Upper San Joaquin River Basin Storage Investigation

Initial Alternatives Information Report

Hydropower Technical Appendix

A Study By:

RECLAMATION
Managing Water in the West

California Department of Water Resources

In Coordination With:

CALFED BAY-DELTA PROGRAM

Prepared By:

MWH

UPPER SAN JOAQUIN RIVER BASIN STORAGE INVESTIGATION

Initial Alternatives Information Report

Hydropower Technical Appendix

TABLE OF CONTENTS

Chapter **Page**

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

BDPAC	California Bay-Delta Public Advisory Committee
CALFED	CALFED Bay-Delta Program
CBDA	California Bay-Delta Authority
CALSIM	CALSIM II water operations simulation model
CFRF	concrete-faced rockfill
cfs	cubic feet per second
CVP	Central Valley Project
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
elevation xxx	elevation in feet above mean sea level
FERC	Federal Energy Regulatory Commission
FPA	Friant Power Authority
FR	Feasibility Report
GWh	gigawatt-hour
GWh/year	gigawatt-hour per year
hp	horsepower
IAIR	Initial Alternatives Information Report
Investigation	Upper San Joaquin River Basin Storage Investigation
K1	Kerckhoff No. 1 Powerhouse
K2	Kerckhoff No. 2 Powerhouse
kV	kilovolt
kW	kilowatt
M&I	municipal and industrial
MAF	million acre-feet
msl	mean sea level
MW	megawatt
MWh	megawatt-hour
PFR	Plan Formulation Report
PG&E	Pacific Gas and Electric Company
P&G	Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
PL&P	Pacific Light and Power Company
RCC	roller-compacted concrete
Reclamation	U.S. Department of the Interior, Bureau of Reclamation

RF	restoration flow
RM	river mile
ROD	Record of Decision
rpm	revolutions per minute
SCE	Southern California Edison Company
SJP	San Joaquin Power Company
SWP	State Water Project
TA	Technical Appendix
TAF	thousand acre-feet
USAN	Upper San Joaquin River Basin Model
USGS	United States Geological Survey
v	volt
WQ	water quality
WS	water supply

CHAPTER 1. INTRODUCTION

This document is the **Hydropower Technical Appendix** (TA) to the Initial Alternatives Information Report (IAIR) for the Upper San Joaquin River Basin Storage Investigation (Investigation). The Investigation is one of five surface water storage studies recommended in the CALFED Bay-Delta Program (CALFED) Programmatic Environmental Impact Statement/Report (PEIS/R) Record of Decision (ROD) of August 2000. It is being performed by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), and the California Department of Water Resources (DWR). The Investigation is a feasibility study evaluating alternatives to develop water supplies from the San Joaquin River that could contribute to the restoration of, and improve water quality in, the San Joaquin River, and enhance conjunctive management and exchanges to provide high-quality water to urban areas.

The Investigation is being prepared in two phases. Phase 1, which included preliminary screening of initial storage sites, was completed in October 2003. Initially, 17 surface water storage sites were considered, of which 6 were retained for further analysis. Phase 2 began in January 2004 with formal initiation of environmental review processes consistent with Federal and State of California (State) regulations, and will continue through completion of all study requirements. The Investigation will culminate in a Feasibility Report (FR) and supporting environmental documents consistent with the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) (WRC, 1983), Reclamation directives, DWR guidance, and applicable environmental laws. Reclamation and DWR are coordinating the Investigation with the California Bay-Delta Public Advisory Committee (BDPAC), which provides advice to the Secretary of the United States Department of the Interior (Secretary) regarding the implementation of the CALFED Program, and the California Bay-Delta Authority (CBDA), which provides general oversight and coordination of all CALFED activities.

To facilitate coordination with other agencies and related ongoing studies, preparation of the FR will include two interim planning documents: an Initial Alternatives Information Report (IAIR) and a subsequent Plan Formulation Report (PFR). The IAIR describes without-project conditions and water resources problems and needs; defines study objectives and constraints; screens surface water storage measures; describes groundwater storage measures development; and identifies preliminary water operations rules and scenarios. Retained storage measures and preliminary water operations scenarios will be included in initial alternatives. This IAIR will be used as an initial component of the FR. The PFR will present the results of initial alternatives evaluation, identify refinements of the alternatives, and define a set of final alternatives. A Draft FR will evaluate and compare the final alternatives and identify a recommended plan. A Draft Environmental Impact Statement (EIS) and Environmental Impact Report (EIR) will be included with the Draft FR. Following public review and comment, a final FR/EIS/EIR will be prepared.

STUDY AREA

The study area emphasis for the Investigation encompasses the San Joaquin River watershed upstream of Friant Dam, the San Joaquin River from Friant Dam to the Sacramento-San Joaquin Delta (Delta), and the portions of the San Joaquin and Tulare Lake hydrologic regions served by the Friant-Kern and Madera canals, as highlighted in **Figure 1-1**. The study area includes all potential storage sites under consideration, the region served by the Friant Division of the Central Valley Project (CVP), the eastern San Joaquin Valley groundwater basins, and the portion of the San Joaquin River most directly affected by the operation of Friant Dam. The study area includes a primary study area and an extended study area. The primary study area for hydropower evaluations presented in this TA is the San Joaquin River watershed upstream of Millerton Lake.

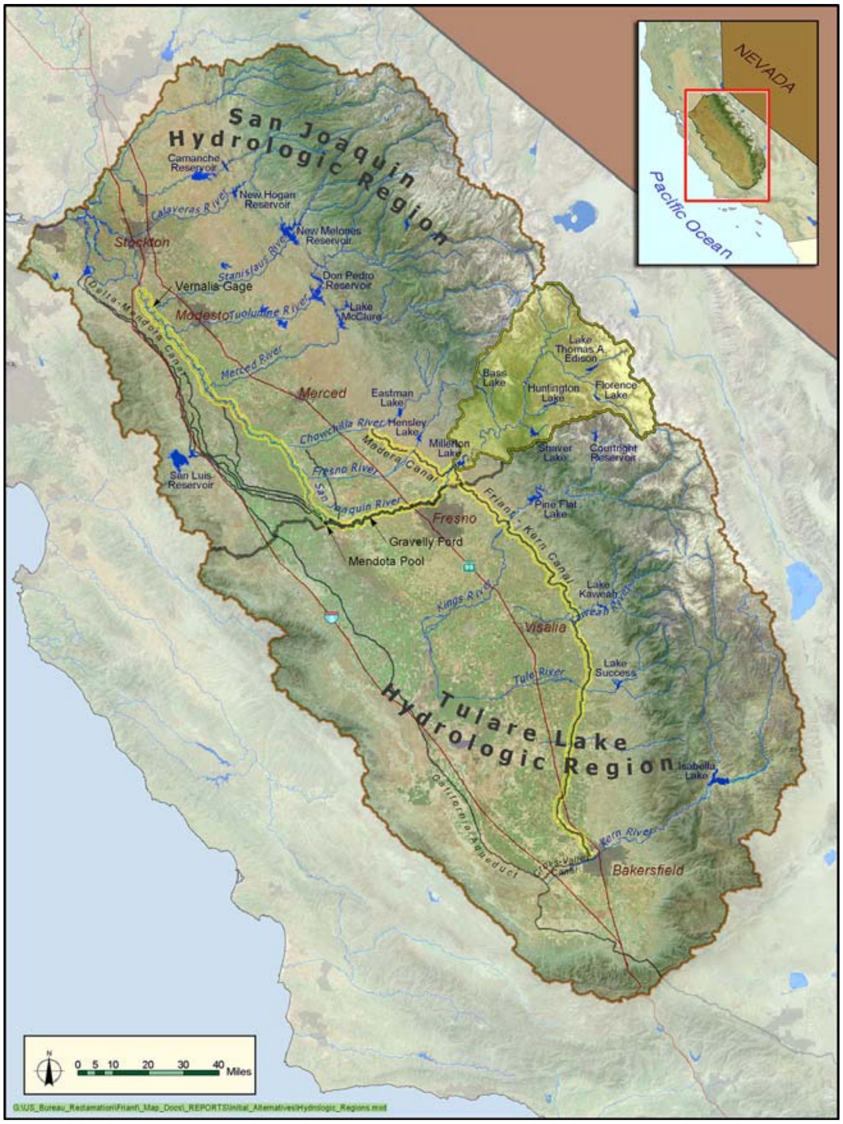

FIGURE 1-1.
UPPER SAN JOAQUIN RIVER BASIN STORAGE INVESTIGATION
STUDY AREA EMPHASIS

SURFACE WATER STORAGE MEASURES CONSIDERED IN THE IAIR

Six potential sites for developing a new surface reservoir or enlarging an existing reservoir were retained from Phase 1 of the Investigation for further consideration in the Investigation. Each site could be configured at various storage sizes, with each configuration identified as a measure. The six surface water storage sites retained from Phase 1 include:

- **Raise Friant Dam.** Enlarging Millerton Lake by raising Friant Dam up to 140 feet.
- **Temperance Flat Reservoir.** Constructing Temperance Flat dam and reservoir at one of three potential dam sites on the San Joaquin River, between Friant and Kerckhoff dams, at River Mile (RM) 274, RM 279, or RM 286.
- **Fine Gold Reservoir.** Constructing a dam and reservoir on Fine Gold Creek to store water diverted from the San Joaquin River or pumped from Millerton Lake.
- **Yokohl Valley Reservoir.** Constructing a dam and reservoir in Yokohl Valley to store water conveyed from Millerton Lake by the Friant-Kern Canal and pumped into the reservoir.

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/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 five additional potential reservoir sites that could store water supplies from the upper San Joaquin River without adversely affecting existing hydropower facility operations.

Suggested storage measures include **RM 315 Reservoir** on the San Joaquin River between Redinger Lake and Mammoth Pool, and **Granite Project** (Granite Creek and Graveyard Meadow reservoirs) and **Jackass-Chiquito Project** (Jackass and Chiquito reservoirs) on tributaries to the San Joaquin River upstream of Mammoth Pool. The scoping comments also suggested combining these upstream storage measures with a gravity diversion tunnel from Kerckhoff Lake to a Fine Gold Reservoir.

The locations of the six surface water storage sites retained from Phase 1 and sites suggested during scoping are shown in **Figure 1-2.** This TA evaluates impacts to existing hydropower facilities, pumping requirements, and potential hydropower generation for all measures considered in the IAIR.

ORGANIZATION OF THIS TECHNICAL APPENDIX

This document is one of several TAs to the IAIR. It presents preliminary information on hydropower generation potential and effects on existing hydropower facilities for the surface storage measures described in the IAIR. The costs for building new hydropower facilities and decommissioning existing hydropower facilities are not presented in this TA. All preliminary cost and design information for the Investigation is included in the **Engineering TA** to the IAIR. Market costs for replacement power are not included in this TA.

This introductory chapter explains the purpose and scope of the **Hydropower TA**, describes the study area, presents an overview of the surface storage sites retained from Phase 1 of the Investigation, and gives the organization of the document. **Chapter 2** presents background information on hydropower generation, provides a historical perspective of events that influenced hydropower and water supply development in the upper San Joaquin River basin, and describes existing hydropower facilities in the basin and future without-project conditions. **Chapter 3** describes the analytical methodology used to prepare hydropower generation estimates for six surface storage sites; preliminary estimates of current generating capacity that would be affected by the storage measures; potential energy that could be generated from new powerhouses developed in connection with each storage measure; and potential pumping energy required to operate offstream surface water storage measures. **Chapter 4** lists the document preparers. **Chapter 5** includes references used in preparing this TA.

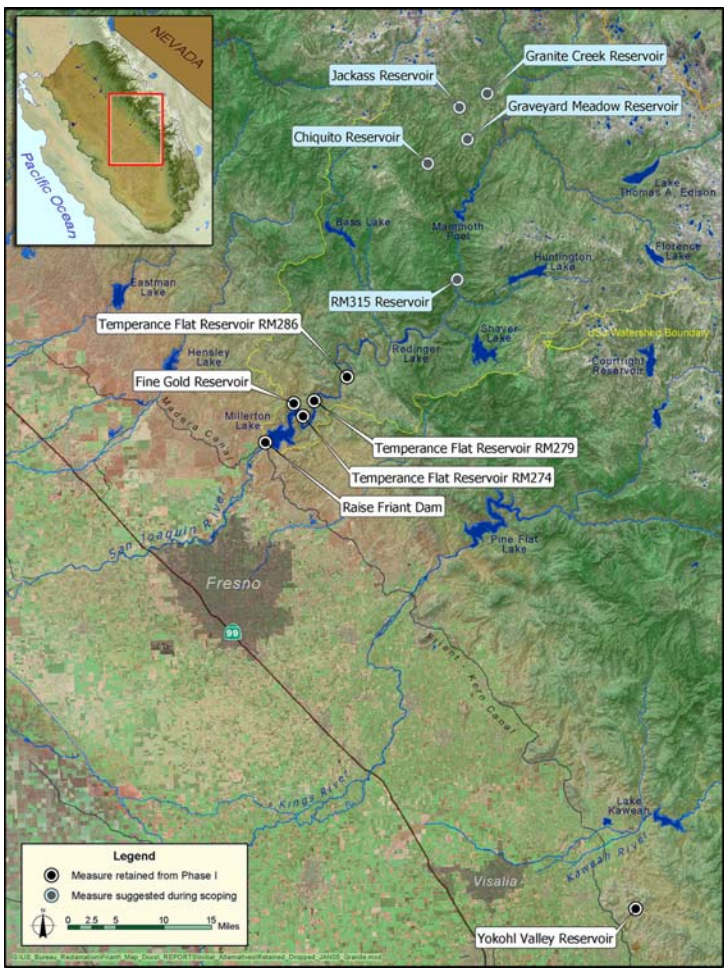

FIGURE 1-2.
SURFACE WATER STORAGE SITES RETAINED FROM PHASE 1
AND SUGGESTED DURING SCOPING

CHAPTER 2. EXISTING AND FUTURE WITHOUT-PROJECT CONDITIONS

This chapter summarizes the background and history of power development in the upper San Joaquin River basin, describes existing storage and hydropower facilities in the basin at and upstream of Friant Dam, and future without-project hydropower conditions in the basin.

HYDROPOWER BACKGROUND

Hydropower long has been an important element of power supply in California. On average, hydropower generation constitutes between 10 to 27 percent of California's annual energy supply, depending on the type of water year. The United States receives between 7 and 12 percent of its electricity from hydropower. Due to its ability to rapidly increase and decrease power generation rates, hydropower often has been used to support peak power loads in addition to base power loads.

The San Joaquin River watershed upstream of Friant Dam is extensively developed for hydroelectric generation. In this area, the Pacific Gas and Electric Company (PG&E) and Southern California Edison Company (SCE) own and operate several hydropower generation facilities. Both the PG&E and SCE systems consist of a series of reservoirs that provide water through tunnels to downstream powerhouses. Hydropower is also generated by the Friant Power Authority (FPA) at the Friant Power Project; water is released from Friant Dam to the Friant-Kern Canal, Madera Canal, and San Joaquin River. In total, the upper San Joaquin River basin has 19 powerhouses with an installed capacity of almost 1,300 megawatts (MW), which represents approximately 9 percent of the hydropower generation capacity in California.

Although some new power generation capacity likely will come on-line, it is expected that new generation capacity will still be required. Developing new storage for water supply, water quality, ecosystem restoration, and flood damage reduction creates opportunities to add hydropower features and increase power generation in the basin. Developing new storage also has the potential to decrease power generation in the basin if existing facilities are impacted.

HISTORICAL PERSPECTIVE

It is said that the upper San Joaquin River is "the hardest working water in the world" because it generates power at several successive powerhouses before reaching Millerton Lake, where it is then diverted for irrigation and municipal and industrial (M&I) use in the eastern San Joaquin Valley (Myers, 1983). The first powerhouse on the San Joaquin River was constructed in 1896 and since has been expanded and incorporated into the PG&E Crane Valley Project. Currently, 19 powerhouses and 18 related reservoirs with a total storage capacity of over 1.1 million acre-feet (MAF) exist in the upper San Joaquin River basin at and upstream of Friant Dam. A summary of events that have influenced development and operation of water supply and hydropower facilities in the upper San Joaquin River basin, as reported in several documents listed in **Chapter 5**, is shown in **Table 2-1**.

TABLE 2-1.
EVENTS INFLUENCING HYDROPOWER AND WATER SUPPLY DEVELOPMENT IN THE UPPER SAN JOAQUIN RIVER BASIN

Year	Event
1848	Gold discovered at Coloma on the South Fork of the American River.
1849	Gold rush begins.
1850	California becomes the 31st state and adopts English Common Law, which includes the concept of riparian water rights.
1872	California legislature adopts the Statues of 1872, which provide for appropriative water rights.
1878	State Engineer, Hall, studies irrigation, drainage, and navigation problems on Sacramento and San Joaquin rivers.
1887	First hydropower plant in the western U.S. constructed in San Bernardino.
1895	J.S. Eastwood, civil engineer for the City of Fresno, and J.J. Seymour form the San Joaquin Electric Company.
1896	Eastwood and Seymour complete construction of a powerhouse (San Joaquin No. 1) on the San Joaquin River between Auberry and North Fork. Power is sent to Fresno by a 38-mile power line (the longest then in use).
1899	San Joaquin Electric Company goes bankrupt because of opposition by Fresno Gas and Electric Company and succeeding dry years that severely reduce power deliveries. Bankholders sell company to W.G. Kerckhoff and Allan Balch.
1900	Eastwood surveys the area now known as Mammoth Pool and organizes the Mammoth Power Company to hold the water rights.
1901	First Federal Water Power Act passed.
1902	Kerckhoff and Balch organize the San Joaquin Power Company (SJP). The new company consists of one powerhouse – San Joaquin No. 1, a small dam at Bass Lake, transmission lines to Fresno and Hanford, and a system of canals and flumes.
1902	Eastwood explores the area between today's Shaver and Huntington lakes. He finds and names "Big Creek."
1902	Reclamation Act passed.
1905	Eastwood submits a report with designs for the Big Creek Project to Kerckhoff and Henry Huntington of the Pacific Light and Power Company.
1905	Pacific Gas and Electric Company (PG&E) incorporated.
1910	San Joaquin No. 1 Powerhouse replaced by a larger and more modern plant (now named A.G. Wishon Powerhouse).
1910	Crane Valley Dam constructed on North Fork of Willow Creek.
1910	Demand for electricity in expanding Southern California exceeds supply.
1910	Huntington, Kerckhoff, and Balch incorporate the Pacific Light and Power Corporation (PL&P) and sell bonds to raise money for construction of the Big Creek Project.
1912	Construction of the San Joaquin and Eastern Railroad completed. It extends 56 miles from El Prado Station (18 miles north of Fresno) to the site of Big Creek No. 1 Powerhouse. More than 400,000 tons of machinery and supplies are hauled to Big Creek between 1912-1933.

TABLE 2-1. (continued)

Year	Event
1913	Huntington gains complete ownership of PL&P (including the Big Creek Project under construction) and water rights on the South Fork of the San Joaquin River.
1913	Kerckhoff and Balch obtain full control of San Joaquin Light and Power Corporation and water rights on the North Fork of the San Joaquin River.
1913	Pacific Light and Power Corporation energizes Big Creek No. 1 Powerhouse (85.2 MW) and Big Creek Eagle Rock Transmission Line (world's longest distance and highest voltage line, extending 241 miles to Los Angeles).
1913	Huntington dams completed.
1914	PL&P Big Creek No. 2 Powerhouse completed (66.5 megawatts (MW)).
1917	Huntington dams raised by 35 feet to double the capacity of the reservoir.
1917	SJP San Joaquin No. 2 Powerhouse commissioned (3.2 MW).
1917	PL&P purchased by Southern California Edison Company (SCE).
1919	SJP Wishon (20 MW), San Joaquin No. 1A (0.4 MW), and Crane Valley (0.9 MW) powerhouses commissioned.
1919	SCE acquires Shaver Lake lands and water rights from Fresno Flume and Lumber Company.
1920	Federal Power Act establishes Federal Power Commission with authority to issue licenses for hydroelectric development on public lands.
1920	SJP Kerckhoff Reservoir and Powerhouse (38 MW) constructed; first powerhouse and dam to use waters of the San Joaquin River.
1920	Construction of Florence Lake Tunnel begins.
1921	SCE Big Creek No. 8 Powerhouse completed (75 MW).
1923	Big Creek Dam No. 6 completed.
1923	SCE Big Creek System voltage increased from 150 kilovolt (kV) to 220 kV.
1923	SCE Big Creek No. 3 Powerhouse completed (originally 99 MW), called the "Electric Giant of the West."
1923	SJP San Joaquin No. 3 Powerhouse commissioned (4.2 MW).
1925	Florence Lake Tunnel completed (2 years ahead of schedule). Later renamed the Ward Tunnel (1936).
1926	Florence Dam completed on South Fork of San Joaquin River.
1927	Shaver Dam completed on Stevenson Creek.
1927	Mono and Bear diversions and siphon completed.
1928	Huntington-Pitman-Shaver Conduit completed.
1928	SCE Big Creek No. 2A Powerhouse completed (110 MW), at that time the highest head powerhouse in the world (2,419 feet).
1930	SJP reorganized as the San Joaquin Light and Power Corporation and purchases or merges with several other power companies.
1936	Merger of San Joaquin Light and Power and PG&E is completed.
1939	Construction of Friant Dam on the San Joaquin River begins.

TABLE 2-1. (continued)

Year	Event
1942	Construction of Friant Dam on the San Joaquin River completed.
1944	Millerton Lake (Friant Dam) begins storing water.
1948	Unit No. 4 (32 MW) added to SCE Big Creek No. 3 Powerhouse.
1951	Redinger Dam completed on San Joaquin River.
1952	SCE Big Creek No. 4 Powerhouse completed (98.8 MW).
1954	Vermilion Valley Dam completed on Mono Creek.
1956	SCE Portal Powerhouse completed (10.8 MW).
1957	Mammoth Pool Agreement between Reclamation and SCE reserved 85 thousand acre-feet (TAF) in Mammoth Pool Reservoir for Millerton Lake flood control space.
1959	SCE Big Creek No. 1 and No. 2 Project relicensed.
1960	SCE Mammoth Pool Dam and Powerhouse (187 MW) completed on San Joaquin River.
1967	Reclamation and PG&E sign agreements to integrate Central Valley Project (CVP) power and capacity with PG&E's system (allow exchanges), and for PG&E to deliver power to CVP customers.
1968	Wild and Scenic Rivers Act passed, which protects rivers in their natural state by excluding them from consideration as hydroelectric power sites.
1969	National Environmental Policy Act passed.
1973	Endangered Species Act passed.
1974	Clean Water Act passed.
1977	Department of Energy formed; marketing and transmission of Reclamation power resources transferred to Western Area Power Administration.
1977	SCE Big Creek No. 3 Project relicensed.
1978	SCE Big Creek No. 2A and No. 8 Project relicensed.
1979	Upper San Joaquin River Water and Power Authority begins study for developing additional hydropower projects upstream of Mammoth Pool.
1979	Friant Power Authority (FPA) board created.
1979	PG&E Kerckhoff Project relicensed.
1980	Unit No. 5 (36 MW) added to SCE Big Creek No. 3 Powerhouse.
1982	Reclamation Reform Act passed.
1983	PG&E Kerckhoff No. 2 Powerhouse completed (155 MW).
1984	California Wilderness Act of 1984 passed, which designates certain lands in the upper San Joaquin River basin as a portion of the Ansel Adams Wilderness, but allows for hydroelectric project development using waters of the North Fork of the San Joaquin River.
1985	FPA Madera (9.8 MW) and River Outlet (2.4 MW) powerhouses completed.
1986	FPA Friant-Kern Powerhouse completed (18.4 MW).
1986	First full year of generation for the FPA Friant Power Project.
1987	SCE Balsam Meadow Dam and Eastwood Powerhouse completed (199.8 MW).

TABLE 2-1. (continued)

Year	Event
1992	Central Valley Project Improvement Act passed.
1995	CALFED Bay-Delta (CALFED) program established.
1998	Deregulation of California's electric power industry takes effect.
2000	CALFED Record of Decision (ROD) signed.
2003	PG&E Crane Valley Project relicensed.
2003	SCE Big Creek No. 4 Project relicensed.
2003	Federal authorization provided to prepare a feasibility report for storage in the upper San Joaquin River basin (PL 108-7, Division D, Title II, Section 215).

Key:

CALFED – CALFED Bay-Delta Program	CVP – Central Valley Project	FPA – Friant Power Authority
kV – kilovolt	MW – megawatts	PG&E – Pacific Gas and Electric Company
PL&P – Pacific Light and Power Corporation	ROD – Record of Decision	Reclamation – Bureau of Reclamation
SCE – Southern California Edison Company	SJP – San Joaquin Power Company	TAF – thousand acre-feet

EXISTING HYDROPOWER FACILITIES IN THE UPPER SAN JOAQUIN RIVER BASIN

All hydropower facilities in the upper San Joaquin River basin are components of one of the following four hydropower projects/systems:

- Friant Power Project – owned by FPA
- Kerckhoff Hydroelectric Project – owned by PG&E
- Crane Valley Hydroelectric Project – owned by PG&E
- Big Creek Hydroelectric System (7 projects) – owned by SCE

Locations of the existing major hydropower facilities, including powerhouses, conveyance features, and reservoirs, are shown in **Figure 1-2**. The upper San Joaquin River basin contains 10 hydropower projects licensed by the Federal Energy Regulatory Commission (FERC). **Table 2-2** summarizes the FERC project numbers, names, license dates, and installed generation. The seven SCE projects in the basin are generally referred to in sum as the Big Creek System.

Table 2-3 provides an overview of the major components for the four power projects/systems in the basin. Generation capacity, dates of installation, and annual reported energy generation from 1986 through 2003 for the Friant Power Project facilities at Friant Dam are summarized in **Table 2-4**. Generation capacity, dates of installation, and annual reported energy generation from 1994 through 2002 for selected PG&E and SCE power facilities above Millerton Lake that may be affected by the surface water storage measures are summarized in **Table 2-5**.

TABLE 2-2. HYDROPOWER PROJECTS IN THE UPPER SAN JOAQUIN RIVER BASIN

FERC Project No.	FERC Project Name	License Issued	License Expires	River or Creek	Owner	Total Installed Capacity (MW)
02892	Friant	9/30/1982	8/31/2032	San Joaquin River	FPA	26
01354	Crane Valley	9/16/2003	9/30/2043	Willow Creek	PG&E	29
00096	Kerckhoff	11/8/1979	11/30/2022	San Joaquin River	PG&E	193
02175	Big Creek No. 1 & No. 2	3/27/1959	2/28/2009	Big Creek	SCE	152
00120	Big Creek No. 3	9/7/1977	2/28/2009	San Joaquin River	SCE	175
02017	Big Creek No. 4	12/4/2003	11/30/2039	San Joaquin River	SCE	100
00067	Big Creek Nos. 2A,8 & Eastwood	8/9/1978	2/28/2009	Big Creek	SCE	385
02085	Mammoth Pool	12/30/1957	11/30/2007	San Joaquin River	SCE	187
02174	Portal	4/19/1955	3/31/2005	Rancheria Creek	SCE	11
02086	Vermilion Valley	9/29/1953	8/31/2003[1]	Mono Creek	SCE	0
					Installed Capacity – Basin Total	*1,258*

Key:
FERC – Federal Energy Regulatory Commission
FPA – Friant Power Authority
MW – megawatt
PG&E – Pacific Gas & Electric
SCE – Southern California Edison Company

Notes:
[1] Vermilion Valley Project is currently in the FERC relicensing process.

TABLE 2-3. SUMMARY OF HYDROELECTRIC PROJECT FEATURES IN THE UPPER SAN JOAQUIN RIVER BASIN

	Friant Power Project	Kerckhoff Project	Crane Valley Project	Big Creek System	Total
No. of Storage Reservoirs	1[1]	1	2	6	9
Additional Regulating Reservoirs [2]	---	---	4	5	9
Total Volume of Storage (TAF)	520.5	4	46	566	1,137
No. of Powerhouses	3	2	5	9	19
Total Installed Capacity (MW)	26	193	29	1,010	1,258
Miles of Conveyance (tunnel, penstock, flume, etc.) [3]	---	9	15	66	90

Key:
GIS – geographic information system
MW – megawatts
TAF – thousand acre-feet

Notes:
[1] Millerton Lake (Friant Dam) is the storage reservoir that provides head and flow to the Friant Power Project, but the reservoir is not owned by the Friant Power Authority.
[2] Diversion dam reservoirs not included in count of additional regulating reservoirs.
[3] Conveyance length approximately measured in GIS.

TABLE 2-4.
HISTORICAL HYDROELECTRIC GENERATION AT FRIANT POWER PROJECT

	Friant Power Authority		
	Friant-Kern Canal	**Madera Canal**	**River Outlet**
Number & Type of Units	1 – Kaplan	1 – Kaplan	1 – Francis
Capacity (MW)	16	8.3	2
Year Constructed	1986	1985	1985
Reported Annual Generation (MWh)[1,2]			
1986	57,379	30,853	11,191
1987	13,394	6,288	7,554
1988	19,202	5,934	9,340
1989	22,238	7,382	10,940
1990	15,442	6,354	12,492
1991	28,805	9,990	13,313
1992	23,032	8,160	13,010
1993	74,090	29,008	12,832
1994	25,145	8,916	14,632
1995	89,244	35,843	14,901
1996	80,371	30,464	14,331
1997	63,653	29,570	10,945
1998	59,539	34,679	17,577
1999	70,128	23,723	14,565
2000	71,520	23,526	13,249
2001	35,541	13,627	11,261
2002	43,262	13,686	13,250
2003	58,694	18,203	14,257
Min. 1986-2003	**13,394**	**5,934**	**7,554**
Max. 1986-2003	**89,244**	**35,843**	**17,577**
Avg. 1986-2003	**47,260**	**18,678**	**12,758**

Key:
MW – megawatt
MWh – megawatt-hour

Notes:
[1] Data source – Friant Power Authority.
[2] First full year of generation for the Friant Power Project was 1986.

TABLE 2-5.
RECENT HYDROELECTRIC GENERATION AT SELECTED FACILITIES UPSTREAM FROM MILLERTON LAKE [1]

	Pacific Gas and Electric			Southern California Edison		
	Wishon	**Kerckhoff**	**Kerckhoff No. 2**	**Big Creek No. 3**	**Big Creek No. 4**	**Mammoth Pool**
Number & Type of Units	4 – Impulse	3 – Francis	1 – Francis	5 – Francis	2 – Francis	2 – Francis
Capacity (MW)	20	38	155	175	100	187
Year Constructed	1910	1920	1983	1923	1952	1960
Reported Annual Generation (MWh)[2]						
1994	27,904	10,348	275,752	567,399	294,398	358,510
1995	113,411	115,930	803,490	1,195,652	623,186	819,824
1996	93,551	52,273	696,653	1,050,192	608,066	867,187
1997	45,475	72,350	695,775	898,483	589,812	835,857
1998	117,762	75,657	735,830	1,094,868	613,169	760,690
1999	73,369	31,959	410,567	539,673	435,868	604,340
2000	73,642	37,632	482,279	837,543	448,810	616,530
2001	47,942	10,768	316,602	570,805	301,216	428,951
2002	54,588	19,639	368,396	717,201	352,915	486,423
Min. 1994-2002	**27,904**	**10,348**	**275,752**	**539,673**	**294,398**	**358,510**
Max. 1994-2002	**117,762**	**115,930**	**803,490**	**1,195,652**	**623,186**	**867,187**
Avg. 1994-2002	**71,960**	**47,395**	**531,705**	**830,202**	**474,160**	**642,035**

Key:
FERC – Federal Energy Regulatory Commission
MW – megawatt
MWh – megawatt – hour

Note:
[1] There are 16 powerhouses above Millerton Lake; the subset in this table includes those that could potentially be impacted by the surface water storage measures under consideration in the Investigation.
[2] Exclusive of plant use, data source – annual FERC licensee reports.

Friant Dam and Millerton Lake

Friant Dam is owned and operated by Reclamation and is a major component of the CVP. It was constructed between 1939 and 1942. The dam is a concrete gravity structure with a structural height of 319 feet, crest length of 3,448 feet, crest width of 20 feet, and maximum base width of 267 feet. The spillway consists of an ogee overflow section, chute, and stilling basin at the center of the dam. The spillway is controlled by one 18-foot-high by 100-foot-wide drum gate, and two comparably sized Obermeyer gates. Madera Canal and outlets are located on the right abutment; Friant-Kern Canal and outlets are located on the left abutment. A river outlet works is located to the left of the spillway within the lower portion of the dam.

Limited river releases are made for downstream water rights. The dam serves the dual purposes of storage for irrigation and flood control. Millerton Lake has a gross storage capacity of 520.5 thousand acre-feet (TAF) at 578 feet above mean sea level (elevation 578), the top of active conservation storage.

Friant Power Project

The Friant Power Project is owned and operated by FPA, which comprises the following eight member districts: Southern San Joaquin Municipal Utility District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District, Lindmore Irrigation District, Terra Bella Irrigation District, Orange Cove Irrigation District, Madera Irrigation District, and Chowchilla Water District. Three powerhouses, owned and operated by FPA, are located on the downstream side of Friant Dam.

The Friant-Kern Powerhouse generates hydroelectricity as water is released through outlets in the left abutment to the Friant-Kern Canal; it has a normal maximum head of 105 feet. The Madera Powerhouse generates hydroelectricity as water is released through outlets in the right abutment to the Madera Canal; it has a normal maximum head of 126 feet. The River Outlet Powerhouse, located at the base of the dam adjacent to the spillway, generates hydroelectricity as water is released to the San Joaquin River through river outlets; it has a normal maximum head of 273 feet. The first full year of generation for the Friant Power Project powerhouses was 1986. The combined installed capacity of the three powerhouses is about 30 MW. This represents less than 3 percent of the generation capacity in the upper San Joaquin River basin. A summary of historical power generation and capacity of the Friant Power Project is shown in **Table 2-4**. Electricity from the Friant Power Project is transmitted to the PG&E power grid over a 70 kilovolt (kV) transmission line.

A small powerhouse owned by Orange Cove Irrigation District that uses the water supplied to the San Joaquin Hatchery for generation also is located at Friant Dam but is not part of the Friant Power Project. It is assumed that this small powerhouse would not be modified with additional storage in the upper San Joaquin River basin and it will not be discussed further in this TA. The Madera-Chowchilla Water and Power Authority owns and operates four powerhouses (combined capacity of almost 4 MW) at various locations along the Madera Canal. It is assumed that Madera Canal capacity would not be increased with additional storage in the upper San Joaquin River basin; Therefore, these powerhouses also were not considered in the hydropower analysis documented in this TA.

PG&E Kerckhoff Hydroelectric Project

The PG&E Kerckhoff Hydroelectric Project accounts for approximately 5 percent of PG&E´s hydroelectric generation capacity, and 15 percent of the generation capacity in the upper San Joaquin River basin. Existing PG&E facilities comprising the Kerckhoff Hydroelectric Project include the following, proceeding upstream:

- Kerckhoff No. 2 Powerhouse
- Kerckhoff Powerhouse
- Kerckhoff Dam and Lake

Kerckhoff No. 2 Powerhouse

The Kerckhoff No. 2 Powerhouse is approximately 200 feet underground in a circular, rock chamber measuring 85 feet in diameter and 124 feet high. It houses a single, vertical Francis-type turbine/generator assembly. The powerhouse operates at a normal maximum gross head of 421 feet and has a normal operating capacity of 155 MW. Turbine speed is 180 revolutions per minute (rpm); the turbine has a butterfly type shut-off valve. The project was commissioned in 1983.

Most of the interior of the Kerckhoff No. 2 Powerhouse is unlined and very little spalling of rock appears to have occurred, an indication of the soundness of the surrounding rock formation.

Water is conveyed from the intake in Kerckhoff Lake to the Kerckhoff No. 2 Powerhouse by means of a tunnel and penstock. The tunnel is approximately 21,632 feet long and has both lined and unlined sections. A surge chamber is located at the end of the tunnel near the intake for the penstock and consists of an unlined, tapered vertical shaft. A penstock approximately 1,013 feet long that is lined with concrete and steel conveys water from the tunnel to the powerhouse. The penstock has a concrete-lined section that is 20 feet in diameter and 481 feet long, a concrete-lined section that is 18 feet in diameter and 338 feet long, and a steel-lined section that is 15 feet in diameter and 194 feet long. This steel-lined section enters the powerhouse chamber. The penstock has a total flow capacity of 5,100 cubic feet per second (cfs).

Kerckhoff Powerhouse

The Kerckhoff Powerhouse, sometimes referred to as the Kerckhoff No. 1 Powerhouse, is a reinforced concrete, tri-level building approximately 46 feet by 99 feet inside. It houses three vertical, Francis-type turbines directly coupled to generators with a total capacity of 38 MW. The normal maximum gross head is 350 feet and the turbine speed is 360 rpm; each turbine has a butterfly type shut-off valve. Generation voltage is 6,600 volts (v). The project was commissioned in 1920.

In the lower sections of the powerhouse, bedrock is exposed in wall sections. These sections appeared very stable with little or no spalling, which attests to the high quality of the rock.

Water supply to the Kerckhoff Powerhouse is conveyed from Kerckhoff Lake by an unlined tunnel that is approximately 16,943 feet and leads to three penstocks, which range from 913 to 945 feet in length and allow for a normal maximum gross head of 350 feet. A surge chamber is located at the end of the tunnel but upstream from the penstock gate valve. Three 115 kV transmission lines serve the Kerckhoff and Kerckhoff No. 2 powerhouses.

Kerckhoff Dam and Lake

Kerckhoff Dam, Kerckhoff Powerhouse, and Kerckhoff No. 2 Powerhouse all are included in FERC Project Number 96, which was originally licensed in 1922.

Kerckhoff Dam impounds Kerckhoff Lake, which serves as the forebay for both the Kerckhoff and Kerckhoff No. 2 powerhouses. The dam is a concrete arch type, approximately 114 feet in height. The top of the dam is at elevation 994.50; the spillway crest is at elevation 971.34, and the normal maximum water surface is at elevation 985.00. The reservoir has a usable capacity of 4,252 acre-feet. The reservoir is only drawn down to elevation 980, which corresponds to an operating capacity of 753 acre-feet between elevations 980 and 985.

Separate intakes and water conveyance systems are provided for the Kerckhoff and Kerckhoff No. 2 powerhouses. For the Kerckhoff Powerhouse, the intake structure is constructed of concrete and is equipped with two steel slide gates. The intake for the Kerckhoff No. 2 Powerhouse is a concrete-lined box structure located upstream of the Kerckhoff Powerhouse intake. Kerckhoff Lake has limited storage capabilities, which allow the powerhouses to provide peak generating loads during periods of high electrical demand.

PG&E Crane Valley Hydroelectric Project

The PG&E Crane Valley Hydroelectric Project accounts for approximately .75 percent of PG&E´s hydroelectric generation capacity, and less than 3 percent of the generation capacity in the upper San Joaquin River basin. Existing PG&E facilities comprising the Crane Valley Hydroelectric Project include the following, proceeding upstream:

- Wishon Powerhouse
- San Joaquin No. 1A Powerhouse
- San Joaquin No. 2 Powerhouse
- San Joaquin No. 3 Powerhouse
- Crane Valley Powerhouse
- Crane Valley Dam and Bass Lake

Bass Lake supplies water to a conveyance system linking five powerhouses (listed above). The Crane Valley Hydroelectric Project also includes several diversion dams, forebay and afterbay dams, conveyance facilities, and a small storage reservoir (Chilkoot Reservoir) that supplements the storage of Bass Lake. The Crane Valley Project is licensed as FERC Project No. 1354. The combined normal operating capacity of all the Crane Valley Project powerhouses is approximately 29 MW.

Wishon Powerhouse

The A.G. Wishon Powerhouse was commissioned in 1919 as part of the Crane Valley Hydroelectric Project. The powerhouse is located on the shore of Kerckhoff Lake. It was constructed in 1910 to replace the San Joaquin No. 1 Powerhouse, constructed in 1896. The Wishon Powerhouse is a reinforced concrete and steel-framed, bi-level building, approximately 75 feet by 150 feet in size. It houses four generating units consisting of horizontal single-overhung impulse turbines connected to generators with a total capacity of 20 MW. The powerhouse has a maximum gross head of 1,412 feet. Wishon accounts for about 70 percent of the Crane Valley Project generating capacity. Generation voltage is 2,300 v. Water from the turbines discharges into Kerckhoff Lake.

The water supply for the Wishon Powerhouse comes from Corrine Lake, located approximately 0.5 miles northeast of the powerhouse. Two penstocks, located east of the Wishon Powerhouse on a steep slope, convey water between Corrine Lake and the powerhouse. The penstocks are approximately 4,300 feet long. The diameter of the top half of the penstocks ranges from 40 to 44 inches. The diameter of the lower half of the penstocks ranges from 34 to 36 inches. The penstocks have a total flow capacity of 235 cfs.

Transmission lines at the project include a 70 kV line from the San Joaquin No. 3 complex and a 70 kV line to the PG&E Coppermine substation, which is about 8 miles south of Friant Dam.

Crane Valley Project Facilities Above Wishon Powerhouse

Upstream of Wishon Powerhouse, the Crane Valley Project consists of four small powerhouses – San Joaquin No. 1A, San Joaquin No. 2, San Joaquin No. 3, and Crane Valley – and Crane Valley Dam and Bass Lake, which supplies most of the water for generation in the project

San Joaquin No. 1A Powerhouse

The San Joaquin No. 1A Powerhouse contains one 600 horsepower (hp) horizontal double discharge Francis turbine with a net head of 40 feet and a normal operating capacity of 0.4 MW. The powerhouse was commissioned in 1919. Water is supplied to the powerhouse by a penstock from a header box forebay. Water through the San Joaquin No. 1A Powerhouse discharges directly into Corrine Lake.

San Joaquin No. 2 Powerhouse

The San Joaquin No. 2 Powerhouse contains one 5,250 hp horizontal double discharge Francis turbine with a net head of 292 feet and a normal operating capacity of 3.2 MW. The powerhouse was commissioned in 1917. Water is supplied to the powerhouse by a penstock from the San Joaquin No. 2 Forebay Dam. Flow from the powerhouse is discharged into the San Joaquin 1A Conduit for use at the San Joaquin No. 1A Powerhouse.

San Joaquin No. 3 Powerhouse

The San Joaquin No. 3 Powerhouse contains one 8,000 hp horizontal shaft Francis turbine with a normal maximum gross head of 405 feet and a normal operating capacity of 4.2 MW. The powerhouse was commissioned in 1923. Water is supplied to the San Joaquin No. 3 Powerhouse by a penstock from the San Joaquin No. 3 Forebay Dam. Flow from the powerhouse enters an open channel tailrace that discharges to the afterbay (Manzanita Lake).

Crane Valley Powerhouse

The Crane Valley Powerhouse contains one 1,740 hp horizontal Francis turbine with a net head 69 feet and a normal operating capacity of 0.9 MW. The Crane Valley Powerhouse was commissioned in 1919. Water is supplied to the Crane Valley Powerhouse by an inlet tunnel and penstock from Crane Valley Dam. Water from the powerhouse is discharged directly into the San Joaquin No. 3 conduit.

Crane Valley Dam and Bass Lake

Bass Lake is located on the North Fork of Willow Creek about 13 miles upstream of the Willow Creek confluence with the San Joaquin River. The lake has a total storage capacity of 45.4 TAF at elevation 3,377. The lake is normally drawn down to about 50 percent of capacity each year, which corresponds with a normal operating capacity of about 23 TAF. Crane Valley Dam is located at the south end of Bass Lake and is a combination hydraulic fill and rockfill dam with a reinforced concrete corewall. It was built in 1910 and has a height of 145 feet and a crest length of 1,880 feet.

SCE Big Creek Hydroelectric System

The SCE Big Creek Hydroelectric System accounts for approximately 90 percent of SCE´s hydroelectric generation capacity, and 80 percent of the generation capacity in the upper San Joaquin River basin. The Big Creek System contains seven FERC projects constructed in the eastern portion of the upper San Joaquin River basin upstream of Kerckhoff Lake. Existing SCE facilities comprising the primary powerhouse and reservoir features in the Big Creek Hydroelectric System include the following, generally proceeding upstream

- Big Creek No. 4 Powerhouse
- Redinger Dam and Lake
- Big Creek No. 3 Powerhouse
- Big Creek No. 8 Powerhouse
- Mammoth Pool Powerhouse
- Mammoth Pool Dam and Reservoir
- Big Creek No. 2 Powerhouse
- Big Creek No. 2A Powerhouse
- Big Creek No. 1 Powerhouse
- Huntington Dams and Lake
- Eastwood Powerhouse
- Shaver Dam and Lake
- Portal Powerhouse
- Florence Dam and Lake
- Vermilion Valley Dam and Lake Thomas A. Edison

Big Creek No. 4 Powerhouse

The Big Creek No. 4 Project was constructed between 1949 and 1952 as FERC Project No. 2017, with a licensed capacity of 98,822 kilowatts (kW). Water is supplied to Big Creek No. 4 by a tunnel and penstock from Redinger Dam. Just upstream from the junction of the tunnel and penstock is a surge chamber.

The powerhouse structure is 91 feet by 135 feet and is constructed of reinforced concrete. The powerhouse has five floors, including a draft tube floor, turbine floor, generator floor, storage floor, and erection floor. Normal tailwater level is at elevation 986.5.

The powerhouse contains two Francis-type, vertical shaft, hydraulic reaction turbines. Each turbine is rated at 66,000 hp, with a design head of 383 feet and speed of 257 rpm. Also, each turbine is equipped with a 120-inch turbine butterfly shut-off valve. Each main turbine is directly connected to a vertical-shaft, totally enclosed generator. Each generator is rated at 50 MW. Generation voltage is 11.5 kV.

Station electrical service is supplied by a small, 450 hp horizontal, Francis-type water turbine with a design head of 383 feet and speed of 1,200 rpm. This turbine is connected to a 300 kW generator. Water is supplied to this small turbine from a 14-inch penstock that branches off the Unit No. 1 main turbine penstock, upstream of its butterfly-type turbine shut-off valve.

Two 220 kV transmission lines convey energy from the project: one proceeds to the Big Creek No. 3 Powerhouse and the other travels in the direction of Springville.

Redinger Dam and Lake

The dam at Redinger Lake (also known as Big Creek Dam No. 7) and intake structure are located about 6.3 RMs upstream of the Big Creek No. 4 Powerhouse. The dam is a concrete gravity dam, 250 feet high, and contains a maximum capacity of 35 TAF. It was completed in 1951. The top of the dam, at elevation 1,413.5, is 875 feet long. The spillway has a crest elevation of 1,373 and is equipped with three 40-foot-wide by 30-foot-high radial gates. These gates are located approximately in the middle section of the dam crest. Normal maximum operating water level is elevation 1,403.

The intake to the power tunnel leading to the Big Creek No. 4 Powerhouse is located on the face of the dam to the right (looking downstream) of the spillway gates. This intake has full-height trash racks. The intake is divided into two rectangular openings, which can be closed by two wheel gates that are cable-suspended, electric-hoist-operated, and 8 feet by 17 feet and 8 inches in size. The outlet makes a transition to a 115-foot-long, 17-foot-diameter, welded steel pipe within and just beyond the dam section; thence, the pipe leads to the unlined power tunnel.

A turbine generator unit installed at the dam recovers energy from water released through the dam for instream flow purposes. The turbine is a Francis-type horizontal shaft, hydraulic reaction turbine rated at 500 hp with a design head of 222 feet and speed of 1,200 rpm. This turbine is connected to a 350 kW generator, which feeds into the local 12 kV distribution system.

Big Creek System Facilities Above Redinger Lake

The Big Creek System is one of the largest hydropower projects in the world; most of the facilities exist upstream of Redinger Lake on the east side of the upper San Joaquin River basin. Each of the storage and powerhouse facilities is briefly described in this section. Hydropower facilities upstream of Redinger Lake would not be directly affected by any of the surface storage measures being considered in the Investigation.

Big Creek No. 3 Powerhouse

Construction of the Big Creek No. 3 Project commenced in 1923 as FERC Project No. 120. The powerhouse has a licensed capacity of 174.45 MW. Water is supplied to Big Creek No. 3 by tunnel and penstock from Big Creek Dam No. 6. The Dam No. 6 Reservoir normal maximum operating water level is at elevation 2,230. At normal maximum operating water levels, the gross head available at the Big Creek No. 3 Powerhouse is 827 feet. The powerhouse structure is constructed of reinforced concrete and contains five turbine-generator units. Flow from the turbines discharges directly into Redinger Lake.

Big Creek No. 8 Powerhouse

The Big Creek No. 8 Powerhouse has a capacity of 75 MW and a head of 713 feet. Water is supplied to the Big Creek No. 8 Powerhouse by a tunnel and penstock from Big Creek Dam No. 5. The powerhouse was completed in 1921 and is a component of FERC Project No. 67.

Mammoth Pool Powerhouse

The Mammoth Pool Powerhouse contains two generating units with a combined capacity of 187 MW and a head of 1,100 feet. Water is supplied to the Mammoth Pool Powerhouse by a tunnel and penstock from Mammoth Pool Reservoir. The powerhouse was completed in 1960 as part of FERC Project No. 2085 and was the first major generating station in the SCE system to be completely remotely controlled.

Mammoth Pool Dam and Reservoir

Mammoth Pool Reservoir is located on the San Joaquin River approximately 14.5 miles upstream of Redinger Lake. It has a storage capacity of 123 TAF at elevation 3,330. Mammoth Pool Dam is a rolled earthfill structure with a height of 411 feet and a crest length of 820 feet. It was constructed between 1958 and 1960 as part of FERC Project No. 2085.

Big Creek No. 2 Powerhouse

The Big Creek No. 2 Powerhouse has a capacity of 66.5 MW and a head of 1,858 feet. Water is supplied to the Big Creek No. 2 Powerhouse by a tunnel and penstock from Big Creek Dam No. 4. The powerhouse was completed in 1914 and is a component of FERC Project No. 2175.

Big Creek No. 2A Powerhouse

The Big Creek No. 2A Powerhouse has a capacity of 110 MW and a head of 2,419 feet. Water is supplied to the Big Creek No. 2A Powerhouse by a tunnel and penstock from Shaver Lake. The powerhouse was completed in 1928 and is a component of FERC Project No. 67.

Big Creek No. 1 Powerhouse

The Big Creek No. 1 Powerhouse has a capacity of 85.2 MW and a head of 2,131 feet. Water is supplied to the Big Creek No. 1 Powerhouse by a tunnel and penstock from Huntington Lake. The powerhouse was completed in 1913 and is a component of FERC Project No. 2175.

Huntington Dams and Lake

Huntington Lake is located on Big Creek about 9 miles upstream of its confluence with the San Joaquin River. It has a storage capacity of 89.2 TAF at elevation 6,950. The lake is impounded by three gravity-arched dams with compacted fill buttressing and heights ranging from 120 to 170 feet and crest lengths ranging from 640 to 1,860 feet. The dams were originally constructed between 1912 and 1913, and raised by 35 feet in 1917.

Eastwood Powerhouse

Eastwood Powerhouse has a capacity of 199.8 MW and a head of 1,338 feet. Eastwood Powerhouse is a pumped storage facility. When Shaver Lake is near capacity, the powerhouse can pump water back from Shaver Lake to Balsam Meadow Reservoir at night. During peak energy use hours, water is supplied to Eastwood Powerhouse by a tunnel from Balsam Meadow Dam and the water returns to Shaver Lake. The powerhouse was completed in 1987 and is a component of FERC Project No. 67.

Shaver Dam and Lake

Shaver Lake is located on Stevenson Creek about 4 miles upstream of its confluence with the San Joaquin River. It has a storage capacity of 135.6 TAF at elevation 5,370. Shaver Lake Dam is a gravity type structure with a height of 185 feet and a crest length of 2,169 feet. The dam was constructed between 1926 and 1927.

Portal Powerhouse

The Portal Powerhouse has a capacity of 10.8 MW and a head of 230 feet. Water is supplied to the Portal Powerhouse by the Ward Tunnel from Florence Lake. The Ward Tunnel also carries water from several other reservoirs, such as the Portal Forebay and Lake Thomas A. Edison. The powerhouse was completed in 1956 and is a component of FERC Project No. 2174.

Florence Dam and Lake

Florence Lake is located on the South Fork of the San Joaquin River about 26 miles upstream of its confluence with the North Fork of the San Joaquin River. It has a storage capacity of 64.4 TAF at elevation 7,328. Florence Lake Dam is a multiple arch type structure with a height of 154 feet and a crest length of 3,156 feet. The dam was constructed between 1925 and 1926.

Vermilion Valley Dam and Lake Thomas A. Edison

Lake Thomas A. Edison is located on Mono Creek about 6 miles upstream of its confluence with the South Fork of the San Joaquin River. It has a storage capacity of 125 TAF at elevation 7,642. Vermilion Valley Dam is a rolled earthfill type structure with a height of 165 feet and a crest length of 4,234 feet. The dam was constructed between 1953 and 1954 as a component of FERC Project No. 2086.

FUTURE WITHOUT-PROJECT CONDITIONS

The planning horizon for the Investigation is 2020. This section describes future hydropower conditions for existing facilities in the upper San Joaquin River basin, future power generation and use in the CVP and State Water Project (SWP) service area, and hydropower trends in the western United States.

Existing Power Projects

More than half (6 of 10) of the FERC projects in the upper San Joaquin River basin (see **Table 2-2**) have licenses that will expire within the planning horizon time frame. It is anticipated that the existing projects would be relicensed and that relicensing would not result in additional power generation at existing facilities. If new mitigation requirements are established for any of the relicensing efforts, it is possible that less generation would occur at the existing facilities in the future. Changes in future generation as a result of relicensing are assumed to be small; therefore, it also is assumed that future generation in the basin would be of similar magnitude to that in place currently.

CVP/SWP Power Generation and Use

The CVP and SWP are the two largest hydropower generators and users in the Central Valley. Although no CVP or SWP hydropower facilities exist in the upper San Joaquin River basin, many of the surface water storage measures under study in this Investigation would generate or use power.

The Shasta, Keswick, Spring Creek, Trinity, Lewiston, Judge Francis Carr, Folsom, Nimbus, New Melones, San Luis, O'Neill, Devil Canyon, and Oroville hydropower facilities produce power for use in the Delta, and remaining power is available for commercial sale. This practice is expected to continue into the future.

CVP powerhouses generate 5,600 gigawatt-hours (GWh) of electricity annually to meet the needs of about 2 million people. SWP powerhouses have an average annual energy generation of 7,600 GWh, but the SWP has an average annual energy use of 12,200 GWh, which results in an average annual net use of 4,600 GWh.

Oroville is currently in the FERC relicensing process. An option to increase the potential hydropower generation capacity at Oroville is being considered to allow for additional flexibility in meeting future demands. However, it is unlikely that annual average hydropower generation at Oroville would increase. Potential generating capacity would increase as a result of relicensing only if installing additional capacity would help offset the cost of lost or foregone generation through existing facilities.

Regional Trends in Power Generation and Valuation

The Investigation will identify power accomplishments and benefits as part of alternatives formulation and evaluation. Hydropower value has not yet been estimated, but will need to be estimated in the future to quantify the cost of impacting hydropower facilities (generation loss) and revenues from new generation.

On average, hydroelectric power generation constitutes between 10 to 27 percent of California's annual electricity supply, depending on the type of water year. In 2003, large hydroelectric power generation accounted for about 14 percent of California's electricity supply produced in-State. California has 386 hydropower facilities capable of producing about 14,100 MW of electricity, which is the second largest source of power supply for the State after oil/gas thermal generating units. The Pacific Northwest has 314 hydropower facilities that produce close to 32,000 MW of electricity. This is a source for about 10 percent of California's overall electricity supply. Western United States hydropower trends, such as in the Pacific Northwest, are applicable to the Central Valley of California. Future study of power valuation will consider sources such as the Northwest Power and Conservation Council's 2004 Northwest Power Plan.

CHAPTER 3. HYDROPOWER EVALUATION OF SURFACE WATER STORAGE MEASURES

Developing any of the surface water storage measures considered in the Investigation may affect the operations of existing hydropower facilities and provide opportunities for new hydroelectric energy generation. This chapter describes the evaluation of future without-project hydropower generation at existing facilities and the estimated effects of Investigation surface water storage measures on hydropower.

GENERAL ANALYTICAL METHODOLOGY

Preliminary energy estimates were made using a spreadsheet approach based on output from the CALSIM II water operations simulation model (CALSIM). CALSIM performs simulations based on a monthly timestep, using water volumes (not flow) and a 73-year (water years 1922 to 1994) simulation period. Estimates were made from single-purpose analyses for restoration and water quality. Restoration flow single-purpose analysis would release water to the San Joaquin River early in the year, whereas single-purpose analysis for water quality would hold new water in storage until it is released to the San Joaquin River late in the irrigation season. Water supply reliability single-purpose analysis would fall within the range of these operations.

Preliminary estimates of energy generation at each of the dam sites and generation at each of the existing powerhouses that could be impacted by the surface water storage measures were produced using a spreadsheet. The spreadsheet tool allows selection of head and flow ranges for generation, head loss percentages, and system efficiencies, and calculates the generation on a monthly timestep based on head and flow data. Assumptions were made regarding pumping and generating efficiencies, equipment submergence requirements, head and flow ranges within which pumping and generating equipment would operate, and head losses in water passages.

For analysis of hydropower generation potential, storage sizes were selected that would correspond to elevations at which total generation losses would significantly change as a result of inundation of existing powerhouses. Results are considered preliminary because of the simplifying assumptions made in this appraisal-level of study, and therefore give an indication only of possible energy generation output and pumping energy requirements. A major factor in selecting pump-turbine and motor-generator unit sizes is the relatively large variation in head and flows available for energy generation over the simulation period. However, this level of analysis is adequate for comparing hydropower effects of the surface water storage measures.

Figure 3-1 shows a typical powerhouse configuration at the base of a dam. Primary variables that affect energy generation are flow rate (volume per time) and head (the elevation difference between the upstream reservoir and the water level below the powerhouse). Energy generation also depends on generating and pumping efficiencies, and equipment operational constraints. Energy generated by a hydroelectric project, therefore, is a function of net head available (gross head less hydraulic losses), water flows available from storage reservoirs, generation efficiency of the pump-turbine equipment, and the period of time under consideration (monthly or annually). Similarly, energy required for pumping is a function of the pumping head (gross head plus hydraulic losses plus requirements for submergence), flow of water to be pumped, efficiency of the pump, and the period of time under consideration.

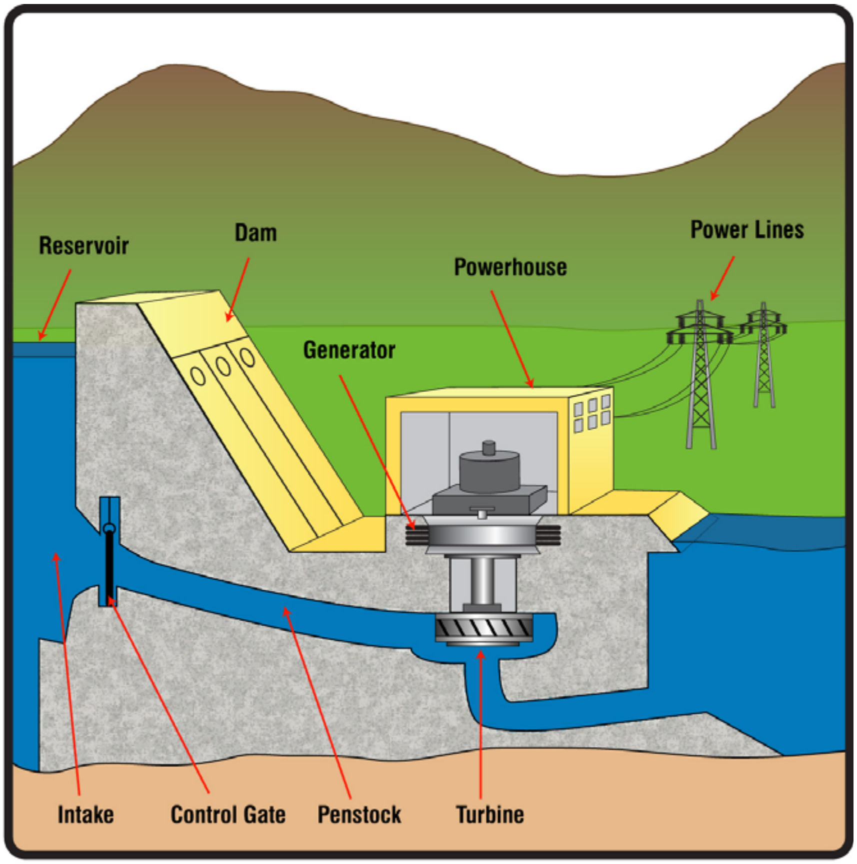

FIGURE 3-1.
TYPICAL HYDROELECTRIC ENERGY GENERATION FACILITY

SOURCE OF HYDROLOGIC DATA

Hydrologic data used in the surface water storage measure hydropower spreadsheets, such as reservoir releases and water level data, were derived from CALSIM output. CALSIM simulates the operation of major water projects throughout California and is widely used to identify how potential projects and actions would affect system-wide water operations. Millerton Lake inflow used in the study is from modeling output of the “Base Plan” of the Upper San Joaquin River Basin Model (USAN), which simulates current San Joaquin River basin operations from the headwaters of the San Joaquin River to Millerton Lake. USAN is a daily timestep model; its Millerton Lake inflow data have been converted to monthly averages for CALSIM. Flow data from USAN were also used in hydropower simulations for some of the existing hydropower facilities upstream of Millerton Lake.

During Phase 1 of the Investigation, CALSIM was revised to reflect the decision-making process used to allocate water supplies at Friant Dam based on hydrologic conditions, and to estimate the availability of water for release to the San Joaquin River or diversion to the Friant-Kern and Madera canals. CALSIM was used to estimate the new water supply that could be developed for a range of storage sizes for surface water storage sites considered in the Investigation. New water supply is defined as water that could be made available at Friant Dam, over and above the amount currently made available for delivery (future without-project conditions).

CALSIM simulations assumed that new water supply would be used for a single purpose (releases to the San Joaquin River for water quality or restoration purposes, or to increase water supply reliability in the Friant Division) to identify how new supply would vary in relationship to the type of water uses under consideration in the Investigation. No modifications were made to CALSIM output from single-purpose analyses to optimize the power generation estimates.

CALSIM output used in hydropower computations included monthly inflows to sites under consideration, water volumes and evaporation at the sites, and canal and river releases from Friant Dam. Output from CALSIM accounted for flood storage and dead storage requirements. Reservoir water levels were calculated using tables of reservoir area and volume with respect to elevation. Flow available for power generation was calculated from CALSIM output, taking into account reservoir inflows, increases or decreases in the volume of water stored, evaporation losses, and outflow requirements.

SIMULATION OF EXISTING FACILITIES

This section describes application of the spreadsheet analysis to existing facilities in the upper San Joaquin River basin. Results of this analysis will be used as the basis of comparison for potential surface water storage measures. Existing hydropower facilities in the upper San Joaquin River basin were described in **Chapter 2**. The spreadsheet analysis tool was used to estimate power generation on a monthly timestep at each of the existing power facilities that could be impacted by one of the surface storage measures.

Existing hydropower facilities could be impacted by one or more of the storage measures include the three powerhouses at Friant Dam (Friant-Kern, Madera, and River Outlet) and four powerhouses between Millerton Lake and Redinger Lake (Kerckhoff, Kerckhoff No. 2, Wishon, and Big Creek No. 4). Simulated average annual future without-project generation at these facilities is summarized in **Table 3-1**. The simulation covers 73 years of hydrologic data, and includes simplifying assumptions such as constant efficiency and consistent operations. Application of these generalized assumptions and the longer simulation period cause differences between future without-project generation values and recent historical generation. Specific assumptions for each of the facilities are presented in the following paragraphs.

Friant Power Project Simulation Assumptions

For the Friant-Kern, Madera, and River Outlet powerhouses, the head for each of the facilities was based on the difference between their normal tailwater elevations and Millerton Lake levels from CALSIM future without-project simulations. Flow data for each of the canals was taken from CALSIM. Flow and head ranges for generation were based on the rated capacities of the units. Capacities of the canals also were taken into account. The Friant-Kern Canal capacity was assumed to be 3,600 cfs and Madera Canal capacity was assumed to be 1,300 cfs.

TABLE 3-1.
FUTURE WITHOUT-PROJECT GENERATION AT EXISTING HYDROPOWER FACILITIES – FRIANT DAM TO REDINGER DAM

	Friant Power Authority			Total – Friant Power Project	Pacific Gas and Electric			Southern California Edison	Total – PG&E/SCE Facilities Below Redinger Dam
	Friant-Kern Canal	Madera Canal	River Outlet		Kerckhoff	Kerckhoff No. 2	Wishon	Big Creek No. 4	
Simulated Avg. Annual Generation (GWh)	56	16	15	87	34	473	50	424	981
Historical Avg. Annual Generation 1994-2002 (GWh)	60	24	14	98	47	532	72	474	1,125

Key:
GWh – gigawatt-hour
PG&E – Pacific Gas and Electric
SCE – Southern California Edison Company

PG&E Kerckhoff Project Simulation Assumptions

Energy calculations for the Kerckhoff Project were based on the assumption that levels in Kerckhoff Lake remain generally constant. The Kerckhoff Powerhouse was assumed to have a net head of 340 feet and a maximum generation flow of 1,900 cfs. The Kerckhoff No. 2 Powerhouse was assumed to have a net head of 390 feet and a maximum generation flow of 5,100 cfs. Inflow data to Kerckhoff Lake was taken from USAN. Flow and head ranges for generation were based on the rated capacities of the units.

PG&E Crane Valley Project - Wishon Powerhouse Simulation Assumptions

The Wishon Powerhouse was assumed to operate under a constant gross head of 1,412 feet, with a constant net head of 1,305 feet. The maximum generation flow was assumed to be 205 cfs. Inflow data to Wishon were Bass Lake outflow data from USAN. Flow and head ranges for generation were based on the rated capacities of the units.

SCE Big Creek System – Big Creek No. 4 Powerhouse Simulation Assumptions

The Big Creek No. 4 Powerhouse was assumed to operate under a constant gross head of 416 feet, with a constant net head of 370 feet. The maximum generation flow was assumed to be 3,550 cfs. Inflow data to Big Creek No. 4 were Redinger Lake outflow data from USAN. Flow and head ranges for generation were based on the rated capacities of the units.

SUMMARY OF SURFACE WATER STORAGE SITES

Six surface storage sites were retained from Phase 1 of the Investigation – Raise Friant Dam, Temperance Flat Reservoir RM 274, Temperance Flat Reservoir RM 279, Temperance Flat Reservoir RM 286, Fine Gold Reservoir, and Yokohl Valley Reservoir. Each storage measure being considered has the potential to generate hydropower and most of the measures also affect existing hydropower facilities. Surface water storage sites located upstream of Millerton Lake also have the potential to increase generation at the Friant Power Project powerhouses. For each storage measure, new energy generation, increased generation at the Friant Power Project, and lost generation due to decommissioning of existing power facilities were estimated to assess overall net generation loss or gain.

After completion of Phase 1 and during the scoping process, stakeholders proposed five additional potential reservoir sites that would avoid hydropower impacts. A reservoir located at RM 315 downstream of Mammoth Pool Reservoir was suggested based on a conceptual understanding of historic flood spills over Mammoth Dam. The Upper San Joaquin River Water and Power Authority (USJRWPA) considered the remaining four of the suggested reservoir sites in previous studies of the Granite and Jackass-Chiquito hydroelectric projects during the late 1970s and early 1980s. 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. Reservoir sites considered by USJRWPA 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. These reservoir sites suggested during scoping were evaluated as three surface water storage measures: the RM 315 Reservoir, Granite Project, and Jackass-Chiquito Project. The scoping comments also suggested combining new upstream storage with a gravity diversion tunnel from Kerckhoff Lake to a Fine Gold Reservoir.

The Investigation has identified a total of 11 sites where surface storage reservoirs could be developed to meet the Investigation objectives; sites include the 6 retained from Phase 1, and 5 additional sites proposed by stakeholders. (Mammoth Pool Enlargement is not included in this list because it is under study by others.) Each of the surface water storage sites is being evaluated at a variety of storage sizes. **Figure 3-2** shows the locations of the surface water storage sites retained in Phase 1 and suggested during scoping. **Table 3-2** summarizes each of the surface water storage measures.

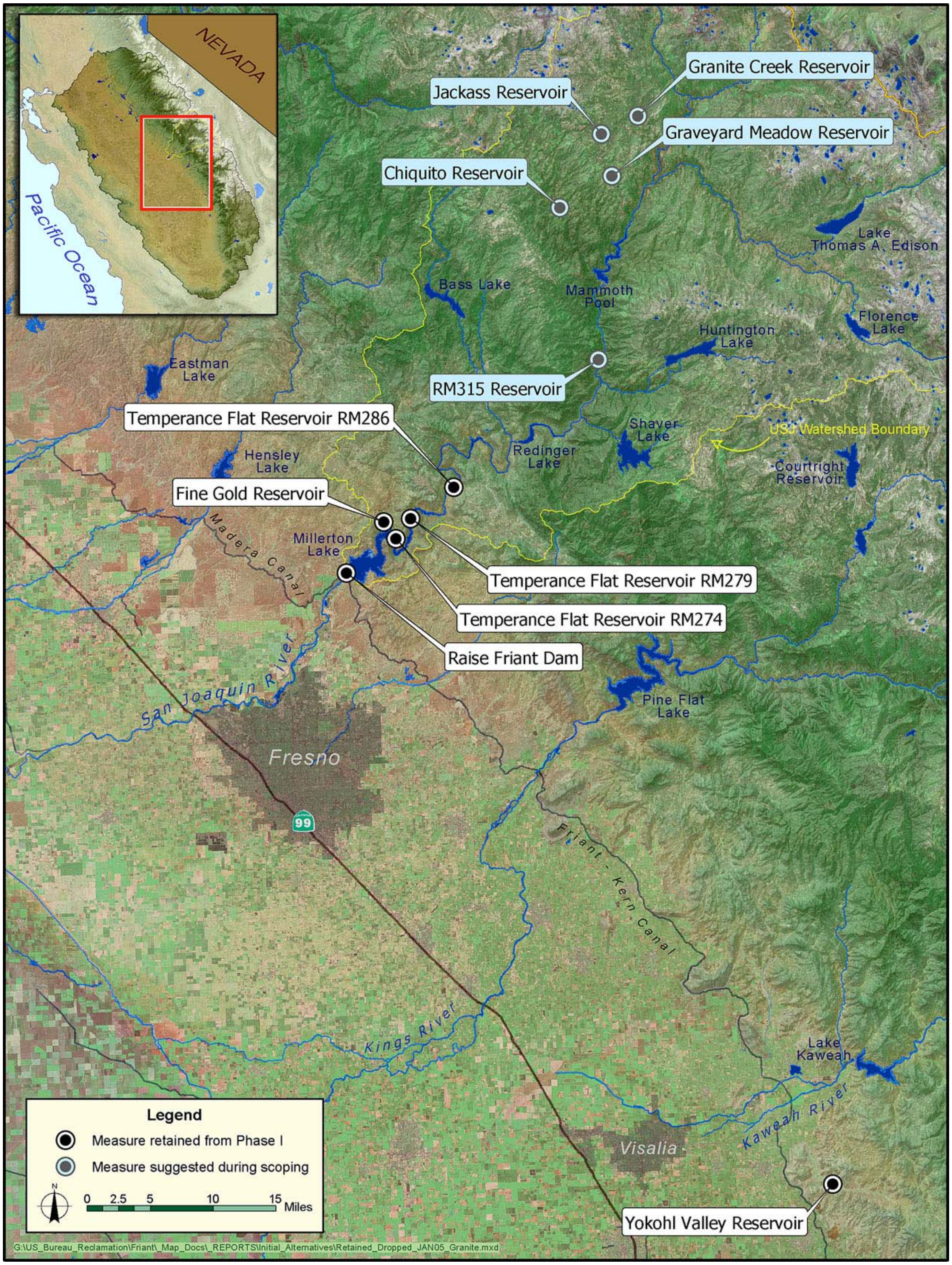

FIGURE 3-2.
SURFACE WATER STORAGE SITES RETAINED FROM PHASE 1 AND SUGGESTED DURING SCOPING

TABLE 3-2.
SUMMARY OF SURFACE WATER STORAGE MEASURES

Surface Water Storage Measure	Dam Height (feet)	Gross Pool Elevation (feet above msl)	New Storage Capacity (TAF)	Comments
Raise Friant Dam	25-foot to 140-foot raise	603 – 718	130 – 920	Retained from Phase 1
Temperance Flat Reservoir RM 274	415 – 715	800 – 1,100	460 – 2,110	Retained from Phase 1
Temperance Flat Reservoir RM 279	440 – 840	900 – 1,300	450 – 2,740	Retained from Phase 1
Temperance Flat Reservoir RM 286	440 – 660	1,180 – 1,400	460 – 1,360	Retained from Phase 1
Yokohl Valley Reservoir	261 – 330	791 – 860	450 – 800	Retained from Phase 1
Fine Gold Reservoir				
Pump-Back from Millerton	380 – 590	900 – 1,110	120 – 800	Retained from Phase 1
Gravity-Fed by Tunnel from Kerckhoff	440	960	230	Suggested during Scoping
RM 315 Reservoir[1]	620	3,000	200	Suggested during Scoping
Granite Project[2]				Suggested during Scoping
Granite Creek Reservoir	355	7,020	105	
Graveyard Meadow Reservoir	90	6,800	9	
Jackass-Chiquito Project[2]				Suggested during Scoping
Chiquito Reservoir	227	5,013	80	
Jackass Reservoir	160	7,070	100	

Key:
msl – mean sea level
RM – river mile
TAF – thousand acre-feet

Notes:
[1] The RM 315 Dam would be located at RM 315 on the San Joaquin River, just upstream of Mammoth Pool Powerhouse. The RM 315 Reservoir would back up to just below base of Mammoth Pool dam and would store Mammoth Pool Reservoir spills. No hydropower facilities would be impacted with this measure.
[2] Previous studies proposed the Granite Project and Jackass-Chiquito Project as hydropower projects each 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 valid only with all components in place and operated to maximize power generation, not necessarily water supply.

RAISE FRIANT DAM

Raising Friant Dam and enlarging Millerton Lake would increase the head at the Friant Power Project powerhouses and allow water that would otherwise spill to be released through the powerhouses, either as canal diversions or releases to the San Joaquin River. The amount of increased generation would depend on the scale of the enlargement and the operations of the enlarged reservoir.

Storage Sizes Considered in Hydropower Evaluation

Potential increased generation at the three Friant Power Project powerhouses was evaluated for three dam raises (25 feet, 60 feet, and 140 feet) for which cost estimates were prepared in Phase 1 of the Investigation. Hydropower analyses also were performed for a Friant Dam raise that would increase storage by 700 TAF (111-foot raise) because simulations were performed for restoration flow and water quality single-purpose scenarios, in addition to the water supply single-purpose scenario.

Power Generation Parameter Assumptions

Several assumptions regarding operation and facility characteristics were incorporated in spreadsheet simulations and applied in the energy generation analysis of all Raise Friant Dam measures. For assumptions on unit size, rated flow, and rated head, flow and head exceedance data were taken into account from the spreadsheet simulations. (Unit size increases with dam height to take advantage of increases in head.) In the generation computations for each of the dam raise scenarios, Millerton Lake levels and canal and river outlet flows were taken from CALSIM single-purpose analysis simulation results.

Powerhouse Considerations

A raise of Friant Dam could be accomplished with a concrete overlay on the crest and face of the existing concrete gravity dam. Detailed study has not been performed regarding modifying the Friant powerhouses with a raised dam. Thus, further study is needed to determine specific powerhouse configurations with Friant Dam raises. For purposes of hydropower analysis, it was assumed that the River Outlet, Friant-Kern Canal, and Madera Canal powerhouse facilities would be modified to accommodate larger turbine-generator units, which would be sized to take advantage of the increased head. Additional power generation at Friant with new storage in places other than Friant is addressed in the sections of this chapter about other storage measures.

Flow passing through the Friant-Kern and Madera canal powerhouses is constrained by canal capacity, and not outlet(s). Assuming all new water would be delivered through canals, canal powerhouse capacities would increase with a Friant Dam raise. River Outlet powerhouse evaluations were made with a Friant Dam raise and new upstream storage. For all Friant Dam raises, it is assumed that new units would be installed. These units were sized assuming a water supply single-purpose operating scenario. The existing combined capacity of the Friant-Kern, Madera, and River Outlet powerhouses is approximately 26 MW. For 25-, 60-, 111-, and 140-foot raises, it was assumed that the total capacity of the powerhouses would be approximately 31, 39, 51, and 57 MW, respectively. For the restoration flow simulation with a 111-foot Friant raise, the River Outlet Powerhouse was assumed to have a new 8 MW unit.

An opportunity exists to recover some of the Kerckhoff Project generation capacity that would be lost with Friant raises greater than 25 feet. A replacement powerhouse could be built farther upstream on an enlarged Millerton Lake. Specific powerhouse configurations were not evaluated for replacing Kerckhoff Project generation. The cost-effectiveness of constructing these powerhouses also was not evaluated. For a 60-foot raise of Friant Dam, a 90 MW powerhouse (two 45 MW units) could be constructed to replace lost generation from the Kerckhoff No. 2 Powerhouse. For a raise of 111 feet, a 50 MW powerhouse (two 25 MW units) could be constructed to replace lost generation from the Kerckhoff and Kerckhoff No. 2 powerhouses. For a raise of 140 feet, a 40 MW powerhouse (two 20 MW units) could be constructed to replace lost generation from the Kerckhoff and Kerckhoff No. 2 powerhouses.

Estimated Energy Generation and Losses

Estimated new energy generation and lost energy generation associated with the four potential Friant Dam raises evaluated are shown in **Table 3-3**. As shown, estimated generation would range from 32 to 112 GWh/year over the range of storage sizes with the single-purpose operational scenarios considered, and Kerckhoff Project replacement generation would range from 274 to 365 GWh/year for Friant Dam raises between 60 and 140 feet.

Any raise of Friant Dam would affect existing power generation at the Kerckhoff No. 2 Powerhouse. For a raise of up to about 25 feet, power losses would be proportional to the reduction in net head. Raises greater than 25 to 30 feet would inundate the Kerckhoff No. 2 Powerhouse. A 60-foot raise of Friant Dam may allow for continued operation of the Kerckhoff Powerhouse with minor modifications. Raises greater than about 90 feet would inundate the Kerckhoff Powerhouse. A 140-foot raise of Friant Dam would require that both the Kerckhoff and Kerckhoff No. 2 powerhouses be abandoned.

Results of the hydropower simulations show that additional energy generated at the Friant Power Project powerhouses for a raise of 25 feet would be equivalent to lost energy generation from existing powerhouses that would be inundated. For a 60-foot raise, additional energy generated at the Friant Power Project powerhouses and at a Kerckhoff No. 2 replacement powerhouse would come close to making up for the lost generation. For raises of 111 and 140 feet, additional energy generated at the Friant Power Project powerhouses and at a Kerckhoff Project replacement powerhouse would be significantly less than lost energy generation from existing powerhouses that would be inundated.

**TABLE 3-3.
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
111	700	689	WS RF WQ	95 95 70	318	Kerckhoff, Kerckhoff No. 2	-507	-94 -94 -119
140	920	718	WS	112	274	Kerckhoff, Kerckhoff No. 2	-507	-121

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
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 generation times ratio of head reduction to present head.
[4] Friant Dam raise of 25 feet does not inundate any powerhouses; no replacement generation needed.

Potential for Pumped Storage Development

Enlarging Millerton Lake by raising Friant Dam does not present an opportunity for pumped storage.

Transmission

If any relocation of powerhouses at Friant Dam was necessary, the powerhouses would be reconnected to the existing power grid. Electricity from the Friant Power Project is transmitted to the PG&E power grid over a 70 kV transmission line. For all Friant Dam raises considered, it is assumed that increased power generation at Friant could be accommodated with existing transmission lines.

TEMPERANCE FLAT RESERVOIR

A Temperance Flat Reservoir is being considered at three locations on the San Joaquin River – RM 274, RM 279, and RM 286. General discussions of the storage sizes considered and generation parameters in the power evaluation are presented in this section. Discussions specific to each of the Temperance Flat Reservoir sites are presented in successive sections.

Storage Sizes Considered in Hydropower Evaluation

The objective of the hydropower analysis is to identify net energy generation or loss associated with the three Temperance Flat sites. Therefore, for analysis of hydropower generation potential at any of the Temperance Flat Reservoir sites, storage sizes were selected that would correspond to elevations at which total generation losses would significantly change as a result of inundating existing powerhouses.

Depending on the location and height of the dam, Temperance Flat Reservoir could affect the operations of up to four powerhouses and two diversion dams upstream of Millerton Lake. Elevations at which power facilities would be affected by each of the reservoirs are shown in **Figure 3-3**, along with corresponding storage capacities. Impacts to installed capacity would increase in discrete steps as storage capacity increases. When reservoir storage for each site surpasses a threshold value, additional energy generation capacity would be impacted as additional powerhouses are affected. More detailed study of each potentially affected powerhouse would be needed to identify specific generation impacts as tailwater levels rise.

To simplify the analysis, reservoir storage volumes of 725 TAF and 1,350 TAF were evaluated for power production potential. These volumes were chosen to generally correspond with storage volumes associated with threshold impacts to existing power generation facilities for each of the three Temperance Flat sites. A storage volume of 725 TAF corresponds with impacts to Wishon and Big Creek No. 4 powerhouses for a new dam at RM 279. A storage volume of 1,350 TAF corresponds with impacts to the Big Creek No. 3 Powerhouse for a new dam at RM 286 and impacts to Wishon and Big Creek No. 4 powerhouses for a new dam at RM 274. These impacts are highlighted in blue on **Figure 3-3**, where storage elevation curves intersect with elevation lines for major facilities at 725 TAF and 1,350 TAF. The maximum elevation of a dam at RM 286 has been limited to 1,400 feet to avoid impacts to facilities upstream of Redinger Lake, such as the Big Creek No. 3 Powerhouse.

Power Generation Parameter Assumptions

Assumptions were made regarding turbine and generator efficiencies, turbine restrictions on minimum and maximum heads and flows for generation, and head losses in water passages. From these data and assumptions, preliminary estimates of energy generated on an annual basis were made.

Other data used in the generation spreadsheet model include CALSIM monthly inflows to Temperance Flat Reservoir; storage volumes and evaporation at Temperance Flat Reservoir and Millerton Lake; and canal and river releases from Friant Dam. Output from CALSIM accounted for flood storage and dead storage requirements. Water levels in Temperance Flat Reservoir and Millerton Lake were calculated using tables of reservoir areas and volumes with respect to elevation. Calculation of flow from Temperance Flat Reservoir to Millerton Lake available for power generation takes into account reservoir inflows, increases or decreases in the volume of water stored, evaporation losses, and outflow requirements based on the assumption that water levels in Millerton Lake would stay the same as in the without-project simulation. Operating criteria for moving water between the two reservoirs affect the magnitude of hydropower generation. Hydropower generation estimates would decrease if Millerton were kept as full as possible, and hydropower generation values would increase if a Temperance Flat Reservoir was operated to remain as full as possible. The assumption that water levels in Millerton Lake would stay the same as in the without-project simulation provides results between these two extreme operating objectives.

Developing new storage in the Temperance Flat area, or in other areas in the basin, also provides an opportunity for additional generation at the Friant Power Project by providing increased controlled flows into and out of Friant Dam. A reservoir of the same size at any of the Temperance Flat dam site locations would provide the same benefits at the Friant Power Project. With new storage upstream of Millerton Lake, an increase in Friant Power Project capacity may not be justified (the existing units could continue to be used), but additional storage could allow for increased generation at the existing powerhouses. The River Outlet Powerhouse capacity could be increased to a capacity of about 6 MW for a single-purpose restoration flow operation.

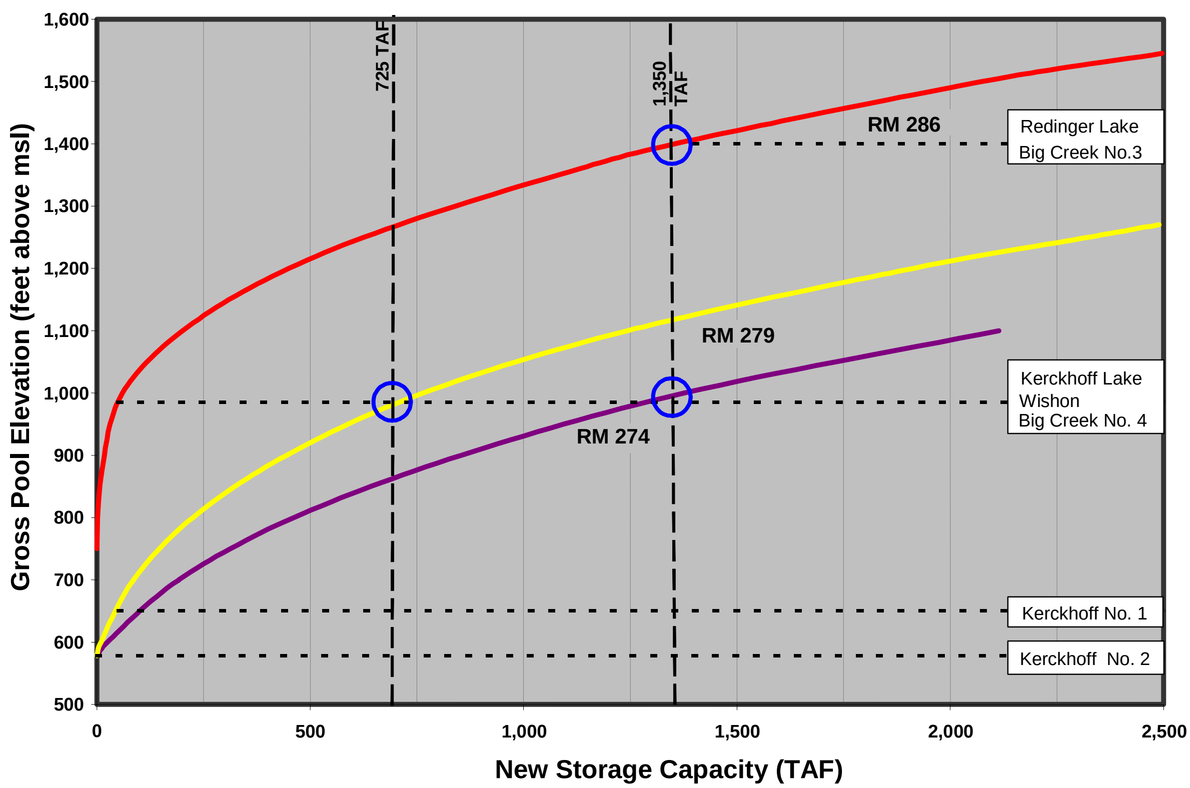

FIGURE 3-3.
EXISTING HYDROPOWER FACILITIES POTENTIALLY AFFECTED BY A TEMPERANCE FLAT RESERVOIR

TEMPERANCE FLAT RESERVOIR - RM 274

At the RM 274 site, the dam would be constructed in Millerton Lake and therefore would have a relatively high water level on the downstream face. This would reduce the net head available for power generation compared to sites farther upstream.

The Kerckhoff and Kerckhoff No. 2 powerhouses would be inundated by the 725 TAF and 1,350 TAF sizes. The 1,350 TAF size would generally correspond with the level of Kerckhoff Lake. Energy generation at the Wishon and Big Creek No. 4 powerhouses would not be affected.

Powerhouse Considerations

Roller-compacted concrete (RCC) and concrete-filled rockfill (CFRF) type dams are being considered for this site. For an RCC dam at this site, a powerhouse could be located integrally with the dam or abutment. For a CFRF type dam, the powerhouse could be located at the base of the left abutment and the river diversion tunnel would be used to supply water to the powerhouse. The powerhouse also could be located across a bend in the river on the left (west) side of the dam and served by a short tunnel with an intake located between RM 274 and RM 275. Flow from the powerhouse would discharge directly into Millerton Lake. This tunnel also could be used for river diversion purposes during dam construction. See the **Engineering TA** to the IAIR for more details on development of appraisal-level designs and costs.

The powerhouse at the RM 274 dam site is assumed to have an installed capacity of approximately 80 MW for the 725 TAF size and 100 MW for the 1,350 TAF size. It is assumed this capacity would be provided by four units so that generation could occur over a wide range of flows and heads. For the 725 TAF size, a new powerhouse also could be built at Kerckhoff Dam to replace some of the lost Kerckhoff Project generation. This powerhouse would have a gross head of 105 feet, and an assumed generating capacity of 20 MW.

Estimated Energy Generation and Losses

Estimated energy generation and potential lost energy generation associated with two storage sizes for the RM 274 reservoir are shown in **Table 3-4**. As shown, estimated generation at RM 274 Dam would range from 206 to 273 GWh/year over the range of storage sizes and operational scenarios considered; generation at the Kerckhoff Dam Powerhouse would be 108 GWh/year; and estimated increased energy generation at Friant would range from 5 to 36 GWh/year. The energy generated from new powerhouses would be significantly less than lost energy generation from existing powerhouses that would be inundated.

The principal reason for the significant difference between new power generation and losses to existing generation is that the existing Kerckhoff powerhouses operate at a fairly constant head, whereas the Temperance Flat powerhouse at RM 274 would operate at a variable, and often lower, head.

TABLE 3-4.
ESTIMATED ENERGY GENERATION AND LOSSES FOR 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 (GWh/year)
		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]	
725	865	WQ	206	108	5	Kerckhoff, Kerckhoff No.2	-507	-188
		RF	207	108	30			-162
1,350	990	WQ	273	---[2]	6	Kerckhoff, Kerckhoff No.2	-507	-228
		RF	266	---[2]	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] Gross pool for a reservoir size of 1,350 TAF would be at the elevation of Kerckhoff Lake; no potential for Kerckhoff Project replacement generation.

Potential for Pumped Storage Development

A pumped storage arrangement could be constructed and operated a RM 274 reservoir. A pumped storage project relies on a water storage reservoir (the lower reservoir) and a second water storage reservoir at a nearby, higher elevation (the upper reservoir). The project operates by releasing water from the upper reservoir through the water conduits and turbines to the lower reservoir to generate electricity during periods of peak demand when electricity is at a premium. During periods of low electricity usage (generally during the late night hours), the turbines are reversed and used as pumps to move water to the upper reservoir for storage until needed for the next peak cycle. Pumped storage projects also provide certain dynamic benefits to electrical systems. Compared with water storage, pumped storage involves more frequent and regular pumping and generating, generally on a daily or weekly basis.

The financial feasibility of a pumped storage project at RM 274 would require additional study under a variety of operational objectives. It is possible operations that would favor power generation and pumped storage would conflict with operations that would maximize water supply benefits or support recreation on Millerton Lake. Water management objectives would need careful evaluation to determine if opportunities exist to combine pumped storage with the water storage project.

An important criterion in the economic assessment of a pumped storage site is its ratio of total length of water conduit to head available at the site. This is especially the case if a surface type powerhouse is to be included in the design. A surface powerhouse with relatively long tunnels in comparison to its head will not be able to provide some of the dynamic benefits of pumped storage because its response time will be too slow. Recent economic and operational experience suggests that maximum acceptable length-to-head ratios range from 10 to 12 for high-head (1,200 to 1,500 feet) projects down to 4 or 5 for low-head (500 to 600 feet) sites. The proximity of the Temperance Flat Reservoir to Millerton Lake would meet the length-to-head ratio criterion presented above. Power generation from a pumped storage project has not been estimated.

Transmission

Due to the proximity of the Temperance Flat dam sites to existing facilities, it is expected that new power generation facilities could connect to existing transmission systems. Existing transmission line capacity from Wishon is 70 kV, from Kerckhoff and Kerckhoff No. 2 is 115 kV, and from Big Creek No. 3 and No. 4 is 220 kV. Existing Big Creek transmission lines do not have surplus capacity during the spring and summer runoff months. Additional study is needed to determine if existing lines have adequate capacity to serve new power facilities, and to ascertain requirements for electrical control and protection. These issues are the same for all of the Temperance Flat dam sites; thus, this discussion will not be repeated for the RM 279 and RM 286 reservoirs.

TEMPERANCE FLAT RESERVOIR - RM 279

For the RM 279 reservoir, the potential dam would be constructed at the upstream end of Millerton Lake. Millerton Lake levels would affect tailwater elevation at the toe of the dam, but the head available for generation would be greater than that for the RM 274 reservoir.

Powerhouse Considerations

As at the RM 274 site, concrete gravity and CFRF type dams would be suitable for the RM 279 site. With RCC or other concrete gravity dams, a new powerhouse could be located integrally with the dam or in the left abutment. For a CFRF type dam, a powerhouse could be located at the base of the left abutment, and the river diversion tunnel would be used to supply water to the powerhouse.

Two replacement power configurations were considered for the RM 279 reservoir site to determine the greatest amount of replacement power. One configuration involves developing new power generation facilities at the base of the dam. The second involves a new powerhouse on an extension of the Kerckhoff No. 2 tunnel and a new smaller powerhouse at the dam. **Figure 3-4** shows existing power features in the RM 279 area.

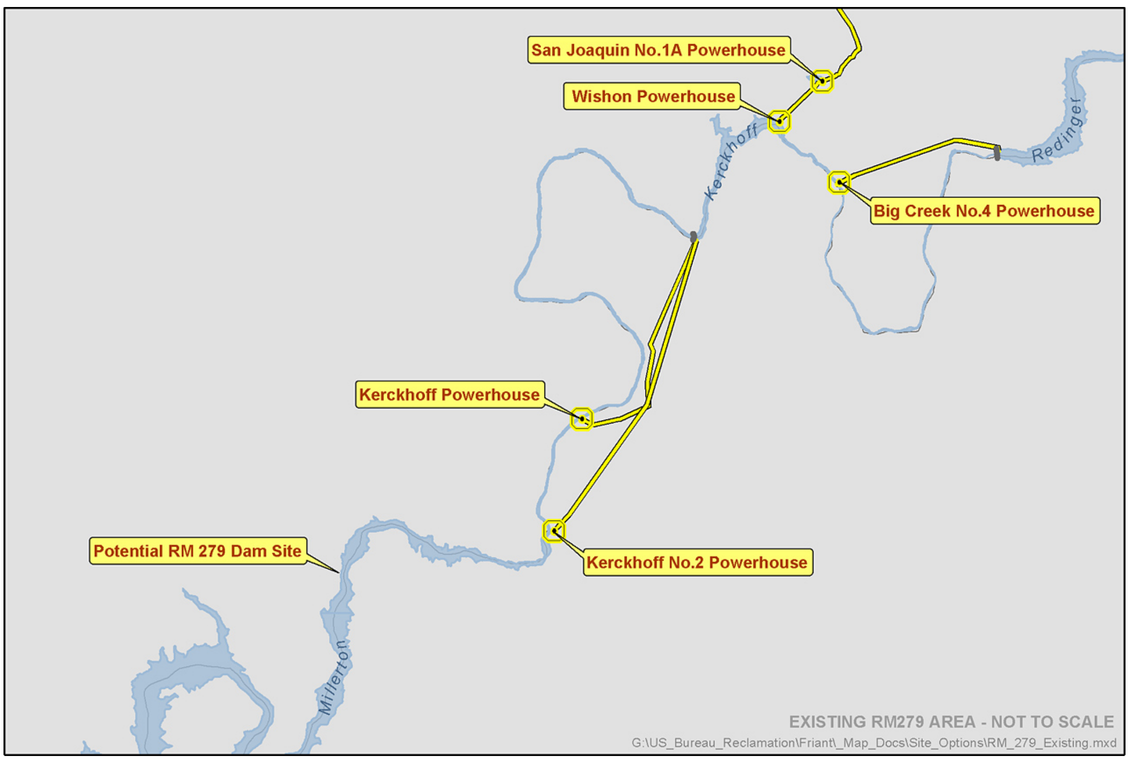

FIGURE 3-4.
EXISTING POWER FEATURES - TEMPERANCE FLAT RM 279 AREA

For the 1,350 TAF size RM 279 Reservoir for both replacement power options described below, 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. Replacement powerhouses for Big Creek No. 4 and Wishon are assumed to have capacities of 80 MW and 18 MW, respectively.

RM 279 Replacement Power Option 1 – New large powerhouse at dam. For this replacement power option, it is assumed that a powerhouse would be located at the RM 279 Dam or in an abutment, with an intake structure and a short conduit leading to the turbines, and discharge from the powerhouse directly into Millerton Lake. This powerhouse is assumed to have an installed capacity of approximately 120 MW provided by four units. A conceptual layout of the components of this replacement power option is shown in **Figure 3-5**.

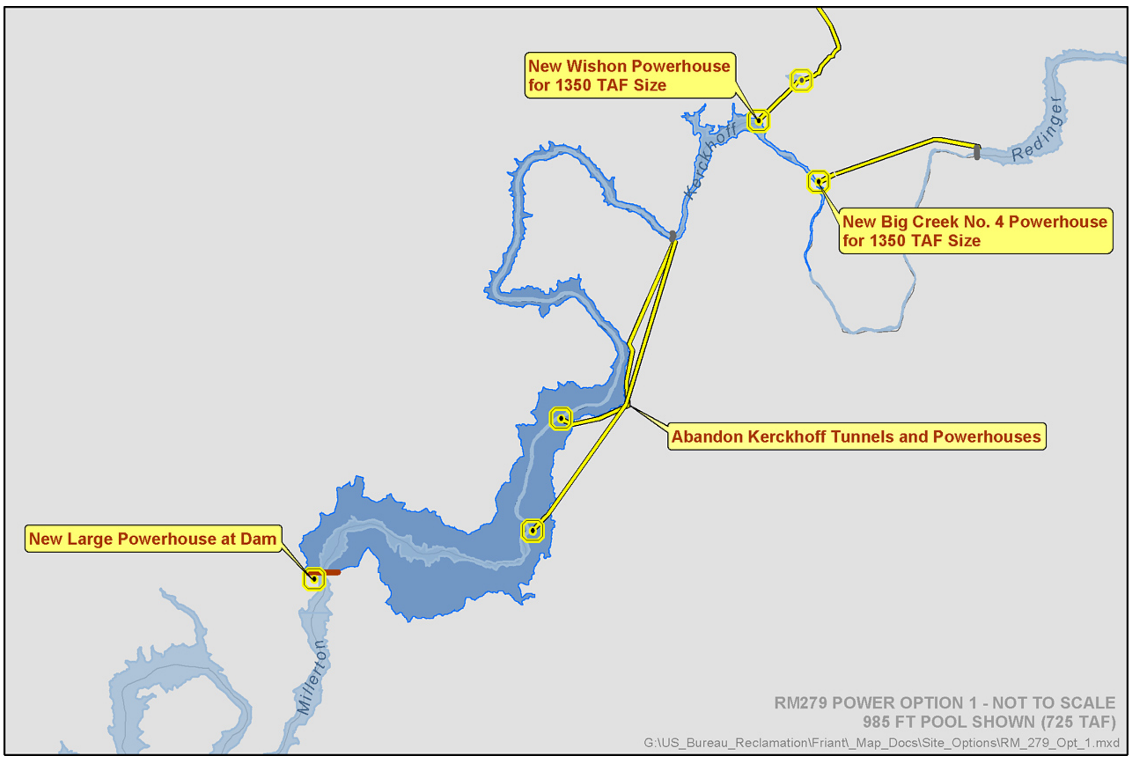

FIGURE 3-5.
REPLACEMENT POWER OPTION 1 - TEMPERANCE FLAT RM 279

RM 279 Replacement Power Option 2 – New large powerhouse on extended Kerckhoff No. 2 tunnel, new small powerhouse at dam. For this replacement power option, it is assumed that the powerhouse would be located at the end of an extended Kerckhoff No. 2 tunnel. The tunnel would be extended almost 5 miles to reach a powerhouse site downstream from RM 279. For the 725 TAF size, the maximum RM 279 Reservoir level would be about equal to the gross pool of Kerckhoff Lake. Inflow to Kerckhoff Lake up to the maximum tunnel capacity (assumed to be 5,000 cfs) would be diverted through the extended tunnel. The powerhouse is assumed to have an installed capacity of approximately 120 MW, provided by three units to take advantage of the wide range of inflows to Kerckhoff Lake. 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. Discharge from both powerhouses would be directly into Millerton Lake. A conceptual layout of the components of this replacement power option is shown in **Figure 3-6**. More study is needed to determine alignment of the extension of the Kerckhoff No. 2 tunnel.

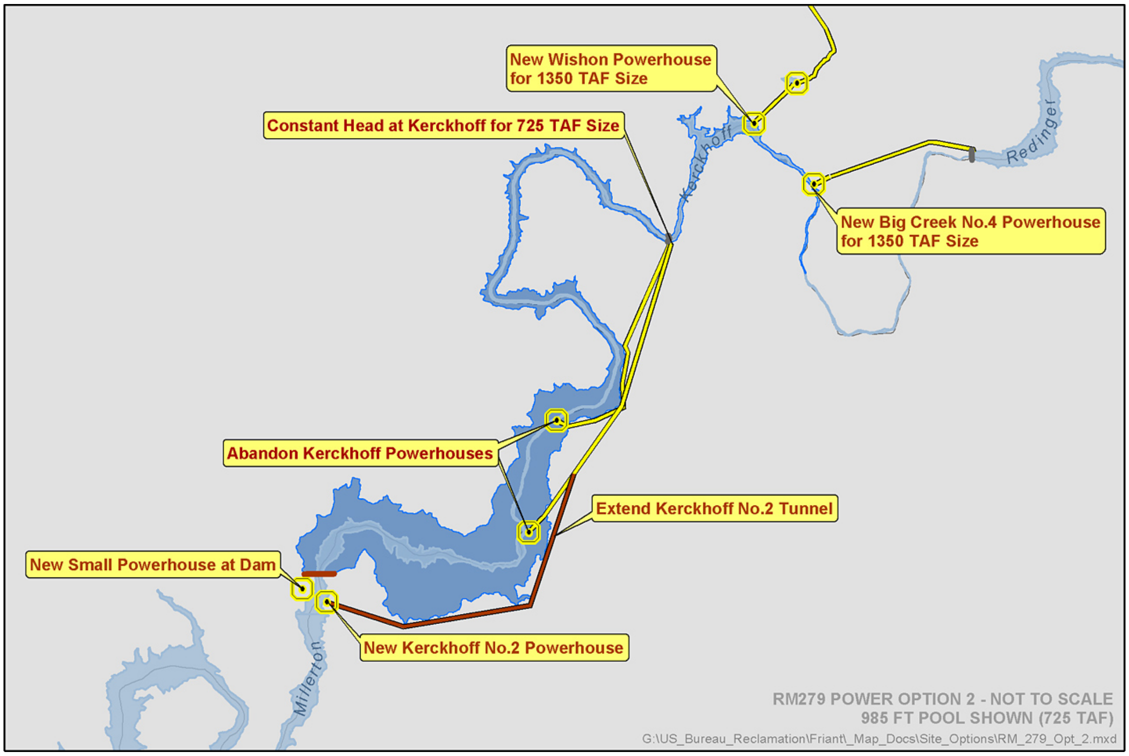

FIGURE 3-6.
REPLACEMENT POWER OPTION 2 - TEMPERANCE FLAT RM 279

Estimated Energy Generation and Losses

Estimated energy generation and potential lost energy generation associated with two storage sizes for the RM 279 site are shown in **Table 3-5**. As shown, estimated generation for Replacement Power Option 1 would range from 368 to 440 GWh/year and Replacement Power Option 2 would range from 460 to 543 GWh/year over the range of storage sizes and operational scenarios considered. Generation from a replacement Big Creek No. 4 Powerhouse would be about 335 GWh/year. Generation from a replacement Wishon Powerhouse would be about 49 GWh/year. Estimated increased generation at Friant would range from 5 to 36 GWh/year.

For Replacement Power Option 1, energy generated from new powerhouses would be significantly less than lost energy generation from existing powerhouses that would be inundated. The principal reason for the difference between new power generation and losses to existing generation is that the existing powerhouses operate at a fairly constant head, and have a higher head than the head available at the RM 279 Dam.

TABLE 3-5.
ESTIMATED ENERGY GENERATION AND LOSSES FOR 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 (GWh/year)
		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]	
Replacement Power Option 1 – New large powerhouse at dam								
725	990	WQ	368	---[2]	5	Kerckhoff, Kerckhoff No. 2	-507	-134
		RF	368	---[2]	30			-109
1,350	1,115	WQ	440	384	6	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-151
		RF	429	384	36			-132
Replacement Power Option 2 - New large powerhouse on extended Kerckhoff No. 2 tunnel, new small powerhouse at dam								
725	990	WQ	460	---[2]	5	Kerckhoff, Kerckhoff No. 2	-507	-42
		RF	472	---[2]	30			-5
1,350	1,115	WQ	543	384	6	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-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 RM 279 Reservoir does not impact Big Creek No. 4 or Wishon Powerhouses.

For Replacement Power Option 2, with an RM 279 size of 725 TAF, analysis shows that energy generated from new powerhouses could essentially make up for lost energy generation from the existing powerhouses (Kerckhoff and Kerckhoff No. 2) that would be inundated. A large powerhouse at the end of the extended tunnel could generate slightly more than the existing Kerckhoff No. 2 Powerhouse because it would have multiple units, allowing a wider range of operation. The small powerhouse at the RM 279 Dam would generate replacement power for the Kerckhoff powerhouse that would be inundated; however, it would be less than Kerckhoff generation because of the fluctuating water levels in the RM 279 Reservoir. Generation at the Wishon and Big Creek No. 4 powerhouses would not be affected by this measure.

The 1,350 TAF size for Replacement Power Option 2 would have a gross pool at elevation 1,115 and would inundate the Kerckhoff plants and Wishon and Big Creek No. 4 powerhouses. Due to the additional head with a larger dam, and the possibility of building replacement powerhouses for Big Creek No. 4 and Wishon, energy generated from new powerhouses for Replacement Power Option 2 with 1,350 TAF storage could almost replace the energy generation lost from existing powerhouses that would be inundated.

Potential for Pumped Storage Development

A pumped storage arrangement could be constructed and operated with the RM 279 reservoir. The financial feasibility of a pumped storage project at RM 279 would require additional study under a variety of operational objectives. It is possible operations that would favor power generation and pumped storage would conflict with operations that would maximize water supply benefits or support recreation on Millerton Lake. Water management objectives would need careful evaluation to determine if opportunities exist to combine pumped storage with the water storage project.

An important criterion in the economic assessment of a pumped storage site is its ratio of total length of water conduit to available head. This is especially the case if a surface type powerhouse is to be included in the design. A surface powerhouse with relatively long tunnels compared to its head would not be able to provide some of the dynamic benefits of pumped storage because its response time would be too slow. Recent economic and operational experience suggests that maximum acceptable length-to-head ratios range from 10 to 12 for high-head (1,200 to1,500 feet) projects down to 4 or 5 for low-head (500 to 600 feet) sites. The proximity of the Temperance Flat Reservoir to Millerton Lake would meet the length-to-head ratio criterion presented above. Power generation from a pumped storage project has not been estimated.

TEMPERANCE FLAT RESERVOIR - RM 286

The RM 286 Dam site is not located at Millerton Lake; thus, the available head would be at least as great as the depth of water behind the dam. The site is located between Kerckhoff Dam and the Kerckhoff powerhouses, which creates the potential for existing facilities to be incorporated into the design.

Both the 725 and 1,350 TAF reservoir sizes would inundate Kerckhoff Lake. The 725 TAF size would have a gross pool elevation near the base of Redinger Dam and the 1,350 TAF size would have a gross pool at the elevation of Redinger Lake.

Powerhouse Considerations

The RM 286 site is located approximately 3 miles upstream from Millerton Lake. In addition to the head available for power generation at the dam, about 140 feet of additional head would be available if the powerhouse were located at RM 283, the approximate location of the Kerckhoff No. 2 Powerhouse.

Three replacement power configurations were evaluated for the RM 286 reservoir site to identify a range of replacement power opportunities. One configuration 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. **Figure 3-7** shows existing power features in the RM 279 area.

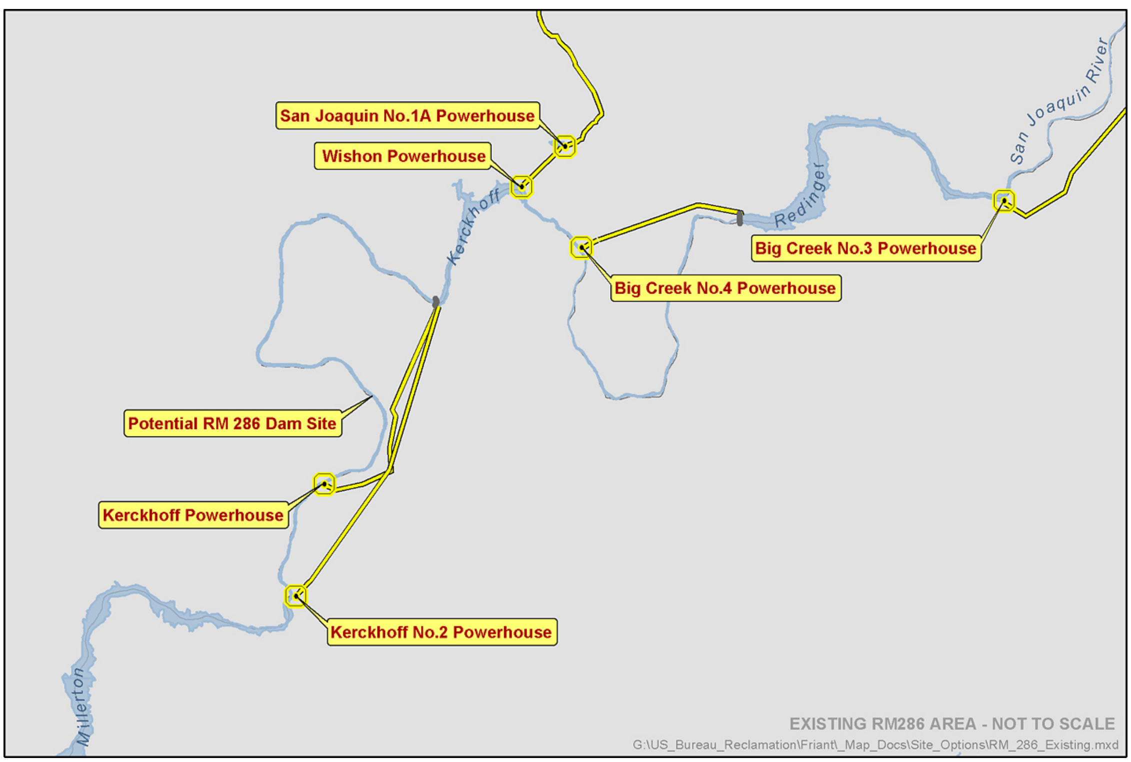

FIGURE 3-7.
EXISTING POWER FEATURES - TEMPERANCE FLAT RM 286 AREA

For the 725 TAF size RM 286 reservoir for all three 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 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. The replacement powerhouses for Big Creek No. 4 and Wishon are assumed to have capacities of 30 MW and 16 MW, respectively. For the 1,350 TAF size, a replacement for the Wishon Powerhouse could be constructed farther upstream on the Wishon penstock with a tailwater elevation of 1,400 feet and an installed capacity of approximately 14 MW.

Replacement Power Option 1 – New large powerhouse at dam. For this replacement power option, a multiple-unit powerhouse would be located on the end of the diversion tunnel (through the right abutment) just downstream of the dam. Installed capacities for the powerhouse are assumed to be 160 MW for the 725 TAF size and 180 MW for the 1,350 TAF size. The powerhouse is assumed to have four turbine-generator units. Both Kerckhoff powerhouses would be abandoned. An opportunity may exist with this reservoir site 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 replacement power option is shown in **Figure 3-8**.

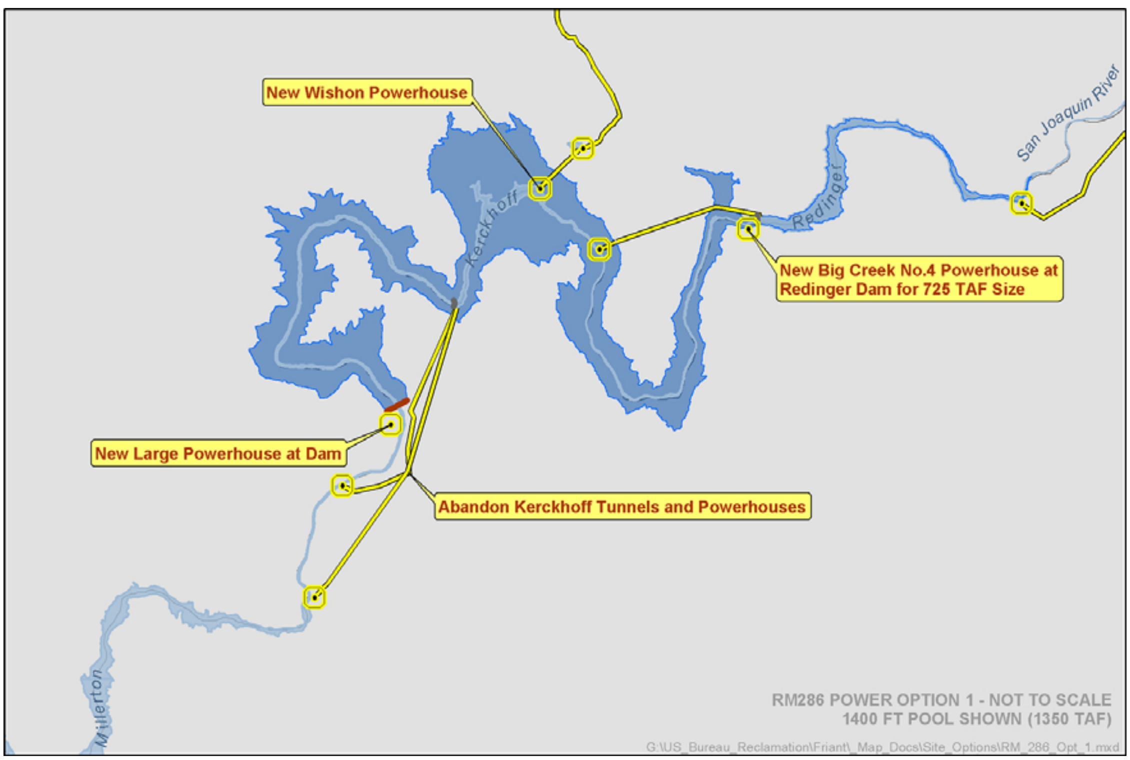

FIGURE 3-8.
REPLACEMENT POWER OPTION 1 - TEMPERANCE FLAT RM 286

Replacement Power Option 2 –New Kerckhoff No. 2 powerhouse. For this replacement power option, it is assumed that a new multiple-unit powerhouse would be located at Millerton Lake at about RM 283 to replace Kerckhoff No. 2. The installed capacities for the powerhouse are assumed to be 180 MW for the 725 TAF size and 200 MW for the 1,350 TAF size. The powerhouse is assumed to have four turbine-generator units. 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 replacement power option is shown in **Figure 3-9**.

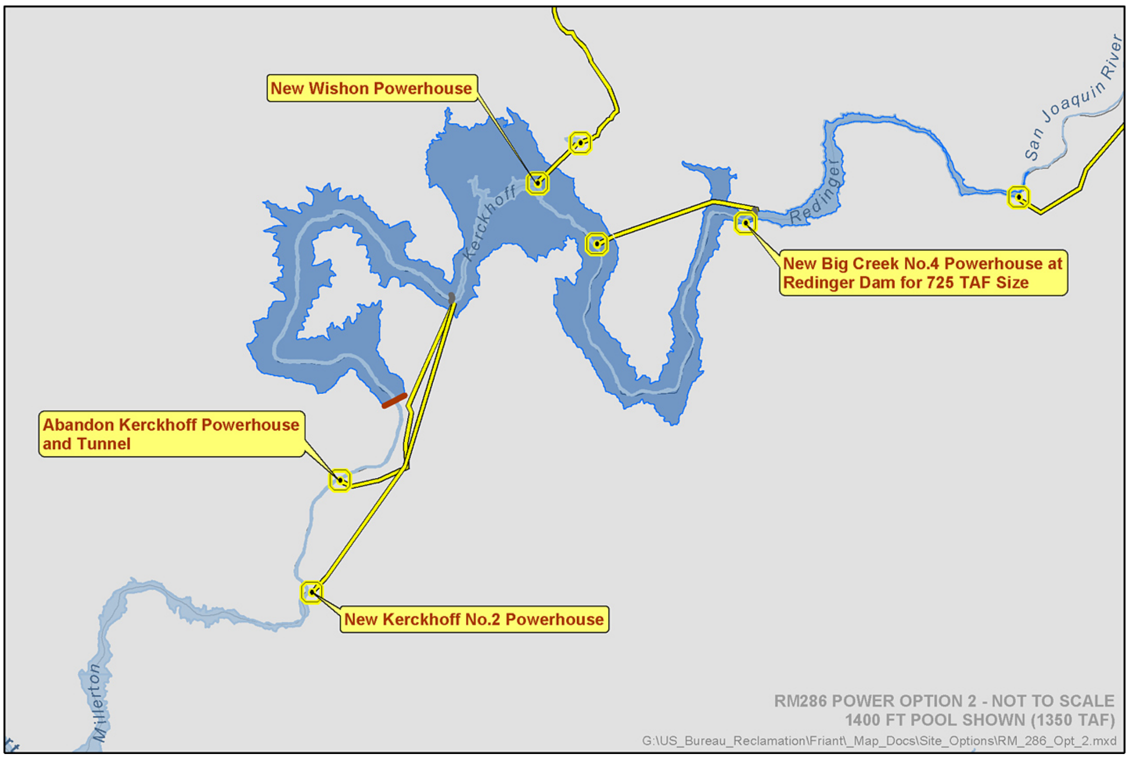

FIGURE 3-9.
REPLACEMENT POWER OPTION 2 - TEMPERANCE FLAT RM 286

Replacement Power Option 3 – New small powerhouse at dam, turbine-generator replacement at Kerckhoff No. 2. For this replacement power option, it is assumed that existing Kerckhoff No. 2 facilities would be used to the maximum extent feasible and that a single-unit powerhouse would be constructed at the base of the dam. Installed capacities for the powerhouse at the dam are assumed to be 45 MW for the 725 TAF size and 50 MW for the 1,350 TAF size. The Kerckhoff No. 2 intake and tunnel would require modification and a new surge chamber and single new turbine-generator would be installed. Installed capacities for the new Kerckhoff No. 2 unit are assumed to be 155 MW for the 725 TAF size and 186 MW for the 1,350 TAF size. Kerckhoff No. 1 would be abandoned. The longer conveyance tunnel and need for a surge chamber and penstocks would result in a greater head loss. A conceptual layout of the components for this replacement power option is shown in **Figure 3-10**.

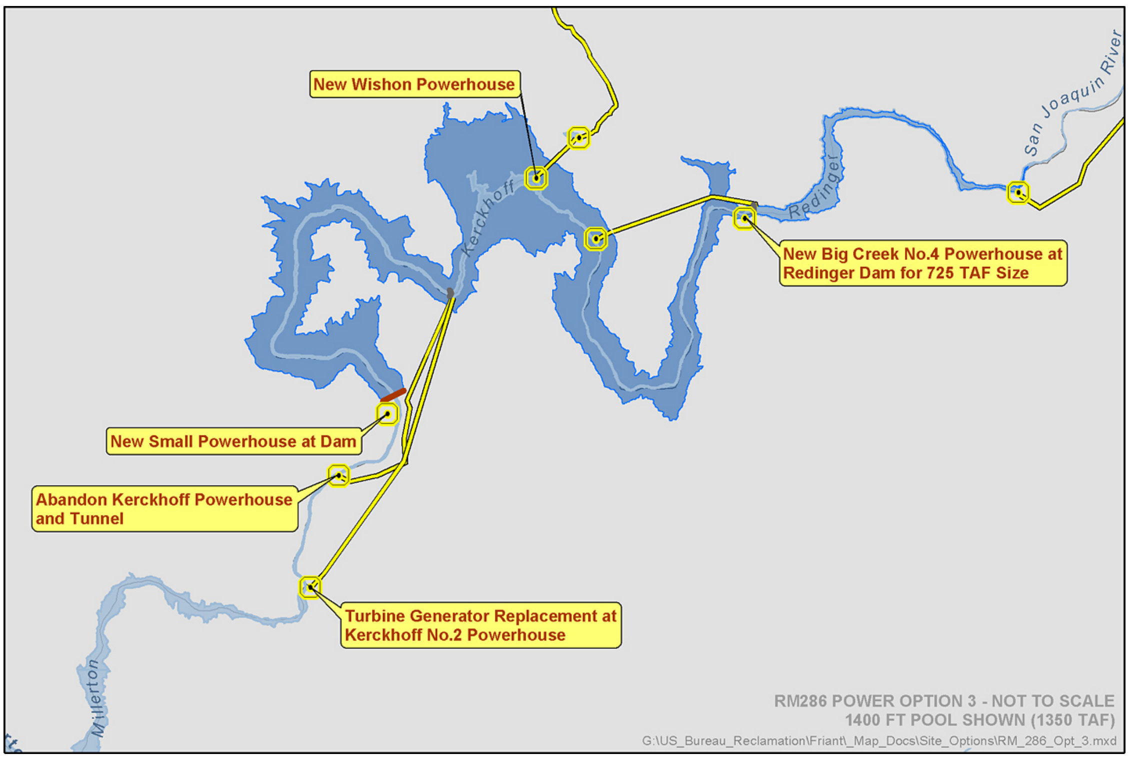

FIGURE 3-10.
REPLACEMENT POWER OPTION 3 - TEMPERANCE FLAT RM 286

Estimated Energy Generation and Losses

Estimated new and potential lost energy generation associated with two storage sizes for the RM 286 reservoir are shown in **Table 3-6**. As shown, estimated generation would range from 637 to 700 GWh/year for Replacement Power Option 1, from 662 to 736 GWh/year for Replacement Power Option 2, and from 532 to 597 GWh/year for Replacement Power Option 3, over the range of storage sizes and operational scenarios considered. A powerhouse at Redinger Dam would contribute about 135 GWh/year for a 725 TAF size. A new Wishon powerhouse would contribute about 43 GWh/year for the 725 TAF size and about 39 GWh/year for the 1,350 TAF size. Estimated increased generation at Friant would range from 5 to 36 GWh/year.

TABLE 3-6.
ESTIMATED ENERGY GENERATION AND LOSSES FOR 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 (GWh/year)
		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]	
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
		RF	534	178	30			-239
1,350	1,400	WQ	597	39	6	Kerckhoff, Kerckhoff No. 2 Wishon, Big Creek No. 4	-981	-339
		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
		RF	665	178	30			-108
1,350	1,400	WQ	736	39	6	Kerckhoff, Kerckhoff No. 2, Wishon, Big Creek No. 4	-981	-200
		RF	731	39	36			-175
Replacement Power Option 3[2] – New small powerhouse at dam, turbine-generator replacement at Kerckhoff No. 2								
725	1,275	WQ	637	178	5	Kerckhoff, Kerckhoff No. 2 Wishon, Big Creek No. 4	-981	-161
		RF	640	178	30			-133
1,350	1,400	WQ	697	39	6	Kerckhoff, Kerckhoff No. 2 Wishon, Big Creek No. 4	-981	-239
		RF	700	39	36			-206

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 generation numbers from without-project spreadsheet simulations.
[2] New generation values for Power Option 3 include generation at modified K2 facility.

For the RM 286 replacement power options and storage sizes, energy generated from new powerhouses would be less than energy generation lost from existing powerhouses that would be affected. The 725 TAF measure would inundate Kerckhoff Lake and Dam, the Wishon Powerhouse, and Big Creek No. 4 Powerhouse. The Kerckhoff powerhouses would not be inundated, since they are downstream from RM 286, but they would either be abandoned or modified as explained earlier in this section. The 1,350 TAF measure would result in a reservoir pool at or below the level of Redinger Lake. It would inundate the same power generation facilities as the 725 TAF measure but would not impact the Big Creek No. 3 Powerhouse. Replacement Power Option 2 at 725 TAF has the smallest amount of net generation loss, ranging from 108 to 136 GWh/year.

Potential for Pumped Storage Development

Feasibility of a pumped storage project at RM 286 requires consideration of a number of operational objectives. It is possible operations that would favor power generation and pumped storage would conflict with operations that would maximize water supply benefits or support recreation on Millerton Lake. Water management objectives would need careful evaluation to determine if opportunities exist to combine pumped storage with the water storage project.

An important criterion in the economic assessment of a pumped storage site is its ratio of total length of water conduit conveying water to the pump-turbine equipment to head available at the site. This is especially the case if a surface type powerhouse is to be included in the design. A surface powerhouse with relatively long tunnels compared to its head would not be able to provide some of the dynamic benefits of pumped storage because its response time would be too slow. Recent economic and operational experience suggests that maximum acceptable length-to-head ratios range from 10 to 12 for high-head (1,200 to 1,500 feet) projects down to 4 or 5 for low-head (500 to 600 feet) sites. The distance from Millerton Lake to the RM 286 site would preclude the economic provision of pumped storage capability. The ratio of water conduit length to available head is greater than 10, and is well outside the criterion required.

FINE GOLD RESERVOIR

Two configurations were considered for Fine Gold Reservoir. One would involve operating Fine Gold Reservoir would be a pump-back project to allow the additional capture of San Joaquin River water in Millerton Lake. 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-turbines 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.

A second configuration for Fine Gold Reservoir, based on comments received during the scoping process, involves a tunnel that could be constructed 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. The spillway at Kerckhoff Dam is at elevation 971 and the top of the spillway gates at Kerckhoff Dam are at elevation 985. A maximum storage capacity of 230 TAF could be served by a gravity-driven tunnel assuming a minimum 10 feet of elevation drop to overcome tunnel friction and minor losses for the tunnel to flow by gravity over the 7-mile length. This reservoir would have a gross pool at approximately elevation 960.

This configuration may be operated in combination with one of the upstream storage measures proposed during scoping, such as the RM 315 Reservoir, 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 able to capture a large volume of water during flood events. With additional storage upstream, the flood flows could be regulated into Fine Gold more effectively. 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 included in the tunnel design. Hydropower would likely not be generated at the discharge end of the Kerckhoff-Fine Gold tunnel because of the small head difference between Kerckhoff Lake and Fine Gold Reservoir.

Part of this configuration also could include a raise of Kerckhoff Dam by installing gates or raising the dam itself. The maximum likely elevation for a raise of Kerckhoff Dam would be limited to about 1,000 feet above msl to avoid impacts to the Big Creek No. 4 and Wishon powerhouses. A raise of Kerckhoff Dam to elevation 1,000 would provide a storage increase of about 810 acre-feet and would allow for a greater amount of fill by gravity into Fine Gold Reservoir. A Fine Gold Reservoir with a gross pool at elevation 990 would have a capacity of about 305 TAF. If desired, the Kerckhoff-Fine Gold tunnel could be pressurized to pump to Fine Gold for elevations up to 1,100 feet. Water would be pumped to a head of about 100 feet to reach Fine Gold Reservoir storage of 800 TAF. Preliminary water supply and hydropower evaluations for this configuration assumed no raise of Kerckhoff Dam and a gravity tunnel only.

Storage Sizes Considered in Hydropower Evaluation

For Configuration 1, pump-back from Millerton Lake, a Fine Gold Reservoir with water storage capacity of 800 TAF was considered to enable comparisons to other potential sites of similar size. For Configuration 2, a tunnel from Kerckhoff Dam and a Fine Gold Reservoir with water storage capacity of 230 TAF was considered because it is the largest size that could fill by a gravity tunnel from the existing Kerckhoff Dam. This configuration was evaluated for water supply and hydropower potential in combination with a 200 TAF RM 315 Reservoir.

Power Generation Parameter Assumptions

For Configuration 1, pump-back from Millerton Lake, to account for head losses in waterway passages during generation, a deduction of 5 percent was made on gross head. To obtain the pumping head, an amount equivalent to 10 percent was added to the gross head.

Other data used in the Configuration 1 generation spreadsheet model include CALSIM data on flows to be pumped into Fine Gold Reservoir from Millerton Lake; releases to be made from Fine Gold Reservoir to Millerton Lake; storage volumes and evaporation at Fine Gold Creek Reservoir and Millerton Lake; inflow to Fine Gold Reservoir from Fine Gold Creek; and canal and river releases from Friant Dam. Water levels in Fine Gold Reservoir and Millerton Lake were calculated using tables of reservoir areas and volumes with respect to elevation.

For Configuration 2, a tunnel from Kerckhoff, a spreadsheet hydrologic analysis model that mimics CALSIM logic was used to establish preliminary numbers for new water supply from a gravity-fed Fine Gold Reservoir in combination with 200 TAF additional upstream storage at RM 315 Reservoir, an upstream surface water storage measure proposed during scoping. The preliminary average annual new water supply for Fine Gold Configuration 2 with the 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.

Powerhouse Considerations

Configuration 1 would consist of a pump-generating station located downstream of Fine Gold Dam in Millerton Lake in a location to meet the pump-turbine requirements for submergence. The pump-turbine station would not, therefore, be located at Fine Gold Dam but instead a short distance downstream. The installed capacity of generating units is assumed to be approximately 100 MW. It is assumed this capacity would be provided by four reversible pump-turbine units so that the pumping-generating station could operate at low and high discharges.

For Configuration 2, a hydropower facility would consist of a powerhouse located at Fine Gold Dam, with discharge directly into Millerton Lake.

Developing new storage in the Fine Gold Creek area also provides an opportunity for additional generation at the Friant Power Project by providing increased controlled flows into and out of Friant Dam. The hydropower evaluation assumed that the existing Friant Power Project units could continue to be used. Additional storage could allow for increased generation at the existing powerhouses.

Estimated Energy Generation and Losses

Neither configuration for Fine Gold Reservoir would impact any existing hydropower facilities. The range of potential net energy generation or loss for Fine Gold Reservoir Configuration 1 is summarized in **Table 3-7**.

Results from the hydropower simulations for Configuration 1 indicate that the pumping energy required is greater than the offsetting energy that might be generated. Further study is needed to determine the cost of the pump-back facilities and to ascertain the preferred facility layout. Further study also may be warranted of water storage requirements and pump-turbine and motor-generator equipment in view of the wide variation in head and flows available for generation in the operating scenarios.

Configuration 2 would not require pumping to fill Fine Gold Reservoir up to 230 TAF. Therefore, this configuration would have no negative power effects. Results from 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 configuration does not appear cost-effective for development of hydropower facilities. Thus, units have not been sized for this configuration 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.

TABLE 3-7.
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 (GWh/year)
		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)	
Fine Gold Reservoir Configuration 1 – Pump-Back							
800	1,110	WQ	103	8	---[1]	-164	-53
		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.

Potential for Pumped Storage Development

For Configuration 1, Fine Gold Reservoir would be a water storage reservoir that would operate as a pump-back hydroelectric energy project. Water would be pumped into the reservoir and released when water requirements dictated. For Configuration 2, releases from Fine Gold Reservoir, and thus the timing of energy generation, would be governed by water management operating objectives. Conversely, a pumped storage project would be governed by hydroelectric energy production objectives. A pumped storage operation typically pumps water into an upper reservoir during non-peak energy price periods and generates when the energy can be sold at peak period prices or when power system requirements make it advantageous for generation capacity to go on-line.

From a hydropower perspective, the proximity of Fine Gold Reservoir to Millerton Lake and the length-to-head ratio make a pumped storage arrangement a potential consideration. Physically, Fine Gold Reservoir could be designed for pumped storage.

Determining whether a pumped storage project would be economically feasible or would conflict with reservoir operating requirements, however, requires further study.

For Configuration 2, with a raise of Kerckhoff Dam, additional hydropower could potentially be generated by releasing water in the upper 100 feet of Fine Gold Reservoir at 800 TAF through the tunnel back to Kerckhoff Lake or through a new Fine Gold powerhouse into Millerton Lake.

Transmission

Two major power lines are located nearby: one is about 6 miles southeast of the site and the other is about 15 miles southwest of the site. It is anticipated that pumping power would be received from, and generation delivered to, one or both of these power lines. Suitable interconnection infrastructure would need to be constructed.

YOKOHL VALLEY RESERVOIR

Yokohl Valley Reservoir would be an off-canal pump-back project along the Friant-Kern Canal. Water would be pumped from the canal to the reservoir and released at a later time to supplement deliveries from Millerton Lake or to offset releases from Millerton Lake to the San Joaquin River. Electricity would be needed to power the pump-turbines when pumping. This energy requirement would be partially offset by generation of electricity from the pump-turbine units when water was conveyed back to the Friant-Kern Canal.

Storage Sizes Considered in Hydropower Evaluation

For both single-purpose operating scenarios (restoration flow and water quality), a water storage capacity of 800 TAF was considered to allow comparisons to other potential reservoirs of similar size.

Power Generation Parameter Assumptions

To account for head losses in waterway passages during generation, a deduction of 6 percent was made on gross head. To obtain pumping head, an amount equivalent to 10 percent was added to the gross head. Other data used in the generation spreadsheet model include CALSIM data on flows to be pumped into Yokohl Valley Reservoir from the Friant-Kern Canal; releases to be made from Yokohl Valley Reservoir to the Friant-Kern Canal; flows along the Friant-Kern Canal upstream and downstream of the canal diversion location; and storage volumes and evaporation at Yokohl Valley Reservoir. Water levels in Yokohl Valley Reservoir and Millerton Lake were calculated using tables of reservoir areas and volumes with respect to elevation. The water elevation at the Friant-Kern Canal was assumed to be constant at 410 feet for calculating heads required for pumping and heads available for power generation.

Powerhouse Considerations

The hydropower project would consist of a pumping-generating station linked to the Friant-Kern Canal by a forebay or intake canal, an approximately 1- to 1.5-mile-long tunnel to Yokohl Valley Reservoir, and an inlet-outlet structure at Yokohl Valley Reservoir. The installed capacity of generating units is assumed to be approximately 100 MW. It is assumed this capacity would be provided by four reversible pump-turbine units so that the pumping-generating station could operate at low and high discharges.

A potential site for the forebay is located on the east side of the Friant-Kern Canal, about ¾ mile northeast of the small community of Tonyville. It is a relatively level, roughly triangular parcel of agricultural land within a small valley at the base of the adjacent low mountains. Based on United States Geological Survey (USGS) topographic maps (20-foot contour intervals), it appears that the forebay could potentially cover about 15 to 20 acres. This site is assumed to be adequate for providing submergence on the pump-generator equipment to ensure good inflow and outflow conditions at the pumping-generating station and in the Friant-Kern Canal, and to maintain the hydraulic grade in the Friant-Kern Canal. Requirements for emergency dewatering of the tunnel without disturbing the hydraulics and hydraulic gradient of the Friant-Kern Canal were not considered in this analysis.

Developing new storage in the Yokohl Valley also provides an opportunity for additional power generation at the Friant Power Project by providing increased controlled flows into and out of Friant Dam. The hydropower evaluation assumed that existing Friant Power Project units could continue to be used. Additional storage could allow for increased power generation at existing powerhouses.

Estimated Energy Generation and Losses

The range of potential pumping energy required and energy potentially generated for an 800 TAF Yokohl Valley Reservoir are summarized in **Table 3-8**. Results of the hydropower simulations indicate the pumping energy that would be required and offsetting energy that might be generated. Further study is needed to determine the cost of the pump-back facilities and to ascertain the preferred facility layout. Further study also may be warranted of water storage requirements and pump-turbine and motor-generator equipment in view of the wide variation in head and flows available for generation in the water supply scenarios.

TABLE 3-8.
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 (GWh/year)
		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)	
800	860 [1]	WQ	76	-7	---[2]	-139	-70
		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.

Potential for Pumped Storage Development

Yokohl Valley Reservoir would be a storage reservoir, supplied from the Friant-Kern Canal by means of a pump-back arrangement. When storage is required, water will be pumped from the Friant-Kern Canal through a tunnel to the Yokohl Valley Reservoir. Water then will be released through the tunnel and back to the Friant-Kern Canal as required for water usage purposes. A powerhouse will be located at the downstream end of the tunnel to take advantage of the head and flow available for generation when water is being released. This pump-back arrangement is common with offstream storage projects, where the timing of pumping and generating is governed by water management operating objectives and not by power production requirements.

Sometimes, water management operations may allow for an element of energy storage involving more frequent and regular pumping and generating, generally on a daily or weekly basis. This is often referred to as pumped storage operation as opposed to pump-back operation. A pumped storage operation typically pumps water into an upper reservoir during non-peak energy price periods and generates when the energy can be sold at peak period prices or when power system requirements make it advantageous for generation capacity to go on-line.

An important criterion in assessing a pumped storage site is its ratio of total length of water conduits leading to the pump-turbines to head available at the site. This is especially true if a surface type powerhouse is to be included in the design. A surface powerhouse with relatively long tunnels compared to its head would not be able to provide some of the dynamic benefits of pumped storage because its response time would be too slow. Recent economic and operational experience suggests that maximum acceptable length-to-head ratios range from 10 to 12 for high-head (1,200 to 1,500 feet) projects down to 4 or 5 for low-head (500 to 600 feet) sites.

Yokohl Valley Reservoir would not meet this criterion. Assuming a 1.5-mile-long tunnel and an average head of 500 feet, the length-to-head ratio is nearly 16. This compares with the required length-to-head ratio of not greater than 4 or 5. Thus, no further consideration has been given to pumped storage operation at the Yokohl Valley Reservoir. In addition, for conventional pumped storage operation at Yokohl Valley Reservoir, a much larger forebay (lower reservoir) would be required than in the case of a pump-back project. This would be located in the vicinity of the off-take from the Friant-Kern Canal. Also, the project, including the forebay, would have to be designed and operated so as to prevent interference with the hydraulic control of the Friant-Kern Canal.

Transmission

Two major power lines are near the site; one is located about 3 miles west of the potential pumping-generating station and the other is about 5 miles east of the station. It is anticipated that pumping power would be obtained from, and generation delivered to, one or both of these power lines. Therefore, one or more suitable interconnection points would need to be established and connecting lines constructed.

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; thus, costs may be roughly equivalent.

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 addition to power that could be generated at a powerhouse at 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. RM 315 Reservoir would not adversely affect existing hydropower facilities.

No previous studies have been done for this reservoir site; thus, its hydropower generation potential has not been previously quantified. A spreadsheet hydrologic analysis model that applies the same logic as CALSIM was used to establish preliminary numbers for new water supply from RM 315 Reservoir. The preliminary average annual new 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.

GRANITE PROJECT

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, Jackass Creek), 2 powerhouses, 18 miles of pipeline and tunnel, and a pumping plant. This project was originally studied as a hydroelectric project by 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.

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 applies the same logic as CALSIM was used to establish preliminary numbers for new water supply from the Granite Project. The preliminary average annual new 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 for 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.

JACKASS-CHIQUITO PROJECT

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.

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 applies the same logic as CALSIM was used to establish preliminary numbers for new water supply from the Jackass-Chiquito Project. The preliminary average annual new 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.

COMPARISON OF NET HYDROPOWER GENERATION

Table 3-9 summarizes results of the hydropower simulations described in this report and ranks the scenarios in order of net power generation. Storage sites proposed during scoping, all of which would have a net positive effect on power generation, are not included in the table. For all of the scenarios evaluated, energy generated from new powerhouses would be less than energy generation lost from existing powerhouses that would be affected, or pumping energy required, with the exception of a 25-foot raise of Friant Dam. Temperance Flat RM 279 Reservoir Replacement Power Option 2 with a storage size of 725 TAF could provide enough replacement power to almost break even with the losses of existing power facilities.

Fine Gold Reservoir Pump-Back has smaller net power requirements than most of the onstream measures, with the exception of the Friant Dam 25-foot raise and 725 TAF RM 279 measures previously mentioned. The measures with the greatest net power loss are Temperance Flat RM 286 Reservoir with a storage size of 1,350 TAF for all replacement power options, Temperance Flat RM 274 Reservoir with a storage size of 1,350 TAF, and Temperance Flat RM 286 Reservoir with a storage size of 725 TAF for Replacement Power Option 3.

NEXT STEPS

Power generation results from the spreadsheet simulations are considered preliminary and subject to change because of simplifying assumptions used and large timestep included in this appraisal-level of study. Future work will provide refined generation estimates as multipurpose operating scenarios are developed and evaluated. Analytical requirements for a higher level of resolution also will need to be addressed. The magnitude and direction of changes in net generation figures for each measure due to future refinements is difficult to quantify at this time.

Power generation results do not represent system operations to optimize power generation. The primary purpose of the Investigation is to develop water supply; power is being considered as an incidental benefit of increasing water supply. One issue that should be studied in the future to further optimize power benefits in the context of water supply operations is a more detailed evaluation of pumped storage opportunities for the surface water storage measures that have potential for this type of operation. This would include model refinements such as disaggregating monthly data to daily data and including peak and off-peak operations.

Refined hydropower analyses will identify how changes in generation affect system-wide operations for the Kerckhoff, Crane Valley, and Big Creek Projects, including ancillary benefits such as spinning reserve. Regional transmission issues also will need to be addressed in greater detail in the future. If any of the storage sites suggested during scoping are studied further, the effects of regulating additional water through existing projects would need to be evaluated.

Power valuation will have a major effect on the cost of the surface water storage measures, since results from this TA illustrate that a net loss of power may occur with many of the measures for increasing storage. This valuation changes significantly with time, so accurately predicting future values could be difficult. However, evaluation of future power value will be necessary to quantify the costs of purchasing power and the revenue from power sales. Finally, the value of new power versus existing impacted power also could be studied in the next phase of the Investigation.

**TABLE 3-9.
EVALUATED SURFACE WATER STORAGE MEASURES RANKED BY
NET POWER GENERATION**

Rank (based on net power)	Surface Water Storage Measure	New Power Generation (GWh/year)[1]	Lost Power Generation (GWh/year)[1]	Net Power Generation (GWh/year)
1	Raise Friant Dam: 25-foot Raise (+132 TAF)	32	-32	0
2	RM 279 Reservoir: 725 TAF, RPO 2	484	-507	-23
3	Fine Gold Reservoir: Pump-Back, 800 TAF	114	-154[2]	-40
4	Raise Friant Dam: 60-foot Raise (+340 TAF)	430	-473	-43
5	RM 279 Reservoir: 1,350 TAF, RPO 2	933	-981	-48
6	Yokohl Valley Reservoir: 800 TAF	73	-133 [2]	-60
7	Raise Friant Dam: 111-foot Raise (+700 TAF)	405	-507	-102
8	RM 279 Reservoir: 725 TAF, RPO 1	386	-507	-121
9	Raise Friant Dam: 140-foot Raise (+920 TAF)	386	-507	-121
10	RM 286 Reservoir: 725 TAF, RPO 2	859	-981	-122
11	RM 279 Reservoir: 1,350 TAF, RPO 1	840	-981	-141
12	RM 286 Reservoir: 725 TAF, RPO 3	834	-981	-147
13	RM 274 Reservoir: 725 TAF	332	-507	-175
14	RM 286 Reservoir: 1,350 TAF, RPO 2	794	-981	-187
15	RM 274 Reservoir: 1350 TAF	291	-507	-216
16	RM 286 Reservoir: 1,350 TAF, RPO 3	759	-981	-222
17	RM 286 Reservoir: 725 TAF, RPO 1	729	-981	-252
18	RM 286 Reservoir: 1,350 TAF, RPO 1	655	-981	-326

Key:
GWh/year – gigawatt-hour per year
RPO – replacement power option
TAF – thousand acre-feet

Notes:
[1] All reported values based on average of simulated single-purpose analysis results.
[2] Fine Gold and Yokohl Valley measures do not impact any existing hydropower facilities. Value shown for lost power represents pumping energy requirement.

THIS PAGE LEFT BLANK INTENTIONALLY

CHAPTER 4. LIST OF PREPARERS

NAME	ROLE
Reclamation	
Brian Zewe	Project Manager
MWH	
William Swanson	Project Manager
Foster Pelton	Hydropower Engineer
Ryan Murdock	Water Resources Engineer
Steve Irving	GIS Analyst
Emily McAlister	Technical Editor
Leonora Antonio	Document Coordinator

ACKNOWLEDGEMENTS

The study team acknowledges the valuable assistance provided by Southern California Edison Company and Pacific Gas and Electric Company in the coordination and preparation of this technical appendix.

THIS PAGE LEFT BLANK INTENTIONALLY

CHAPTER 5. REFERENCES

CALFED. 2000a. CALFED Bay-Delta Program Record of Decision. August.

CALFED. 2000b. CALFED Bay-Delta Program Final Programmatic Environmental Impact Statement/Environmental Impact Report. July.

Educators for the Environment. 2003. Energy for Keeps: Electricity from Renewable Energy. Tiburon, California.

Myers, William A. 1983. Iron Men and Copper Wires: A Centennial History of the Southern California Edison Company. Trans-Anglo Books, Glendale, California.

Newcom, S. Joshua. 2001. Western Water Magazine. Dealing with the Shock: Shedding Light on the Link Between Water and Power in California. Sept/Oct Issue.

Northwest Power and Conservation Council. 2004. Draft Fifth Power Plan. Portland, Oregon.

Pacific Gas and Electric (PG&E). 2002. Supplemental Environmental Assessment for Hydropower License, Crane Valley Project, FERC No. 1354-005, California. Filed with the Federal Energy Regulatory Commission. September.

PG&E. n.d. Kerckhoff Project, Exhibit W. Filed with the Federal Energy Regulatory Commission. San Francisco, California.

Redinger, David H. 1949. The Story of Big Creek. 1987 Edition. Trans-Anglo Books, Glendale, California.

Southern California Edison Company (SCE). 2003. Initial Information Package for the Big Creek Hydroelectric System.

United States Water Resources Council (WRC). 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. March 10.

Upper San Joaquin River Water and Power Authority. 1982a. Consultation Package: Granite Hydroelectric Project. Prepared by Tudor Engineering Company, San Francisco, California. March.

Upper San Joaquin River Water and Power Authority. 1982b. Definitive Report: Granite Hydroelectric Project – North Fork, California. Prepared by Tudor Engineering Company, San Francisco, California. February.

Upper San Joaquin River Water and Power Authority. 1984. Application for Preliminary Permit for Jackass Chiquito or Granite Creek Water Conservation and Hydroelectric Development. Filed with the Federal Energy Regulatory Commission. Terra Bella, California.

Westmann, Russell. PG&E in the Sierra. Central Sierra Historical Society Feature Article. http://www.sierrahistorical.org/feature/pgeinsierra.html.

THIS PAGE LEFT BLANK INTENTIONALLY