STORAGE MEASURES RETAINED FROM PHASE 1

This section describes the technical characteristics of surface water storage measures retained from Phase 1. The evaluation is based on technical studies completed during and after Phase 1 and a review of previous studies. Each size and/or configuration of a storage site is considered a separate measure. For each surface water storage measure, information is presented related to site characteristics, dam design considerations, potential new water supply, hydropower generation effects, estimated costs, and environmental considerations. Based on this information, recommendations are made regarding whether the measure will be dropped from further consideration in the Investigation, or retained for comparison with other measures that provide similar new water supply in **Chapter 7**.

All cost estimates are represented at July 2004 price levels. Construction cost estimates for the surface water storage measures represent the sum of field costs and indirect costs for planning, engineering, design, and construction management, which are estimated at 25 percent of field costs. Cost estimates for each measure do not include environmental mitigation, new or relocated recreation facilities, or acquisition of impacted power generation facilities and compensation for loss of future power generation associated with the Raise Friant Dam and three Temperance Flat Reservoir locations. These costs will be estimated during a later stage of the Investigation. Information on engineering assumptions and cost estimates is included in the **Engineering TA** and information on hydropower evaluations is included in the **Hydropower TA**.

Raise Friant Dam

Friant Dam impounds Millerton Lake and is a 319-foot-high concrete gravity dam on the San Joaquin River, located about 20 miles northeast of Fresno. Options for increasing storage in Millerton Lake involve raising the dam up to 140 feet. Three specific optional dam raise heights were considered, including 25-foot, 60-foot and 140-foot raises. For all three sizes considered, Friant Dam would be raised by adding an overlay of RCC on the downstream face, as illustrated in **Figure 6-3**.

The dam crest would be extended vertically and defining features of the spillway and stilling basin would be reconstructed. In addition to the dam raise, up to three earthfill saddle dams would be required to contain the reservoir. The most extensive would be a saddle dam on the southwest rim of the reservoir (i.e., left side, looking downstream). Two additional, but considerably smaller, saddle dams would be required on the northwest side of Millerton Lake. Up to 2 miles of Millerton Road would need to be rerouted.

A 25-foot raise, which would increase storage capacity by about 130 TAF, would require a saddle dam approximately 3,000 feet long at the southwest shoreline. A 60-foot raise would increase capacity by 340 TAF and entail raising the dam crest and constructing approximately 8,500 feet of new saddle dams. A 140-foot raise would increase the storage capacity of Millerton Lake by approximately 920 TAF and would require new saddle dams of approximately 9,500 feet in total length. **Figure 6-4** shows the extent of an enlarged Millerton Lake and facilities associated with raising Friant Dam 140 feet.

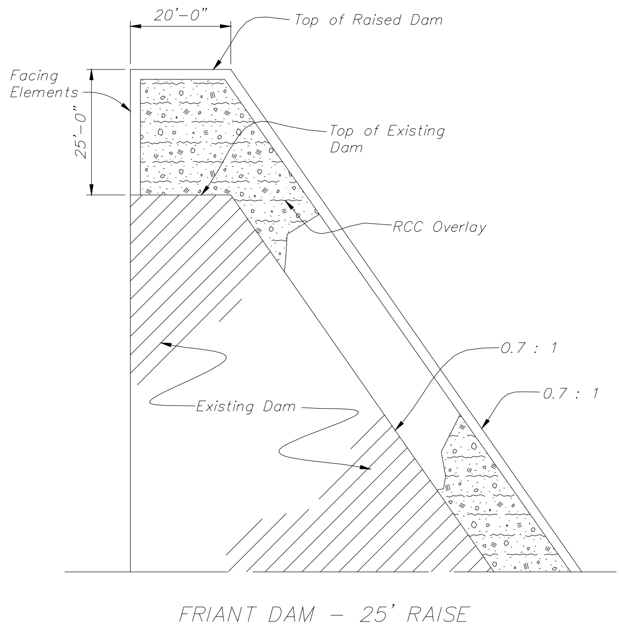

FIGURE 6-3.
FRIANT DAM RAISE SIMPLIFIED CROSS SECTION

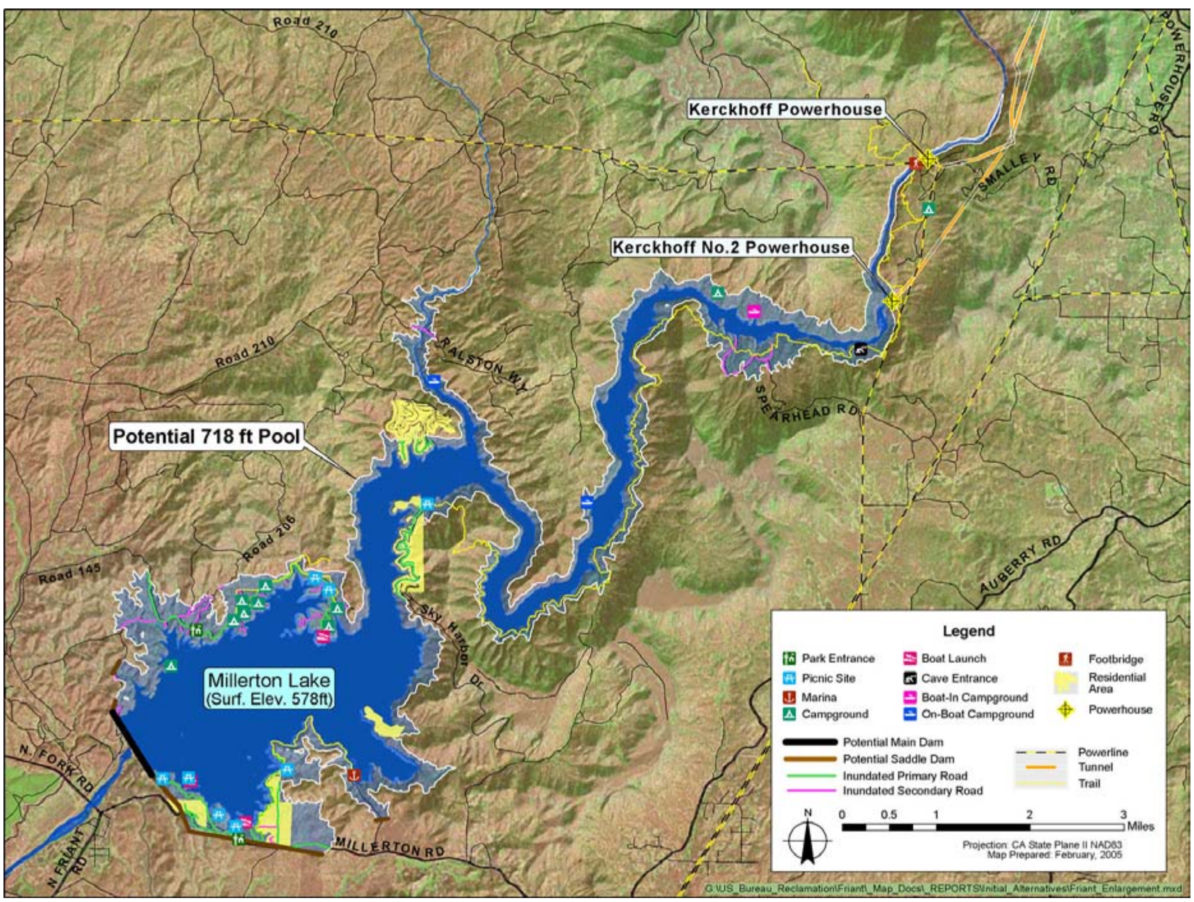

FIGURE 6-4.
POTENTIAL ENLARGEMENT OF MILLERTON LAKE

Potential New Water Supply

An enlarged Friant Dam and Millerton Lake would capture additional flow on the San Joaquin River. Additional storage capacity would provide opportunities to store larger flood volumes than with the current reservoir. Stored water would be available for diversion to the Friant-Kern Canal, the Madera Canal, and/or released to the San Joaquin River.

CALSIM water operations model simulations completed during Phase 1 indicate that the potential new water supply resulting from raising Friant Dam 140 feet could be up to about 150 TAF/year on average. As summarized in **Table 6-1**, development of new water supplies varies in relationship to the amount of new storage created and management of the new water. The table shows that releasing water to the San Joaquin River could result in developing more new water supply than releasing new water supplies to the Friant-Kern and Madera canals only. This is because water deliveries are limited by contract amounts and available conveyance capacity, whereas simulated releases to the river were maximized to the extent that they would not reduce water deliveries from without-project levels. The new water supply for restoration flow single-purpose analysis is higher than that for water quality analysis because releases would be made earlier in the year, providing more opportunity to capture San Joaquin River inflow during late spring months. A more detailed description of the single-purpose analyses is presented in the Phase 1 Investigation Report.

TABLE 6-1.
NEW WATER SUPPLY FROM FRIANT DAM RAISE SIZES

Friant Dam Raise Height (feet)	Gross Pool Elevation (feet above msl)	New Storage Capacity (TAF)	New Water Supply Estimated in Single-Purpose Analysis (average TAF/year)		
			RF	WQ	WS
25	603	130	n/s	n/s	24
45	623	250	n/s	n/s	51
60	638	340	n/s	n/s	68
75	653	440	n/s	n/s	93
112	690	700	152	139	128
140	718	920	n/s	n/s	146

Key:
msl – mean sea level
n/s – not simulated
RF – San Joaquin River restoration flow single-purpose analysis
TAF – thousand acre-feet
WQ – San Joaquin River water quality single-purpose analysis
WS – water supply reliability single-purpose analysis

Hydropower Generation Effects and Potential Replacement Power Options

As shown schematically in **Figure 6-5**, any raise of Friant Dam would affect power generation at the Kerckhoff No. 2 Powerhouse. For a 25-foot raise, it is anticipated that a concrete wall would be constructed to protect the Kerckhoff No. 2 Powerhouse adit from raised water surfaces; however, energy generation would be reduced due to increased tailwater elevation. For any raise substantially greater than a 25-foot raise, it is anticipated that the Kerckhoff No. 2 Powerhouse would be inundated, resulting in the loss of all existing generation at this facility.

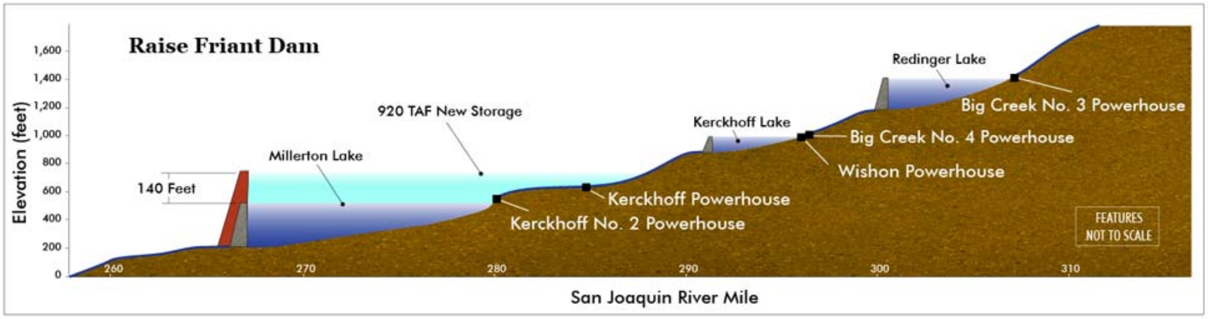

FIGURE 6-5.
HYDROPOWER FEATURES AFFECTED BY
FRIANT DAM RAISE

Raises of Friant Dam above about 60 feet would begin to affect power generation at the Kerckhoff Powerhouse due to increased tailwater elevation. It is expected that the Kerckhoff Powerhouse would be inundated for raises greater than about 90 feet, resulting in the loss of all existing generation from the Kerckhoff Hydroelectric Project.

Table 6-2 summarizes estimated energy generation and losses for each of the three sizes considered for raising Friant Dam. Generation and loss estimates were made using a monthly timestep spreadsheet model that accounts for flow and head at each affected and potential new or modified power facility. Raising Friant Dam up to about 25 feet would not significantly affect power generation. Reduced power generation at the Kerckhoff No. 2 Powerhouse due to increased tailwater elevations would be offset by increased generation at the Friant Power Project on Friant Dam as a result of increased flows through the powerhouses, increased head, and new, larger turbine-generator units.

Raising Friant Dam more than 25 feet would significantly affect power generation and would likely require replacement power generation measures. As noted in **Table 6-2**, a raise of 60 feet would reduce existing generation by 473 gigawatt-hours (GWh) per year on average due to the loss of the Kerckhoff No. 2 Powerhouse, and a raise of 140 feet would reduce existing generation by 507 GWh/year on average due to the loss of the Kerckhoff No. 2 and Kerckhoff powerhouses. For both of these options, the potential to develop replacement power was considered through a possible replacement of the Kerckhoff No. 2 Powerhouse to an elevation corresponding with the gross pool of a raised Millerton Lake and new larger turbine-generator units at the Friant Power Project powerhouses. As shown, generation from a relocated Kerckhoff No. 2 Powerhouse, in combination with additional generation at the Friant Power Project, would result in a decrease in net power generation of about 40 GWh/year for a 60-foot raise and a net loss of more than 100 GWh/year, on average, for the 140-foot raise.

**TABLE 6-2.
ESTIMATED ENERGY GENERATION AND LOSSES FOR
FRIANT DAM RAISE HEIGHTS**

Dam Raise (feet)	New Storage Capacity (TAF)	Gross Pool Elevation (feet above msl)	Estimated Additional Energy Generation			Estimated Losses of Energy Generation		Net Energy Generation (GWh/year)
			Operating Scenario	Estimated Additional Generation at Friant Power Project (GWh/year)[1]	Estimated Generation at Kerckhoff No. 2 Replacement Powerhouse (GWh/year)	Powerhouses Potentially Affected	Estimated Reduction in Existing Energy Generation (GWh/year)[2]	
25	130	603	WS	32	---[4]	Kerckhoff No. 2 reduced head (25 feet)	-32 [3]	0
60	340	638	WS	65	365	Kerckhoff No. 2	-473	-43
140	920	718	WS	112	274	Kerckhoff, Kerckhoff No. 2	-507	-121

Key
GWh/year – gigawatt-hour per year
msl – mean sea level
TAF – thousand acre-feet
WS – water supply single-purpose analysis

Notes:
[1] Generation above estimated without-project Friant Power Project generation.
[2] Based on estimated generation numbers from without-project spreadsheet simulations.
[3] Without-project Kerckhoff No. 2 Powerhouse generation times ratio of head reduction to present head.
[4] A 25-foot raise of Friant Dam does not inundate any powerhouses; no replacement generation needed.

Cost Estimates

Construction costs associated with raising Friant Dam increase substantially as the level of raise is increased. Increases in construction costs are attributed in part to the amount of concrete work needed and the volume of material needed for constructing new saddle dams around the reservoir. In addition, construction costs for replacement energy generation facilities are included with the higher raise options, and property acquisition costs increase as dam crest elevation increases. **Table 6-3** summarizes construction costs for Friant raise measures.

Privately owned lands, including numerous residential properties around Millerton Lake and existing improvements on those lands, would need to be acquired in the expanded reservoir area associated with a raise of Friant Dam. Acquisition costs are included in the construction costs shown for the dam raise (RCC overlay and saddle dams), along with an allowance of 20 percent of the property costs for indirect costs associated with property acquisition transactions. It is assumed that no land acquisition is required for the construction site since lands are already public and held either by Reclamation or other Federal agencies.

TABLE 6-3.
CONSTRUCTION COSTS FOR RAISE FRIANT DAM MEASURES
($ MILLION)

Dam Raise Height (feet)	**25**	**60**	**140**
New Storage Capacity (TAF)	**130**	**340**	**920**
Storage Components			
RCC Overlay, Saddle Dams, Reservoir Lands	170	390	970
Concrete Wall to protect Kerckhoff No. 2 Powerhouse Access	2	-	-
Abandon Kerckhoff No. 2 Powerhouse	-	2	2
Abandon and Restore Kerckhoff Powerhouse	-	-	4
Abandon Intake for Kerckhoff Powerhouse	-	-	1
Millerton Road Relocation	28	28	28
Construction Cost, Storage Components	**200**	**420**	**1,005**
Replacement Power Components			
Additional Generation Capacity at Friant Dam (5, 13 or 30 MW)[1]	18	49	115
New Kerckhoff No. 2 Powerhouse (40 to 90 MW)	-	130	88
Construction Cost, Replacement Power Components	**18**	**179**	**203**
Construction Cost[2, 3]	**218**	**599**	**1,208**

Key:
RCC – roller-compacted concrete
TAF – thousand-acre feet
Notes:

[1] Additional generation capacity provided by replacing one or more existing units with new larger units.

[2] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design and construction management, estimated at 25 percent of field costs.

[3] Costs do not include environmental mitigation, new or relocated recreation facilities, acquisition of impacted power facilities, or compensation for lost future power generation.

Costs are included in **Table 6-3** for relocating Millerton Road and constructing a replacement powerhouse that would discharge to Millerton Lake. For the 60-foot raise, it is estimated that the reduced head would support a 90 MW powerhouse, which is significantly less than the installed capacity of 155 MW at the existing Kerckhoff No. 2 Powerhouse. For the 140-foot raise, the reduced head would support a 40 MW powerhouse. Costs also are included for new turbine-generator units at the Friant powerhouses.

Figure 6-6 shows construction cost in relation to the new storage capacity that would be developed by the Raise Friant Dam measures. As evident, costs increase significantly above a 25- foot raise because the Kerckhoff No. 2 Powerhouse would be inundated and additional costs would be incurred to construct replacement generation facilities.

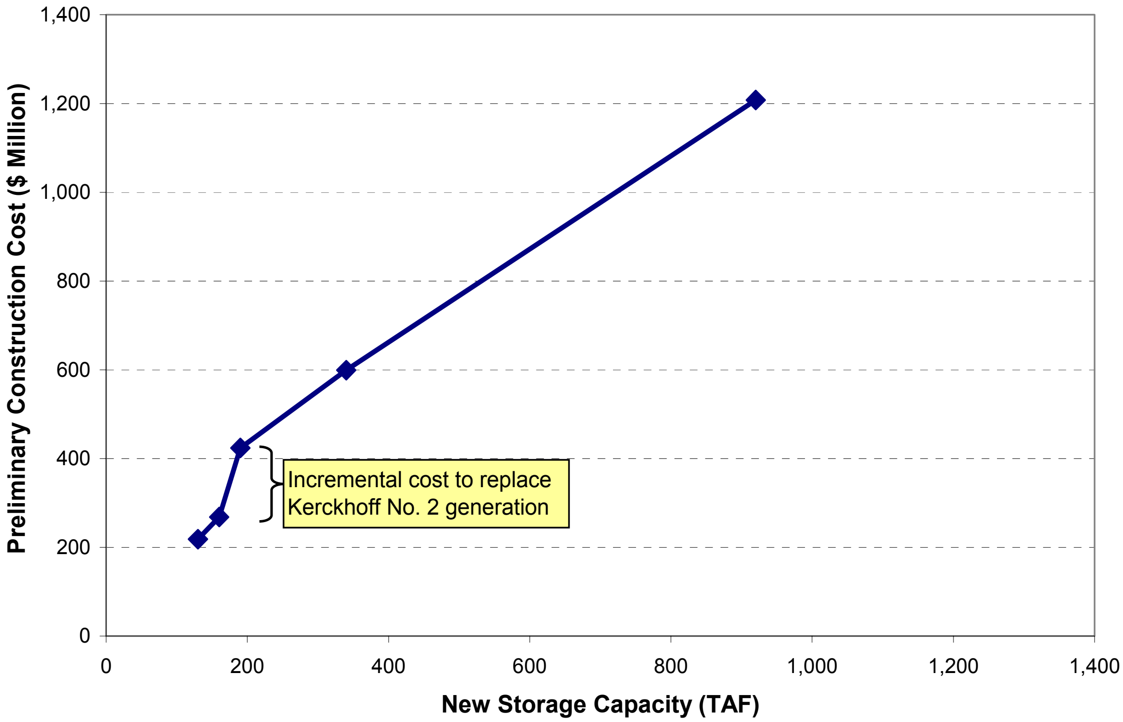

FIGURE 6-6.
CONSTRUCTION COSTS FOR RAISE FRIANT DAM MEASURES VS. NEW STORAGE CAPACITY

Environmental Considerations

Raising Friant Dam and the level of Millerton Lake would impact vegetation, wildlife and fisheries, recreation, land use, and cultural resources. Affected river reaches, as described in **Chapter 3**, include the Millerton Lake and Big Bend, Temperance Flat and Millerton Bottoms, and Patterson Bend reaches of the San Joaquin River. Raising Millerton Lake also would affect the lower portions of Fine Gold Creek, an ADMA.

Any raise of Friant Dam would extend Millerton Lake beyond its current shoreline and decrease the length of river between Millerton Lake and Kerckhoff Dam. The extent of habitat loss and the combined numbers of vegetation and wildlife species that may be affected would increase in magnitude as larger reservoir sizes are considered, and could result in design or operational constraints. Several special status species occur in the region. **Table 6-4** summarizes the special status species, identified in **Chapter 3,** occurring in each river reach potentially affected by a raise of Friant Dam. For convenience, information pertaining to additional storage measures is also provided in **Table 6-4**. Potential impacts to vegetation and wildlife species are anticipated to be proportional to the increase in the mean pool elevation of Millerton Lake.

TABLE 6-4.
SPECIAL STATUS SPECIES TOTALS BY RIVER REACH POTENTIALLY AFFECTED BY SURFACE STORAGE MEASURES

	Millerton Lake/ Big Bend	Temperance Flat/ Millerton Bottoms	Patterson Bend	Kerckhoff Lake/ Horseshoe Bend	Mammoth Reach	Granite Creek	Jackass Creek	Chiquito Creek	Fine Gold Creek	Yokohl Valley
SPECIAL STATUS PLANT SPECIES REPORTED PRESENT IN THE STUDY AREA										
Federally Listed and/or State-Listed	5		1	1						2
Federal and/or State Rare										
State/Management Agency Species of Concern	1									2
Special Interest Species of Concern						3	3	3		
SPECIAL STATUS PLANT SPECIES POTENTIALLY PRESENT IN THE STUDY AREA										
Federally Listed and/or State-Listed	6	6	6	2					6	3
Federal and/or State Rare						1	1	1		
State/Management Agency Species of Concern	3	3	3	2	5	6	6	6	2	2
Special Interest Species of Concern				1		10	10	11		2
SPECIAL STATUS ANIMAL SPECIES REPORTED PRESENT IN THE STUDY AREA										
Federally Listed and/or State- Listed	2	2	2	2	1				1	1
Federal and/or State Candidate for Listing	1	1	1	1	1					
Federal and/or State Candidate for Delisting	1	1	1	1	1					
State/Management Agency Species of Concern	4	6	6	3	1	2	2	2	2	3
SPECIAL STATUS ANIMAL SPECIES POTENTIALLY PRESENT IN THE STUDY AREA										
Federally Listed and/or State-Listed	8	9	9	9	7	6	6	7	2	4
Federal and/or State Candidate for Listing	2	2	2	2	3	2	2	2		1
Federal and/or State Candidate for Delisting	2	2	2	2	2					
State/Management Agency Species of Concern	15	21	21	15	16	17	17	17	6	4
STORAGE MEASURE	POTENTIALLY AFFECTED AREA									
Raise Friant Dam 25 feet	▒	▒							▒ (partial)	
Raise Friant Dam 60-140 feet	■	■	■ (partial)						■ (partial)	
Temperance Flat RM 274 900-985 feet above msl	▒	▒	▒							
Temperance Flat RM 274 1100 feet above. msl	■	■	■	■ (partial)						
Temperance Flat RM 279 900-985 feet above msl		▒	▒							
Temperance Flat RM 279 1100 feet above msl		■	■	■ (partial)						
Temperance Flat RM 286 1200-1400 feet above msl			▒	▒						
RM 315 Reservoir 3000 feet above msl					■					
Granite Creek Reservoir						▒				
Jackass and Chiquito Reservoirs							■	■		
Fine Gold Reservoir									▒	
Yokohl Valley Reservoir										■

The 60-foot and 140-foot raises of Friant Dam would inundate additional lotic habitat of native fishes between Friant Dam and Kerckhoff Dam, and likely establish lentic habitat favored by introduced game fishes. Additionally, a raise of Friant Dam would extend the inundation pool of Millerton Reservoir into the Fine Gold Creek watershed, and may lead to increased invasion of non-native fishes, such as bass species. Potential impacts to fisheries are expected to be proportional to the storage size considered for the Raise Friant measure, with the lower raise measure likely creating lesser impacts to fisheries.

Any raise of Millerton Lake would affect numerous recreational facilities associated with the Millerton Lake SRA on the current shoreline. It is anticipated that recreation facilities would be relocated and would remain accessible, although specific locations for replacement recreation facilities and corresponding costs have not been identified yet. Opportunities for additional recreational opportunities would result from higher or longer storage levels in Millerton Lake; these would increase the reservoir surface area during peak recreation months. Raising Friant Dam could impact the Millerton Bottoms and Patterson Bend whitewater runs, depending on how the enlarged reservoir is operated. A 60-foot raise or higher would inundate several mines associated with the abandoned Sullivan mine in Temperance Flat. A 25-foot raise of Millerton Lake would inundate the lower segment of the Millerton Lake Caves near the shoreline of Millerton Lake, and raises of 60 and 140 feet would inundate all entrances to the Millerton Lake Caves system.

Raising the level of Millerton Lake would affect residential properties around the reservoir. All private property subject to inundation would be acquired. A 25-foot raise would begin to inundate portions of four residential developments at Millerton Lake and portions of residential property at Temperance Flat. All developed property in the portion of Lakeview Estates east of the SRA boat launch area would be inundated by a 60-foot raise. A 140-foot raise also would completely inundate the developed portion of the Winchell Bay development and Temperance Flat residences.

Archaeological sites within or near the existing pool of Millerton Lake, as well as sites upstream to the Patterson Bend reach, would be adversely affected by raising the level of Millerton Lake up to 140 feet.

Recommendations for Further Study

Friant Dam raises of 25 and 60 feet will be retained for further evaluation and comparison with other measures that provide similar water supply, as described in **Chapter 7**. Raises of Friant Dam above 60 feet do not appear to be viable measures for continued study. Key concerns include extensive residential relocation, significant losses of power generation, and environmental impacts around Millerton Lake, along the San Joaquin River, and in the Fine Gold Creek watershed. Therefore, raises of Friant Dam greater than 60 feet are dropped from further consideration in the Investigation.

Temperance Flat Reservoir Measures

Temperance Flat is a wide, bowl-shaped topographic feature in the upper portion of Millerton Lake, approximately 13 miles upstream of Friant Dam, at about RM 281. Initially, four potential dam sites were identified between Friant Dam and Kerckhoff Dam on the basis of topographic characteristics and previous studies. Three of these sites, at RM 274, RM 279, and RM 280, would result in the inundation of Temperance Flat. A fourth site, at RM 286, is upstream of Temperance Flat and could be considered a downstream enlargement of Kerckhoff Lake. For purposes of the Investigation, all potential dam sites on the mainstem of the San Joaquin River between Friant Dam and Kerckhoff Dam are referred to as Temperance Flat sites.

Temperance Flat Reservoir would capture the flow of the San Joaquin River before it enters Millerton Lake. Water would be released from Temperance Flat Reservoir to Millerton Lake for canal diversion and/or release to the San Joaquin River. Operating criteria for the two reservoirs could be influenced by ecosystem needs in the reservoirs, recreation opportunities, and hydropower generation.

An initial comparison of site features showed that the RM 279 site is superior to the RM 280 site. These sites are close in proximity and would result in similar environmental effects for a reservoir at a given elevation. Both sites have similar geologic conditions, would be accessed in the same manner, would use a portion of the Temperance Flat area as a construction lay-down area, would have similar cofferdam and river diversion requirements, and would obtain dam materials from the same general borrow area. A dam at RM 280, however, would require more material than a dam at RM 279 to create the same storage capacity at a higher cost. Therefore, RM 280 was dropped from further consideration. The remaining three Temperance Flat dam sites are shown in **Figure 6-7**, and are described in the following sections.

Foundation conditions at all of the dam sites considered for Temperance Flat measures would be competent granitic rock. Foundation preparation would be typical for each measure.

Potential New Water Supply

Constructing a dam at any of the three Temperance Flat locations could create a reservoir of up to 2 MAF or greater in storage capacity, depending on the height of the dam. Reservoir operations simulations completed during Phase 1 considered a range of storage capacities for a Temperance Flat Reservoir. Because the relationship of storage volume to surface area is similar for the three reservoir measures, estimated losses to evaporation would be similar for all three measures and modeling results would be generally applicable to all three sites. Initial estimates of new water supplies that could be developed with a Temperance Flat Reservoir are listed in **Table 6-5**. As indicated, preliminary results show that the average annual new water supply, measured as additional water available for delivery or controlled releases to the river, would approach 200 TAF/year for a reservoir in excess of 2 MAF storage capacity.

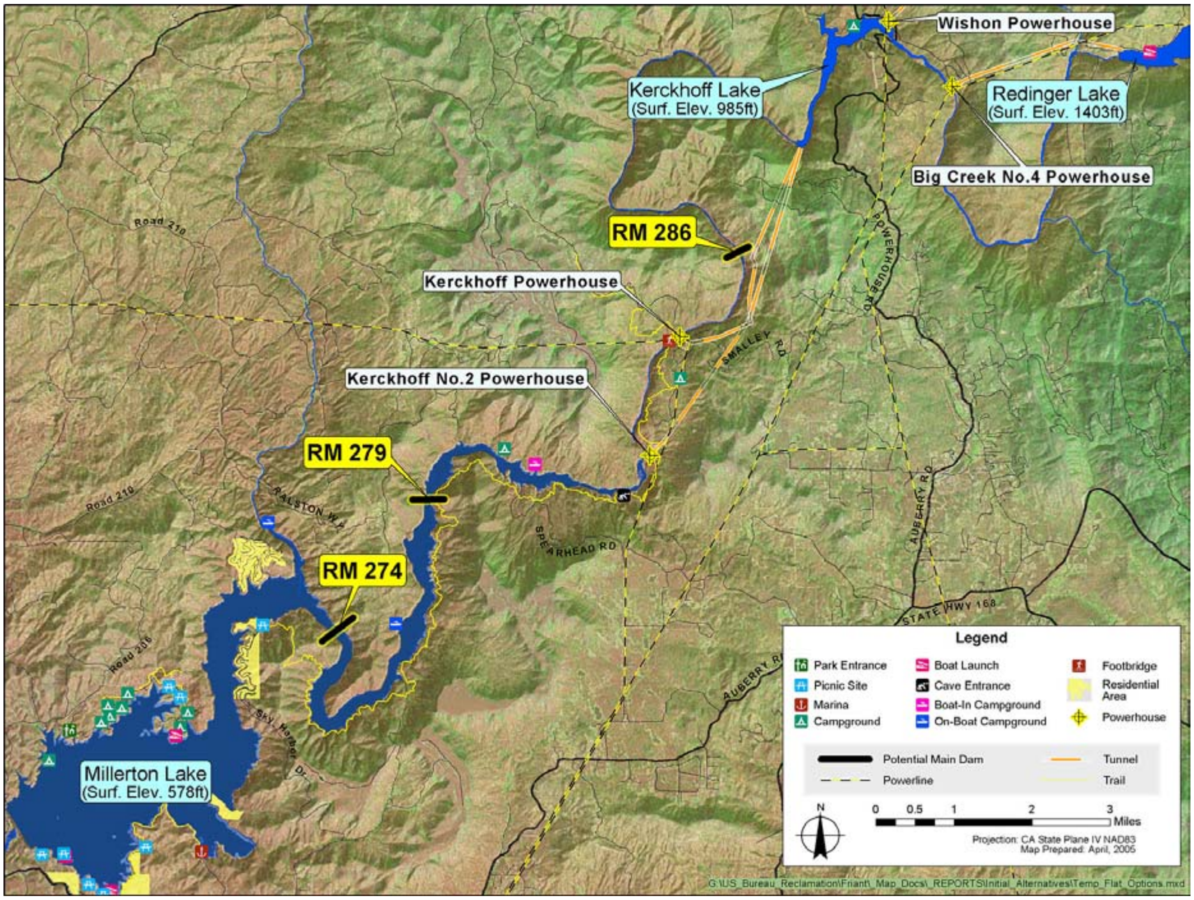

FIGURE 6-7.
POTENTIAL TEMPERANCE FLAT DAM SITES

TABLE 6-5.
NEW WATER SUPPLY FROM TEMPERANCE FLAT RESERVOIR SIZES

New Storage Capacity (TAF)	New Water Supply Estimated in Single-Purpose Analysis (average TAF/year)		
	WS	WQ	RF
725	122	123	146
1,350	168	187	185
2,100	197	n/s	n/s

Key:
n/s – not simulated
RF – San Joaquin River restoration flow single-purpose analysis
TAF – thousand acre-feet
WQ – San Joaquin River water quality single-purpose analysis
WS – water supply reliability single-purpose analysis

Potentially Affected Hydropower Facilities

As described in **Chapter 3**, the upper San Joaquin River basin upstream from Millerton Lake is extensively developed for hydropower generation. PG&E and SCE own and operate multi-facility hydropower projects that affect inflow to Millerton Lake. In the evaluation of Temperance Flat Reservoir measures, several hydropower impact and potential replacement evaluations were completed, as described in the **Hydropower TA**.

To facilitate the evaluation, approximate break points were identified that would correspond to storage capacities for each Temperance Flat measure that would impact power generation facilities. In general, a break point was identified for storage capacities that would inundate powerhouses that discharge into Kerckhoff Lake and capacities that would inundate powerhouses that discharge into Redinger Lake.

Storage capacities above 1,310 TAF for the RM 274 site and above 725 TAF for the RM 279 site would result in inundation of powerhouses that discharge into Kerckhoff Lake. A capacity of about 725 TAF at the RM 286 site would correspond to a reservoir elevation at about the lower part of the spillway at Redinger Dam. A reservoir capacity greater than 1,360 TAF at the RM 286 site would begin to affect the Big Creek No. 3 Powerhouse, which discharges into Redinger Lake.

Because impacts to existing hydropower facilities from the various Temperance Flat Reservoir measures change substantially at storage capacities of approximately 725 TAF and 1,350 TAF, water operations simulations were conducted for a Temperance Flat Reservoir at those two sizes. Data from the reservoir operations simulations were then used in hydropower evaluations of the Temperance Flat measures specific to each potential dam site. The following sections describe site characteristics, dam design considerations, impacts to hydropower generation, and potential for replacement power, costs, and environmental considerations for the three Temperance Flat Reservoir measures.

Temperance Flat RM 274 Reservoir

The RM 274 site is located in Millerton Lake approximately 1 mile upstream of the confluence of Fine Gold Creek and Millerton Lake. It was one of three sites in the original planning studies for Friant Dam in the 1930s, when it was referred to as the Temperance Flat site. From a water storage perspective, it was considered superior to both the Friant Dam site and a site at Fort Miller (just downstream of Fine Gold Creek). The Friant Dam site was selected, however, because construction of a dam at RM 274 would have required canals around the current Millerton Lake area or a diversion dam at Friant.

Site Characteristics and Dam Design Considerations

The topography of the RM 274 site is fairly uniform on both the left and right abutments. The San Joaquin River channel at the site is at elevation 385. The left abutment rises uniformly to elevation 1,582 at Pincushion Mountain and the right abutment rises uniformly to elevation 1,473 at an unnamed peak.

A low point along a ridge making up part of the left abutment adjacent to RM 275 limits the maximum reservoir level to elevation 1,100 for the RM 274 site. This elevation would correspond to a dam height of about 715 feet and a reservoir capacity of about 2,110 TAF of new storage. The potential reservoir for the RM 274 site at elevation 985, which corresponds to a capacity of approximately 1,310 TAF of new storage, is shown in **Figure 6-8**.

From an engineering geology perspective, the RM 274 site is suitable for a concrete arch, concrete gravity, or concrete face rockfill (CFRF) dam. A concrete arch dam was not considered in the prefeasibility-level review because the relatively flat slopes would result in a wide canyon with potentially large volumes of concrete. However, this measure should not be excluded from future consideration since further studies may show that an arch dam is economical. A design for an RCC type dam was not developed in detail for this site but would be similar to the structure considered for the RM 279 site. Preliminary designs and cost estimates were prepared for rockfill dams at elevations 800 and 1,100 at the RM 274 site. Cost estimates for intermediate sizes were developed by interpolation of the lower and higher cost estimates.

Upstream and downstream cofferdams would be required for diverting river flows during construction and to prevent inundation of the site from Millerton Lake. Cofferdams would be sized for estimated diversion flows and to allow normal operation of Millerton Lake during construction. A significant portion of both cofferdams would be constructed within the existing reservoir to a maximum depth of nearly 200 feet.

Temperance Flat RM 274 Site in Millerton Lake

Diversion tunnels through both abutments of the new dam would be required to pass San Joaquin River flows around the construction site. One of the diversion tunnels would be used for the outlet works, and the other would be plugged at the end of construction or could be used as part of the spillway, depending on the dam height.

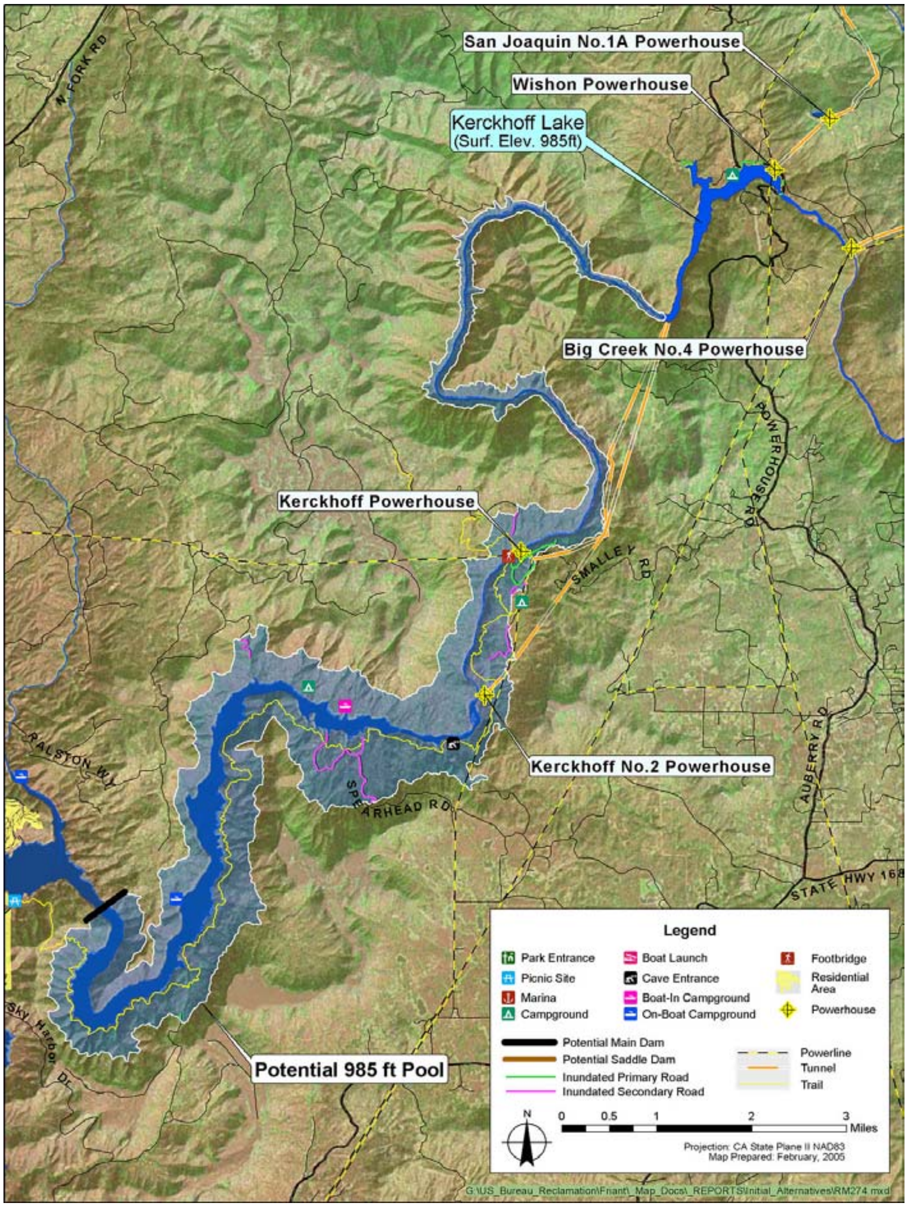

FIGURE 6-8.
POTENTIAL TEMPERANCE FLAT RM 274 RESERVOIR

Hydropower Generation Effects and Potential Replacement Power Options

Construction of a dam at RM 274 would adversely affect energy generation at existing hydropower facilities upstream of Millerton Lake, as shown in **Figure 6-9**. All storage capacities considered would completely inundate both the Kerckhoff and Kerckhoff No. 2 powerhouses, which have a combined installed generation capacity of 193 MW. Lost annual generation at impacted facilities is estimated at 507 GWh/year.

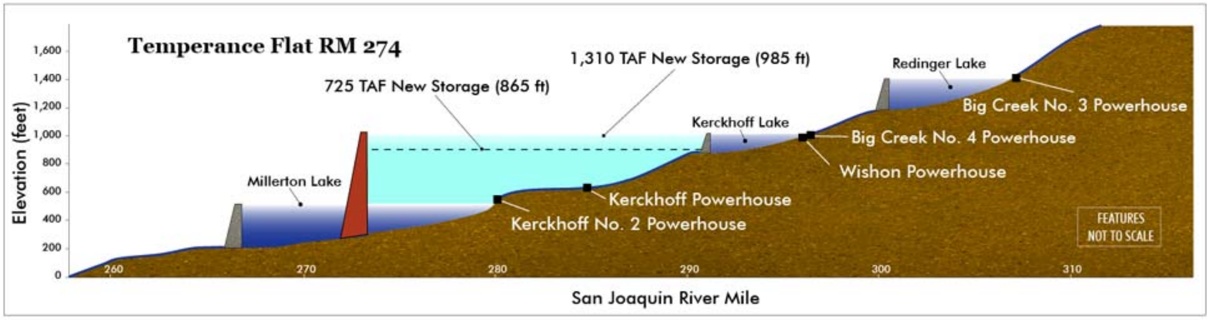

FIGURE 6-9.
HYDROPOWER FEATURES AFFECTED BY
TEMPERANCE FLAT RM 274 RESERVOIR

A RM 274 Reservoir above elevation 985, which corresponds to the elevation of Kerckhoff Lake and would have a net storage capacity of about 1,310 TAF, also would affect generation of and potentially inundate the A.G. Wishon and Big Creek No. 4 powerhouses, with installed generation capacities of 20 MW and 100 MW, respectively.

Potential options identified for developing replacement energy generation include a powerhouse at the base of the dam, development of a new powerhouse at the base of Kerckhoff Dam for storage sizes up to 725 TAF, or extending the Kerckhoff No. 2 tunnel to a new powerhouse downstream of the dam. Extending the Kerckhoff No. 2 tunnel was not considered because it would require approximately 10 miles of tunnel and a siphon under the San Joaquin River.

The principal power generation feature would be a powerhouse at the dam or at the base of an abutment, with an intake structure and a short conduit leading to the turbines. Discharge from the powerhouse would be directly into Millerton Lake. Potential for power generation for this option would be limited compared to existing generation from impacted facilities. The net head available for generation would be lower than that currently available from the Kerckhoff Project under most conditions. The existing head from the Kerckhoff Project would be matched only when the new reservoir was generating power under full (1,310 TAF) conditions. Typical storage levels would be considerably less, and the corresponding head would be lower.

The powerhouse capacity would vary depending on the storage capacity and corresponding head and flow characteristics of the RM 274 Reservoir. For a 1,310 TAF capacity reservoir (elevation 985), a 100 MW powerhouse was assumed. For a 725 TAF capacity reservoir (elevation 865), an 80 MW powerhouse at the base of the dam and a supplemental 20 MW powerhouse at the base of Kerckhoff Dam were assumed.

As shown in **Table 6-6**, replacement energy generation would be significantly less than lost energy generation from existing powerhouses that would be inundated, based on simulated generation for the Kerckhoff Hydroelectric Project. As described previously in this chapter, hydrologic reservoir simulations were completed for Temperance Flat Reservoir sizes of 725 TAF and 1,350 TAF of new storage and used as input to the hydropower analysis for the specific dam sites. At RM 274, a storage capacity of 1,310 TAF corresponds to the elevation of Kerckhoff Lake.

TABLE 6-6. ESTIMATED ENERGY GENERATION AND LOSSES FOR TEMPERANCE FLAT RM 274 RESERVOIR SIZES

New Storage Capacity (TAF)	Gross Pool Elev. (feet above msl)	Estimated New Energy Generation				Estimated Losses of Energy Generation		Net Energy Generation	
		Operating Scenario	Estimated Generation at RM 274 Dam Powerhouse (GWh/year)	Estimated Generation at Kerckhoff Dam Powerhouse (GWh/year)	Additional Generation at Friant (GWh/year)	Powerhouses Potentially Affected	Estimated Reduction in Existing Energy Generation (GWh/year)[1]	Net Generation for WQ or RF Operating Scenario (GWh/year)	Average Net Generation (GWh/year)
725	865	WQ	206	108	5	Kerckhoff, Kerckhoff No. 2	-507	-188	-175
		RF	207	108	30			-162	
1,310[2]	985	WQ	273	---[3]	6	Kerckhoff, Kerckhoff No. 2	-507	-228	-216
		RF	266	---[3]	36			-205	

Key:
GWh/year – gigawatt-hour per year
msl – mean sea level
RF – restoration flow single-purpose analysis
TAF – thousand acre-feet
WQ – water quality single-purpose analysis
Notes:
[1] Based on estimated power generation numbers from without-project spreadsheet simulations.
[2] Power generation analysis based on water operations data for a net storage capacity of 1,350 TAF, which is assumed to be roughly equivalent to the power impact break point of 985 feet (1,310 TAF).
[3] Gross pool for a reservoir size of 1,310 TAF would be at the elevation of Kerckhoff Lake; no potential for Kerckhoff Project replacement generation.

Cost Estimates

Construction cost estimates for dams, appurtenant features, and power replacement facilities, and relocations for other impacted infrastructure were developed for capacities up to about 2,110 TAF of new storage at the RM 274 site. Sizes greater than about 1,310 TAF capacity would inundate Kerckhoff Lake and the Wishon and Big Creek No. 4 powerhouses. **Table 6-7** summarizes construction costs for all components associated with several sizes of the RM 274 measure, up to a capacity of 1,310 TAF.

All storage sizes considered for the RM 274 site would require abandoning the Kerckhoff powerhouses and intakes. For the elevation 800 and 865 measures, the cost for a new replacement powerhouse at the base of Kerckhoff Dam, with a single 20 MW generating unit, has been included for consistency with the hydropower generation analysis. No replacement powerhouse at Kerckhoff Dam would be constructed for measures with a dam crest at elevation 960 or above.

The dam and appurtenant structures would be located on public land. Parcels of land immediately upstream from the construction area and in the potential area of inundation are privately owned and would need to be acquired, including a few residences at Temperance Flat. Costs to acquire private property in the reservoir area are included with the cost of the dam and appurtenances.

TABLE 6-7.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 274 MEASURES
($ MILLION)

Gross Pool Elevation (feet above msl)	800	865	985	1,100
New Storage Capacity (TAF)	**460**	**725**	**1,310**	**2,110**
Storage Components				
CFRF Dam, Spillway, Outlet Works, River Diversion, Reservoir Lands	560	650	810	970
Abandon Kerckhoff Powerhouse	2	2	2	2
Abandon Intake for Kerckhoff Powerhouse	1	1	1	1
Abandon Kerckhoff No. 2 Powerhouse	2	2	2	2
Abandon Intake for Kerckhoff No. 2 Powerhouse	1	1	1	1
Remove Kerckhoff Dam Outlet Works and Gates	-	-	2	2
Abandon Wishon Powerhouse	-	-	-	2
Abandon Big Creek No. 4 Powerhouse	-	-	-	4
Powerhouse Road Relocation	-	-	-	18
Powerhouse Bridge Relocation	-	-	-	21
Construction Cost, Storage Components	**566**	**656**	**818**	**1,023**
Replacement Power Components				
New Powerhouse at RM 274 Dam (80 to 100 MW)	170	170	195	195
New Powerhouse at Kerckhoff Dam (20 MW)	59	59	-	-
New Wishon Powerhouse (18 MW)	-	-	-	46
New Big Creek No. 4 Powerhouse (80 MW)	-	-	-	115
Construction Cost, Replacement Power Components	**229**	**229**	**195**	**356**
Construction Cost[1, 2]	**795**	**885**	**1,013**	**1,379**

Key:
CFRF – concrete-face rockfill
msl – mean sea level
MW – megawatt
RM – river mile
TAF – thousand acre-feet

Notes:

[1] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design and construction management, which are estimated at 25 percent of field costs.

[2] Costs do not include environmental mitigation, new or relocated recreation facilities, acquisition of impacted power facilities, or compensation for lost future power generation.

Figure 6-10 shows the relationship between new storage capacity that would be developed with a reservoir at RM 274 versus construction cost. Costs increase when the storage capacity exceeds 1,310 TAF because costs would be incurred to replace generation capacity lost by the inundation of Wishon and Big Creek No. 4 powerhouses and to rebuild at a higher elevation a bridge that crosses the San Joaquin River at Kerckhoff Lake. It is expected that the incremental cost increase associated with sizes that exceed 1,310 TAF would not be justified in relationship to the additional storage and water supply that could be developed.

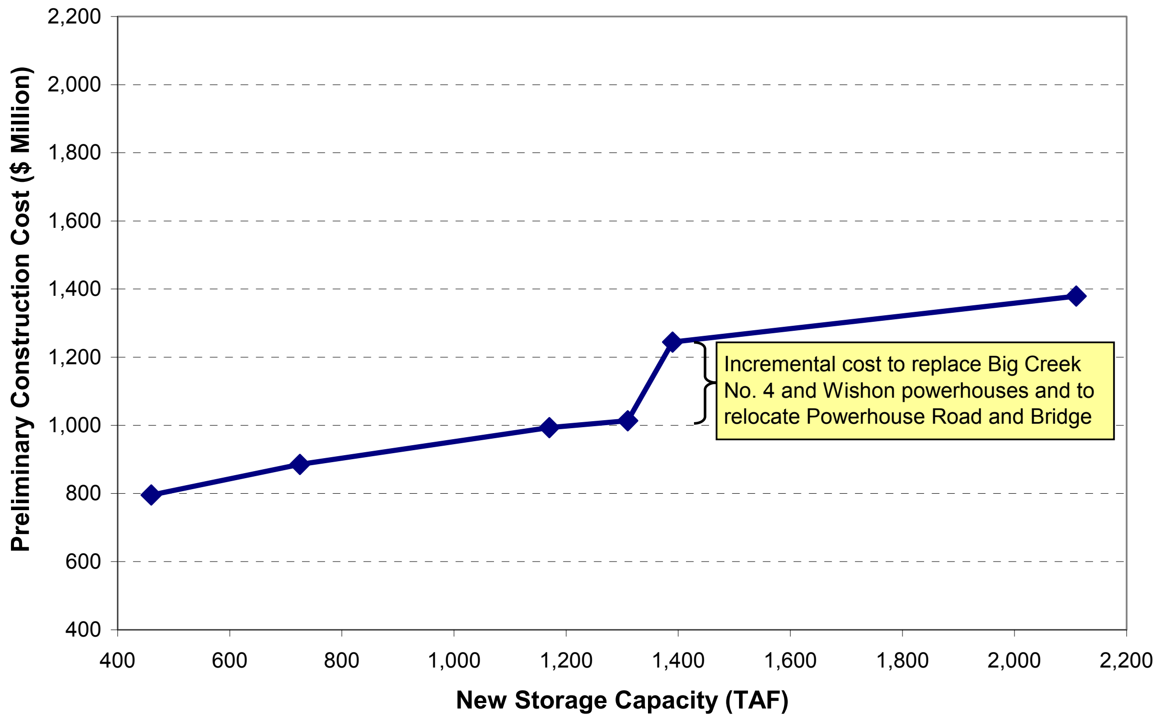

FIGURE 6-10.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 274 MEASURES VS. NEW STORAGE CAPACITY

Environmental Considerations

A reservoir at RM 274 may impact vegetation, wildlife and fisheries, recreation, land use and cultural resources. Discrete river reaches defined in **Chapter 3** potentially affected by a dam at RM 274 include the Millerton Lake and Big Bend, Temperance Flat and Millerton Bottoms, and Patterson Bend reaches of the San Joaquin River.

Several special status species occur in the region and are identified in **Chapter 3**. **Table 6-4** provides a sum of special status species occurring in each river reach potentially affected by a RM 274 Reservoir. The extent of habitat loss and the combined numbers of vegetation and wildlife species that may be affected would increase in magnitude as larger reservoir sizes are considered, and could result in design or operational constraints. Potential impacts to vegetation and wildlife species are anticipated to be proportional to the increase in mean pool elevation of the RM 274 Reservoir.

Existing fisheries in Millerton Lake and the Big Bend reach of the San Joaquin River would be affected by a dam at RM 274. Millerton Lake would be divided into upper and lower portions, separated by the dam. Impacts associated with this barrier are not likely to vary with measures on the size of the reservoir to be created. With a dam at RM 274, a permanent pool would be established in Big Bend and extend to Patterson Bend, replacing lotic habitat of native fishes with lentic habitat favored by introduced game fishes.

All reservoir sizes considered for RM 274 would inundate entrances to the Millerton Lake Caves located in the Temperance Flat area, and would affect whitewater recreation at Millerton Bottoms and Patterson Bend. A RM 274 Reservoir also may inundate several mines associated with the abandoned Sullivan mine.

A few residences in the Temperance Flat area, along with recreational facilities associated with the Millerton Lake SRA and BLM San Joaquin River Gorge, would be inundated by a RM 274 Reservoir. Archaeological sites within or near the existing pool of Millerton Lake and upstream to Kerckhoff dam would be adversely affected with a dam at RM 274.

Recommendations for Further Study

Temperance Flat RM 274 Reservoir measures ranging in size from 460 TAF to 1,310 TAF (elevations 800 to 985) will be retained for further evaluation and comparison with other measures in **Chapter 7**. Sizes greater than 1,310 TAF would adversely affect all reaches of the San Joaquin River from Millerton Lake to Horseshoe Bend, including Millerton Bottoms and Big Bend. Measures exceeding 1,310 TAF of storage also would inundate four powerhouses representing nearly 1,000 GWh/year of generation, at considerable additional expense and with limited opportunity to replace the lost generation. The additional impacts and expenses are considered unlikely to be justified by the additional water supply that would be created when other measures are available that could provide the same new water supply. Thus, sizes of Temperance Flat RM 274 Reservoir larger than 1,310 TAF are dropped from further consideration in the Investigation.

Temperance Flat RM 279 Reservoir

The RM 279 site also is located in Millerton Lake approximately 2 miles downstream of the Temperance Flat area. The RM 279 site rises uniformly from elevation 460 in the original San Joaquin River channel to elevation 1,080 on the left abutment, and then through a saddle at elevation 1,040 before continuing to elevation 1,416 at an unnamed peak. The right abutment rises uninterrupted to elevation 1,566 at an unnamed peak. The potential reservoir for the RM 279 site at elevation 1,000 feet is shown in **Figure 6-11**.

Site Characteristics and Dam Design Considerations

The RM 279 site is appropriate for concrete arch, concrete gravity, and CFRF types. A central-core earthfill dam is not considered economically viable, due to the limited availability of plastic, fine-grained materials for the core. A concrete arch dam was not considered for prefeasibility-level designs because the abutments have relatively flat slopes, which would result in a wide canyon requiring potentially large volumes of concrete. However, this design option was not evaluated sufficiently to exclude it from future consideration.

Upstream and downstream cofferdams would be required for diverting stream flows during construction and to prevent inundation of the site from Millerton Lake. Cofferdams were sized for estimated diversion flows and to allow normal operation of Millerton Lake during construction. The upstream cofferdam would have a crest at elevation 635, and a height of approximately 185 feet. The downstream cofferdam would have a crest at about elevation 578, and height of about 125 feet.

Temperance Flat RM 279 Site in Millerton Lake

Diversion tunnels through both abutments of the new dam would be required to pass San Joaquin River flows around the construction site. One of the diversion tunnels would be used for the outlet works, and the other would be plugged at the end of construction or could be used as part of the spillway, depending on the dam type and height.

Access to the RM 279 site would require constructing new roads on the Fresno County side of the river. Construction staging and lay-down would be located in the reservoir area.

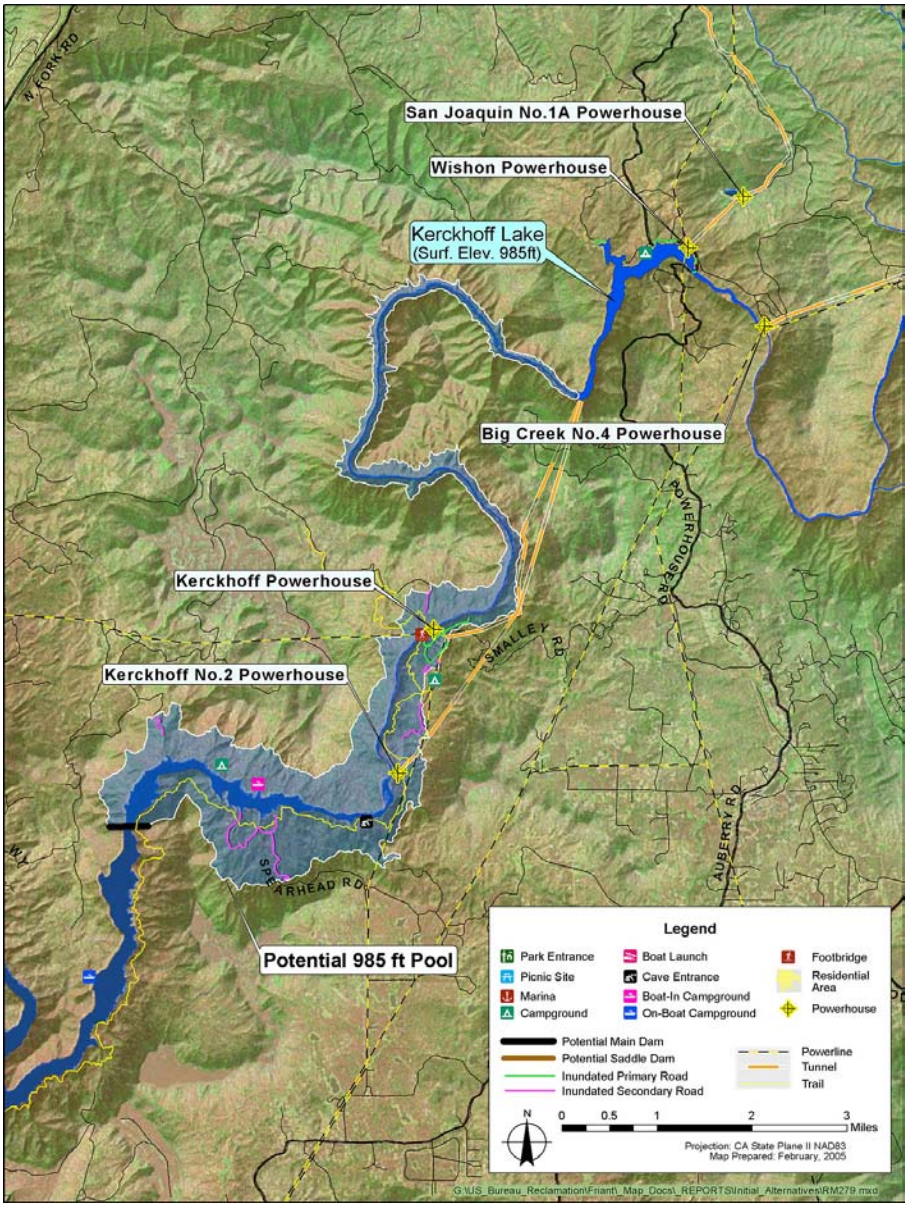

FIGURE 6-11.
POTENTIAL TEMPERANCE FLAT RM 279 RESERVOIR

Hydropower Generation Effects and Potential Replacement Power Options

Construction of a dam at RM 279 would adversely affect energy generation at existing hydropower facilities upstream of Millerton Lake, as shown in **Figures 6-11** and **6-12**. All storage capacities considered would completely inundate both the Kerckhoff and Kerckhoff No. 2 powerhouses, which have a combined installed generation capacity of 193 MW. Impacted annual generation at these facilities is estimated at 507 GWh/year. In addition, a reservoir at RM 279 above elevation 985 would inundate the Wishon and Big Creek No. 4 powerhouses, with installed generation capacities of 20 MW and 100 MW, respectively.

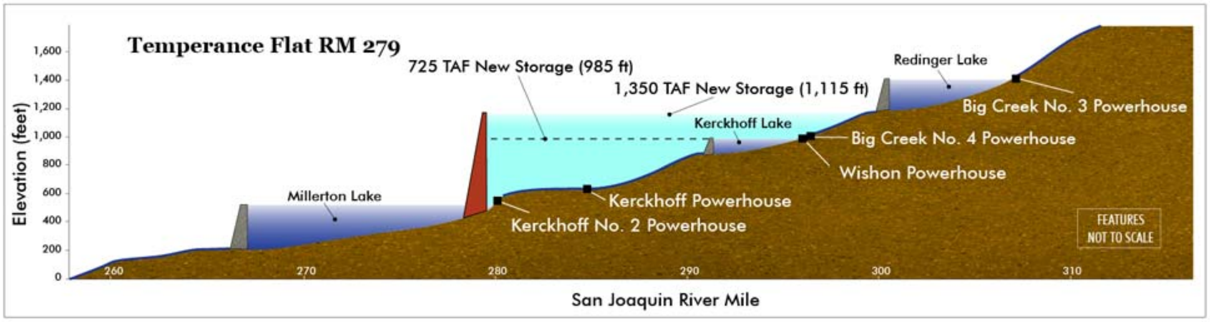

FIGURE 6-12.
HYDROPOWER FEATURES AFFECTED BY
TEMPERANCE FLAT RM 279 RESERVOIR

Two replacement power options were considered for the RM 279 Reservoir, each at two storage capacities. A capacity of 725 TAF corresponds to a reservoir surface at elevation 985, which is at the elevation of Kerckhoff Lake. A capacity of 1,350 TAF corresponds to a reservoir surface at approximately elevation 1,115.

The two power configurations for the RM 279 Reservoir site were evaluated to identify a range of replacement power opportunities. One option involves developing new power generation facilities at the base of the dam and abandoning the Kerckhoff Project facilities. The second involves a new powerhouse on an extension of the Kerckhoff No. 2 tunnel and a new, smaller powerhouse at the dam.

For the 1,350 TAF size RM 279 Reservoir for both replacement power options, new powerhouses could be constructed to replace some of the generation lost from the Big Creek No. 4 and Wishon powerhouses.

The Big Creek No. 4 replacement powerhouse could be constructed farther upstream on the Big Creek No. 4 penstock and the Wishon replacement powerhouse could be constructed farther upstream on the Wishon penstock. Both powerhouses would have a tailwater level at elevation 1,115. The replacement powerhouses for Big Creek No. 4 and Wishon are assumed to have capacities of 80 MW and 18 MW, respectively.

Results of replacement power evaluations for the RM 279 site are summarized in **Table 6-8**. Descriptions of replacement power options are provided in the following sections.

TABLE 6-8. ESTIMATED ENERGY GENERATION AND LOSSES FOR TEMPERANCE FLAT RM 279 RESERVOIR SIZES

New Storage Capacity (TAF)	Gross Pool Elev. (feet above msl)	Estimated New Energy Generation				Estimated Losses of Energy Generation		Net Energy Generation	
		Operating Scenario	Estimated New Energy Generation (GWh/year)	Estimated Generation at Big Creek No. 4 and Wishon Powerhouse Replacements (GWh/year)	Additional Generation at Friant (GWh/year)	Powerhouses Potentially Affected	Estimated Reduction in Existing Energy Generation (GWh/year)[1]	Net Generation for WQ or RF Operating Scenario (GWh/year)	Average Net Generation (GWh/year)
Replacement Power Option 1 – New large powerhouse at dam									
725	985	WQ	368	2	5	Kerckhoff, Kerckhoff No. 2	-507	-134	-121
		RF	368	2	30			-109	
1,350	1,115	WQ	440	384	6	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-151	-141
		RF	429	384	36			-132	
Replacement Power Option 2 – New large powerhouse on extended Kerckhoff No. 2 tunnel, new small powerhouse at dam									
725	985	WQ	460	---[2]	5	Kerckhoff, Kerckhoff No. 2	-507	-42	-23
		RF	472	---[2]	30			-5	
1,350	1,115	WQ	543	384	6	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-48	-48
		RF	513	384	36			-48	

Key:
GWh/year – gigawatt-hour per year
msl – mean sea level
RF – restoration flow single-purpose analysis
TAF – thousand acre-feet
WQ – water quality single-purpose analysis

Notes:
[1] Based on estimated energy generation numbers from without-project spreadsheet simulations.
[2] The 725 TAF size of a RM 279 Reservoir would not impact Big Creek No. 4 or Wishon powerhouses.

RM 279 Replacement Power Option 1

This option includes constructing a large powerhouse at the base of the RM 279 dam, as shown in **Figure 6-13**. For a 725 TAF reservoir, the powerhouse would have a capacity of 120 MW. For a 1,350 TAF reservoir, the powerhouse would have a capacity of 120 MW and would be supplemented with replacement powerhouses for the Wishon and Big Creek No. 4 powerhouses, with combined capacities of 98 MW.

As shown in **Table 6-8**, this option would not provide full replacement power for either the 725 TAF or 1,350 TAF storage capacity reservoir, resulting in a new loss ranging from about 100 to about 150 GWh/year, depending on the reservoir size and water operations. This option would result in net energy losses because the head available for replacement generation would be lower than the head available to the existing projects under most conditions.

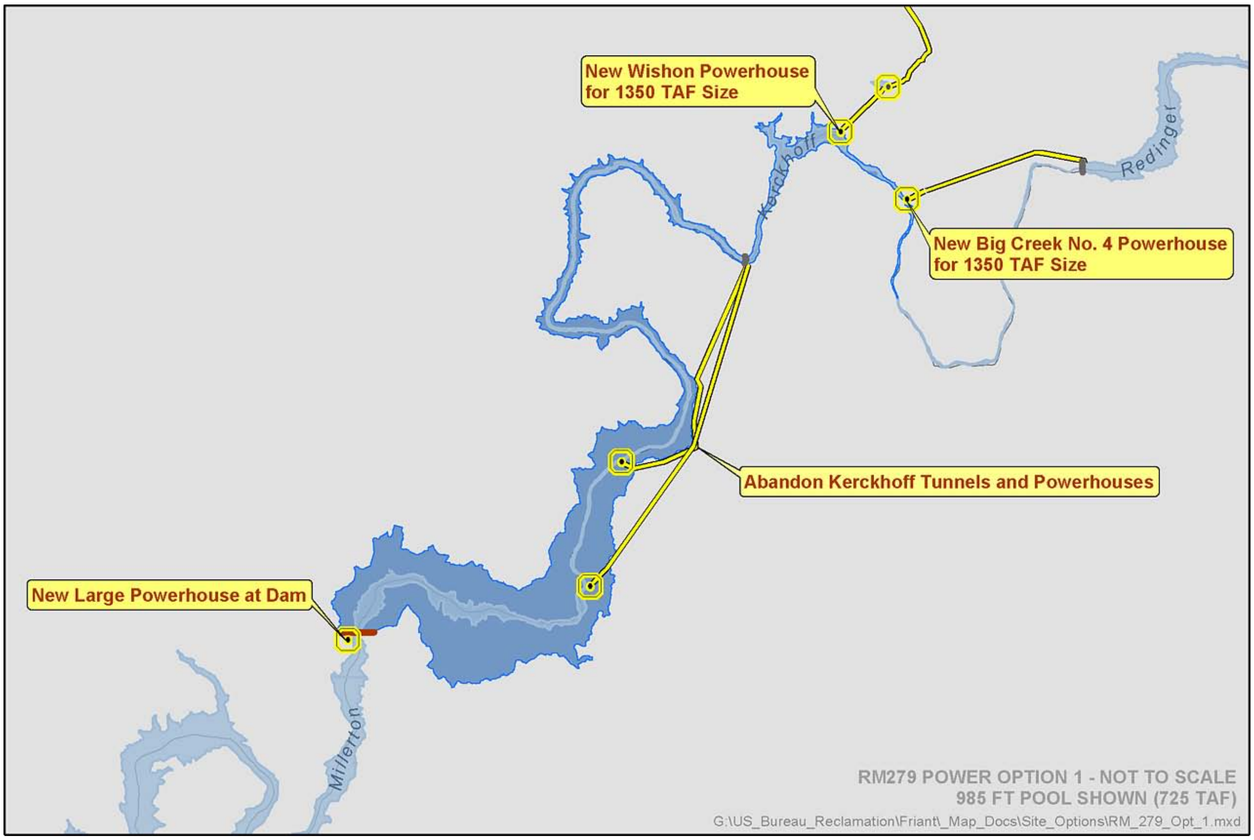

FIGURE 6-13.
REPLACEMENT POWER OPTION 1 FOR TEMPERANCE FLAT RM 279 RESERVOIR

RM 279 Replacement Power Option 2

This option would involve extending the Kerckhoff No. 2 tunnel and constructing a new powerhouse downstream of the RM 279 dam that discharges into Millerton Lake, as shown in **Figure 6-14**. Kerckhoff Dam would be retained and flows would continue to be diverted to the Kerckhoff No. 2 tunnel in a similar manner as for the without-project condition. Flood flows that spill over Kerckhoff Dam would flow into the RM 279 Reservoir for storage and release.

The powerhouse is assumed to have an installed capacity of approximately 120 MW. Inflow to Kerckhoff Lake in excess of the Kerckhoff No. 2 tunnel capacity would be released into the RM 279 Reservoir and stored. A small, single-unit powerhouse with an assumed installed capacity of approximately 15 MW would be constructed at the dam for generation from RM 279 releases to Millerton Lake. For the 725 TAF storage capacity, generation at the relocated Kerckhoff No. 2 powerhouse would similar to the historic generation of Kerckhoff No. 2 because the constant head of Kerckhoff Lake would be maintained and flows would be similar to existing project operations. Lost generation from the Kerckhoff Powerhouse would be replaced by additional generation at the Friant Power Project and by generation at a new, small powerhouse at the base of the RM 279 dam.

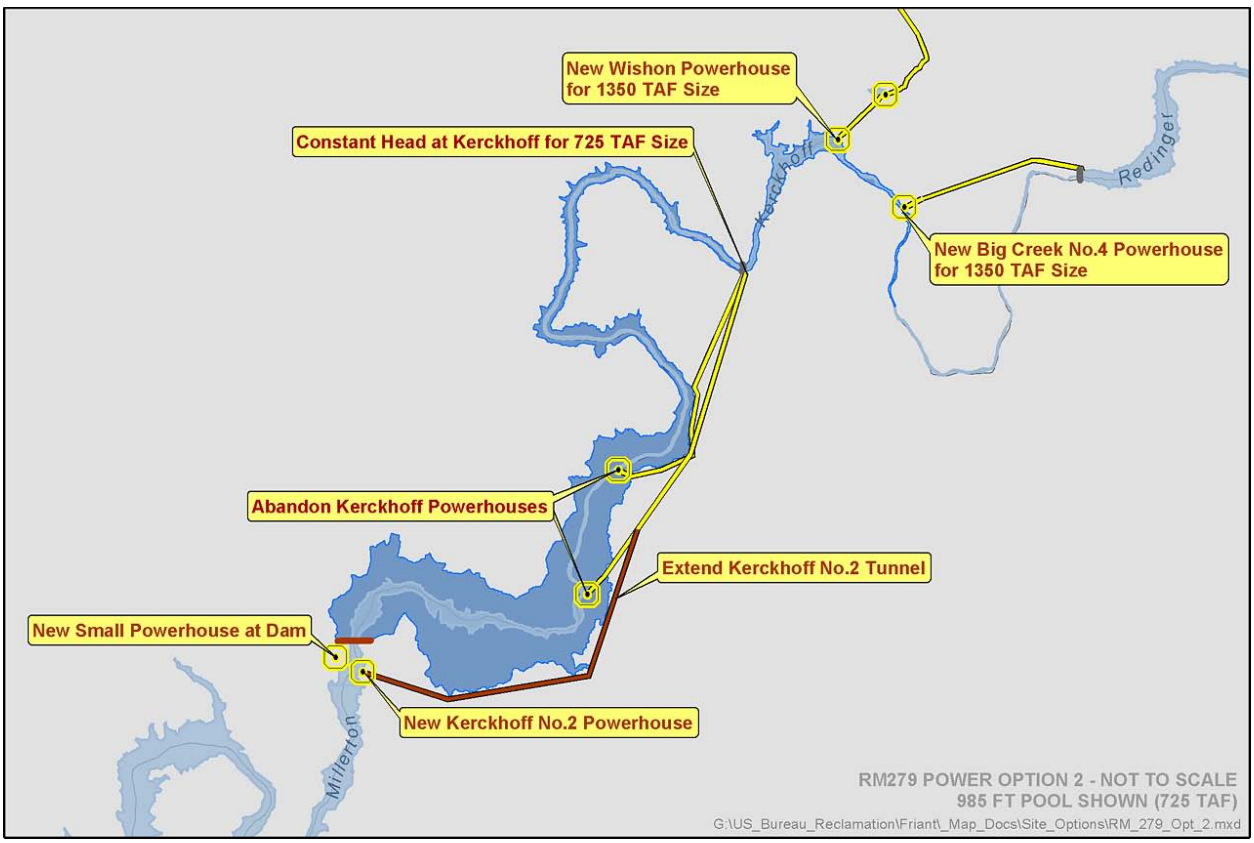

FIGURE 6-14.
REPLACEMENT POWER OPTION 2 FOR TEMPERANCE FLAT RM 279 RESERVOIR

Replacement Power Option 2 would result in a very small net loss of power generation for the 725 TAF size reservoir, depending on the water management scenario. For the 1,350 TAF reservoir size, replacement Power Option 2 would not fully replace lost power generation, and would result in a net loss of approximately 50 GWh/year. This is because the Wishon and Big Creek No. 4 powerhouses generate power under relatively constant head conditions. A constant, but lower, head could be maintained through relocating smaller versions of these powerhouses to elevation 1,115. The remaining reduction in power generation would not be replaced with higher head generation at a relocated Kerckhoff No. 2 powerhouse and a small powerhouse at the base of RM 279 dam because water levels in the RM 279 Reservoir would vary.

Cost Estimates

Construction costs for dams, appurtenant features, and power replacement facilities, and relocations for other impacted infrastructure were developed for capacities up to about 2,700 TAF of new storage at the RM 279 site. This capacity would correspond to a reservoir at elevation 1,300 that would inundate Kerckhoff Lake and the Wishon and Big Creek No. 4 powerhouses.

Construction costs for RM 279 storage measures at several sizes, combined with Power Replacement Options 1 and 2, are summarized in **Tables 6-9** and **6-10**, respectively. These costs include constructing the main dam and appurtenant features, and costs for abandoning, modifying, or relocating existing facilities.

The dam and appurtenant structures would be located on public land. Parcels of land immediately upstream from the construction area and in the potential area of inundation are privately owned and would need to be acquired, including a few residences at Temperance Flat. Costs to acquire private property in the reservoir area are included with the cost of the dam and appurtenances.

A comparison of cost estimates prepared during Phase 1 of the Investigation suggests that RCC is the lower cost dam type up to elevation 1,100, after which the CFRF type becomes less expensive. Accordingly, only costs for the apparent lower cost dam type are included in **Tables 6-9** and **6-10**. However, cost differences between dam types are not great enough to conclusively identify the most cost-efficient design at all crest elevations.

Costs for many of the construction components vary according to hydropower configuration or elevation. For both power replacement options, relocating and abandoning existing powerhouses that currently discharge to Kerckhoff Lake are treated identically, as are road and bridge relocations. For measures above elevation 985, costs for abandoning the Wishon and Big Creek No. 4 powerhouses are included. This would involve constructing a replacement Big Creek No. 4 Powerhouse below Redinger Dam with 30 MW to 80 MW of generating capacity, depending on reservoir elevation, and an 18 MW powerhouse to partially replace Wishon generating capacity at a higher elevation. The costs to relocate Powerhouse Road and Bridge to a higher elevation also are included for reservoir elevations above 985.

TABLE 6-9.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 279 MEASURES WITH REPLACEMENT POWER OPTION 1 ($ MILLION)

Gross Pool Elevation (feet above msl)	900	985	1,115	1,200	1,300
New Storage Capacity (TAF)	450	725	1,350	1,910	2,740
Dam Type	RCC	RCC	CFRF	CFRF	CFRF
Storage Components					
RCC Dam, Spillway, Outlet Works, River Diversion, Reservoir Lands	450	650	940	1,200	1,550
Abandon Kerckhoff Powerhouse	2	2	2	2	2
Abandon Intake for Kerckhoff Powerhouse	1	1	1	1	1
Abandon Kerckhoff No. 2 Powerhouse	2	2	2	2	2
Abandon Intake for Kerckhoff No. 2 Powerhouse	1	1	1	1	1
Remove Kerckhoff Dam Outlet Works and Gates	2	2	2	2	2
Abandon Wishon Powerhouse	-	-	2	2	2
Abandon Big Creek No. 4 Powerhouse	-	-	4	4	4
Powerhouse Road Relocation	-	-	18	18	40
Powerhouse Road Bridge Relocation	-	-	21	34	38
Construction Cost, Storage Components	**458**	**658**	**993**	**1,266**	**1,642**
Replacement Power Components					
New Powerhouse at RM 279 Dam (120 MW)	210	210	210	210	210
New Wishon Powerhouse (18 MW)	-	-	46	46	46
New Big Creek No. 4 Powerhouse (30 to 80 MW)	-	-	115	69	69
Construction Cost, Replacement Power Components	**210**	**210**	**371**	**325**	**325**
Construction Cost[1, 2]	**668**	**868**	**1,364**	**1,591**	**1,967**

Key:
CFRF – concrete face rockfill
RCC – roller-compacted concrete
msl – mean sea level
RM – river mile
MW – megawatt
TAF – thousand acre-feet

Notes:

[1] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design, and construction management, estimated at 25 percent of field costs.

[2] Costs do not include environmental mitigation, new or relocated recreation facilities, acquisition of impacted power facilities, or compensation for lost future power generation.

TABLE 6-10.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 279 MEASURES WITH REPLACEMENT POWER OPTION 2 ($ MILLION)

Gross Pool Elevation (feet above msl)	900	985	1,115	1,200	1,300
New Storage Capacity (TAF)	**450**	**725**	**1,350**	**1,910**	**2,740**
Dam Type	**RCC**	**RCC**	**CFRF**	**CFRF**	**CFRF**
Storage Components					
RCC Dam, Spillway, Outlet Works, River Diversion, Reservoir Lands	450	650	940	1,200	1,550
Abandon Kerckhoff Powerhouse	2	2	2	2	2
Abandon Intake for Kerckhoff Powerhouse	1	1	1	1	1
Abandon Kerckhoff No. 2 Powerhouse	2	2	2	2	2
Remove Kerckhoff Dam Outlet Works and Gates	2	2	2	2	2
Abandon Wishon Powerhouse	-	-	2	2	2
Abandon Big Creek No. 4 Powerhouse	-	-	4	4	4
Powerhouse Road Relocation	-	-	18	18	40
Powerhouse Road Bridge Relocation	-	-	21	34	38
Construction Cost, Storage Components	**457**	**657**	**992**	**1,265**	**1,641**
Replacement Power Components					
New Powerhouse at RM 279 Dam (15 MW)	75	75	75	75	75
New Powerhouse on Extended Kerckhoff No. 2 Tunnel (120 MW)	150	150	150	150	150
Kerckhoff No. 2 Diversion Tunnel Extension	120	120	120	120	120
Kerckhoff No. 2 Diversion Tunnel, Steel Liner	-	-	45	85	125
Kerckhoff No. 2 Diversion Tunnel, Backfill Concrete	-	-	3	3	3
Modify Kerckhoff No. 2 Diversion Intake	-	-	18	33	39
New Wishon Powerhouse (18 MW)	-	-	46	46	46
New Big Creek No. 4 Powerhouse (30 to 80 MW)	-	-	115	69	69
Construction Cost, Replacement Power Components	**364**	**364**	**591**	**600**	**646**
Construction Cost[1, 2]	**802**	**1,002**	**1,564**	**1,846**	**2,268**

Key:
CFRF – concrete face rockfill
msl – mean sea level
MW – megawatt

Notes:

[1] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design, and construction management, estimated at 25 percent of field costs.

[2] Costs do not include environmental mitigation, new or relocated recreation facilities, acquisition of impacted power facilities, or compensation for lost future power generation.

Costs for the two replacement power options differ in several respects. The cost for Replacement Power Option 1 includes a powerhouse at the end of the RM 279 dam diversion tunnel and decommissioning and abandonment of the intake for the Kerckhoff No. 2 Powerhouse.

Replacement Power Option 2 involves extending the Kerckhoff No. 2 diversion tunnel to a new 120 MW powerhouse downstream of the RM 279 dam that would discharge to Millerton Lake. It also involves a 15 MW powerhouse at the end of the RM 279 dam diversion tunnel. For Option 2, **Table 6-10** includes costs for these features and costs to extend and partially line the Kerckhoff No. 2 diversion tunnel.

Figure 6-15 shows the relationship between new storage capacity that would be developed with a reservoir at RM 279 versus construction cost. Costs increase when storage capacity exceeds about 725 TAF because costs would be incurred to replace generation capacity lost by the inundation of Wishon and Big Creek No. 4 powerhouses and to rebuild at a higher elevation a bridge that crosses the San Joaquin River at Kerckhoff Lake.

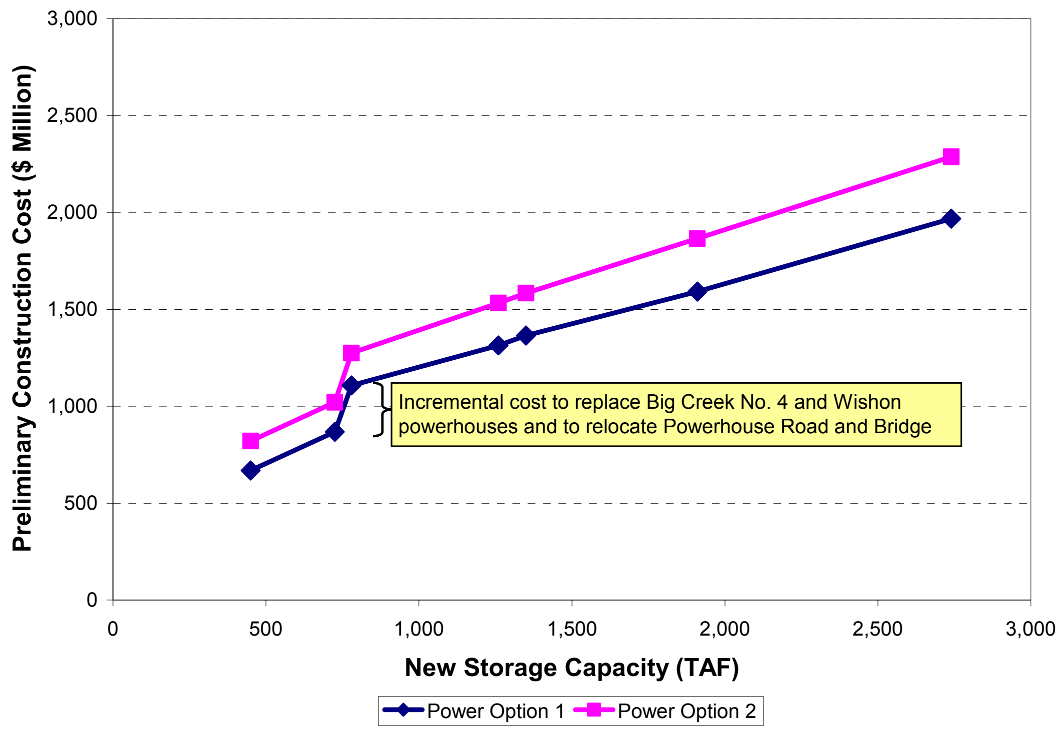

FIGURE 6-15.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 279 MEASURES VS. NEW STORAGE CAPACITY

Environmental Considerations

A reservoir at RM 279 may impact vegetation, wildlife and fisheries, recreation, land use, and cultural resources. River reaches potentially affected by a dam at RM 279 include Temperance Flat and Millerton Bottoms, Patterson Bend, and Kerckhoff Lake and Horseshoe Bend.

Reservoir measures for RM 279 are anticipated to have similar impacts on habitat, vegetation and wildlife species as for the RM 274 measures. **Table 6-4** provides a sum of special status species, identified in **Chapter 3**, occurring in each river reach potentially affected by a RM 279 Reservoir. A RM 279 Reservoir with a pool elevation greater than the crest elevation of Kerckhoff Dam would require management of fisheries to prevent the introduction of non-native centrarchid species to Kerckhoff Lake and Horseshoe Bend, a designated CAR.

RM 279 Reservoir measures that exceed elevation 1,000 could impact the USFS Backbone Creek RNA, which hosts one of the largest populations of tree anemone. The Backbone Creek RNA includes 262 acres of chaparral and riparian habitat along the San Joaquin River to be preserved and protected in perpetuity (USFS, 2004).

Environmental considerations for a dam at RM 279 related to social and cultural resources are expected to be similar to those for RM 274. Either of the RM 279 measures would inundate entrances to the Millerton Lake Caves system located in the Temperance Flat area, and potentially affect whitewater recreation in the Millerton Bottoms, Patterson Bend, and Horseshoe Bend reaches of the river. A RM 279 Reservoir also may inundate several mines associated with the abandoned Sullivan mine and Patterson mine. In addition to cultural resources mentioned above near Kerckhoff Lake, a high probability exists of archaeological sites, including BRMs and hunting and fishing camps, throughout the Horseshoe Bend reach (White, 1986).

Recommendations for Further Study

Temperance Flat RM 279 Reservoir measures ranging in size from 450 TAF to 1,350 TAF (elevations 900 to 1,115) will be retained for further evaluation and comparison with other measures in **Chapter 7**. Temperance Flat RM 279 Reservoir measures above 1,350 TAF up to 2,740 TAF (elevations above 1,115 up to 1,300) will be dropped from further consideration in the Investigation because such large reservoir sizes are likely not justifiable based on the small incremental water supply above about 1,400 TAF, increased environmental impacts, and increased construction costs. A specific size of 1,350 TAF was chosen so it would be comparable to the maximum sizes at the other Temperance Flat sites. Tradeoffs exist between the two replacement power options for Temperance Flat RM 279 Reservoir. Replacement Power Option 1 appears to be more efficient for developing replacement power based on the ratio of cost for replacement facilities to new generation, but does not provide full replacement power. Replacement Power Option 2 can provide full replacement power at a higher cost. Therefore, Replacement Power Options 1 and 2 will be included with the RM 279 measures retained for further comparison in **Chapter 7**.

Temperance Flat RM 286 Reservoir

Unlike the RM 274 and RM 279 sites, the RM 286 site is not located in Millerton Lake, but is approximately 6 miles downstream of Kerckhoff Dam, between the dam and the Kerckhoff powerhouses. The RM 286 site rises uniformly from elevation 740 in the San Joaquin River channel to elevation 1,450 on the left abutment, and then through a flatter slope at elevation 1,450 to 1,650 before continuing to elevation 2,100. The right abutment rises uninterrupted and uniformly to beyond elevation 1,850 at an unnamed peak.

Site Characteristics and Dam Design Considerations

A dam crest up to elevation 1,400 was considered, which would result in a dam height of 660 feet and a reservoir capacity of 1,360 TAF of new storage. Although the topography would support a higher dam at the RM 286 site, it would create a reservoir that would inundate the Big Creek No. 3 Powerhouse. The incremental cost of impacts to the Big Creek No. 3 Powerhouse were not considered justified by the additional new water supply associated with larger sizes. The potential reservoir for the RM 286 site at elevation 1,400 is shown in **Figure 6-16**.

Temperance Flat RM 286 Dam Site on the San Joaquin River

Upstream and downstream cofferdams would be required for diverting stream flows during construction. The downstream cofferdam would have a crest at about elevation 770, and height of about 30 feet. The upstream cofferdam would have a crest at about elevation 850, and a height of approximately 110 feet.

Diversion tunnels through both abutments of the new dam would be required to pass San Joaquin River flows around the construction site. One of the diversion tunnels would be used for the outlet works, and the other would be plugged after construction.

Prefeasibility-level designs and cost estimates were prepared for concrete arch and RCC dam types at the RM 286 site with crests at elevations 1,200, 1,300, and 1,400. Designs and cost estimates also were developed for CFRF measures at elevations 1,200 and 1,400. Costs for a 1,275 TAF capacity measure were developed by interpolating costs for each line item.

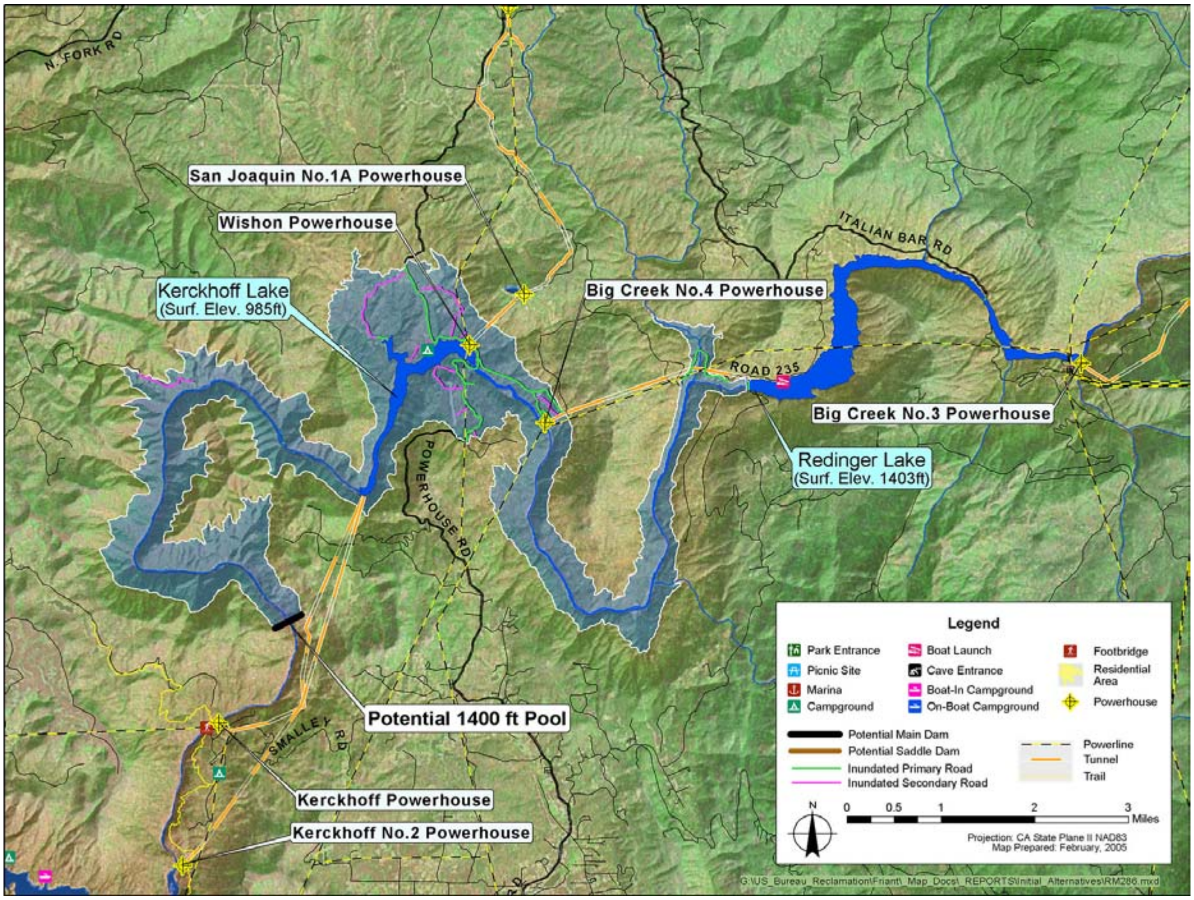

FIGURE 6-16.
POTENTIAL TEMPERANCE FLAT RM 286 RESERVOIR

Hydropower Generation Effects and Potential Replacement Power Options

Construction of a dam at RM 286 would adversely affect energy generation at existing hydropower facilities upstream of Millerton Lake, as shown in **Figures 6-16** and **6-17**. All storage capacities considered would completely inundate Kerckhoff Lake. The Kerckhoff Project powerhouses, however, would not be inundated, although their operation would be affected by significantly raising the head at the tunnel diversions. Modifications to intakes, tunnels, surge capacity, penstocks, turbines, generating equipment, and likely substations would be required to continue operation of Kerckhoff Project powerhouses. In addition, a reservoir at RM 286 would inundate the Wishon and Big Creek No. 4 powerhouses, with installed generation capacities of 20 MW and 100 MW, respectively.

Three replacement power options were considered for the RM 286 Reservoir, each at two storage capacities. A capacity of 725 TAF corresponds to a reservoir surface at elevation 1,275, which is close to the base of the Redinger Dam spillway. A capacity of 1,360 TAF corresponds to a reservoir surface at elevation 1,400, which approximately represents the existing normal maximum water surface elevation of Redinger Lake (1,403).

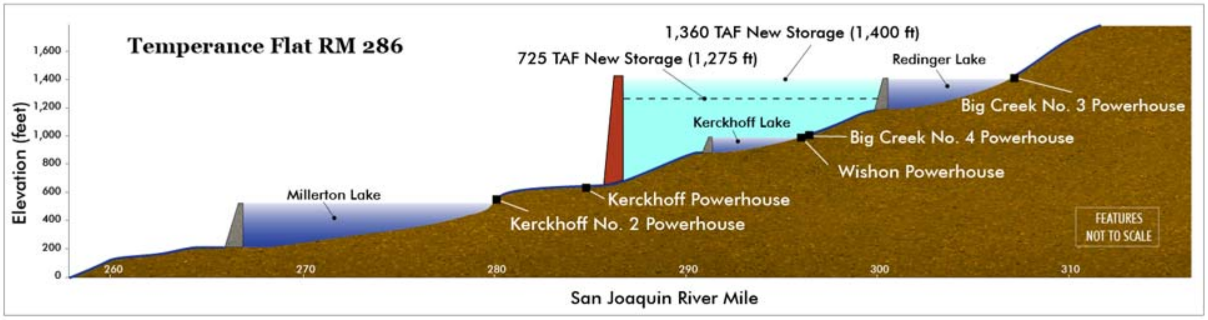

FIGURE 6-17.
HYDROPOWER FEATURES AFFECTED BY
TEMPERANCE FLAT RM 286 RESERVOIR

The three power configurations for the RM 286 Reservoir site were evaluated to identify a range of replacement power opportunities. One option involves developing new power generation facilities at the base of the dam and abandoning the Kerckhoff Project facilities. The second involves constructing a new, multiple-unit powerhouse to replace Kerckhoff No. 2. The third involves modifying the Kerckhoff No. 2 power facilities and a powerhouse at the dam.

For the 725 TAF size RM 286 Reservoir for all three power options, new powerhouses could be constructed to replace some of the generation lost from the Big Creek No. 4 and Wishon powerhouses. The Big Creek No. 4 replacement powerhouse could be constructed at Redinger Dam and the Wishon replacement powerhouse could be constructed farther upstream on the Wishon penstock. Both powerhouses would have a tailwater elevation of 1,275 feet. Replacement powerhouses for Big Creek No. 4 and Wishon are assumed to have capacities of 30 MW and 16 MW, respectively.

For the 1,360 TAF size, a replacement for the Wishon Powerhouse could be constructed upstream on the Wishon penstock with a tailwater elevation of nearly 1,400 feet and an installed capacity of approximately 14 MW. Big Creek No. 4 Powerhouse would not be able to be replaced with a 1,360 TAF RM 286 Reservoir (elevation 1,400) feet because the new reservoir level would be equal to Redinger Lake, which is the forebay for the Big Creek No. 4 Powerhouse.

Results of replacement power evaluations for the RM 286 site are summarized in **Table 6-11.** Descriptions of replacement power options are provided in the following sections.

TABLE 6-11.
ESTIMATED ENERGY GENERATION AND LOSSES FOR TEMPERANCE FLAT RM 286 RESERVOIR SIZES

New Storage Capacity (TAF)	Gross Pool Elev. (feet above msl)	Estimated New Energy Generation				Estimated Losses of Energy Generation		Net Energy Generation	
		Operating Scenario	Estimated New Energy Generation (GWh/year)	Estimated Generation at Big Creek No. 4 and Wishon Powerhouse Replacements (GWh/year)	Additional Generation at Friant (GWh/year)	Powerhouses Potentially Affected	Estimated Reduction in Existing Energy Generation (GWh/year)[1]	Net Generation for WQ or RF Operating Scenario (GWh/year)	Average Net Generation (GWh/year)
Replacement Power Option 1 – New large Powerhouse at dam									
725	1,275	WQ	532	178	5	Kerckhoff, Kerckhoff No. 2 Wishon, Big Creek No. 4	-981	-266	-252
		RF	534	178	30			-239	
1,360[2]	1,400	WQ	597	39	6	Kerckhoff, Kerckhoff No. 2 Wishon, Big Creek No. 4	-981	-339	-326
		RF	592	39	36			-314	
Replacement Power Option 2 – New Kerckhoff No. 2 Powerhouse									
725	1,275	WQ	662	178	5	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-136	-122
		RF	665	178	30			-108	
1,360[2]	1,400	WQ	736	39	6	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-200	-187
		RF	731	39	36			-175	
Replacement Power Option 3 – New small powerhouse at dam, turbine-generator replacement at Kerckhoff No. 2 Powerhouse									
725	1,275	WQ	637[3]	178	5	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-161	-147
		RF	640[3]	178	30			-133	
1,360[2]	1,400	WQ	697[3]	39	6	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-239	-222
		RF	700[3]	39	36			-206	

Key:
GWh/year – gigawatt-hour per year
RM – river mile
msl – mean sea level
TAF – thousand acre-feet
RF – restoration flow single-purpose analysis
WQ – water quality single-purpose analysis

Notes:
1 Based on estimated generation numbers from without-project spreadsheet simulations.
2 Power generation analysis based on water operations data for a net storage capacity of 1,350 TAF, which is assumed to be roughly equivalent to the power impact break point of 1,400 feet (1,360 TAF).
3 New generation values for Replacement Power Option 3 include generation at modified Kerckhoff No. 2 facility.

RM 286 Replacement Power Option 1

This option includes a multiple-unit powerhouse located on the right abutment diversion tunnel just downstream of the dam and abandonment of all Kerckhoff facilities. Installed capacities for the powerhouse are assumed to be 160 MW for the 725 TAF size and 180 MW for the 1,360 TAF size. The powerhouse would have four turbine-generator units to take greatest advantage of various flow and head conditions. An opportunity may exist with this option to move the powerhouse farther downstream and gain up to 50 feet more head; however, additional study is needed to identify how much farther the powerhouse can be moved downstream without requiring a surge chamber. A conceptual layout of the components of this option is shown in **Figure 6-18**.

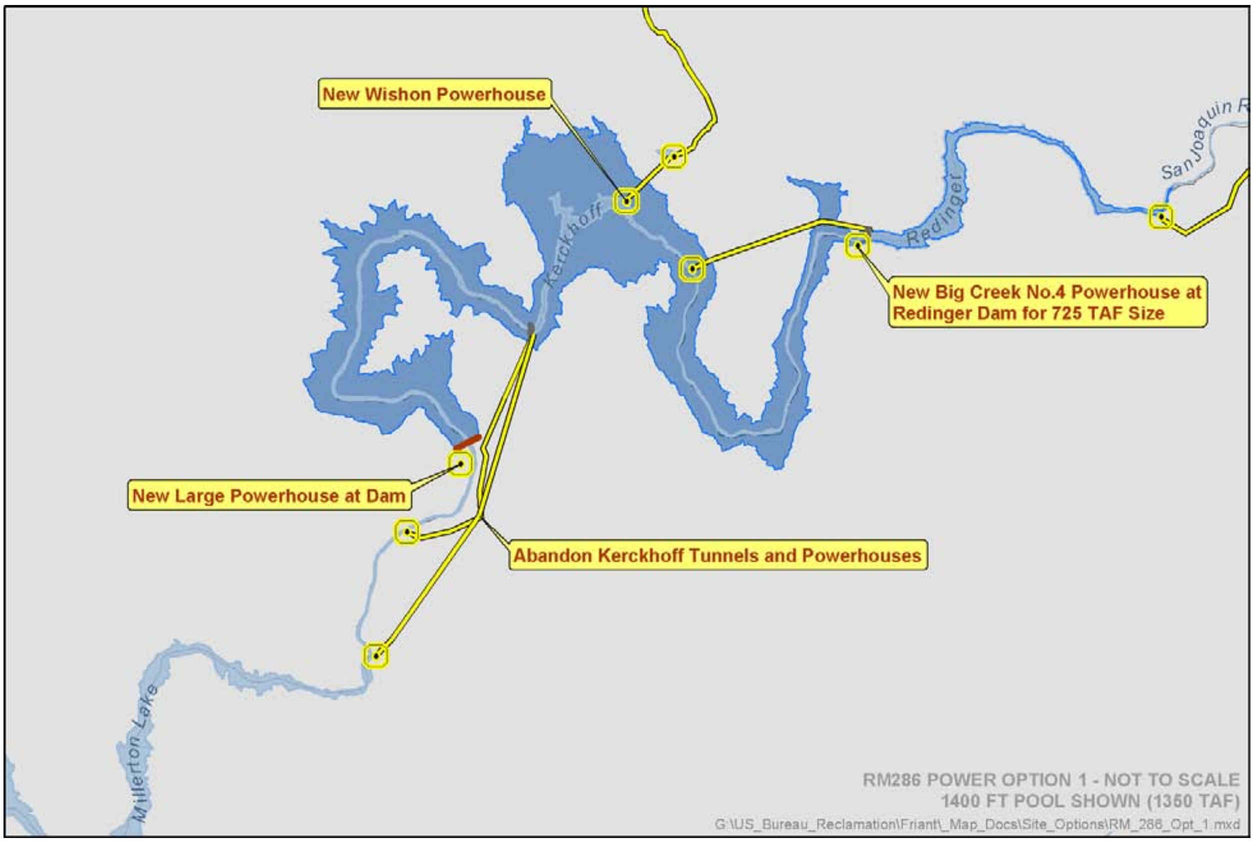

FIGURE 6-18.
REPLACEMENT POWER OPTION 1 FOR TEMPERANCE FLAT RM 286 RESERVOIR

RM 286 Replacement Power Option 2

This option would involve constructing a new multiple-unit powerhouse that would be located at Millerton Lake at about RM 283 to replace Kerckhoff No. 2. Installed capacities for the powerhouse are assumed to be 180 MW for the 725 TAF size and 200 MW for the 1,360 TAF size. The powerhouse would have four turbine-generator units to take greatest advantage of variable flow and head conditions. The existing Kerckhoff No. 2 intake and tunnel would be modified to supply water to the new powerhouse. A new surge chamber on the Kerckhoff No. 2 tunnel also would be required. Both existing Kerckhoff Project powerhouses would be abandoned. The longer conveyance tunnel and need for a surge chamber and penstocks also would result in a greater head loss. A conceptual layout of the components for this option is shown in **Figure 6-19**.

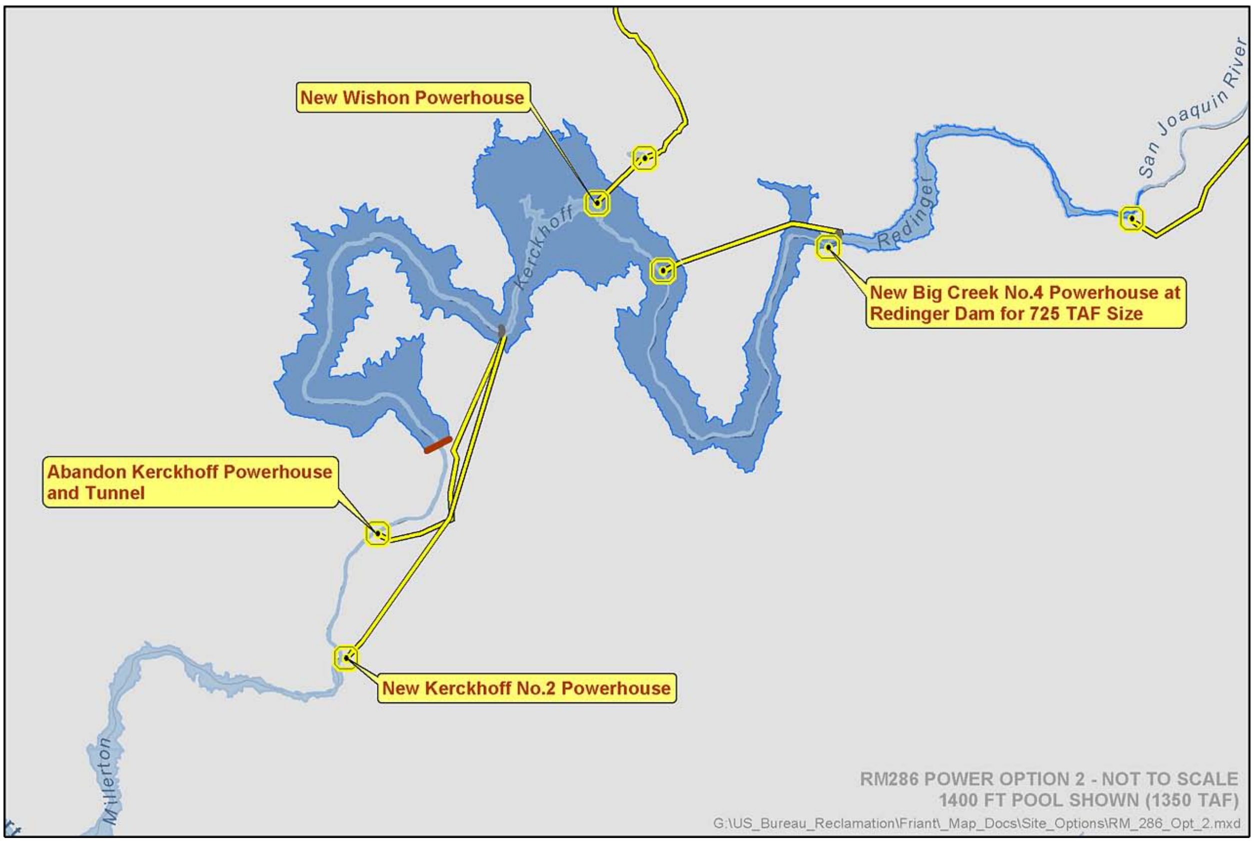

FIGURE 6-19.
REPLACEMENT POWER OPTION 2 FOR TEMPERANCE FLAT RM 286 RESERVOIR

RM 286 Replacement Power Option 3

This option would use existing Kerckhoff No. 2 facilities to the maximum extent by replacing the single-unit turbine and generation equipment in the Kerckhoff No. 2 Powerhouse with appropriate equipment to accommodate greater head. The Kerckhoff No. 2 intake and tunnel would be modified and a new surge chamber and single new turbine-generator would be installed. The longer conveyance tunnel and need for a surge chamber and penstocks would result in a greater head loss. Installed capacities for a new Kerckhoff No. 2 unit are assumed to be 155 MW for the 725 TAF size and 186 MW for the 1,360 TAF size.

The Kerckhoff powerhouse, intake, and tunnel would be abandoned, and a small, single-unit powerhouse would be constructed at the base of the RM 286 dam. Installed capacities for the dam powerhouse would be 45 MW for the 725 TAF size and 50 MW for the 1,360 TAF size. A conceptual layout of the components for this option is shown in **Figure 6-20**.

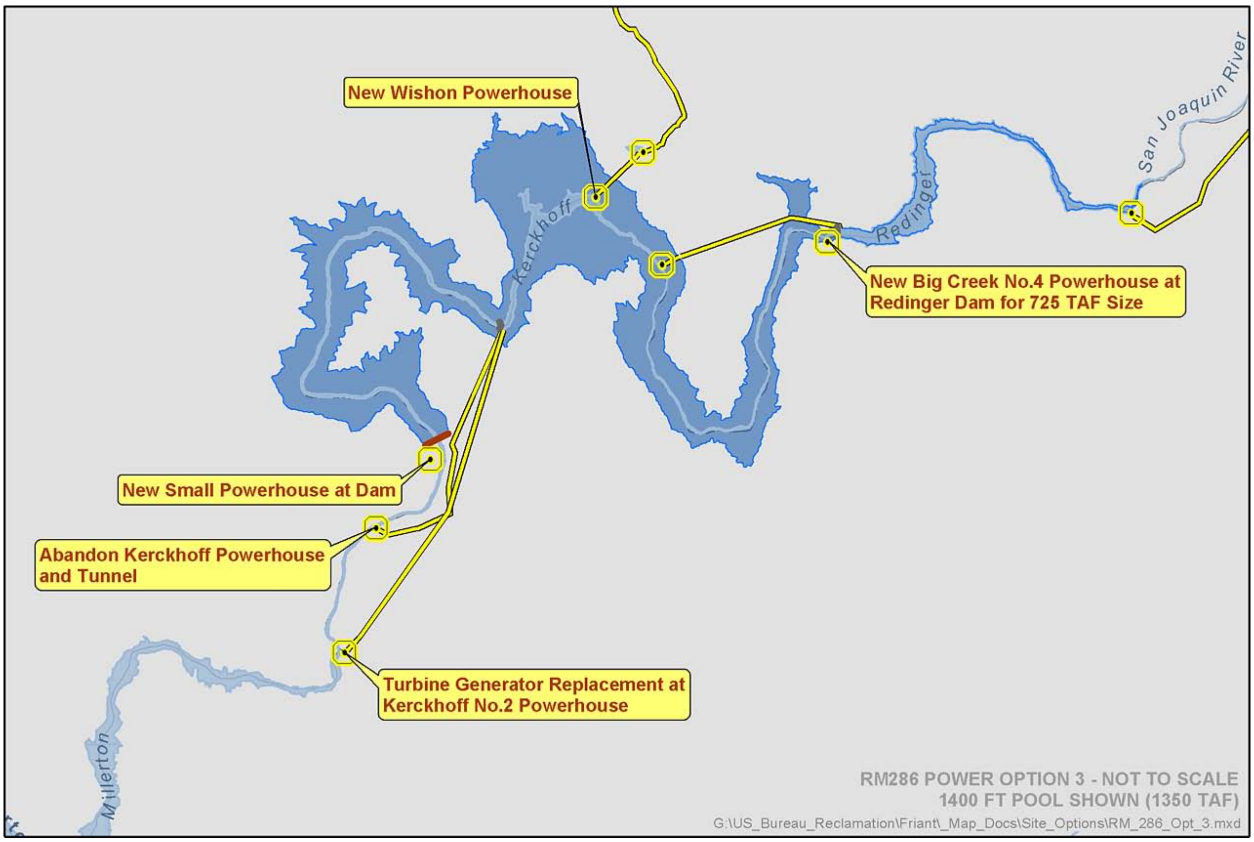

FIGURE 6-20.
REPLACEMENT POWER OPTION 3 FOR TEMPERANCE FLAT RM 286 RESERVOIR

Cost Estimates

Construction costs for dams, appurtenant features, power replacement facilities, and other impacted infrastructure were developed for storage capacities up to 1,360 TAF at the RM 286 site. This capacity would correspond to a reservoir at elevation 1,400, which would be at the top of Redinger Dam, and would inundate Kerckhoff Lake and the Wishon and Big Creek No. 4 powerhouses.

Costs for constructing RM 286 storage measures at several sizes, combined with Power Replacement Options 1 through 3, are summarized in **Tables 6-12** through **6-14**. These costs include constructing the main dam and appurtenant features, and costs for abandoning, modifying, or relocating existing facilities. The dam and appurtenant structures would be located on public land. Parcels of land immediately upstream from the construction area and in the potential area of inundation are privately owned and would need to be acquired. Property acquisition costs are included in the construction costs shown in **Tables 6-12** through **6-14**.

A comparison of cost estimates prepared during Phase 1 of the Investigation suggests that RCC has the lowest cost of the dam types examined for RM 286, except at elevation 1,200, where the concrete arch design would have a slightly lower cost. However, cost differences between dam types are not great enough to conclusively identify the most cost-efficient design at all crest elevations. For simplicity and ease of comparison, only costs for the RCC dam type are included in **Tables 6-12** through **6-14**.

Tables 6-12 through **6-14** show construction costs for RM 286 dam and reservoir measures with each of the three replacement powerhouse configurations. Costs include dam and appurtenant features; abandonment, modification, or relocation of existing facilities; land acquisition; and indirect costs.

Costs for all storage measures include costs for relocating Powerhouse Road and Bridge and for decommissioning and abandoning the Kerckhoff Powerhouse and its intake structure; Kerckhoff Dam, gates, hoist, and outlet works; the Wishon Powerhouse; and Big Creek No. 4 Powerhouse. All power configurations include the cost to construct a 14 to 16 MW replacement Wishon Powerhouse at a higher elevation, and for reservoir elevations up to and including 1,300, the cost to construct a 30 MW powerhouse at Redinger Dam to replace the Big Creek No. 4 Powerhouse.

Construction costs for the three replacement power options at the various storage sizes are shown in **Figure 6-21**.

TABLE 6-12.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 286 MEASURES WITH REPLACEMENT POWER OPTION 1 ($ MILLION)

Gross Pool Elevation (feet above msl)	1,200	1,275	1,400
New Storage Capacity (TAF)	**460**	**725**	**1,360**
Storage Components			
RCC Dam, Spillway, River Diversion, Reservoir Lands	320	360	560
River Outlet Works at RM 286	70	88	105
Abandon Kerckhoff No. 2 Powerhouse	2	2	2
Abandon Intake for Kerckhoff No. 2 Powerhouse	1	1	1
Abandon and Restore Kerckhoff Powerhouse	4	4	4
Abandon Intake for Kerckhoff Powerhouse	1	1	1
Remove Kerckhoff Dam Outlet Works and Gates	2	2	2
Abandon Wishon Powerhouse	2	2	2
Abandon Big Creek No. 4 Powerhouse	4	4	4
Remove Redinger Dam Operating Equipment	-	-	8
Powerhouse Road Relocation	18	36	55
Powerhouse Road Bridge Relocation	34	35	49
Construction Cost, Storage Components	**458**	**535**	**793**
Replacement Power Components			
New Powerhouse at RM 286 Dam (150 to 180 MW)	115	120	125
RM 286 Switchyard and Transmission Line	18	18	18
New Wishon Powerhouse (14 to 16 MW)	46	46	46
New Big Creek No. 4 Powerhouse at Redinger Dam (30 MW)	69	69	-
Construction Cost, Replacement Power Components	**248**	**253**	**189**
Construction Cost[1, 2]	**706**	**788**	**982**

Key:
msl – mean sea level MW – megawatt RCC – roller-compacted concrete
RM – river mile TAF – thousand acre-feet
Notes:
[1] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design and construction management, estimated at 25 percent of field costs.
[2] Costs do not include environmental mitigation, new or relocated recreation facilities, acquisition of impacted power facilities, or compensation for lost future power generation.

TABLE 6-13.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 286 MEASURES WITH REPLACEMENT POWER OPTION 2 ($ MILLION)

Gross Pool Elevation (feet above msl)	1,200	1,275	1,400)
New Storage Capacity (TAF)	**460**	**725**	**1,360**
Storage Components			
RCC Dam, Spillway, River Diversion, Reservoir Lands	320	360	560
River Outlet Works at RM 286	70	88	105
Abandon Kerckhoff No. 2 Powerhouse	2	2	2
Abandon and Restore Kerckhoff Powerhouse	4	4	4
Abandon Intake for Kerckhoff Powerhouse	1	1	1
Remove Kerckhoff Dam Outlet Works and Gates	2	2	2
Abandon Wishon Powerhouse	2	2	2
Abandon Big Creek No. 4 Powerhouse	4	4	4
Remove Redinger Dam Operating Equipment	-	-	8
Powerhouse Road Relocation	18	36	55
Powerhouse Road Bridge Relocation	34	35	49
Construction Cost, Storage Components	**457**	**534**	**792**
Replacement Power Components			
New Kerckhoff No. 2 Powerhouse (170 to 200 MW)	175	180	190
Kerckhoff No. 2 Diversion Tunnel, Steel Liner	85	115	165
Kerckhoff No. 2 Diversion Tunnel, Backfill Concrete	3	3	3
Modify Kerckhoff No. 2 Diversion Intake	33	36	45
New Wishon Powerhouse (14 to 16 MW)	46	46	46
New Big Creek No. 4 Powerhouse at Redinger Dam (30 MW)	69	69	-
Construction Cost, Replacement Power Components	**411**	**449**	**449**
Construction Cost[1, 2]	**868**	**983**	**1,241**

Key:
msl – mean sea level; MW – megawatt; RCC – roller-compacted concrete
RM – river mile; TAF – thousand acre-feet

Notes:

[1] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design and construction management, estimated at 25 percent of field costs.

[2] Costs do not include environmental mitigation, new or relocated recreation facilities, acquisition of impacted power facilities, or compensation for lost future power generation.

TABLE 6-14. CONSTRUCTION COSTS FOR RM 286 MEASURES WITH REPLACEMENT POWER OPTION 3 ($ MILLION)

Gross Pool Elevation (feet above msl)	**1,200**	**1,275**	**1,400**
New Storage Capacity (TAF)	**460**	**725**	**1,360**
Storage Components			
RCC Dam, Spillway, River Diversion, Reservoir Lands	320	360	560
River Outlet Works at RM 286	70	88	105
Abandon and Restore Kerckhoff Powerhouse	4	4	4
Abandon Intake for Kerckhoff Powerhouse	1	1	1
Remove Kerckhoff Dam Outlet Works and Gates	2	2	2
Abandon Wishon Powerhouse	2	2	2
Abandon Big Creek No. 4 Powerhouse	4	4	4
Remove Redinger Dam Operating Equipment	-	-	8
Powerhouse Road Relocation	18	36	55
Powerhouse Road Bridge Relocation	34	35	49
Construction Cost, Storage Components	**455**	**532**	**790**
Replacement Power Components			
New Powerhouse at RM 286 Dam (40 to 60 MW)	130	145	155
RM 286 Switchyard and Transmission Line	18	18	18
Kerckhoff No. 2 Turbine Generator Replacement (140 to 186 MW)	68	70	78
Kerckhoff No. 2 Penstock, Ring Follower Gate	28	28	28
Kerckhoff No. 2 Diversion Tunnel, Steel Liner	85	115	165
Kerckhoff No. 2 Diversion Tunnel, Backfill Concrete	3	3	3
Modify Kerckhoff No. 2 Diversion Intake	33	36	45
New Wishon Powerhouse (14 to 16 MW)	46	46	46
New Big Creek No. 4 Powerhouse at Redinger Dam (30 MW)	69	69	-
Construction Cost, Replacement Power Components	**480**	**530**	**538**
Construction Cost[1, 2]	**935**	**1,062**	**1,328**

Key:
msl – mean sea level; MW – megawatt; RCC – roller-compacted concrete
RM – river mile; TAF – thousand acre-feet

Notes:

[1] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design and construction management, estimated at 25 percent of field costs.

[2] Costs do not include environmental mitigation, new or relocated recreation facilities, acquisition of impacted power facilities, or compensation for lost future power generation.

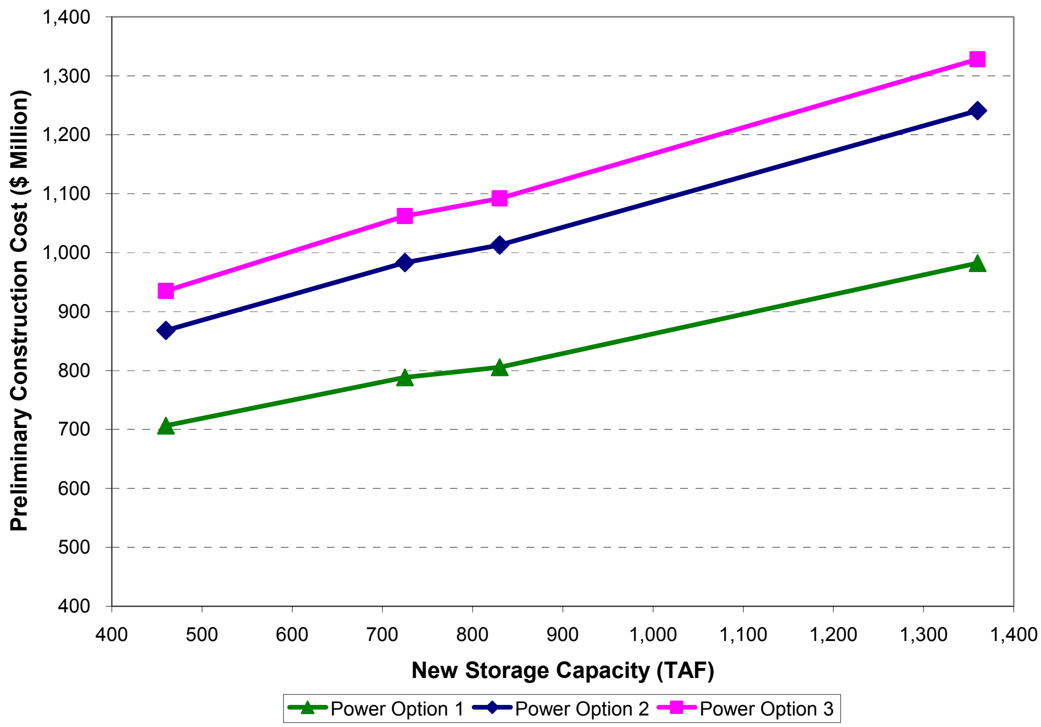

FIGURE 6-21.
CONSTRUCTION COSTS FOR TEMPERANCE FLAT RM 286 MEASURES VS. NEW STORAGE CAPACITY

Environmental Considerations

A reservoir at RM 286 may impact vegetation, wildlife and fisheries, recreation, land use, and cultural resources but will not affect most environmental resources in Millerton Lake, in contrast to the other Temperance Flat reservoir measures. River reaches potentially affected by a dam at RM 286 include Patterson Bend and Kerckhoff Lake and Horseshoe Bend.

Special status species associated with the above river reaches are described in **Chapter 3**. **Table 6-4** provides a sum of special status species occurring in each river reach potentially affected by a RM 279 Reservoir. A dam at RM 286 would present a barrier to fish populations between Friant Dam and Redinger Dam, but would replace only the existing Kerckhoff Dam located a few miles upstream. As described above for a potential dam at RM 279, fisheries management would be required with a new reservoir at RM 286 to prevent the introduction of non-native fishes to Kerckhoff Lake and Horseshoe Bend, a designated CAR.

Lands potentially affected by a dam at RM 286 contain no residences, and are managed by either the BLM as the San Joaquin River Gorge Management Area or the USFS as the SNF. Within the Horseshoe Bend reach, the USFS Backbone Creek RNA, described above, may be partially inundated with the considered RM 286 measures. Road 222 and Powerhouse Road Bridge, which crosses over Kerckhoff Lake, the Patterson mine, and facilities associated with the Wishon and Big Creek No. 4 powerhouses also may be affected by a RM 279 Reservoir.

The maximum pool elevation considered for RM 286 is just below the crest elevation of Big Creek Dam No. 7, also referred to as Redinger Dam. Whitewater recreation would be affected in the Patterson Bend and Horseshoe Bend reaches of the river. Environmental considerations for a dam at RM 286 related to cultural resources are expected to be similar to those of RM 279.

Recommendations for Further Study

No large changes in incremental cost or impacts to hydropower and environmental resources were evident for the three evaluated RM 286 reservoir measures ranging from 460 to 1,360 TAF (elevations 1,200 to 1,400). All three measures will be retained for comparison to other measures providing similar amounts of new water supply in **Chapter 7**. Tradeoffs exist between the three Replacement Power Options for a Temperance Flat RM 286 Reservoir. Replacement Power Option 1 appears to be the most efficient at developing replacement power based on the ratio of cost for replacement facilities to new generation. Replacement Power Option 2 provides more replacement power at a lower cost than Replacement Power Option 3 for all storage sizes considered. Therefore, Replacement Power Options 1 and 2 will be included with the RM 286 measures retained for further comparison in **Chapter 7**.

Fine Gold Reservoir

Fine Gold Creek watershed north of Millerton Lake

Fine Gold Creek is a tributary to the San Joaquin River that enters Millerton Lake from the north at about RM 273 and drains a watershed area of approximately 91 square miles. Fine Gold Reservoir could be filled by pumping water from Millerton Lake or fed by water diverted through a tunnel from Kerckhoff Lake. Options for storing water pumped from Millerton Lake are discussed in this section of the chapter. The concept of diverting San Joaquin River water from Kerckhoff Lake was suggested during the scoping process and is discussed later in this chapter.

Options for developing storage in the Fine Gold Creek watershed involve building a dam and reservoir with a gross pool of up to approximately elevation 1,110. Preliminary designs and cost estimates were developed for potential dam and reservoir sizes between elevations 900 and 1,110. A gross pool at elevation 900 would correspond to a dam 380 feet high with 120 TAF of storage capacity. A gross pool at elevation 1,110 would correspond to a dam 590 feet high with 800 TAF of storage capacity. Two potential dam types were considered: CFRF and RCC gravity dams. A reservoir with 800 TAF of storage and an intermediate 400 TAF reservoir were considered for hydrologic modeling purposes.

The elevation 1,100 measure would require constructing a saddle dam approximately 100 feet high and 3,200 feet long on the west rim of the reservoir. **Figure 6-22** shows the extent of a Fine Gold Reservoir at elevation 1,100.

During construction, a temporary cofferdam approximately 80 feet high would be required above the permanent dam site on Fine Gold Creek to divert flows, and a second cofferdam approximately 60 feet high would be required to keep water from Millerton Lake out of the construction zone. One or more tunnels would be required to divert flood flows in Fine Gold Creek during construction; the number and placement of tunnels would depend on the dam type selected.

Potential New Water Supply

Fine Gold Reservoir as a pump-back project would involve pumping water from Millerton Lake in the winter or spring, thereby evacuating space for the capture of additional San Joaquin River inflow to Millerton Lake. Water stored in Fine Gold Reservoir subsequently would be released to Millerton Lake, then diverted to the Friant-Kern or Madera canals and/or released to the San Joaquin River.

CALSIM water operations model simulations completed during Phase 1 indicate that the potential new water supply resulting from developing a Fine Gold Reservoir of 800 TAF could be up to almost 140 TAF/year on average. As summarized in **Table 6-15**, development of new water supplies varies in relationship to the amount of new storage created and management of the new water.

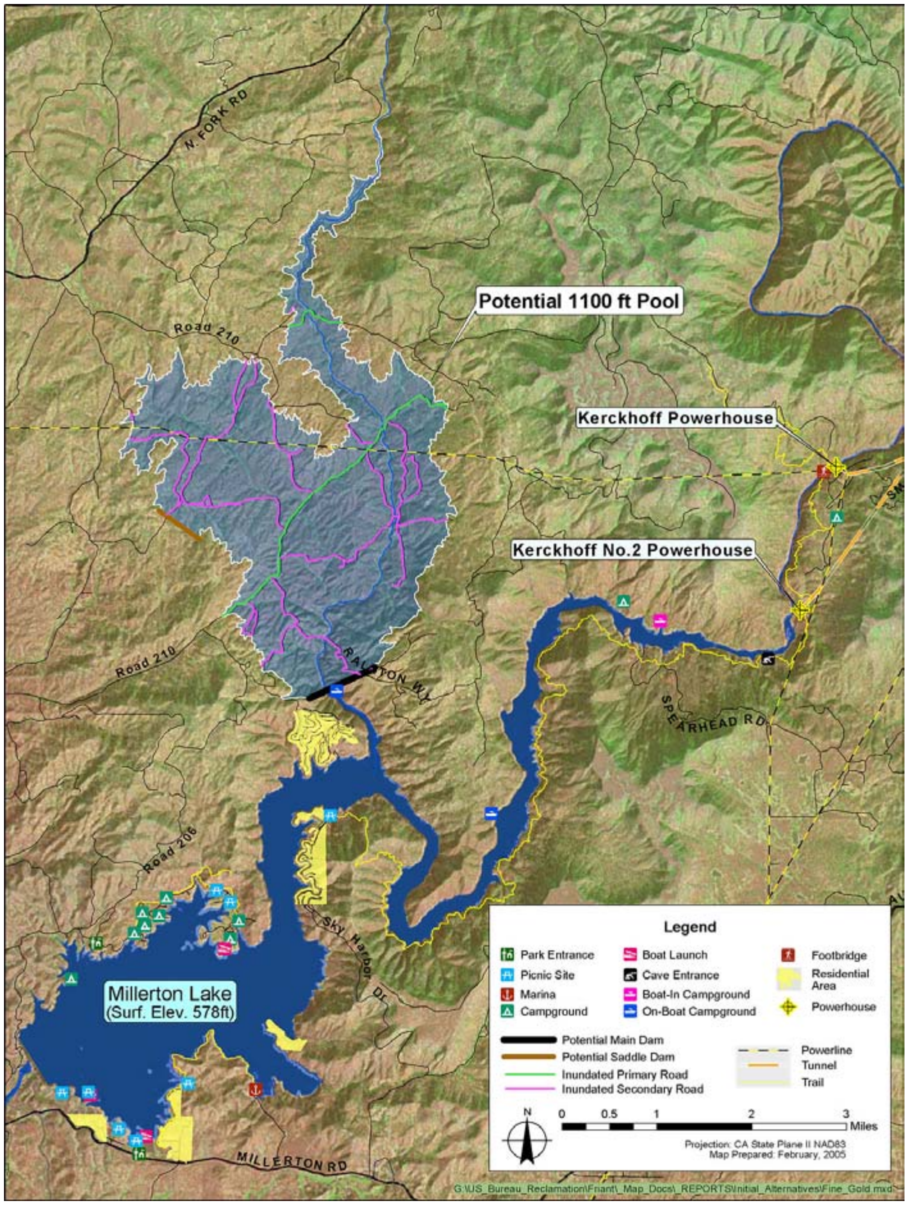

FIGURE 6-22.
POTENTIAL FINE GOLD RESERVOIR

Table 6-15 shows that releasing water to the San Joaquin River could result in developing more new water supply than releasing new water supplies to the Friant-Kern and Madera canals only. This is because water deliveries are limited by contract amounts and available conveyance capacity, whereas simulated releases to the river were maximized to the extent that they would not reduce water deliveries from without-project levels. The smaller dam size considered at elevation 900 has only a fifth of the storage capacity of the elevation 1,110 reservoir measure, and would not be expected to produce more than 20 TAF/year on average.

TABLE 6-15.
NEW WATER SUPPLY FROM FINE GOLD RESERVOIR SIZES

Gross Pool Elevation (feet above msl)	New Storage Capacity (TAF)	New Water Supply Estimated in Single-Purpose Analysis (average TAF/year)		
		RF	WQ	WS
1,020	400	n/s	n/s	65
1,110	800	136	124	113

Key:
msl – mean sea level
n/s – not simulated
TAF – thousand acre-feet
RF – San Joaquin River restoration flow single-purpose analysis
WQ – San Joaquin River water quality single-purpose analysis
WS – water supply reliability single-purpose analysis

Hydropower Generation Effects and Pumping Requirements

Fine Gold Reservoir would not impact power generation at any existing hydropower facilities. Power generation and use were estimated for a Fine Gold Reservoir of 800 TAF to enable comparisons to other potential sites of similar size, such as Yokohl Valley Reservoir at 800 TAF and the Temperance Flat measures at 725 TAF. Water would be pumped from Millerton Lake to the new reservoir and later released back to Millerton Lake. The pump head would range from a minimum of 60 feet (full Millerton Lake) up to 580 feet (full Fine Gold Reservoir). Electricity would need to be supplied to power the pump-turbine units when pumping. This energy requirement would be partially offset by generating electricity from the pump-turbine units when water was released back to Millerton Lake. **Figure 6-23** shows Fine Gold Reservoir in profile and highlights the pumping and generating features.

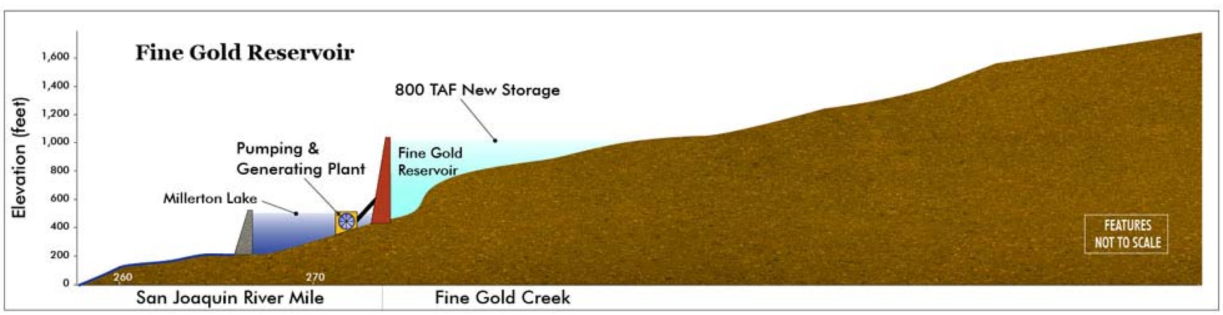

FIGURE 6-23.
FINE GOLD RESERVOIR PROFILE

Table 6-16 summarizes estimated energy generation and pumping energy requirements for Fine Gold Reservoir at 800 TAF. Generation and pumping energy requirement estimates were made using a monthly timestep spreadsheet model that accounts for flow and head at each potential new power facility. As shown in **Table 6-16**, pumping energy requirements would exceed generation potential by 25 to 50 percent, resulting in a net energy requirement of up to about 50 GWh/year.

TABLE 6-16.
ESTIMATED PUMPING REQUIREMENTS AND GENERATING POTENTIAL FOR FINE GOLD RESERVOIR

New Storage Capacity (TAF)	Gross Pool Elev. (feet above msl)	Estimated New Energy Generation			Estimated Losses of Energy Generation		Net Energy Generation	
		Operating Scenario	Estimated New Energy Generation (GWh/year)	Additional Generation at Friant (GWh/year)	Estimated Reduction in Existing Energy Generation (GWh/year)	Avg. Annual Pumping Energy Requirement (GWh/year)	Net Generation for WQ or RF Operating Scenario (GWh/year)	Average Net Generation (GWh/year)
800	1,110	WQ	103	8	---[1]	-164	-53	-40
		RF	91	25	---[1]	-144	-28	

Key:
GWh/year – gigawatt-hour per year
msl – mean sea level
RF – restoration flow single-purpose analysis
TAF – thousand acre-feet
WQ – water quality single-purpose analysis

Notes:
[1] Fine Gold Reservoir would not impact any existing hydropower facilities.

Cost Estimates

Construction costs associated with building Fine Gold Dam and Reservoir increase with elevation. This is due in part to the dam volume and also to the need for construction of a saddle dam on the reservoir rim for reservoir elevations greater than 1,000.

Table 6-17 summarizes construction costs of the Fine Gold Reservoir measures considered. Appurtenant features bundled with the cost of the dam include spillway, diversion during construction, outlet works, and pumping-generating plant. Cost estimates for the elevation 900 and 1,100 dam measures are based on preliminary designs; CFRF measures at other elevations were interpolated or projected. Costs have been estimated separately for road relocations, completion of which would involve constructing one or two short crossings over a neck of the reservoir, depending on the reservoir elevation and relocation route.

Privately owned lands, including up to 10 residences, would be acquired in the reservoir area. An estimate of these acquisition costs is included in the construction costs shown for the dam and appurtenances, along with an allowance of approximately 20 percent of the property costs for indirect costs associated with property acquisition transactions.

Figure 6-24 shows construction costs in relation to the new storage capacity that would be developed by the Fine Gold Reservoir measures.

TABLE 6-17.
CONSTRUCTION COSTS FOR FINE GOLD RESERVOIR MEASURES
($ MILLION)

Gross Pool Elevation (feet above msl)	900	1,020	1,110
New Storage Capacity (TAF)	120	400	800
Dam Type	CFRF	CFRF	CFRF
Components			
Dam, Appurtenant Features, Reservoir Lands[1]	240	430	610
Road 210 Relocation	28	23	18
Road 210 Bridges	15	15	15
Construction Costs[2,3]	**283**	**468**	**643**

Key:
CFRF – concrete face rockfill
msl – mean sea level
RCC – roller-compacted concrete
TAF – thousand acre-feet

Notes:
[1] Appurtenant features include spillway, diversion during construction, outlet works, and pumping-generating plant.
[2] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design and construction management, estimated at 25 percent of field costs
[3] Costs do not include environmental mitigation, new or relocated recreation facilities.

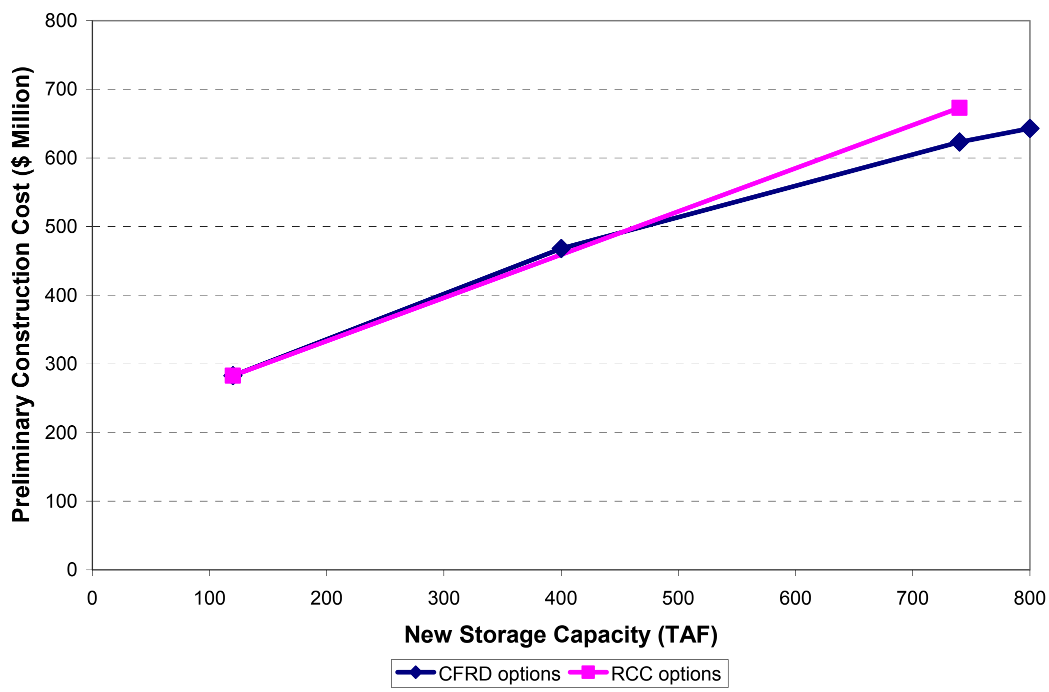

FIGURE 6-24.
CONSTRUCTION COSTS FOR FINE GOLD RESERVOIR MEASURES VS. NEW STORAGE CAPACITY

Environmental Considerations

Creation of Fine Gold Creek Reservoir may result in adverse environmental impacts to physical and biological resources, and some social and cultural resources. River reaches potentially affected include Fine Gold Creek and Millerton Lake. The relatively pristine watershed of Fine Gold Creek supports many biological resources, and is considered an ADMA. A reservoir would replace the largely intermittent foothill stream, comprising bouldery pools connected by long sandy-bottomed sections of stream (Moyle et al., 1996).

Extensive areas of pine and oak woodland habitat would be affected, as would pockets of riparian and wetland habitats. Vernal pools and special status species of plants and wildlife, described in **Chapter 3**, may be present in the inundation area. **Table 6-4** summarizes special status species occurring in each river reach potentially affected by a Fine Gold Creek reservoir. Pumped storage operations could affect water temperatures in Millerton Lake and cause fluctuations in water levels in both Millerton Lake and the new Fine Gold Creek reservoir.

Impacts to social and economic resources are anticipated to be minimal since the Fine Gold Creek watershed appears to be largely undeveloped. Some scattered single-family homes, related farm structures and access roads are present in the area. Road 210, Hidden Lake Boulevard, and Ralston Way traverse the watershed. Additionally, three archaeological sites were identified in the Fine Gold Creek watershed (Welch, 2002).

Recommendations for Further Study

A Fine Gold Reservoir of 120 TAF (elevation 900) does not appear to be cost-effective. It has the highest unit cost of water of any of the surface storage measures under consideration. The topography of the site is such that at elevation 900 a large dam (380 feet high) is required, but only a small amount of storage is developed. Therefore, the 120 TAF size of Fine Gold Reservoir is dropped from further consideration in the Investigation. A threshold size between 120 TAF and 800 TAF where the reservoir becomes more cost-effective has yet to be determined; however, a 400 TAF size will be used in the evaluation. Fine Gold Reservoir measures ranging in size from 400 TAF to 800 TAF will be retained for further evaluation and comparison with other measures in **Chapter 7**.

Yokohl Valley Reservoir

Yokohl Valley (looking toward Lindsay Peak)

Yokohl Valley Reservoir would be located approximately 15 miles east of Visalia and 8 miles south of Lake Kaweah (**Figure 6-25**). Yokohl Valley Reservoir would be operated as a pump-back project served by the Friant-Kern Canal. This is a variation of an option that was described initially in a study of the Mid-Valley Canal by Reclamation (1964). Options for developing storage in Yokohl Valley Reservoir involve building a dam with a gross pool at up to elevation 860. Two potential dam and reservoir sizes were considered. A gross pool at elevation 790 would correspond to a dam 260 feet high with a crest length of nearly 3,000 feet and 450 TAF of storage capacity. A gross pool at elevation 860 would correspond to a dam 330 feet high with 800 TAF of storage capacity. **Figure 6-25** shows the extent of a Yokohl Valley Reservoir at elevation 860. Two small saddle dams in the hills west of the main dam site would be required.

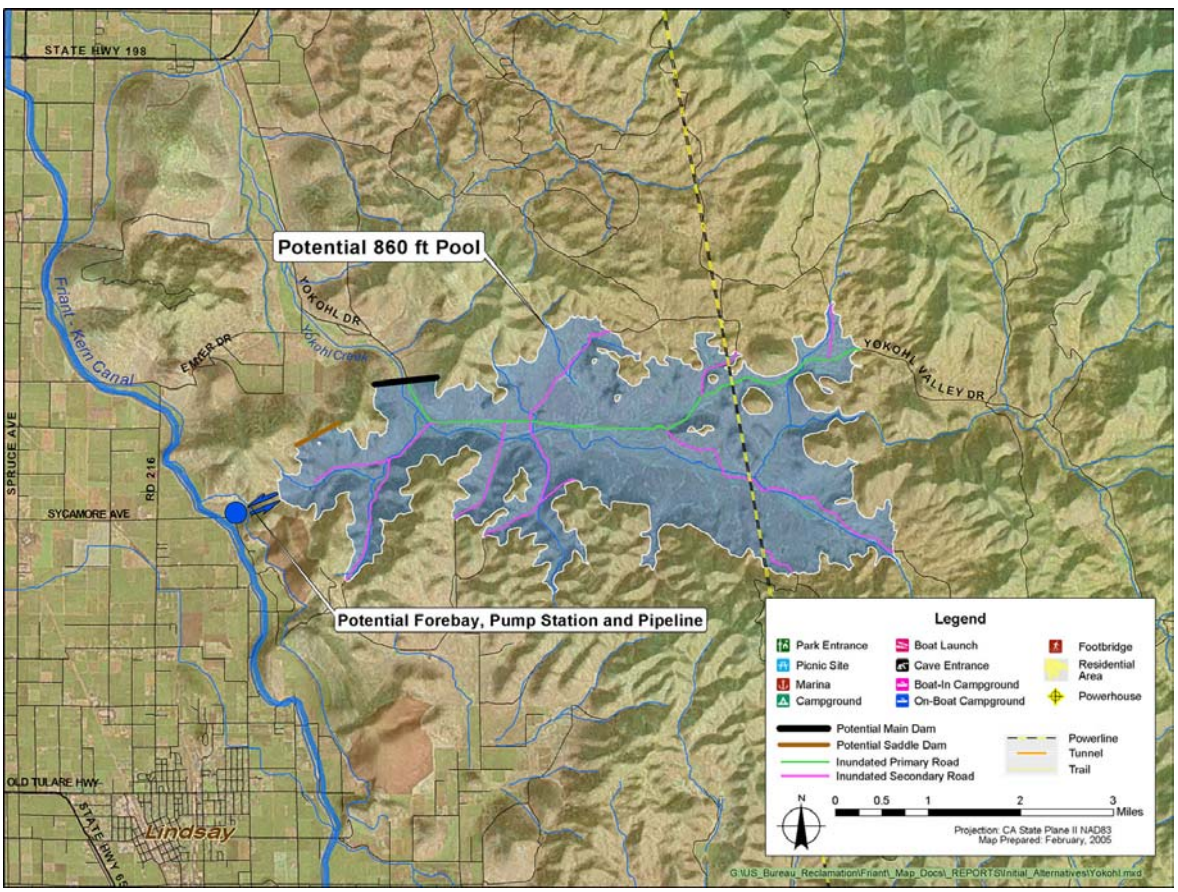

FIGURE 6-25.
POTENTIAL YOKOHL VALLEY RESERVOIR

Site characteristics at the Yokohl Valley dam site appear to pose no barriers to construction. Underlying rock conditions would be adequate for a dam foundation; sufficient impervious, pervious, and riprap materials exist within 2 miles of the proposed dam site; and potential staging and lay-down areas are located immediately upstream and downstream of the project site. An improved road provides access directly to the dam site and electrical power would likely be available from sources in Exeter or along Highway 198.

Potential New Water Supply

Yokohl Valley Reservoir would operate as a pump-back storage reservoir served by the Friant-Kern Canal, as shown in **Figure 6-26**. This offstream and off-basin storage would rely on Friant-Kern Canal diversion as the only water source for the pump-storage operation. In wet months, any water that exceeded demand would be diverted to the Friant-Kern Canal and stored in Yokohl Valley Reservoir to free up Millerton Lake for capture of floodwater. During irrigation season, water released from Yokohl Valley Reservoir could supplement Millerton Lake diversions to satisfy demand along the Friant-Kern Canal. To avoid significant fluctuation in Friant-Kern Canal water levels, pumping and releasing would be through a forebay off the canal (see **Figure 6-26**).

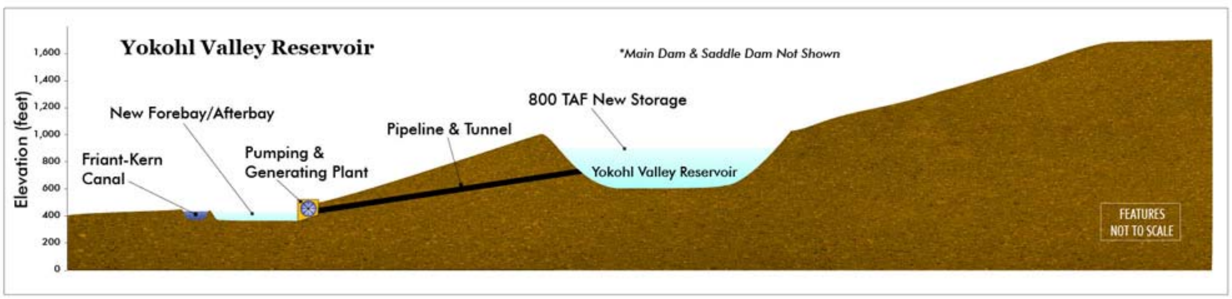

FIGURE 6-26.
POTENTIAL YOKOHL VALLEY RESERVOIR PROFILE

CALSIM water operations model simulations completed during Phase 1 indicate that the potential new water supply resulting from developing a Yokohl Valley Reservoir of 800 TAF could be up to almost 100 TAF/year on average. As summarized in **Table 6-18**, development of new water supplies varies in relationship to the amount of new storage created and management of the new water. Pumping capacity to Yokohl Valley Reservoir was assumed at 2,000 cfs. The new water supply from Yokohl Valley Reservoir would be similar to, but lower than, similar reservoir sizes at Fine Gold Creek because of conveyance constraints in the Friant-Kern Canal and because evaporation losses from Yokohl Valley Reservoir are higher.

TABLE 6-18. NEW WATER SUPPLY FROM YOKOHL VALLEY RESERVOIR SIZES

New Storage Capacity (TAF)	New Water Supply Estimated in Single-Purpose Analysis (average TAF/year)		
	RF	WQ	WS
400	n/s	n/s	60
800	88	82	97

Key:
n/s – not simulated
RF – San Joaquin River restoration flow single-purpose analysis
TAF – thousand acre-feet
WQ – San Joaquin River water quality single-purpose analysis
WS – water supply reliability single-purpose analysis

Hydropower Generation Effects and Pumping Requirements

Yokohl Valley Reservoir would not impact power generation at any existing hydropower facilities. Power generation and use were estimated for a Yokohl Valley Reservoir of 800 TAF to enable comparisons to other potential sites of similar size. Water would be pumped from the Friant-Kern Canal to the new reservoir and later released back to the Friant-Kern Canal. The water surface level at the Friant-Kern Canal was assumed to be constant at elevation 410. Electricity would need to be supplied to power the pump-turbine units when pumping. This energy requirement would be partially offset by generating electricity from the pump-turbine units when water was released back to the Friant-Kern Canal.

Table 6-19 summarizes estimated energy generation and pumping energy requirements for Yokohl Valley Reservoir at 800 TAF of storage. Generation and pumping energy requirement estimates were made using a monthly timestep spreadsheet model that accounts for flow and head at each potential new power facility. As shown in **Table 6-19**, pumping energy requirements would exceed generation potential by 65 to 100 percent, resulting in a net energy loss of up to about 70 GWh/year.

TABLE 6-19. ESTIMATED PUMPING REQUIREMENTS AND GENERATING POTENTIAL FOR YOKOHL VALLEY RESERVOIR

New Storage Capacity (TAF)	Gross Pool Elev. (feet above msl)	Potential New Energy Generation			Potential Losses of Energy Generation		Net Energy Generation	
		Operating Scenario	Potential New Energy Generation (GWh/year)	Additional Generation at Friant (GWh/year)	Potential Reduction in Existing Energy Generation (GWh/year)	Avg. Annual Pumping Energy Requirement (GWh/year)	Net Generation for WQ or RF Operating Scenario (GWh/year)	Average Net Generation (GWh/year)
800	860 [1]	WQ	76	-7	---[2]	-139	-70	-60
		RF	69	8	---[2]	-127	-50	

Key:
GWh/year – gigawatt-hour per year
msl – mean sea level
RF – restoration flow single-purpose analysis
TAF – thousand acre-feet
WQ – water quality single-purpose analysis
Notes:
[1] Elevation capacity data not available above 740 TAF; elevation corresponding to 800 TAF extrapolated.
[2] Yokohl Valley Reservoir would not impact any existing hydropower facilities.

Cost Estimates

Table 6-20 summarizes construction costs for the Yokohl Valley Reservoir measures considered. Appurtenant features included with the cost of the dam are a spillway, diversion during construction, outlet works, pumping-generating plant, and conveyance between the Friant Kern Canal and reservoir. Costs for relocation of Yokohl Drive and power transmission lines are listed separately.

Construction costs for Yokohl Valley Dam and appurtenant features for a 450 TAF reservoir are based on a 1975 design and cost estimate, revised to reflect current price levels. The index-adjusted cost estimate shown in **Table 6-20** is likely low because the 1975 design would not conform to current design standards.

Reservoir area lands are privately owned and would need to be acquired. An estimate of these acquisition costs is included in the construction cost shown for the dam and appurtenances, along with an allowance of approximately 20 percent of the property costs for indirect costs associated with property acquisition transactions.

TABLE 6-20.
CONSTRUCTION COSTS FOR YOKOHL VALLEY RESERVOIR MEASURES
($ MILLION)

Gross Pool Elevation (feet above msl)	790
New Storage Capacity (TAF)	**450**
Components	
Dam, Appurtenant Features, Reservoir Lands[1]	400
Yokohl Drive Relocation	56
Transmission Lines Relocation	12
Construction Cost [2,3,4,5]	**468**

Key:
msl – mean sea level
TAF – thousand acre-feet
Notes:
[1] Appurtenant features include spillway, diversion during construction, outlet works, pumping-generating plant, and conveyance between the Friant Kern Canal and the reservoir.
[2] Costs for the 450 TAF size are based on an index-adjusted cost estimate prepared in 1975 and are likely low because design features do not include current standards.
[3] Costs for the 800 TAF size have not been estimated.
[4] All cost estimates are preliminary. Construction cost represents the sum of field costs and indirect costs for planning, engineering, design and construction management, estimated at 25 percent of field costs.
[5] Costs do not include environmental mitigation or potential recreation facilities.

Environmental Considerations

A reservoir in Yokohl Valley may result in impacts to vegetation, wildlife, and cultural resources. Yokohl Creek, from its headwaters to the Friant-Kern Canal, potentially may be affected by a Yokohl Valley reservoir. Yokohl Valley hosts a relatively well-developed mesic grassland habitat, with several special status plant and wildlife species potentially present, as described in **Chapter 3**. **Table 6-4** provides a sum of special status species potentially affected by a Yokohl Valley reservoir. The annual grassland, meadow, and oak woodland habitats found in Yokohl Valley, and vernal pools possibly present in the flatter valley bottoms, would be replaced by a reservoir supplied by the Friant-Kern Canal and supplemented by Yokohl Creek.

Numerous cultural resources, as described in **Chapter 3**, are known to be present in the area and may be affected by a Yokohl Valley reservoir. Mitigation strategies for inundation damage to archaeological sites could include recovery, indexing, and cataloging of artifacts. Further site investigations and research would be needed to evaluate the significance of environmental impacts and associated mitigation requirements for biological and cultural resources. Potential land use impacts would be relatively low, and anticipated to be mitigable. No recreational resources would be affected.

Recommendations for Further Study

Yokohl Valley Reservoir appears to be the least effective surface storage measure retained from Phase 1 of the Investigation. The new water supply from an 800 TAF Yokohl Valley Reservoir would be less than a Temperance Flat Reservoir, a raise of Friant Dam, or a Fine Gold Reservoir of comparable size because of conveyance restrictions along the Friant-Kern Canal.

Yokohl Valley Reservoir would be filled with water evacuated from Millerton Lake and conveyed through the Friant-Kern Canal. This creates the potential that water in Millerton Lake could warm to a greater extent than under without-project condition. This could decrease the potential for water released from Friant Dam to contribute to restoration of fish species that require cold water.

Because Yokohl Valley Reservoir would be shallower than any other comparably sized surface storage measure considered, it presents the highest potential for warming stored water and algae formation. The presence of algae in water supplies could adversely affect the ability of Friant contractors to beneficially irrigate or to exchange high-quality water with urban areas.

Public acceptance of the Yokohl Valley Reservoir measure is likely low with limited willingness of landowners in Yokohl Valley to participate. Yokohl Valley also is outside the area of study authorized by PL 108-361, which specifies planning and feasibility studies for "the Upper San Joaquin River storage in Fresno and Madera Counties."

Considering all of the factors described above, Yokohl Valley Reservoir is dropped from further consideration in the Investigation.

SURFACE WATER STORAGE MEASURES SUGGESTED DURING SCOPING

Most of the surface water storage measures retained from Phase 1 would result in a net loss in power generation. Five additional potential reservoir sites that would avoid adverse hydropower impacts were proposed by stakeholders after completion of Phase 1 and during the scoping process. This section describes the technical characteristics of the surface water storage measures suggested during scoping. The evaluation is based on a review of previous studies and preliminary technical evaluations completed after Phase 1.

Comments received during scoping from power utilities that own and operate hydropower projects in the upper San Joaquin River basin raised concerns about impacts of lost power generation and the ability of retained measures to develop adequate replacement power. They suggested surface storage measures not considered during Phase 1 that may provide water storage and new hydropower generation without adversely affecting existing hydropower facility operations. These measures include RM 315 Reservoir, Granite Project, and Jackass-Chiquito Project. All of these measures are located upstream of Redinger Lake. The scoping comments also suggested combining these upstream storage measures with a gravity diversion tunnel from Kerckhoff Lake to a Fine Gold Reservoir. Locations for the measures suggested during scoping are shown in **Figure 6-27**.

No new designs or cost estimates were prepared for these measures, which were not included in Phase 1 of the Investigation. Some preliminary water supply and hydropower simulations were completed for these measures, and where information was available, summaries of previous cost and hydropower studies are given in this chapter.

RM 315 Reservoir

A RM 315 Reservoir would be formed by a dam on the San Joaquin River at RM 315, about one mile upstream of the Mammoth Pool Powerhouse. A maximum pool at elevation 3,000 would correspond to a storage capacity of about 200 TAF, and the reservoir would extend upstream to the base of Mammoth Pool Dam. The dam would be approximately 620 feet high with a crest width of 1,700 feet. Preliminary designs and costs have not been developed for this dam. However, the dam height and crest length are similar to the RM 286 dam site at elevation 1,400 (capacity 1,360 TAF); thus, costs may be roughly equivalent. **Table 6-21** summarizes the dam height, gross pool elevation, and storage capacity for a RM 315 Reservoir.

Water that flows through a tunnel from Mammoth Pool Reservoir to the Mammoth Pool Powerhouse currently bypasses the RM 315 Reservoir area. The RM 315 Reservoir would be designed to capture spills from Mammoth Pool Reservoir, which occur in about 50 percent of the years. In many cases, spills from Mammoth Pool are captured in Millerton Lake downstream, and do not represent potential additional water supply that could be developed.

In addition to power that could be generated at a powerhouse at the RM 315 Dam, controlled releases from the RM 315 Reservoir also would allow for additional generation at the Big Creek No. 3, Big Creek No. 4, Kerckhoff, and Kerckhoff No. 2 powerhouses, and the Friant Power Project. These increments of additional generation have not been quantified. A RM 315 Reservoir would not adversely affect existing hydropower facilities.

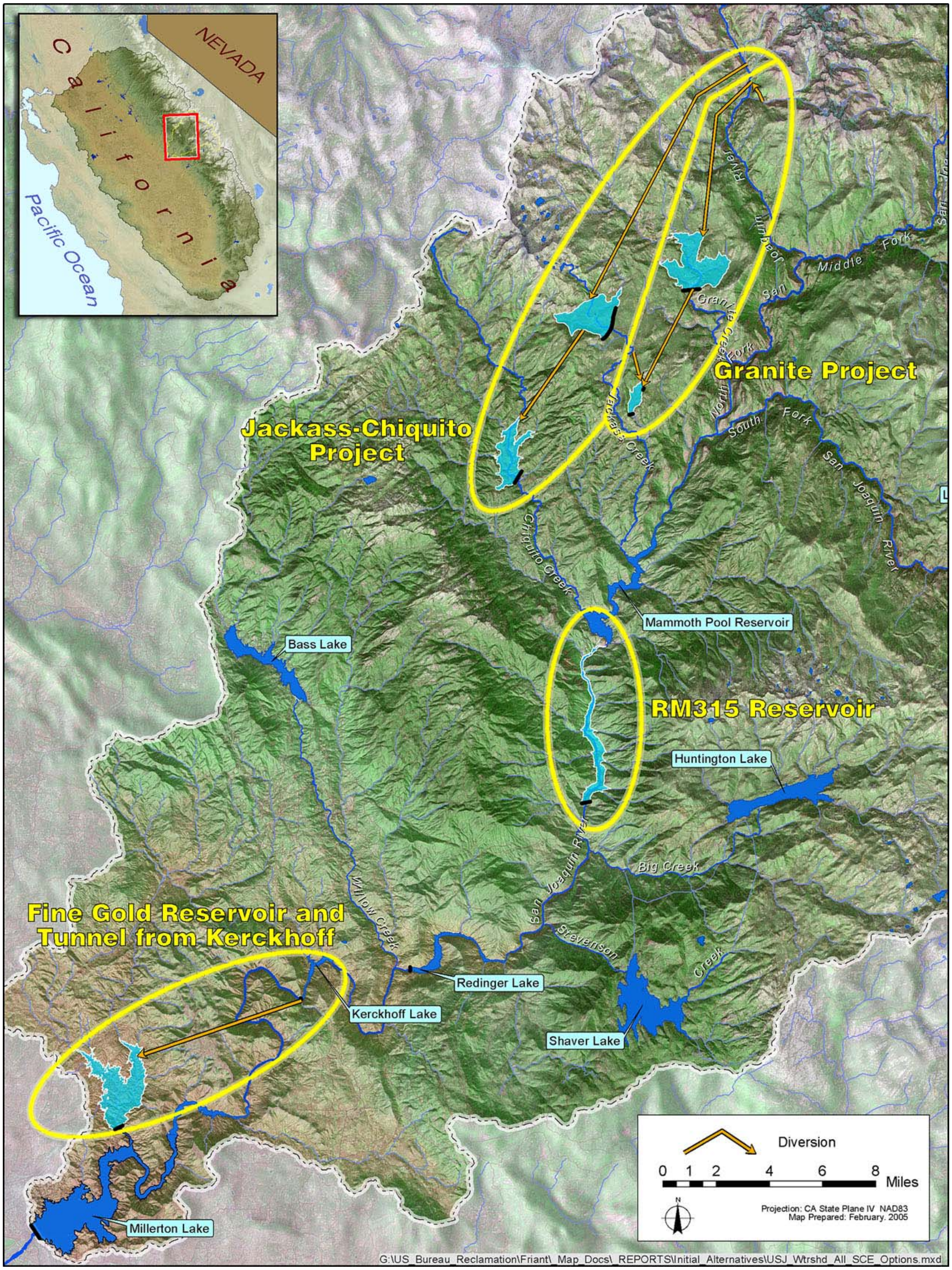

FIGURE 6-27.
SURFACE WATER STORAGE MEASURES SUGGESTED DURING SCOPING

TABLE 6-21.
RM 315 RESERVOIR SUMMARY

Storage Measure	Dam Height (feet)	Gross Pool Elevation (feet above msl)	New Storage Capacity (TAF)
RM 315 Reservoir [1]	620	3,000	200

Key:
msl – mean sea level
RM – river mile
TAF – thousand acre-feet
Note:
[1] The RM 315 Dam would be located at RM 315 on the San Joaquin River, just upstream from the Mammoth Pool Powerhouse. The RM 315 Reservoir would back up to just below the base of Mammoth Pool dam and would store Mammoth Pool Reservoir spills. No hydropower facilities would be impacted with this measure.

No previous studies have been done for this reservoir site; thus, the hydropower generation potential has not been previously quantified. A spreadsheet hydrologic analysis model that mimics CALSIM logic was used to establish preliminary numbers for new water supply from RM 315 Reservoir. The preliminary average annual water supply was estimated at approximately 40 TAF. Preliminary data from the hydrologic analysis were used in the hydropower spreadsheet. Potential average annual hydropower generation at the RM 315 powerhouse was estimated at about 14 GWh/year.

Recommendations for Further Study

The RM 315 Reservoir does not appear to be cost-effective as a water supply measure and will be dropped from further consideration in the Investigation. Construction costs would be comparable to those for a dam at the Temperance Flat RM 286 site to elevation 1,400 (capacity 1,360 TAF). However, this measure would provide only about 25 percent of the new water supply of a 1,360 TAF reservoir. Further consideration of this measure would require participation by a non-Federal sponsor with an interest in power development.

Granite Project

Granite Creek, Sierra National Forest
(Source: Yosemite-Madera County Film Commission)

The Granite Project would be located upstream of Mammoth Pool Reservoir on the west side of the basin. The project would include a major dam and storage reservoir on Granite Creek, a forebay dam and reservoir (Graveyard Meadow), 5 diversion dams (North Fork San Joaquin River, Iron Creek, Cora Creek, Chetwood Creek, and Jackass Creek), 2 powerhouses, 18 miles of pipeline and tunnel, and a pumping plant.

This project was originally studied as a hydroelectric project by the USJRWPA in the late 1970s and early 1980s. In contrast to a RM 315 Reservoir, which would capture spills from Mammoth Pool Reservoir, the Granite Project would capture inflow to Mammoth Pool Reservoir and would reduce spills. **Table 6-22** summarizes the dam height, gross pool elevation, and storage capacity for Granite Creek Reservoir and Graveyard Meadow Reservoir, the two storage components of the Granite Project.

TABLE 6-22.
GRANITE PROJECT SUMMARY

Storage Component of Granite Project[1]	Dam Height (feet)	Gross Pool Elevation (feet above msl)	New Storage Capacity (TAF)
Granite Creek Reservoir	355	7,020	105
Graveyard Meadow Reservoir	90	6,800	9

Key:
msl – mean sea level
TAF – thousand acre-feet
Notes:
[1] Previous studies proposed the Granite Hydroelectric Project as a hydropower project with two storage reservoirs, multiple diversion dams, several miles of tunnel, and two powerhouses. Not all of these facilities would necessarily be considered for development in this Investigation. Hydropower generation figures given in previous studies are only valid with all components in place and operated to maximize power generation, not necessarily water supply.

The California Wilderness Act of 1984 designated various lands in California as wilderness and as components of the National Wilderness Preservation System, including the Ansel Adams Wilderness, which is in the SNF in the northern portion of the upper San Joaquin River basin. The Act specifically allows for development of the Granite Creek Project or the Jackass-Chiquito Project (described in the next section), both of which would divert water from the North Fork of the San Joaquin River, which is within the Ansel Adams Wilderness Area. The Act states the following:

> …nothing in this title shall be construed to prejudice, alter, or affect in any way, any rights or claims of right to the diversion and use of waters from the North Fork of the San Joaquin River, or in any way to interfere with the construction, maintenance, repair, or operation of a hydroelectric project similar in scope to the Jackass-Chiquito hydroelectric power project (or the Granite Creek-Jackass alternative project) as initially proposed by the Upper San Joaquin River Water and Power Authority.

The main source of data available for this project comes from the document entitled Definitive Report: Granite Hydroelectric Project (USJRWPA, 1982b). The report includes preliminary cost estimates, designs, hydrology data, environmental data, and hydropower estimates. Hydropower estimates were derived from a project operation study with a monthly timestep and simulation period from 1922 to 1978. As estimated in the 1982 report, the project would generate an average annual energy of 489 GWh and would have a dependable capacity of 284 MW. The generation estimate does not include additional energy that could be generated at downstream powerhouses.

If a project in this area were planned for water supply, as opposed to the hydropower-focused project detailed in the 1982 report, the magnitude of hydropower generation would be much less due to greater fluctuations in storage reservoirs and likely changes in project configuration. A spreadsheet hydrologic analysis model that mimics CALSIM logic was used to establish preliminary numbers for new water supply from the Granite Project. The preliminary average annual water supply was estimated at approximately 23 TAF. Preliminary data from the hydrologic analysis were used in the hydropower spreadsheet. Potential average annual hydropower generation at the Granite Project was estimated at about 116 GWh/year. This represents a power generation reduction of about 75 percent due to operations for water supply.

Recommendations for Further Study

The Granite Project does not appear to be cost-effective as a water supply measure and will be dropped from further consideration in the Investigation. Cost estimates developed in the early 1980s indexed to 2004 would be comparable to those for a dam at the Temperance Flat RM 286 site to elevation 1,400 (capacity 1,360 TAF). However, this measure would provide only about 25 percent of the new water supply of a 1,360 TAF reservoir. Further consideration of this measure would require participation by a non-Federal sponsor with an interest in power development.

Jackass-Chiquito Project

Jackass Creek northwest of Mammoth Pool Reservoir

The Jackass-Chiquito Project would be located upstream of Mammoth Pool Reservoir on the west side of the basin. It would use essentially the same sources of water as the Granite Project. The project would include a major dam and storage reservoir on Jackass Creek, a major dam and storage reservoir on Chiquito Creek, 5 diversion dams (North Fork San Joaquin River, Cora Creek, East Fork, Middle Fork, and West Fork of Granite Creek), 2 powerhouses, and 18 miles of pipeline and tunnel.

This project was originally studied by USJRWPA as a hydroelectric project in the late 1970s and early 1980s as an alternative to the Granite Hydroelectric Project. **Table 6-23** summarizes the dam height, gross pool elevation, and storage capacity for Jackass Reservoir and Chiquito Reservoir, the two storage components of the Jackass-Chiquito Project.

TABLE 6-23.
JACKASS-CHIQUITO PROJECT SUMMARY

Storage Component of Jackass-Chiquito Project[1]	Dam Height (feet)	Gross Pool Elevation (feet above msl)	New Storage Capacity (TAF)
Chiquito Reservoir	227	5,013	80
Jackass Reservoir	160	7,070	100

Key:
msl – mean sea level
TAF – thousand acre-feet
Notes:
[1] Previous studies proposed the Jackass-Chiquito Hydroelectric Project as a hydropower project with two storage reservoirs, multiple diversion dams, several miles of tunnel, and two powerhouses. Not all of these facilities would necessarily be considered for development in this Investigation. Hydropower generation figures given in previous studies are only valid with all components in place and operated to maximize power generation, not necessarily water supply.

Very little data are available regarding the Jackass-Chiquito Project. The main source of data is from a 1984 Preliminary Permit Application to FERC (USJRWPA, 1984). This application contains a brief description of project facilities, but no designs, cost estimates, environmental data, or hydropower estimates. The Granite Hydroelectric Project Definitive Report (USJRWPA, 1982b) contains a comparison of various alternatives to the Granite Project, and reports that the Jackass-Chiquito Project would generate an average annual energy of 508 GWh, and would cost about 10 percent more than the Granite Project. The generation estimate does not include additional energy that could be generated at downstream powerhouses.

If a project in this area were planned for water supply, as opposed to the hydropower-focused project detailed in the 1984 preliminary application, the magnitude of hydropower generation would be much less due to greater fluctuations in storage reservoirs and likely changes in project configuration. A spreadsheet hydrologic analysis model that mimics CALSIM logic was used to establish preliminary numbers for new water supply from the Jackass-Chiquito Project. The preliminary average annual water supply was estimated at approximately 37 TAF. Potential average annual hydropower generation of the Jackass-Chiquito Project has not been estimated. The order of magnitude of generation from this project (operated for water supply) is assumed to be similar to the Granite Project.

Recommendations for Further Study

The Jackass-Chiquito Project does not appear to be cost-effective as a water supply measure and will be dropped from further consideration in the Investigation. Cost estimates developed in the early 1980s indexed to 2004 would be comparable to those for a dam at the Temperance Flat RM 286 site to elevation 1,400 (capacity 1,360 TAF). However, this measure would provide only about 25 percent of the new water supply of a 1,360 TAF reservoir. Further consideration of this measure would require participation by a non-Federal sponsor with an interest in power development.

Fine Gold Reservoir with Diversion from Kerckhoff Lake

Fine Gold Reservoir, as evaluated in Phase 1 and discussed earlier in this chapter, would be a pump-back project from Millerton Lake. Another configuration for Fine Gold Reservoir suggested during the scoping would involve constructing a tunnel to divert water by gravity from Kerckhoff Lake to Fine Gold Reservoir. The tunnel would be about 7 miles long and possibly 12 to 15 feet in diameter. Diverted water would consist of spills from upstream power projects.

A maximum storage capacity of 230 TAF could be served by a gravity-driven tunnel from Kerckhoff Lake assuming a minimum 10 feet of elevation drop to overcome tunnel head losses. Fine Gold Reservoir would have a gross pool at approximately elevation 960. Further study is needed to determine tunnel design parameters. No engineering studies have been performed for the tunnel route. Provisions for crossing the San Joaquin River (near RM 288), such as a siphon, would need to be considered in the tunnel design.

This measure could be operated in combination with one of the upstream storage measures proposed during scoping to increase the amount of water that could be regulated through the tunnel from Kerckhoff. Without additional upstream storage, the tunnel from Kerckhoff to Fine Gold would not be capable of capturing a large volume of water during flood events. With additional upstream storage, flood flows could be regulated into Fine Gold more effectively.

A spreadsheet hydrologic analysis model that applies the same logic as CALSIM was used to establish preliminary numbers for new water supply from a gravity-fed Fine Gold Reservoir in combination a RM 315 Reservoir with a new storage capacity of 200 TAF. As described in the previous sections, all three storage measures upstream of Redinger Lake suggested during scoping would have a cost similar to or greater than the Temperance Flat RM 286 measure with a new storage capacity of 1,360 TAF. The RM 315 Reservoir measure was used for this evaluation because it appeared to provide the greatest new water supply and be the least costly of the three upstream storage measures considered. The preliminary average annual water supply for Fine Gold Reservoir with a tunnel from Kerckhoff and a RM 315 Reservoir was estimated at approximately 80 TAF. Water supply operations data (dam releases and heads) were reviewed to assess the level of potential for hydropower development.

Neither configuration for Fine Gold Reservoir would impact existing hydropower facilities. A powerhouse could be located at Fine Gold Dam, with discharge directly into Millerton Lake. Water released from Fine Gold Reservoir would provide additional generation at the Friant Power Project by increasing controlled flows from Friant Dam. Hydropower evaluations assumed that the existing Friant Power Project units could continue to be operated.

Results from the preliminary water supply operations modeling indicate that releases from Fine Gold Dam would not be able to support cost-effective hydropower development. Fine Gold would store spills from upstream power projects, which would not be consistent, resulting in a wide variation of heads and intermittent releases occurring on average about 2 months per year. Some small amount of hydropower could be developed, but this measure does not appear cost-effective for development of hydropower facilities. Thus, units have not been sized for this measure and hydropower generation has not been specifically estimated. Hydropower generation at this site is assumed to be of a similar magnitude to potential generation at the RM 315 site.

This measure also could include a raise of Kerckhoff Dam by installing gates or raising the dam crest. The maximum likely elevation for a raise of Kerckhoff Dam would be limited to about elevation 1,000 to avoid impacts to the Big Creek No. 4 and Wishon powerhouses. Raising Kerckhoff Dam to elevation 1,000 would add about 810 acre-feet of new storage capacity. A Fine Gold Reservoir with a gross pool at elevation 990 would have a capacity of about 305 TAF. The Kerckhoff-Fine Gold tunnel also could be pressurized by pumping to Fine Gold for elevations above 1,000. Water would be pumped to a head of about 100 feet to reach a Fine Gold Reservoir storage of 800 TAF.

Table 6-24 summarizes the dam height, gross pool elevation, and storage capacity for Fine Gold Reservoir with diversion by gravity from Kerckhoff Lake. Information presented in **Table 6-24** assumes no raise of Kerckhoff Dam and a gravity tunnel only.

TABLE 6-24.
FINE GOLD RESERVOIR WITH DIVERSION FROM KERCKHOFF LAKE SUMMARY

Storage Measure	Dam Height (feet)	Gross Pool Elevation (feet above msl)	New Storage Capacity (TAF)
Fine Gold Reservoir (Gravity-Fed by Tunnel from Kerckhoff Lake)	440	960	230[1]

Key:
msl – mean sea level
TAF – thousand acre-feet
Notes:
[1] 230 TAF storage capacity is largest size that could be developed without pressurizing the diversion tunnel from Kerckhoff Lake to Fine Gold Reservoir or raising Kerckhoff Dam.

Recommendations for Further Study

Fine Gold Reservoir with a diversion from Kerckhoff Lake does not appear to be a cost-effective water supply measure as a stand-alone measure or in combination with additional upstream storage. By itself, the new water supply from this measure would be very low because of an inability to capture a large volume of water from upstream storage spills through a tunnel during flood events. If combined with development of additional upstream storage, such as the RM 315, Granite, or Jackass-Chiquito projects described above, the new water supply from this measure would increase, but costs and environmental impacts would rise dramatically. Therefore, Fine Gold Reservoir with a diversion from Kerckhoff Lake is dropped as a water supply measure in the Investigation. Further consideration of this measure would require participation by a non-Federal sponsor with an interest in power development.

GROUNDWATER STORAGE AND CONJUNCTIVE MANAGEMENT MEASURES

As described in **Chapter 3**, the Friant Division supports conjunctive management of surface water and groundwater supplies in the eastern San Joaquin Valley. Water deliveries under Class 2 contracts and Section 215 during wetter years reduce groundwater pumping and, in many locations, are used for groundwater recharge. In this manner, eastern San Joaquin Valley groundwater basins are used for water storage.

During Phase 1, many stakeholders suggested that the potential to develop and operate additional groundwater storage facilities should be considered as measures. In response, an approach to identifying potential groundwater storage and conjunctive management components of the Investigation was developed in coordination with DWR's Conjunctive Water Management Program and with stakeholder input.

The approach began with conducting a theoretical analysis to evaluate the potential for groundwater recharge and determine if groundwater storage was a measure that should be further considered. Analysis focused on estimating the amount of water that could be made available at Friant Dam for groundwater recharge if adequate recharge facilities were in place. The outcome of this evaluation as presented in the Phase 1 Investigation Report suggested that groundwater storage may be possible to support Investigation purposes, but that specific facilities had not been identified. Following the completion of the theoretical analysis, DWR initiated a regional Conjunctive Management Opportunities Study (Study), which is being conducted in parallel with the Investigation. The objective of the Study is to identify potential conjunctive management projects and programs in the San Joaquin River and Tulare Lake hydrologic regions that could contribute to the overall CALFED Program objectives of water supply reliability, water quality, and ecosystem restoration.

The first phase of the Study identified the groundwater sub-basins in the San Joaquin Valley that possess the greatest potential for groundwater recharge, and assessed potential conjunctive management opportunities within these regions. Preliminary results from the first phase of the Study identified 12 potential projects.

Upon completion of the Study, the Investigation will review projects recommended in the Study for potential conjunctive management and groundwater storage measures. This will include an evaluation of the extent to which a project could contribute to Investigation objectives, either individually or in combination with surface water storage measures.

A set of evaluation criteria will be applied to assess the applicability of each recommended conjunctive management or groundwater storage project for inclusion as a measure in the Investigation. The following sections describe the current findings by the Study, and present criteria that will be used to evaluate recommended projects for application to the Investigation.

Groundwater Basins with Significant Potential for Development of Additional Conjunctive Management Actions and Projects

Most of the groundwater use in the San Joaquin and Tulare Lake hydrologic regions is within the San Joaquin Valley, which overlies the San Joaquin Valley groundwater basin (Basin). The Basin comprises 16 groundwater sub-basins, of which nine underlie the San Joaquin River hydrologic region and seven underlie the Tulare Lake hydrologic region (**Figure 3-4**). Groundwater is an important resource in the region, and accounts for approximately 35 percent of the total overall water supply.

Many groundwater recharge programs are already in place throughout the Basin, but these current efforts do not take full advantage of existing storage space in many sub-basins. Several of the sub-basins have either experienced significant overdraft and, as a result, have available aquifer storage space, or are naturally hydrogeologically situated for groundwater banking. As part of the Study, an initial evaluation of potential storage capacity was made using information presented in DWR Bulletin 118-03 (DWR, 2003b). On the basis of this review, six sub-basins were identified with the greatest potential for large-scale conjunctive management enhancement and development opportunities. The six sub-basins identified are the Eastern San Joaquin, Merced, Madera, Westside, Kings, and Kern County sub-basins.

Preliminary Projects Identified in the Conjunctive Management Opportunities Study

During preparation of the Study, DWR interviewed a broad array of stakeholders to identify conjunctive management concepts and projects for initial consideration. In general, all interviewed stakeholders were supportive of expanding conjunctive management opportunities in the region. During the initial screening process, over 100 projects and programmatic concepts were identified. Some projects are well defined with detailed information on water sources, required facilities, and operational objectives. Some projects are described as concepts that had been identified in previous studies of theoretical opportunities by others, but have not been sufficiently developed to identify specific project features. In addition to the defined and conceptual projects, stakeholders suggested programmatic concepts that would address institutional issues that may be limiting conjunctive management opportunities.

The projects and programmatic concepts were screened based on three types of criteria, including the following:

- Potential project water supply – Projects with the potential to provide the greatest new water supply were retained. No minimum water supply was established.
- Ability to provide multiple benefits – Projects that present the opportunity to address multiple local and regional needs and CALFED objectives were considered preferable to projects that provided limited benefits or served local needs only.
- Potential stakeholder acceptance and support – Projects with local support that satisfied the above criteria were retained to assure consistency with the CALFED solution principle that conjunctive management and groundwater storage projects be locally supported and controlled.

Through the application of the above criteria, 12 conjunctive management and groundwater storage projects were preliminarily identified for consideration. The locations of preliminary recommended projects listed below are shown in **Figure 6-28**.

- Eastern San Joaquin County Groundwater Bank
- Gravelly Ford
- Madera Ranch
- Merced Irrigation District Groundwater Banking
- Westlands Water District Conjunctive Use Water Management Project
- Waldron Banking Facility Expansion
- Raisin City Recharge
- Arvin-Edison Water Storage District Expansion
- Kern Water Bank Expansion
- Semitropic Water Bank Expansion
- Poso Creek
- Deer Creek Expansion

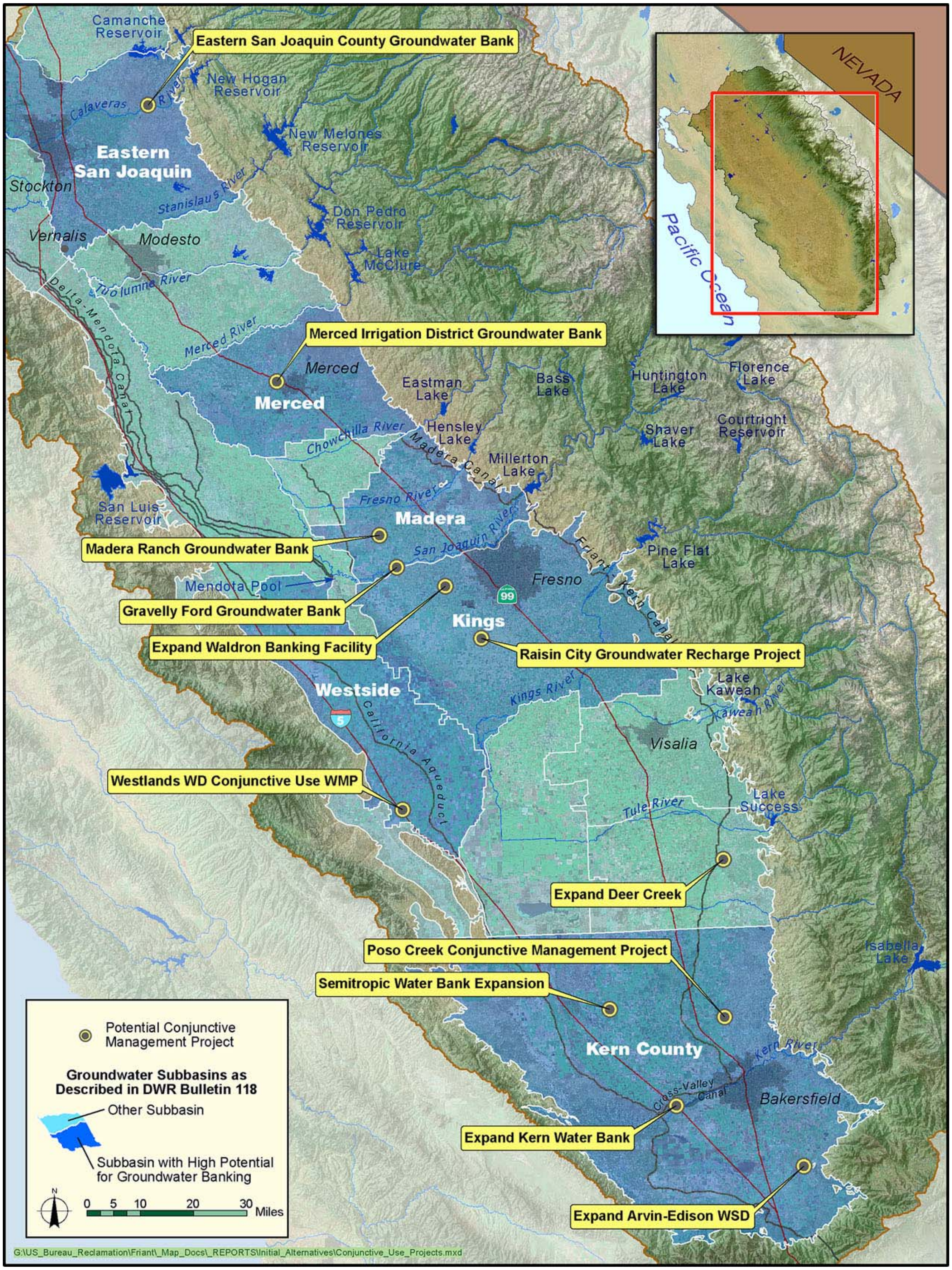

FIGURE 6-28.
POTENTIAL CONJUNCTIVE MANAGEMENT PROJECTS

Criteria to Be Applied in the Evaluation of Potential Projects

Conjunctive management projects recommended in the final Study report will be evaluated to determine if they are applicable for consideration in the Investigation. A set of hydrologic, physical, institutional, and legal criteria will be applied to identify how recommended projects could contribute to the purposes of the Investigation. Each project will be evaluated according to the following criteria and considerations:

- Increase water supply reliability – The potential projects selected for further consideration were initially identified with the principal objective of increasing local and regional water supply reliability. The quantity of increased supply for local and regional uses will be estimated.
- Geographic location – The location of a conjunctive management project in relation to the San Joaquin River downstream of Friant Dam could affect its ability to contribute to Investigation objectives. Projects located a significant distance from Friant Dam may require multiple linked institutional agreements for implementation.
- Cost – Some of the retained projects would include developing new infrastructure, including recharge and extraction facilities. Some projects also include or would require expanding regional conveyance facilities. Costs of conjunctive management projects will include all facility and operating costs.
- Reduce groundwater overdraft and subsidence – Many retained projects were formulated to reduce groundwater overdraft and reduce the rate of subsidence. The ability of a project to replenishment groundwater could be reduced if it is reformulated to support Investigation objectives.
- Improve groundwater quality – Some projects were formulated, in part, to address local and regional groundwater quality problems. The ability of a project to reduce groundwater quality problems while addressing Investigation objectives will be identified.
- Contribute to river releases for restoration and water quality – Some of the retained projects would derive water from multiple sources, including Millerton Lake. The evaluation will consider the extent that the project would make water available at Millerton Lake for river releases to contribute to restoration and improve river water quality
- Contribute to other local and regional benefits – Some of the retained projects have the potential to contribute to other local and regional objectives, including developing upland, riparian, and wetland habitat.
- Reduce local flooding – Although no retained projects were formulated specifically to reduce local flooding, some projects could provide local flood protection benefits.
- Stakeholder acceptance and support – Consistent with CALFED solution principles, each retained project will be reviewed to identify the level of stakeholder acceptance and support.
- Local control – Retained projects that have the ability to contribute to meeting Investigation objectives would be included in project alternatives only if a local entity is identified that would be responsible for development and control of the project.

FLOOD DAMAGE REDUCTION MEASURES

Friant Dam – January 1997 Flood Release

Additional storage in the upper San Joaquin River basin could provide opportunities to increase flood protection to areas downstream of Friant Dam. As described in **Chapter 5**, increased flood control is a secondary planning objective of the Investigation and therefore will not be the focus of plan formulation. Opportunities for additional flood protection will be considered, however, to the extent they can be implemented consistent with plans that address the primary planning objectives.

Several measures were identified that could reduce flood damages along the San Joaquin River. These include increasing the dedicated flood management space and operating the new space to existing or modified objective flood releases from Friant Dam, strengthening levees or otherwise increasing the flood carrying capacity of floodways downstream of Friant Dam, and modifying or removing damageable property in the floodplain. Only measures that would increase flood management space or modify objective flows from Friant Dam were considered because they would be directly related to changes in total available storage.

Potential flood damage reduction benefits are identified as changes in expected annual damages (EAD) that would result from flooding. Evaluations were completed using hydrologic, hydraulic, and economic models and data developed by the Corps and The Reclamation Board of the State of California for the 2002 Comprehensive Study. These models are based on a system-wide approach that considers the combined effect of equally probable storm events located at various locations in the San Joaquin Valley. The models consider the combined effects of flood flows on all major river systems. Additional information on flood damage reduction evaluations can be found in the **Flood Damage Reduction TA**. This section describes preliminary evaluations of the potential changes in flood damages that could result from increasing dedicated flood management space at Friant Dam and operating the space under existing and reduced objective releases.

Development of new storage, either through raising Friant Dam or implementation of other surface water storage measures, could trigger a change to the Corps Water Control Manual for Friant Dam. Changes could include descriptions of how existing flood management objectives would be attained with a new or modified storage facility. They also could include the establishment of changes in dedicated flood management space or objective flood releases from Friant Dam.

Additional Flood Management Space – Existing Objective Releases

A series of model evaluations were completed with various amounts of increased dedicated flood management space at Friant Dam. All simulations assume water conservation storage space is at capacity at the beginning of each flood event, therefore only the dedicated flood management space would be available. The evaluations assumed the flood management space would be increased from the current level of 170 TAF to a maximum of 500 TAF. The enlarged space would be subject to the same seasonal flood management rules as the current space. Four increments of additional flood management space were evaluated, as summarized in **Table 6-25**. The results in **Table 6-25** show that additional flood management space could reduce EAD by up to 13 percent.

TABLE 6-25.
EVALUATIONS OF ADDITIONAL FLOOD MANAGEMENT SPACE

Evaluation	Total Flood Space (TAF)	Existing Objective Release (cfs)	Total Expected Annual Damages ($1,000)[1]	Change in Expected Annual Damages ($1,000)[1]
Without-Project	170	8,000	29,010	---
Existing Objective Release 40 TAF Additional Flood Space	210	8,000	27,646	-1,364
Existing Objective Release 80 TAF Additional Flood Space	250	8,000	27,201	-1,809
Existing Objective Release 170 TAF Additional Flood Space	340	8,000	26,427	-2,583
Existing Objective Release 330 TAF Additional Flood Space	500	8,000	25,258	-3,752

Key:
cfs – cubic feet per second
TAF – thousand acre-feet

Notes:
[1] October 2001 prices.

Additional Flood Management Space – Reduced Objective Releases

A review of the results from the initial evaluations described above revealed that flood damages would result under nearly all flow conditions, including releases below the objective flow of 8,000 cfs. This is because the levees along the flood conveyance channels downstream of Friant Dam are subject to underseepage at flow rates at or below the current objective flow. On the basis of these findings, a series of model evaluations were completed with various amounts of increased dedicated flood management space and a reduction in the objective flood release at Friant Dam. These evaluations were completed to determine if reducing objective flows downstream of Friant Dam, in combination with additional dedicated flood storage space, would reduce flood damages and to determine how reducing objective flows would impact the effectiveness of additional dedicated flood management space.

All simulations assume water conservation storage space is at capacity at the beginning of each flood event, therefore only the dedicated flood management space would be available. The evaluations assumed the flood management space would be increased from the current level of 170 TAF to a maximum of 500 TAF, and that the objective flood release would be reduced from 8,000 cfs to 4,000 cfs. The enlarged space would be subject to the same seasonal flood management rules as the current space. Two increments of additional flood management space were evaluated in combination with a 50 percent reduction in objective release, as summarized in **Table 6-26**. The results in **Table 6-26** show that additional flood management space and reduction in objective release could reduce EAD by up to 18 percent. In particular, reduction in EAD would be greater for the 340 TAF flood space managed with reduced objective flows than a similar flood space operated at the current objective flows. Similar findings also apply for the 500 TAF flood space evaluations.

TABLE 6-26.
EVALUATIONS OF REDUCED OBJECTIVE FLOW WITH ADDITIONAL FLOOD MANAGEMENT SPACE

Evaluation	Total Flood Space (TAF)	Reduced Objective Release (cfs)	Total Expected Annual Damages ($1,000)[1]	Change in Expected Annual Damages ($1,000)[1]
Without-Project	170	8,000	29,010	---
Reduced Objective Release 170 TAF Additional Flood Space	340	4,000	24,503	-4,507
Reduced Objective Release 330 TAF Additional Flood Space	500	4,000	23,870	-5,140

Key:
cfs – cubic feet per second
TAF – thousand acre-feet

Notes:
[1] October 2001 prices.