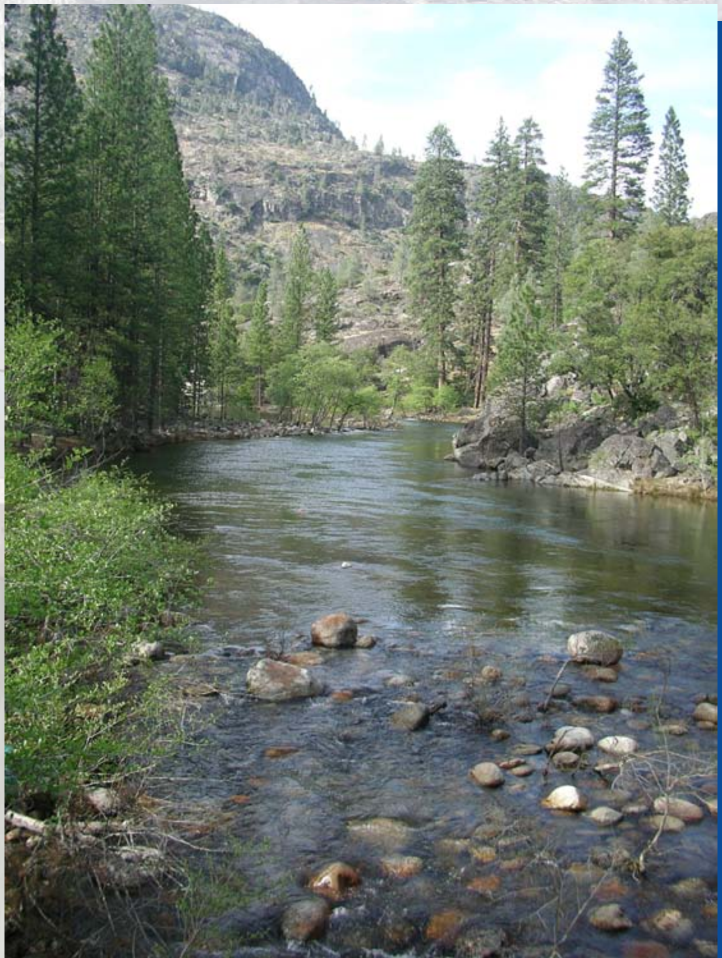
Upper Tuolumne River:
Available Data Sources, Field Work Plan, and Initial Hydrology Analysis



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RMC

Upper Tuolumne River:
Available Data Sources, Field Work Plan, and Initial Hydrology Analysis

Final Report

Prepared by:

RMC Water and Environment

and

McBain & Trush, Inc.

October 2006

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ab	above
CCblDHPH	Cherry Creek below Don Holm Powerhouse
CCblVD	Cherry Creek below Valley Dam
CCEI	Cherry Creek near Early Intake
CDFG	California Department of Fish and Game
CDT	Cherry Diversion Tunnel
CDWR	California Department of Water Resources
cfs	cubic feet per second
DA	drainage area
EC	Eleanor Creek near Hetch Hetchy
ECDT	Eleanor-Cherry Diversion Tunnel
FERC	Federal Energy Regulatory Commission
ft	feet
mi^2	square miles
MRPB	Merced River at Pohono Bridge near Yosemite
NPS	National Park Service
nr	near
Qe	estimated streamflow
Qg	gaged streamflow
RM	River Mile
S.J. River	San Joaquin River
S_d	reservoir storage
SFPUC	San Francisco Public Utilities Commission
TID	Turlock Irrigation District
TRblEI	Tuolumne River below Early Intake
TRBM	Tuolumne River near Buck Meadow
TRCC	Tuolumne River at Cherry Creek confluence
TRHH	Tuolumne River near Hetch Hetchy
TRPT	Tuolumne River Preservation Trust
USDI	U.S. Department of Interior
USFS	U.S. Forest Service
USFS	United States Forest Service

USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WY	water year

Section 1 Introduction

The San Francisco Public Utilities Commission (SFPUC) owns and operates the Hetch Hetchy Water and Power system. This system, located in the upper Tuolumne River watershed, includes dams and flow diversions on the Tuolumne River, Cherry Creek (a tributary to the Tuolumne River), and Eleanor Creek (a tributary to Cherry Creek). As part of establishing a common foundation of environmental information for the river and stream reaches affected by operation of the Hetch Hetchy system, the SFPUC Natural Resources and Hetch Hetchy Water and Power Divisions have embarked on an intensive one-year effort to describe current ecological and geomorphic conditions in the Tuolumne River from O'Shaughnessy Dam to New Don Pedro Reservoir, Cherry Creek downstream of Cherry Lake Dam, and Eleanor Creek downstream of Lake Eleanor Dam. Numerous agencies and other stakeholders are also contributing to this study, including the Yosemite National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), and the U.S. Forest Service (USFS). Study plans and reports will also be reviewed by the Tuolumne River Stakeholder Group, which includes representatives from federal, state, and local agencies; local water districts; environmental organizations; and the whitewater rafting community.

This first year effort to establish a common foundation from which future work will be developed includes four phases:

1. Identify and compile existing information, identify key information gaps, and develop a reconnaissance-level field plan to begin gathering additional information in 2006;
2. Implement the 2006 field plan;
3. Summarize and synthesize available information and information collected in 2006 in an initial report that describes current ecologic and geomorphic conditions in key reaches below the Hetch Hetchy project; and
4. Identify short- and long-term future monitoring activities necessary to build on this foundation.

This technical memorandum presents the results of the first phase described above.

The draft initial report is scheduled for completion in January 2007, and its purposes are to:

1. Inform existing Hetch Hetchy project operations to promote opportunities to protect ecologic and geomorphic values within the context of meeting current water supply, power generation, and water quality objectives, and minimum flow requirements;
2. Describe key flow-related river ecosystem processes and how these processes are affected by historic and current Hetch Hetchy project operations;
3. Guide future work to better understand the relationship between the Tuolumne River ecosystem and Hetch Hetchy project operations; and
4. Identify short- and long-term annual monitoring activities necessary to support this work.

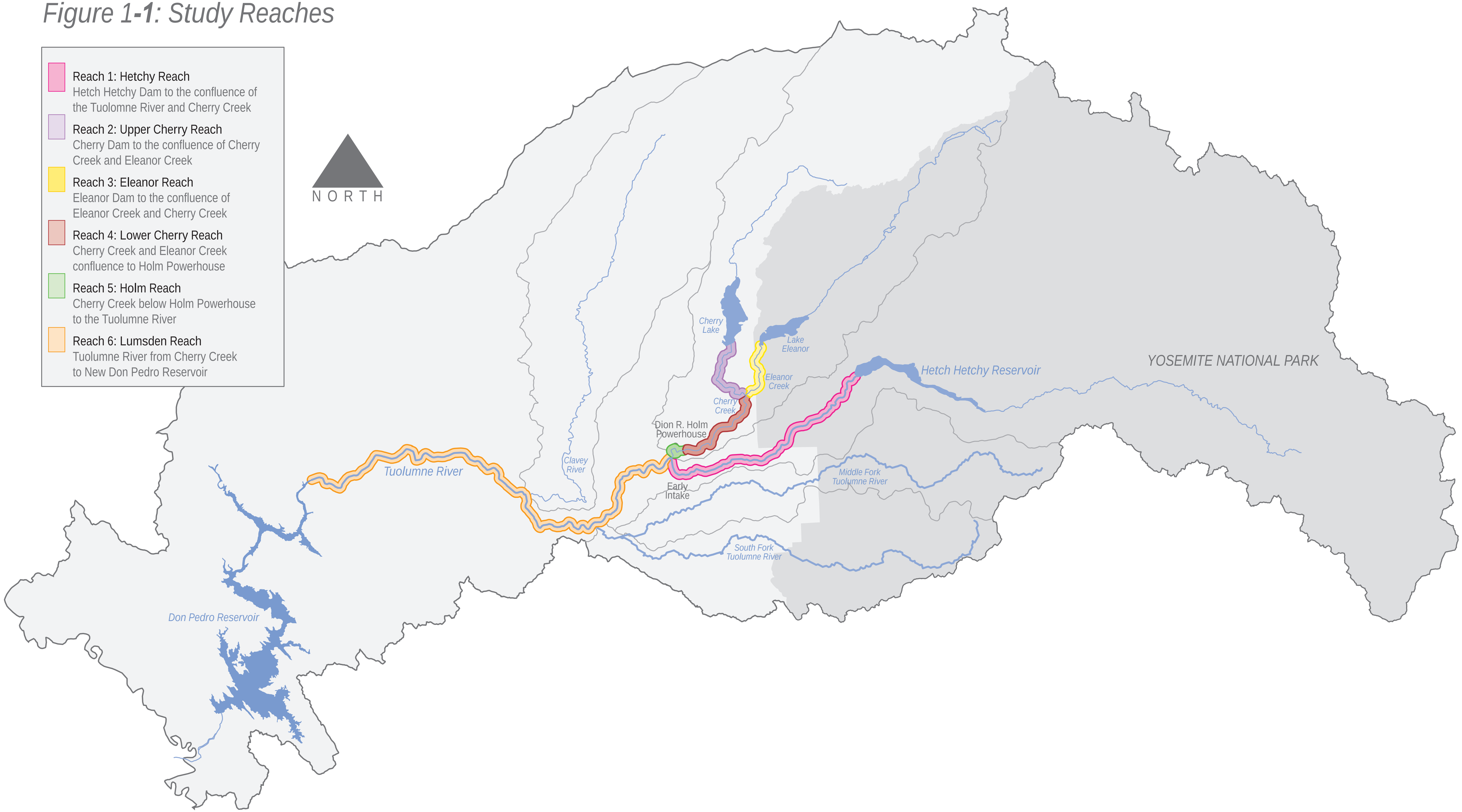
Supporting documents compiled or generated by this effort will be made available to the Tuolumne River Stakeholder Group and other interested parties.

Based on the effect of Hetch Hetchy project operations, the study area is broken down into six specific reaches (Figure 1-1):

- Hetchy Reach – O'Shaughnessy Dam (RM 117.5) to the Cherry Creek confluence (RM 103.8);
- Upper Cherry Reach – Cherry Valley Dam (RM 11.3) to the Eleanor Creek confluence (RM 7.0);
- Eleanor Reach – Eleanor Dam (RM 3.5) to the confluence with Cherry Creek (RM 0);
- Lower Cherry Reach –Eleanor Creek confluence (RM 7.0) to Holm Powerhouse (RM 0.8);

- Holm Reach –Holm Powerhouse (RM 0.8) to the confluence with the Tuolumne River (RM 0); and
- Lumsden Reach – Tuolumne River from Cherry Creek confluence (RM 103.8) to New Don Pedro Reservoir (RM 78.5).

Figure 1-1: Study Reaches



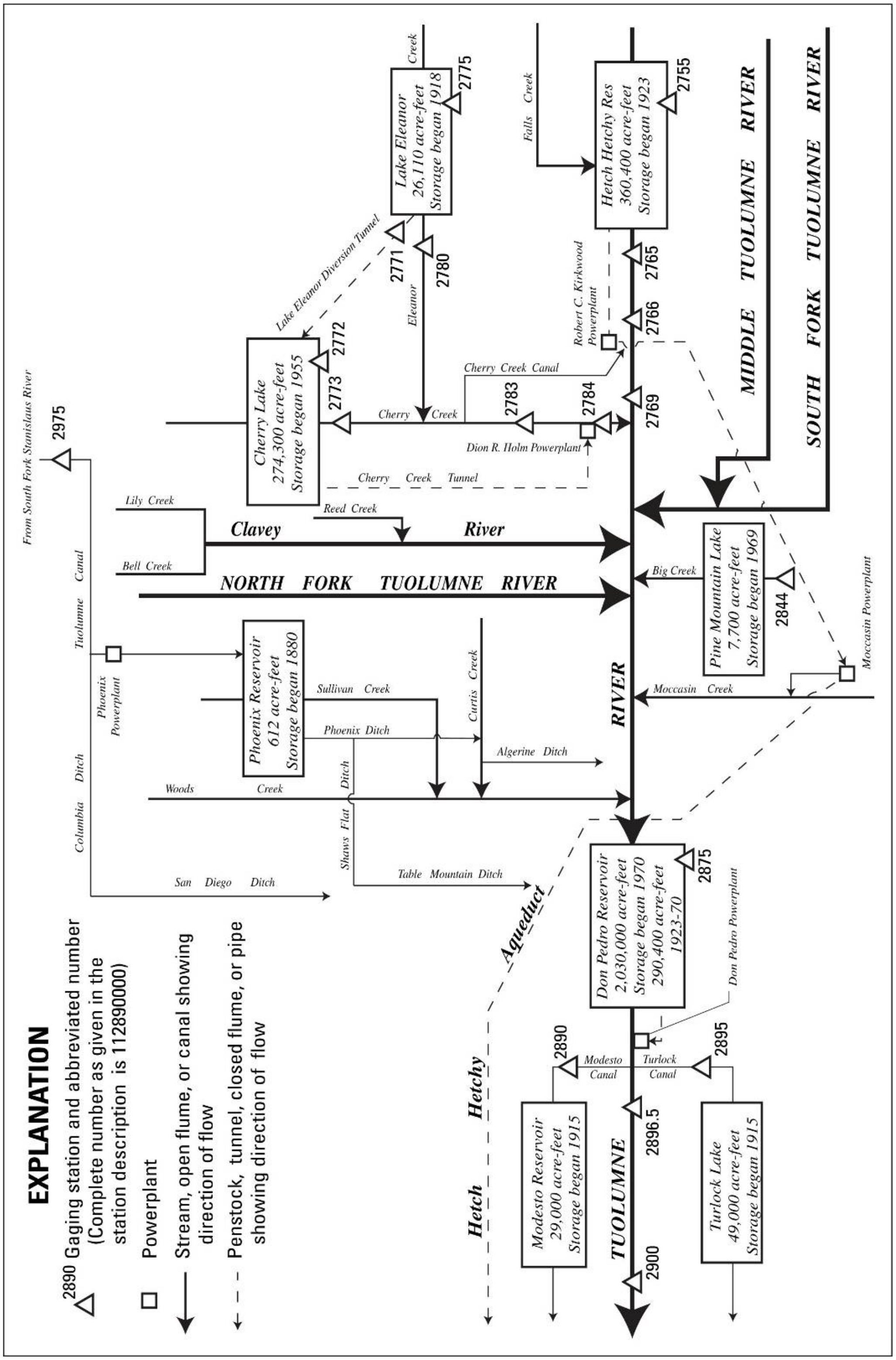
Section 2 Hetch Hetchy Facilities in the Study Area

The Tuolumne River is one of the largest rivers draining the western slope of the Sierra Nevada Range. Its watershed encompasses 1,960 mi^2 on the western slope of the Sierra Nevada Range and extends from the peaks of Mt. Lyell and Mt. Dana (peak elevations exceed 13,000 ft) in Yosemite National Park to the Central Valley's San Joaquin River (elevation 40 ft). Within the study area, most of the watershed is within Yosemite National Park and the Stanislaus National Forest. The upper 6.5 miles (47%) of the Hetchy Reach and the upper 2.8 miles (80%) of the Eleanor Reach are within Yosemite National Park. The remainder of Hetchy and Eleanor Reaches, as well as the Upper Cherry Reach, Lower Cherry Reach, Holm Reach, and the upper 22.2 miles (88%) of the Lumsden Reach are within the Stanislaus National Forest. The lower 3.1 miles of the Lumsden Reach are within lands managed by the Bureau of Land Management. At the downstream end of the study area, the river flows into New Don Pedro Reservoir. The entire mainstem river within the study area, except a short section at Early Intake, is federally-designated as a Wild and Scenic River.

In the Tuolumne River watershed, Hetch Hetchy Water and Power Project includes facilities on the Tuolumne River, Moccasin Creek (a tributary to the Tuolumne River), Cherry Creek (a tributary to the Tuolumne River), and Eleanor Creek (a tributary to Cherry Creek) (Figure 2-1). The project was constructed in phases beginning in 1917 and continues to evolve as facilities and operations are modified to meet current needs and objectives. Project facilities and key dates in project development relevant to its effects on flow are:

- 1918: Eleanor Dam and Early Intake Powerhouse begin storing and diverting runoff from the upper 78 mi^2 of the Eleanor Creek watershed to the Tuolumne River. Water is stored in Lake Eleanor (27,100 acre-feet). Water released from the reservoir flows through the Eleanor Reach and is diverted at the Lower Cherry Creek Aqueduct (160–200 cfs) to Early Intake Powerhouse on the Tuolumne River. Powerhouse outflow is released to the Tuolumne River.
- 1923: O'Shaughnessy Dam (Hetch Hetchy Reservoir [260,000 acre-feet]) begins storing runoff from the upper 457 mi^2 of the Tuolumne River watershed.
- 1925: Early Intake Diversion Dam and Mountain Tunnel begin diverting water from the Tuolumne River. Water released from Hetch Hetchy Reservoir and Early Intake Powerhouse (diverted from Cherry and Eleanor creeks) is diverted at Early Intake Diversion Dam to Mountain Tunnel, which conveys up to 670 cfs to Moccasin Powerhouse.
- 1938: O'Shaughnessy Dam crest raised 85.5 feet, increasing Hetch Hetchy Reservoir capacity to 360,360 acre-feet. Increased storage allows an increase in the annual volume of water that is diverted at Early Intake to Moccasin Powerhouse and then to the Bay Area. (Aqueduct connection to the Bay Area was completed in 1934.)
- 1950: Department of the Interior and SFPUC agree to minimum flow schedule for Cherry Creek downstream of Cherry Valley Dam.
- 1956: Department of the Interior and SFPUC agree to minimum flow schedule for Eleanor Creek downstream of Eleanor Dam.
- 1955: Cherry Valley Dam begins storing runoff from the upper 117 mi2 of the Cherry Creek watershed. Until the Holm Powerhouse is completed in 1960, water stored in Cherry Lake (274,300 acre-feet) is released downstream to the Upper Cherry and Lower Cherry reaches. The Lower Cherry Creek Aqueduct continues to divert 160–200 cfs to Early Intake Powerhouse on the Tuolumne River. Cherry Valley Dam is operated for hydropower generation and providing water to be stored at Don Pedro Reservoir. Until the New Don Pedro Project is completed in 1971, Cherry Valley Dam is also operated to reduce flood inflow to Don Pedro Reservoir.

Figure 2-1. Schematic Diagram Showing Reservoirs and Flow Diversions in the Tuolumne River Watershed (source: USGS 2004)



- 1960: Diversions from Lake Eleanor to Cherry Lake and from Cherry Lake to Holm Powerhouse begin. Water from Lake Eleanor is diverted to Cherry Lake via the Eleanor-Cherry Diversion Tunnel and Pump Station. Cherry Creek flows and inflow from Lake Eleanor are diverted from Cherry Lake to Holm Powerhouse via Cherry Power Tunnel. The tunnel, which can divert 810 cfs (with Cherry Lake empty) to 990 cfs (with Cherry Lake full), bypasses flows around the Upper Cherry, Eleanor, and Lower Cherry reaches. Outflow from Holm Powerhouse discharges to the Tuolumne River at the upstream end of the Holm Reach. With the completion of Holm Powerhouse, the Lower Cherry Aqueduct is no longer required for power generation, and the Early Intake Powerhouse is dismantled. The Lower Cherry Aqueduct is retained and used to divert water from Cherry Creek to the Hetch Hetchy Aqueduct during critical drought years.
- 1961: Department of the Interior and SFPUC agree to interim minimum flow schedule for the Tuolumne River downstream of O'Shaughnessy Dam.
- 1967: Canyon Power Tunnel begins operating. Canyon Tunnel diverts water from Hetch Hetchy Reservoir to Kirkwood Powerhouse. The project shifts the SFPUC point of diversion from Early Intake to O'Shaughnessy Dam (bypassing flow around the Hetchy Reach). Water stored in Hetch Hetchy Reservoir is either diverted to Kirkwood and then Moccasin powerhouses and into the SFPUC watery delivery system, or released downstream to Lake New Don Pedro from Kirkwood or Moccasin. Water from Hetch Hetchy Reservoir can be released through 14 outlet conduits, three of which connect to the Canyon Tunnel and 11 of which release water downstream. The downstream outlets have a maximum capacity of approximately 10,000 cfs.

  After passing through the powerhouse, up to 670 cfs of the flow diverted from Hetch Hetchy can be routed directly to Mountain Tunnel and Moccasin Powerhouse without returning to the Tuolumne River. Powerhouse outflows exceeding 670 cfs are discharged to the Tuolumne River at Early Intake Reservoir. Moccasin Powerhouse flows in excess of SFPUC water delivery are discharged to Don Pedro Reservoir for 5-6 months per year. While the Canyon Tunnel diversion capacity is 1,400 cfs, the generation capacity limit at Kirkwood Powerhouse is 920 cfs. Until the additional generator is added at Kirkwood Powerhouse in 1988, Canyon Tunnel diversion is operated at or below 920 cfs.
- 1982: Department of the Interior and SFPUC agree to amend minimum flow schedule below Eleanor Dam.
- 1984: Department of the Interior and SFPUC agree to revised minimum flow schedule below O'Shaughnessy Dam.
- 1986: Cherry Lake operations revised to increase carry-over storage. Before 1986, operations typically drafted Cherry Lake to between 50,000 and 100,000 acre-feet each year. Revised operations increase minimum storage at Cherry Lake to between 150,000 and 200,000 acre-feet, increasing spill frequency and volume to the Upper Cherry and Lower Cherry reaches and reducing summer outflow from Holm Powerhouse.
- 1987: Department of the Interior and SFPUC agree to further revise minimum flow schedule below O'Shaughnessy Dam.
- 1988: Third generator added at Kirkwood Powerhouse increases powerhouse capacity to 1,400 cfs, allowing the Canyon Tunnel to operate at its diversion capacity.
- 1993: After facing water supply shortages during the six-year 1987–1993 drought, a major change is instituted to increase the firm yield of the SFPUC water system. Reservoir operations are modified significantly to increase water supply reliability. Increased carry-over storage at the three project reservoirs increases frequency and magnitude or duration of spills to all reaches in the study area.

Section 3 Preliminary Analysis of the Effects of Hetch Hetchy Project Facilities and Operations on Flow in Study Reaches

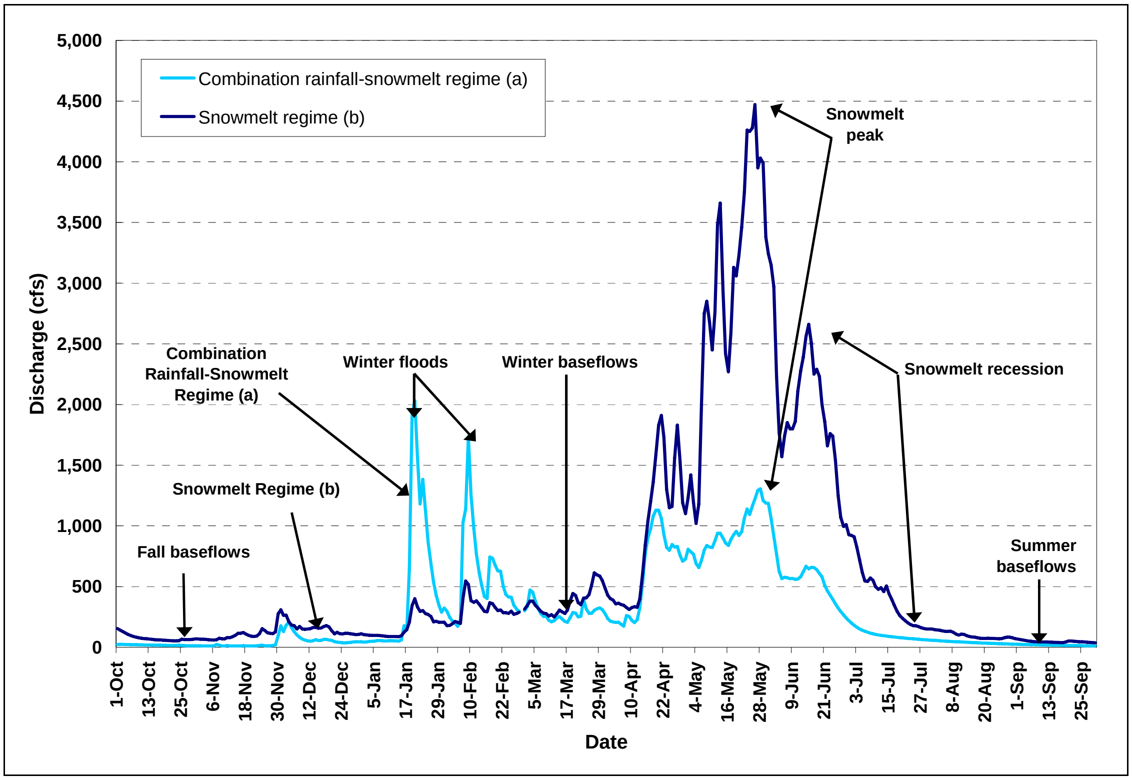
McBain & Trush, Inc. has completed preliminary analysis of the hydrologic effects of Hetch Hetchy facilities and operations in the six study reaches. The objectives of this preliminary analysis were to: (1) describe pre-dam (unregulated) flow conditions, (2) illustrate the general effects of current project operations by quantifying changes in the daily average flow for a representative (median) water year and comparing flood magnitude and frequency for the available period of record, and (3) develop initial hypotheses of potential effects of flow regulation and diversion on geomorphic processes and ecological conditions in each study reach. These preliminary results and hypotheses, which are neither conclusive nor comprehensive, are presented to help frame and prioritize questions or hypotheses to be investigated during the 2006 field season. Additional analysis and synthesis of available data and reports (see Section 4) and results from the 2006 field surveys will be completed over the next several months to develop a more comprehensive and detailed assessment of current ecologic and geomorphic conditions in the study reaches and short- and long-term future monitoring needed to address data gaps and uncertainties that affect resource management decisions.

3.1 Analysis Approach

Unregulated rivers exhibit "natural flow regimes" that are controlled by climate, watershed topography, watershed geology, and other regional factors. For each flow regime, seasonal (intra-annual) flow patterns and the intra- and inter-annual variation in flow magnitude are fairly predictable over a range of water year types (i.e., from dry years to wet years). These predictable annual flow patterns can be broken down into seasonal "hydrograph components," each of which has important geomorphic and biological functions (Trush et al. 2000, McBain and Trush 2004). For example, floods transport sediment, erode channel banks, recruit large wood to the channel and perform other geomorphic functions that affect channel morphology and habitat structure. Also, native plant and animal species are often adapted to the "natural flow regime" for their specific river or region (e.g., Nilsson and Svedmark 2002, Naiman et al. 2002, Lytle and Poff 2004). In the Sierra Nevada, life history timing for many fish, amphibian, and riparian plant species is tied to the hydrograph components. Generalized hydrograph components for unregulated snowmelt and rainfall-and-snowmelt flow regimes in the project area are shown in Figure 3-1. Analyses to be completed during this study (and presented in the final report) will, to the extent feasible, identify and quantify linkages between each hydrograph component (timing, duration, and magnitude), geomorphic processes that maintain channel morphology, riparian vegetation recruitment and establishment, and habitat availability for selected analysis species (analysis species will be selected in the next phase of this study). These linkages enable hypotheses between project operations and ecosystem changes to be developed, and also provides information needed to evaluate trade-offs between potential flow management adjustments and ecosystem outcomes.

The preliminary analysis focuses on hydrograph shape and flow magnitude for a representative pre- and post-project median water years. Representative years were selected based on unimpaired runoff computed for the San Joaquin River Index (http://cdec.water.ca.gov/cgi-progs/iodir/wsihist). This index, which was specified in the 1995 State Water Resources Control Board Bay-Delta Water Quality Control Plan, is used for water management across the San Joaquin Basin. Unimpaired runoff is computed as the sum of Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake.

Figure 3-1. Hydrograph Components for a Snowmelt-dominated and Combination Rainfall-snowmelt Flow Regimes similar to the Tuolumne River, Cherry Creek, and Eleanor Creek



Footnotes:

(a) WY1999 Estimated flow at USGS gage Clavey River nr Buck Meadows, CA (11283500): drainage area = 144 sq. mi., elev. = 2,374 ft NGVD (TID, unpublished data).

(b) WY1999 USGS gage Merced R at Pohono Bridge nr Yosemite CA (11266500): drainage area = 321 sq. mi., elev. = 3,862 ft NGVD.

For San Joaquin River Index period of record (1901–2005), unimpaired runoff was 5.61 million acre-feet. WY1917 was selected to represent median years for pre-project (pre-1918), and WY 1999 was selected to represent median years for current operations (1993–2005). San Joaquin River Index runoff for WY1917 was 6.66 million acre-feet, 19% above the 1901–2005 median (Table 3-1). Although WY1917 was wetter than the 1901–2005 median, it was the closest year for which complete flow data were available for the study reaches complete pre-project data were available for the Lumsden Reach for WY1913, WY1914, and WY1917. The San Joaquin River Index runoff for WY1999 runoff was 5.91 million acre-feet, 300,000 acre-feet (5%) more than the median unimpaired runoff (Table 3-1).

Table 3-1: Unimpaired Annual Runoff for the Period of Record and Representative Water Years

Period		Median Runoff[a] (10^6 acre-feet)	Representative Year		
			Water Year	Runoff[a]	Water Year Type
S.J. River Index	1901-2005	5.61	N/A	N/A	N/A
Pre-Eleanor	1911-1917	6.66	1917	6.66	wet
Post-Eleanor/Pre-Hetchy	1911-1922	6.15	1921	5.90	above normal
Current Infrastructure and Operations	1993-2005	5.91	1999	5.91	above normal

Footnote:

a. Computed San Joaquin River unimpaired runoff (Source: http://cdec.water.ca.gov/cgi-progs/iodir/wsihist).

For each representative median water year, annual hydrographs were developed for each study reach using a combination of streamflow gage data (WY1917 and WY1999) and estimated unimpaired flow (WY1999). At certain locations where streamflow gages were not available, flow was estimated by summing flow from upstream gages. Also, where published unimpaired flow estimates were not available for WY1999, unimpaired streamflow was estimated by: (1) scaling data from a nearby unregulated river, or (2) computing unimpaired flow as a function of change in reservoir storage, diversion rate, and downstream flow releases. Regulated and unimpaired flows were computed as follows:

(Eq. 1) $Qe_{TRCC\ regulated} = Qg_{TRblEI} + Qg_{CCblDHPH}$

(Eq. 2) $Qe_{TRBM\ regulated} = (Qg_{TRblEI} + Qg_{CCblDHPH} + Qg_{SFTR} + Qg_{MTR}) * (DA_{TRBM}/(DA_{TRblEI} + DA_{CCblDHPH} + DA_{SFTR} + DA_{MTR})$

(Eq. 3) $Qe_{TRHH\ unimpaired} = Qg_{MRPB} * (DA_{TRHH/}\ DA_{MRPB})$

(Eq. 4) $Qe_{EC\ unimpaired} = (S_d - S_{d-1}) + Qg_{ECDT} + Qg_{EC}$

(Eq. 5) $Qe_{CCblVD\ unimpaired} = (S_d - S_{d-1}) - Qg_{ECDT} + Qg_{CCblVD\ regulated} + Qg_{CDT}$

(Eq. 6) $Qe_{CCEI\ unimpaired} = Qe_{CCblVD\ unimpaired} + Qe_{EC\ unimpaired}$

(Eq. 7) $Qe_{TRCC\ unimpaired} = Qe_{CCEI\ unimpaired} + Qe_{TRHH\ unimpaired}$

(Eq. 8) $Qe_{TRBM\ unimpaired} = Qe_{TRCC\ unimpaired} + Qg_{SFTR} + Qg_{MTR}$

Where: Qe is estimated streamflow; Qg is gaged streamflow; DA is drainage area; and S_d is reservoir storage on date (d) from USGS reservoir gages. Subscripts denote location as follows: Tuolumne River at Cherry Creek confluence (TRCC), Tuolumne River below Early Intake (TRblEI), Cherry Creek below Don Holm Powerhouse (CCblDHPH), Tuolumne River near Buck Meadow (TRBM), South Fork Tuolumne River (SFTR), and Middle Tuolumne River (MTR), Tuolumne River near Hetch Hetchy (TRHH), Merced River at Pohono Bridge near Yosemite (MRPB), Eleanor Creek nr Hetch Hetchy (EC), Eleanor-Cherry Diversion Tunnel (ECDT), Cherry Creek below Valley Dam (CCblVD), Cherry Diversion Tunnel (CDT), Cherry Creek near Early Intake (CCEI).

These flow estimates make several simplifications that limit their accuracy, including:

- Unimpaired flow estimates below Cherry Creek Valley Dam and Eleanor Dam do not include evaporation from the reservoirs. Also, the quality of reservoir data and diversion gaging data reported by the USGS is rated fair.
- Summing flows from upstream gages does not account for time required for flow to route from one gage to the next, and does not adjust for inflow downstream of each gage (except for equations 2 and 3 adjust estimated flow by drainage area).
- Flow estimates that sum multiple unimpaired or regulated estimates (equations 6, 7, and 8) can compound error from each individual estimate.

Because the effects of project operation on flow magnitude and timing typically exceed the error in the estimated flows, these flow estimates are useful for illustrating (though not necessarily quantifying) effects on most hydrograph components despite their simplifications. During low-flow periods, however, (such as summer baseflows), prediction error could exceed project effects. This is particularly true for unimpaired estimates downstream of Cherry Valley and Eleanor Dams and inflow to New Don Pedro Reservoir. At these locations, estimated unimpaired flow computed from equations 4 and 5 and reported by CDWR (For New Don Pedro Reservoir) is often negative during summer and fall baseflows.

3.2 The Natural Hydrograph

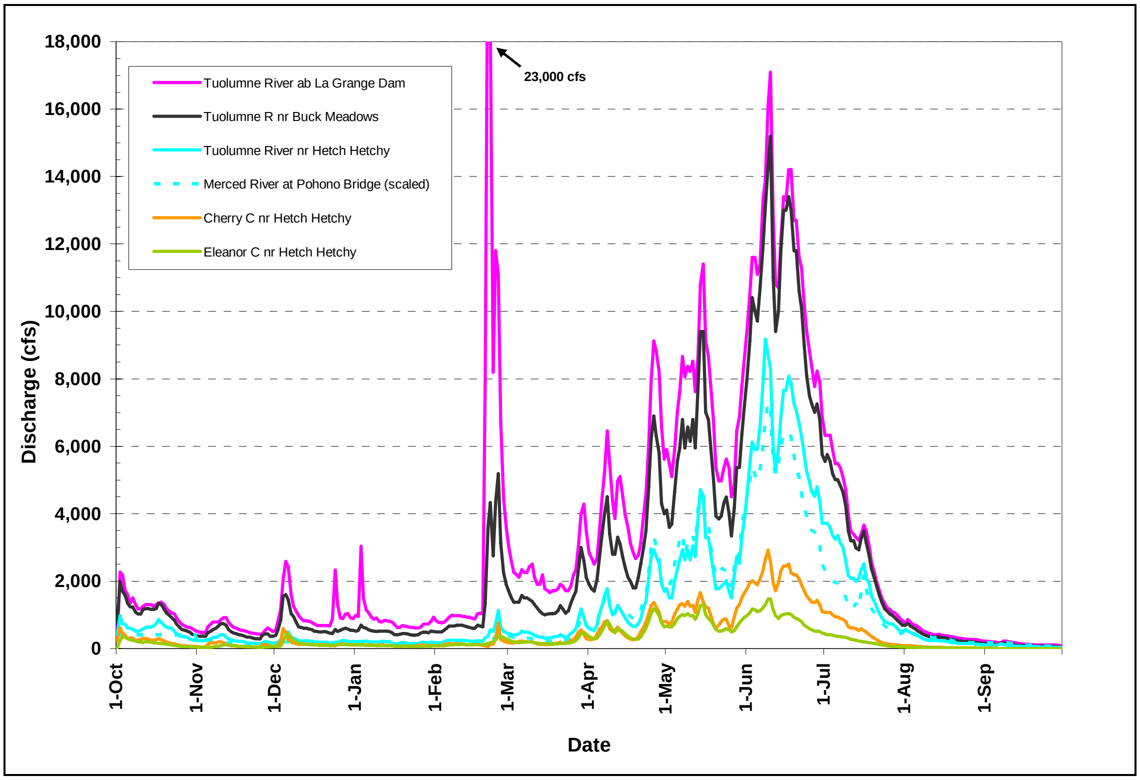
The Tuolumne River's unregulated flow regime is snowmelt in the upper watershed and combination rainfall-snowmelt at lower elevations (Figure 3-2, Table 3-2). In the Hetchy Reach (Tuolumne River), Eleanor Reach, and all Cherry Creek reaches, watershed elevations range from 2,100 ft to more than 13,000 ft, and flow regime is snowmelt-dominated. For WY1917:

- winter baseflow was 80 cfs in Eleanor Creek to 200 cfs in the Hetchy Reach;
- winter rainfall generated small peaks in daily average flow, but winter peak flow magnitude was insignificant relative to spring peak flow;
- snowmelt flow extended from late March through late August; and
- peak snowmelt flow was in late spring (June 9–10) and ranged 1,580 cfs in Eleanor Creek to 10,000 cfs in the Hetchy Reach;
- summer baseflow was 2–4 cfs in Eleanor and Cherry creeks and 72 cfs in the Hetchy Reach.

Flow regime transitions from snowmelt-dominated to combination rainfall-and-snowmelt-dominated in the Lumsden Reach, where river elevation ranges from 2,100 ft (at the Cherry Creek confluence) to 830 ft (at Lake New Don Pedro). Pre-project flows in this reach are represented by data from the Tuolumne River at Buck Meadows (elevation 1,420 ft) and Tuolumne River at La Grange Dam gages (elevation 330 ft). For WY1917:

- Winter baseflow was 500 cfs at Buck Meadows and 700 cfs at La Grange.
- Snowmelt flow extended from late March through late August;
- Peak daily average snowmelt flow was in late spring (June 9) and was 15,200 cfs at Buck Meadows and 17,100 cfs at La Grange;
- The annual flood at Buck Meadows was in spring (17,700 cfs [instantaneous peak]). Late February rain-on-snow generated a moderate peak (5,190 cfs), but this peak was only 1/3 the spring peak magnitude (15,200 cfs [daily average peak]).
- At La Grange, the February rain-on-snow peak was the annual flood. Flow peaked at 36,500 cfs, a 10-year flood.

Figure 3-2. Tuolumne River Natural Hydrograph (WY1917)



Footnotes:

a. USGS gage Tuolumne R ab La Grange Dam nr La Grange CA (11288000)
b. USGS gage Tuolumne R nr Buck Meadows CA (11283000)
c. USGS gage Tuolumne River nr Hetch Hetchy, CA (11276500)
d. USGS gage Merced R at Pohono Bridge nr Yosemite CA (11266500) scaled by drainage area to Tuolumne River nr Hetch Hetchy
e. USGS gage Cherry Creek near Hetch Hetchy, CA (11277000)
f. USGS gage Eleanor C nr Hetch Hetchy CA (11278000)

Table 3-2: Pre-project Streamflow Gages, Elevation, and Hydrograph Components

Streamflow Gage	Elevation (ft NGVD)	Drainage Area (mi^2)	Winter Baseflow (cfs)	Winter Peak[a] (cfs)	Spring Peak[a] (cfs)	Summer Baseflow (cfs)
Eleanor C nr Hetch Hetchy CA (11278000)	4,500	78	80	430	1,470 (1,580)	2
Cherry C nr Hetch Hetchy CA (11277000)	4,500	111	90	755	2,920 (3,800)	4
Tuolumne R nr Hetch Hetchy CA (11276500)	3,480	457	200	1,130	9,170 (10,000)	72

Streamflow Gage	Elevation (ft NGVD)	Drainage Area (mi^2)	Winter Baseflow (cfs)	Winter Peak[a] (cfs)	Spring Peak[a] (cfs)	Summer Baseflow (cfs)
Tuolumne R nr Buck Meadows CA (11283000)	1,420	924	500	5,190	15,200 (17,700)	98
Tuolumne R ab La Grange Dam nr La Grange CA (11288000)	330	1,532	700	23,000 (36,500)	17,100	150

Footnote:

a. Daily average flow. Instantaneous peak shown in parentheses ().

3.3 Effects of Flow Regulation on Annual Hydrograph Components

The effects of dams and flow diversion on downstream flow regime (and thus on channel morphology and aquatic and riparian habitat) are functions of facility size, facility location in the watershed, and the manner in which the project is operated. Large dams typically have greater capacity to alter flow regimes (including reducing flood flows, altering seasonal flow patterns, and shifting water yield between years), trap bedload and suspended sediment load, capture large wood, and reduce wood recruitment downstream. Smaller diversion dams have less of an effect on downstream flows, sediment supply, and large wood. The Hetch Hetchy Project dams vary in size relative to their watersheds and thus the magnitude of their impacts on downstream flows varies (Table 3-3). Eleanor Dam is the smallest dam in the system and has capacity to store only 14% of its watershed's unimpaired runoff. Hetch Hetchy Dam can store 46% of its watershed's unimpaired runoff. Cherry Valley Dam can store 103% of the watershed's unimpaired runoff.

Table 3-3: Tuolumne River Dams, Drainage Areas, and Reservoir Capacities

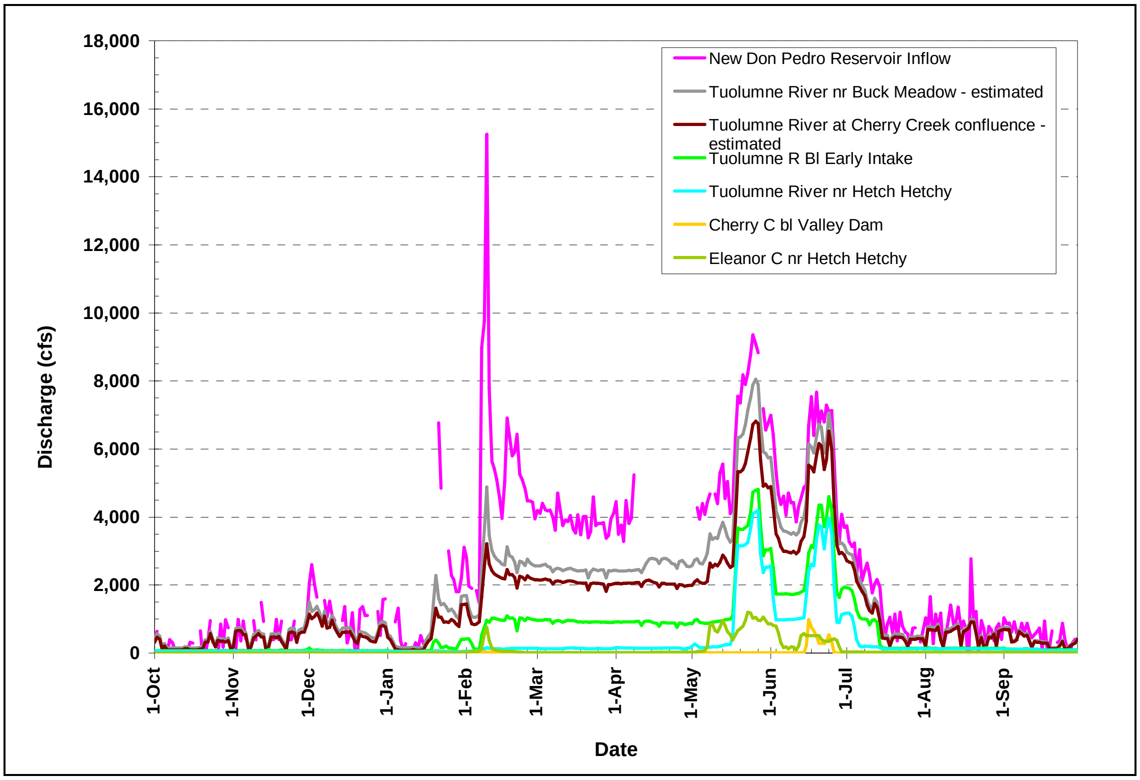
Dam	Year Completed	Drainage Area (mi^2)	Reservoir Capacity (acre-feet)	Unimpaired Annual Runoff (acre-feet)	Reservoir Capacity: Unimpaired Runoff
Eleanor	1918	78	27,100	187,300 (1910–1917)	14%
Cherry Valley	1956	117	274,300	267,003 (1911–1955)	103%
Hetch Hetchy	1923, enlarged 1938	459	360,360	780,230 (1911–1922)	46%
Don Pedro	1923, enlarged 1971	1,532	2,030,000	1,870,859 (1918–2005)	109%

Regulated hydrographs for WY1999 for all study reaches are shown in Figure 3-3. Relative to the wetter-than-median year pre-project hydrograph (WY1917) (see Figure 3-2), project effects on hydrograph shape and magnitude include:

- Reduced winter and spring flow in the downstream of project dams (Hetchy, Upper Cherry, Lower Cherry, and Eleanor reaches);

- Increased late-winter baseflow downstream of Early Intake and Holm Powerhouse (Lumsden Reach and downstream end of Hetchy Reach);
- Later onset of the snowmelt hydrograph and reduced snowmelt peak in all reaches;
- Shorter snowmelt recession in the channel below project dams (Hetchy, Upper Cherry, Lower Cherry, and Eleanor reaches);
- Large flow fluctuations throughout summer and fall downstream of Holm Powerhouse (Lumsden Reach); and
- Increased summer baseflow in the Hetchy and Lumsden reaches.

Figure 3-3. Regulated Tuolumne River Hydrograph WY1999



Footnotes:

a. Computed estimate (source: http://cdec.water.ca.gov/cgi-progs/)
b. See equation 2
c. See equation 1
d. USGS gage Tuolumne River nr Hetch Hetchy, CA (11276500)
e. USGS gage Cherry Creek below Valley Dam, CA (11277300)
f. USGS gage Eleanor C nr Hetch Hetchy CA (11278000)

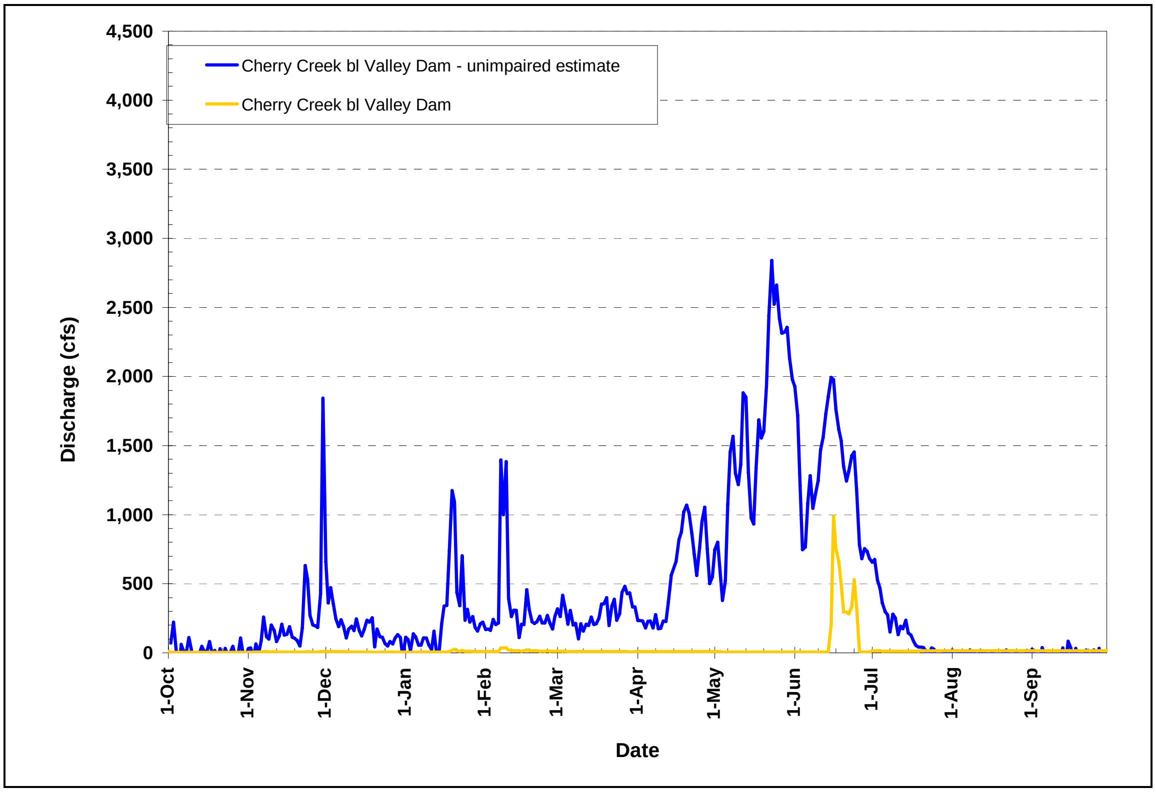
The effects of project operation in each reach, relative to estimated unimpaired flow for WY1999, are discussed below.

3.3.1 Cherry and Eleanor Creeks

Upper Cherry Reach

Required minimum flow releases from Cherry Valley Dam are 5 cfs from October through June and 15.5 cfs from July through September. In most years, flow in the Upper Cherry Reach is maintained at or near minimum flows year-round. WY1999 is shown in Figure 3-4. As shown, Cherry Valley Dam eliminates virtually all components of the natural hydrograph, except during a brief spring spill. Significant spring spills (May through July) occurred in 7 of 13 years since current operations were instituted in 1993. The only winter spill was in WY1997.

Figure 3-4. Unimpaired and Regulated Upper Cherry Reach Hydrograph WY1999



Footnotes:

a. See equation 5

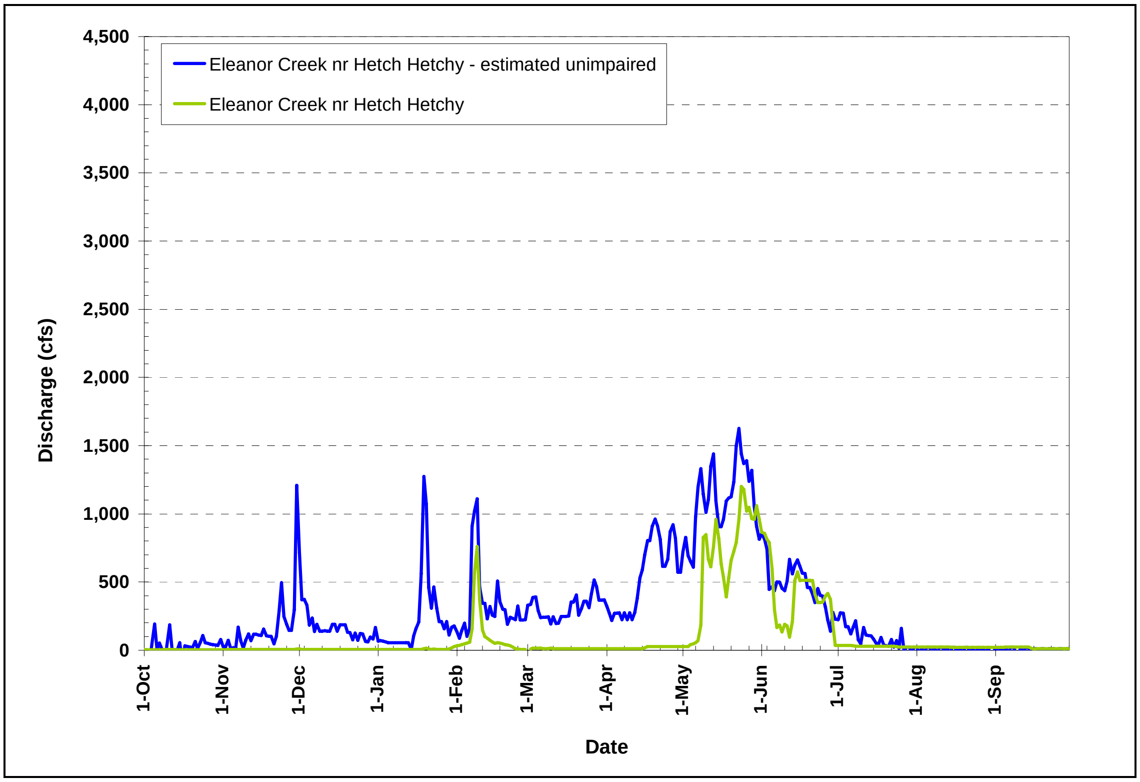
b. USGS gage Cherry Creek below Valley Dam, CA (11277300)

Eleanor Reach

In Eleanor Reach, required minimum flows range from 5 cfs to 20 cfs depending on month and whether the pumping station for the diversion to Cherry Lake is operating. Because the reservoir capacity is small relative to annual runoff from the watershed, spills are frequent. Since 1993, winter spills occurred in 6 of 13 years and spring spills occurred in 11 of 13 years.

For WY1999, project operation (1) reduced winter baseflows; (2) eliminated two winter peaks and reduced a third peak, (3) delayed the onset of spring snowmelt by several weeks to early May, (4) truncated the snowmelt hydrograph by 2 weeks,, (5) reduced snowmelt peak by about 30%, and (6) increased summer baseflows (Figure 3-5).

Figure 3-5. Unimpaired and Regulated Eleanor Reach Hydrograph WY1999



Footnotes:

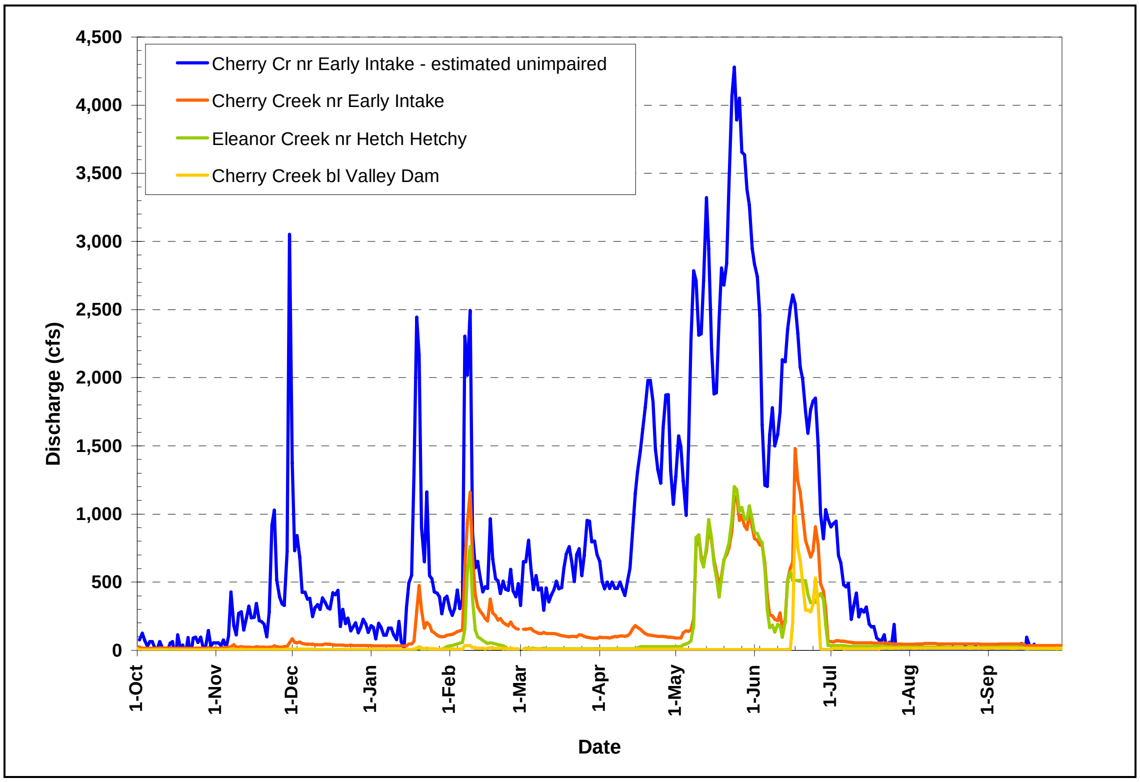
c. See equation 4

d. USGS gage Eleanor C nr Hetch Hetchy CA (11278000)

Lower Cherry Reach

In the Lower Cherry Reach, inflow from Eleanor Creek reduces the effect of Cherry Valley Dam. Because most inflow to this reach is from Eleanor Creek (except during infrequent releases from Cherry Valley Dam), flow conditions in this reach are similar to those described for Eleanor Creek above. Compared to unimpaired conditions, all hydrograph components remain substantially reduced. The combined effects of Cherry Valley Dam and Eleanor Dam for this example water year include: (1) reduced winter baseflow, (2) elimination or reduction of winter storm peaks, (3) delayed onset and reduced duration of spring snowmelt hydrograph component, (4) reduced spring snowmelt flow magnitude, and (5) increased spring snowmelt recession rate (Figure 3-6). Net effects on summer baseflows appear to be minor in most years, and in some years, project operations may increase summer baseflow above unimpaired conditions.

Figure 3-6. Unimpaired and Regulated Lower Cherry Reach Hydrograph WY1999



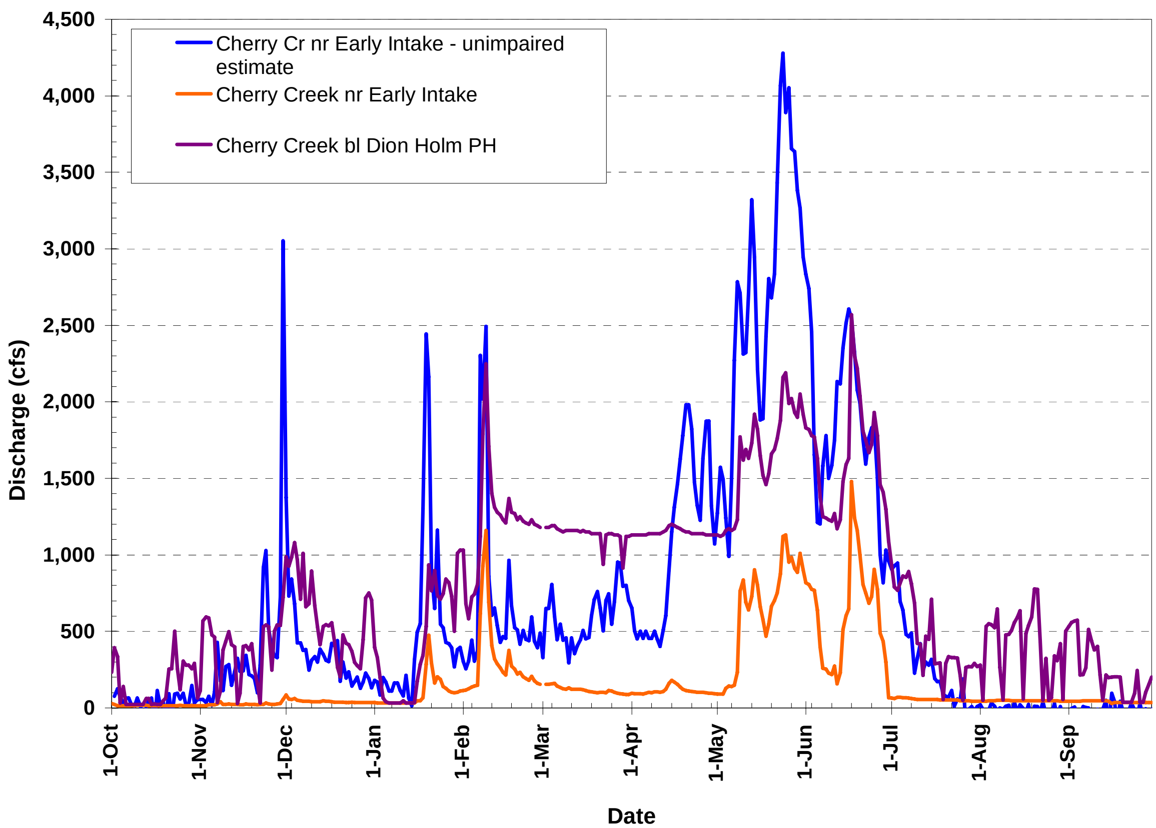
Footnotes:

a. See equation 6
b. USGS gage Cherry C nr Early Intake CA (11278300)
c. USGS gage Eleanor C nr Hetch Hetchy CA (11278000)
d. USGS gage Cherry Creek below Valley Dam, CA (11277300)

Holm Reach

In the Holm Reach, return flow from the Holm Powerhouse increases flow magnitude. For WY1999, project operation: (1) increased winter and summer baseflow by at least an order of magnitude, (2) increased early spring snowmelt flow, (3) slight delay of snowmelt peak, (4) reduced snowmelt peak magnitude, and (5) daily or weekly power production fluctuations (Figure 3-7). Daily fluctuations support recreational needs during summer between Memorial Day and Labor Day (Pers. Communication, B. McGurk).

Figure 3-7. Unimpaired and Regulated Holm Reach Hydrograph WY1999



Footnotes:

a. See equation 6

b. USGS gage Cherry C nr Early Intake CA (11278300)

c. USGS gage Cherry C bl Dion R Holm PH, nr Mather CA (11278400)

3.3.2 Tuolumne River

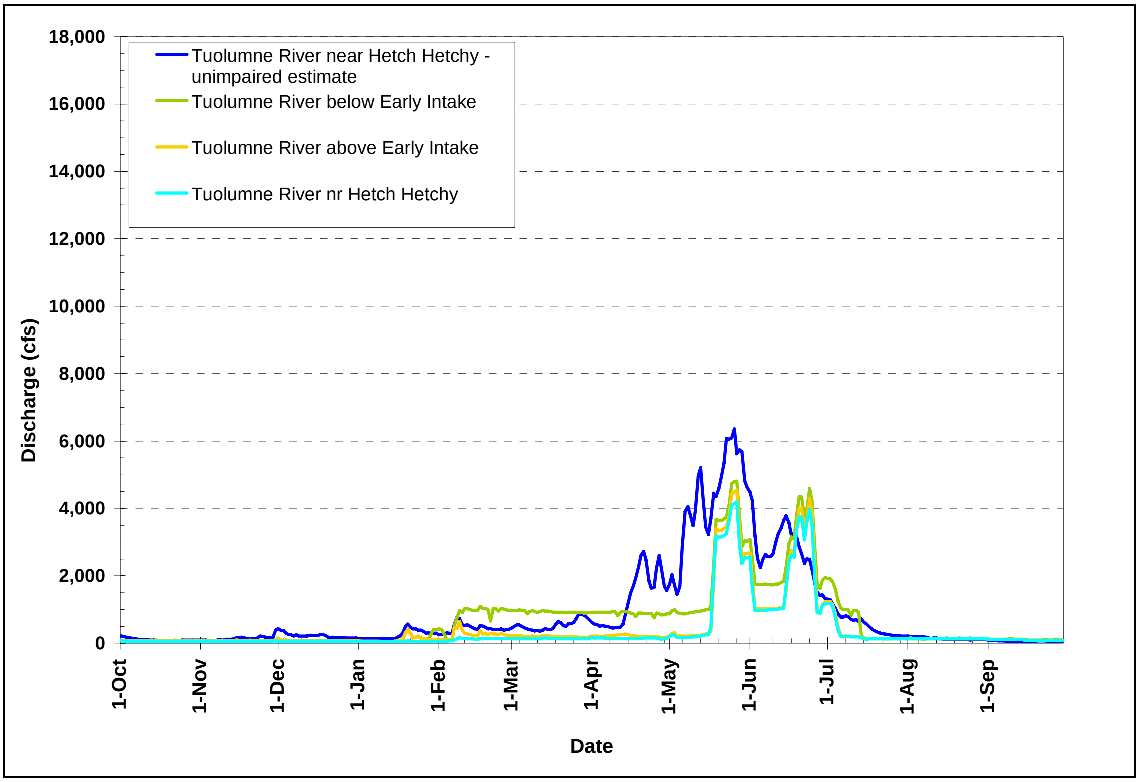
Hetchy Reach

Required minimum flows range from 35 cfs to 125 cfs depending on time of year and water year type. Flow in this reach is typically maintained at or near stipulated minimum flows, except during spring and summer spills (Figure 3-8). Spill releases increase flows well above the minimum flow stipulation. Since current operations were instituted in 1993, spring spills were released in 10 of 13 years. The only winter spill since 1993 was in WY1997.

For WY1999, project operation had the following effects on hydrograph components:

- reduce winter baseflows to 50 cfs upstream of Early Intake and increase winter baseflows to 900 cfs downstream of Early Intake from 400 cfs (umimpaired);
- delay onset of spring snowmelt from late March (WY1917)/mid-April (Pohono Bridge) to mid-May;
- truncate the end of the snowmelt hydrograph at early July upstream of Early Intake and mid-July downstream of Early Intake compare to late July (Pohono Bridge and 1917)
- reduce snowmelt peak by about 2,000 cfs (30%);
- increased snowmelt recession rate; and
- increase summer baseflow from 65 cfs (Pohono Bridge), 72 cfs (HH 1917) to 98 cfs 1999, 65 cfs (Pohono Bridge), 72 cfs (HH 1917).

Figure 3-8. Unimpaired and Regulated Hetchy Reach Hydrograph WY1999



Footnotes:

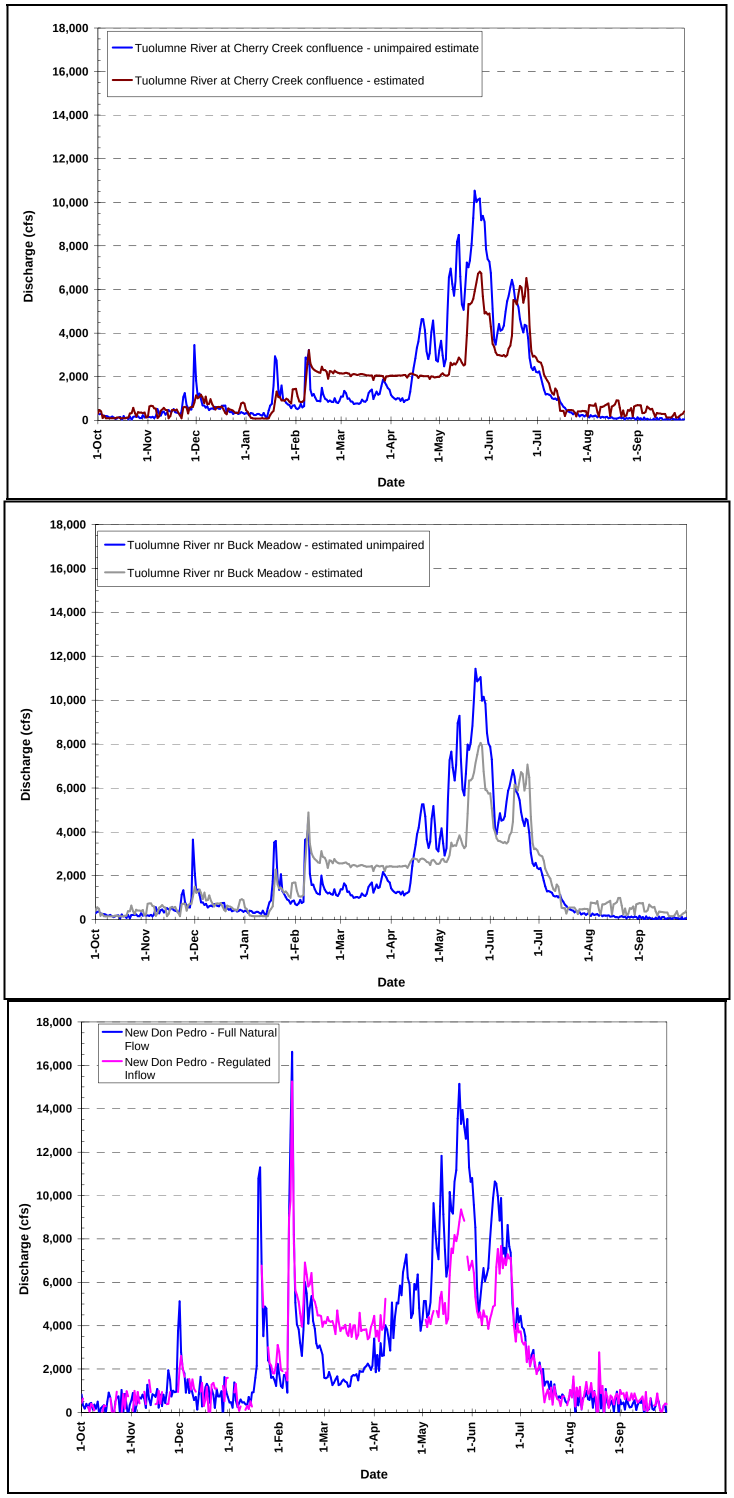
a. USGS gage Merced R at Pohono Bridge nr Yosemite CA (11266500) scaled by drainage area to Tuolumne River nr Hetch Hetchy
b. USGS gage Tuolumne River nr Hetch Hetchy, CA (11276500)
c. USGS gage Tuolumne River ab Early Intake nr Mather, CA (11276600)
d. USGS gage Tuolumne River bl Early Intake nr Mather, CA (11276900)

Lumsden Reach

This reach receives inflow from the regulated Hetchy and Holm reaches and from several major unregulated tributaries. From upstream to downstream, major tributaries in this reach are Cherry Creek, South Fork Tuolumne River, Clavey River, and North Fork Tuolumne River. Big Creek, a small tributary that flows into the Tuolumne River between the Clavey River and North Fork Tuolumne River confluences, is the only tributary to this reach downstream of Cherry Creek affected by flow regulation or diversion. Big Creek is regulated by Pine Mountain Lake, a 7,700-acre-foot reservoir constructed in 1969. The Tuolumne Utilities District diverts up to 52 cfs from the South Fork Stanislaus River into the Tuolumne River watershed via the Tuolumne Canal for power, irrigation, and domestic supply for Phoenix Lake, East Sonora, Sonora, and Jamestown. After passing through the Phoenix Powerhouse, diverted flow distributed through a systems of canals for irrigation and domestic use.

The Hetch Hetchy Project dams regulate 90% of the drainage area at the upstream end of the reach, 70% at the Tuolumne River nr Buck Meadows (located between South Fork Tuolumne River and Clavey River confluences), and 42% at the New Don Pedro Dam. Project effects are most pronounced at the upstream end of the reach, and include: reduced winter peaks, increased winter baseflows, reduced snowmelt duration and peak (Figures 3-9). Summer and fall baseflows are augmented compared to unimpaired conditions, and fluctuate due to flow releases for whitewater rafting and power generation operations. For 5–7 days each week, flow fluctuates between approximately 175 cfs and 1,100 cfs, then returns to baseflow for the remainder of the week. The rate of spring snowmelt recession is similar to unimpaired conditions.

Figures 3-9 a, b and c. Unimpaired and Regulated Hydrograph at Three Locations in the Lumsden Reach WY1999



Footnotes:

a. at Cherry Creek (top), equations 1 and 7;

b. at Buck Meadows (middle), equations 2 and 8;
c. at New Don Pedro Reservoir (bottom), estimates published by CDWR (http://cdec.water.ca.gov/cgi-progs/previous/FNF and http://cdec.water.ca.gov/cgi-progs/)

3.4 Effects of Flow Regulation on Annual Flood Magnitude and Timing

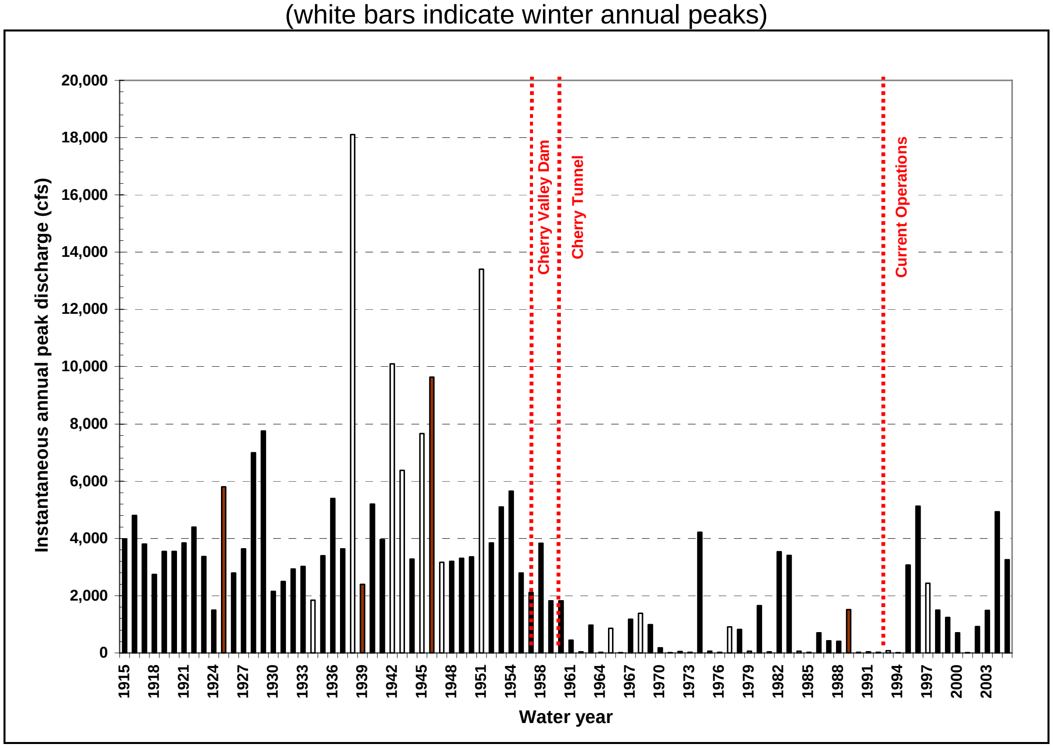
3.4.1 Cherry and Eleanor Creeks

Upper Cherry Creek

Flood history at Cherry Creek is shown in Figure 3-10. During the 41-year period of record, annual floods were in spring (April-June) in 27 years and winter (October–February) in 11 years. The largest floods were in winter, including seven of the nine largest annual floods of record and all floods exceeding the 9-year recurrence interval. The largest spring annual flood was 7,750 cfs (an 8.4-year flood). Since Cherry Valley Dam and Cherry Power Tunnel were completed, annual floods have shifted from spring to summer, and winter peaks are no longer significant. The January 1997 flood was the largest winter peak during this period, but this flood peaked at only 2,430 cfs downstream of the dam (a post-dam 5.6 year flood).

Figure 3-10. Cherry Creek Flood History

(white bars indicate winter annual peaks)

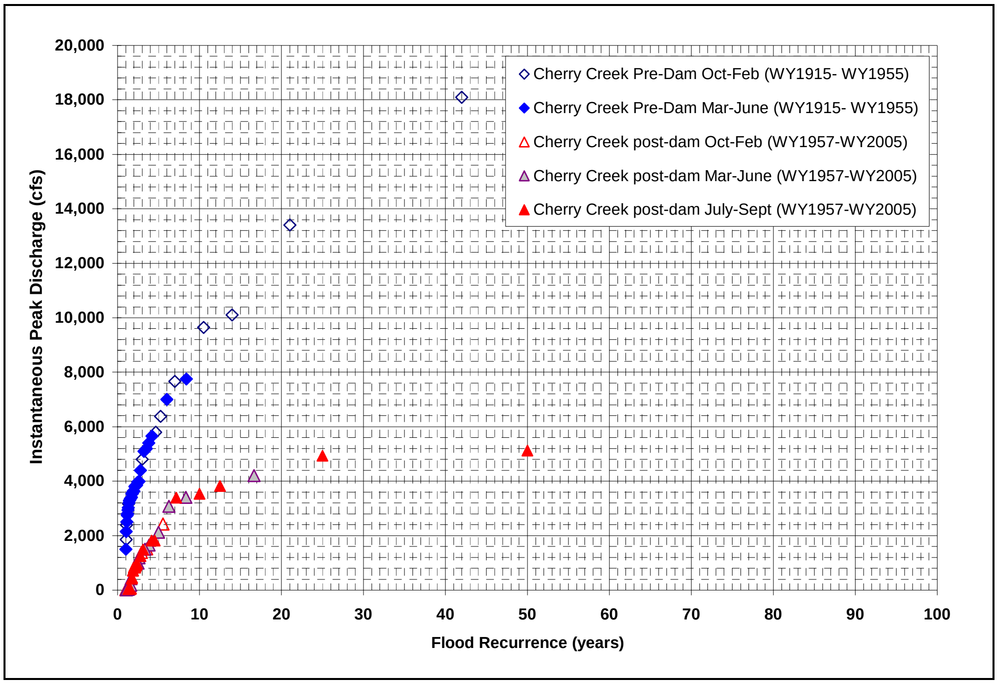


Footnotes:
a. USGS gage Cherry Creek near Hetch Hetchy, CA (11277000)
b. USGS gage Cherry Creek below Valley Dam, CA (11277300)

Operation of Cherry Valley Dam and the Cherry Power Tunnel has reduced annual flood magnitude for all recurrence intervals evaluated (Table 3-4, Figure 3-11). The maximum controlled release from Cherry

Valley Dam is 5,000 cfs, equivalent to a pre-dam 3-year flood and a post-dam 34-year flood. Since Cherry Valley Dam was completed, the annual floods have approached 5,000 cfs in three years – WY1996, WY2004, and WY2006. The largest flood of record since the dam was built was in May 1996. This flood peaked at 5,120 cfs, a post-dam 50-year flood but only a pre-dam 3.2-year flood. The May 2006 peak (provisional data 6,570 cfs) was the largest annual flood in this reach since the dam was completed. The May 2006 peak is equivalent to a pre-dam 6-year flood and exceeds the post-dam 50-year flood.

Figure 3-11. Cherry Creek Flood Frequency



Footnotes:

a. USGS gage Cherry Creek near Hetch Hetchy, CA (11277000)
b. USGS gage Cherry Creek below Valley Dam, CA (11277300)

Table 3-4: Effect of Cherry Valley Dam on Annual Peak Flood Magnitude

Recurrence Interval (years)	Flood Magnitude (cfs)		
	Pre-dam (1915-1955)	Post-dam (1957-2005)	Percent Change
1.5	3,310	65	-98
2.33	3,850	951	-75
5	6,131	2,120	-65
10	9,190	3,530	-62
25	14,295	4,930	-66
50	N/A	5,120	N/A

Footnotes:

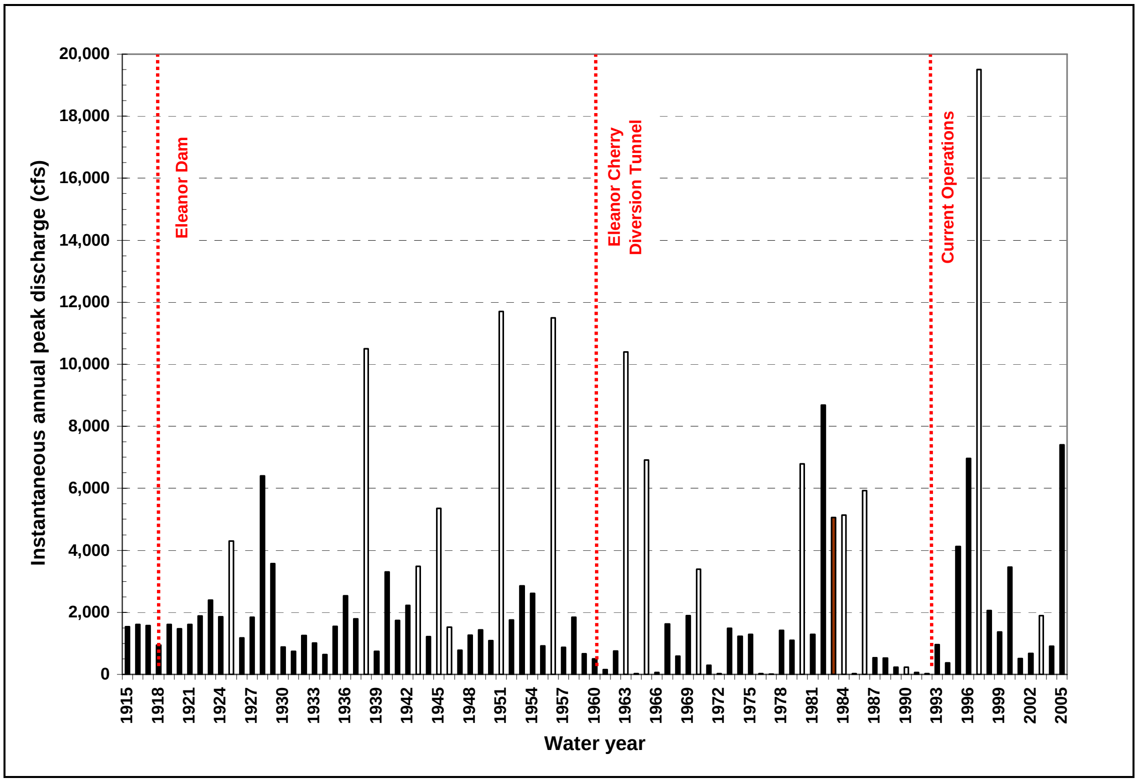
a. USGS gage Cherry Creek near Hetch Hetchy, CA (11277000)
b. USGS gage Cherry Creek below Valley Dam, CA (11277300)

Eleanor Creek

The pre-dam annual flood period of record for Eleanor Creek nr Hetch Hetchy is only three years (WY1915–WY1917), which is too short to compute the pre-dam flood frequency (Figure 3-12). While operation of the reservoir and diversion likely reduces the magnitude of small, frequent floods, the reservoir has insufficient capacity to capture larger floods, thereby allowing the majority of larger peak flood flows to pass. To provide a rough comparison of pre- and post-dam flood magnitude, pre-dam data from Cherry Creek nr Hetch Hetchy, which has a much longer period of record, were scaled to the Eleanor Creek nr Hetch Hetchy drainage area (Figure 3-13). Comparison of pre-dam annual floods from Cherry Creek nr Hetch Hetchy scaled to Eleanor Creek nr Hetch Hetchy by drainage area suggest that the greatest reduction in flood magnitude caused by Eleanor Dam is for floods smaller than the 5-year flood (Table 3-5).

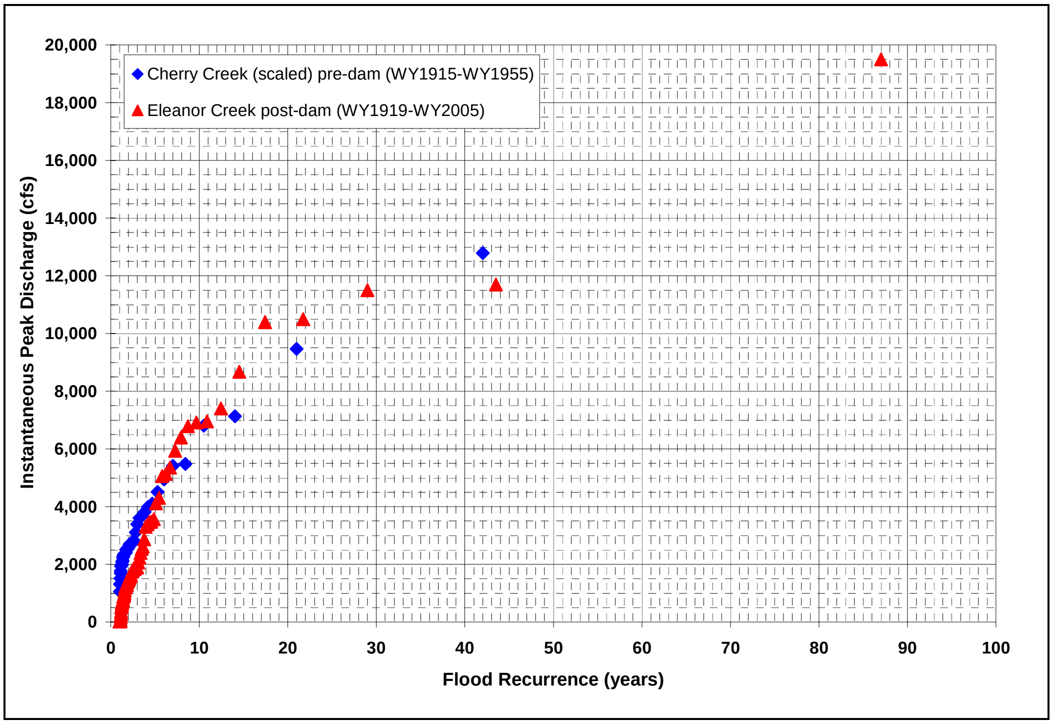
Figure 3-12. Eleanor Creek Flood History

(white bars indicate winter annual peaks)



Footnote:
a. USGS gage Eleanor C nr Hetch Hetchy CA (11278000)

Figure 3-13. Cherry Creek Flood Frequency Scaled to Eleanor Creek Drainage Area



Footnote:

a. USGS gage Cherry Creek near Hetch Hetchy, CA (11277000) scaled to Eleanor C nr Hetch Hetchy by drainage area

b. USGS gage Eleanor C nr Hetch Hetchy CA (11278000)

Table 3-5: Effect of Eleanor Dam on Annual Peak Flood Magnitude

Recurrence Interval (years)	Flood Magnitude (cfs)		
	Unimpaired Estimate[a]	Post-dam[b] (1919-2004)	Percent Change
1.5	2,338	926	-60
2.33	2,719	1,617	-41
5	4,330	3,533	-18
10	6,491	6,826	5
25	10,097	10,948	8
50	N/A	12,866	N/A

Footnote:

a. USGS gage Cherry Creek near Hetch Hetchy, CA (11277000) scaled to Eleanor C nr Hetch Hetchy by drainage area

b. USGS gage Eleanor C nr Hetch Hetchy CA (11278000)

Lower Cherry and Holm Reaches

Project effects on flood flows in the Lower Cherry and Holm reaches have not been analyzed.

3.4.2 Tuolumne River

Hetchy Reach

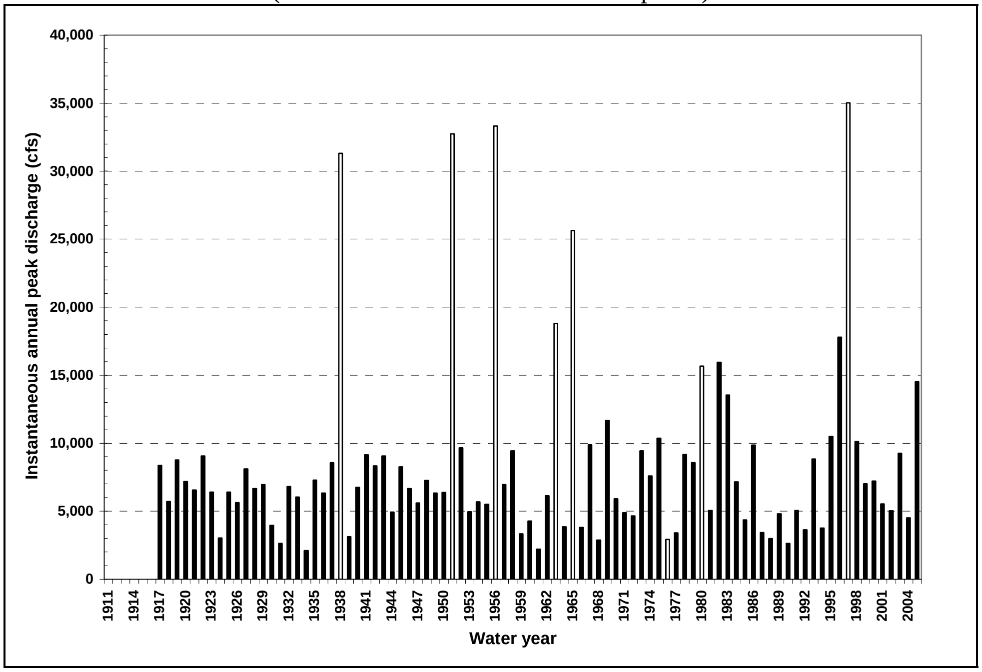
The pre-dam annual flood period of record at the Tuolumne gages spans only 12 years. To provide a longer-term unimpaired flow record against which to compare managed flows, annual flood data from the Merced River at Pohono Bridge near Yosemite gage (USGS Stn 11283500) were scaled by drainage area at the Tuolumne River at Hetch Hetchy gage. This Merced gage has a long period of record (WY1917–present), and its elevation and drainage area are similar to the Tuolumne River nr Hetch Hetchy gage (see Table 4-3 on page 34). For the six pre-dam years during which both gages were in operation, the scaled data underestimated annual peak flow at the Hetch Hetchy by 4–33%. The scaled unimpaired record, therefore, underestimates Tuolumne River flood peaks and the effects of project operation on annual flood magnitude. Despite these shortcomings, we feel that these data provide a useful benchmark against which to compare managed flow conditions, but we emphasize that this error must be considered when interpreting results.

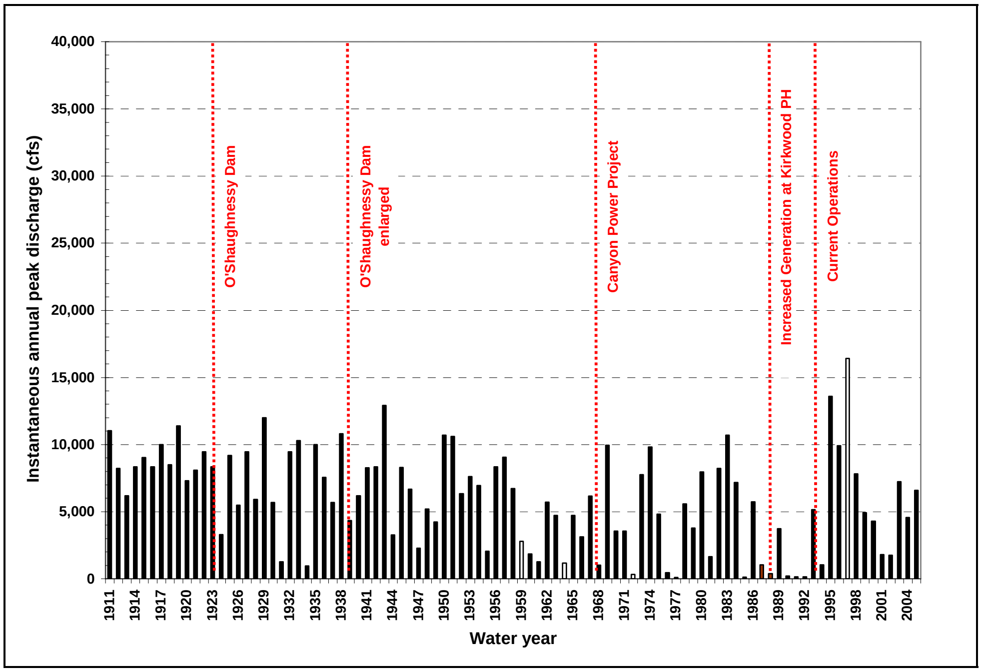
For pre-dam and unimpaired conditions, annual peak floods were typically in spring, but the largest and most geomorphically significant floods were winter rain-on-snow events. Pre-dam floods at the Hetch Hetchy gage were all in May and June and ranged from 6,202 cfs (WY1913) to 11,400 cfs (WY1919) (Figures 3-14). Annual floods scaled from the Merced River at Pohono Bridge gage were in spring (April–June) in 79 of 89 (89%) years of record. Spring annual peaks were most common in May and June, which accounted for 68% and 19% of spring peaks, respectively. Spring peaks ranged from 2,093 cfs in WY1934 to 17,796 cfs (a 12.7-year flood) in WY1996. The longer unimpaired period of record at the Merced River at Pohono Bridge gage records several large winter floods that are not included in the pre-dam period of record. Winter rain-on-snow events generated annual floods in 7 of 89 (8%) years of record and occurred from November through January. These floods accounted for the six largest floods for the period of record (WY1917–WY2005) and all floods exceeding the 13-year recurrence interval.

Dam operation has reduced flood magnitude for all flood recurrence intervals evaluated. Small, frequent floods ($\leq$2.33-year pre-dam recurrence interval) and floods exceeding 10,700 cfs (pre-dam 6.2-year recurrence interval) were most affected (Figure 3-15). Compared to the pre-dam record, the 1.5- and 2.33-year floods decreased 58% and 33%, respectively (Table 3-6). Moderate floods (2.8-year to 7-year recurrence interval) decreased approximately 18%. Larger floods are limited by the capacity of the O'Shaughnessy Dam outlet works, which is approximately 10,000 cfs. Since WY1939, annual floods exceeded 10,700 cfs in three years (WY1943, WY1995, WY1997). For the same period, annual floods scaled from the Merced gage exceeded 10,700 cfs in 11 years. Six of these floods were winter events. The January 1997 flood was the largest flood of record in the reach for both the pre- and post-dam periods and was the only post-dam winter flood. At the Tuolumne River near Hetch Hetchy gage, the 1997 flood peaked at 16,400 cfs (an unimpaired 12-year flood and a post-dam 67-year flood). The estimated unimpaired flow from this event (from the scaled Merced River at Pohono Bridge data) was approximately 35,000 cfs (an unimpaired 89-year flood). Although major changes in project operations after 1993 have caused longer spills, spill magnitudes have not greatly changed.

Figures 3-14 a and b. Tuolumne River Hetchy Reach Flood History

(white bars indicate winter annual peaks)





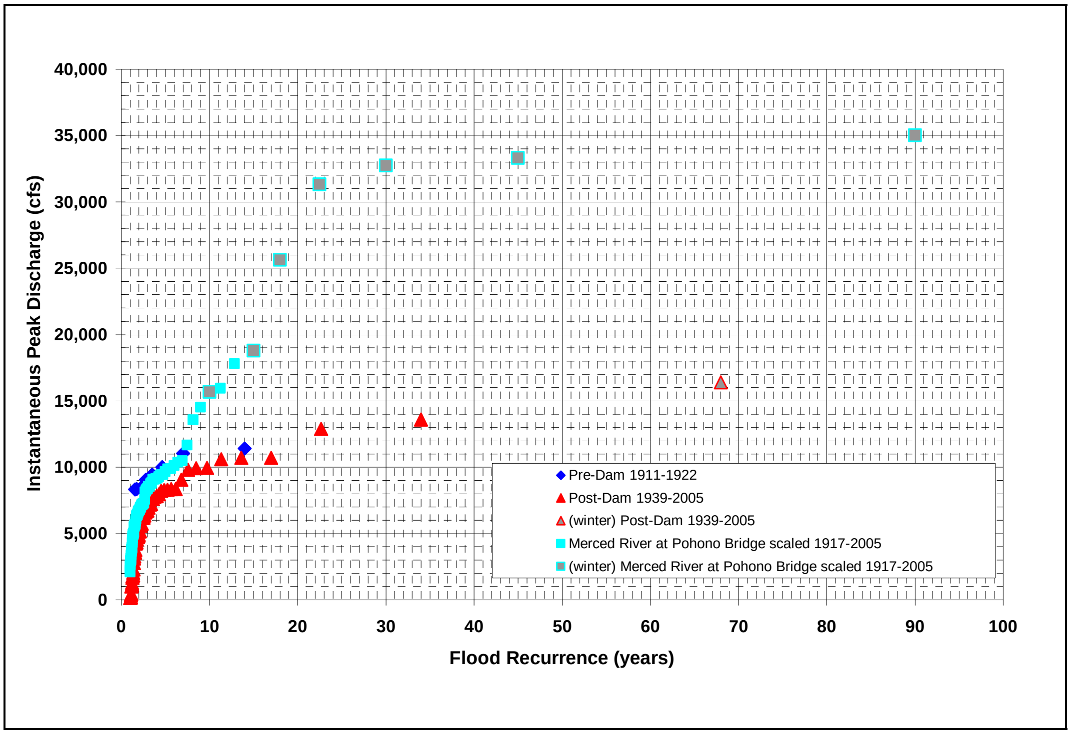
Footnote:

a. Upper: USGS gage Merced R at Pohono Bridge nr Yosemite CA (11266500) scaled by drainage area to Tuolumne River nr Hetch Hetchy

b. Lower: USGS gage Tuolumne River at Hetch Hetchy nr Sequoia, CA (11274800)

c. Lower: USGS gage Tuolumne River nr Hetch Hetchy, CA (11276500)

Figure 3-15. Tuolumne River Hetchy Reach Flood Frequency



Footnote:
a. USGS gage Merced R at Pohono Bridge nr Yosemite CA (11266500) scaled by drainage area to Tuolumne River nr Hetch Hetchy
d. USGS gage Tuolumne River at Hetch Hetchy nr Sequoia, CA (11274800)
e. USGS gage Tuolumne River nr Hetch Hetchy, CA (11276500)

Table 3-6: Pre- and Post-dam Annual Flood Peaks in the Hetchy Reach

Recurrence Interval (years)	Annual Peak Flood Magnitude (cfs)			Percent Change
	Unimpaired Estimate [a] (1917-2005)	Pre-dam [b, c] (1911–1922)	Post-dam [c] (1939-2005)	
1.5	5,524	8,294	3,455	-58
2.33	7,172	8,500	5,734	-33
5	9,667	10,147	8,281	-18
10	15,660	11,190	10,056	-36
25	31,795	N/A	13,044	-59
50	33,504	N/A	14,918	-55

Footnote:
a. USGS gage Merced R at Pohono Bridge nr Yosemite CA (11266500) scaled by drainage area to Tuolumne River nr Hetch Hetchy
b. USGS gage Tuolumne River at Hetch Hetchy nr Sequoia, CA (11274800)
c. USGS gage Tuolumne River nr Hetch Hetchy, CA (11276500)

Lumsden Reach

Project effects on flood flows in the Lumsden Reaches have not been analyzed.

3.4.3 Potential Effects of Flow Regulation and Diversion in the Study Reaches

Hypotheses of potential effects on geomorphic and ecological conditions in the study reaches are summarized in Table 3-7. It is important to note that these potential effects are based on the preliminary hydrologic analysis represented in Section 3.4.1 and 3.4.2, brief review of available data and reports, and field surveys at sites in the Upper Cherry and Hetchy reaches. The purpose of Table 3-7 is to guide the development of the 2006 study plan and subsequent efforts. More comprehensive and detailed analyses may conclude that some effects presented in Table 3-7 do not occur (or occur to greater or lesser degrees than anticipated) and will likely identify additional effects that are not listed in Table 3-7.

Table 3-7: Hypotheses of Potential Project Effects on Geomorphic and Ecological Conditions in the Study Reaches

Effect on Hydrograph Component	Reach						Hypothesized Effect on Geomorphic and Ecological Conditions		
	Hetchy	Upper Cherry	Lower Cherry	Eleanor	Holm	Lumsden	Geomorphic	Vegetation	Fish, Amphibians, and Invertebrates
Reduced winter peak flood magnitude	○	●	○	○	○	??	reduced frequency and duration of sediment scour and redeposition necessary to maintain channel morphology woody riparian encroachment increases the flow magnitude required to scour the channel bed	riparian vegetation encroachment onto formerly active depositional surfaces reduced riparian habitat complexity	• reduced habitat area for species/life stages that require open bars and channel margins, such as foothill yellow-legged frog and salmonid fry • reduced cobble surface area suitable for macroinvertebrate production, and thus reduced food supply for native fish, bats, and other species • reduced habitat for riparian nesting bird species that occupy lower (sub-canopy) vegetation strata
	○	●	○	○	--	--	sand deposition and accumulation in pools	N/A	• reduced habitat for adult rainbow trout, California roach, and Sacramento sucker
Reduced magnitude and duration of snowmelt flows	●	●	○	○	--	○	• reduced depth and duration of inundation of depositional surfaces (such as lateral bars) and side channels	• reduced area suitable for riparian seedling germination and initiation during spring seed release • encroachment of upland vegetation into the riparian corridor and onto formerly active bar surfaces	• reduced oviposition and tadpole rearing habitat for native amphibians that breed on cobble bars and in side channels • reduced fry early rearing habitat for trout, California roach, and Sacramento sucker • reduced macroinvertebrate production area
Earlier and increased rate of snowmelt recession	●	●	●	●	●	--	N/A	• if stage drop exceeds seedling root growth, seedlings die of desiccation	• stage drop could desiccate amphibian eggs and tadpoles incubating or rearing on bar surfaces, in side channels, and in isolated pools
Cold-water dam	●	●	○	○	●	●	N/A	N/A	• alteration of temperature regime to

Effect on Hydrograph Component	Reach						Hypothesized Effect on Geomorphic and Ecological Conditions		
	Hetchy	Upper Cherry	Lower Cherry	Eleanor	Holm	Lumsden	Geomorphic	Vegetation	Fish, Amphibians, and Invertebrates
and powerhouse releases and changes in flow magnitude alter water temperature regimes									which native species are adapted, potentially affecting the breeding timing, embryo and larvae development rates, and survival • cooler or warmer water temperatures may shift fish distribution and alter habitat suitability
Reduced summer and winter baseflows	--	--	--	--	--	--	N/A	• lowering of shallow groundwater table elevation causes desiccation of mature riparian vegetation and (possibly in floodplains and low terraces, leading to encroachment by conifers)	• reduced habitat area (wetted channel) for native species • increased temperatures (depending on location relative to cold-water releases from the dams and powerhouse) may reduce or improve habitat suitability for native trout.
Frequent (daily or weekly), rapid flow fluctuations during spring and summer	--	--	--	--	●	●	N/A	• reduced initiation and establishment of woody riparian vegetation.	• scour and/or desiccation of redds and egg clusters • reduced benthic macroinvertebrate biomass • reduced foodweb support
Infrequent rapidflow fluctuations during spring and summer	--	●	○	--	--	--	N/A	• reduced initiation and establishment of woody riparian vegetation.	• scour and/or desiccation of redds and egg clusters

Footnote:

● high probability and magnitude
○ moderate probability or magnitude
-- low or no probability or magnitude

Section 4 Available Data and Reports

From April through July 2006, McBain & Trush, Inc. compiled data and reports for the study reaches available through resource agencies, water and irrigation districts, university libraries, and on-line resources. McBain & Trush and SFPUC staff contacted staff at the USFWS, California Department of Fish and Game (CDFG), NPS, USFS, Turlock Irrigation District (TID), Tuolumne River Preservation Trust (TRPT), and U.S. Geologic Survey (USGS), met with faculty at University of California – Davis, and searched files at the USFWS Sacramento Office and SFPUC archives at Moccasin (Table 4-1). Immediately relevant reports and data identified as of August 2006 are listed in Tables Table 4-2 through Table 4-5.

Table 4-1: Persons Contacted for Available Reports and Data

Contact	Agency/Organization
Heather Dempsey	TRPT (Bay Area Program Director)
Tim Ford	TID (Aquatic Biologist)
Jim Frazier	USFS Stanislaus National Forest (Forest Hydrologist)
Mark Gard	USFWS (Fish and Wildlife Biologist)
John Maschi	USFS Stanislaus National Forest (Land Management Planner)
Bruce McGurk	SFPUC Hetch Hetchy Water & Power (Operations Manager)
Peter Moyle	University of California – Davis
Clinton Nagel	USGS Water Resources Division
Niki Nicholas	Yosemite National Park (Chief, Resource Management and Science)
Brian Quelvog	CDFG (District Fisheries Biologist)
Tim Ramirez	SFPUC (Division Manager, Natural Resources)
Sharon Shiba	CDFG Strategic Trout Planning (Associate Fishery Biologist)
Arthur Smith	SFPUC (Watershed Forester)
Steven Holdeman	USFS Stanislaus National Forest (Forest Aquatic Biologist)

4.1 General Reports and Planning Documents

Abundant information is available in environmental compliance and planning documents for each reach (Table 4-2). General reports and planning documents span various the study reaches and disciplines.

Table 4-2: General Reports and Planning Documents

Title	Date	Author	Reach
Draft Tuolumne Wild and Scenic River Study and Environmental Impact Statement	1979	USDA & USDI	Hetchy, Lumsden
Environmental Assessment Tuolumne River Flow Schedule Revision	1981	USFWS	Hetchy
Supplement to Environmental Assessment Tuolumne River Flow Schedule Revision (Canyon Power Project) California	1983	USFWS	Hetchy
Environmental Assessment on the Proposed Third Power Generator Unit at Kirkwood Powerhouse	1985	BIP Associates	Hetchy

Title	Date	Author	Reach
Tuolumne Wild and Scenic River Management Plan	1988	USFS	Hetchy (downstream of Yosemite National Park), Lumsden
Draft EIS/EIR Proposed Clavey Project Tuolumne County, California FERC 10081-002	1994	TID & Tuolumne County	Lumsden
Final EIS Reservoir Release Requirements for Fish at the New Don Pedro Project, California FERC 2299-024	1996	FERC	N/A
Draft EIS for Hydropower Licenses Stanislaus River Projects (Spring Gap-Stanislaus Hydroelectric Project FERC 2130; Beardsley/Donnells Hydroelectric Project FERC 2005; Donnells/Curtis Transmission Line Project FERC 2118; Tulloch Hydroelectric Project FERC 2067)	2004	FERC	N/A
Stanislaus National Forest Plan Direction	2005	USFS	Hetchy (downstream of Yosemite National Park), Lumsden
Tuolumne Wild and Scenic River Outstandingly Remarkable Values (Draft Report)	2006	NPS	Hetchy (Yosemite National Park),

4.1.1 Streamflow Data

Streamflow data are available from numerous gages in the study reaches (Figure 4-1, Table 4-3). Additional gages on Merced River at Pohono Bridge near Yosemite and unregulated tributaries to the Tuolumne River in the Lumsden Reach provide data from unregulated streams to augment data available from gages on the study reaches. Historic data are also published in “The Hetch Hetchy Water Supply for San Francisco, 1912” (Freeman 1912).

Temperature data are available at various locations in the study reaches (Figure 4-1). Late summer thermograph records at several locations in the watershed are available from instream flow studies conducted in the 1970s and 1980s. These records are hard copy data sheets and thermograph tapes. Additional weekly temperature and turbidity data are available for the O’Shaughnessy Diversion and above Early Intake in the SFPUC SFLIMS database. Long-term, continuous data are available for WY1988–present at the Tuolumne River near Hetch Hetchy and Tuolumne River below Early Intake gages. McBain & Trush, Inc. has obtained the data (electronic files) for the period of record. In spring 2006, the USGS (under contract to the SFPUC) added temperature monitoring devices to all streamflow gages in the study reaches (Table 4-3).

*Figure **4-1**: Temperature and Streamflow Data Available for the Study Reaches*

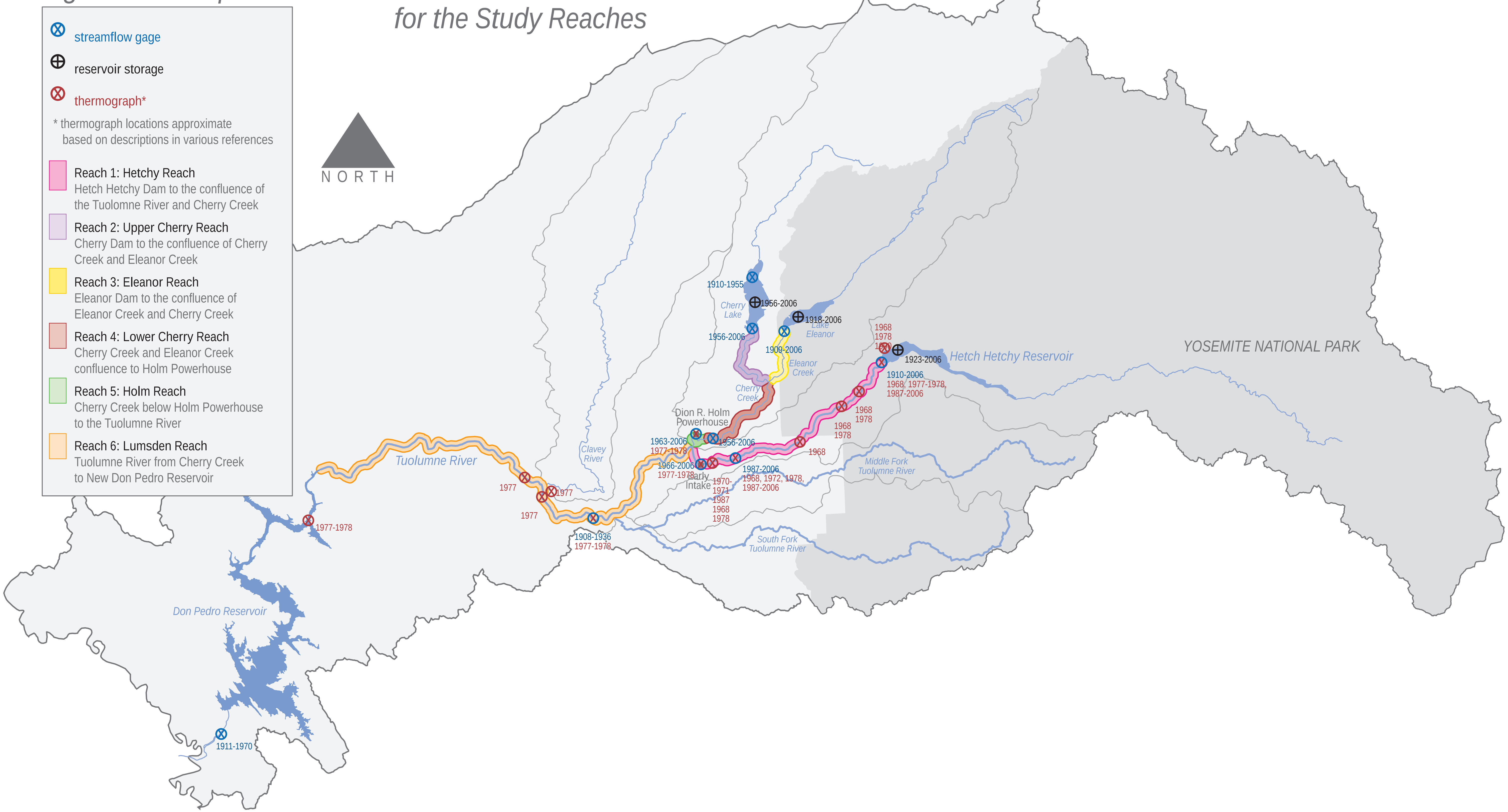


Table 4-3: Streamflow Data and Computed Flow Estimates

Station		Elevation (ft NGVD)	Drainage Area (mi²)			Period of Record			
ID	Name		Total	Unregulated	Regulated	Total	Pre-dam	Post-dam	Post-dam + diversion
Eleanor Creek									
11277500	Lake Eleanor nr Hetch Hetchy CA		78	N/A	78.1	June 1918-present	N/A	1919-present	N/A
11277100	Lk Eleanor Div to Cherry Lake nr Hetch Hetchy CA	4,670	N/A	N/A	N/A	July 1996-present	N/A	N/A	1997-present
11278000	Eleanor C nr Hetch Hetchy CA[a]	4,500	78	0.3	78.1	Oct. 1909-present	1910-1917	1919-1959	1961-present
Cherry Creek									
11277000	Cherry C nr Hetch Hetchy CA	4,500	111	111	N/A	Apr. 1910-Sept. 1955	1911-1955	N/A	N/A
11277200	Cherry Lake nr Hetch Hetchy CA		117	N/A	117	Aug. 1956-present	N/A	1957-present	1921-present
11277300	Cherry C bl Valley Dam nr Hetch Hetchy CA[a]	4,337	118	1	117	Nov. 1956-present	N/A	1957-present	1961-present
11278200	Cherry C Canal nr Early Intake CA		N/A	N/A	N/A	Apr. 1956-May 1971, June 1987- Sept. 1996	N/A	1957-1970, 1988-1996	1957-1970, 1988-1996
11278300	Cherry C nr Early Intake CA[a]	2,272	226	31	195	May 1956-present	N/A	1957-present	1961-present
11278400	Cherry C bl Dion R Holm PH, nr Mather CA[a]	2,134	234	39	195	Mar. 1963-present	N/A	1964-present	1964-present
Tuolumne River Mainstem									
11274800	Tuolumne R at Hetch Hetchy nr Sequoia CA		404	404	N/A	Oct. 1910-Sept. 1916	1911-1916	N/A	N/A

Station		Elevation (ft NGVD)	Drainage Area (mi^2)			Period of Record			
ID	Name		Total	Unregulated	Regulated	Total	Pre-dam	Post-dam	Post-dam + diversion
11276500	Tuolumne R nr Hetch Hetchy CA[b]	3,480	457	2	455	Oct. 1910-present	1911-1922	1924-1938, 1939-present	1968-present
11275500	Hetch Hetchy Reservoir at Hetch Hetchy CA		455	N/A	455	May 1923-present	N/A	May 1923-present	1968-present
11276600	Tuolumne R ab Early Intake nr Mather CA[c]	2,420	484	29	455	Oct. 1971-June 1972, Aug. 1987 to present	N/A	1972, 1987-present	1968-present
11276900	Tuolumne R bl Early Intake nr Mather CA[a]	2,200	487	32	455	Oct. 1966-present	N/A	1967-present	1968-present
11283000	Tuolumne R nr Buck Meadows CA	1,420	924	274	650	Oct. 1907-Sept. 1908, Oct. 1910-Sept.1936	1908, 1911-1922	1924-1935	1935–1936
11287500	Don Pedro Reservoir nr La Grange, CA	830	1,533	N/A	1,533	Sept. 1923-present	N/A	1924-present	1935-present
DNP	Regulated Inflow to New Don Pedro Reservoir (daily)[d]		~1,533	883	650	Jan. 1994-present	N/A	1995-present	1995-present
DNP	Full Natural Flow at Don Pedro Reservoir		~1,533	883	650	1901-present	N/A	N/A	N/A
11288000	Tuolumne R ab La Grange Dam nr La Grange CA	330	1,532	N/A	~1,532	Oct. 1911-Oct. 1970	1896-1922	1924-1970	1935-1970
--	Unimpaired flow at La Grange (daily)[d]	330	1,532	1,532	N/A	Sept. 1918-Oct. 2005	N/A	N/A	N/A
11266500	Merced River at Pohono Bridge nr Yosemite CA[e]	3,862	321	321	N/A	Oct. 1916-present	N/A	N/A	N/A
					Lumsden Reach Tributaries				
11279500	SF Tuolumne R at Italian F nr Sequoia CA		65	65	NA	1924-1933			
11280000	SF Tuolumne R nr Sequoia CA		68	68	NA	1914-1917			

Station		Elevation (ft NGVD)	Drainage Area (mi^2)			Period of Record			
ID	Name		Total	Unregulated	Regulated	Total	Pre-dam	Post-dam	Post-dam + diversion
11281000	SF Tuolumne R nr Oakland Recreation Camp CA		87	87	N/A	1923-2002			
11281500	M Tuolumne R nr Mather CA		52	52	NA	1924-1933			
11282000	M Tuolumne R at Oakland Recreation Camp CA		73.5	73.5	N/A	1917-2002			
11282500	SF Tuolumne R nr Buck Meadows CA		164	164	NA	1911-1921			
11283250	Clavey R nr Long Barn CA		49	49	NA	1986-1994			
11283500	Clavey R nr Buck Meadows CA		144	144	NA	1959-1995			
11284400	Big C ab Whites Gulch nr Groveland CA		16	16	NA	1969-present			
11284500	Big C nr Groveland CA		25	25	NA	1931-1974			
11284700	NF Tuolumne R nr Long Barn CA		23	23	NA	1962-1966			
11285000	NF Tuolumne R Ab Dyer C Nr Tuolumne CA		69	69	NA	1958-1966			
11278500	Jawbone C nr Tuolumne CA		19	19	NA	1911			

Footnote:

a. Temperature monitoring devices added in spring and summer 2006.
b. Temperature data available for Oct. 1971–Sept. 1972, Aug. 1987–present.
c. Temperature data available for Oct. 1971–June 1972, Aug. 1987–present.
d. Computed flow estimates.
e. Reference gage on unregulated reach of the Merced River.

4.1.2 Geomorphic Data

While numerous reports and maps describing local and regional geology are available, geomorphic information specific to the study reaches was limited to general reach descriptions in instream flow study reports (Table 4-4) and the planning and environmental compliance documents (Table 4-2). Additional geomorphic information can be developed through analysis of available topographic maps, aerial photographs, digital terrain models, and ground photographs.

Table 4-4: Geomorphic Data and Reports

Title	Date	Author	Reach
Generalized Geologic Map of the Yosemite National Park Area	no date	Huber et al.	Hetchy (Yosemite National Park)
Generalized Geologic Map of the Yosemite National Park Area	no date	Huber et al.	Hetchy (Yosemite National Park)
Memorandum re: Tuolumne River Review	1977	M. Bell	Hetchy
IFIM data transmittal from USFWS to Hetch Hetchy Water and Power	1977	USFWS	Hetchy
Evaluation of Tuolumne River Fishery with the Canyon Power Project	1980	Bell et al.	Hetchy
Tuolumne River Flow Study Report – 1980	1980	R. Lewis	Hetchy
Geology of Yosemite National Park[a]	1984	Huber et al.	Hetchy (Yosemite National Park)
The Geologic Story of Yosemite National Park: A Comprehensive Geologic View of the Natural Processes that have Created and are Still Creating the Stunning Terrain we know as Yosemite[a]	1987	N. Huber	Hetchy (Yosemite National Park)
Habitat Map (60 cfs) and IFIM Transect Sites	1988	USFWS	Hetchy
The late Cenozoic evolution of the Tuolumne River, central Sierra Nevada, California	1990	N. Huber	Hetchy, Lumsden
Hydrology and Water Resources [from Sierra Nevada Ecosystem Project, Final Report to Congress, vol. 2]	1996	R. Kattelmann	N/A
Snow-melt Streamflow Timing at Different Basin Scales: Case Study of the Tuolumne River above Hetch Hetchy, Yosemite, California	2005	Lundquist et al.	Yosemite National Park upstream of Hetch Hetchy
Site-specific cross section surveys, pebble counts, and tracer rock studies	2005	McBain and Trush (unpublished data)	Upper Cherry
Developing a Maintenance Flow Methodology: A Sample Plan for Steep Bedrock-Controlled Rivers	1994	Institute for River Ecosystems	Upper Cherry

Footnote:

a. Report has been identified as potentially relevant but has not been obtained or reviewed.

4.1.3 Biologic Data

Biological data and reports include instream flow studies conducted in the mainstem Tuolumne River from O'Shaughnessy to Early Intake, Eleanor Creek, and Cherry Creek (1960s through 1980s) and biological monitoring conducted within Yosemite National Park (primarily for birds and bats) (Figure 4-2, Table 4-5). The National Park Service also has completed a Wildlife Habitat Relationships analysis to identify species potentially occurring along the Tuolumne River within Yosemite National Park. In addition to reports listed in Table 4-5, angler surveys (data sheets and summary reports) were obtained from the SFPUC archive and the USFWS office. Additional angler data for 2003 and 2004 are available at http://www.dfg.ca.gov/fishing/html/WildAndHeritageTrout/waters/TuolumneRiver.htm. Angler surveys from Poopenaut Valley, Early Intake, and other locations are available through the CDFG.

Table 4-5: Biologic Data and Reports

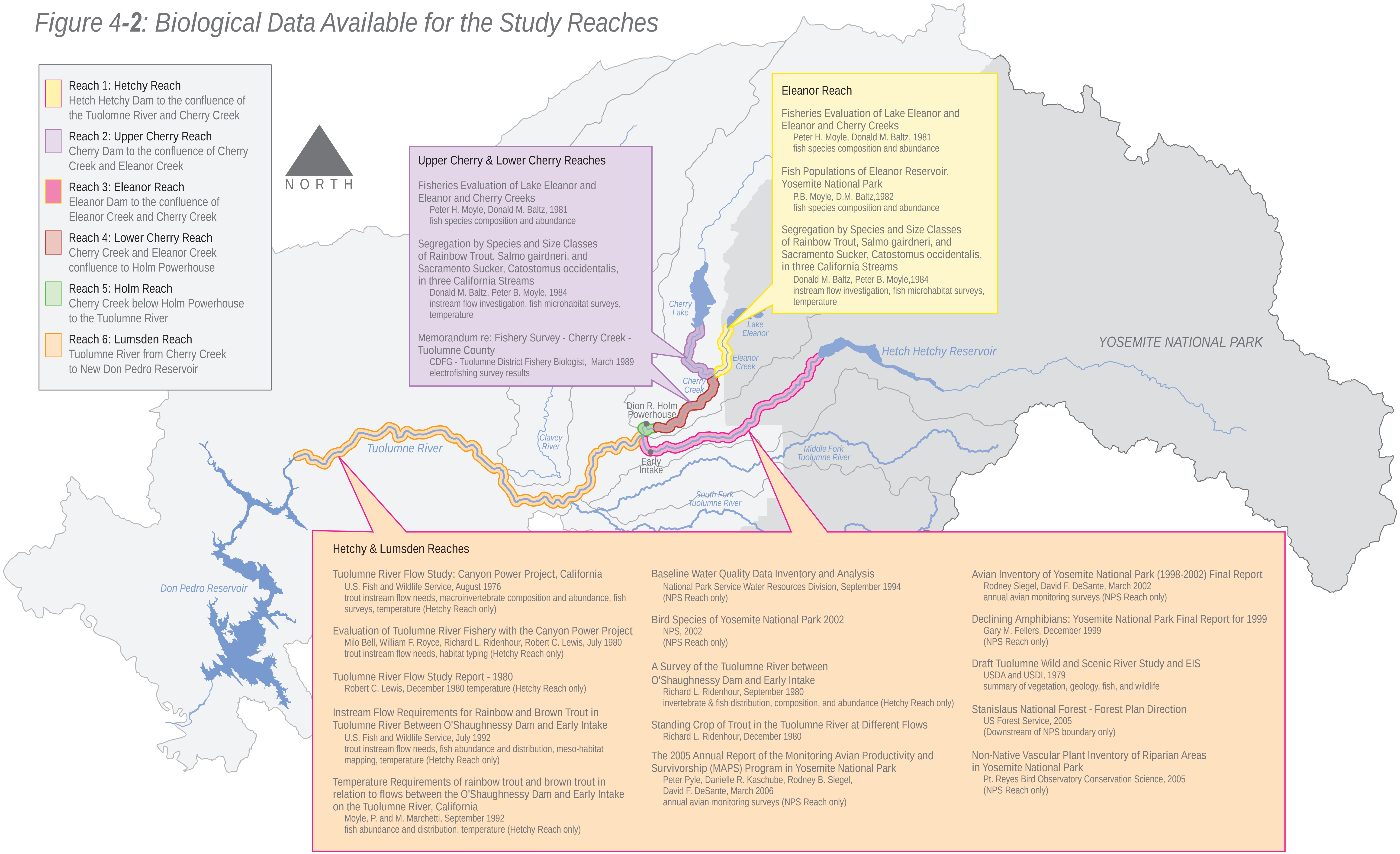
Title	Date	Author	Reach
General/Multiple Species			
Animal Life in the Yosemite[a]	1924	J. Grinnell & T. Storer	Hetchy (Yosemite National Park)
Biological Inventory Plan: The Sierra Nevada Network National Park Service	2001	Sierra Nevada Working Group	Hetchy (Yosemite National Park)
Draft EIS for Hydropower Licenses Stanislaus River Projects (Spring Gap-Stanislaus Hydroelectric Project FERC 2130; Beardsley/Donnells Hydroelectric Project FERC 2005; Donnells/Curtis Transmission Line Project FERC 2118; Tulloch Hydroelectric Project FERC 2067)	1994	FERC	N/A
Fish/Benthic Macroinvertebrates			
Tuolumne River Canyon Power Project: Environmental Analysis of Flow Reduction Request by City and County of San Francisco	1977	USFS	Hetchy
Letter from USFWS to SFPUC providing thermograph data (1968), fish survey data (1970), and fish planting records (1967-70)	1977	USFWS	Hetchy (Yosemite National Park)
Evaluation of Tuolumne River Fishery with the Canyon Power Project	1980	Bell et al.	Hetchy
Tuolumne River Flow Study Report – 1980	1980	R. Lewis	Hetchy, Lumsden
A Survey of the Tuolumne River between O'Shaughnessy Dam and Early Intake	1980	R. Ridenhour	Hetchy
Standing Crop of Trout in the Tuolumne River at Different Flows	1980	R. Ridenhour	Hetchy
Fisheries Evaluation of Lake Eleanor and Eleanor and Cherry Creeks	1981	P. Moyle & D. Baltz	Upper Cherry, Lower Cherry, Holm, Eleanor
Review of the Tuolumne River Flow Studies with Particular Consideration of the Fishery Flow Requirements	1981	R. Ridenhour	Hetchy
Environmental Assessment Tuolumne River Flow Schedule Revision	1981	USFWS	Hetchy
Environmental Assessment Tuolumne River Flow Schedule Revision: Appendices	1981	USFWS	Hetchy

Title	Date	Author	Reach
Fish Populations of Eleanor Reservoir, Yosemite National Park	1982	P. Moyle & D. Baltz	Eleanor
Draft Fishery Study Plan for Clavey - Ward's Ferry Project	1983	EA Engineering	Lumsden
Segregation by Species and Size Classes of Rainbow Trout, *Salmo gairdneri*, and Sacramento Sucker, *Catostomus occidentalis*, in three California Streams	1984	D. Baltz & P. Moyle	Upper Cherry, Lower Cherry, Holm, Eleanor
Tuolumne Fish Population Survey 1985	1985	B. Vondracek	Hetchy
A Report on Tuolumne River (Hetch Hetchy) Water Temperature Monitoring July 27 through Sept. 29, 1987	1987	M. Aceituno	Hetchy
Memorandum re: Fishery Survey - Cherry Creek - Tuolumne County	1989	CDFG	Upper Cherry, Lower Cherry
Hetch Hetchy Fishery Investigation Preference Criteria Development Fiscal Year 1988 Progress Report	1989	USFWS	Hetchy
Hetch Hetchy Fishery Investigation Tuolumne River, California 1989 Progress Report	1990	USFWS	Hetchy
Hetch Hetchy Fishery Investigation Tuolumne River, California 1990 Progress Report	1991	USFWS	Hetchy
Temperature Requirements of rainbow trout and brown trout in relation to flows between the O'Shaughnessy Dam and Early Intake on the Tuolumne River, California	1992	P. Moyle & M. Marchetti	Hetchy
(Rough Draft) Instream Flow Requirements for Rainbow and Brown Trout in the Tuolumne River Between O'Shaughnessy Dam and Early Intake	1992	USFWS	Hetchy
Status of Fish and Fisheries [from Sierra Nevada Ecosystem Project, Final Report to Congress, vol. 2]	1996	Centers for Wildlands and Water Resources	N/A
Amphibians			
The toad genus *Bufo* in the Sierra Nevada of California: Ecological and systematic relationships.	1962	E. Karlstrom	N/A
Population Census of a Species of Special Concern: the Yosemite Toad (*Bufo canorus*)[a]	1991	C. Martin	Hetchy (Yosemite National Park)
Effects of low pH and aluminum on amphibians at high elevation in the Sierra Nevada, California	1994	Bradford et al.	Hetchy /A
Collapse of a regional frog fauna in the Yosemite area of the California Sierra Nevada	1996	C. Drost & G. Fellers	Hetchy

Title	Date	Author	Reach
The Genetics of Amphibian Declines: Population Substructure and Molecular Differentiation in the Yosemite Toad, *Bufo canorus* (Anura, Bufonidae), Based on Single-Strand Conformation Polymorphism Analysis (SSCP) and Mitochondrial DNA Sequence Data	2000	Shaffer et al.	N/A
Aquatic Amphibians in the Sierra Nevada: Current Status and Potential Effects of Acidic Deposition on Populations	1992	D. Bradford & M. Gordon	Hetchy
An Assessment of the Status of Amphibians in the Vicinity of California National Parks: 1993 Progress Report[a]	1994	G. Fellers	Hetchy
Status of Amphibians (from Sierra Nevada Ecosystem Project, Final Report to Congress, vol. 2)	1996	M. Jennings	All
Declining Amphibians: Yosemite National Park Final Report for 1999[a]	1999	G. Fellers	Hetchy
Birds			
The Status and Distribution of the Willow Flycatcher (*Empidonax trailii*) in Selected Portions of the Sierra Nevada[a]	1992	M. Serena	
Bird Species of Yosemite National Park 2002	2002	NPS	Hetchy (Yosemite National Park)
Avian Inventory of Yosemite National Park (1998-2002) Final Report	2002	R. Siegel & D. DeSante	Hetchy (Yosemite National Park)
The 2005 Annual Report of the Monitoring Avian Productivity and Survivorship (MAPS) Program in Yosemite National Park	2006	Pyle et al.	Hetchy (Yosemite National Park)
Bats			
Bat Surveys: Yosemite National Park, 1994[a]	1994	E. Pierson & W. Rainey	Hetchy (Yosemite National Park)
Habitat Use by Two Cliff Dwelling Bat Species, the Spotted Bat, *Euderma maculatum*, and the Mastiff Bat, *Eumops perotis,* in Yosemite National Park[a]	1996	E. Pierson & W. Rainey	Yosemite National Park
Seasonal Patterns of Bat Distribution along an Altitudinal Gradient in the Sierra Nevada[a]	2000	Pierson et al.	Yosemite National Park

Footnote:
a. Report has been identified as potentially relevant but has not been obtained or reviewed.

Figure 4-2: Biological Data Available for the Study Reaches



4.1.4 Vegetation Data

Vegetation data identified included general reach-level descriptions presented in the Wild and Scenic River Study and Environmental Impact Statement and the USFS Tuolumne Wild and Scenic River Management Plan, landscape-scale vegetation mapping within Yosemite National Park (0.5 acre minimum mapping unit), and reconnaissance-level and site-specific surveys conducted on Cherry Creek downstream of Cherry Valley Dam (Figure 4-2, Table 4-6). The NPS recently completed an invasive plants study throughout the park and is currently preparing and Environmental Assessment for managing invasive plants. The NPS also plans to conduct rare plant surveys in the Tuolumne River corridor in summer 2006. Additional vegetation information can be developed through analysis of available aerial photographs and ground photographs.

Table 4-6: Vegetation Data and Reports

Title or Description	Date	Author	Reach
Vegetation mapping GIS data files (draft)	??	NPS	Hetchy, Eleanor
Changes in thirty-one years in a Sierra Nevada ecotone	1971	J. Heath	Yosemite National Park
Study of the Phenology of Subalpine Plants in Yosemite[a]	1975	H. Dobson	Yosemite National Park
Spatial Analysis of Vegetation Types in Yosemite National Park[a]	1992	J. van Wagtendonk	Hetchy (Yosemite National Park)
Status of Rare and Endemic Plants [from Sierra Nevada Ecosystem Project, Final Report to Congress, vol. 2]	1996	J. Shevock	--
Status of Riparian Habitat [from Sierra Nevada Ecosystem Project, Final Report to Congress, vol. 2]	1996	Kondolf et al.	--
Alien Plant Species Threat Assessment and Management Prioritization for Sequoia-Kings Canyon and Yosemite National Parks	2003	Gerlach et al.	Hetchy (Yosemite National Park)
Non-native Vascular Plant Inventory of Riparian Areas in Yosemite National Park, California	2005	Pt. Reyes Bird Observatory Conservation Science	Hetchy (Yosemite National Park)
Reconnaissance-level vegetation surveys and site-specific surveys	2005	McBain & Trush (unpublished)	Upper Cherry

Footnote:

a. Report has been identified as potentially relevant but has not been obtained or reviewed.

4.1.5 Relevant Aerial and Ground Photographs

Historic and recent aerial and ground photographs are valuable for identifying changes in channel morphology and riparian vegetation over recent decades. Aerial photographs suitable for reach-scale analysis are identified in Figure 4-3 and Table 4-7. In addition to photographs identified in Table 4-7, the USFS maintains an archive of 1:24,000-scale aerial photographs covering the national forest from the 1940s through the 1990s. The 1:24,000-scale photographs typically are not useful for reach-scale analyses, and these photographs have not been obtained or reviewed.

In addition to aerial photographs, McBain & Trush has obtained and scanned historic pre- and post-dam ground photographs from the Tuolumne River (O'Shaughnessy-to-Early Intake reach) and Cherry Creek (near USGS Stn 11277300). The locations of these photographs can be reoccupied to identify changes in channel morphology and riparian vegetation characteristics since construction of O'Shaughnessy Dam, Cherry Valley Dam, and Canyon Tunnel.

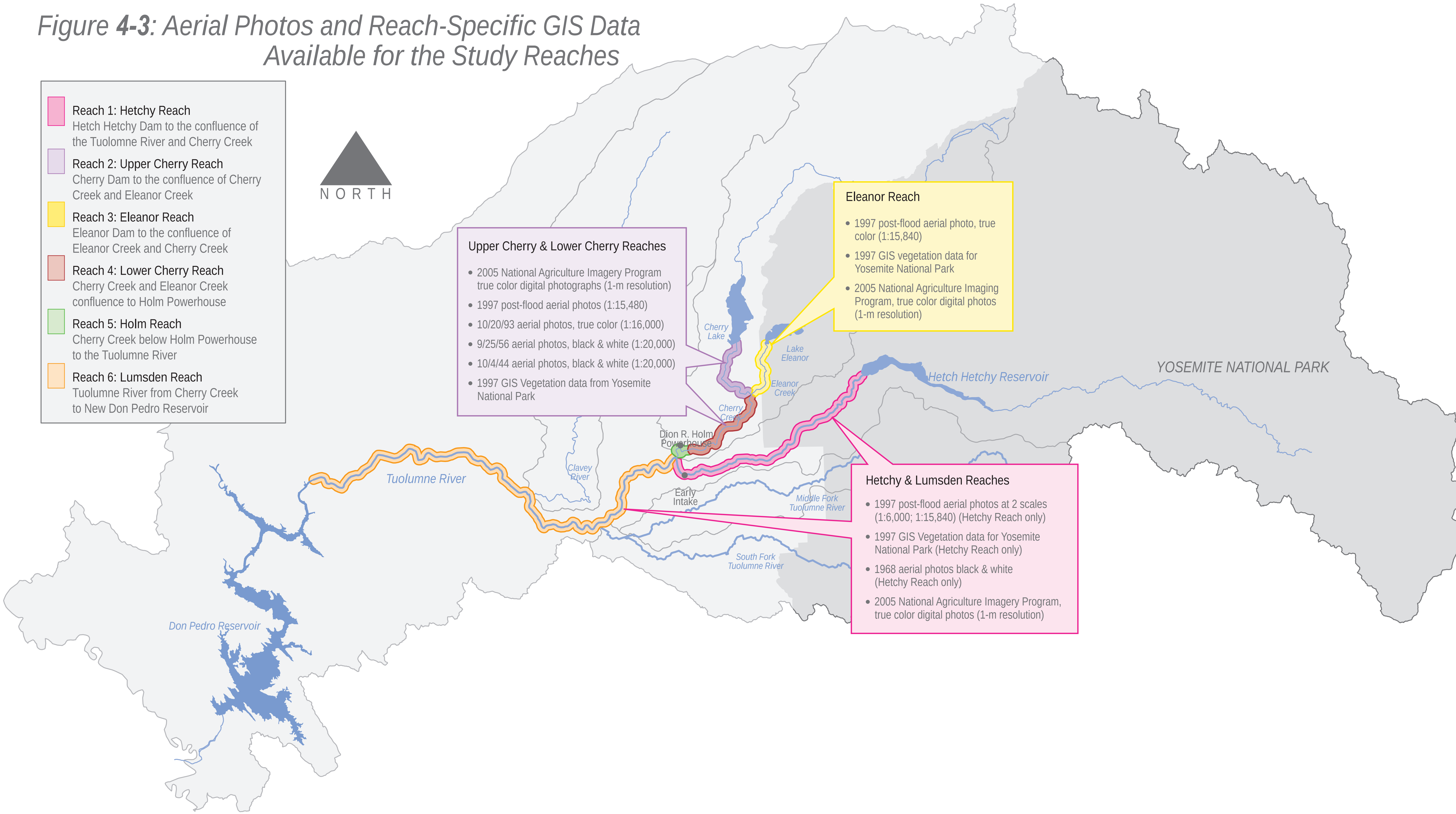
Table 4-7: Aerial Photographs

Stream	Photo Date	Scale	Geographic Extent (Study Reach)
Cherry Creek	1944	1:20,000	Cherry Valley Dam to Tuolumne River (Upper Cherry, Lower Cherry, Holm)
Cherry Creek	1956	1:20,000	Cherry Valley Dam to Tuolumne River (Upper Cherry, Lower Cherry, Holm)
Cherry Creek	1993	1:6,000	Cherry Valley Dam to Tuolumne River (Upper Cherry, Lower Cherry, Holm)
Tuolumne River	1968	1:3,600	Hetch Hetchy to Early Intake (Hetchy)
Tuolumne River[a, b]	1997	1:6,000	Hetch Hetchy to New Don Pedro Reservoir (Hetchy, Lumsden)
Tuolumne River, Cherry Creek, Eleanor Creek[a, b, c]	1997	1:15,840	Tuolumne River - headwaters to Early Intake (Hetchy) Cherry and Eleanor Creeks – full study reaches (Upper Cherry, Lower Cherry, Holm, Eleanor)
Tuolumne River, Cherry Creek, Eleanor Creek	2005	1 meter resolution	All

Footnote:

a. Photographs have been identified as potentially relevant but not obtained or reviewed.
b. Available through NPS
c. Available through SFPUC

Figure 4-3: Aerial Photos and Reach-Specific GIS Data Available for the Study Reaches



Section 5 Information Gaps

Numerous information resources have been identified and collected thus far. Much of the available information, however, is from studies conducted in the Hetchy Reach in conjunction with the Canyon Power Project. Information gaps identified through review of information collected to date are:

- *Suitable basemap*: No suitable basemap for detailed, contemporary surveys and analyses is available. The 2005 aerial photographs available for the study reach are 1-meter resolution. While these photographs provide suitable basemaps for reach-scale reconnaissance-level surveys typically used for environmental impact studies, their resolution is too coarse to be usable as basemaps for more detailed site-specific surveys (such as habitat mapping).
- *Streamflow and Temperature:* Streamflow and temperature in the Tuolumne River are not currently monitored downstream of the Cherry Creek confluence. Better current or compiled historic streamflow data are needed to identify and quantify the effects of SFPUC operations on flow conditions (and thus geomorphic and ecologic conditions) in the mainstem river.
- *Geomorphic processes:* No reach-scale or site-specific geomorphic studies were identified. Basic geomorphic thresholds (such as flow required to mobilize depositional features in the channel bed and scour riparian vegetation) have not been evaluated.
- *Fish species composition, distribution, and relative abundance:* Fish community data for the study reaches is dated. Surveys were conducted to document fish species composition, distribution, and relative abundance at various locations in the study reaches in the 1970s and 1980s for instream flow studies related to SFPUC and TID projects. CDFG also conducted surveys in 1992 (these data have not yet been obtained or reviewed).
- *Amphibian species composition and distribution:* The Tuolumne River and its tributaries potentially support populations of California red-legged frog (*Rana aurora draytoni*), foothill yellow-legged frog (*Rana boylii*), western toad (*Bufo boreas*), Yosemite toad (*Bufo canorus*), and other important management species. No recent surveys of amphibian habitat or distribution in the study reaches were identified, and the occurrence and distribution of these species and potential habitat for these species in the study area is not known.
- *Flow:habitat relationships:* Several instream flow studies have been conducted in the study area. These studies focus on minimum flow requirements for juvenile and adult brown and rainbow trout. These studies do not consider riparian vegetation, amphibians, or non-salmonid fish species. Flow:habitat relationships at higher flows or for other native fish and amphibian species have not been assessed.
- *Riparian vegetation:* Broad, reach-scale descriptions of riparian vegetation species composition and distribution are available from several reports. Effects of flow on riparian vegetation establishment and species composition have not been evaluated.

5.1 2006 Work Plan

When the project team met with the Tuolumne River Stakeholder Group on April 2006, we proposed to present a draft field plan in July 2006 and conduct field surveys in September 2006. High flows in spring 2006, however, provided an opportunity to make quantitative observations of bed mobility thresholds and other geomorphic effects of high flows in the study reaches. To take advantage of this opportunity, McBain & Trush, Inc. and SFPUC staff began field work in May 2006, making two trips to Upper Cherry and Hetchy reaches. The work plan presented below includes follow-up surveys needed to complete the high flow experiments, as well as data analyses and field surveys. Tasks presented herein are contingent on budget availability.

- Complete Hydrograph Components Analyses: Flow data have been acquired from all gages in the study reaches and two nearby reference gages, and preliminary analyses of natural flow conditions in the study reaches and the effects of SFPUC operations on flows have been completed. More detailed analysis is required to quantify the effects of operations on flow in the study reaches, refine or revise hypothesized effects of flow management on geomorphic and ecological conditions, and refine future monitoring needs. *Analyses to be completed for the 2006-07 report will:*
  - Refine analysis of data from Merced River at Pohono Bridge near Yosemite gage to represent unimpaired flow conditions in the Tuolumne River;
  - For each study reach, quantify the effects of project operations on each hydrograph components for a complete range of water year types (i.e., from critically dry to extremely wet) using the available period of record at relevant gages;
  - Acquire or synthesize flow data from major tributaries to the Tuolumne River downstream of Cherry Creek to New Don Pedro Reservoir. Using these data, describe the effects of project operations on flow conditions in the Tuolumne River downstream of Cherry Creek to New Don Pedro Reservoir.
- Complete 2006 High Flow Surveys: High flow experiments were installed in Cherry Creek (near Cherry Valley Dam) and the Tuolumne River (Preston Falls to Early Intake) in May 2006. Experiments included scour cores and pre-high flow photographs of depositional features. Pre-high flow photographs were also taken at two sites on the Tuolumne River: Poopenaut Valley and Hetch Hetchy to the Tuolumne River near Hetch Hetchy CA gage (USGS Stn 11276500). High flows following installation of the scour cores and pre-high flow photographs exceeded 6,500 cfs (provisional data) on Cherry Creek (pre-dam Q_5, post-dam $>Q_{50}$) and 8,030 cfs (provisional data) on the Tuolumne River (pre-dam ~ Q_2, post-dam $Q_{3.6}$). Scour cores on Cherry Creek were re-surveyed in May 2006, but photopoints could not be re-occupied due to high flows during the follow-up survey. Sites on the Tuolumne River have not been reoccupied.

  Proposed 2006 Actions:
  - Re-occupy photopoints at the Upper Cherry Reach study sites;
  - Re-occupy photopoints at the three Hetchy Reach study sites;
  - Re-survey scour cores in the Upper Hetchy Reach (Preston Falls-to-Early Intake); and
  - Recover thermographs in the Upper Cherry Reach; and
  - Recover thermographs and time-lapse cameras in the Upper Hetchy Reach (Preston Falls-to-Early Intake).
- Conduct Reconnaissance-level Surveys of All Study Reaches: Although extensive information has been compiled for the study reaches, available data and reports are not sufficient to describe (1) detailed geomorphic characteristics, controls, and processes, (2) local habitat conditions and distribution for key management or analysis species, or (3) detailed riparian vegetation characteristics in each reach or sub-reach. In spite of the extensive exiting data and reports, their scale is insufficient to resolve the linkages between geomorphic and ecological conditions and the effects of flow management.

  Proposed 2006 Actions:
  - Using the 2005 aerial photographs as a basemap, conduct reconnaissance-level surveys at accessible points in each study reach. Objectives of the reconnaissance surveys are to identify:

    (1) geomorphic conditions, habitat character, and general riparian vegetation characteristics in each reach;

    (2) potential reference sites for more detailed, site-specific surveys;

(3) geomorphic controls and depositional features at various scales,

(4) riparian vegetation species composition and the extent of riparian encroachment onto formerly active depositional surfaces; and

(5) potential habitat for native fish and amphibian species.

- o Revisit sites where relevant historical photographs are available and take current photographs from the same vantage point to identify changes in channel morphology and riparian vegetation that can be linked to specific flow conditions.

- Compile Life History Information for a Suite of Analysis Species: To focus the analysis, a manageable number of species must be selected to represent ecosystem conditions. Potential analysis species will be identified from review of available resource management plans and other reports. Potential analysis species identified thus far include: California red-legged frog, foothill yellow-legged frog, western toad, Yosemite toad, rainbow trout *(Oncorhynchus mykiss)*, California roach (*Lavinia symmetricus*), Sacramento sucker (*Catostomus occidentalis)*, riparian obligate bird species (to be determined), woody riparian species (to be determined), and benthic macroinvertebrate (to be determined).

  Proposed 2006 Actions:

  - o Review existing invertebrate and other species-specific data and reports for each study reach;
  - o With input from resource management agencies and other experts, develop a suite of species to carry forward for further analysis;
  - o Compile life history and habitat information for each analysis species, including life history periodicity specific to the elevation range within in each study reach; and
  - o Based in life history and habitat requirements, predict effects of flow regulation and diversion on available habitat for each analysis species in each study reaches.

5.2 Potential Future Tasks

- Obtain Aerial Photographs Suitable for Geomorphic and Ecological Analyses and to Provide Basemaps for 2007 and Future Surveys: Contract with an aerial photography firm to obtain color, orthorectified aerial photographs of each study reach. Photographs should be at a scale of 1:6,000 or larger and should be flown during low-flow conditions in fall 2006 after deciduous riparian trees have shed their leaves.
- Update Past Surveys of Fish Distribution and Relative Abundance: Conduct quantitative snorkel surveys at reference sites to document fish species composition, distribution, and relative abundance and provide a comparison to surveys reported by Vondracek (1985) and Moyle and Baltz (1982). In conjunction with fish surveys, conduct presence-absence surveys for foothill yellow-legged frog and other amphibians using accepted survey protocols.
- Quantify Flow:Habitat Relationships for One or More High Priority Analysis Species: At appropriate reference sites, conduct Expert Habitat Mapping (EHM) with participation from SFPUC and resource agency staff over a range of flows.
- Model Water Temperature in All Study Reaches*:* One of the major effects of project operation on ecological conditions in the study reaches is the effect of flow management on steam temperature. Temperature models are efficient for analyzing effects of project operations on stream temperature. Developing a temperature model requires water temperature and meteorological data.
- Monitor or Model Streamflow in the Lumsden Reach: Flow in the Tuolumne River is not monitored downstream of the Cherry Creek confluence, but the USGS operates gages on several tributaries. It may be possible to model flows in the mainstem Tuolumne River using available

tributary data. The capacity of a flow routing model to predict flow magnitude and timing in the Tuolumne River with sufficient accuracy for future monitoring should be tested. Testing the model will require short-term streamflow monitoring and discharge measurements in the Lumsden Reach.

Section 6 References Cited

Citations for sources identified in Tables Table 4-2 *through Table* 4-7 *will be provided via the completed database.*

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