Modesto Irrigation District
Water and Power

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SENT VIA E-MAIL

June 5, 2012

Charles R. Hoppin, Chairman
State Water Resources Control Board
1001 I Street
P.O. Box 2815
Sacramento, CA 95812-2815
CHoppin@waterboards.ca.gov

**Re: Economic Impact**

Dear Chairman Hoppin:

The State Water Resources Control Board ("State Water Board") staff released draft technical appendices on February 24, 2012. In several stakeholder meetings with State Water Board staff, our office has discussed the shortfalls of the economic analyses in these appendices. One of the major inadequacies is the lack of analysis regarding the adverse water supply and economic impacts to the Bay Area communities served by the regional water system of the City and County of San Francisco ("San Francisco").

The State Water Board proposes to implement amendments to the San Joaquin River flow objectives of the Bay-Delta Plan through the use of Section 401 certifications for Federal Energy Regulatory Commission ("FERC') orders. (*See* April 1, 2011 Notice, p. 4, attachment 2.) For the Tuolumne River, that means the State Water Board would seek to implement amendments to the Bay-Delta Plan through the Section 401 certification for the upcoming new license for the Don Pedro Project.

Funding for construction of the Don Pedro Project came from federal flood control monies, my client, the Modesto Irrigation District ("MID"), the Turlock Irrigation District ("TID") and San Francisco. San Francisco paid for most of the cost of constructing the Don Pedro Project. San Francisco, MID and TID have agreements specifying the rights and entitlements of each party and their respective responsibilities for the Don Pedro Project.

One of the agreements, the Fourth Agreement, established a San Francisco "water bank account" to allow San Francisco to meet the senior water rights entitlements of TID and MID, while maximizing the use of water from the upstream Hetch Hetchy Project to meet the water needs of San Francisco's customers. Basically, San Francisco deposits water into the water bank account whenever the inflow to Don Pedro Reservoir exceeds the TID and MID entitlements; conversely, San Francisco debits from the water bank account whenever it diverts or stores Tuolumne River water that would otherwise be within the entitlements of TID and MID. However, San Francisco holds no rights to water stored in Don Pedro Reservoir, is not a FERC licensee and has not been involved in project operations.

When San Francisco, MID and TID entered into the Fourth Agreement, they allocated the responsibility of future fish flow requirements that might be imposed on the Don Pedro Project through future FERC orders and licenses. The SFPUC Water System Improvement Program Final Programmatic Environmental Impact Report describes this allocation of responsibility under the Fourth Agreement (relevant pages are attached). It states in part:

> "The Districts [TID and MID] and City [CCSF] recognize that Districts, as licensees under the [FERC] license for the New Don Pedro project, have certain responsibilities regarding the water release conditions contained in said license, and that such responsibilities may be changed pursuant to further proceedings before the [FERC]. As to those responsibilities, as they exist under the terms of the proposed license or as they may be changed pursuant to further proceedings before the [FERC], Districts and City agree:
>
> ". . . (b) That at any time Districts demonstrate that their water entitlements, as they are presently recognized by the parties, are being adversely affected by making water releases that are made to comply with [FERC] license requirements, and that the [FERC] has not relieved them of such burdens, City and Districts agree that there will be a re-allocation of storage credits so as to apportion such burdens on the following basis: 51.7121% to City and 48.2879% to Districts." (CCSF/TID/MID, 1966.)

As such, should the State Water Board adopt a program of implementation for its proposed objectives based upon Section 401 water quality certification of FERC orders for the Don Pedro Project, the associated functional equivalent CEQA document must analyze potential water supply and economic impacts to San Francisco and its water customers.

In order to assist the State Water Board with this analysis, excerpts from the recent FERC-Administrative Law Judge ("FERC-ALJ") proceeding to increase flows in the Tuolumne River are herein enclosed.

Of particular note is the following finding by David L. Sunding, an expert in natural resource and environmental economics:

> "According to all three studies, economic losses increase relative to increased water shortages. Doubling the water storage from 10% to 20% roughly doubles the industrial losses ($0.5 billion to $1.1 billion) according to the most recent study and more than triples the industrial losses ($2.5 billion to $7.66 billion) according to the 2005 study. The earlier study showed an even more dramatic increase. Doubling water storage from 15% to 30% resulted in a five-fold increase

> in industrial losses ($0.4 billion to $2.1 billion). The most recent study found that a 30% water shortage would result in industrial losses totaling $3.6 billion with job losses exceeding 8,000."

Given the potential significant water supply and economic impacts to the Bay Area of the State Water Board's proposed amendments to the Bay-Delta Plan, it is incumbent upon the State Water Board to fully analyze and disclose the potential water supply and economic impacts to San Francisco in its substitute environmental document. (Water Code, §13241(d) and Cal. Code of Regs., tit. 23, § 3777.)

Very truly yours,

TIM O'LAUGHLIN, General Counsel
MODESTO IRRIGATION DISTRICT

TO/tb

Attachments
cc: San Joaquin Tributaries Authority
Frances Spivy-Weber, State Water Board Vice-Chair
Tam Doduc, State Water Board Member
Caren Trgovcich
Les Grober

As previously described in Section 2.3.4, the SFPUC recently installed a low-flow valve at Calaveras Dam to allow for future lower volume releases.

## Other Tuolumne River Fishery Release Requirements

As described above, TID and MID own and operate the New Don Pedro Project and make fishery releases below Don Pedro Reservoir at La Grange Dam consistent with a FERC license. In general, TID and MID are required to conform releases to one of seven basic flow schedules based on hydrologic year type. The total volume of release ranges from 94,000 acre-feet to 300,923 acre-feet, depending on the wetness of the San Joaquin River basin, with a summer flow ranging from 50 cfs to 250 cfs. Annual minimum flow schedules vary by three periods, defined as October 1 to October 15, October 16 to May 31, and June 1 to September 30, with additional fall and spring pulse flows for salmon adult attraction and smolt out-migration, respectively (FERC, 1996a).

In conjunction with the 1966 FERC license to TID and MID for the New Don Pedro Project, the CCSF, TID, and MID executed the Fourth Agreement to finance construction and establish operations for the project (CCSF/TID/MID, 1966). The three parties agreed to allocate the potential water supply risk that might result from a change in the interim flow schedules as follows:

> The Districts [TID and MID] and City [CCSF] recognize that Districts, as licensees under the [FERC] license for the New Don Pedro project, have certain responsibilities regarding the water release conditions contained in said license, and that such responsibilities may be changed pursuant to further proceedings before the [FERC]. As to these responsibilities, as they exist under the terms of the proposed license or as they may be changed pursuant to further proceedings before the [FERC], Districts and City agree:
>
>> … (b) That at any time Districts demonstrate that their water entitlements, as they are presently recognized by the parties, are being adversely affected by making water releases that are made to comply with [FERC] license requirements, and that the [FERC] has not relieved them of such burdens, City and Districts agree that there will be a re-allocation of storage credits so as to apportion such burdens on the following basis: 51.7121% to City and 48.2879% to Districts. (CCSF/TID/MID, 1966)

In 1994, FERC initiated mediation among 12 parties, including the CCSF, TID, and MID, on flow schedules and other matters related to releases in support of fisheries in the lower Tuolumne River. In February 1996, TID and MID filed with FERC an uncontested settlement agreement that included minimum flow schedules that are greater than the previous flow schedules. In July 1996, FERC amended the New Don Pedro Project license to incorporate the settlement agreement flow schedules (FERC, 1996b).

The CCSF, TID, and MID entered into a settlement agreement regarding the FERC flow schedules. Under this agreement, the CCSF makes annual payments to TID and MID, and TID and MID meet all flow requirements of the minimum flow schedules. The 1996 settlement agreement extends through the remainder of the FERC license (i.e., 2016) and any annual licenses. FERC may modify the fishery release requirements for the New Don Pedro Project in 2016 when TID and MID apply for a new license for hydroelectric operations (CCSF/TID/MID, 1995).

## 2.5.4 Rafting Flows

There are two whitewater runs in the Tuolumne River watershed above Don Pedro Reservoir: an 18-mile run on the Main Fork from Lumsden Campground to Ward's Ferry Bridge, known as the Lumsden Run, and a 9-mile run that begins at Holm Powerhouse on Cherry Creek and ends at Lumsden Campground, known as the Cherry Creek Run (refer to Chapter 5, Figure 5.3.8-1). Commercial companies operate under special-use permits issued by the U.S. Forest Service, Stanislaus National Forest. Private whitewater boaters must obtain permits from the Forest Service to boat the Tuolumne River between April 1 and September 30. Over the last 10 years, an average of 6,000 people per year participated in whitewater rafting on the river (see Chapter 5, Section 5.3.8, for more description of whitewater recreational use).

The flow schedules for Hetch Hetchy projects were intended to benefit fish and recreational fishing, not whitewater recreation. Neither the Raker Act nor the existing stipulations require the CCSF to make instream flow releases to maintain or enhance whitewater recreation. However, as described above, the 1996 FERC Settlement Agreement for the New Don Pedro Project requires the CCSF to consult, cooperate, and communicate with whitewater recreational interests with respect to SFPUC flow releases.

Subject to the availability of water and the CCSF's need for energy, the SFPUC attempts to accommodate whitewater recreation in the Tuolumne River by adjusting the day and hour of releases (i.e., "shaping" releases) from Holm Powerhouse to meet the needs of whitewater rafters. For rafting flows, the SFPUC attempts to meet up to 1,100 cfs on the Tuolumne River at Lumsden Campground. SFPUC staff meets annually with stakeholders representing the whitewater recreational community to develop, to the degree practicable, schedules of releases for whitewater recreation.

## 2.5.5 Customer Agreements – Master Water Sales Contracts

The SFPUC currently holds individual agreements with its wholesale customers, who are represented by the Bay Area Water Supply and Conservation Agency (BAWSCA) (formerly the Bay Area Water Users Association, or BAWUA). A list of the current BAWSCA members is provided in Chapter 3, Table 3.1, and their locations are shown on Figure 3.2. Wholesale water rates are set in accordance with the 1984 Settlement Agreement and Master Sales Water Contract (Master Water Sales Agreement) between the CCSF and each of the wholesale customers (CCSF, 1984). The current master contract expires in June 2009.

In addition to providing terms for the rate schedule and allocation of operating and capital costs, the Master Water Sales Agreement also addresses water supply and use of local water. Under the Master Water Sales Agreement, the CCSF has agreed that the wholesale customers may collectively purchase up to 184 mgd on an average annual basis through June 2009 subject to

Exhibit No. CSF-10

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

| | | |
|---|---|---|
| Turlock Irrigation District and<br>Modesto Irrigation District | | Project Nos. 2299-065<br>2299-053 |

**DIRECT TESTIMONY OF DANIEL B. STEINER**

**Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.**

A. My name is Daniel B. Steiner, and I have the business address of Post Office Box 2175, Granite Bay California, 95746.

**Q. WHAT IS YOUR OCCUPATION?**

A. I am a consulting civil engineer, registered in the State of California, specializing in water supply and water system operation analysis.

**Q. ON WHOSE BEHALF DO YOU APPEAR IN THIS PROCEEDING?**

A. I am appearing on behalf of the San Francisco Public Utilities Commission (SFPUC).

**Q. PLEASE SUMMARIZE YOUR BACKGROUND AND EXPERIENCE.**

A. I have over 30 years of experience in water resources planning, development and management, including operations planning for multipurpose water systems which have water and power supply, flood control, recreation, fishery and wildlife enhancement and water quality objectives. I have a substantial background in water resource planning and operations, with significant experience in hydrologic analysis and water supply forecasting, water demand projections, and operations analysis including modeling and operation plan formulation. I have evaluated urban water use and assisted with the development of water management policies and protocols, including water delivery policies during times of drought-induced shortages.

I currently provide technical analyses and interpretation of water and power system operation studies for the San Francisco Public Utilities Commission, including continuing support of investigations for the Water System Improvement Program (WSIP). The assistance includes the formulation, review and interpretation of hydrologic studies concerning the proposed program. I also am experienced in hydrologic and water system operational analysis of the San Joaquin River Basin and its tributary river systems.

**Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?**

A. I have been asked to explain the potential effect of requiring the SFPUC Regional Water System to provide flows from its water system to the Turlock and Modesto Irrigation Districts (Districts) for release to the lower Tuolumne River below La Grange Dam.

**Q. WHAT IS THE CURRENT STATE OF RESERVOIR STORAGE IN THE SFPUC REGIONAL WATER SYSTEM?**

A. At the end of August, 2009, the total system storage was reported by the SFPUC as 1,310,800 acre-feet, and is projected to be 1,273,500 acre-feet at the end of September, 2009. Within California, October 1 designates the beginning of a water year and the system storage that occurs at the end of September is carried forward into the next year's, and ensuing years' water supply.

**Q. WHAT IS THE OUTLOOK FOR NEXT YEAR'S WATER SUPPLY FROM THE SFPUC'S REGIONAL WATER SYSTEM?**

A. There is no ability to forecast next year's, or the ensuing years' rainfall and runoff. From the perspective of SFPUC water supply reliability planning (as described by Ms. Levin in Exhibit No. CSF-6), next year's water supply allocation to customer deliveries will be guided by the knowledge of existing reservoir storage and assumptions for runoff yet to occur – *i.e.*, runoff we do not know about as of today. At this early juncture in the year, the protocol for forecasting next year's supply is to assume that next year and the following years will experience the SFPUC's drought planning sequence. This sequence assumes the recurrence of actual runoff that was experienced during 1987 through 1992, and an additional drought period thereafter. This protocol is consistent with the water supply planning reliability practice since 1993, and the water supply reliability goals adopted in 2008 by the SFPUC in the development of the WSIP.

**Q. WHAT DOES THE ASSUMPTION THAT THE SFPUC REGIONAL WATER SYSTEM MAY BE ENTERING ITS DROUGHT PLANNING SEQUENCE SUGGEST IN TERMS OF WATER DELIVERIES NEXT YEAR AND IN ENSUING YEARS?**

A. If the runoff that was experienced in 1987 were to recur next year, 2010, SFPUC's forecasting protocols suggest that SFPUC system wide deliveries would be reduced by 10 percent during 2010. If runoff conditions were to continue after 2010 for 5 more years, the same as experienced between 1988 and 1992 (that is, 2010 looks like 1987, 2011 looks like 1988, 2012 looks like 1989, and so on), the forecasting protocols suggest that SFPUC's system wide deliveries would be reduced by an additional 10 percentage points, for a total reduction of 20 percent during those 5 ensuing years.

**Q. HOW DID YOU DERIVE THOSE PROJECTIONS?**

A. The SFPUC adopted the drought planning sequence and associated forecasting and operating procedures in 1993 to provide assurance that some level of water deliveries could be sustained during drought. As noted, these water supply planning reliability protocols were also adopted last year when the SFPUC approved the WSIP. Those procedures balance the water supply available to the SFPUC with its deliveries and other water demands. The water available to the SFPUC system consists of runoff from its watersheds and other minor resources. The amount of water available to the SFPUC system from the Tuolumne River is limited by the Raker Act and Fourth Agreement. Reservoir storage plays an important role in the water supply of the SFPUC system with its ability to provide regulation of runoff within a year, and very importantly from one year to the next.

The delivery forecast in my previous answer assumes the recurrence of 1987 through 1992 runoff and water releases required by the 1995 FERC Settlement. The amount of water available during this period from runoff and reservoir storage is less than full delivery demands and storage objectives. As a result, the procedures establish the level of shortages needed to balance supplies with deliveries over the entire multi-year drought planning sequence. Basically, the deliveries (and conversely the level of shortages) are the mathematical result of delivering all of the water available to the SFPUC from its existing resources during the drought planning sequence. There is no water left in the SFPUC system at the end of the drought planning sequence, and during the sequence, deliveries had to be reduced below full demands.

**Q. PLEASE EXPLAIN THE MODELING PROCESS THAT LEADS TO THE FORECAST OF SHORTAGES YOU JUST DESCRIBED.**

A. The SFPUC uses a personal computer based mathematical model known as the Hetch Hetchy/Local Simulation Model (HH/LSM) to simulate system operations for a long-duration period depicting 82 years of historical hydrologic conditions and the drought planning sequence. The model incorporates information about key aspects of the SFPUC system such as reservoir and conveyance attributes, stream runoff, and water demands. By iteratively running the model for the drought planning sequence and other key periods of the historical period, operating procedures and "rules" are developed that provide a viable system operation for all tested hydrologic sequences. One of the procedures developed from this modeling is the protocol triggering a reduction to deliveries during drought so as to not run out of water before the drought ends.

The delivery forecast described above, whereby shortages are projected for the recurrence of the 1987 through 1992 historical hydrology, is directly representative of the result of the protocols that were developed for the existing SFPUC system and 1996 FERC flow regime. Also, in this instance of forecasting operations beginning next year should 1987 through 1992 hydrology repeat itself, the specific study that is used by the SFPUC to depict its water during such a period is documented in its Final Programmatic Environmental Impact Report (PEIR) for the SFPUC's WSIP (SFPUC, Water System Improvement Program, *Programmatic Environmental Impact Report* (updated Sept. 30, 2008), *available at* http://www.sfgov.org/site/planning_index.asp?id=80530). The illustration of anticipated shortages with the recurrence of the 1987 through 1992 period conditions is explicitly shown in the report at Volume 3, Page 5.1-19, Figure 5.1-4 Water Supply Sources and Shortages – Existing Conditions (265 mgd Delivery).

A description of HH/LSM and the modeling that accompanies the PEIR, including the just described modeling of the existing system, is provided in the cited PEIR at Volume 5, Appendix H, and again in Volume 8, Appendix O. A more detailed description of HH/LSM is included in my work papers, and is titled "Water Supply System Modeling Report, Hetch Hetchy/Local Simulation Model."

HH/LSM is the planning tool used by the SFPUC in its water supply planning process. The current version of the model is a refined and enhanced successor version of the model that was relied upon by the SFPUC and Oak Ridge National Laboratory during the analysis of the 1995 FERC Settlement Agreement. This analysis, in turn, was used to prepare the Final EIS that FERC relied on in approving its 1996 order amending the Article 37 flow schedules.

**Q. WHAT IS THE IMPACT ON THESE FORECASTS IF ADDITIONAL WATER IS REQUIRED TO BE RELEASED AT LA GRANGE DAM,**

**BEYOND WHAT IS CURRENTLY REQUIRED BY THE 1995 FERC SETTLEMENT, AND THE SFPUC SYSTEM IS REQUIRED TO PROVIDE THE DISTRICTS WATER FROM THE SFPUC'S WATER BANK ACCOUNT TO MEET THE ADDITIONAL REQUIREMENT?**

A. If the SFPUC System is required to provide additional water to the Districts, it would reduce the amount of water available for delivery to the SFPUC's wholesale and retail customers. As just described, after assuming no change in release requirements below La Grange Dam, the forecast of SFPUC water supply requires a reduction to SFPUC deliveries below full demand in order to provide a managed approach to delivering a limited supply of water. Additional water provided to the Districts would come from the same finite "bucket of water" that was to be delivered to SFPUC customers – more water provided to the Districts from the SFPUC results in less water delivered to SFPUC customers.

**Q. WHAT IS THE AMOUNT OF ADDITIONAL SHORTAGE THAT WOULD BE CAUSED BY THE ADDITIONAL RELEASES FROM LA GRANGE DAM?**

A. The amount of additional shortage would be approximately equal to the amount of additional release responsibility assigned to the SFPUC. Table 1 below illustrates an example of shortages that could be anticipated. For purposes of this illustration I am assuming the following:

- As described above, the SFPUC system is entering year 2010 with the storage previously stated, and year 2010 runoff equals the runoff actually experienced during 1987. Runoff during year 2011 through year 2015 equals runoff experienced during the drought years 1988 through 1992.

- The current annual water delivery of the SFPUC system (without the current response to drought conservation effects) is 265 MGD.
- The total incremental required release from La Grange Dam to the Tuolumne River is approximately 190,000 acre-feet per year as described by Mr. Monier, TID. This value is the difference between the required release (approximately 307,600 acre-feet/year) proposed by the resource agencies and the current required release under the 1995 FERC Settlement (approximately 115,400 acre-feet/year). The values include the operational buffer described by Mr. Monier and are averaged over the 6-year period.
- The SFPUC system is assumed to provide the Districts with approximately 52% of the incremental required release of 190,000 acre-feet per year, which is an additional release to the Districts of approximately 99,000 acre-feet/year.
- The provision of additional releases to the Districts (i.e., 99,000 acre-feet/year) will come from the diversions to SFPUC customers that would otherwise have occurred, and the SFPUC distributes the incremental shortages across the entire period at a constant level.

*Table 1. Effect of Proposed Incremental Water Releases on Forecast of SFPUC Water Delivery Shortages (2010-2015)*

| **SFPUC Water Supply Outlook** | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 |
|---|---|---|---|---|---|---|
| Projected Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Recurring Year | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
| Existing System Delivery Shortage (%) [1] | 10 | 20 | 20 | 20 | 20 | 20 |
| Existing Delivery (MGD) [2] | 239 | 212 | 212 | 212 | 212 | 212 |
| Existing Delivery (Acre-feet/year) [3] | 267,700 | 237,500 | 237,500 | 237,500 | 237,500 | 237,500 |
| Additional Reduction (Acre-feet) [4] | 99,300 | 99,300 | 99,300 | 99,300 | 99,300 | 99,300 |
| Remaining Delivery (Acre-feet) [5] | 168,400 | 138,200 | 138,200 | 138,200 | 138,200 | 138,200 |
| Remaining Delivery (MGD) [6] | 150 | 123 | 123 | 123 | 123 | 123 |
| Remaining Delivery (%) [7] | 57 | 47 | 47 | 47 | 47 | 47 |
| Shortage after Additional Release (%) [8] | 43 | 53 | 53 | 53 | 53 | 53 |

1. Shortage as a percentage of current delivery of average annual 265 MGD.
   Assumes sequence of 2010 - 2015 runoff is equal to runoff experienced during 1987 - 1992.
2. Average annual delivery after reduction. Full current delivery is an average annual 265 MGD.
3. Average annual delivery after reduction, converted to acre-feet per year.
4. Average annual reduction in SFPUC water supply, illustrated as approximately 52% of the incremental difference in required flow schedule. The reduction calculation assumes that CCSF provides 51.7121% of the difference between the USFWS May 1, 2008 proposal and the existing Article 37 fish flow requirements. While CCSF and the Districts have agreed on the use of this assumption for purposes of modeling in this proceeding, CCSF contends that this assumption is not dictated by the Fourth Agreement and the Districts contend that it is. Neither CCSF nor the Districts waive their respective rights to challenge whether this assumption is required by the Fourth Agreement. Further, this modeling assumption shall not be used as evidence in any proceeding relating to and shall not act as precedence for any allocation of Tuolumne River water between CCSF and the Districts for any purpose.
6. Remaining delivery converted to MGD.
7. Remaining delivery after additional reduction, as a percentage of full current delivery (265 MGD).
8. Shortage as a percentage of current delivery of average annual 265 MGD.

The top half of Table 1 shows the outlook for water supply under current release requirements if the hydrology of 1987 through 1992 were to recur beginning next year. SFPUC's forecast protocols project that full water deliveries would be reduced by 10 percent next year and then subsequently by 20 percent for the remaining 5 years.

The bottom half of the table shows the effects if the La Grange Dam flow schedule of approximately 307,600 acre-feet, which I understand has been recommended by the resource agencies for the near-term, is implemented during this period and the SFPUC is responsible for a portion of the required increment of flow greater than the current requirements. Based on the modeling assumptions I stated earlier, approximately 99,000 acre-feet of water supply would be removed from SFPUC supplies each year of this example. For each year of the forecast period, that reduction in SFPUC's supplies would reduce the amount of water available for delivery to SFPUC's wholesale and retail water customers by an additional 33 percentage points below SFPUC's forecast demand. During 2010, this means that water supply available for delivery would be *43 percent* less than forecast demand, rather than the 10 percent currently projected under the existing flow regime. For the remaining five years, the shortage of 20 percent forecast under existing conditions would be increased to a shortage of 53 percent less per year of forecasted demand.

**Q. IN YOUR FORECASTS YOU HAVE ASSUMED THE RECURRENCE OF THE 1987-1992 DROUGHT PERIOD. ARE THERE OTHER PERIODS OF HISTORY DURING WHICH THEIR RECURRENCE WOULD CAUSE SHORTAGES TO SFPUC DELIVERIES?**

A. Yes. In addition to the 1987-1992 drought sequence, under the current 1995 FERC Settlement the SFPUC system anticipates the need to reduce deliveries to its wholesale and retail customers during the recurrence of drought events such as the single drought year of 1924, and multi-year drought periods such as 1929-1934, 1959-1961, and 1976-1977.

**Q. DOES THIS CONCLUDE YOUR TESTIMONY?**

A. Yes it does.

# DANIEL B. STEINER

CONSULTING ENGINEER

## RESUME

Mr. Steiner is a registered Civil Engineer with 30 years of experience in water resources planning, development and management, including operations planning for multipurpose water systems which have water and power supply, flood control, recreation, fishery and wildlife enhancement and water quality objectives.

## PROFESSIONAL HISTORY

Self-employed: Daniel B. Steiner, Consulting Engineer
Bookman-Edmonston Engineering, Inc., 1991-1993
Resource Management International, Inc., 1983 to 1991
U.S. Bureau of Reclamation, 1977 to 1983

## REGISTRATION AND EDUCATION

Registered Civil Engineer, California

B.S., Civil Engineering, University of California, Davis, 1977

## REPRESENTATIVE EXPERIENCE

Providing technical analyses and interpretation of water and power system operation studies for the San Francisco Public Utilities Commission investigation of a Water System Improvement Program. On behalf of San Francisco, the assistance has included the formulation, review and interpretation of hydrologic studies concerning the proposed program and alternatives. Technical memorandum of modeling procedures and study results were provided for incorporation into an Environmental Impact Statement.

Assisted with the development of an operations simulation model of the New Melones Project. On behalf of the Oakdale Irrigation District and the South San Joaquin Irrigation District a model was developed to simulate the current operation of the New Melones Project as guided by the current Interim Plan of Operations. The model was structured to allow incorporation of alternative operational protocols for water allocations and project objectives, and simulates flow and water quality conditions of the Stanislaus River and the San Joaquin River.

Provided system operation analysis of the Friant Division, Central Valley Project – California, on behalf of the Friant Water Users Authority. The analysis required the development of a model to simulate reservoir, canal and river operations under varying assumptions of river release requirements. The analysis provided an identification of potential water supply impacts to Friant Division water users due to alternative flow requirements, and the effects of alternative releases to San Joaquin River hydrology.

Assisted the San Joaquin River Exchange Contractors Water Authority with an investigation of developing a water transfer program utilizing groundwater substitution for its Bureau of Reclamation exchange water supply. The investigation required the development of a canal operation model to simulate water diversions and deliveries of the Central California Irrigation District and how the deliveries would be affected by pump-in operations.

Participated in the State Water Resources Control Board Periodic Review of the Water Quality Control Plan for Bay-Delta. Developed and presented the results of an analysis depicting the current hydrology and water quality of the San Joaquin River using the CALSIM model. Also provided the results of analyses concerning modifications of water quality and flow objectives at Vernalis.

Assisted with the development of a hydrologic database for the San Joaquin Valley for implementation into the CALSIM II

State-wide simulation model. The effort included research and development of a long-term hydrologic record of streamflows, depletions and accretions. The effort also developed the depiction of current water project operations throughout the Valley. The operations include considerations for water supply, power generation, flood control, water quality and fisheries. The result of the effort is being used within on-going State-wide water modeling and planning.

Directed and performed the hydrologic analyses for the development of water supply alternatives for use in the restoration of habitat in the San Joaquin River. The analyses included the formulation of water supply and management alternatives and the development of models for their evaluation. The scope of the analyses incorporated water conveyance and storage opportunities within the San Joaquin Valley, with an objective to develop water for the restoration of the San Joaquin River below Friant Dam while maintaining diversions to the Friant Division of the Central Valley Project.

Assisted with the development of a system operation planning model for the Marin Municipal Water District. This effort included direct interaction with District staff and its Board of Directors in formulating a model that could simulate the operations of the existing system, and proposed changes to that system in terms of contracted purchases and a potential desalination plant. The current operational criteria and objectives of the system were incorporated into the model to provide a simulation of operations over various hydrologic sequences.

Participated in the California State Water Resources Control Board hearing process regarding the implementation of the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. On behalf of the City and County of San Francisco and other major water right holders in the San Joaquin Valley, provided analyses and testimony regarding alternative methods of implementing the Water Quality Control Plan. The analyses included the determination of anticipated water supply impacts to various water right holders under different theories of responsibility.

Concurrent with the implementation process of the 1995 Water Quality Control Plan, participated in the development of an implementation plan for the San Joaquin River portion of the Water Quality Control Plan. Assistance included technical analyses that supported the negotiation and development of the San Joaquin River Agreement, which incorporates a plan for improving fishery and water quality conditions in the San Joaquin River.

Assisted with the preparation and update of the Urban Water Management Plan report for the City and County of San Francisco. This report to the California legislature includes identification of the City's water supplies and demands, conservation efforts and a plan of operation during drought. In support of this report, directed the development of an end-use water demand forecast model that incorporates factors that represent water conservation programs.

Provided peer review on a proposed groundwater aquifer storage and recovery project in Sacramento County. On behalf of Sacramento County, the project proponent's water demand and water supply concept were reviewed. The water supply concept involved the storage of surface water in a groundwater basin to meet within-year and year-to-year demands, and the intensive management and use of reclaimed water. Assistance was provided to the County with the development of project operation requirements and mitigation measures.

Responsible for the development and performance of technical analyses to determine the yield of the water supply of the City and County of San Francisco. These analyses include evaluation of surface water hydrology and contractual, legislated and water rights entitlements, and the development of operational criteria for a water supply system that provides water to over 2.3 million people. Recent investigations include opportunities to enhance dry-year water supply reliability with the development of reservoir and groundwater storage in the Bay Area, and the exercise of water purchase opportunities.

Participated in the negotiation of a settlement agreement concerning water diversions within the Tuolumne River basin and the mitigation of impacts to the lower Tuolumne River. As the result of a Federal Energy Regulatory Commission evaluation of the New Don Pedro Project, an agreement was reached among water users, resource agencies and environmental and recreation interests for instream flows and non-flow programs for the lower Tuolumne River. Participated as a representative of the City and County of San Francisco in this forum which included the negotiation of an agreement to mitigate potential water supply impacts to the City.

Directed the operation of Central Valley Project facilities in California, including Trinity, Shasta, Folsom, New Melones, Millerton and San Luis Reservoirs and associated water conveyance facilities. These operations required the satisfaction of water quality objectives for the Sacramento-San Joaquin Delta and flood control requirements for project facilities.

Work Papers of Daniel B. Steiner

Index:

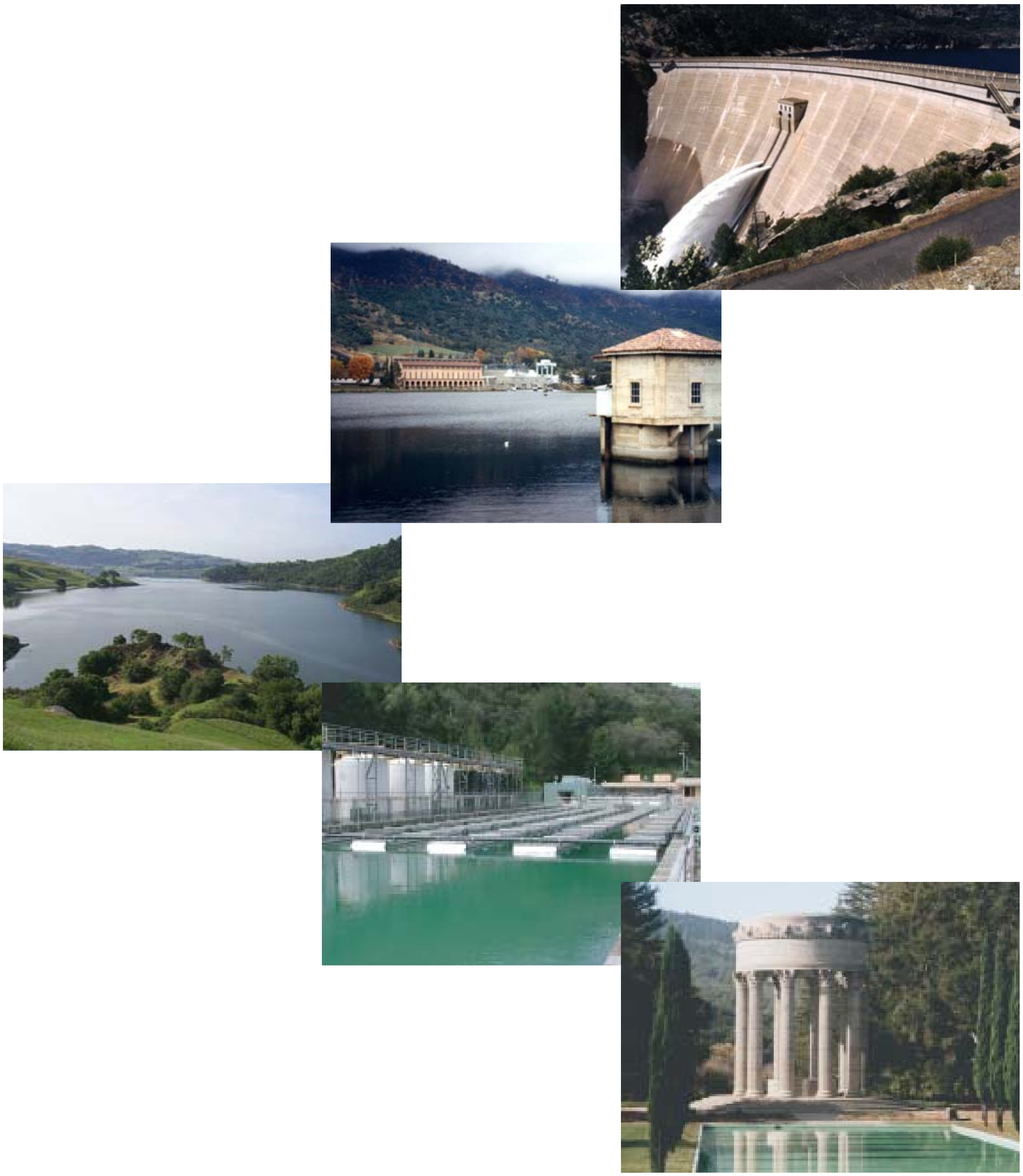
1. Water Supply System Modeling Report – Hetch Hetchy/Local Simulation Model, San Francisco Public Utilities Commission, Prepared by Daniel B. Steiner, Consulting Engineer, May 2007.

2. Figure 5.1-4 Water Supply Sources and Shortages – Existing Conditions (265 mgd Delivery), excerpt from Program Environmental Impact Report for the San Francisco Public Utilities Commission's Water System Improvement Program, City and County of San Francisco Planning Department, June 2007.

3. Computational sheet for Table 1 of direct testimony of Dan Steiner.

September 14, 2009

# Water Supply System Modeling Report
## Hetch Hetchy / Local Simulation Model



**San Francisco Public Utilities Commission**

**Prepared by Daniel B. Steiner, Consulting Engineer**

**May 2007**

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# 1. Introduction

The City and Count of San Francisco (San Francisco), through the San Francisco Public Utilities Commission (SFPUC), owns and operates a complex water supply system that serves 2.4 million people, primarily in San Francisco and the south San Francisco Bay region. The system extends about 167 miles, from Yosemite National Park to San Francisco, and develops water supply from three principal watersheds: the Tuolumne, Alameda, and Peninsula watersheds. The amount of water available to the SFPUC Regional Water System varies depending on meteorological conditions and several authorized, legislated and assigned obligations. The SFPUC operates the Regional Water System to meet customer water demand as fully and efficiently as it can in light of the fact that the amount of water available to it varies from year-to-year.

The operations of the Regional Water System are complex, involving numerous reservoirs, pipelines, and pumping plants. The SFPUC utilizes a computerized mathematical model to assist in the evaluation of its operations: the Hetch Hetchy/Local Simulation Model water supply planning model (referred to as HH/LSM or model). The purpose of this document is to describe this model in terms of the Regional Water System, and how the model represents the system.

HH/LSM incorporates information about key aspects of the SFPUC Regional Water System including facilities (i.e., reservoir and conveyance capacities) and operating procedures and “rules” that determine how and when water is moved through the system to SFPUC customers. Operations of Regional Water System can be generally described by rules and strategies affecting the operation of the Bay Area system and rules and strategies affecting the operation of the Hetch Hetchy Water and Power System (Hetch Hetchy). Although generally viewed separately, the two sub-systems are integrally linked, and are interdependent to each other.

The Bay Area system is depicted as a linked series of inflows, reservoirs, conveyance routes and areas of water demand. Numerous operational constraints are incorporated including considerations for downstream channel conveyance capacity, treatment plant capacity, and water transmission capacity. In general, the Bay Area system is operated to conserve local Bay Area watershed runoff and Tuolumne River water resources. Seasonal storage level objectives for each reservoir have been developed to guide an operation that will conserve local watershed runoff while recognizing an objective to provide emergency and drought protection storage. The operation provides empty reservoir storage space prior to the winter season. This reservoir space is filled with Bay Area watershed runoff and Tuolumne River water by late spring in order to carry maximum reservoir storage into the summer season.

The SFPUC Bay Area system is supplemented with diversions from the Tuolumne River Basin. The model integrates operations at the SFPUC’s three major reservoirs, Hetch Hetchy Reservoir, Lake Lloyd and Lake Eleanor with the operation of the Don Pedro Water Bank Account and the need for supplemental water from the Bay Area system. The operation of these reservoirs and the Don Pedro Water Bank Account is guided by two primary objectives: 1) conserve reservoir storage to optimize diversions, and 2) fulfill the entitlements of Modesto Irrigation District and Turlock Irrigation District (collectively referred to as “MID/TID” or the “Districts”) to flow of the Tuolumne River. Underlying the operations at SFPUC reservoirs are the minimum fishery release requirements prescribed for Hetch Hetchy Reservoir, Lake Lloyd and Lake Eleanor. Water that is released from SFPUC reservoirs and not diverted to San Francisco, and runoff that originates below SFPUC reservoirs flows to Don Pedro Reservoir. HH/LSM simulates the Districts’ operation of Don Pedro Reservoir, including simulation of canal diversions, flood control operations, and releases to meet flow requirements below La Grange Dam. The model also simulates the accounting for the Don Pedro Water Bank Account.

The model uses a watershed runoff forecasting routine (for snowmelt and rainfall) that projects the amount of runoff that can be expected to occur in the Tuolumne River Basin. Once the amount of anticipated runoff is projected, the runoff is compared to the availability of reservoir storage to capture the runoff and the anticipated releases required from the SFPUC reservoirs for downstream requirements and diversions to San Francisco. If SFPUC reservoirs are projected to spill, discretionary releases are managed in order to enhance power generation from Hetch Hetchy.

The model provides a simulation of Regional Water System operations for a long-duration period depicting historical hydrologic conditions. The 82-year period includes many different types and sequences of actual hydrological events that have occurred ranging from flood events to droughts of different magnitude and duration. The long-term 82-year historical record is used in the model to represent the range of hydrologic conditions that could occur in the future. The model is used to assess how the system would perform in terms of an assumed system configuration and assumed operational objectives.

## 2. System Description

The Regional Water System currently provides an annual average normal-year delivery of 265 million gallons per day (mgd), of which the Bay Area watershed resources provide on average approximately 15 percent of the water delivered by San Francisco. The local watershed facilities are operated to conserve local runoff for delivery and provide emergency and drought protection reservoir storage. The water demands that are not met with the conserved local runoff, about 85 percent of current deliveries, require the importation of water from the Tuolumne River Basin. The amount of water available to San Francisco from Hetch Hetchy is constrained by hydrology, physical facilities, and the institutional parameters that allocate the water supply of the Tuolumne River.

The Regional Water System is generally geographically delineated between Hetch Hetchy Water and Power Project facilities and Bay Area system facilities. Hetch Hetchy is generally comprised of the reservoirs, hydroelectric generation and transmission facilities, and water transmission lines from Hetch Hetchy Valley west to the Alameda East Portal. The local Bay Area water system is generally comprised of the facilities from this point west and includes the local watershed reservoirs and distribution system that delivers water to San Francisco’s retail and wholesale customers. Figure 2-1 shows the major facilities of the San Francisco water system.

### 2.1 Hetch Hetchy and the San Joaquin System

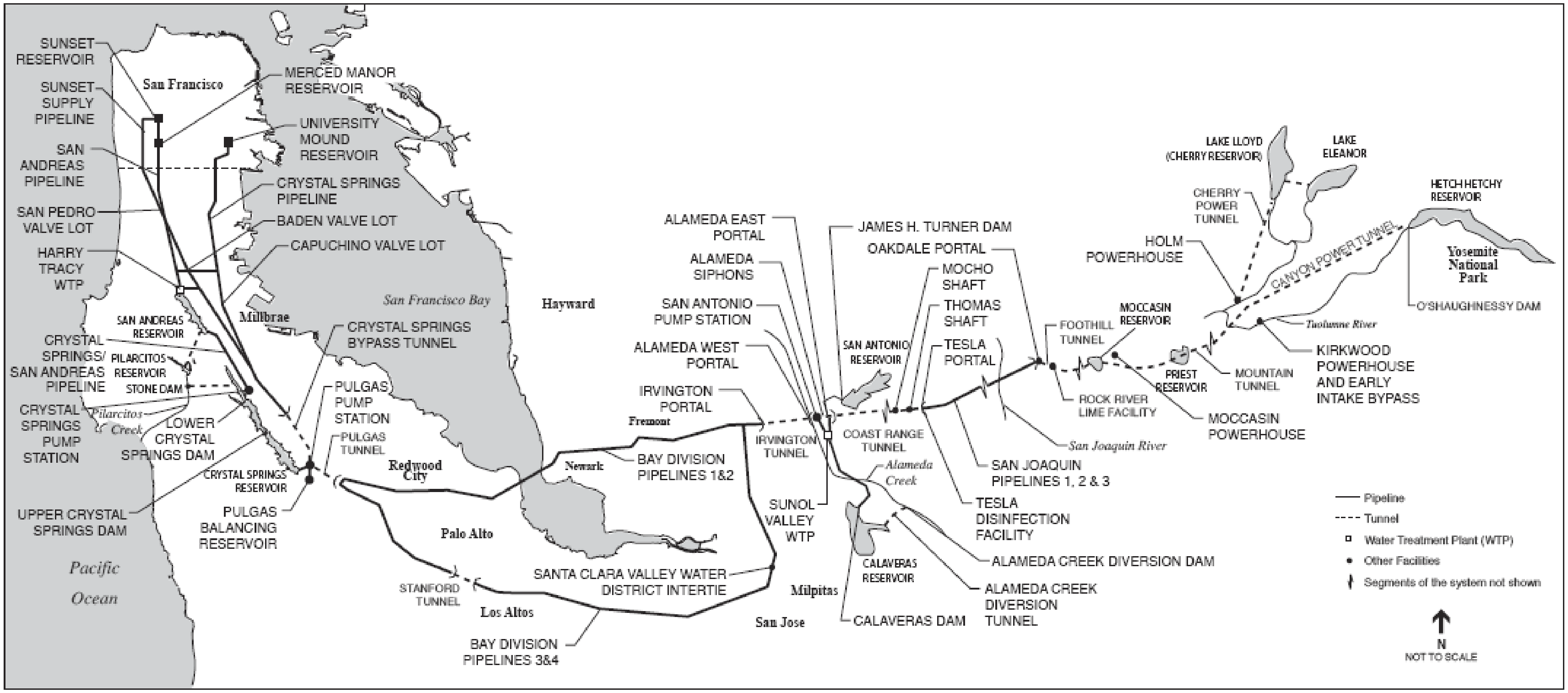
Hetch Hetchy is operated to conserve water from the Tuolumne River watershed for consumptive municipal and industrial use and the production of hydroelectricity. The project is also operated to provide stream flows to benefit fisheries and other wildlife, and for recreation.

Hetch Hetchy Reservoir is located on the main stem of the Tuolumne River at Hetch Hetchy Valley and is formed by the water impounded by O’Shaughnessy Dam. Hetch Hetchy Reservoir has a capacity of 360,400 acre-feet (with drum gates raised, and 340,000 acre-feet with the drum gates lowered) with its inflow primarily occurring from snowmelt within a 459 square mile watershed that is located entirely within Yosemite National Park. The water from Hetch Hetchy Reservoir is used for municipal and industrial water supply, to fulfill downstream obligations and to generate hydroelectric power. Water from Hetch Hetchy Reservoir is delivered to customers without filtration since the quality of this water supply has warranted a filtration exemption from the U.S. Environmental Protection Agency (USEPA) and the California Department of Health Services (DHS). Under normal hydrologic operating conditions, Hetch Hetchy Reservoir is the only reservoir of the project that directly supplies water to the Bay Area.

San Francisco’s other two impounding reservoirs in the Tuolumne River Basin, Lake Eleanor and Lake Lloyd (also called Cherry Reservoir) are used primarily to satisfy downstream obligations to Districts, produce hydroelectric power, and provide flows for fish and other wildlife, and recreational use. Although Lake Eleanor and Lake Lloyd do not normally supply water directly to the Bay Area, they facilitate San Francisco’s use of Hetch Hetchy Reservoir for that purpose. Release of water from these reservoirs can partially fulfill San Francisco’s downstream release obligations thereby allowing flows to be captured in Hetch Hetchy Reservoir for diversion to the Bay Area.

Lake Eleanor has a capacity of 27,100 acre-feet (with flashboards installed, 21,500 acre-feet without flashboards), and is located approximately three miles above the confluence of Eleanor and Cherry Creeks. Lake Lloyd is located on Cherry Creek about four miles above the confluence with Eleanor Creek. Lake Lloyd has a capacity of 273,300 acre-feet with flashboards installed, and 268,800 acre-feet without flashboards. Lake Eleanor and Lake Lloyd are linked by a tunnel and pump facilities that allow water to flow from Lake Eleanor to Lake Lloyd. As a result of this linkage, the two reservoirs may be operated as a single unit. If necessary during emergency or drought conditions, San Francisco can divert water from Cherry Creek through the Lower Cherry Aqueduct to Early Intake where the water can be diverted into the Mountain Tunnel for transport to the Bay Area. This diversion is not currently utilized for

**Figure 2-1**
**Major Facilities of the SFPUC Regional Water System**



water supply delivery. In the event that water from Cherry Creek is diverted into Mountain Tunnel, filtration would be necessary per requirements of the USEPA and the DHS.

As a condition to federal authorization of the Hetch Hetchy, numerous conditions and obligations were imposed on San Francisco which included the requirement to recognize the prior rights of the Districts to divert water from the Tuolumne River. This obligation was formalized in 1913 in the Raker Act as flow entitlements to the Districts. Subsequently during the development of the Don Pedro Project, San Francisco and the Districts entered into agreements to specify the rights and entitlements of each party, and their respective responsibilities for the Don Pedro Project. Among other items, one of the agreements allocates storage space in Don Pedro Reservoir which creates for San Francisco a "water bank account." San Francisco does not directly divert water from Don Pedro Reservoir; however, the water bank account allows San Francisco to balance the Districts' water entitlements with the operation of Hetch Hetchy.

San Francisco's maximum allocation of storage space in Don Pedro Reservoir varies from 570,000 acre-feet (during the flood control season) to 740,000 acre-feet. San Francisco's water bank account grows when the Districts receive inflows to Don Pedro Reservoir greater than their entitlements, and conversely San Francisco debits the water bank account by diverting or storing water that would otherwise be within the entitlements of the Districts.

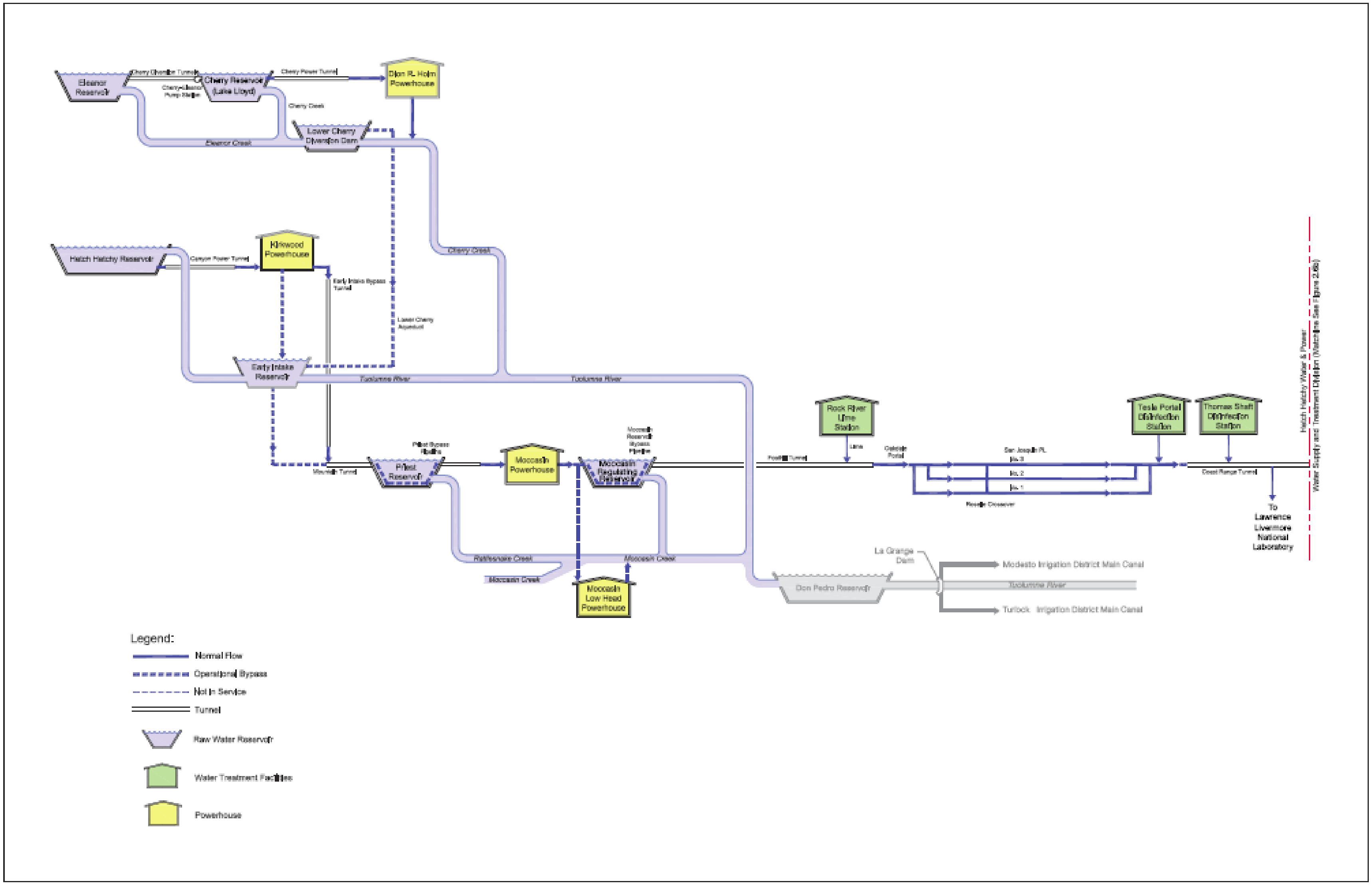
Water that is not released from Lake Eleanor and Lake Lloyd immediately below the impoundments is diverted for generation of hydroelectric power at Holm Powerhouse. Holm Powerhouse is located on Cherry Creek about two miles upstream of its confluence with the Tuolumne River and includes two turbine generators. Water released to Holm Powerhouse returns to Cherry Creek where it flows into the Tuolumne River and subsequently into Don Pedro Reservoir.

Water is diverted at O'Shaughnessy Dam for delivery to the Bay Area and for hydroelectric generation. Water that is diverted at O'Shaughnessy Dam flows through the Canyon Tunnel to the Kirkwood Powerhouse. The powerhouse has three turbine generators. From Kirkwood Powerhouse, water is directly diverted into the Early Intake Bypass, which carries the water into Mountain Tunnel. At times, water diverted to Kirkwood Powerhouse can exceed the conveyance capacity of Mountain Tunnel. At those times, flow that exceeds that capacity is released to the Tuolumne River and flows past Early Intake Dam. These releases eventually reach Don Pedro Reservoir.

Groveland Community Services District, a retail customer, receives its delivery from Mountain Tunnel. Diversions to Mountain Tunnel flow into Priest Reservoir which is located on Rattlesnake Creek near the town of Big Oak Flat. From there the water flows to Moccasin Powerhouse and through two turbine generators. Local watershed inflow at Priest Reservoir is bypassed with the Grizzly Creek diversion structure. Flows through the powerhouse enter Moccasin Reservoir where the water either flows through the Moccasin Reservoir Bypass into the Foothill Tunnel, or is released into Moccasin Creek where it flows to Don Pedro Reservoir. Some of the Moccasin Creek release is diverted through a low head generator. Local watershed runoff to Moccasin Reservoir is bypassed with the Moccasin Creek Diversion Dam and conduit. The Foothill Tunnel runs sixteen miles from Moccasin Reservoir and connects with the three San Joaquin Pipe Lines at the Oakdale Portal.

The San Joaquin Pipelines convey water across the San Joaquin Valley to the Tesla Portal. From Tesla Portal, water travels through the Coast Range Tunnel and emerges at the Alameda East Portal. Figure 2.1-1 shows a general schematic of the linkage of facilities in the Tuolumne River Basin and the facilities traversing the San Joaquin Valley and Coast Range, west to Alameda East Portal.

**Figure 2.1-1**
**Tuolumne River Basin Facilities, West to Alameda East Portal**



## 2.2 Bay Area System

Water supplies from the Alameda watershed are combined with the Hetch Hetchy water supply in Sunol Valley. The Alameda watershed generally refers to the SFPUC-owned lands that are located within the much larger hydrologic boundaries of the greater southern Alameda Creek watershed. Local water supply sources contributing to the water system include Alameda, Arroyo Hondo, and Calaveras Creeks, which provide inflow to Calaveras Reservoir, and San Antonio Creek, which flows to San Antonio Reservoir.

The Alameda East Portal is the connection between the Coast Range Tunnel and the Alameda Siphons. The Alameda Siphons are three pipelines that cross Sunol Valley and travel beneath Alameda Creek, connecting the Coast Range Tunnel at the Alameda East Portal to the Irvington Tunnel at the Alameda West Portal. At the Alameda Siphons, Hetch Hetchy water is combined with water from the Calaveras and San Antonio Reservoirs that has been treated at the Sunol Valley Water Treatment Plant (Sunol Valley WTP). Water deliveries to the Town of Sunol, a retail customer, occur from two of the siphons downstream of the mixing point of Sunol Valley WTP treated water with Hetch Hetchy water.

Calaveras Reservoir, located at the south end of the Alameda watershed, collects and stores water from the local watershed, including drainage from Calaveras Creek and Arroyo Hondo. The reservoir was constructed to a capacity of 96,800 acre-feet (31.5 billion gallons, “bg”) but is currently constrained by California Safety of Dams (DSOD) interim operating restrictions to an operating capacity of 37,800 acre-feet (12.4 bg). Alameda Diversion Dam and Tunnel divert flows from the southern Alameda Creek watershed into Calaveras Reservoir. Water from Calaveras Reservoir flows by gravity through the Calaveras Pipeline to the Sunol Valley WTP for treatment, and then flows to the Alameda Siphons where it is combined with the Hetch Hetchy water supply. Water from Calaveras Reservoir can also be transferred to San Antonio Reservoir.

San Antonio Reservoir and Turner Dam impound water from San Antonio Creek. This reservoir can also receive and store water from the Hetch Hetchy water supply or from Calaveras Reservoir. The reservoir was constructed to a capacity of 50,600 acre-feet (16.4 bg). Water stored in San Antonio Reservoir must be conveyed in the San Antonio Pipeline to the Sunol Valley WTP for treatment before it can be added to the system at the Alameda Siphons.

At the Alameda West Portal, the combined flows enter the Irvington Tunnel. The Irvington Portal in Fremont, at the west end of Irvington Tunnel is where the tunnel connects to the four Bay Division Pipelines (BDPL). BDPL Nos. 1, 2, 3, and 4, two sets of two parallel pipelines, serve multiple purposes: providing water to customers in the East Bay, South Bay, and Peninsula through turnouts along the pipelines; conveying water to users in the northern Peninsula and in San Francisco; and transmitting water to Crystal Springs and San Andreas Reservoirs to supplement local storage in the Bay Area.

BDPL Nos. 1 and 2 pass through the cities of Fremont and Newark, cross San Francisco Bay at the Dumbarton Strait, and continue through East Palo Alto, Redwood City, Menlo Park, and Atherton. The SFPUC’s Palo Alto Pipeline is fed by BDPL Nos. 1 and 2.

BDPL Nos. 3 and 4 extend around the south end of San Francisco Bay. The two pipelines pass through the cities of Fremont, Milpitas, San Jose, Santa Clara, Sunnyvale, Mountain View, Los Altos, Palo Alto, Menlo Park, Atherton, Woodside, and Redwood City. BDPL Nos. 3 and 4 converge into a tunnel at Stanford. BDPL Nos. 3 and 4 reconnect with BDPL Nos. 1 and 2 at the Pulgas Portal entrance to Pulgas Tunnel just west of Redwood City.

Water that is not directly delivered to SFPUC customers flows from Pulgas Portal into Crystal Springs Reservoir. There, Hetch Hetchy water is stored along with water from the local watersheds for later use. As needed, water from Crystal Springs Reservoir is pumped into San Andreas Reservoir.

Crystal Springs Reservoir, which is comprised of upper and lower reservoirs, was constructed to a capacity of approximately 69,360 acre-feet (22.6 bg). Since 1983, the DSOD has placed operational restrictions on Lower Crystal Springs Dam which limits the operational storage to approximately 58,300 acre-feet (19.0 bg). San Andreas Reservoir is supplied water from Crystal Springs Reservoir, Pilarcitos Reservoir and its own watershed. It has a capacity of 19,000 acre-feet (6.2 bg). Before entering the SFPUC distribution system, all water from the peninsula reservoirs is treated at the Harry Tracy Water Treatment Plant.

Pilarcitos Reservoir is located on Pilarcitos Creek on the west slope of the Coast Range in San Mateo County. Pilarcitos Dam collects local drainage and water from Pilarcitos Creek, forming Pilarcitos Reservoir. The reservoir has a capacity of 2,980 acre-feet (0.97 bg). Stone Dam, two miles downstream of Pilarcitos Dam, captures drainage along Pilarcitos Creek below the dam. Water from Pilarcitos Reservoir may be diverted to San Andreas and Crystal Springs Reservoirs through a system of tunnels and pipes. Almost half of Pilarcitos Reservoir supply is used to serve the Half Moon Bay area through wholesale service to the Coastside County Water District (Coastside CWD). Figure 2.2-1 shows a general schematic representation of Bay Area system facilities.

## 2.3 Regional Water System Customers

The SFPUC provides water delivery service to retail and wholesale customers in San Francisco, San Mateo, Santa Clara, Alameda, and Tuolumne Counties to a total of about 2.4 million people. The SFPUC serves about one-third of its water supplies directly to retail customers located primarily in San Francisco, and about two-thirds of its water supplies to 27 wholesale customers by contractual agreement. The 27 wholesale customers consist of 25 cities and water districts and 2 private utilities in San Mateo, Santa Clara, and Alameda Counties, which are represented by the Bay Area Water Supply and Conservation Agency (BAWSCA). Some of these customers have other sources of water in addition to what they receive from the SFPUC system. The SFPUC also provides service to some isolated regional retail customers along the water system, including customers in Tuolumne County. Table 2.3-1 lists the major Regional Water System customers and indicates the wholesale customers that receive water supplies from sources other than the SFPUC. Figure 2.3-1 provides a map of the service area in the Bay Area. The SFPUC currently provides an average annual normal-year delivery of about 265 mgd.

**Table 2.3-1**
**SFPUC Regional Water System Customers**

| **Wholesale Regional Customers (BAWSCA Members)** | | **Major Regional Retail Customers** |
|---|---|---|
| **Peninsula** | **South Bay** | |
| California Water Service Company (South San Francisco* and Mid-Peninsula)<br>City of Brisbane<br>Guadalupe Valley Municipal Improvement District<br>City of Burlingame<br>City of Daly City*<br>City of Millbrae<br>City of San Bruno*<br>Coastside County Water District*<br>Estero Municipal Improvement District (Foster City)<br>North Coast County Water District<br>Town of Hillsborough<br>Westborough County Water District | Alameda County Water District*<br>Mid-Peninsula Water District<br>California Water Service Company (Bear Gulch*)<br>City of Hayward<br>City of Menlo Park*<br>City of Milpitas*<br>City of Mountain View*<br>City of Palo Alto*<br>City Redwood City*<br>City of San Jose (North San Jose Service Area*)<br>City of Sunnyvale*<br>City of Santa Clara*<br>City of East Palo Alto<br>Purissima Hills Water District<br>Skyline County Water District<br>Stanford University* | City and County of San Francisco<br>San Francisco County Jail (San Bruno)<br>San Francisco International Airport (San Mateo Co.)<br>Lawrence Livermore National Laboratory (Site 200/300)<br>National Aeronautics and Space Administration (Santa Clara Co.)<br>Town of Sunol (Alameda Co.)<br>Groveland Community Services District (Tuolumne Co.) |

* Indicates wholesale customers that receive water supplies from sources other than the SFPUC.

**Figure 2.2-1**
**Bay Area System Facilities**

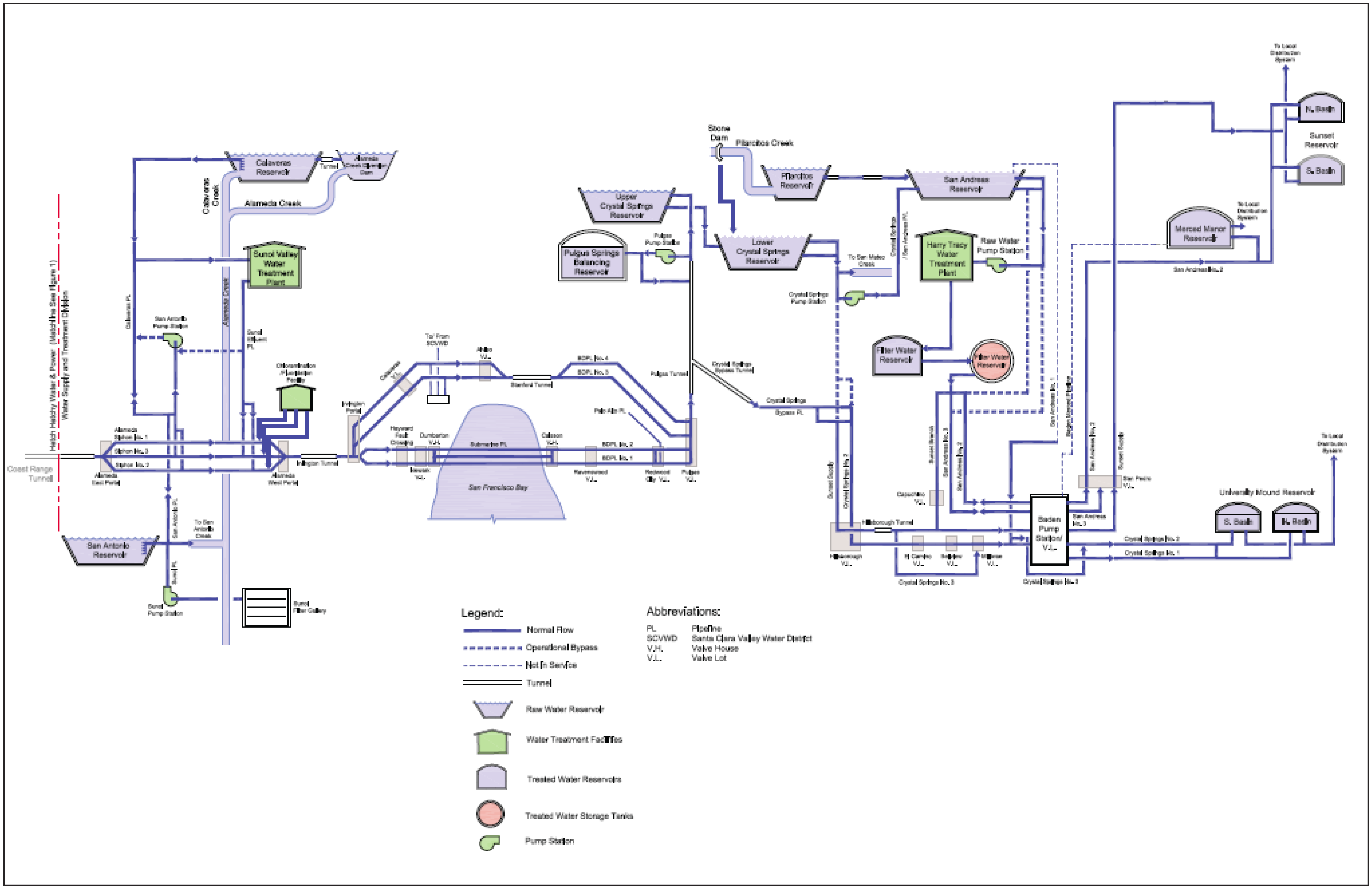
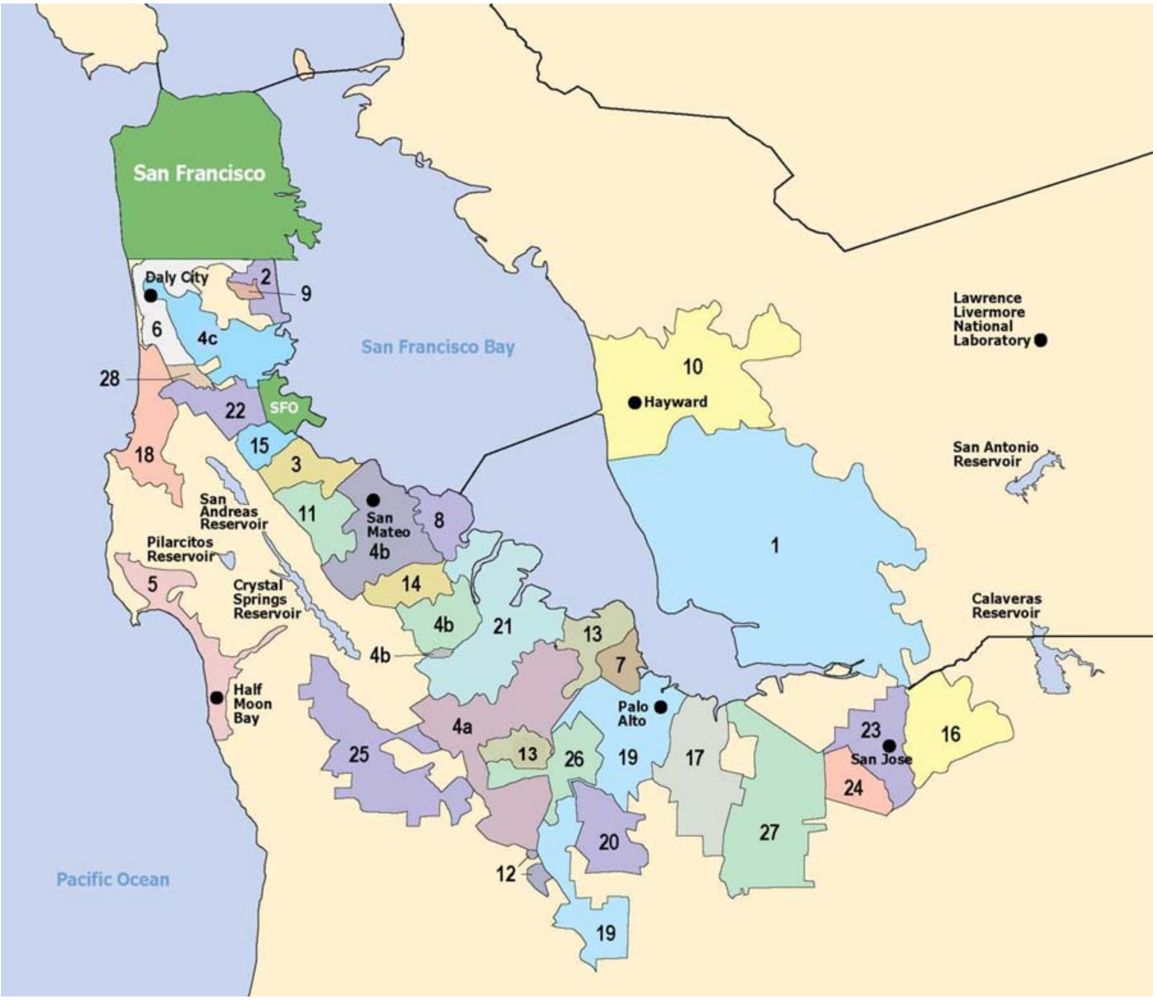


**Figure 2.3-1**
**SFPUC Wholesale and Retail Customers – Bay Area**




*Map courtesy of BAWSCA website*

| # | SFPUC Wholesale Customer |
|---|---|
| 1 | Alameda County Water District |
| 2 | Brisbane, City of |
| 3 | Burlingame, City of |
| 4a | CWS – Bear Gulch District |
| 4b | CWS – Mid Peninsula District |
| 4c | CWS – South San Francisco District |
| 5 | Coastside County Water District |
| 6 | Daly City, City of |
| 7 | East Palo Alto, City of |
| 8 | Estero MID/Foster City |
| 9 | Guadalupe Valley MID |
| 10 | Hayward, City of |
| 11 | Hillsborough, Town of |
| 12 | Los Trancos County Water District |
| 13 | Menlo Park, City of |
| 14 | Mid-Peninsula Water District |
| 15 | Millbrae, City of |
| 16 | Milpitas, City of |
| 17 | Mountain View, City of |
| 18 | North Coast County Water District |
| 19 | Palo Alto, City of |
| 20 | Purissima Hills Water District |
| 21 | Redwood City, City of |
| 22 | San Bruno, City of |
| 23 | San Jose, City of (portion of north San Jose) |
| 24 | Santa Clara, City of |
| 25 | Skyline County Water District |
| 26 | Stanford University |
| 27 | Sunnyvale, City of |
| 28 | Westborough Water District |

CWS - California Water Service (Company)
MID - Municipal Improvement District
Los Trancos Water District was purchased by California Water Service Company following the SFPUC studies published in 2004.

This illustration includes Los Trancos County Water District as a separate customer of the SFPUC. Subsequent to the publication of this illustration Los Trancos County Water District was purchased by California Water Service Company, which now results in 27 customers.

## 2.4 System Operations

Operation of the water system can be generally described by rules and strategies affecting the operation of the Bay Area system and rules and strategies affecting the operation of the Hetch Hetchy system. Although generally viewed separately, the two systems are integrally linked and are interdependent on each other.

SFPUC customer purchase requests are met with a combination of flows from the Hetch Hetchy system and the Bay Area system (sometimes referred to as the “local” system). The SFPUC operates the local reservoirs to conserve local watershed runoff, with diversions from the Hetch Hetchy system used to supplement the supply developed by the local reservoirs. The overriding operating goal of meeting system demand is to ensure that sufficient water is available year-round regardless of hydrologic conditions (drought or nondrought).

System operations and the amount of water delivered to customers vary throughout the year based on the seasonal demand and the availability of water. The availability of water for delivery to customers is affected by numerous factors, including meteorological and hydrologic conditions, the capacity and operating condition of physical facilities and infrastructure, and regulatory/institutional parameters that regulate and allocate the distribution of water from the various sources.

### *2.4.1 Normal System Operations*

Under normal conditions there are sufficient water supplies from rainfall, snowmelt and storage such that water deliveries fulfill customer purchase requests and no systemwide water delivery reduction (rationing) is required.

Water in the Hetch Hetchy system (which includes Hetch Hetchy Reservoir, Lake Lloyd and Lake Eleanor) comes from a combination of rainfall and inflow from the melting snow pack in the Tuolumne River watershed. The majority (approximately 80 percent) of the inflow to the reservoirs occurs during the snowmelt period from April through July.

The SFPUC integrates the operation of its three major Tuolumne River reservoirs, Hetch Hetchy Reservoir, Lake Lloyd, and Lake Eleanor with the operation of the Water Bank Account in Don Pedro Reservoir. The operation of these reservoirs and the Water Bank Account is guided by two primary objectives: 1) conserve Hetch Hetchy Reservoir storage for diversion to meet the water purchase needs of the SFPUC customers, and 2) fulfill the Districts’ entitlement to Tuolumne River water under the Raker Act. There are also downstream release requirements prescribed for Hetch Hetchy Reservoir, Lake Lloyd, and Lake Eleanor.

The primary objective of Hetch Hetchy Reservoir operation is to maximize the volume of water stored in the reservoir (referred to as “carryover storage[1]”) by July 1 of every year. After July 1, typically the end of snowmelt season, Hetch Hetchy Reservoir levels decline as diversions to the Bay Area exceed inflow to the reservoir.

Diversions from the Tuolumne River primarily originate from Hetch Hetchy Reservoir, and incidentally provide hydroelectric generation at Kirkwood and Moccasin Powerhouses. In general, large downstream releases immediately below Hetch Hetchy Reservoir are avoided by regulation of inflow and controlled smaller releases from the reservoir. In anticipation of snowmelt runoff, the SFPUC releases water from Hetch Hetchy Reservoir by sending water through Kirkwood Powerhouse, thus lowering the level of the reservoir and reducing the storage volume to allow room for inflow from snowmelt runoff. This reduction in storage normally begins in early winter as forecasts of snowmelt runoff become available. Drawdown of

[1] “Carryover storage is storage that is in a reservoir available for use in a succeeding period. For the SFPUC system, it is normally defined as the reservoir storage on July 1 of a given year. Carryover storage is a measurement of excess water captured when water is available from preceding periods, such as during the rainy season or wet years, and subsequently available for later use during the dry season and/or drought years.

reservoir storage is determined first by releases necessary to meet water demand and second by the capacity of Kirkwood Powerhouse. If determined necessary due to hydrologic conditions and reservoir storage capacity, additional controlled releases are made to the river.

Similar to the Hetch Hetchy Reservoir operation, the Lake Lloyd and Lake Eleanor system is operated to conserve reservoir inflow for both water supply and hydroelectric generation. Winter and spring operations rely on the occurrence and forecast of runoff that at times allows drawdown of reservoir storage. The drawdown of storage provides for inflow regulation and allows greater utilization of Holm Powerhouse. The water transfer capability from Lake Eleanor to Lake Lloyd through the Eleanor-Cherry Tunnel allows for the utilization of runoff from the Eleanor Creek watershed through Holm Powerhouse. Like Hetch Hetchy Reservoir, maximum carryover storage into the summer season is the primary objective for reservoir operations.

As previously stated, the primary operating strategy is to fill all Hetch Hetchy system reservoirs on or about July 1 of each year. Historically, this occurs in about 75 percent of the years, and generally by April 15 of each year the SFPUC can project the amount of water that will be stored in the system by July 1 of that year.

Operation of the Hetch Hetchy system is integrally linked with and dependent on the local watershed system. While the Hetch Hetchy system provides the majority of the water (about 85 percent), the production from the local watersheds is used first in system operations, and then supplemented with diversions from Hetch Hetchy. The local reservoirs are closer to customers and are operated to maximize emergency and drought protection storage.

San Antonio and Crystal Springs Reservoirs supplement the storage capacity of Hetch Hetchy Reservoir and are operated to maximize use of local resources for annual water deliveries, drought supply, and emergencies. Deliveries from Calaveras Reservoir can be offset by diversions from Hetch Hetchy. Carryover storage in these reservoirs is critical to support the drought preparedness of the water system.

When water in excess of customer demands is available from Hetch Hetchy Reservoir and there is available capacity in the transmission system and local reservoirs, the SFPUC diverts water from the Hetch Hetchy system for storage in local reservoirs, namely San Antonio Reservoir in Sunol Valley and Crystal Springs Reservoir on the Peninsula. This ‘topping off’ or replenishment operation develops carryover storage in the system. Replenishment of local reservoirs is part of the overall strategy for maximizing the available water supply. The operational goal is to replenish storage in local reservoirs during the end of the rainy season with a combination of inflow from the local watershed and water conveyed from the Hetch Hetchy system.

The SFPUC operates the local reservoir system to manage water captured from local watershed runoff and water conveyed from the Hetch Hetchy system. A primary objective of the local reservoir system is to conserve local watershed runoff for delivery. The local reservoir system’s operation is seasonally driven. During the winter season, when rainfall and local watershed runoff occurs, the local reservoirs are managed to maintain sufficient available storage in the reservoirs in order to minimize spills from the reservoirs. In anticipation of or subsequent to storm events, runoff is conveyed to the Harry Tracy and Sunol Valley WTPs to maintain reservoir storage at winter storage objective levels. Towards the end of the winter as the likelihood of rain decreases, the reservoirs are operated to capture local watershed runoff with a goal of maximizing carryover storage in combination with Hetch Hetchy system storage.

During the summer, water drawn from the local reservoirs is minimized in order to preserve the carryover-storage water so it is available in the event of a disruption of flow from Hetch Hetchy or unplanned outages within the system. As the system demand increases past the capacity of flow from the Hetch Hetchy system, water is drawn from the local reservoirs to serve demands. At the beginning of fall, if the demand on local reservoir supplies has not drawn each reservoir down to its winter-time storage objective level, conveyance between the reservoirs, Hetch Hetchy flow rates, and treatment plant flow rates are adjusted to reach winter storage objective levels. However, if storage levels are below objectives, additional water may be conveyed from the Hetch Hetchy system to replenish a reservoir.

While the local watershed systems all have a common general operating strategy, there are unique operations within the different watersheds. As previously described, Calaveras Reservoir's inflow is supplemented by diversions from Alameda Creek through the Alameda Creek Diversion Dam and Tunnel. The typical operation of the diversion is to divert flow from Alameda Creek when it is available up to the capacity of the tunnel. Flow at the diversion site that exceeds the diversion capacity will flow over the diversion dam and contribute to flows in Alameda Creek downstream of the dam. Other than debris-flushing operations normally at the beginning and end of the rainy-season, the diversion tunnel will remain open. The exception to this operation is when Calaveras Reservoir is at or nearing its winter-time storage objective level. During these periods, the gates to the diversion tunnel are closed and all Alameda Creek flow passes the diversion dam. The closed-gate operation is more prevalent under the current DSOD restricted-operation condition of Calaveras Reservoir.

Pilarcitos Reservoir regulates water for delivery to Coastside County Water District (Coastside CWD) and for transfer into the system's San Andreas and Crystal Springs Reservoirs. Pilarcitos Reservoir regulates runoff into the reservoir for release to Pilarcitos Creek for rediversion at Stone Dam to Coastside CWD. Excess water in the watershed is diverted to the water system in the San Mateo Creek watershed. When runoff is greater than the water demand of Coastside CWD and the diversion and storage capacity of the system, the runoff will spill past Stone Dam and continue downstream in Pilarcitos Creek. At times when the water supply from Pilarcitos Reservoir and flow above Stone Dam is less than required by Coastside CWD, Coastside CWD can draw water from Crystal Springs Reservoir as a supplemental source.

None of the local system reservoirs currently have an instream release requirement immediately below its dam. Although the SFPUC has agreed with the California Department of Fish and Game to the maintenance of flows below Calaveras Reservoir, the restricted capacity of Calaveras Reservoir has delayed the implementation of the releases. Both San Mateo Creek, downstream of Crystal Springs Reservoir, and Pilarcitos Creek below Stone Dam, have limited channel capacity due to urban (San Mateo Creek) and agricultural (Pilarcitos Creek) encroachments. Therefore, both reservoirs are operated to minimize reservoir spills.

The water system is highly dependent on storage, both in the Sierras and locally in the Bay Area, to be able to serve water under a wide variety of meteorological/ hydrologic and operating conditions. During system upsets or when unusual water quality conditions occur in any of the reservoirs, the system includes a number of operational bypasses and backup facilities that allow the SFPUC to modify its normal operations and continue to meet water quality standards without interrupting service to its customers.

### *2.4.2 Operations during Drought Periods*

System operations during drought periods require more complex planning and system management than during nondrought years. SFPUC drought planning uses as a backdrop the concepts of a "design drought" and "system firm yield." System firm yield is a measure of the amount of water that can be delivered to customers without shortages during all anticipated hydrologic sequences, including drought periods when rainfall, snowmelt, and/or streamflow conditions are substantially below normal for consecutive years. For planning purposes, the SFPUC uses a design drought that contemplates a more severe drought than historical events and evaluates the system firm yield assuming the system is experiencing the design drought. This premise is founded on experience that illustrates that drought sequences can get more extreme as our hydrologic record lengthens. Studies suggest that there is a 30 percent chance that the SFPUC system will experience a drought in the next 75 years equal to or more severe than the 1987-1992 drought. The design drought is a planning tool developed by the SFPUC used to anticipate and plan for drought; the SFPUC uses a design drought based on the hydrology of the six years of the worst sequential historical drought (1987-1992) plus the 2½ years of the 1976-1977 drought for a combined total of an 8½ year design drought sequence.

With no DSOD storage restriction on Calaveras Dam but with the DSOD restriction on Lower Crystal Springs Dam, the existing system firm yield of the Regional Water System is 226 mgd; however, due to the operating restriction on Calaveras Dam imposed by the DSOD, the existing firm yield of the system is reduced to about 219 mgd. The Regional Water System currently (2005) provides an average normal-year systemwide delivery of about 265 mgd of water to customers on an annual basis. Since these current deliveries (265 mgd) are greater than the system firm yield (226 mgd under normal conditions or 219 under the DSOD restricted conditions), the Regional Water System cannot currently fully meet water deliveries to current customers during a prolonged drought. Reductions in deliveries (i.e., customer rationing) are required during drought periods.

The Regional Water System has experienced drought periods in the last 30 years: most notable are the droughts that occurred from 1976 through 1977, and from 1987 through 1992. During the 1987–1992 drought, even with the implementation of customer rationing, the amount of carryover storage in the regional system was more severely depleted than during any previous period of time, and the SFPUC had to adjust its normal operating procedures to avoid ‘running out of water’.

The 1987–1992 drought began at the end of the 1986 rainy season. Subsequent annual flows in the Tuolumne River were about 50 percent of average. The SFPUC’s entitlement to Tuolumne River flow was reduced to about 16 percent of the total river flow, and less than 50 percent of the normal amount of water delivered to customers was available from the river. As the drought progressed, the SFPUC developed and implemented short-term procedures to impose rationing on customers that resulted in a near 25 percent annual systemwide reduction in water deliveries. The extended drought resulted in the SFPUC adopting a mandatory rationing program from 1988 to 1989 and again from 1990 to 1993. Based on the experience of the 1987–1992 drought, the SFPUC modified its operational procedures with regard to drought planning.

The SFPUC system operations currently include a process for declaring a water shortage and a method for allocating reductions. The general protocol links total reservoir storage conditions to suggested delivery reductions. Each year, during the spring snowmelt period, the SFPUC evaluates the amount of total water storage throughout the system and determines if there is enough water available to serve full deliveries to customers within the context of the current year’s supply and the design drought. At a certain reservoir storage the SFPUC may impose delivery reductions. If reservoir storage becomes further depleted in a following year, the SFPUC may need to impose further delivery reductions. Currently with existing purchase requests there are three stages of delivery reduction: the first stage involves a 5 to 10 percent systemwide delivery reduction and is achieved by voluntary rationing; the second stage imposes an 11 to 20 percent systemwide delivery reduction and requires mandatory rationing; and, at the third stage of response, a 20 percent or greater systemwide delivery reduction would result in mandatory rationing with further reduced allocations. Prior to the initiation of any water delivery reductions, the SFPUC would hold a public meeting, open for public comment, to outline the water supply situation, the proposed water use reduction objectives, alternatives to water use reduction, and compliance monitoring methods.

## 3. Overview of Model

The SFPUC has developed a computerized mathematical model to simulate system operations. The model, known as the Hetch Hetchy/Local Simulation Model (HH/LSM), simulates the operation of San Francisco's Hetch Hetchy facilities, the Don Pedro Project, and the Bay Area reservoir, conveyance and treatment system.

HH/LSM is personal computer-based and is written in Fortran code, with spreadsheet input and output interfaces. The model accommodates modification to incorporate changes in operation assumptions or to allow the testing of proposed modifications to the operation of SFPUC or the Districts' facilities. Certain hydrologic and hydraulic parameters are "input driven" allowing the user to modify hydrology and the representation of physical characteristics such as reservoir capacity, preferred operational storage levels and water demands.

The model simulates system operations over the course of an 82-year sequential hydrologic period from July 1920 through September 2002. The model incorporates actual historic information about the hydrology (the amount of runoff as snowmelt and rainfall) that occurred in each year over the 82-year record for each of the three watershed areas under consideration: the Tuolumne River system, the Alameda Creek system and the Peninsula watershed system. This 82-year period includes many different types and sequences of actual hydrological events that have occurred ranging from flood events to droughts of different magnitude and duration. The long-term 82-year historical record is used in the model to represent the range of hydrologic conditions that could occur in the future. The model is used to assess how the system would perform as the result of an assumed system configuration and assumed operational objectives.

The model uses actual historic hydrology for the depiction of runoff within the watersheds. However, the model is not expected to explicitly replicate observed historical operations in all cases. The past operation of the system in an actual year will differ to some degree from the operations simulated by the model for that year as a result of many factors. These factors include the anomalies in past operation that required system operators to adjust operations throughout the year to respond to prevailing, changing conditions of weather, demand, and facility conditions (maintenance or unplanned facility outages). Also, the model does not incorporate the dynamic physical and institutional changes that have occurred to the system throughout history. Rather, the model is intended to depict operations with an assumed consistent set of systematic operational rules and objectives with a defined system configuration. This steady state of system configuration and operation is then evaluated over a broad range of hydrologic conditions. The utility of the model is the comparison of system performance that changes due to altering the assumptions for the operational rules and objectives, and system configuration.

The model simulates sequential hydrologic events on a monthly time step. That is, the model simulates the operation of facilities on a continuum, from one month to the next, one year to the next. This method of modeling allows the investigation of hydrologic events that vary in sequential duration, and which have varying distributions of runoff. This monthly time-step, with input and results depicted by monthly volumes of water, will not always adequately depict the day-to-day variation of operations, or an operational decision that can occur in less than monthly intervals. For instance, although the model will accurately depict that several thousand acre-feet of reservoir spill will occur from a reservoir in a month (e.g., 24,000 acre-feet in a month), the model results do not provide sufficient information regarding the daily magnitude or duration of the release during that month. A 24,000 acre-foot release during a month could occur as a constant release of 400 cfs per day, or it could represent an 800 cfs release during half of the days during a month. If such information is needed, additional supplemental analyses tiering from the HH/LSM results are required.

HH/LSM is used iteratively, adjusting model input after the review of results from a model study. The model simulates system performance and operations during the recurrence of historical hydrologic events. Parameters reviewed are typically the simulated delivery of water to SFPUC customers and reservoir levels and releases. Model inputs that affect model decisions are adjusted until a simulation achieves an accepted, or desired, performance of the scenario being modeled. Results from two or more simulations are compared to illustrate the effects of alternative system objectives and requirements, operational assumptions and system configurations.

### 3.1 Water Demands

The water demands (purchase requests) of the SFPUC Regional Water System are modeled in HH/LSM. The geographical placement of these demands within the model is important for a representative depiction of system operations. Certain water demands of the SFPUC system are either fully dependent upon certain SFPUC facilities, or are most conveniently or historically served by certain facilities.

The SFPUC system water demand is defined by the summation of the individual water demands of the SFPUC's directly-served customers and the 27 wholesale customers. Almost all of these water demands are located in areas wrapping the San Francisco Bay from the city of Hayward in the east bay, southward to the city of Sunnyvale and portions of Santa Clara County, and then northward up the peninsula into the City and County of San Francisco. The model aggregates these demands into five demand centers (gradients): 1) City, 2) Crystal Springs, 3) San Andreas, 4) South Bay, and 5) Coastside. Figure 3.1-1 illustrates the general geographical delineation of the demand centers as incorporated into HH/LSM.

Each SFPUC system customer is either partially or fully assigned to a demand center for modeling purposes. Lawrence Livermore Laboratory and the directly-served customers in Sunol Valley are assigned to the South Bay demand center; Suburban municipal, commercial and single-family accounts are divided among the South Bay and Crystal Springs demand centers; and the San Francisco Airport is assigned to the Crystal Springs demand center. Groveland Community Services District and other Tuolumne River Basin demands are modeled within the Hetch Hetchy logic of HH/LSM. The monthly pattern of demands for each customer reflects a monthly distribution of historical deliveries, and the individual customer's contribution to a demand center's aggregated total demand shape is weight-averaged.

A single level of average annual water demand, e.g., 265 mgd for a current system simulation, is assumed for all years of the simulation. This average annual water demand is distributed among the demand centers and shaped monthly according to the protocols just described.

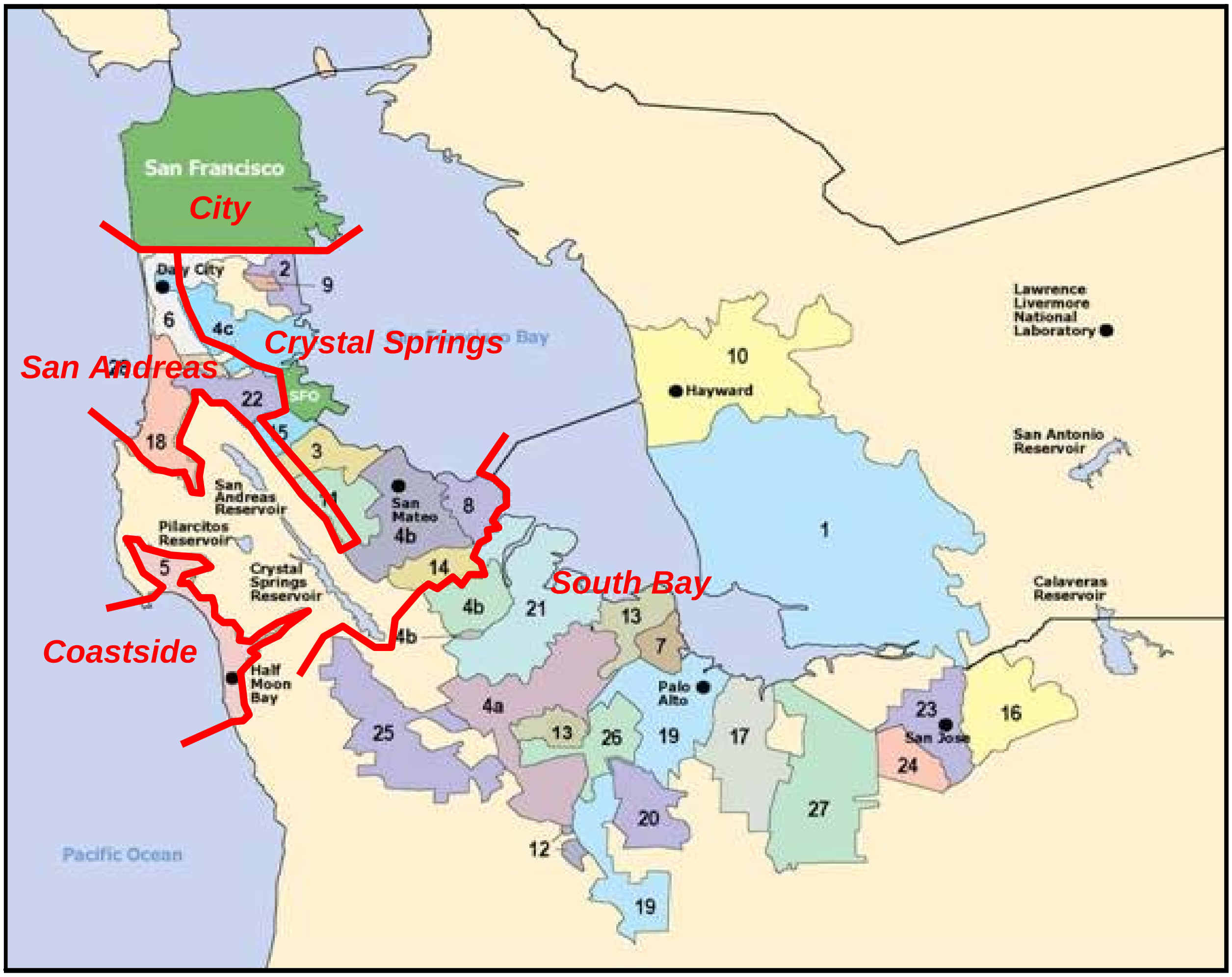
### 3.2 Water Availability and System Performance Studies

The SFPUC quantifies water availability through the performance of two types of analyses. Each of these analyses provides a statement of the ability of the SFPUC Regional Water System to deliver water. The first type of analysis defines the system firm yield of the SFPUC system. As stated above, system firm yield is a measure of the amount of water that can be delivered to customers without shortages during all anticipated hydrologic sequences. System firm yield is the average annual water delivery that can be sustained without shortage throughout the 8½ year design drought. The second type of analysis identifies the reliability of the SFPUC Regional Water System during a recurrence of a long record of hydrologic conditions. The hydrologic record used for these analyses is the 82-year sequence of hydrology previously described. A system firm yield study will identify the rules of operation and delivery rationing that maximizes water deliveries during the design drought. Those rules are then applied within a system performance study to identify the reliability of water deliveries and system operation over a long sequence of hydrology.

#### *3.2.1 System Firm Yield Study*

The system firm yield study is focused on operations and water deliveries during drought sequences. As described previously, the SFPUC uses a design drought that contemplates a more severe drought than historical events, and defines the system firm yield assuming the system is experiencing the design drought. To quantify the system firm yield, operation of the SFPUC system is tested during the design

**Figure 3.1-1**
**SFPUC Water Demand Grouping for Modeling**




| # | SFPUC Wholesale Customer | # | SFPUC Wholesale Customer |
|---|---|---|---|
| 1 | Alameda County Water District | 14 | Mid-Peninsula Water District |
| 2 | Brisbane, City of | 15 | Millbrae, City of |
| 3 | Burlingame, City of | 16 | Milipitas, City of |
| 4a | CWS - Bear Gulch District | 17 | Mountain View, City of |
| 4b | CWS - Mid Peninsula District | 18 | North Coast County Water District |
| 4c | CWS - South San Francisco District | 19 | Palo Alto, City of |
| 5 | Coastside County Water District | 20 | Purissima Hills Water District |
| 6 | Daly City, City of | 21 | Redwood City, City of |
| 7 | East Palo Alto, City of | 22 | San Bruno, City of |
| 8 | Estero MID/Foster City | 23 | San Jose,City (portion of North San Jose) |
| 9 | Guadalupe Valley MID | 24 | Santa Clara, City of |
| 10 | Hayward, City of | 25 | Skyline County Water District |
| 11 | Hillsboruough, Town of | 26 | Stanford University |
| 12 | Los Tancos County Water Distict* | 27 | Sunnyvale, City of |
| 13 | Menlo Park, City of | 28 | Wesborough Water District |

** Los Trancos County Water District is now a part of California Water Service Company*

drought with increasing levels of delivery and varying protocols for rationing until useable reservoir storage is depleted at the end of the design drought. These deliveries are the metric of the amount of water available after satisfying all of the other commitments of the system such as required stream releases and flow obligations to the Districts. Since the level of delivery (percentage of full purchase request) can vary year to year within the design drought, the system firm yield is expressed as the average annual water delivery that can be sustained throughout the entire 8½ year design drought. The analysis that defines system firm yield simulates system reservoir storage being fully depleted at the end of the design drought sequence.

### *3.2.2 Protocol for Modeling System Drought Response and Shortage Levels*

As described above, SFPUC system operations currently include a process for declaring a water shortage and a method for allocating reductions. The protocol links total reservoir storage conditions to suggested delivery reductions. The model mimics this protocol simulating drought related system actions in response to simulated total reservoir storage projected for July 1 of each year. For the current system, modeled drought response occurs as three levels of curtailed (rationed) deliveries, with each successively more severe rationing level occurring as total system reservoir storage is depleted. Modeling results for the design drought period provide the relationship between total system reservoir storage and the level of rationing. The severity of rationing, the frequency of rationing and total system reservoir storage “triggers” are iteratively tested until a viable operation and systematic and acceptable water delivery rule occurs.

Currently with existing purchase requests, there are three modeled stages of drought response: the first stage models a 10 percent systemwide delivery reduction; the second stage models a 20 percent systemwide delivery reduction; and, at the third stage a 25 percent systemwide delivery reduction occurs.

HH/LSM has the functionality to incorporate four levels of drought response. The fourth level of response is also triggered by total system reservoir storage, and can be used as a “switch” to activate a non-rationing form of water supply action. This “level” has been used to activate water purchases, groundwater retrieval, and desalination production prior to, or coincidental to initiating water delivery reductions. The model is also capable of monitoring additional system parameters such as Hetch Hetchy Reservoir storage to additionally constrain system deliveries. The model will make its decision to constrain (or not constrain) system deliveries each year based on the total system reservoir storage, and applies the level of action for a complete year running from July through the following June. Within a year of operation, the action level will be unset when total system reservoir storage reaches a user-specified level, which mimics the relaxation of rationing when the system has recovered from drought conditions.

### 3.3 Model Outputs

HH/LSM provides a robust array of monthly time-step results for each model simulation. Once the operation of the system is modeled under a particular set of assumptions, the model provides output information about how the system performs under that scenario in terms of water in reservoir storage, releases and stream flows, water deliveries, and other parameters associated with the system’s reservoirs, conveyance facilities and treatment plants. The model provides information representing monthly volumes of water, although certain parameters have been converted to flow rates. Table 3.3-1 lists some of the most salient output information provided by the model.

### 3.4 Generalized Model Representation

HH/LSM mimics the operation of the SFPUC Regional Water System, as that operation would vary from season to season and year to year as hydrology changes. A constant level of annual system water demand (purchase request) is assumed each year of simulated operation. The full demand will be met each year except during periods when depleted system storage triggers a reduction from full deliveries. The amount of water demand met by simulated diversions from Hetch Hetchy is the residual amount of water demand that is not met from the Bay Area water supplies.

The water system is depicted as a linked series of inflows, reservoirs, conveyance routes and areas of water demand. The two major groups of logic components of the model separately represent the system as the Hetch Hetchy system and the Bay Area system. The two groups of logic components are joined by the representation of the San Joaquin Pipelines. Diversions from Hetch Hetchy to the Bay Area are dependent on an interaction between the water demand, local Bay Area water supplies and system operation, and the total system reservoir storage of the SFPUC system.

**Table 3.3-1**
**Hetch Hetchy/Local System Model Outputs**

| Feature | Output Parameter |
|---|---|
| Calaveras (MG) | Calaveras Reservoir Storage |
| | Calaveras Reservoir Inflow from Arroyo Hondo |
| | Calaveras Reservoir Inflow from Upper Alameda Creek |
| | Calaveras Reservoir Release to San Antonio Reservoir |
| | Calaveras Reservoir Release to SVWTP |
| | Calaveras Reservoir Release to Calaveras Creek |
| | Calaveras Reservoir Spill to Calaveras Creek |
| | Calaveras Reservoir Evaporation |
| San Antonio (MG) | San Antonio Reservoir Storage |
| | San Antonio Reservoir Inflow from San Antonio Creek |
| | San Antonio Reservoir Inflow from Calaveras Reservoir/SJPL |
| | San Antonio Reservoir Release to Sunol Valley WTP |
| | San Antonio Reservoir Release to San Antonio Creek |
| | San Antonio Reservoir Spill to San Antonio Creek |
| | San Antonio Reservoir Evaporation |
| Crystal Springs (MG) | Crystal Springs Reservoir Storage |
| | Crystal Springs Reservoir Inflow from San Mateo Creek |
| | Crystal Springs Reservoir Inflow from San Andreas Reservoir |
| | Crystal Springs Reservoir Inflow from BDPL |
| | Crystal Springs Reservoir Pumping to San Andreas Reservoir |
| | Crystal Springs Reservoir Pumping to Coastside CWD |
| | Crystal Springs Reservoir Release to San Mateo Creek |
| | Crystal Springs Reservoir Spill to San Mateo Creek |
| | Crystal Springs Reservoir Evaporation |
| San Andreas (MG) | San Andreas Reservoir Storage |
| | San Andreas Reservoir Inflow from Watershed |
| | San Andreas Reservoir Inflow from Crystal Springs, San Mateo Creek & Pilarcitos |
| | San Andreas Reservoir Release to Harry Tracy WTP |
| | San Andreas Reservoir Release to San Mateo Creek |
| | San Andreas Reservoir Spill to San Mateo Creek |
| | San Andreas Reservoir Evaporation |
| Pilarcitos (MG) | Pilarcitos Reservoir Storage |
| | Pilarcitos Reservoir Inflow |
| | Pilarcitos Reservoir Release to San Andreas Reservoir |
| | Pilarcitos Reservoir Release for Stone Diversion to CCWS |
| | Pilarcitos Reservoir Pre-Release to Pilarcitos Creek |
| | Pilarcitos Reservoir Spill to Pilarcitos Creek |
| | Pilarcitos Reservoir Evaporation |
| Stone Dam (MG) | Stone Dam Inflow (Accretion) |
| | Stone Dam Release to Coastside CWD |
| | Stone Dam Release to Crystal Springs Reservoir |
| Reservoir Storage (MG) | Total Reservoir Storage – East Bay |
| | Total Reservoir Storage – Peninsula |
| | Total Local Storage |
| | Maximum Targeted Total Local Storage |

**Table 3.3-1 (continued)**
**Hetch Hetchy/Local System Model Outputs**

| Feature | Output Parameter |
|---|---|
| Demand (MGD) | Delivery to South Bay Demand Center |
| | Delivery to Crystal Springs Demand Center |
| | Delivery to San Andreas Demand Center |
| | Delivery to In-City Demand Center |
| | Total Delivery to Demand Centers (not including Coastside CWD) |
| Demand (MG) | Delivery to South Bay Demand Center |
| | Delivery to Crystal Springs Demand Center |
| | Delivery to San Andreas Demand Center |
| | Delivery to In-City Demand Center |
| | Total Delivery to Demand Centers (not including Coastside CWD) |
| San Joaquin Pipelines (SJPL) | SJPL Flow – MG |
| | SJPL Flow – MGD |
| SJPL (MG) | SJPL Flow to Crystal Springs Reservoir - MG |
| | SJPL Flow to San Antonio Reservoir – MG |
| West Basin Reservoir (MG) | Beginning of Month Storage |
| | West Basin Reservoir - Input Resulting from San Andreas Gradient Deliveries |
| | West Basin Reservoir - Input Resulting from Crystal Springs Gradient Deliveries |
| | End of Month Storage |
| Desalination Project (MG) | Input from Desalination Project |
| Treatment Plant Delivery (MGD) | Calaveras Reservoir Flow to Sunol Valley WTP |
| | San Antonio Reservoir Flow to Sunol Valley WTP |
| | Sunol Valley WTP Production |
| | Harry Tracy WTP Production |
| Unimpaired Inflow (acre-feet) | Inflow to Hetch Hetchy Reservoir |
| | Inflow to Cherry Reservoir |
| | Inflow to Eleanor Reservoir |
| | Unregulated Flow below Hetch Hetchy Reservoirs |
| End-of-month Storage (acre-feet) | Hetch Hetchy Reservoir Storage |
| | Cherry Reservoir Storage |
| | Eleanor Reservoir Storage |
| | Don Pedro Water Bank Account Storage |
| | Don Pedro Reservoir Storage |
| | Total Up-Country Reservoir Storage |
| | Total Hetch Hetchy System Storage |
| Releases (acre-feet) | Hetch Hetchy Reservoir Release to Stream |
| | Hetch Hetchy Reservoir Release to Canyon Tunnel |
| | Lake Lloyd Release to Stream |
| | Lake Lloyd Release to Holm Powerhouse |
| | Lake Eleanor Release to Stream |
| | Lake Eleanor Tunnel to Lake Lloyd |
| Evaporation (acre-feet) | Hetch Hetchy Reservoir |
| | Lake Lloyd |
| | Lake Eleanor |
| SJPL (acre-feet) | SJPL Flow from Lower Cherry Aqueduct |
| | Total SJPL |

**Table 3.3-1 (continued)**
**Hetch Hetchy/Local System Model Outputs**

| Feature | Output Parameter |
|---|---|
| Precipitation (inches) | Hetch Hetchy Precipitation – Accumulated |
| Power Production (MWh) | Moccasin PH |
| | Kirkwood PH |
| | Holm PH |
| | Total |
| Unimpaired Runoff (acre-feet) | Unimpaired Runoff at La Grange |
| | Districts' Rights and Entitlements |
| | Unimpaired Runoff Available to San Francisco |
| Don Pedro Operations (acre-feet) | Inflow |
| | Storage |
| | Don Pedro Reservoir Flood Control Limit |
| | Don Pedro Reservoir Evaporation (San Francisco) |
| | Total Don Pedro Reservoir Evaporation |
| | Don Pedro Reservoir Power – MWh |
| | Total MID Diversion at LaGrange |
| | Total TID Diversion at LaGrange |
| | La Grange Minimum Release Requirement |
| | Total La Grange Release to River |
| | Total Release from Don Pedro Reservoir |
| Water Bank Account – (acre-feet) | Water Bank Account Balance |
| | Water Bank Account Maximum |
| | Transfer to Water Bank Account |
| Miscellaneous | SFPUC Shortage Level |
| | Hetch Hetchy Minimum Stream Release (acre-feet) |

All of the system's reservoirs are guided by an underlying objective to conserve inflow for diversions and required releases. Underlying the Hetch Hetchy system operation are the regulatory and institutional obligations that necessitate releases below SFPUC reservoirs. The model will only release the minimum amount of required flow unless otherwise desired. The model allows the user to select a desired level of water supply certainty. Through model input, the user can choose an operation that varies from making no discretionary releases to the Tuolumne River (e.g., for power) that might result in a lessening of water supply during drought, to making discretionary releases to the Tuolumne River based on a risk assessment of anticipated runoff.

Diversions from Hetch Hetchy Reservoir will incidentally provide hydroelectric generation at Kirkwood and Moccasin powerhouses. The model simulates the power operation of these facilities in addition to simulating the operation of Holm Powerhouse which develops hydroelectric generation from releases from the Lake Lloyd and Lake Eleanor system.

Water that is released from SFPUC reservoirs and not diverted to municipal use, and runoff that originates below SFPUC reservoirs flows to Don Pedro Reservoir. HH/LSM simulates the Districts' operation of Don Pedro Reservoir including the simulation of canal diversions, flood control operations, and releases to meet flow requirements below La Grange Dam. The model also simulates the accounting for the Water Bank Account in Don Pedro Reservoir.

The group of model components that represent the Bay Area system integrates with the Hetch Hetchy operation, and determines the call for water from Hetch Hetchy. Numerous operational constraints are incorporated into the local system's modeled operation including considerations for limited downstream channel conveyance capacity, treatment plant capacity, and water transmission capability. In general, the Bay Area system is modeled to conserve local Bay Area watershed runoff and when possible, to conserve Tuolumne River water resources. Seasonal storage targets for each Bay Area reservoir have been developed. The seasonal process (storage targets) provides empty reservoir storage space prior to the winter season. This reservoir space is filled with Bay Area watershed runoff and Tuolumne River water by late spring in order to carry maximum reservoir storage into the summer season. The reservoir storage targets incorporate several considerations including downstream channel capacity constraints (Crystal Springs Reservoir) and treatment plant capacity constraints which limit the rate of use of Bay Area reservoir waters.

# 4. Model Inputs

Numerous user-defined data and parameters provide HH/LSM the information to define and perform a study. This section describes the inputs to HH/LSM. The inputs are grouped into subsections: Hydrology, Facilities, Minimum Release Requirements, and Operations.

## 4.1 Hydrology

This section describes the basic hydrologic data that are included in operation simulations. Regardless of operational assumptions these data remain constant among simulations providing the underlying hydrology for the system. These basic data represent inflows to reservoirs and other required basic hydrologic information.

### *4.1.1 Precipitation*

As will be described later, minimum stream releases below Hetch Hetchy Reservoir depend, in part, on the annual accumulated precipitation at Hetch Hetchy Reservoir. Table 4.1.1-1 illustrates the accumulated precipitation at Hetch Hetchy Reservoir for each month of the simulation period. This is the only precipitation parameter used for modeling the system.

### *4.1.2 Unimpaired Runoff and Reservoir Inflows*

Underlying the regulated flow within the system is the runoff that naturally occurs due to precipitation and snowmelt. Regardless of the ability of San Francisco and the Districts to regulate this runoff, natural runoff will only vary due to the day-to-day, season-to-season and year-to-year variability of weather. The historical, naturally occurring runoff at the various locations of interest was determined by several methods of analysis. The methods of analysis used to estimate runoff varied among the locations due to the availability of recorded data or the nature of the data item being determined. Common to all the developed data is the length of record used during the simulation of operations.

4.1.2.1 Unimpaired Runoff at La Grange Dam

A fundamental hydrologic parameter of the Tuolumne River is the calculated unimpaired runoff at La Grange Dam. These data represent the amount of flow which would occur at this location if San Francisco and District facilities did not regulate or divert the naturally occurring runoff in the basin. The annual unimpaired runoff at La Grange Dam for the 1921-2002 hydrologic period has ranged from a minimum of 381,900 acre-feet (1977) to 4,631,400 acre-feet (1983). The average annual unimpaired runoff is computed to be 1,850,100 acre-feet.

Table 4.1.2.1-1 depicts the record of unimpaired runoff at La Grange Dam for the hydrologic period October 1921, through September 2002.

4.1.2.2 Inflow to Hetch Hetchy Reservoir

Tributaries upstream of Hetch Hetchy Reservoir are essentially in their natural state, with few diversions or regulation occurring. The record of inflow for Hetch Hetchy Reservoir has been developed by use of actual stream measurements (prior to construction of Hetch Hetchy Reservoir), and subsequently the calculation of inflow based on the operation records of Hetch Hetchy Reservoir. Table 4.1.2.2-1 depicts the record of inflow for Hetch Hetchy Reservoir. Annual inflow has ranged from a low of 206,400 acre-feet (1977) to a maximum of 1,697,700 acre-feet (1983). The average annual inflow to Hetch Hetchy Reservoir is 749,600 acre-feet.

**Table 4.1.1-1**
**Accumulated Precipitation at Hetch Hetchy Reservoir (Inches – Beginning October 1)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 6 | 11 | 16 | 27 | 31 | 35 | 36 | 39 | 39 | 39 | 39 | 39 |
| 1922 | 1 | 1 | 11 | 15 | 21 | 28 | 28 | 31 | 31 | 31 | 31 | 31 |
| 1923 | 2 | 5 | 13 | 18 | 19 | 19 | 28 | 29 | 30 | 31 | 31 | 33 |
| 1924 | 1 | 2 | 4 | 7 | 9 | 13 | 15 | 15 | 15 | 15 | 15 | 15 |
| 1925 | 5 | 8 | 14 | 16 | 29 | 35 | 39 | 42 | 43 | 43 | 44 | 45 |
| 1926 | 3 | 5 | 7 | 11 | 19 | 20 | 25 | 26 | 26 | 27 | 27 | 27 |
| 1927 | 0 | 12 | 13 | 18 | 28 | 32 | 36 | 37 | 38 | 38 | 38 | 38 |
| 1928 | 5 | 11 | 15 | 17 | 20 | 31 | 34 | 35 | 36 | 36 | 36 | 36 |
| 1929 | 0 | 3 | 7 | 8 | 12 | 18 | 22 | 23 | 26 | 26 | 26 | 27 |
| 1930 | 0 | 0 | 4 | 11 | 15 | 19 | 23 | 25 | 25 | 25 | 25 | 27 |
| 1931 | 1 | 5 | 5 | 10 | 13 | 15 | 18 | 20 | 22 | 22 | 22 | 22 |
| 1932 | 1 | 5 | 17 | 22 | 30 | 31 | 33 | 37 | 38 | 38 | 38 | 38 |
| 1933 | 0 | 0 | 3 | 11 | 13 | 16 | 17 | 20 | 21 | 22 | 22 | 22 |
| 1934 | 1 | 2 | 8 | 12 | 19 | 19 | 20 | 21 | 23 | 23 | 23 | 24 |
| 1935 | 2 | 8 | 12 | 22 | 25 | 31 | 40 | 41 | 41 | 41 | 41 | 41 |
| 1936 | 2 | 4 | 6 | 14 | 31 | 32 | 35 | 36 | 38 | 38 | 38 | 38 |
| 1937 | 1 | 2 | 11 | 16 | 28 | 34 | 36 | 36 | 36 | 37 | 37 | 37 |
| 1938 | 1 | 4 | 14 | 20 | 34 | 47 | 52 | 54 | 55 | 56 | 56 | 57 |
| 1939 | 5 | 7 | 9 | 13 | 16 | 21 | 22 | 24 | 25 | 25 | 25 | 28 |
| 1940 | 5 | 6 | 7 | 20 | 30 | 37 | 38 | 39 | 39 | 39 | 39 | 39 |
| 1941 | 3 | 4 | 19 | 25 | 32 | 37 | 42 | 44 | 44 | 44 | 44 | 44 |
| 1942 | 2 | 6 | 19 | 23 | 29 | 31 | 37 | 41 | 41 | 41 | 41 | 42 |
| 1943 | 1 | 8 | 13 | 23 | 26 | 37 | 39 | 40 | 41 | 41 | 41 | 41 |
| 1944 | 2 | 5 | 7 | 12 | 18 | 22 | 27 | 28 | 29 | 29 | 29 | 29 |
| 1945 | 2 | 11 | 15 | 16 | 26 | 33 | 34 | 36 | 37 | 37 | 38 | 38 |
| 1946 | 6 | 12 | 22 | 23 | 26 | 33 | 33 | 35 | 35 | 36 | 36 | 36 |
| 1947 | 3 | 11 | 15 | 17 | 19 | 23 | 25 | 27 | 27 | 27 | 27 | 27 |
| 1948 | 5 | 7 | 8 | 10 | 14 | 22 | 30 | 32 | 33 | 33 | 33 | 33 |
| 1949 | 1 | 2 | 8 | 11 | 16 | 23 | 23 | 26 | 26 | 26 | 26 | 26 |
| 1950 | 0 | 4 | 6 | 16 | 18 | 24 | 29 | 30 | 30 | 30 | 30 | 30 |
| 1951 | 5 | 20 | 32 | 37 | 41 | 44 | 46 | 48 | 49 | 49 | 49 | 49 |
| 1952 | 2 | 7 | 19 | 29 | 35 | 42 | 46 | 47 | 48 | 48 | 48 | 49 |
| 1953 | 0 | 2 | 11 | 17 | 17 | 20 | 24 | 28 | 29 | 31 | 31 | 31 |
| 1954 | 1 | 4 | 6 | 13 | 19 | 27 | 30 | 31 | 33 | 33 | 33 | 33 |
| 1955 | 0 | 3 | 11 | 16 | 18 | 20 | 24 | 26 | 26 | 26 | 26 | 26 |
| 1956 | 0 | 7 | 30 | 41 | 43 | 44 | 48 | 52 | 52 | 52 | 52 | 53 |
| 1957 | 3 | 3 | 4 | 9 | 14 | 20 | 23 | 28 | 29 | 29 | 29 | 29 |
| 1958 | 2 | 5 | 10 | 16 | 24 | 35 | 40 | 41 | 44 | 44 | 44 | 46 |
| 1959 | 0 | 2 | 3 | 9 | 17 | 18 | 21 | 22 | 22 | 23 | 23 | 27 |
| 1960 | 0 | 0 | 1 | 5 | 13 | 19 | 21 | 22 | 22 | 22 | 22 | 22 |
| 1961 | 1 | 6 | 9 | 11 | 13 | 18 | 20 | 22 | 23 | 23 | 24 | 25 |
| 1962 | 1 | 4 | 7 | 9 | 24 | 29 | 30 | 31 | 31 | 32 | 32 | 33 |
| 1963 | 2 | 3 | 5 | 11 | 19 | 25 | 33 | 36 | 39 | 39 | 39 | 40 |
| 1964 | 2 | 9 | 10 | 14 | 14 | 18 | 20 | 23 | 25 | 25 | 25 | 25 |
| 1965 | 2 | 9 | 26 | 31 | 33 | 36 | 40 | 41 | 41 | 41 | 45 | 45 |
| 1966 | 1 | 12 | 16 | 18 | 21 | 21 | 24 | 25 | 25 | 26 | 26 | 26 |
| 1967 | 0 | 7 | 15 | 23 | 24 | 33 | 46 | 47 | 49 | 49 | 49 | 50 |
| 1968 | 0 | 3 | 6 | 10 | 15 | 18 | 19 | 20 | 20 | 20 | 21 | 21 |
| 1969 | 3 | 9 | 18 | 37 | 46 | 49 | 54 | 54 | 56 | 56 | 56 | 56 |
| 1970 | 4 | 6 | 10 | 24 | 27 | 30 | 33 | 33 | 35 | 35 | 35 | 35 |
| 1971 | 1 | 10 | 18 | 20 | 21 | 25 | 27 | 30 | 30 | 30 | 30 | 31 |
| 1972 | 1 | 6 | 15 | 17 | 19 | 19 | 23 | 23 | 24 | 24 | 24 | 25 |
| 1973 | 1 | 7 | 12 | 19 | 28 | 33 | 34 | 35 | 35 | 35 | 36 | 36 |
| 1974 | 3 | 11 | 19 | 24 | 25 | 33 | 38 | 38 | 38 | 38 | 38 | 38 |
| 1975 | 3 | 5 | 9 | 12 | 22 | 30 | 36 | 36 | 37 | 39 | 41 | 41 |
| 1976 | 7 | 8 | 9 | 9 | 13 | 16 | 18 | 20 | 20 | 20 | 21 | 22 |
| 1977 | 2 | 3 | 3 | 5 | 8 | 9 | 10 | 14 | 16 | 16 | 16 | 17 |
| 1978 | 1 | 6 | 16 | 26 | 37 | 46 | 55 | 55 | 56 | 56 | 56 | 60 |
| 1979 | 0 | 4 | 7 | 19 | 28 | 33 | 35 | 37 | 37 | 37 | 37 | 37 |
| 1980 | 3 | 7 | 12 | 28 | 41 | 46 | 48 | 51 | 51 | 51 | 51 | 51 |
| 1981 | 1 | 2 | 5 | 13 | 16 | 23 | 25 | 27 | 27 | 27 | 27 | 27 |
| 1982 | 5 | 13 | 21 | 29 | 35 | 44 | 50 | 50 | 52 | 52 | 52 | 56 |
| 1983 | 6 | 16 | 25 | 35 | 45 | 61 | 68 | 69 | 70 | 70 | 70 | 73 |
| 1984 | 1 | 15 | 27 | 27 | 32 | 35 | 37 | 38 | 40 | 40 | 40 | 40 |
| 1985 | 4 | 13 | 14 | 15 | 18 | 24 | 25 | 25 | 26 | 26 | 26 | 28 |
| 1986 | 3 | 9 | 13 | 17 | 34 | 41 | 43 | 44 | 44 | 45 | 45 | 47 |
| 1987 | 0 | 0 | 1 | 5 | 9 | 13 | 15 | 16 | 16 | 17 | 17 | 17 |
| 1988 | 3 | 7 | 11 | 16 | 17 | 17 | 21 | 23 | 24 | 24 | 24 | 24 |
| 1989 | 0 | 7 | 13 | 13 | 17 | 26 | 28 | 29 | 30 | 30 | 30 | 30 |
| 1990 | 0 | 1 | 7 | 12 | 14 | 16 | 19 | 19 | 20 | 20 | 20 | 21 |
| 1991 | 1 | 2 | 4 | 4 | 5 | 21 | 22 | 24 | 25 | 25 | 25 | 25 |
| 1992 | 4 | 6 | 8 | 10 | 16 | 19 | 19 | 20 | 22 | 25 | 25 | 25 |
| 1993 | 4 | 4 | 12 | 23 | 31 | 35 | 37 | 38 | 40 | 40 | 40 | 40 |
| 1994 | 2 | 4 | 6 | 8 | 13 | 15 | 18 | 20 | 20 | 20 | 20 | 21 |
| 1995 | 2 | 11 | 15 | 30 | 30 | 47 | 55 | 60 | 61 | 61 | 61 | 61 |
| 1996 | 0 | 0 | 8 | 17 | 27 | 31 | 35 | 39 | 40 | 40 | 41 | 41 |
| 1997 | 2 | 12 | 27 | 44 | 44 | 45 | 46 | 47 | 48 | 48 | 48 | 48 |
| 1998 | 1 | 5 | 9 | 21 | 35 | 42 | 46 | 53 | 56 | 56 | 56 | 58 |
| 1999 | 0 | 5 | 9 | 18 | 27 | 29 | 32 | 33 | 34 | 34 | 34 | 34 |
| 2000 | 1 | 4 | 4 | 14 | 26 | 29 | 33 | 36 | 38 | 38 | 38 | 39 |
| 2001 | 4 | 5 | 6 | 12 | 17 | 20 | 26 | 26 | 26 | 27 | 27 | 27 |
| 2002 | 1 | 8 | 18 | 20 | 22 | 26 | 28 | 31 | 31 | 31 | 31 | 31 |
| Avg (21-02) | 2 | 6 | 12 | 18 | 23 | 28 | 32 | 34 | 34 | 35 | 35 | 35 |

## Table 4.1.2.1-1
## Unimpaired Flow at La Grange Dam (Acre-feet)

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 41,076 | 53,296 | 69,546 | 196,199 | 155,944 | 231,774 | 254,350 | 442,185 | 458,320 | 95,173 | 13,498 | 6,563 | 2,017,924 |
| 1922 | 5,796 | 6,084 | 54,599 | 71,722 | 189,459 | 181,279 | 260,346 | 717,525 | 751,926 | 194,559 | 27,217 | 10,393 | 2,470,905 |
| 1923 | 10,604 | 31,609 | 123,931 | 113,587 | 79,515 | 113,105 | 265,739 | 521,296 | 319,127 | 157,837 | 27,338 | 22,266 | 1,785,954 |
| 1924 | 28,512 | 13,624 | 13,757 | 25,335 | 41,623 | 37,857 | 138,855 | 209,395 | 16,850 | 16,810 | -1,890 | -3,917 | 536,811 |
| 1925 | 14,660 | 47,909 | 51,045 | 44,255 | 227,090 | 165,638 | 350,329 | 538,439 | 352,379 | 111,858 | 22,649 | 5,853 | 1,932,104 |
| 1926 | 15,116 | 16,209 | 32,763 | 18,952 | 100,584 | 127,438 | 382,302 | 303,784 | 89,230 | 18,914 | 3,253 | 1,377 | 1,109,922 |
| 1927 | 5,482 | 74,075 | 60,016 | 63,203 | 223,125 | 159,717 | 351,499 | 454,088 | 476,184 | 146,291 | 24,589 | 13,119 | 2,051,388 |
| 1928 | 15,342 | 87,011 | 44,108 | 51,263 | 82,207 | 343,418 | 263,768 | 447,773 | 152,652 | 27,622 | 7,301 | 2,563 | 1,525,028 |
| 1929 | -543 | 5,788 | 18,115 | 19,057 | 40,449 | 99,404 | 148,100 | 378,119 | 224,686 | 40,740 | 4,568 | -9,271 | 969,212 |
| 1930 | 1,860 | 1,236 | 23,026 | 39,027 | 70,064 | 146,572 | 245,919 | 274,802 | 286,227 | 48,843 | 9,989 | -970 | 1,146,595 |
| 1931 | 9,023 | 20,372 | 10,715 | 26,087 | 44,485 | 66,268 | 154,028 | 209,322 | 49,010 | 10,219 | 940 | 1,805 | 602,274 |
| 1932 | 1,680 | 6,042 | 93,661 | 79,368 | 240,198 | 171,588 | 245,048 | 524,154 | 532,657 | 175,844 | 31,968 | 12,044 | 2,114,252 |
| 1933 | 5,718 | 3,197 | 10,858 | 26,901 | 31,476 | 82,585 | 170,939 | 250,816 | 426,145 | 75,096 | 16,066 | 4,540 | 1,104,337 |
| 1934 | -292 | 7,958 | 40,848 | 64,905 | 89,980 | 150,248 | 186,390 | 149,036 | 95,092 | 12,073 | 6,109 | 4,566 | 806,913 |
| 1935 | 11,183 | 47,622 | 51,951 | 105,903 | 107,268 | 136,887 | 465,489 | 530,698 | 511,475 | 109,587 | 20,725 | 4,070 | 2,102,858 |
| 1936 | 11,591 | 19,587 | 18,155 | 104,787 | 351,981 | 207,525 | 392,941 | 520,229 | 390,216 | 122,450 | 17,810 | 2,924 | 2,160,196 |
| 1937 | 4,318 | 8,610 | 27,322 | 31,434 | 273,903 | 209,510 | 295,599 | 633,901 | 399,410 | 91,359 | 16,854 | 4,798 | 1,997,018 |
| 1938 | 9,154 | 18,758 | 312,561 | 101,938 | 322,739 | 424,839 | 422,380 | 720,160 | 711,600 | 305,191 | 55,468 | 19,537 | 3,424,325 |
| 1939 | 40,248 | 43,485 | 36,718 | 42,594 | 59,919 | 144,114 | 281,901 | 216,036 | 74,337 | 17,344 | 7,484 | 16,834 | 981,014 |
| 1940 | 44,943 | 16,616 | 20,248 | 226,488 | 250,001 | 344,136 | 324,857 | 571,098 | 347,501 | 54,156 | 10,755 | 2,015 | 2,212,814 |
| 1941 | 11,306 | 15,005 | 129,055 | 115,450 | 218,996 | 260,080 | 279,587 | 662,676 | 534,437 | 224,055 | 30,489 | 8,189 | 2,489,325 |
| 1942 | 7,038 | 37,559 | 161,534 | 164,811 | 142,433 | 148,707 | 336,994 | 471,991 | 597,584 | 253,443 | 30,160 | 3,279 | 2,355,533 |
| 1943 | 5,053 | 86,407 | 92,847 | 246,319 | 163,756 | 371,921 | 385,171 | 494,527 | 352,890 | 140,897 | 24,802 | 5,205 | 2,369,795 |
| 1944 | 11,602 | 15,626 | 20,933 | 42,727 | 80,413 | 135,224 | 164,620 | 455,797 | 267,180 | 87,627 | 11,203 | 2,362 | 1,295,314 |
| 1945 | 9,122 | 89,046 | 81,309 | 55,601 | 304,843 | 164,410 | 284,264 | 455,072 | 462,260 | 163,056 | 16,762 | -1,174 | 2,084,571 |
| 1946 | 60,306 | 98,295 | 207,738 | 118,911 | 69,889 | 155,802 | 347,842 | 488,513 | 264,554 | 56,169 | 7,927 | 3,364 | 1,879,310 |
| 1947 | 16,070 | 64,001 | 76,715 | 41,875 | 80,221 | 136,057 | 192,224 | 352,497 | 110,745 | 20,882 | -601 | 2,884 | 1,093,570 |
| 1948 | 38,204 | 28,149 | 17,171 | 39,677 | 25,862 | 73,007 | 220,653 | 436,245 | 433,764 | 87,725 | 5,173 | 2,475 | 1,408,105 |
| 1949 | 5,147 | 8,211 | 17,768 | 19,899 | 39,117 | 123,239 | 318,247 | 436,422 | 240,367 | 29,469 | 4,511 | 3,717 | 1,246,114 |
| 1950 | 3,915 | 14,216 | 13,418 | 77,458 | 124,323 | 128,314 | 329,129 | 467,436 | 319,386 | 62,240 | 6,514 | -817 | 1,545,532 |
| 1951 | 24,439 | 521,560 | 508,994 | 159,244 | 138,911 | 168,700 | 253,809 | 372,863 | 256,731 | 60,101 | 9,570 | 272 | 2,475,194 |
| 1952 | 9,023 | 30,850 | 121,412 | 218,693 | 147,758 | 239,843 | 466,417 | 791,330 | 594,182 | 291,864 | 54,091 | 16,905 | 2,982,368 |
| 1953 | 8,666 | 11,861 | 53,056 | 145,087 | 63,531 | 106,649 | 269,599 | 259,519 | 414,411 | 169,821 | 17,793 | 5,397 | 1,525,390 |
| 1954 | 7,325 | 17,169 | 24,196 | 41,891 | 101,379 | 213,203 | 349,174 | 447,548 | 185,141 | 37,924 | 3,082 | 1,154 | 1,429,186 |
| 1955 | 4,062 | 15,380 | 49,991 | 66,700 | 61,166 | 82,395 | 143,952 | 366,448 | 292,177 | 39,300 | 924 | 1,204 | 1,123,699 |
| 1956 | 3,965 | 12,962 | 649,624 | 431,296 | 156,099 | 178,525 | 281,786 | 559,662 | 581,816 | 244,241 | 40,675 | 12,165 | 3,152,816 |
| 1957 | 21,366 | 24,262 | 24,202 | 35,042 | 123,753 | 153,535 | 172,495 | 379,989 | 404,981 | 67,160 | 8,739 | 2,041 | 1,417,565 |
| 1958 | 11,296 | 18,389 | 48,032 | 58,124 | 176,735 | 256,766 | 425,004 | 761,395 | 579,215 | 231,899 | 54,873 | 16,633 | 2,638,361 |
| 1959 | 5,891 | 5,831 | 5,234 | 78,639 | 116,210 | 119,022 | 224,043 | 231,483 | 138,833 | 18,216 | 1,496 | 44,721 | 989,619 |
| 1960 | 5,320 | 9,533 | 12,301 | 25,202 | 119,381 | 149,498 | 238,389 | 303,406 | 162,351 | 16,064 | 5,798 | 5,141 | 1,052,384 |
| 1961 | 5,389 | 15,656 | 32,686 | 18,660 | 46,554 | 71,391 | 164,818 | 219,808 | 122,305 | 18,756 | 12,514 | 3,836 | 732,373 |
| 1962 | 4,996 | 8,029 | 23,685 | 23,869 | 233,312 | 139,023 | 389,026 | 362,479 | 445,575 | 116,886 | 14,063 | 4,992 | 1,765,935 |
| 1963 | 17,284 | 8,747 | 29,449 | 93,094 | 308,729 | 112,197 | 247,529 | 533,657 | 463,438 | 179,127 | 31,868 | 16,034 | 2,041,153 |
| 1964 | 17,677 | 104,941 | 48,020 | 53,546 | 51,804 | 75,267 | 169,186 | 323,074 | 225,025 | 41,217 | 12,351 | 8,158 | 1,130,266 |
| 1965 | 8,854 | 52,247 | 517,140 | 288,696 | 141,060 | 140,884 | 326,033 | 448,977 | 476,527 | 227,611 | 87,414 | 22,931 | 2,738,374 |
| 1966 | 7,436 | 129,568 | 88,854 | 77,750 | 74,930 | 146,418 | 298,544 | 354,857 | 86,348 | 22,324 | 9,308 | 9,759 | 1,306,096 |
| 1967 | 7,083 | 67,331 | 221,595 | 134,965 | 115,037 | 306,311 | 289,535 | 648,922 | 743,532 | 472,504 | 77,528 | 20,259 | 3,104,602 |
| 1968 | 9,935 | 11,141 | 31,620 | 47,230 | 134,487 | 122,791 | 187,492 | 287,671 | 141,007 | 18,655 | 10,028 | 4,558 | 1,006,615 |
| 1969 | 12,657 | 80,850 | 81,259 | 577,549 | 285,997 | 263,459 | 489,687 | 960,266 | 716,378 | 316,146 | 54,805 | 13,182 | 3,852,235 |
| 1970 | 38,505 | 39,314 | 112,293 | 408,401 | 134,261 | 191,575 | 161,494 | 410,581 | 336,311 | 95,259 | 22,778 | 11,611 | 1,962,383 |
| 1971 | 10,708 | 86,508 | 123,262 | 120,518 | 94,171 | 146,321 | 194,344 | 348,928 | 418,237 | 110,670 | 19,622 | 9,844 | 1,683,133 |
| 1972 | 6,181 | 34,871 | 76,542 | 59,357 | 78,033 | 181,513 | 155,728 | 344,130 | 219,544 | 28,377 | 11,399 | 10,977 | 1,206,652 |
| 1973 | 11,383 | 36,095 | 86,247 | 139,557 | 186,063 | 173,431 | 259,406 | 655,184 | 400,351 | 57,348 | 19,710 | 5,921 | 2,030,696 |
| 1974 | 17,349 | 171,392 | 136,459 | 179,857 | 68,703 | 228,524 | 273,856 | 560,604 | 441,592 | 122,525 | 28,530 | 9,509 | 2,238,900 |
| 1975 | 14,696 | 12,097 | 35,351 | 53,853 | 144,319 | 224,186 | 176,275 | 582,040 | 596,315 | 151,335 | 27,588 | 14,616 | 2,032,671 |
| 1976 | 70,107 | 55,737 | 31,628 | 7,883 | 37,805 | 70,677 | 99,529 | 208,988 | 39,701 | 14,412 | 20,685 | 14,767 | 671,919 |
| 1977 | 12,087 | 8,437 | 3,219 | 10,694 | 16,739 | 24,385 | 78,645 | 105,949 | 104,440 | 10,840 | 3,643 | 2,862 | 381,940 |
| 1978 | 1,642 | 11,780 | 96,345 | 189,976 | 195,780 | 331,033 | 354,174 | 603,286 | 661,360 | 309,814 | 60,841 | 83,950 | 2,899,981 |
| 1979 | 9,937 | 28,398 | 33,087 | 153,677 | 151,480 | 238,925 | 260,239 | 626,236 | 314,832 | 66,625 | 17,080 | 9,644 | 1,910,160 |
| 1980 | 29,209 | 42,379 | 49,369 | 528,787 | 394,146 | 221,193 | 304,076 | 497,417 | 538,735 | 346,614 | 58,826 | 22,257 | 3,033,008 |
| 1981 | 7,634 | 6,617 | 25,775 | 48,161 | 63,489 | 125,911 | 243,170 | 328,483 | 151,210 | 21,814 | 19,142 | 8,773 | 1,050,179 |
| 1982 | 29,096 | 173,742 | 220,245 | 227,881 | 388,399 | 339,749 | 660,325 | 693,110 | 566,805 | 322,582 | 79,983 | 103,860 | 3,805,777 |
| 1983 | 152,862 | 176,231 | 244,606 | 261,243 | 327,834 | 560,146 | 303,525 | 695,933 | 1,016,194 | 629,625 | 205,170 | 58,030 | 4,631,399 |
| 1984 | 43,833 | 310,276 | 402,190 | 175,424 | 150,674 | 199,589 | 202,812 | 535,744 | 329,550 | 92,967 | 21,172 | 6,534 | 2,470,765 |
| 1985 | 26,106 | 85,226 | 45,811 | 40,205 | 69,556 | 127,513 | 302,646 | 341,359 | 134,995 | 25,101 | 15,302 | 17,837 | 1,231,657 |
| 1986 | 30,748 | 49,202 | 92,981 | 126,875 | 637,580 | 490,232 | 322,500 | 539,958 | 501,005 | 146,719 | 30,228 | 18,821 | 2,986,849 |
| 1987 | 18,345 | 7,168 | 7,714 | 6,492 | 43,150 | 89,948 | 191,657 | 206,001 | 66,198 | 10,915 | 5,879 | 1,732 | 655,199 |
| 1988 | 10,278 | 27,191 | 48,859 | 70,254 | 58,572 | 105,225 | 158,215 | 211,686 | 99,215 | 23,681 | 5,324 | 2,154 | 820,654 |
| 1989 | 1,849 | 22,391 | 26,707 | 36,978 | 62,233 | 286,026 | 307,446 | 319,049 | 208,254 | 25,970 | 2,575 | 13,751 | 1,313,229 |
| 1990 | 49,972 | 25,428 | 20,551 | 35,542 | 54,896 | 133,057 | 221,034 | 179,627 | 101,655 | 19,799 | 2,450 | 1,206 | 845,217 |
| 1991 | 996 | 9,297 | 4,183 | 4,758 | 8,904 | 168,480 | 179,883 | 334,909 | 299,079 | 66,849 | 18,875 | 7,029 | 1,103,242 |
| 1992 | 15,909 | 26,027 | 17,316 | 25,129 | 95,340 | 113,070 | 231,963 | 187,646 | 46,526 | 56,033 | 13,075 | 4,112 | 832,146 |
| 1993 | 11,154 | 12,990 | 45,514 | 278,917 | 165,991 | 319,517 | 321,485 | 628,258 | 505,489 | 211,712 | 41,623 | 13,093 | 2,555,743 |
| 1994 | 13,209 | 6,607 | 17,759 | 19,494 | 50,633 | 103,252 | 185,944 | 274,469 | 115,029 | 23,351 | 14,067 | 7,313 | 831,127 |
| 1995 | 6,620 | 62,478 | 59,639 | 344,976 | 147,234 | 579,813 | 409,402 | 658,222 | 792,023 | 640,439 | 149,915 | 26,793 | 3,877,554 |
| 1996 | 2,924 | 3,199 | 70,495 | 124,057 | 350,186 | 293,825 | 333,354 | 577,824 | 384,502 | 126,879 | 25,099 | 13,609 | 2,305,953 |
| 1997 | 10,653 | 111,170 | 395,894 | 1,002,378 | 164,046 | 229,017 | 286,768 | 527,215 | 314,417 | 89,358 | 31,046 | 36,083 | 3,198,045 |
| 1998 | 8,111 | 17,342 | 36,357 | 216,603 | 367,555 | 348,605 | 350,987 | 469,938 | 849,272 | 540,484 | 70,201 | 25,265 | 3,300,720 |
| 1999 | 15,096 | 51,582 | 68,280 | 142,245 | 257,908 | 170,034 | 254,676 | 567,221 | 424,883 | 100,290 | 25,252 | 16,645 | 2,094,112 |
| 2000 | 8,466 | 18,149 | 10,557 | 131,588 | 278,491 | 249,687 | 326,189 | 529,229 | 306,514 | 51,554 | 21,475 | 14,386 | 1,946,285 |
| 2001 | 16,515 | 15,960 | 22,036 | 30,614 | 63,287 | 189,894 | 235,833 | 416,614 | 60,383 | 23,445 | 11,526 | 8,065 | 1,094,172 |
| 2002 | 7,719 | 38,942 | 104,488 | 98,046 | 79,499 | 143,234 | 303,241 | 385,295 | 216,551 | 30,549 | 11,468 | 6,585 | 1,425,617 |
| Avg (21-02) | 16,412 | 47,758 | 88,726 | 125,017 | 148,971 | 191,270 | 274,352 | 445,104 | 351,699 | 123,674 | 25,343 | 11,800 | 1,850,126 |
| Max (21-02) | 152,862 | 521,560 | 649,624 | 1,002,378 | 637,580 | 579,813 | 660,325 | 960,266 | 1,016,194 | 640,439 | 205,170 | 103,860 | 4,631,399 |
| Min (21-02) | -543 | 1,236 | 3,219 | 4,758 | 8,904 | 24,385 | 78,645 | 105,949 | 16,850 | 10,219 | -1,890 | -9,271 | 381,940 |

**Table 4.1.2.2-1**
**Inflow to Hetch Hetchy Reservoir (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 14,852 | 16,935 | 19,452 | 23,179 | 28,957 | 53,234 | 83,494 | 201,540 | 270,010 | 61,178 | 7,025 | 1,817 | 781,673 |
| 1922 | 1,037 | 728 | 4,582 | 12,895 | 15,291 | 26,892 | 58,915 | 291,927 | 392,271 | 111,925 | 16,296 | 3,578 | 936,337 |
| 1923 | 1,827 | 4,594 | 17,778 | 18,060 | 15,939 | 22,723 | 63,362 | 241,769 | 175,305 | 100,040 | 13,400 | 7,860 | 682,657 |
| 1924 | 15,665 | 2,174 | 3,537 | 5,825 | 10,346 | 13,333 | 58,284 | 128,382 | 14,194 | 9,517 | 2,156 | -809 | 262,604 |
| 1925 | 3,183 | 16,022 | 17,157 | 13,444 | 39,753 | 45,429 | 106,132 | 285,650 | 229,938 | 78,141 | 18,355 | 4,022 | 857,226 |
| 1926 | 8,463 | 7,767 | 13,000 | 5,901 | 16,532 | 41,300 | 168,649 | 178,836 | 59,494 | 12,524 | 4,233 | 1,795 | 518,494 |
| 1927 | 2,626 | 17,280 | 19,335 | 15,134 | 38,394 | 39,015 | 85,146 | 234,284 | 318,714 | 96,655 | 13,932 | 4,318 | 884,833 |
| 1928 | 5,066 | 29,462 | 13,291 | 14,731 | 14,971 | 70,485 | 77,141 | 266,757 | 99,675 | 17,310 | 5,258 | 2,503 | 616,650 |
| 1929 | 2,299 | 1,408 | 4,544 | 4,362 | 6,956 | 28,869 | 48,361 | 201,505 | 132,204 | 27,394 | 6,002 | 2,569 | 466,473 |
| 1930 | 3,437 | 1,309 | 5,758 | 10,052 | 18,103 | 37,301 | 95,952 | 138,674 | 187,152 | 30,060 | 5,639 | 2,458 | 535,895 |
| 1931 | 4,756 | 5,508 | 3,626 | 6,002 | 10,264 | 22,019 | 74,089 | 127,418 | 32,666 | 7,569 | 2,176 | 865 | 296,958 |
| 1932 | 1,051 | 1,797 | 7,807 | 16,542 | 32,846 | 41,647 | 76,018 | 231,493 | 326,652 | 107,478 | 13,303 | 3,634 | 860,268 |
| 1933 | 2,904 | 3,300 | 3,166 | 5,052 | 6,855 | 20,678 | 62,701 | 113,109 | 267,192 | 43,119 | 5,885 | 2,557 | 536,518 |
| 1934 | 2,765 | 3,213 | 6,893 | 13,359 | 19,686 | 49,880 | 91,043 | 89,484 | 61,749 | 11,185 | 5,361 | 3,780 | 358,398 |
| 1935 | 4,211 | 17,710 | 16,907 | 23,461 | 31,232 | 32,356 | 110,765 | 234,141 | 318,149 | 63,447 | 12,002 | 4,338 | 868,719 |
| 1936 | 3,568 | 5,024 | 4,054 | 17,179 | 35,823 | 50,640 | 136,975 | 283,146 | 244,255 | 81,882 | 11,998 | 3,057 | 877,601 |
| 1937 | 2,949 | 3,314 | 6,238 | 6,986 | 37,170 | 34,171 | 75,221 | 323,224 | 239,706 | 58,483 | 7,426 | 2,059 | 796,947 |
| 1938 | 2,110 | 4,407 | 93,614 | 20,271 | 30,623 | 49,130 | 107,766 | 299,718 | 430,110 | 195,755 | 32,243 | 9,505 | 1,275,252 |
| 1939 | 16,621 | 16,090 | 11,780 | 10,538 | 13,549 | 44,307 | 127,226 | 124,155 | 46,657 | 11,449 | 6,994 | 6,581 | 435,947 |
| 1940 | 20,057 | 5,915 | 3,437 | 39,677 | 33,610 | 61,315 | 101,447 | 310,891 | 225,366 | 34,665 | 6,470 | 2,791 | 845,641 |
| 1941 | 3,221 | 4,328 | 28,562 | 23,873 | 31,813 | 43,041 | 61,743 | 300,319 | 329,966 | 150,875 | 21,505 | 4,568 | 1,003,814 |
| 1942 | 4,342 | 19,029 | 53,589 | 40,512 | 25,821 | 35,960 | 92,025 | 191,841 | 363,447 | 169,206 | 19,743 | 4,243 | 1,019,758 |
| 1943 | 2,870 | 22,503 | 24,844 | 35,766 | 27,871 | 58,475 | 133,978 | 280,032 | 228,994 | 101,286 | 15,034 | 5,076 | 936,729 |
| 1944 | 4,915 | 5,091 | 6,781 | 12,395 | 16,929 | 35,499 | 54,664 | 214,677 | 159,701 | 60,520 | 8,582 | 3,925 | 583,679 |
| 1945 | 3,529 | 21,771 | 21,332 | 15,297 | 43,783 | 29,849 | 94,538 | 214,921 | 301,569 | 115,038 | 15,142 | 5,046 | 881,815 |
| 1946 | 22,217 | 39,079 | 43,014 | 29,397 | 17,087 | 41,863 | 138,684 | 263,421 | 165,157 | 37,481 | 8,925 | 4,452 | 810,777 |
| 1947 | 8,914 | 18,554 | 22,770 | 14,441 | 20,727 | 41,246 | 84,131 | 224,365 | 79,202 | 15,943 | 4,804 | 3,082 | 538,179 |
| 1948 | 17,102 | 14,090 | 8,430 | 14,413 | 8,567 | 17,611 | 62,051 | 204,468 | 259,748 | 55,424 | 5,988 | 2,087 | 669,979 |
| 1949 | 2,176 | 3,312 | 5,328 | 6,339 | 9,967 | 20,700 | 119,136 | 217,737 | 153,936 | 19,136 | 4,952 | 2,592 | 565,311 |
| 1950 | 1,589 | 5,849 | 5,440 | 19,216 | 26,971 | 33,698 | 122,164 | 243,106 | 202,040 | 39,814 | 4,863 | 2,877 | 707,627 |
| 1951 | 4,909 | 185,303 | 125,968 | 33,374 | 31,331 | 40,921 | 114,170 | 219,386 | 183,747 | 43,874 | 6,994 | 3,223 | 993,200 |
| 1952 | 2,322 | 8,120 | 23,578 | 23,332 | 26,105 | 38,023 | 126,111 | 335,010 | 318,139 | 189,368 | 31,865 | 7,379 | 1,129,352 |
| 1953 | 2,987 | 2,686 | 10,780 | 30,397 | 16,249 | 28,149 | 98,914 | 110,634 | 248,842 | 112,477 | 10,350 | 3,838 | 676,303 |
| 1954 | 1,654 | 2,878 | 5,278 | 6,524 | 23,482 | 46,812 | 124,794 | 240,434 | 107,883 | 23,248 | 4,544 | 1,869 | 589,400 |
| 1955 | 1,680 | 2,930 | 11,645 | 12,645 | 14,368 | 19,886 | 50,900 | 177,620 | 188,313 | 27,790 | 4,919 | 882 | 513,578 |
| 1956 | 1,133 | 3,814 | 136,376 | 67,583 | 26,711 | 50,554 | 102,553 | 264,194 | 390,375 | 177,794 | 28,005 | 8,315 | 1,257,407 |
| 1957 | 7,607 | 10,979 | 6,676 | 7,146 | 29,133 | 36,202 | 65,851 | 168,240 | 263,393 | 42,849 | 6,115 | 1,642 | 645,833 |
| 1958 | 3,550 | 6,892 | 12,298 | 11,833 | 30,333 | 30,313 | 84,615 | 329,998 | 301,934 | 138,555 | 34,114 | 6,831 | 991,266 |
| 1959 | 2,289 | 2,400 | 2,519 | 13,979 | 21,241 | 35,207 | 101,746 | 129,291 | 90,409 | 11,159 | 2,977 | 20,838 | 434,055 |
| 1960 | 5,931 | 2,723 | 3,271 | 5,195 | 20,811 | 45,519 | 100,259 | 166,413 | 109,680 | 13,363 | 4,360 | 1,448 | 478,973 |
| 1961 | 2,297 | 5,018 | 9,173 | 5,195 | 12,920 | 24,785 | 81,630 | 129,146 | 83,615 | 11,326 | 7,379 | 2,069 | 374,553 |
| 1962 | 3,178 | 3,304 | 7,045 | 7,690 | 34,225 | 29,675 | 153,711 | 170,100 | 282,153 | 78,292 | 10,524 | 2,551 | 782,448 |
| 1963 | 4,719 | 2,886 | 4,814 | 19,795 | 68,884 | 28,080 | 50,997 | 232,272 | 283,414 | 119,714 | 16,610 | 5,437 | 837,622 |
| 1964 | 4,449 | 29,635 | 15,380 | 11,756 | 12,125 | 20,493 | 62,723 | 166,986 | 130,925 | 23,042 | 5,332 | 2,241 | 485,087 |
| 1965 | 1,095 | 12,186 | 152,678 | 54,303 | 30,567 | 35,292 | 89,798 | 201,509 | 271,747 | 144,631 | 53,845 | 9,614 | 1,057,265 |
| 1966 | 2,987 | 24,409 | 17,935 | 16,151 | 12,377 | 42,704 | 132,016 | 209,923 | 52,477 | 10,742 | 6,180 | 3,094 | 530,995 |
| 1967 | 1,757 | 14,682 | 54,046 | 27,580 | 25,731 | 55,924 | 42,472 | 246,942 | 350,743 | 268,320 | 44,616 | 12,194 | 1,145,007 |
| 1968 | 4,104 | 4,251 | 8,963 | 11,621 | 34,933 | 33,880 | 76,796 | 164,257 | 94,907 | 13,617 | 5,174 | 3,360 | 455,863 |
| 1969 | 9,869 | 33,915 | 20,273 | 69,743 | 28,451 | 42,192 | 123,412 | 426,825 | 380,150 | 198,988 | 29,640 | 5,169 | 1,368,627 |
| 1970 | 10,385 | 11,837 | 23,818 | 70,709 | 26,576 | 40,967 | 52,088 | 214,551 | 205,000 | 53,607 | 6,230 | 1,543 | 717,311 |
| 1971 | 341 | 17,486 | 27,925 | 30,218 | 25,509 | 32,991 | 62,576 | 165,927 | 257,223 | 69,867 | 9,909 | 3,481 | 703,453 |
| 1972 | 2,194 | 7,955 | 16,812 | 14,928 | 16,465 | 61,035 | 56,053 | 188,521 | 137,183 | 15,718 | 2,239 | 4,709 | 523,812 |
| 1973 | 5,399 | 9,848 | 24,736 | 24,218 | 21,495 | 24,964 | 80,634 | 327,362 | 239,477 | 34,204 | 9,445 | 95 | 801,877 |
| 1974 | 2,424 | 55,910 | 34,705 | 41,950 | 17,691 | 45,580 | 71,101 | 283,357 | 274,778 | 72,419 | 15,695 | 440 | 916,050 |
| 1975 | 583 | 688 | 9,043 | 12,785 | 20,196 | 34,844 | 35,010 | 239,478 | 328,058 | 89,885 | 8,307 | 3,114 | 781,991 |
| 1976 | 23,762 | 20,019 | 8,894 | 5,399 | 10,276 | 21,602 | 37,154 | 121,991 | 25,392 | 7,416 | 5,746 | 5,185 | 292,836 |
| 1977 | 5,288 | 2,440 | 1,315 | 1,743 | 3,683 | 8,305 | 40,064 | 52,768 | 76,764 | 10,181 | 2,257 | 1,583 | 206,391 |
| 1978 | 783 | 3,275 | 24,609 | 35,653 | 34,189 | 66,018 | 79,482 | 246,492 | 378,644 | 216,061 | 38,083 | 35,361 | 1,158,650 |
| 1979 | 4,336 | 5,131 | 9,780 | 30,085 | 21,665 | 45,483 | 75,033 | 303,299 | 187,442 | 36,311 | 5,246 | 375 | 724,186 |
| 1980 | 9,209 | 13,626 | 13,700 | 107,381 | 54,960 | 40,941 | 104,152 | 219,691 | 315,953 | 232,032 | 32,943 | 4,504 | 1,149,092 |
| 1981 | 1,154 | 1,753 | 5,056 | 4,588 | 18,811 | 27,326 | 98,630 | 183,890 | 100,737 | 9,477 | 2,100 | 863 | 454,385 |
| 1982 | 7,956 | 47,328 | 55,652 | 36,462 | 73,410 | 41,306 | 136,834 | 311,236 | 334,205 | 191,546 | 52,620 | 51,162 | 1,339,717 |
| 1983 | 55,380 | 50,053 | 47,982 | 34,850 | 36,060 | 58,570 | 45,287 | 263,161 | 543,562 | 385,789 | 144,621 | 32,396 | 1,697,711 |
| 1984 | 18,615 | 69,094 | 65,341 | 33,901 | 28,011 | 50,793 | 87,166 | 329,749 | 210,990 | 68,297 | 13,107 | 4,296 | 979,360 |
| 1985 | 7,718 | 24,006 | 13,115 | 12,835 | 15,183 | 28,036 | 122,325 | 198,841 | 92,807 | 12,827 | 2,991 | 5,601 | 536,285 |
| 1986 | 13,853 | 12,079 | 26,140 | 33,354 | 86,703 | 100,867 | 131,716 | 311,165 | 343,860 | 95,790 | 17,704 | 3,915 | 1,177,146 |
| 1987 | 7,361 | 2,364 | 883 | 3,051 | 9,447 | 19,593 | 88,955 | 131,331 | 45,402 | 5,903 | 988 | -79 | 315,199 |
| 1988 | 2,456 | 12,000 | 13,755 | 20,733 | 18,079 | 36,916 | 75,665 | 128,497 | 67,468 | 11,679 | 2,727 | 1,492 | 391,467 |
| 1989 | 206 | 1,827 | 5,294 | 11,411 | 18,781 | 76,844 | 141,707 | 204,379 | 142,963 | 24,188 | 3,804 | 3,933 | 635,337 |
| 1990 | 10,979 | 9,600 | 9,207 | 10,477 | 13,533 | 40,633 | 100,504 | 102,996 | 66,175 | 16,302 | 3,295 | 1,006 | 384,707 |
| 1991 | 315 | 1,706 | 1,031 | -139 | 2,158 | 35,205 | 53,950 | 151,374 | 184,304 | 33,721 | 3,832 | 1,287 | 468,744 |
| 1992 | 3,144 | 10,731 | 6,712 | 7,815 | 19,299 | 28,223 | 101,113 | 118,177 | 30,595 | 24,760 | 3,782 | 1,158 | 355,509 |
| 1993 | 2,660 | 4,812 | 9,509 | 37,287 | 26,108 | 71,544 | 95,135 | 299,573 | 284,156 | 127,180 | 19,898 | 3,120 | 980,982 |
| 1994 | 3,485 | 1,793 | 4,901 | -5,605 | 8,741 | 34,195 | 81,661 | 152,920 | 76,171 | 5,246 | -2,099 | -85 | 361,324 |
| 1995 | 7,053 | 24,575 | 20,719 | 55,252 | 41,397 | 89,730 | 98,023 | 217,664 | 414,470 | 377,198 | 94,955 | 17,661 | 1,458,697 |
| 1996 | 2,646 | 1,886 | 17,151 | 23,706 | 74,208 | 61,771 | 120,313 | 275,730 | 249,195 | 88,608 | 13,414 | 3,340 | 931,968 |
| 1997 | 3,241 | 37,019 | 57,181 | 221,464 | 33,620 | 69,408 | 122,053 | 313,971 | 226,964 | 60,103 | 14,723 | 3,846 | 1,163,593 |
| 1998 | 2,003 | 2,934 | 9,330 | 32,943 | 38,045 | 62,993 | 74,914 | 146,517 | 392,983 | 300,932 | 37,789 | 15,612 | 1,116,995 |
| 1999 | 6,793 | 12,054 | 18,778 | 23,802 | 43,724 | 37,448 | 70,814 | 274,613 | 249,060 | 57,100 | 8,737 | 3,683 | 806,606 |
| 2000 | 2,870 | 4,387 | 2,517 | 16,846 | 31,561 | 43,587 | 114,375 | 261,592 | 177,751 | 27,471 | 7,771 | 2,793 | 693,521 |
| 2001 | 2,493 | 4,019 | 5,389 | 5,161 | 11,790 | 54,458 | 88,560 | 231,844 | 37,841 | 10,334 | 2,527 | 1,311 | 455,727 |
| 2002 | 1,571 | 9,638 | 25,618 | 24,613 | 22,982 | 35,141 | 127,402 | 213,037 | 145,006 | 17,750 | 2,696 | 1,964 | 627,418 |
| Avg (21-02) | 5,945 | 14,274 | 21,236 | 23,781 | 25,741 | 40,910 | 90,558 | 218,730 | 210,862 | 77,604 | 14,723 | 5,243 | 749,605 |
| Max (21-02) | 55,380 | 185,303 | 152,678 | 221,464 | 86,703 | 100,867 | 168,649 | 426,825 | 543,562 | 385,789 | 144,621 | 51,162 | 1,697,711 |
| Min (21-02) | 206 | 688 | 883 | -5,605 | 2,158 | 8,305 | 35,010 | 52,768 | 14,194 | 5,246 | -2,099 | -809 | 206,391 |

#### 4.1.2.3 Inflow to Lake Lloyd and Lake Eleanor

The watershed upstream of Lake Lloyd and Lake Eleanor are also largely unregulated. Prior to the operation of the Eleanor-Cherry Diversion Tunnel and Pumping Plant, inflow values were determined by measurement. These measurements no longer occur, and flows between Lake Eleanor and Lake Lloyd are measured, but the gage does not always provide reliable results. Therefore, inflow to each separate reservoir cannot be determined from current reservoir operation records. The inflow for each reservoir for the period October, 1920 through February, 1960 was determined by measurement. For the remaining period, the inflow for each reservoir is calculated by a relationship representing the historical division of total inflow among the two watersheds. The average annual inflow to Lake Lloyd and Lake Eleanor is 279,300 acre-feet and 169,600 acre-feet, respectively. Table 4.1.2.3-1 and Table 4.1.2.3-2 depict the assumed inflow to Lake Lloyd and Lake Eleanor, respectively

#### 4.1.2.4 Unregulated Flow Below Hetch Hetchy Reservoirs

Over one-third of the calculated total unimpaired flow of the Tuolumne River originates from the watersheds downstream of San Francisco's reservoirs. These flows are unregulated and contribute to the inflow to Don Pedro Reservoir. Table 4.1.2.4-1 depicts the monthly record for these flows. The average annual runoff of this portion of Tuolumne River flow is 651,600 acre-feet

#### 4.1.2.5 Inflow to Calaveras Reservoir

Calaveras Reservoir captures runoff from Calaveras and Arroyo Hondo creeks, and receives runoff from Alameda Creek through the Upper Alameda Diversion Tunnel. Table 4.1.2.5-1 depicts the monthly inflow to Calaveras Reservoir from its watershed. The average annual inflow to Calaveras Reservoir from Calaveras and Arroyo Hondo creeks and its watershed has been estimated to be 38,000 acre-feet. Inflow has varied from essentially no runoff (1924) to almost 151,000 acre-feet (1983) in a year

#### 4.1.2.6 Runoff at Alameda Creek Diversion Dam

Calaveras Reservoir’s inflow is supplemented by diversions from Alameda Creek through the Alameda Creek Diversion Tunnel. The typical operation of the diversion is to divert flow of Alameda Creek when it is available up to the capacity of the tunnel. Runoff at the diversion site that exceeds the diversion capacity will flow over the dam and contribute to flows in the creek downstream of the dam. Runoff at the Alameda Creek Diversion Dam is depicted in Table 4.1.2.6-1, and has ranged from essentially no flow to about 50,200 acre-feet in a year. The average annual runoff at the dam is 12,900 acre-feet.

#### 4.1.2.7 Unregulated Runoff below Alameda Creek Diversion Dam

As will be described later, HH/LSM can simulate the supplemental releases from Calaveras Reservoir necessary to comply with a flow requirement below the confluence of the Alameda Creek and Calaveras Creek. The flow requirement is assumed to be partially met by releases from Alameda Creek Diversion Dam to Alameda Creek and the unregulated flows that occur between the diversion dam and the confluence. Table 4.1.2.7-1 depicts the estimation of these unregulated flows.

#### 4.1.2.8 Inflow to San Antonio Reservoir

Located on San Antonio Creek, San Antonio Reservoir receives local runoff averaging 7,600 acre-feet per year. Table 4.1.2.8-1 depicts the estimated inflow to San Antonio Reservoir. The average annual inflow has ranged from essentially none (1924) to about 30,200 acre-feet (1983). San Antonio Reservoir can also receive inflow from Hetch Hetchy, transfers from Calaveras Reservoir, and imported water from the South Bay Aqueduct (State Water Project) through turnouts.

**Table 4.1.2.3-1**
**Inflow to Lake Lloyd (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 10,784 | 11,653 | 10,086 | 10,340 | 11,831 | 25,000 | 40,451 | 75,608 | 89,568 | 14,440 | 718 | 145 | 300,624 |
| 1922 | 69 | 52 | 3,590 | 7,150 | 5,068 | 10,939 | 28,865 | 111,788 | 143,187 | 37,745 | 2,382 | 173 | 351,008 |
| 1923 | 680 | 5,187 | 12,833 | 8,083 | 7,539 | 17,986 | 35,359 | 91,658 | 60,801 | 25,823 | 1,664 | 3,457 | 271,070 |
| 1924 | 5,679 | 2,426 | 1,626 | 3,961 | 8,535 | 6,567 | 28,370 | 38,249 | 2,130 | 123 | 26 | 14 | 97,706 |
| 1925 | 6,339 | 11,147 | 10,072 | 6,298 | 19,642 | 22,007 | 47,232 | 95,564 | 61,660 | 13,779 | 4,001 | 716 | 298,457 |
| 1926 | 4,735 | 4,459 | 7,769 | 3,172 | 7,958 | 24,264 | 66,567 | 52,604 | 11,086 | 1,095 | 69 | 24 | 183,802 |
| 1927 | 196 | 10,770 | 9,987 | 7,924 | 18,752 | 18,353 | 42,091 | 79,519 | 94,195 | 22,145 | 1,728 | 218 | 305,878 |
| 1928 | 5,716 | 20,531 | 4,905 | 7,275 | 7,111 | 43,690 | 35,082 | 75,654 | 21,112 | 1,799 | 107 | 38 | 223,020 |
| 1929 | 42 | 1,662 | 2,503 | 2,225 | 4,114 | 18,228 | 23,575 | 69,334 | 39,025 | 3,828 | 216 | 52 | 164,804 |
| 1930 | 58 | 52 | 7,692 | 5,383 | 11,879 | 19,660 | 44,894 | 52,320 | 51,076 | 5,516 | 339 | 407 | 199,276 |
| 1931 | 1,353 | 3,961 | 1,690 | 3,848 | 6,186 | 13,896 | 35,256 | 38,957 | 7,355 | 432 | 28 | 12 | 112,974 |
| 1932 | 174 | 1,432 | 4,645 | 7,063 | 15,386 | 22,302 | 37,825 | 89,889 | 102,383 | 27,001 | 1,418 | 232 | 309,750 |
| 1933 | 224 | 256 | 1,146 | 1,956 | 3,165 | 10,959 | 33,840 | 46,124 | 72,949 | 6,623 | 327 | 186 | 177,755 |
| 1934 | 1,601 | 1,246 | 8,763 | 8,906 | 10,449 | 30,902 | 41,599 | 29,540 | 14,908 | 889 | 139 | 454 | 149,396 |
| 1935 | 2,670 | 11,385 | 9,179 | 9,957 | 13,025 | 13,581 | 49,002 | 86,969 | 100,756 | 19,983 | 897 | 397 | 317,801 |
| 1936 | 2,337 | 3,201 | 2,358 | 10,673 | 16,296 | 24,910 | 58,683 | 97,293 | 74,210 | 14,329 | 692 | 530 | 305,512 |
| 1937 | 748 | 649 | 6,290 | 3,366 | 23,222 | 13,402 | 35,722 | 110,186 | 68,884 | 7,402 | 464 | 305 | 270,640 |
| 1938 | 789 | 3,304 | 59,615 | 11,262 | 12,045 | 23,314 | 49,079 | 112,020 | 129,521 | 48,385 | 3,269 | 930 | 453,533 |
| 1939 | 7,214 | 8,287 | 5,752 | 5,072 | 6,357 | 22,794 | 54,101 | 39,108 | 8,287 | 664 | 230 | 2,582 | 160,448 |
| 1940 | 11,431 | 2,223 | 4,770 | 26,959 | 16,756 | 36,432 | 47,038 | 115,448 | 68,057 | 5,345 | 468 | 236 | 335,163 |
| 1941 | 805 | 2,251 | 13,436 | 10,223 | 15,388 | 22,213 | 31,216 | 121,864 | 99,747 | 34,871 | 1,509 | 278 | 353,801 |
| 1942 | 1,020 | 8,422 | 30,904 | 17,639 | 9,759 | 15,027 | 41,155 | 73,142 | 113,613 | 42,331 | 1,862 | 242 | 355,116 |
| 1943 | 399 | 19,710 | 14,467 | 21,299 | 14,888 | 29,405 | 65,568 | 87,812 | 59,494 | 15,842 | 855 | 139 | 329,878 |
| 1944 | 1,428 | 2,420 | 3,243 | 6,212 | 7,025 | 16,713 | 26,551 | 91,051 | 51,854 | 10,364 | 413 | 179 | 217,453 |
| 1945 | 2,176 | 17,068 | 15,013 | 8,557 | 27,923 | 12,232 | 44,118 | 84,173 | 89,177 | 24,123 | 1,079 | 419 | 326,058 |
| 1946 | 18,934 | 20,951 | 21,094 | 12,171 | 7,805 | 18,587 | 54,651 | 93,340 | 48,746 | 5,264 | 347 | 442 | 302,332 |
| 1947 | 3,134 | 10,534 | 11,375 | 5,266 | 10,437 | 20,077 | 35,643 | 65,377 | 17,343 | 1,075 | 109 | 60 | 180,430 |
| 1948 | 10,984 | 6,270 | 2,594 | 8,836 | 4,637 | 7,555 | 29,234 | 73,799 | 79,617 | 10,284 | 367 | 305 | 234,482 |
| 1949 | 847 | 1,882 | 2,743 | 2,771 | 4,873 | 7,150 | 62,218 | 84,621 | 43,900 | 2,475 | 494 | 383 | 214,357 |
| 1950 | 240 | 3,261 | 2,102 | 11,472 | 12,847 | 16,454 | 52,675 | 89,591 | 67,240 | 9,348 | 764 | 452 | 266,446 |
| 1951 | 8,936 | 82,634 | 50,632 | 13,736 | 12,270 | 19,325 | 48,841 | 67,859 | 42,658 | 4,421 | 547 | 456 | 352,315 |
| 1952 | 1,494 | 7,119 | 12,252 | 9,360 | 10,699 | 14,233 | 57,249 | 129,659 | 110,489 | 59,536 | 4,822 | 1,537 | 418,449 |
| 1953 | 633 | 1,855 | 5,823 | 20,443 | 9,465 | 16,292 | 48,172 | 45,199 | 76,330 | 29,000 | 1,148 | 498 | 254,858 |
| 1954 | 660 | 3,295 | 4,163 | 4,623 | 12,851 | 29,562 | 55,874 | 82,610 | 37,174 | 3,925 | 432 | 196 | 235,365 |
| 1955 | 178 | 3,511 | 9,398 | 6,438 | 8,993 | 13,357 | 24,964 | 71,072 | 54,129 | 4,318 | 365 | 212 | 196,935 |
| 1956 | 327 | 3,199 | 97,952 | 27,931 | 12,430 | 20,670 | 42,260 | 92,999 | 106,024 | 37,865 | 5,950 | 105 | 447,712 |
| 1957 | 3,052 | 6,682 | 5,563 | 5,520 | 20,789 | 19,107 | 34,534 | 72,040 | 76,969 | 8,013 | -9,771 | 488 | 242,986 |
| 1958 | 2,103 | 4,834 | 9,600 | 7,301 | 16,306 | 15,047 | 40,076 | 123,616 | 111,156 | 38,850 | 6,502 | -345 | 375,046 |
| 1959 | -2,933 | 1,277 | 1,008 | 14,868 | 13,702 | 21,412 | 46,465 | 48,901 | 29,798 | 1,265 | 2 | 10,290 | 186,055 |
| 1960 | 242 | 1,093 | 1,337 | 3,614 | 13,047 | 26,069 | 43,363 | 53,625 | 24,630 | 473 | 192 | 521 | 168,206 |
| 1961 | 167 | 3,195 | 5,802 | 2,829 | 8,472 | 11,482 | 30,827 | 38,339 | 19,046 | 1,330 | 564 | 56 | 122,109 |
| 1962 | 524 | 1,206 | 5,568 | 5,052 | 18,808 | 12,287 | 68,421 | 70,182 | 83,550 | 15,324 | -226 | -628 | 280,068 |
| 1963 | 3,730 | -1,375 | 4,094 | 11,270 | 48,132 | 10,345 | 25,109 | 90,072 | 69,631 | 17,722 | -1,436 | -1,504 | 275,790 |
| 1964 | 3,106 | 26,252 | 8,389 | 5,962 | 6,859 | 11,390 | 30,426 | 59,848 | 44,901 | 4,728 | 186 | 176 | 202,223 |
| 1965 | 508 | 10,050 | 77,857 | 20,874 | 12,005 | 15,157 | 38,824 | 77,670 | 91,046 | 38,855 | 9,344 | 2,174 | 394,364 |
| 1966 | 537 | 21,368 | 8,497 | 5,848 | 5,048 | 22,669 | 48,595 | 58,822 | 13,232 | 952 | 954 | 508 | 187,030 |
| 1967 | -1,650 | 17,052 | 33,759 | 11,110 | 11,540 | 32,724 | 14,700 | 101,386 | 136,643 | 79,183 | 7,358 | -76 | 443,729 |
| 1968 | -945 | 972 | 5,550 | 6,449 | 21,124 | 16,131 | 33,941 | 51,841 | 21,537 | 758 | -270 | -1,712 | 155,376 |
| 1969 | 1,130 | 19,583 | 10,517 | 44,888 | 11,109 | 17,159 | 54,976 | 159,465 | 122,368 | 50,614 | 1,676 | 238 | 493,723 |
| 1970 | 8,237 | 5,204 | 25,820 | 47,970 | 11,489 | 18,724 | 23,266 | 71,384 | 56,718 | 7,932 | -862 | -390 | 275,492 |
| 1971 | -365 | 17,228 | 14,655 | 15,338 | 12,236 | 19,337 | 29,812 | 62,715 | 76,642 | 16,518 | -631 | -575 | 262,910 |
| 1972 | -1,977 | 7,770 | 9,406 | 5,101 | 8,242 | 29,747 | 26,912 | 62,994 | 40,813 | 842 | -1,095 | -282 | 188,473 |
| 1973 | 1,193 | 4,976 | 15,024 | 12,018 | 9,017 | 11,268 | 39,796 | 118,684 | 66,835 | 3,683 | -724 | -1,939 | 279,831 |
| 1974 | 1,974 | 43,305 | 16,256 | 20,983 | 7,506 | 24,914 | 35,386 | 100,595 | 78,147 | 18,669 | 521 | -1,864 | 346,392 |
| 1975 | -1,505 | 466 | 4,754 | 6,986 | 9,301 | 17,064 | 19,243 | 110,163 | 108,405 | 26,220 | 1,425 | 694 | 303,216 |
| 1976 | 19,634 | 9,518 | 4,292 | 1,801 | 5,876 | 11,683 | 19,565 | 37,983 | 4,622 | 422 | 3,263 | 1,804 | 120,463 |
| 1977 | 2,347 | 881 | -52 | 1,669 | 3,759 | 5,413 | 16,850 | 24,619 | 14,773 | 183 | -466 | -55 | 69,921 |
| 1978 | -774 | 2,756 | 20,944 | 17,502 | 13,635 | 33,130 | 40,077 | 108,249 | 120,590 | 46,297 | 4,349 | 13,264 | 420,019 |
| 1979 | 124 | 2,577 | 5,194 | 16,780 | 10,192 | 21,404 | 41,763 | 110,515 | 55,998 | 7,897 | 2,304 | 1,812 | 276,560 |
| 1980 | 8,107 | 11,209 | 11,108 | 73,558 | 30,749 | 19,020 | 49,008 | 88,499 | 105,509 | 61,521 | 5,779 | 1,935 | 466,002 |
| 1981 | -3,134 | 815 | 3,833 | 4,136 | 11,836 | 14,172 | 48,284 | 58,569 | 22,616 | 3,025 | 2,887 | 1,582 | 168,621 |
| 1982 | 7,322 | 43,215 | 36,750 | 13,596 | 41,954 | 28,146 | 75,423 | 106,393 | 93,115 | 45,426 | 4,446 | 14,999 | 510,785 |
| 1983 | 40,037 | 21,615 | 20,819 | 14,469 | 17,159 | 30,284 | 25,507 | 114,749 | 200,209 | 120,908 | 25,772 | 5,935 | 637,463 |
| 1984 | 6,204 | 58,217 | 46,017 | 16,377 | 11,170 | 24,569 | 33,201 | 90,475 | 55,317 | 10,427 | 783 | 787 | 353,544 |
| 1985 | 6,480 | 17,199 | 7,448 | 6,298 | 8,220 | 14,399 | 53,270 | 59,362 | 19,701 | 2,094 | 1,003 | 1,472 | 196,946 |
| 1986 | 7,747 | 8,810 | 19,240 | 22,677 | 64,155 | 55,145 | 49,560 | 92,006 | 86,338 | 19,921 | 2,117 | 2,481 | 430,197 |
| 1987 | 2,803 | 969 | 1,289 | 2,474 | 7,859 | 13,024 | 41,189 | 33,773 | 7,300 | 513 | 492 | 351 | 112,036 |
| 1988 | 2,563 | 5,123 | 8,777 | 2,600 | 4,919 | 17,408 | 29,142 | 36,357 | 15,023 | 2,469 | 61 | -206 | 124,236 |
| 1989 | 749 | 5,731 | 5,476 | 6,398 | 10,361 | 50,015 | 53,802 | 55,782 | 36,501 | 4,540 | 1,267 | 4,392 | 235,014 |
| 1990 | 19,209 | 7,665 | 4,295 | 6,815 | 6,951 | 21,960 | 42,059 | 34,604 | 17,128 | 2,820 | 1,181 | 1,285 | 165,972 |
| 1991 | 1,516 | 531 | -109 | 837 | 1,826 | 26,089 | 35,151 | 66,134 | 53,018 | 8,333 | 855 | 167 | 194,348 |
| 1992 | 1,777 | 6,901 | 2,851 | 3,717 | 12,175 | 17,832 | 43,224 | 28,557 | 5,050 | 12,099 | 1,072 | 57 | 135,312 |
| 1993 | 2,955 | 3,910 | 6,841 | 24,155 | 11,887 | 38,418 | 53,290 | 118,990 | 95,486 | 35,585 | 2,979 | 532 | 395,028 |
| 1994 | 2,369 | 831 | 3,854 | 3,360 | 6,621 | 19,500 | 36,962 | 50,397 | 14,826 | 1,056 | 18 | 25 | 139,819 |
| 1995 | 3,059 | 15,895 | 8,006 | 29,890 | 17,554 | 47,532 | 54,494 | 101,754 | 145,328 | 116,674 | 18,035 | 1,089 | 559,310 |
| 1996 | 1,316 | 655 | 17,996 | 13,625 | 44,280 | 29,733 | 52,811 | 113,298 | 63,109 | 16,260 | 2,059 | 903 | 356,045 |
| 1997 | 1,917 | 23,880 | 49,029 | 109,513 | 14,237 | 34,373 | 54,645 | 92,360 | 56,272 | 9,415 | 1,083 | 1,717 | 448,441 |
| 1998 | 2,020 | 3,345 | 7,049 | 13,563 | 18,499 | 34,160 | 41,874 | 78,128 | 173,556 | 103,217 | 7,800 | 3,582 | 486,793 |
| 1999 | 2,537 | 13,179 | 12,802 | 15,654 | 19,541 | 19,343 | 36,711 | 108,924 | 77,580 | 12,668 | 594 | 32 | 319,565 |
| 2000 | -345 | 3,471 | 1,244 | 20,226 | 19,776 | 24,814 | 56,888 | 102,977 | 54,412 | 5,781 | 1,230 | 1,368 | 291,842 |
| 2001 | 3,080 | 4,221 | 4,999 | 5,181 | 8,985 | 32,771 | 41,168 | 73,276 | 7,989 | 2,903 | 1,787 | 949 | 187,309 |
| 2002 | 668 | 10,999 | 19,065 | 15,532 | 11,670 | 20,944 | 53,300 | 71,488 | 36,017 | 1,461 | 1,122 | 550 | 242,816 |
| Avg (21-02) | 3,347 | 9,433 | 12,988 | 12,857 | 13,514 | 21,407 | 41,694 | 78,690 | 63,758 | 18,759 | 1,803 | 1,045 | 279,293 |
| Max (21-02) | 40,037 | 82,634 | 97,952 | 109,513 | 64,155 | 55,145 | 75,423 | 159,465 | 200,209 | 120,908 | 25,772 | 14,999 | 637,463 |
| Min (21-02) | -3,134 | -1,375 | -109 | 837 | 1,826 | 5,413 | 14,700 | 24,619 | 2,130 | 123 | -9,771 | -1,939 | 69,921 |

**Table 4.1.2.3-2**
**Inflow to Lake Eleanor (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 6,141 | 9,158 | 9,483 | 11,381 | 11,572 | 23,903 | 30,831 | 41,387 | 30,524 | 5,298 | 1,228 | 837 | 181,743 |
| 1922 | 0 | 0 | 1,890 | 8,422 | 6,617 | 10,965 | 28,191 | 78,450 | 59,203 | 12,349 | 1,031 | 1,065 | 208,183 |
| 1923 | 712 | 3,249 | 11,829 | 7,533 | 6,480 | 16,110 | 33,261 | 55,672 | 26,836 | 10,865 | 1,734 | 2,618 | 176,899 |
| 1924 | 3,215 | 2,878 | 2,287 | 3,418 | 7,500 | 5,355 | 17,389 | 15,239 | 444 | 153 | 200 | 95 | 58,173 |
| 1925 | 2,555 | 8,301 | 7,904 | 5,443 | 23,619 | 20,638 | 37,452 | 47,197 | 25,650 | 6,089 | 1,976 | 829 | 187,653 |
| 1926 | 2,438 | 2,337 | 5,211 | 3,128 | 7,726 | 19,704 | 42,347 | 22,381 | 4,834 | 1,162 | 672 | 343 | 112,283 |
| 1927 | 157 | 13,825 | 7,950 | 6,591 | 20,834 | 19,337 | 34,348 | 40,227 | 37,107 | 9,023 | 1,581 | 1,242 | 192,222 |
| 1928 | 3,178 | 14,269 | 4,270 | 6,496 | 8,138 | 44,067 | 26,876 | 33,092 | 7,281 | 2,132 | 165 | -71 | 149,893 |
| 1929 | 1,345 | 974 | 2,918 | 3,140 | 5,288 | 16,122 | 19,908 | 32,622 | 18,589 | 2,340 | 807 | 129 | 104,182 |
| 1930 | -129 | 355 | 5,094 | 5,506 | 10,199 | 16,945 | 30,778 | 25,932 | 17,131 | 2,428 | 1,505 | 833 | 116,577 |
| 1931 | 563 | 3,267 | 1,825 | 3,804 | 6,569 | 11,177 | 19,620 | 16,756 | 5,460 | 1,319 | 268 | 139 | 70,767 |
| 1932 | 107 | 418 | 5,167 | 6,908 | 17,419 | 23,203 | 32,479 | 54,466 | 39,931 | 9,479 | 1,347 | 1,269 | 192,193 |
| 1933 | 103 | 99 | 321 | 1,861 | 2,823 | 10,318 | 25,075 | 29,576 | 28,199 | 3,432 | 1,452 | 1,275 | 104,534 |
| 1934 | 67 | 377 | 6,948 | 6,660 | 8,759 | 21,132 | 16,701 | 11,003 | 7,393 | 845 | 984 | 70 | 80,939 |
| 1935 | 789 | 7,218 | 7,222 | 8,388 | 11,451 | 12,901 | 44,840 | 60,280 | 42,531 | 6,791 | 490 | 339 | 203,240 |
| 1936 | 998 | 2,368 | 2,235 | 11,219 | 18,323 | 24,383 | 47,782 | 54,528 | 31,448 | 6,567 | 599 | 311 | 200,761 |
| 1937 | 313 | 163 | 4,766 | 3,451 | 17,576 | 15,124 | 33,919 | 71,056 | 26,785 | 4,183 | 627 | 766 | 178,729 |
| 1938 | 341 | 2,116 | 45,199 | 7,561 | 10,481 | 20,795 | 38,767 | 72,616 | 52,693 | 14,346 | 1,111 | 16 | 266,042 |
| 1939 | 2,963 | 4,149 | 3,001 | 3,638 | 4,784 | 16,994 | 31,031 | 15,979 | 3,174 | 182 | -466 | 498 | 85,927 |
| 1940 | 5,044 | 758 | 1,941 | 24,825 | 17,272 | 34,691 | 34,207 | 48,972 | 20,328 | 2,327 | -127 | -48 | 190,190 |
| 1941 | -276 | 895 | 14,626 | 9,586 | 15,106 | 19,317 | 24,756 | 70,177 | 34,713 | 11,651 | 706 | 145 | 201,402 |
| 1942 | 210 | 3,780 | 22,358 | 14,418 | 9,338 | 13,581 | 35,970 | 52,161 | 47,415 | 15,288 | 954 | 155 | 215,628 |
| 1943 | 298 | 17,401 | 14,038 | 20,616 | 12,498 | 29,357 | 43,269 | 38,192 | 21,195 | 6,571 | 462 | 351 | 204,248 |
| 1944 | 533 | 985 | 1,495 | 5,306 | 5,908 | 14,154 | 20,486 | 46,744 | 18,543 | 4,294 | 200 | 153 | 118,801 |
| 1945 | 774 | 12,599 | 11,201 | 5,643 | 27,332 | 10,852 | 31,622 | 46,149 | 33,210 | 8,436 | 627 | 492 | 188,937 |
| 1946 | 8,175 | 12,953 | 18,400 | 9,244 | 6,264 | 17,460 | 36,151 | 43,861 | 15,675 | 2,501 | 693 | 315 | 171,692 |
| 1947 | 605 | 9,064 | 9,594 | 3,713 | 8,926 | 16,858 | 20,979 | 24,280 | 7,260 | 1,331 | -109 | 98 | 102,599 |
| 1948 | 5,913 | 3,488 | 1,390 | 6,870 | 3,231 | 7,001 | 24,702 | 46,677 | 32,587 | 4,598 | 641 | 468 | 137,566 |
| 1949 | 91 | 184 | 1,628 | 2,487 | 3,166 | 8,110 | 41,266 | 42,212 | 14,684 | 1,690 | 682 | 197 | 116,397 |
| 1950 | -60 | 889 | 1,300 | 9,673 | 11,381 | 15,239 | 38,364 | 45,490 | 23,159 | 3,751 | 602 | 197 | 149,985 |
| 1951 | 4,246 | 67,103 | 47,080 | 10,606 | 10,982 | 15,372 | 26,690 | 27,063 | 11,433 | 1,771 | -12 | -36 | 222,298 |
| 1952 | -375 | 4,278 | 10,081 | 8,473 | 9,479 | 14,640 | 46,943 | 82,542 | 46,306 | 17,548 | 2,116 | 672 | 242,703 |
| 1953 | 406 | 686 | 4,503 | 15,957 | 6,365 | 12,946 | 36,058 | 28,306 | 31,291 | 9,142 | 512 | 335 | 146,507 |
| 1954 | 361 | 950 | 2,656 | 4,144 | 10,566 | 26,696 | 44,331 | 40,691 | 14,107 | 2,031 | 308 | 143 | 146,984 |
| 1955 | 64 | 1,277 | 8,168 | 5,294 | 7,648 | 10,263 | 18,857 | 34,808 | 17,843 | 1,878 | 18 | -91 | 106,027 |
| 1956 | -387 | 1,121 | 56,350 | 27,669 | 9,880 | 18,774 | 30,514 | 55,474 | 37,158 | 11,405 | 1,033 | -365 | 248,626 |
| 1957 | 1,263 | 2,771 | 2,596 | 3,491 | 16,974 | 16,974 | 24,450 | 40,984 | 27,070 | 4,711 | 95 | 56 | 141,435 |
| 1958 | 381 | 2,410 | 8,743 | 6,083 | 14,567 | 12,853 | 29,169 | 82,499 | 51,779 | 16,348 | 2,283 | 682 | 227,797 |
| 1959 | 359 | 198 | 208 | 11,970 | 9,673 | 16,975 | 26,136 | 18,500 | 10,046 | 625 | 54 | 6,196 | 100,940 |
| 1960 | 375 | 391 | 141 | 2,051 | 12,256 | 23,776 | 32,579 | 29,773 | 9,722 | 179 | 139 | 422 | 111,804 |
| 1961 | 77 | 2,202 | 4,413 | 2,488 | 7,851 | 10,473 | 23,161 | 21,286 | 7,517 | 505 | 410 | 45 | 80,428 |
| 1962 | 242 | 831 | 4,234 | 4,445 | 17,430 | 11,207 | 51,406 | 38,966 | 32,977 | 5,812 | -165 | -509 | 166,876 |
| 1963 | 1,723 | -947 | 3,114 | 9,915 | 44,607 | 9,436 | 18,865 | 50,009 | 27,484 | 6,722 | -1,045 | -1,221 | 168,662 |
| 1964 | 1,435 | 18,092 | 6,380 | 5,245 | 6,357 | 10,389 | 22,860 | 33,228 | 17,723 | 1,794 | 135 | 143 | 123,781 |
| 1965 | 234 | 6,927 | 59,215 | 18,363 | 11,126 | 13,823 | 29,169 | 43,123 | 35,936 | 14,738 | 6,794 | 1,765 | 241,213 |
| 1966 | 248 | 14,727 | 6,463 | 5,144 | 4,679 | 20,676 | 36,510 | 32,658 | 5,222 | 361 | 694 | 412 | 127,794 |
| 1967 | -762 | 11,752 | 25,676 | 9,774 | 10,695 | 29,845 | 11,045 | 56,290 | 53,933 | 30,035 | 5,350 | -61 | 243,572 |
| 1968 | -437 | 670 | 4,221 | 5,674 | 19,577 | 14,712 | 25,500 | 28,783 | 8,501 | 287 | -196 | -1,390 | 105,902 |
| 1969 | 522 | 13,497 | 7,999 | 39,487 | 10,295 | 15,650 | 41,304 | 88,536 | 48,298 | 19,199 | 1,218 | 193 | 286,198 |
| 1970 | 3,805 | 3,587 | 19,637 | 42,199 | 10,647 | 17,077 | 17,480 | 39,633 | 22,386 | 3,008 | -626 | -316 | 178,517 |
| 1971 | -169 | 11,873 | 11,146 | 13,492 | 11,341 | 17,637 | 22,399 | 34,820 | 30,251 | 6,266 | -458 | -466 | 158,132 |
| 1972 | -913 | 5,355 | 7,154 | 4,487 | 7,639 | 27,131 | 20,219 | 34,975 | 16,109 | 320 | -797 | -228 | 121,451 |
| 1973 | 551 | 3,430 | 11,427 | 10,572 | 8,357 | 10,277 | 29,899 | 65,894 | 26,380 | 1,397 | -527 | -1,574 | 166,083 |
| 1974 | 912 | 29,845 | 12,364 | 18,458 | 6,957 | 22,723 | 26,586 | 55,851 | 30,845 | 7,082 | 379 | -1,512 | 210,490 |
| 1975 | -695 | 321 | 3,616 | 6,145 | 8,620 | 15,564 | 14,458 | 61,163 | 42,787 | 9,945 | 1,036 | 564 | 163,524 |
| 1976 | 9,071 | 6,560 | 3,264 | 1,585 | 5,445 | 10,655 | 14,700 | 21,088 | 1,824 | 160 | 2,372 | 1,465 | 78,189 |
| 1977 | 1,084 | 608 | -40 | 1,469 | 3,483 | 4,936 | 12,660 | 13,668 | 5,831 | 69 | -338 | -44 | 43,386 |
| 1978 | -358 | 1,899 | 15,929 | 15,397 | 12,637 | 30,216 | 30,110 | 60,101 | 47,597 | 17,561 | 3,162 | 10,765 | 245,016 |
| 1979 | 57 | 1,776 | 3,950 | 14,761 | 9,446 | 19,521 | 31,377 | 61,359 | 22,103 | 2,996 | 1,675 | 1,470 | 170,491 |
| 1980 | 3,746 | 7,725 | 8,449 | 64,708 | 28,497 | 17,347 | 36,821 | 49,136 | 41,645 | 23,336 | 4,202 | 1,570 | 287,182 |
| 1981 | -1,448 | 562 | 2,915 | 3,639 | 10,970 | 12,926 | 36,277 | 32,518 | 8,927 | 1,148 | 2,099 | 1,284 | 111,817 |
| 1982 | 3,383 | 29,783 | 27,951 | 11,961 | 38,882 | 25,670 | 56,666 | 59,070 | 36,753 | 17,230 | 3,232 | 12,173 | 322,754 |
| 1983 | 18,497 | 14,897 | 15,834 | 12,728 | 15,903 | 27,621 | 19,163 | 63,710 | 79,022 | 45,862 | 18,739 | 4,817 | 336,793 |
| 1984 | 2,866 | 40,122 | 34,998 | 14,406 | 10,353 | 22,408 | 24,944 | 50,232 | 21,834 | 3,955 | 570 | 639 | 227,327 |
| 1985 | 2,993 | 11,853 | 5,664 | 5,541 | 7,618 | 13,132 | 40,023 | 32,959 | 7,776 | 794 | 729 | 1,194 | 130,276 |
| 1986 | 3,579 | 6,072 | 14,634 | 19,948 | 59,457 | 50,294 | 37,235 | 51,082 | 34,078 | 7,556 | 1,539 | 2,014 | 287,488 |
| 1987 | 1,295 | 667 | 980 | 2,177 | 7,283 | 11,878 | 30,946 | 18,751 | 2,881 | 195 | 357 | 284 | 77,694 |
| 1988 | 1,184 | 3,531 | 6,676 | 2,287 | 4,558 | 15,877 | 21,895 | 20,186 | 5,930 | 937 | 44 | -167 | 82,938 |
| 1989 | 346 | 3,950 | 4,164 | 5,628 | 9,603 | 45,616 | 40,423 | 30,971 | 14,407 | 1,722 | 921 | 3,564 | 161,315 |
| 1990 | 8,875 | 5,283 | 3,266 | 5,996 | 6,443 | 20,028 | 31,599 | 19,212 | 6,761 | 1,070 | 858 | 1,042 | 110,433 |
| 1991 | 700 | 366 | -83 | 736 | 1,693 | 23,795 | 26,410 | 36,719 | 20,926 | 3,161 | 621 | 136 | 115,180 |
| 1992 | 821 | 4,756 | 2,169 | 3,297 | 11,238 | 16,460 | 32,608 | 15,377 | 1,964 | 4,705 | 842 | 52 | 94,289 |
| 1993 | 1,327 | 2,832 | 5,161 | 21,420 | 10,972 | 35,462 | 40,202 | 64,071 | 37,133 | 13,839 | 2,341 | 491 | 235,251 |
| 1994 | 1,064 | 601 | 2,908 | 2,979 | 6,112 | 18,000 | 27,884 | 27,137 | 5,765 | 410 | 14 | 23 | 92,897 |
| 1995 | 1,374 | 11,510 | 6,039 | 26,507 | 16,203 | 43,875 | 41,110 | 54,791 | 56,516 | 45,373 | 14,171 | 1,006 | 318,475 |
| 1996 | 591 | 474 | 13,576 | 12,083 | 40,873 | 27,446 | 39,840 | 61,006 | 24,542 | 6,324 | 1,618 | 833 | 229,206 |
| 1997 | 861 | 17,293 | 36,986 | 97,115 | 13,141 | 31,729 | 41,223 | 49,733 | 21,884 | 3,662 | 851 | 1,585 | 316,063 |
| 1998 | 908 | 2,423 | 5,318 | 12,028 | 17,076 | 31,533 | 31,589 | 42,069 | 67,494 | 40,140 | 6,128 | 3,306 | 260,012 |
| 1999 | 1,140 | 9,544 | 9,657 | 13,881 | 18,038 | 17,855 | 27,694 | 58,651 | 30,170 | 4,927 | 467 | 30 | 192,054 |
| 2000 | -155 | 2,513 | 938 | 17,936 | 18,255 | 22,906 | 42,916 | 55,449 | 21,160 | 2,248 | 966 | 1,262 | 186,394 |
| 2001 | 1,384 | 3,057 | 3,772 | 4,595 | 8,293 | 30,250 | 31,057 | 39,456 | 3,107 | 1,129 | 1,404 | 876 | 128,380 |
| 2002 | 300 | 7,965 | 14,383 | 13,774 | 10,772 | 19,332 | 40,209 | 38,494 | 14,006 | 568 | 881 | 507 | 161,191 |
| Avg (21-02) | 1,538 | 6,591 | 9,885 | 11,307 | 12,493 | 19,493 | 30,946 | 43,125 | 24,867 | 7,142 | 1,364 | 868 | 169,617 |
| Max (21-02) | 18,497 | 67,103 | 59,215 | 97,115 | 59,457 | 50,294 | 56,666 | 88,536 | 79,022 | 45,862 | 18,739 | 12,173 | 336,793 |
| Min (21-02) | -1,448 | -947 | -83 | 736 | 1,693 | 4,936 | 11,045 | 11,003 | 444 | 69 | -1,045 | -1,574 | 43,386 |

**Table 4.1.2.4-1**
**Unregulated Flows below Hetch Hetchy Reservoirs (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 9,299 | 15,550 | 30,525 | 151,299 | 103,584 | 129,637 | 99,574 | 123,650 | 68,218 | 14,257 | 4,527 | 3,764 | 753,884 |
| 1922 | 4,690 | 5,304 | 44,537 | 43,255 | 162,483 | 132,483 | 144,375 | 235,360 | 157,265 | 32,540 | 7,508 | 5,577 | 975,377 |
| 1923 | 7,385 | 18,579 | 81,491 | 79,911 | 49,557 | 56,286 | 133,757 | 132,197 | 56,185 | 21,109 | 10,540 | 8,331 | 655,328 |
| 1924 | 3,953 | 6,146 | 6,307 | 12,131 | 15,242 | 12,602 | 34,812 | 27,525 | 82 | 7,017 | -4,272 | -3,217 | 118,328 |
| 1925 | 2,583 | 12,439 | 15,912 | 19,070 | 144,076 | 77,564 | 159,513 | 110,028 | 35,131 | 13,849 | -1,683 | 286 | 588,768 |
| 1926 | -520 | 1,646 | 6,783 | 6,751 | 68,368 | 42,170 | 104,739 | 49,963 | 13,816 | 4,133 | -1,721 | -785 | 295,343 |
| 1927 | 2,503 | 32,200 | 22,744 | 33,554 | 145,145 | 83,012 | 189,914 | 100,058 | 26,168 | 18,468 | 7,348 | 7,341 | 668,455 |
| 1928 | 1,382 | 22,749 | 21,642 | 22,761 | 51,987 | 185,176 | 124,669 | 72,270 | 24,584 | 6,381 | 1,771 | 93 | 535,465 |
| 1929 | -4,229 | 1,744 | 8,150 | 9,330 | 24,091 | 36,185 | 56,256 | 74,658 | 34,868 | 7,178 | -2,457 | -12,021 | 233,753 |
| 1930 | -1,506 | -480 | 4,482 | 18,086 | 29,883 | 72,666 | 74,295 | 57,876 | 30,868 | 10,839 | 2,506 | -4,668 | 294,847 |
| 1931 | 2,351 | 7,636 | 3,574 | 12,433 | 21,466 | 19,176 | 25,063 | 26,191 | 3,529 | 899 | -1,532 | 789 | 121,575 |
| 1932 | 348 | 2,395 | 76,042 | 48,855 | 174,547 | 84,436 | 98,726 | 148,306 | 63,691 | 31,886 | 15,900 | 6,909 | 752,041 |
| 1933 | 2,487 | -458 | 6,225 | 18,032 | 18,633 | 40,630 | 49,323 | 62,007 | 57,805 | 21,922 | 8,402 | 522 | 285,530 |
| 1934 | -4,725 | 3,122 | 18,244 | 35,980 | 51,086 | 48,334 | 37,047 | 19,009 | 11,042 | -846 | -375 | 262 | 218,180 |
| 1935 | 3,513 | 11,309 | 18,643 | 64,097 | 51,560 | 78,049 | 260,882 | 149,308 | 50,039 | 19,366 | 7,336 | -1,004 | 713,098 |
| 1936 | 4,688 | 8,994 | 9,508 | 65,716 | 281,539 | 107,592 | 149,501 | 85,262 | 40,303 | 19,672 | 4,521 | -974 | 776,322 |
| 1937 | 308 | 4,484 | 10,028 | 17,631 | 195,935 | 146,813 | 150,737 | 129,435 | 64,035 | 21,291 | 8,337 | 1,668 | 750,702 |
| 1938 | 5,914 | 8,931 | 114,133 | 62,844 | 269,590 | 331,600 | 226,768 | 235,806 | 99,276 | 46,705 | 18,845 | 9,086 | 1,429,498 |
| 1939 | 13,450 | 14,959 | 16,185 | 23,346 | 35,229 | 60,019 | 69,543 | 36,794 | 16,219 | 5,049 | 726 | 7,173 | 298,692 |
| 1940 | 8,411 | 7,720 | 10,100 | 135,027 | 182,363 | 211,698 | 142,165 | 95,787 | 33,750 | 11,819 | 3,944 | -964 | 841,820 |
| 1941 | 7,556 | 7,531 | 72,431 | 71,768 | 156,689 | 175,509 | 161,872 | 170,316 | 70,011 | 26,658 | 6,769 | 3,198 | 930,308 |
| 1942 | 1,466 | 6,328 | 54,683 | 92,242 | 97,515 | 84,139 | 167,844 | 154,847 | 73,109 | 26,618 | 7,601 | -1,361 | 765,031 |
| 1943 | 1,486 | 26,793 | 39,498 | 168,638 | 108,499 | 254,684 | 142,356 | 88,491 | 43,207 | 17,198 | 8,451 | -361 | 898,940 |
| 1944 | 4,726 | 7,130 | 9,414 | 18,814 | 50,551 | 68,858 | 62,919 | 103,325 | 37,082 | 12,449 | 2,008 | -1,895 | 375,381 |
| 1945 | 2,643 | 37,608 | 33,763 | 26,104 | 205,805 | 111,477 | 113,986 | 109,829 | 38,304 | 15,459 | -86 | -7,131 | 687,761 |
| 1946 | 10,980 | 25,312 | 125,230 | 68,099 | 38,733 | 77,892 | 118,356 | 87,891 | 34,976 | 10,923 | -2,038 | -1,845 | 594,509 |
| 1947 | 3,417 | 25,849 | 32,976 | 18,455 | 40,131 | 57,876 | 51,471 | 38,475 | 6,940 | 2,533 | -5,405 | -356 | 272,362 |
| 1948 | 4,205 | 4,301 | 4,757 | 9,558 | 9,427 | 40,840 | 104,666 | 111,301 | 61,812 | 17,419 | -1,823 | -385 | 366,078 |
| 1949 | 2,033 | 2,833 | 8,069 | 8,302 | 21,111 | 87,279 | 95,627 | 91,852 | 27,847 | 6,168 | -1,617 | 545 | 350,049 |
| 1950 | 2,146 | 4,217 | 4,576 | 37,097 | 73,124 | 62,923 | 115,926 | 89,249 | 26,947 | 9,327 | 285 | -4,343 | 421,474 |
| 1951 | 6,348 | 186,520 | 285,314 | 101,528 | 84,328 | 93,082 | 64,108 | 58,555 | 18,893 | 10,035 | 2,041 | -3,371 | 907,381 |
| 1952 | 5,582 | 11,333 | 75,501 | 177,528 | 101,475 | 172,947 | 236,114 | 244,119 | 119,248 | 25,412 | 15,288 | 7,317 | 1,191,864 |
| 1953 | 4,640 | 6,634 | 31,950 | 78,290 | 31,452 | 49,262 | 86,455 | 75,380 | 57,948 | 19,202 | 5,783 | 726 | 447,722 |
| 1954 | 4,650 | 10,046 | 12,099 | 26,600 | 54,480 | 110,133 | 124,175 | 83,813 | 25,977 | 8,720 | -2,202 | -1,054 | 457,437 |
| 1955 | 2,140 | 7,662 | 20,780 | 42,323 | 30,157 | 38,889 | 49,231 | 82,948 | 31,892 | 5,314 | -4,378 | 201 | 307,159 |
| 1956 | 2,892 | 4,828 | 358,946 | 308,113 | 107,078 | 88,527 | 106,459 | 146,995 | 48,259 | 17,177 | 5,687 | 4,110 | 1,199,071 |
| 1957 | 9,444 | 3,830 | 9,367 | 18,885 | 56,857 | 81,252 | 47,660 | 98,725 | 37,549 | 11,587 | 12,300 | -145 | 387,311 |
| 1958 | 5,262 | 4,253 | 17,391 | 32,907 | 115,529 | 198,553 | 271,144 | 225,282 | 114,346 | 38,146 | 11,974 | 9,465 | 1,044,252 |
| 1959 | 6,176 | 1,956 | 1,499 | 37,822 | 71,594 | 45,428 | 49,696 | 34,791 | 8,580 | 5,167 | -1,537 | 7,397 | 268,569 |
| 1960 | -1,228 | 5,326 | 7,552 | 14,342 | 73,267 | 54,134 | 62,188 | 53,595 | 18,319 | 2,049 | 1,107 | 2,750 | 293,401 |
| 1961 | 2,848 | 5,241 | 13,298 | 8,148 | 17,311 | 24,651 | 29,200 | 31,037 | 12,127 | 5,595 | 4,161 | 1,666 | 155,283 |
| 1962 | 1,052 | 2,688 | 6,838 | 6,682 | 162,849 | 85,854 | 115,488 | 83,231 | 46,895 | 17,458 | 3,930 | 3,578 | 536,543 |
| 1963 | 7,112 | 8,183 | 17,427 | 52,114 | 147,106 | 64,336 | 152,558 | 161,304 | 82,909 | 34,969 | 17,739 | 13,322 | 759,079 |
| 1964 | 8,687 | 30,962 | 17,871 | 30,583 | 26,463 | 32,995 | 53,177 | 63,012 | 31,476 | 11,653 | 6,698 | 5,598 | 319,175 |
| 1965 | 7,017 | 23,084 | 227,390 | 195,156 | 87,362 | 76,612 | 168,242 | 126,675 | 77,798 | 29,387 | 17,431 | 9,378 | 1,045,532 |
| 1966 | 3,664 | 69,064 | 55,959 | 50,607 | 52,826 | 60,369 | 81,423 | 53,454 | 15,417 | 10,269 | 1,480 | 5,745 | 460,277 |
| 1967 | 7,738 | 23,845 | 108,114 | 86,501 | 67,071 | 187,818 | 221,318 | 244,304 | 202,213 | 94,966 | 20,204 | 8,202 | 1,272,294 |
| 1968 | 7,213 | 5,248 | 12,886 | 23,486 | 58,853 | 58,068 | 51,255 | 42,790 | 16,062 | 3,993 | 5,320 | 4,300 | 289,474 |
| 1969 | 1,136 | 13,855 | 42,470 | 423,431 | 236,142 | 188,458 | 269,995 | 285,440 | 165,562 | 47,345 | 22,271 | 7,582 | 1,703,687 |
| 1970 | 16,078 | 18,686 | 43,018 | 247,523 | 85,549 | 114,807 | 68,660 | 85,013 | 52,207 | 30,712 | 18,036 | 10,774 | 791,063 |
| 1971 | 10,901 | 39,921 | 69,536 | 61,470 | 45,085 | 76,356 | 79,557 | 85,466 | 54,121 | 18,019 | 10,802 | 7,404 | 558,638 |
| 1972 | 6,877 | 13,791 | 43,170 | 34,841 | 45,687 | 63,600 | 52,544 | 57,640 | 25,439 | 11,497 | 11,052 | 6,778 | 372,916 |
| 1973 | 4,240 | 17,841 | 35,060 | 92,749 | 147,194 | 126,922 | 109,077 | 143,244 | 67,659 | 18,064 | 11,516 | 9,339 | 782,905 |
| 1974 | 12,039 | 42,332 | 73,134 | 98,466 | 36,549 | 135,307 | 140,783 | 120,801 | 57,822 | 24,355 | 11,935 | 12,445 | 765,968 |
| 1975 | 16,313 | 10,622 | 17,938 | 27,937 | 106,202 | 156,714 | 107,564 | 171,236 | 117,065 | 25,285 | 16,820 | 10,244 | 783,940 |
| 1976 | 17,640 | 19,640 | 15,178 | -902 | 16,208 | 26,737 | 28,110 | 27,926 | 7,863 | 6,414 | 9,304 | 6,313 | 180,431 |
| 1977 | 3,368 | 4,508 | 1,996 | 5,813 | 5,814 | 5,731 | 9,071 | 14,894 | 7,072 | 407 | 2,190 | 1,378 | 62,242 |
| 1978 | 1,991 | 3,850 | 34,863 | 121,424 | 135,319 | 201,669 | 204,505 | 188,444 | 114,529 | 29,895 | 15,247 | 24,560 | 1,076,296 |
| 1979 | 5,420 | 18,914 | 14,163 | 92,051 | 110,177 | 152,517 | 112,066 | 151,063 | 49,289 | 19,421 | 7,855 | 5,987 | 738,923 |
| 1980 | 8,147 | 9,819 | 16,112 | 283,140 | 279,940 | 143,885 | 114,095 | 140,091 | 75,628 | 29,725 | 15,902 | 14,248 | 1,130,732 |
| 1981 | 11,062 | 3,487 | 13,971 | 35,798 | 21,872 | 71,487 | 59,979 | 53,506 | 18,930 | 8,164 | 12,056 | 5,044 | 315,356 |
| 1982 | 10,435 | 53,416 | 99,892 | 165,862 | 234,153 | 244,627 | 391,402 | 216,411 | 102,732 | 68,380 | 19,685 | 25,526 | 1,632,521 |
| 1983 | 38,948 | 89,666 | 159,971 | 199,196 | 258,712 | 443,671 | 213,568 | 254,313 | 193,401 | 77,066 | 16,038 | 14,882 | 1,959,432 |
| 1984 | 16,148 | 142,843 | 255,834 | 110,740 | 101,140 | 101,819 | 57,501 | 65,288 | 41,409 | 10,288 | 6,712 | 812 | 910,534 |
| 1985 | 8,915 | 32,168 | 19,584 | 15,531 | 38,535 | 71,946 | 87,028 | 50,197 | 14,711 | 9,386 | 10,579 | 9,570 | 368,150 |
| 1986 | 5,569 | 22,241 | 32,967 | 50,896 | 427,265 | 283,926 | 103,989 | 85,705 | 36,729 | 23,452 | 8,868 | 10,411 | 1,092,018 |
| 1987 | 6,886 | 3,168 | 4,562 | -1,210 | 18,561 | 45,453 | 30,567 | 22,146 | 10,615 | 4,304 | 4,042 | 1,176 | 150,270 |
| 1988 | 4,075 | 6,537 | 19,651 | 44,634 | 31,016 | 35,024 | 31,513 | 26,646 | 10,794 | 8,596 | 2,492 | 1,035 | 222,013 |
| 1989 | 548 | 10,883 | 11,773 | 13,541 | 23,488 | 113,551 | 71,514 | 27,917 | 14,383 | -4,480 | -3,417 | 1,862 | 281,563 |
| 1990 | 10,909 | 2,880 | 3,783 | 12,254 | 27,969 | 50,436 | 46,872 | 22,815 | 11,591 | -393 | -2,884 | -2,127 | 184,105 |
| 1991 | -1,535 | 6,694 | 3,344 | 3,324 | 3,227 | 83,391 | 64,372 | 80,682 | 40,831 | 21,634 | 13,567 | 5,439 | 324,970 |
| 1992 | 10,167 | 3,639 | 5,584 | 10,300 | 52,628 | 50,555 | 55,018 | 25,535 | 8,917 | 14,469 | 7,379 | 2,845 | 247,036 |
| 1993 | 4,212 | 1,436 | 24,003 | 196,055 | 117,024 | 174,093 | 132,858 | 145,624 | 88,714 | 35,108 | 16,405 | 8,950 | 944,482 |
| 1994 | 6,291 | 3,382 | 6,096 | 18,760 | 29,159 | 31,557 | 39,437 | 44,015 | 18,267 | 16,639 | 16,134 | 7,350 | 237,087 |
| 1995 | -4,866 | 10,498 | 24,875 | 233,327 | 72,080 | 398,676 | 215,775 | 284,013 | 175,709 | 101,194 | 22,754 | 7,037 | 1,541,072 |
| 1996 | -1,629 | 184 | 21,772 | 74,643 | 190,825 | 174,875 | 120,391 | 127,790 | 47,656 | 15,687 | 8,008 | 8,533 | 788,735 |
| 1997 | 4,634 | 32,978 | 252,698 | 574,286 | 103,048 | 93,507 | 68,847 | 71,151 | 9,297 | 16,178 | 14,389 | 28,935 | 1,269,948 |
| 1998 | 3,180 | 8,640 | 14,660 | 158,069 | 293,935 | 219,919 | 202,610 | 203,224 | 215,239 | 96,195 | 18,484 | 2,765 | 1,436,920 |
| 1999 | 4,626 | 16,805 | 27,043 | 88,908 | 176,605 | 95,388 | 119,457 | 125,033 | 68,073 | 25,595 | 15,454 | 12,900 | 775,887 |
| 2000 | 6,096 | 7,778 | 5,858 | 76,580 | 208,899 | 158,380 | 112,010 | 109,211 | 53,191 | 16,054 | 11,508 | 8,963 | 774,528 |
| 2001 | 9,558 | 4,663 | 7,876 | 15,677 | 34,219 | 72,415 | 75,048 | 72,038 | 11,446 | 9,079 | 5,808 | 4,929 | 322,756 |
| 2002 | 5,180 | 10,340 | 45,422 | 44,127 | 34,075 | 67,817 | 82,330 | 62,276 | 21,522 | 10,770 | 6,769 | 3,564 | 394,192 |
| Avg (21-02) | 5,582 | 17,460 | 44,618 | 77,074 | 97,223 | 109,460 | 111,155 | 104,559 | 52,213 | 20,169 | 7,452 | 4,645 | 651,610 |
| Max (21-02) | 38,948 | 186,520 | 358,946 | 574,286 | 427,265 | 443,671 | 391,402 | 285,440 | 215,239 | 101,194 | 22,754 | 28,935 | 1,959,432 |
| Min (21-02) | -4,866 | -480 | 1,499 | -1,210 | 3,227 | 5,731 | 9,071 | 14,894 | 82 | -4,480 | -5,405 | -12,021 | 62,242 |

**Table 4.1.2.5-1**
**Inflow to Calaveras Reservoir from Watershed (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 40 | 598 | 10,091 | 14,286 | 7,617 | 2,099 | 899 | 577 | 172 | 110 | 61 | 46 | 36,597 |
| 1922 | 64 | 68 | 5,739 | 3,508 | 29,495 | 13,743 | 4,809 | 1,335 | 307 | 166 | 89 | 61 | 59,383 |
| 1923 | 98 | 629 | 14,893 | 7,893 | 6,687 | 1,387 | 4,355 | 617 | 295 | 110 | 61 | 46 | 37,072 |
| 1924 | 25 | 0 | 0 | 0 | 0 | 3 | 12 | 0 | 0 | 0 | 0 | 0 | 40 |
| 1925 | 18 | 46 | 1,246 | 1,175 | 10,944 | 755 | 1,633 | 1,691 | 184 | 61 | 37 | 31 | 17,821 |
| 1926 | 43 | 46 | 101 | 1,215 | 21,697 | 1,636 | 6,095 | 430 | 270 | 95 | 55 | 40 | 31,723 |
| 1927 | 61 | 4,919 | 1,614 | 4,257 | 20,233 | 5,521 | 6,973 | 841 | 338 | 129 | 74 | 52 | 45,012 |
| 1928 | 77 | 83 | 3,167 | 1,614 | 3,035 | 19,414 | 7,436 | 746 | 28 | 107 | 61 | 43 | 35,811 |
| 1929 | 64 | 71 | 2,836 | 2,173 | 2,200 | 3,152 | 1,329 | 371 | 172 | 49 | 31 | 25 | 12,472 |
| 1930 | 37 | 46 | 101 | 2,872 | 2,872 | 11,877 | 967 | 448 | 98 | 68 | 40 | 31 | 19,457 |
| 1931 | 71 | 74 | 175 | 1,215 | 519 | 626 | 209 | 157 | 83 | 40 | 31 | 28 | 3,225 |
| 1932 | 25 | 46 | 9,762 | 5,223 | 9,418 | 1,169 | 826 | 408 | 239 | 83 | 49 | 37 | 27,286 |
| 1933 | 80 | 83 | 147 | 2,774 | 948 | 1,366 | 936 | 626 | 129 | 52 | 37 | 31 | 7,209 |
| 1934 | 34 | 49 | 3,247 | 4,382 | 4,465 | 1,464 | 442 | 215 | 163 | 55 | 37 | 28 | 14,580 |
| 1935 | 49 | 184 | 371 | 10,787 | 994 | 3,965 | 8,955 | 1,826 | 307 | 107 | 61 | 46 | 27,654 |
| 1936 | 68 | 89 | 387 | 2,673 | 18,033 | 2,955 | 2,980 | 1,102 | 307 | 107 | 61 | 46 | 28,808 |
| 1937 | 68 | 71 | 276 | 1,200 | 13,994 | 18,791 | 5,641 | 1,541 | 374 | 144 | 80 | 58 | 42,237 |
| 1938 | 68 | 129 | 6,033 | 6,478 | 36,996 | 24,809 | 6,767 | 1,869 | 531 | 230 | 123 | 83 | 84,115 |
| 1939 | 218 | 411 | 1,703 | 1,200 | 2,584 | 2,240 | 718 | 307 | 184 | 68 | 46 | 37 | 9,716 |
| 1940 | 34 | 46 | 101 | 10,867 | 26,414 | 16,210 | 7,884 | 1,541 | 442 | 184 | 98 | 68 | 63,888 |
| 1941 | 98 | 157 | 5,634 | 12,328 | 27,491 | 20,393 | 25,506 | 4,576 | 611 | 273 | 141 | 95 | 97,302 |
| 1942 | 153 | 338 | 6,933 | 20,203 | 18,192 | 7,246 | 10,870 | 3,799 | 479 | 203 | 107 | 74 | 68,596 |
| 1943 | 129 | 1,237 | 1,160 | 22,022 | 8,176 | 9,369 | 3,210 | 1,439 | 402 | 157 | 86 | 61 | 47,448 |
| 1944 | 107 | 242 | 476 | 902 | 7,101 | 5,766 | 1,550 | 899 | 242 | 83 | 52 | 40 | 17,462 |
| 1945 | 55 | 344 | 786 | 1,909 | 16,333 | 4,913 | 2,010 | 1,534 | 316 | 110 | 64 | 46 | 28,421 |
| 1946 | 64 | 448 | 14,746 | 7,589 | 3,640 | 2,207 | 1,811 | 1,132 | 310 | 110 | 64 | 46 | 32,168 |
| 1947 | 117 | 783 | 1,080 | 1,105 | 1,961 | 2,731 | 1,835 | 706 | 230 | 83 | 55 | 46 | 10,732 |
| 1948 | 61 | 132 | 399 | 384 | 537 | 1,949 | 3,250 | 1,476 | 181 | 68 | 46 | 40 | 8,522 |
| 1949 | 46 | 64 | 528 | 574 | 1,488 | 16,523 | 1,875 | 1,307 | 307 | 101 | 61 | 46 | 22,922 |
| 1950 | 52 | 58 | 313 | 5,812 | 6,405 | 1,525 | 1,221 | 611 | 184 | 61 | 40 | 31 | 16,314 |
| 1951 | 46 | 7,424 | 18,217 | 8,424 | 7,019 | 8,415 | 1,737 | 1,445 | 427 | 172 | 95 | 64 | 53,485 |
| 1952 | 83 | 218 | 8,458 | 34,464 | 13,577 | 20,644 | 5,051 | 1,605 | 540 | 236 | 126 | 86 | 85,088 |
| 1953 | 150 | 218 | 9,811 | 14,381 | 3,127 | 4,082 | 1,584 | 1,587 | 325 | 120 | 68 | 49 | 35,501 |
| 1954 | 86 | 534 | 316 | 3,416 | 6,132 | 5,186 | 2,142 | 890 | 264 | 89 | 55 | 40 | 19,150 |
| 1955 | 58 | 199 | 3,597 | 5,549 | 1,682 | 1,798 | 1,295 | 893 | 209 | 71 | 46 | 34 | 15,430 |
| 1956 | 37 | 86 | 35,572 | 22,787 | 16,422 | 6,190 | 2,240 | 1,212 | 528 | 230 | 123 | 83 | 85,509 |
| 1957 | 190 | 203 | 310 | 967 | 7,556 | 2,007 | 1,329 | 1,881 | 221 | 77 | 49 | 37 | 14,826 |
| 1958 | 40 | 175 | 1,077 | 5,656 | 27,074 | 23,882 | 35,243 | 3,759 | 626 | 279 | 144 | 98 | 98,054 |
| 1959 | 163 | 172 | 353 | 3,597 | 10,428 | 1,565 | 844 | 494 | 196 | 64 | 40 | 31 | 17,947 |
| 1960 | 49 | 55 | 138 | 1,025 | 5,595 | 654 | 503 | 396 | 120 | 46 | 31 | 25 | 8,636 |
| 1961 | 55 | 325 | 295 | 694 | 534 | 1,608 | 365 | 273 | 110 | 46 | 37 | 31 | 4,373 |
| 1962 | 31 | 52 | 264 | 319 | 14,795 | 5,960 | 1,215 | 939 | 255 | 86 | 49 | 37 | 24,002 |
| 1963 | 58 | 138 | 939 | 15,596 | 22,391 | 6,322 | 12,632 | 5,895 | 516 | 215 | 117 | 80 | 64,898 |
| 1964 | 138 | 1,528 | 749 | 5,407 | 927 | 1,046 | 810 | 537 | 166 | 61 | 40 | 31 | 11,441 |
| 1965 | 37 | 417 | 16,035 | 28,835 | 4,757 | 1,666 | 9,682 | 1,614 | 448 | 187 | 101 | 71 | 63,851 |
| 1966 | 120 | 1,590 | 3,848 | 3,275 | 4,392 | 1,620 | 316 | 356 | 190 | 64 | 40 | 31 | 15,842 |
| 1967 | 43 | 356 | 4,981 | 18,275 | 7,261 | 14,792 | 14,660 | 6,202 | 485 | 203 | 110 | 74 | 67,442 |
| 1968 | 132 | 196 | 758 | 7,497 | 4,014 | 3,198 | 1,580 | 890 | 230 | 77 | 46 | 37 | 18,656 |
| 1969 | 46 | 230 | 2,437 | 27,918 | 31,561 | 11,054 | 3,535 | 1,169 | 549 | 196 | 95 | 89 | 78,880 |
| 1970 | 147 | 196 | 991 | 17,330 | 3,842 | 10,358 | 1,267 | 654 | 276 | 101 | 74 | 58 | 35,295 |
| 1971 | 64 | 1,633 | 12,512 | 6,233 | 1,108 | 3,106 | 1,780 | 804 | 335 | 110 | 52 | 40 | 27,777 |
| 1972 | 68 | 117 | 3,281 | 1,145 | 2,145 | 470 | 335 | 157 | 95 | 37 | 12 | 18 | 7,878 |
| 1973 | 46 | 4,873 | 2,452 | 18,140 | 31,668 | 15,035 | 2,836 | 1,062 | 430 | 181 | 98 | 92 | 76,913 |
| 1974 | 270 | 3,029 | 13,227 | 12,797 | 2,013 | 12,368 | 12,509 | 1,746 | 669 | 347 | 129 | 55 | 59,159 |
| 1975 | 166 | 295 | 908 | 1,832 | 22,219 | 24,579 | 6,871 | 1,722 | 598 | 316 | 193 | 157 | 59,856 |
| 1976 | 203 | 239 | 270 | 242 | 276 | 678 | 276 | 120 | 52 | 31 | 25 | 31 | 2,443 |
| 1977 | 89 | 95 | 101 | 457 | 193 | 405 | 206 | 147 | 55 | 25 | 15 | 18 | 1,808 |
| 1978 | 18 | 46 | 1,157 | 21,298 | 12,214 | 15,203 | 6,165 | 1,455 | 562 | 196 | 101 | 92 | 58,509 |
| 1979 | 89 | 160 | 236 | 4,168 | 11,189 | 6,012 | 1,958 | 694 | 206 | 98 | 52 | 43 | 24,904 |
| 1980 | 110 | 335 | 2,820 | 18,825 | 36,164 | 7,691 | 2,891 | 1,148 | 470 | 224 | 114 | 68 | 70,858 |
| 1981 | 80 | 107 | 328 | 9,339 | 1,817 | 8,372 | 1,574 | 577 | 199 | 49 | 28 | 25 | 22,495 |
| 1982 | 40 | 2,167 | 4,508 | 22,526 | 13,607 | 10,057 | 31,527 | 4,260 | 583 | 258 | 135 | 92 | 89,759 |
| 1983 | 126 | 1,946 | 9,142 | 29,102 | 34,857 | 53,571 | 12,368 | 8,231 | 875 | 408 | 209 | 138 | 150,971 |
| 1984 | 285 | 4,272 | 18,539 | 2,912 | 1,633 | 1,811 | 1,593 | 1,366 | 341 | 123 | 71 | 52 | 32,997 |
| 1985 | 98 | 2,823 | 1,427 | 700 | 2,949 | 3,523 | 516 | 528 | 227 | 80 | 52 | 40 | 12,963 |
| 1986 | 37 | 166 | 460 | 436 | 41,430 | 23,394 | 4,014 | 1,320 | 485 | 206 | 110 | 46 | 72,104 |
| 1987 | 71 | 77 | 242 | 427 | 1,329 | 1,175 | 393 | 129 | 86 | 34 | 25 | 21 | 4,008 |
| 1988 | 31 | 80 | 881 | 1,691 | 384 | 279 | 344 | 157 | 83 | 34 | 25 | 21 | 4,008 |
| 1989 | 34 | 52 | 377 | 417 | 371 | 1,409 | 377 | 110 | 80 | 34 | 25 | 21 | 3,308 |
| 1990 | 31 | 374 | 298 | 945 | 1,117 | 638 | 316 | 236 | 89 | 37 | 25 | 21 | 4,128 |
| 1991 | 40 | 61 | 212 | 193 | 178 | 8,768 | 1,185 | 402 | 169 | 61 | 40 | 31 | 11,340 |
| 1992 | 40 | 52 | 476 | 697 | 15,344 | 3,818 | 1,495 | 509 | 252 | 83 | 49 | 37 | 22,851 |
| 1993 | 52 | 55 | 1,694 | 21,559 | 18,711 | 8,065 | 2,342 | 1,528 | 402 | 163 | 89 | 61 | 54,721 |
| 1994 | 110 | 166 | 798 | 620 | 5,981 | 1,080 | 786 | 691 | 144 | 52 | 37 | 28 | 10,493 |
| 1995 | 21 | 169 | 494 | 33,693 | 4,324 | 37,975 | 5,054 | 2,314 | 1,142 | 571 | 246 | 166 | 86,168 |
| 1996 | 160 | 150 | 2,019 | 14,961 | 27,700 | 13,202 | 2,225 | 1,565 | 691 | 252 | 120 | 114 | 63,158 |
| 1997 | 166 | 4,870 | 22,648 | 43,161 | 4,376 | 1,774 | 1,007 | 555 | 310 | 160 | 101 | 110 | 79,239 |
| 1998 | 135 | 755 | 2,575 | 22,265 | 58,199 | 11,036 | 10,170 | 3,990 | 1,900 | 921 | 442 | 279 | 112,665 |
| 1999 | 344 | 460 | 1,139 | 5,318 | 13,442 | 4,947 | 7,384 | 1,924 | 921 | 310 | 206 | 89 | 36,483 |
| 2000 | 117 | 239 | 295 | 3,916 | 19,242 | 11,260 | 1,605 | 826 | 384 | 206 | 89 | 123 | 38,300 |
| 2001 | 147 | 206 | 347 | 1,507 | 8,663 | 7,203 | 1,709 | 537 | 184 | 77 | 46 | 37 | 20,663 |
| 2002 | 46 | 199 | 5,398 | 3,443 | 1,841 | 4,367 | 1,142 | 531 | 215 | 55 | 28 | 21 | 17,287 |
| Avg (21-02) | 87 | 684 | 3,835 | 8,402 | 10,979 | 7,819 | 4,219 | 1,319 | 339 | 141 | 77 | 56 | 37,957 |
| Max (21-02) | 344 | 7,424 | 35,572 | 43,161 | 58,199 | 53,571 | 35,243 | 8,231 | 1,900 | 921 | 442 | 279 | 150,971 |
| Min (21-02) | 18 | 0 | 0 | 0 | 0 | 3 | 12 | 0 | 0 | 0 | 0 | 0 | 40 |

**Table 4.1.2.6-1**
**Runoff at Alameda Creek Diversion Dam (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 3 | 199 | 3,370 | 4,772 | 2,544 | 700 | 301 | 193 | 58 | 9 | 6 | 3 | 12,159 |
| 1922 | 6 | 6 | 1,918 | 1,172 | 9,857 | 4,591 | 1,608 | 445 | 104 | 12 | 6 | 3 | 19,730 |
| 1923 | 6 | 212 | 5,012 | 2,655 | 2,250 | 466 | 1,464 | 209 | 21 | 9 | 6 | 3 | 12,312 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 3 | 9 | 0 | 0 | 0 | 0 | 0 | 12 |
| 1925 | 0 | 3 | 420 | 396 | 3,695 | 255 | 552 | 571 | 15 | 6 | 3 | 3 | 5,920 |
| 1926 | 3 | 3 | 9 | 411 | 7,325 | 552 | 2,056 | 144 | 21 | 6 | 3 | 3 | 10,539 |
| 1927 | 3 | 1,504 | 494 | 1,301 | 6,184 | 1,688 | 2,130 | 258 | 25 | 9 | 6 | 3 | 13,604 |
| 1928 | 6 | 6 | 1,062 | 540 | 1,016 | 6,500 | 2,489 | 249 | 9 | 9 | 6 | 3 | 11,895 |
| 1929 | 6 | 6 | 957 | 733 | 743 | 1,062 | 448 | 126 | 58 | 3 | 3 | 3 | 4,149 |
| 1930 | 3 | 3 | 34 | 964 | 964 | 3,980 | 325 | 150 | 34 | 6 | 3 | 3 | 6,469 |
| 1931 | 6 | 6 | 61 | 430 | 184 | 221 | 74 | 55 | 31 | 3 | 3 | 3 | 1,077 |
| 1932 | 3 | 3 | 3,265 | 1,746 | 3,149 | 390 | 276 | 135 | 80 | 6 | 3 | 3 | 9,059 |
| 1933 | 6 | 6 | 49 | 951 | 325 | 470 | 319 | 215 | 43 | 3 | 3 | 3 | 2,394 |
| 1934 | 3 | 3 | 1,089 | 1,470 | 1,498 | 491 | 147 | 71 | 55 | 3 | 3 | 3 | 4,837 |
| 1935 | 3 | 15 | 126 | 3,627 | 335 | 1,335 | 3,014 | 614 | 104 | 9 | 6 | 3 | 9,191 |
| 1936 | 6 | 6 | 129 | 896 | 6,052 | 991 | 1,000 | 368 | 104 | 9 | 6 | 3 | 9,572 |
| 1937 | 6 | 6 | 92 | 402 | 4,686 | 6,291 | 1,887 | 516 | 126 | 12 | 6 | 3 | 14,034 |
| 1938 | 6 | 9 | 2,016 | 2,164 | 12,362 | 8,289 | 2,262 | 626 | 178 | 18 | 9 | 6 | 27,945 |
| 1939 | 18 | 34 | 605 | 424 | 915 | 795 | 255 | 107 | 64 | 6 | 3 | 3 | 3,228 |
| 1940 | 3 | 3 | 34 | 3,627 | 8,820 | 5,414 | 2,633 | 516 | 147 | 15 | 6 | 6 | 21,224 |
| 1941 | 6 | 12 | 1,884 | 4,118 | 9,188 | 6,816 | 8,525 | 1,528 | 206 | 21 | 12 | 6 | 32,325 |
| 1942 | 12 | 25 | 2,326 | 6,779 | 6,104 | 2,431 | 3,646 | 1,274 | 160 | 15 | 9 | 6 | 22,787 |
| 1943 | 9 | 95 | 396 | 7,519 | 2,793 | 3,201 | 1,096 | 491 | 138 | 12 | 6 | 6 | 15,762 |
| 1944 | 9 | 18 | 163 | 307 | 2,415 | 1,961 | 528 | 307 | 83 | 6 | 3 | 3 | 5,803 |
| 1945 | 3 | 28 | 264 | 644 | 5,518 | 1,660 | 678 | 519 | 107 | 9 | 6 | 3 | 9,440 |
| 1946 | 6 | 34 | 4,987 | 2,566 | 1,231 | 746 | 611 | 384 | 104 | 9 | 6 | 3 | 10,686 |
| 1947 | 9 | 64 | 390 | 399 | 706 | 985 | 660 | 255 | 83 | 6 | 6 | 3 | 3,566 |
| 1948 | 6 | 9 | 138 | 132 | 184 | 669 | 1,114 | 506 | 61 | 6 | 3 | 3 | 2,833 |
| 1949 | 3 | 6 | 178 | 193 | 500 | 5,549 | 629 | 439 | 101 | 9 | 6 | 3 | 7,617 |
| 1950 | 3 | 3 | 104 | 1,955 | 2,154 | 513 | 411 | 206 | 61 | 6 | 3 | 3 | 5,423 |
| 1951 | 3 | 632 | 6,819 | 3,155 | 2,627 | 3,149 | 651 | 540 | 160 | 15 | 9 | 6 | 17,766 |
| 1952 | 6 | 15 | 2,830 | 11,527 | 4,542 | 6,905 | 1,691 | 537 | 181 | 18 | 9 | 6 | 28,268 |
| 1953 | 12 | 15 | 3,302 | 4,840 | 1,053 | 1,375 | 534 | 534 | 110 | 9 | 6 | 3 | 11,794 |
| 1954 | 6 | 43 | 107 | 1,172 | 2,105 | 1,780 | 737 | 307 | 92 | 6 | 3 | 3 | 6,362 |
| 1955 | 3 | 15 | 1,218 | 1,881 | 571 | 611 | 439 | 304 | 71 | 6 | 3 | 3 | 5,125 |
| 1956 | 3 | 6 | 11,877 | 7,608 | 5,484 | 2,065 | 749 | 405 | 175 | 18 | 9 | 6 | 28,406 |
| 1957 | 15 | 15 | 104 | 331 | 2,584 | 687 | 454 | 644 | 77 | 6 | 3 | 3 | 4,926 |
| 1958 | 3 | 12 | 359 | 1,890 | 9,047 | 7,979 | 11,775 | 1,255 | 209 | 21 | 12 | 6 | 32,570 |
| 1959 | 12 | 12 | 120 | 1,218 | 3,535 | 531 | 285 | 169 | 68 | 6 | 3 | 3 | 5,963 |
| 1960 | 3 | 3 | 46 | 347 | 1,894 | 221 | 172 | 135 | 40 | 3 | 3 | 3 | 2,869 |
| 1961 | 3 | 28 | 107 | 252 | 193 | 586 | 132 | 98 | 40 | 3 | 3 | 3 | 1,449 |
| 1962 | 3 | 3 | 89 | 107 | 4,956 | 1,998 | 408 | 316 | 86 | 6 | 3 | 3 | 7,979 |
| 1963 | 150 | 9 | 313 | 5,183 | 7,442 | 2,102 | 4,198 | 1,958 | 172 | 15 | 9 | 6 | 21,559 |
| 1964 | 12 | 132 | 282 | 2,044 | 350 | 396 | 307 | 203 | 64 | 6 | 3 | 3 | 3,802 |
| 1965 | 3 | 31 | 5,380 | 9,673 | 1,596 | 559 | 3,250 | 540 | 150 | 15 | 6 | 6 | 21,209 |
| 1966 | 9 | 132 | 1,406 | 1,194 | 1,602 | 592 | 114 | 129 | 71 | 6 | 3 | 3 | 5,260 |
| 1967 | 3 | 28 | 1,669 | 6,126 | 2,434 | 4,959 | 4,916 | 2,078 | 163 | 15 | 9 | 6 | 22,406 |
| 1968 | 9 | 15 | 258 | 2,541 | 1,360 | 1,083 | 537 | 301 | 80 | 6 | 3 | 3 | 6,196 |
| 1969 | 3 | 18 | 813 | 9,333 | 10,551 | 3,695 | 1,182 | 390 | 184 | 15 | 6 | 6 | 26,196 |
| 1970 | 12 | 15 | 335 | 5,831 | 1,292 | 3,483 | 427 | 221 | 92 | 9 | 6 | 3 | 11,726 |
| 1971 | 6 | 129 | 4,389 | 2,185 | 390 | 1,089 | 623 | 282 | 117 | 9 | 3 | 3 | 9,225 |
| 1972 | 6 | 9 | 1,117 | 390 | 730 | 160 | 114 | 52 | 34 | 3 | 0 | 0 | 2,615 |
| 1973 | 3 | 390 | 859 | 6,365 | 11,109 | 5,275 | 994 | 371 | 150 | 15 | 9 | 6 | 25,549 |
| 1974 | 21 | 242 | 4,625 | 4,474 | 703 | 4,324 | 4,373 | 611 | 233 | 28 | 9 | 3 | 19,647 |
| 1975 | 12 | 21 | 307 | 617 | 7,491 | 8,286 | 2,317 | 580 | 203 | 25 | 15 | 12 | 19,886 |
| 1976 | 18 | 21 | 107 | 98 | 110 | 270 | 110 | 49 | 21 | 3 | 3 | 3 | 816 |
| 1977 | 6 | 9 | 37 | 169 | 71 | 150 | 77 | 55 | 21 | 3 | 0 | 0 | 598 |
| 1978 | 0 | 3 | 387 | 7,117 | 4,082 | 5,082 | 2,059 | 488 | 187 | 15 | 6 | 6 | 19,432 |
| 1979 | 6 | 12 | 80 | 1,402 | 3,769 | 2,025 | 660 | 233 | 71 | 6 | 3 | 3 | 8,271 |
| 1980 | 9 | 25 | 945 | 6,313 | 12,125 | 2,578 | 970 | 384 | 157 | 18 | 9 | 6 | 23,538 |
| 1981 | 6 | 9 | 110 | 3,133 | 611 | 2,808 | 528 | 193 | 68 | 3 | 3 | 3 | 7,476 |
| 1982 | 3 | 169 | 1,534 | 7,660 | 4,628 | 3,419 | 10,720 | 1,449 | 199 | 18 | 9 | 6 | 29,814 |
| 1983 | 9 | 150 | 3,081 | 9,811 | 11,751 | 18,057 | 4,168 | 2,774 | 295 | 31 | 15 | 9 | 50,152 |
| 1984 | 25 | 365 | 6,939 | 1,089 | 611 | 678 | 595 | 513 | 129 | 9 | 6 | 3 | 10,962 |
| 1985 | 9 | 261 | 580 | 285 | 1,200 | 1,436 | 209 | 215 | 92 | 6 | 6 | 3 | 4,303 |
| 1986 | 3 | 12 | 153 | 147 | 13,847 | 7,820 | 1,341 | 442 | 163 | 15 | 9 | 3 | 23,956 |
| 1987 | 6 | 6 | 86 | 147 | 463 | 408 | 138 | 46 | 31 | 3 | 3 | 3 | 1,341 |
| 1988 | 3 | 6 | 304 | 583 | 132 | 95 | 120 | 55 | 28 | 3 | 3 | 3 | 1,335 |
| 1989 | 3 | 3 | 132 | 144 | 129 | 485 | 129 | 37 | 28 | 3 | 3 | 3 | 1,099 |
| 1990 | 3 | 31 | 107 | 347 | 408 | 233 | 117 | 86 | 34 | 3 | 3 | 3 | 1,375 |
| 1991 | 3 | 6 | 71 | 64 | 61 | 2,961 | 399 | 135 | 58 | 6 | 3 | 3 | 3,772 |
| 1992 | 3 | 3 | 160 | 233 | 5,143 | 1,280 | 500 | 172 | 86 | 6 | 3 | 3 | 7,592 |
| 1993 | 3 | 3 | 568 | 7,206 | 6,251 | 2,694 | 783 | 513 | 135 | 12 | 6 | 6 | 18,180 |
| 1994 | 9 | 12 | 273 | 212 | 2,044 | 368 | 267 | 236 | 49 | 3 | 3 | 3 | 3,480 |
| 1995 | 0 | 52 | 417 | 14,528 | 927 | 12,954 | 1,182 | 1,679 | 583 | 166 | 34 | 21 | 32,543 |
| 1996 | 6 | 9 | 841 | 9,679 | 14,372 | 7,807 | 1,117 | 491 | 163 | 74 | 31 | 12 | 34,602 |
| 1997 | 28 | 1,350 | 7,681 | 14,593 | 1,476 | 660 | 331 | 169 | 77 | 34 | 18 | 9 | 26,426 |
| 1998 | 12 | 227 | 1,111 | 9,151 | 16,968 | 3,127 | 3,284 | 1,197 | 559 | 230 | 110 | 74 | 36,050 |
| 1999 | 52 | 89 | 288 | 3,618 | 6,307 | 2,216 | 3,170 | 589 | 236 | 77 | 40 | 28 | 16,710 |
| 2000 | 18 | 37 | 46 | 2,520 | 7,513 | 4,192 | 562 | 279 | 107 | 37 | 12 | 6 | 15,329 |
| 2001 | 9 | 15 | 37 | 390 | 3,182 | 1,915 | 473 | 166 | 37 | 9 | 6 | 3 | 6,242 |
| 2002 | 3 | 31 | 2,461 | 1,224 | 694 | 1,356 | 353 | 184 | 77 | 15 | 6 | 0 | 6,405 |
| Avg (21-02) | 9 | 88 | 1,327 | 2,993 | 3,759 | 2,683 | 1,425 | 454 | 111 | 17 | 8 | 5 | 12,880 |
| Max (21-02) | 150 | 1,504 | 11,877 | 14,593 | 16,968 | 18,057 | 11,775 | 2,774 | 583 | 230 | 110 | 74 | 50,152 |
| Min (21-02) | 0 | 0 | 0 | 0 | 0 | 3 | 9 | 0 | 0 | 0 | 0 | 0 | 12 |

**Table 4.1.2.7-1**
**Unregulated Runoff below Alameda Creek Diversion Dam (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 0 | 0 | 383 | 955 | 517 | 181 | 101 | 80 | 22 | 0 | 0 | 0 | 2,239 |
| 1922 | 0 | 0 | 299 | 246 | 1,767 | 705 | 221 | 46 | 10 | 1 | 0 | 0 | 3,295 |
| 1923 | 0 | 19 | 576 | 432 | 287 | 70 | 112 | 16 | 1 | 0 | 0 | 0 | 1,513 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1925 | 0 | 0 | 36 | 30 | 584 | 78 | 116 | 33 | 6 | 0 | 0 | 0 | 883 |
| 1926 | 0 | 0 | 0 | 2 | 876 | 57 | 260 | 6 | 0 | 0 | 0 | 0 | 1,200 |
| 1927 | 0 | 75 | 82 | 198 | 838 | 273 | 278 | 89 | 37 | 0 | 0 | 0 | 1,872 |
| 1928 | 0 | 0 | 94 | 133 | 197 | 830 | 360 | 21 | 7 | 3 | 0 | 0 | 1,645 |
| 1929 | 0 | 5 | 39 | 37 | 68 | 117 | 15 | 3 | 1 | 0 | 0 | 0 | 284 |
| 1930 | 0 | 0 | 17 | 172 | 108 | 642 | 57 | 37 | 24 | 0 | 0 | 0 | 1,057 |
| 1931 | 0 | 0 | 7 | 47 | 20 | 40 | 13 | 10 | 0 | 0 | 0 | 0 | 138 |
| 1932 | 0 | 0 | 504 | 251 | 485 | 75 | 53 | 26 | 8 | 1 | 0 | 0 | 1,403 |
| 1933 | 0 | 0 | 5 | 114 | 37 | 88 | 60 | 40 | 2 | 0 | 0 | 0 | 346 |
| 1934 | 0 | 0 | 141 | 204 | 208 | 94 | 29 | 14 | 4 | 0 | 0 | 0 | 693 |
| 1935 | 0 | 5 | 15 | 561 | 38 | 238 | 502 | 117 | 12 | 2 | 0 | 0 | 1,489 |
| 1936 | 0 | 0 | 15 | 109 | 904 | 184 | 186 | 71 | 12 | 2 | 0 | 0 | 1,482 |
| 1937 | 0 | 0 | 11 | 47 | 733 | 1,023 | 326 | 99 | 15 | 4 | 1 | 0 | 2,259 |
| 1938 | 0 | 2 | 296 | 321 | 1,710 | 1,342 | 386 | 120 | 23 | 9 | 3 | 1 | 4,213 |
| 1939 | 2 | 17 | 66 | 47 | 103 | 145 | 46 | 19 | 5 | 0 | 0 | 0 | 449 |
| 1940 | 0 | 0 | 4 | 566 | 1,260 | 886 | 445 | 99 | 19 | 6 | 2 | 0 | 3,287 |
| 1941 | 1 | 3 | 273 | 647 | 1,306 | 1,108 | 1,379 | 270 | 28 | 11 | 4 | 2 | 5,031 |
| 1942 | 2 | 13 | 347 | 996 | 911 | 411 | 604 | 228 | 21 | 7 | 2 | 0 | 3,542 |
| 1943 | 2 | 61 | 45 | 1,074 | 416 | 524 | 197 | 92 | 16 | 5 | 1 | 0 | 2,433 |
| 1944 | 1 | 8 | 19 | 35 | 356 | 333 | 99 | 58 | 8 | 1 | 0 | 0 | 918 |
| 1945 | 0 | 13 | 30 | 74 | 832 | 287 | 130 | 99 | 12 | 2 | 0 | 0 | 1,479 |
| 1946 | 0 | 19 | 765 | 383 | 162 | 142 | 117 | 73 | 12 | 2 | 0 | 0 | 1,674 |
| 1947 | 2 | 37 | 42 | 43 | 76 | 172 | 118 | 46 | 7 | 1 | 0 | 0 | 543 |
| 1948 | 0 | 2 | 16 | 15 | 21 | 126 | 200 | 95 | 5 | 0 | 0 | 0 | 479 |
| 1949 | 0 | 0 | 20 | 23 | 57 | 903 | 120 | 84 | 12 | 2 | 0 | 0 | 1,221 |
| 1950 | 0 | 0 | 12 | 284 | 317 | 98 | 78 | 39 | 5 | 0 | 0 | 0 | 833 |
| 1951 | 0 | 393 | 912 | 430 | 351 | 473 | 112 | 93 | 18 | 5 | 2 | 0 | 2,789 |
| 1952 | 0 | 6 | 431 | 1,602 | 715 | 1,121 | 295 | 103 | 24 | 9 | 3 | 1 | 4,310 |
| 1953 | 2 | 7 | 507 | 749 | 134 | 244 | 102 | 102 | 12 | 2 | 0 | 0 | 1,860 |
| 1954 | 0 | 23 | 12 | 150 | 301 | 302 | 138 | 57 | 9 | 1 | 0 | 0 | 995 |
| 1955 | 0 | 5 | 160 | 269 | 65 | 116 | 83 | 57 | 6 | 0 | 0 | 0 | 762 |
| 1956 | 0 | 0 | 1,649 | 1,106 | 836 | 355 | 145 | 78 | 23 | 9 | 2 | 1 | 4,204 |
| 1957 | 2 | 5 | 12 | 37 | 381 | 129 | 85 | 121 | 7 | 0 | 0 | 0 | 779 |
| 1958 | 0 | 5 | 42 | 275 | 1,288 | 1,293 | 1,895 | 227 | 29 | 11 | 4 | 2 | 5,070 |
| 1959 | 2 | 4 | 14 | 160 | 542 | 101 | 54 | 32 | 5 | 0 | 0 | 0 | 914 |
| 1960 | 0 | 0 | 5 | 40 | 271 | 42 | 33 | 26 | 2 | 0 | 0 | 0 | 418 |
| 1961 | 0 | 12 | 12 | 26 | 21 | 103 | 23 | 18 | 1 | 0 | 0 | 0 | 217 |
| 1962 | 0 | 0 | 10 | 12 | 767 | 343 | 78 | 61 | 9 | 1 | 0 | 0 | 1,281 |
| 1963 | 51 | 2 | 37 | 801 | 1,089 | 362 | 697 | 340 | 23 | 8 | 2 | 1 | 3,412 |
| 1964 | 5 | 77 | 29 | 261 | 36 | 68 | 52 | 34 | 4 | 0 | 0 | 0 | 565 |
| 1965 | 0 | 17 | 820 | 1,364 | 225 | 107 | 541 | 104 | 19 | 6 | 2 | 0 | 3,203 |
| 1966 | 2 | 80 | 174 | 142 | 204 | 104 | 20 | 23 | 5 | 0 | 0 | 0 | 755 |
| 1967 | 0 | 14 | 238 | 914 | 364 | 811 | 804 | 356 | 21 | 7 | 2 | 0 | 3,532 |
| 1968 | 2 | 5 | 30 | 378 | 183 | 197 | 102 | 57 | 7 | 0 | 0 | 0 | 960 |
| 1969 | 0 | 7 | 96 | 1,324 | 1,479 | 613 | 214 | 75 | 24 | 7 | 2 | 1 | 3,841 |
| 1970 | 2 | 5 | 38 | 874 | 174 | 576 | 82 | 42 | 9 | 2 | 0 | 0 | 1,805 |
| 1971 | 0 | 82 | 657 | 307 | 43 | 192 | 115 | 52 | 13 | 2 | 0 | 0 | 1,464 |
| 1972 | 0 | 1 | 142 | 44 | 83 | 30 | 22 | 10 | 0 | 0 | 0 | 0 | 333 |
| 1973 | 0 | 256 | 96 | 909 | 1,483 | 824 | 178 | 68 | 18 | 6 | 2 | 1 | 3,842 |
| 1974 | 8 | 158 | 698 | 674 | 78 | 683 | 690 | 113 | 31 | 15 | 3 | 0 | 3,149 |
| 1975 | 3 | 11 | 35 | 71 | 1,082 | 1,330 | 392 | 111 | 27 | 13 | 6 | 5 | 3,086 |
| 1976 | 5 | 8 | 10 | 9 | 11 | 44 | 18 | 8 | 0 | 0 | 0 | 0 | 112 |
| 1977 | 0 | 0 | 4 | 18 | 8 | 26 | 13 | 9 | 0 | 0 | 0 | 0 | 78 |
| 1978 | 0 | 0 | 45 | 1,043 | 641 | 833 | 354 | 94 | 25 | 7 | 2 | 1 | 3,044 |
| 1979 | 0 | 3 | 9 | 192 | 583 | 346 | 126 | 44 | 6 | 2 | 0 | 0 | 1,311 |
| 1980 | 1 | 13 | 117 | 938 | 1,674 | 435 | 180 | 74 | 20 | 9 | 2 | 0 | 3,463 |
| 1981 | 0 | 1 | 12 | 480 | 70 | 471 | 101 | 37 | 5 | 0 | 0 | 0 | 1,178 |
| 1982 | 0 | 111 | 211 | 1,095 | 716 | 560 | 1,698 | 253 | 26 | 10 | 3 | 1 | 4,686 |
| 1983 | 2 | 99 | 469 | 1,374 | 1,619 | 2,866 | 683 | 464 | 42 | 18 | 8 | 4 | 7,648 |
| 1984 | 9 | 224 | 926 | 122 | 63 | 117 | 103 | 88 | 13 | 3 | 0 | 0 | 1,667 |
| 1985 | 1 | 146 | 55 | 27 | 124 | 214 | 33 | 34 | 7 | 1 | 0 | 0 | 643 |
| 1986 | 0 | 4 | 18 | 17 | 1,898 | 1,267 | 240 | 85 | 21 | 7 | 2 | 0 | 3,559 |
| 1987 | 0 | 0 | 9 | 16 | 51 | 75 | 26 | 9 | 0 | 0 | 0 | 0 | 186 |
| 1988 | 0 | 0 | 34 | 65 | 15 | 18 | 23 | 10 | 0 | 0 | 0 | 0 | 165 |
| 1989 | 0 | 0 | 15 | 16 | 14 | 91 | 24 | 7 | 0 | 0 | 0 | 0 | 167 |
| 1990 | 0 | 15 | 12 | 37 | 43 | 41 | 20 | 16 | 0 | 0 | 0 | 0 | 183 |
| 1991 | 0 | 0 | 9 | 8 | 7 | 492 | 76 | 26 | 4 | 0 | 0 | 0 | 621 |
| 1992 | 0 | 0 | 19 | 27 | 790 | 230 | 96 | 33 | 9 | 1 | 0 | 0 | 1,204 |
| 1993 | 0 | 0 | 65 | 1,054 | 933 | 455 | 151 | 99 | 16 | 5 | 1 | 0 | 2,778 |
| 1994 | 1 | 4 | 31 | 24 | 293 | 70 | 51 | 44 | 2 | 0 | 0 | 0 | 520 |
| 1995 | 0 | 4 | 19 | 1,569 | 200 | 2,039 | 295 | 149 | 56 | 27 | 9 | 5 | 4,375 |
| 1996 | 3 | 3 | 78 | 774 | 1,315 | 727 | 143 | 101 | 32 | 10 | 2 | 2 | 3,190 |
| 1997 | 3 | 256 | 1,100 | 1,972 | 204 | 114 | 64 | 36 | 12 | 5 | 2 | 2 | 3,770 |
| 1998 | 2 | 36 | 103 | 1,084 | 2,611 | 612 | 566 | 239 | 97 | 46 | 20 | 11 | 5,427 |
| 1999 | 11 | 19 | 44 | 256 | 709 | 290 | 419 | 124 | 44 | 13 | 7 | 1 | 1,938 |
| 2000 | 1 | 8 | 12 | 178 | 956 | 624 | 103 | 53 | 16 | 7 | 1 | 3 | 1,960 |
| 2001 | 2 | 6 | 13 | 58 | 443 | 409 | 110 | 35 | 5 | 0 | 0 | 0 | 1,081 |
| 2002 | 0 | 5 | 260 | 152 | 71 | 259 | 74 | 34 | 6 | 0 | 0 | 0 | 862 |
| Avg (21-02) | 2 | 30 | 179 | 409 | 530 | 432 | 236 | 80 | 14 | 4 | 1 | 1 | 1,918 |
| Max (21-02) | 51 | 393 | 1,649 | 1,972 | 2,611 | 2,866 | 1,895 | 464 | 97 | 46 | 20 | 11 | 7,648 |
| Min (21-02) | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 4.1.2.8-1**
**Inflow to San Antonio Reservoir (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 0 | 0 | 1,513 | 3,772 | 2,044 | 715 | 399 | 316 | 86 | 0 | 0 | 0 | 8,845 |
| 1922 | 0 | 0 | 1,182 | 973 | 6,979 | 2,787 | 872 | 181 | 40 | 3 | 0 | 0 | 13,015 |
| 1923 | 0 | 77 | 2,274 | 1,706 | 1,135 | 276 | 442 | 61 | 3 | 0 | 0 | 0 | 5,975 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| 1925 | 0 | 0 | 141 | 120 | 2,308 | 307 | 457 | 132 | 25 | 0 | 0 | 0 | 3,489 |
| 1926 | 0 | 0 | 0 | 6 | 3,459 | 224 | 1,028 | 25 | 0 | 0 | 0 | 0 | 4,741 |
| 1927 | 0 | 298 | 325 | 783 | 3,311 | 1,080 | 1,099 | 353 | 147 | 0 | 0 | 0 | 7,396 |
| 1928 | 0 | 0 | 371 | 525 | 776 | 3,278 | 1,424 | 83 | 28 | 12 | 0 | 0 | 6,497 |
| 1929 | 0 | 18 | 153 | 144 | 270 | 463 | 58 | 12 | 3 | 0 | 0 | 0 | 1,123 |
| 1930 | 0 | 0 | 68 | 678 | 427 | 2,535 | 227 | 144 | 95 | 0 | 0 | 0 | 4,174 |
| 1931 | 0 | 0 | 28 | 184 | 80 | 160 | 52 | 40 | 0 | 0 | 0 | 0 | 543 |
| 1932 | 0 | 0 | 1,992 | 991 | 1,915 | 298 | 209 | 104 | 31 | 3 | 0 | 0 | 5,542 |
| 1933 | 0 | 0 | 21 | 451 | 144 | 347 | 236 | 160 | 6 | 0 | 0 | 0 | 1,366 |
| 1934 | 0 | 0 | 555 | 804 | 822 | 371 | 114 | 55 | 15 | 0 | 0 | 0 | 2,737 |
| 1935 | 0 | 18 | 58 | 2,216 | 150 | 939 | 1,983 | 463 | 46 | 6 | 0 | 0 | 5,880 |
| 1936 | 0 | 0 | 58 | 430 | 3,572 | 727 | 733 | 279 | 46 | 9 | 0 | 0 | 5,855 |
| 1937 | 0 | 0 | 43 | 184 | 2,894 | 4,042 | 1,289 | 393 | 58 | 15 | 3 | 0 | 8,921 |
| 1938 | 0 | 6 | 1,169 | 1,267 | 6,755 | 5,300 | 1,525 | 476 | 92 | 34 | 12 | 3 | 16,640 |
| 1939 | 6 | 68 | 261 | 184 | 408 | 571 | 181 | 77 | 18 | 0 | 0 | 0 | 1,774 |
| 1940 | 0 | 0 | 15 | 2,234 | 4,978 | 3,502 | 1,758 | 393 | 74 | 25 | 6 | 0 | 12,985 |
| 1941 | 3 | 12 | 1,080 | 2,556 | 5,159 | 4,376 | 5,447 | 1,065 | 110 | 43 | 15 | 6 | 19,874 |
| 1942 | 6 | 52 | 1,369 | 3,934 | 3,600 | 1,623 | 2,385 | 902 | 83 | 28 | 9 | 0 | 13,991 |
| 1943 | 6 | 242 | 178 | 4,241 | 1,642 | 2,068 | 779 | 365 | 64 | 18 | 3 | 0 | 9,609 |
| 1944 | 3 | 31 | 74 | 138 | 1,406 | 1,317 | 393 | 230 | 31 | 3 | 0 | 0 | 3,624 |
| 1945 | 0 | 52 | 120 | 292 | 3,287 | 1,135 | 513 | 390 | 46 | 9 | 0 | 0 | 5,843 |
| 1946 | 0 | 74 | 3,020 | 1,513 | 641 | 562 | 460 | 288 | 46 | 9 | 0 | 0 | 6,613 |
| 1947 | 6 | 144 | 166 | 169 | 301 | 681 | 466 | 181 | 28 | 3 | 0 | 0 | 2,145 |
| 1948 | 0 | 9 | 61 | 58 | 83 | 497 | 789 | 374 | 18 | 0 | 0 | 0 | 1,890 |
| 1949 | 0 | 0 | 80 | 89 | 227 | 3,566 | 476 | 331 | 46 | 6 | 0 | 0 | 4,821 |
| 1950 | 0 | 0 | 49 | 1,120 | 1,252 | 387 | 310 | 153 | 18 | 0 | 0 | 0 | 3,290 |
| 1951 | 0 | 1,553 | 3,603 | 1,697 | 1,387 | 1,869 | 442 | 368 | 71 | 21 | 6 | 0 | 11,017 |
| 1952 | 0 | 25 | 1,703 | 6,328 | 2,823 | 4,428 | 1,166 | 408 | 95 | 34 | 12 | 3 | 17,026 |
| 1953 | 6 | 28 | 2,001 | 2,958 | 528 | 964 | 402 | 402 | 49 | 9 | 0 | 0 | 7,347 |
| 1954 | 0 | 92 | 49 | 592 | 1,191 | 1,194 | 546 | 227 | 37 | 3 | 0 | 0 | 3,931 |
| 1955 | 0 | 21 | 632 | 1,062 | 258 | 457 | 328 | 227 | 25 | 0 | 0 | 0 | 3,011 |
| 1956 | 0 | 0 | 6,515 | 4,370 | 3,302 | 1,402 | 571 | 307 | 92 | 34 | 9 | 3 | 16,606 |
| 1957 | 6 | 21 | 46 | 147 | 1,504 | 509 | 338 | 479 | 28 | 0 | 0 | 0 | 3,078 |
| 1958 | 0 | 18 | 166 | 1,086 | 5,088 | 5,107 | 7,485 | 896 | 114 | 43 | 15 | 6 | 20,025 |
| 1959 | 6 | 15 | 55 | 632 | 2,139 | 399 | 215 | 126 | 21 | 0 | 0 | 0 | 3,609 |
| 1960 | 0 | 0 | 21 | 157 | 1,071 | 166 | 129 | 101 | 6 | 0 | 0 | 0 | 1,651 |
| 1961 | 0 | 49 | 46 | 104 | 83 | 408 | 92 | 71 | 3 | 0 | 0 | 0 | 856 |
| 1962 | 0 | 0 | 40 | 49 | 3,029 | 1,356 | 310 | 239 | 34 | 3 | 0 | 0 | 5,061 |
| 1963 | 199 | 9 | 144 | 3,164 | 4,303 | 1,430 | 2,753 | 1,341 | 89 | 31 | 9 | 3 | 13,476 |
| 1964 | 18 | 304 | 114 | 1,031 | 141 | 267 | 206 | 135 | 15 | 0 | 0 | 0 | 2,231 |
| 1965 | 0 | 68 | 3,238 | 5,386 | 887 | 424 | 2,136 | 411 | 74 | 25 | 6 | 0 | 12,653 |
| 1966 | 6 | 316 | 687 | 562 | 807 | 411 | 80 | 92 | 21 | 0 | 0 | 0 | 2,983 |
| 1967 | 0 | 55 | 939 | 3,612 | 1,439 | 3,204 | 3,176 | 1,406 | 83 | 28 | 9 | 0 | 13,951 |
| 1968 | 6 | 21 | 117 | 1,491 | 724 | 776 | 402 | 227 | 28 | 0 | 0 | 0 | 3,793 |
| 1969 | 0 | 28 | 377 | 5,229 | 5,840 | 2,421 | 847 | 298 | 95 | 28 | 6 | 3 | 15,173 |
| 1970 | 9 | 21 | 150 | 3,453 | 687 | 2,277 | 322 | 166 | 37 | 6 | 0 | 0 | 7,129 |
| 1971 | 0 | 325 | 2,596 | 1,212 | 169 | 758 | 454 | 206 | 52 | 9 | 0 | 0 | 5,782 |
| 1972 | 0 | 3 | 562 | 175 | 328 | 120 | 86 | 40 | 0 | 0 | 0 | 0 | 1,313 |
| 1973 | 0 | 1,013 | 381 | 3,591 | 5,859 | 3,256 | 703 | 270 | 71 | 25 | 6 | 3 | 15,176 |
| 1974 | 31 | 623 | 2,756 | 2,661 | 307 | 2,698 | 2,725 | 445 | 123 | 58 | 12 | 0 | 12,438 |
| 1975 | 12 | 43 | 138 | 279 | 4,275 | 5,254 | 1,547 | 439 | 107 | 52 | 25 | 18 | 12,190 |
| 1976 | 18 | 31 | 40 | 37 | 43 | 172 | 71 | 31 | 0 | 0 | 0 | 0 | 442 |
| 1977 | 0 | 0 | 15 | 71 | 31 | 104 | 52 | 37 | 0 | 0 | 0 | 0 | 310 |
| 1978 | 0 | 0 | 178 | 4,118 | 2,532 | 3,290 | 1,399 | 371 | 98 | 28 | 6 | 3 | 12,024 |
| 1979 | 0 | 12 | 37 | 758 | 2,305 | 1,366 | 497 | 175 | 25 | 6 | 0 | 0 | 5,180 |
| 1980 | 3 | 52 | 460 | 3,704 | 6,613 | 1,719 | 712 | 292 | 80 | 34 | 9 | 0 | 13,678 |
| 1981 | 0 | 3 | 49 | 1,897 | 276 | 1,860 | 399 | 147 | 21 | 0 | 0 | 0 | 4,652 |
| 1982 | 0 | 439 | 835 | 4,327 | 2,830 | 2,213 | 6,706 | 1,000 | 104 | 40 | 12 | 3 | 18,509 |
| 1983 | 6 | 393 | 1,854 | 5,429 | 6,396 | 11,321 | 2,698 | 1,832 | 166 | 71 | 31 | 15 | 30,210 |
| 1984 | 34 | 884 | 3,658 | 482 | 249 | 460 | 405 | 347 | 52 | 12 | 0 | 0 | 6,583 |
| 1985 | 3 | 577 | 218 | 107 | 491 | 847 | 132 | 135 | 28 | 3 | 0 | 0 | 2,541 |
| 1986 | 0 | 15 | 71 | 68 | 7,497 | 5,005 | 948 | 335 | 83 | 28 | 9 | 0 | 14,059 |
| 1987 | 0 | 0 | 37 | 64 | 203 | 298 | 101 | 34 | 0 | 0 | 0 | 0 | 737 |
| 1988 | 0 | 0 | 135 | 258 | 58 | 71 | 89 | 40 | 0 | 0 | 0 | 0 | 651 |
| 1989 | 0 | 0 | 58 | 64 | 55 | 359 | 95 | 28 | 0 | 0 | 0 | 0 | 660 |
| 1990 | 0 | 58 | 46 | 144 | 169 | 163 | 80 | 61 | 0 | 0 | 0 | 0 | 721 |
| 1991 | 0 | 0 | 34 | 31 | 28 | 1,943 | 301 | 101 | 15 | 0 | 0 | 0 | 2,452 |
| 1992 | 0 | 0 | 74 | 107 | 3,121 | 908 | 381 | 129 | 34 | 3 | 0 | 0 | 4,757 |
| 1993 | 0 | 0 | 258 | 4,164 | 3,686 | 1,795 | 595 | 390 | 64 | 18 | 3 | 0 | 10,974 |
| 1994 | 3 | 15 | 123 | 95 | 1,157 | 276 | 199 | 175 | 9 | 0 | 0 | 0 | 2,053 |
| 1995 | 0 | 15 | 77 | 6,199 | 792 | 8,056 | 1,166 | 589 | 221 | 107 | 37 | 21 | 17,281 |
| 1996 | 12 | 12 | 307 | 3,057 | 5,193 | 2,872 | 565 | 399 | 126 | 40 | 9 | 9 | 12,601 |
| 1997 | 12 | 1,013 | 4,346 | 7,789 | 804 | 451 | 255 | 141 | 46 | 18 | 6 | 9 | 14,890 |
| 1998 | 9 | 141 | 408 | 4,281 | 10,311 | 2,418 | 2,237 | 942 | 384 | 181 | 80 | 43 | 21,436 |
| 1999 | 43 | 77 | 175 | 1,013 | 2,802 | 1,145 | 1,654 | 488 | 175 | 52 | 28 | 3 | 7,654 |
| 2000 | 3 | 31 | 46 | 703 | 3,775 | 2,464 | 408 | 209 | 61 | 28 | 3 | 12 | 7,743 |
| 2001 | 9 | 25 | 52 | 230 | 1,749 | 1,614 | 436 | 138 | 18 | 0 | 0 | 0 | 4,272 |
| 2002 | 0 | 21 | 1,028 | 598 | 282 | 1,022 | 292 | 135 | 25 | 0 | 0 | 0 | 3,403 |
| Avg (21-02) | 6 | 117 | 709 | 1,617 | 2,093 | 1,706 | 932 | 318 | 55 | 16 | 5 | 2 | 7,575 |
| Max (21-02) | 199 | 1,553 | 6,515 | 7,789 | 10,311 | 11,321 | 7,485 | 1,832 | 384 | 181 | 80 | 43 | 30,210 |
| Min (21-02) | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |

4.1.2.9 Inflow to Crystal Springs Reservoir

Crystal Springs Reservoir receives inflow from its own watershed on San Mateo Creek, transfers of water from Pilarcitos Creek, and transfers from Hetch Hetchy and the East Bay watersheds. Inflow to Crystal Springs Reservoir from its watershed is depicted in Table 4.1.2.9-1. The average annual inflow to Crystal Springs Reservoir is estimated to be 11,400 acre-feet. Inflow to the reservoir from the other sources is an operational result and can vary in each study.

4.1.2.10 Inflow to San Andreas Reservoir

San Andreas Reservoir receives inflow from its own watershed and transfers from San Mateo Creek and Pilarcitos Creek. The reservoir also receives inflow from pumping from Crystal Springs Reservoir. Table 4.1.2.10-1 depicts the estimated inflow to San Andreas Reservoir from its watershed. The average annual runoff is estimated to be 4,400 acre-feet. Inflow to the reservoir from the other sources is an operational result and can vary in each study.

4.1.2.11 Inflow to Pilarcitos Reservoir

Located in the upper Pilarcitos Creek watershed, Pilarcitos Reservoir receives runoff averaging 4,000 acre-feet per year. Table 4.1.2.11-1 depicts the estimated inflow to Pilarcitos Reservoir. The inflow has ranged from essentially none during an extreme drought year such as 1924, to over 15,800 acre-feet in 1983.

4.1.2.12 Unregulated Runoff below Pilarcitos Reservoir

Unregulated tributary flow occurs between Pilarcitos Dam and Stone Dam. This water is available for diversion at Stone Dam in addition to the flows being released from Pilarcitos Dam. Table 4.1.2.12-1 depicts this unregulated runoff. The unregulated runoff in this reach of stream is estimated to be an average annual 1,800 acre-feet.

**Table 4.1.2.9-1**
**Inflow to Crystal Springs Reservoir from Watershed (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 12 | 181 | 3,032 | 4,293 | 2,289 | 632 | 270 | 172 | 52 | 34 | 18 | 12 | 10,999 |
| 1922 | 18 | 21 | 1,725 | 1,056 | 8,866 | 4,131 | 1,445 | 402 | 92 | 49 | 28 | 18 | 17,852 |
| 1923 | 31 | 190 | 4,478 | 2,372 | 2,010 | 417 | 1,310 | 184 | 89 | 34 | 18 | 12 | 11,146 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |
| 1925 | 6 | 15 | 374 | 353 | 3,290 | 227 | 491 | 509 | 55 | 18 | 12 | 9 | 5,361 |
| 1926 | 12 | 15 | 31 | 365 | 6,521 | 491 | 1,832 | 129 | 80 | 28 | 15 | 12 | 9,532 |
| 1927 | 18 | 1,479 | 485 | 1,280 | 6,083 | 1,660 | 2,096 | 252 | 101 | 40 | 21 | 15 | 13,531 |
| 1928 | 25 | 25 | 951 | 485 | 911 | 5,837 | 2,234 | 224 | 9 | 34 | 18 | 12 | 10,766 |
| 1929 | 18 | 21 | 853 | 654 | 663 | 948 | 399 | 110 | 52 | 15 | 9 | 6 | 3,750 |
| 1930 | 12 | 15 | 31 | 862 | 862 | 3,569 | 292 | 135 | 31 | 18 | 12 | 9 | 5,849 |
| 1931 | 21 | 21 | 52 | 365 | 157 | 187 | 61 | 46 | 25 | 12 | 9 | 9 | 967 |
| 1932 | 9 | 12 | 2,934 | 1,571 | 2,833 | 353 | 249 | 123 | 71 | 25 | 15 | 9 | 8,203 |
| 1933 | 25 | 25 | 43 | 835 | 285 | 411 | 282 | 187 | 40 | 15 | 12 | 9 | 2,170 |
| 1934 | 9 | 15 | 976 | 1,317 | 1,341 | 442 | 132 | 64 | 49 | 15 | 12 | 9 | 4,382 |
| 1935 | 15 | 55 | 114 | 3,244 | 298 | 1,191 | 2,691 | 549 | 92 | 31 | 18 | 12 | 8,311 |
| 1936 | 21 | 28 | 117 | 804 | 5,420 | 890 | 896 | 331 | 92 | 34 | 18 | 12 | 8,663 |
| 1937 | 21 | 21 | 83 | 362 | 4,207 | 5,650 | 1,697 | 463 | 114 | 43 | 25 | 18 | 12,705 |
| 1938 | 21 | 40 | 1,814 | 1,949 | 11,122 | 7,457 | 2,035 | 562 | 160 | 71 | 37 | 25 | 25,291 |
| 1939 | 64 | 123 | 513 | 359 | 776 | 675 | 215 | 92 | 55 | 21 | 15 | 12 | 2,922 |
| 1940 | 9 | 15 | 31 | 3,265 | 7,939 | 4,873 | 2,369 | 463 | 132 | 55 | 31 | 21 | 19,205 |
| 1941 | 31 | 46 | 1,694 | 3,704 | 8,265 | 6,132 | 7,666 | 1,375 | 184 | 83 | 43 | 28 | 29,250 |
| 1942 | 46 | 101 | 2,084 | 6,073 | 5,469 | 2,179 | 3,268 | 1,142 | 144 | 61 | 34 | 21 | 20,623 |
| 1943 | 40 | 371 | 350 | 6,620 | 2,458 | 2,817 | 964 | 433 | 120 | 46 | 28 | 18 | 14,264 |
| 1944 | 31 | 74 | 144 | 273 | 2,136 | 1,734 | 466 | 270 | 74 | 25 | 15 | 12 | 5,254 |
| 1945 | 15 | 104 | 236 | 574 | 4,910 | 1,476 | 605 | 460 | 95 | 34 | 18 | 15 | 8,544 |
| 1946 | 18 | 135 | 4,431 | 2,280 | 1,096 | 663 | 543 | 341 | 92 | 34 | 18 | 15 | 9,667 |
| 1947 | 34 | 236 | 325 | 331 | 589 | 822 | 552 | 212 | 71 | 25 | 18 | 12 | 3,228 |
| 1948 | 18 | 40 | 120 | 117 | 163 | 586 | 976 | 445 | 55 | 21 | 15 | 12 | 2,569 |
| 1949 | 12 | 18 | 160 | 172 | 448 | 4,969 | 565 | 393 | 92 | 31 | 18 | 12 | 6,890 |
| 1950 | 15 | 18 | 95 | 1,746 | 1,927 | 457 | 368 | 184 | 55 | 18 | 12 | 9 | 4,907 |
| 1951 | 15 | 2,231 | 5,475 | 2,532 | 2,111 | 2,529 | 522 | 433 | 129 | 52 | 28 | 18 | 16,075 |
| 1952 | 25 | 64 | 2,544 | 10,361 | 4,082 | 6,205 | 1,519 | 482 | 163 | 71 | 37 | 25 | 25,576 |
| 1953 | 46 | 64 | 2,949 | 4,324 | 939 | 1,228 | 476 | 476 | 98 | 37 | 21 | 15 | 10,674 |
| 1954 | 28 | 160 | 95 | 1,028 | 1,844 | 1,559 | 644 | 267 | 80 | 28 | 15 | 12 | 5,760 |
| 1955 | 18 | 58 | 1,080 | 1,669 | 506 | 540 | 390 | 267 | 61 | 21 | 12 | 9 | 4,634 |
| 1956 | 12 | 25 | 10,692 | 6,850 | 4,938 | 1,860 | 675 | 365 | 160 | 71 | 37 | 25 | 25,708 |
| 1957 | 58 | 61 | 92 | 292 | 2,271 | 605 | 399 | 565 | 68 | 21 | 15 | 12 | 4,459 |
| 1958 | 12 | 52 | 325 | 1,700 | 8,139 | 7,181 | 10,594 | 1,129 | 187 | 83 | 43 | 31 | 29,477 |
| 1959 | 49 | 52 | 107 | 1,080 | 3,133 | 470 | 255 | 147 | 58 | 18 | 12 | 9 | 5,392 |
| 1960 | 15 | 15 | 40 | 307 | 1,682 | 196 | 150 | 120 | 37 | 12 | 9 | 6 | 2,590 |
| 1961 | 15 | 98 | 89 | 209 | 160 | 485 | 110 | 83 | 34 | 15 | 12 | 9 | 1,320 |
| 1962 | 9 | 15 | 80 | 95 | 4,447 | 1,792 | 365 | 282 | 77 | 25 | 15 | 12 | 7,215 |
| 1963 | 18 | 43 | 282 | 4,689 | 6,730 | 1,900 | 3,796 | 1,771 | 153 | 64 | 34 | 25 | 19,506 |
| 1964 | 40 | 460 | 224 | 1,627 | 279 | 316 | 242 | 163 | 49 | 18 | 12 | 9 | 3,440 |
| 1965 | 12 | 126 | 4,821 | 8,670 | 1,430 | 500 | 2,912 | 485 | 135 | 55 | 31 | 21 | 19,199 |
| 1966 | 37 | 479 | 1,157 | 985 | 1,320 | 488 | 95 | 107 | 58 | 18 | 12 | 9 | 4,766 |
| 1967 | 12 | 107 | 1,498 | 5,493 | 2,182 | 4,447 | 4,407 | 1,863 | 144 | 61 | 34 | 21 | 20,270 |
| 1968 | 40 | 58 | 227 | 2,253 | 1,206 | 961 | 476 | 267 | 71 | 25 | 15 | 12 | 5,610 |
| 1969 | 15 | 68 | 733 | 8,393 | 9,486 | 3,324 | 1,062 | 350 | 166 | 58 | 28 | 28 | 23,710 |
| 1970 | 43 | 58 | 298 | 5,211 | 1,154 | 3,115 | 381 | 196 | 83 | 31 | 21 | 18 | 10,609 |
| 1971 | 18 | 491 | 3,762 | 1,875 | 335 | 933 | 534 | 242 | 101 | 34 | 15 | 12 | 8,354 |
| 1972 | 21 | 34 | 985 | 344 | 644 | 141 | 101 | 46 | 28 | 12 | 3 | 6 | 2,366 |
| 1973 | 15 | 1,464 | 737 | 5,453 | 9,520 | 4,520 | 853 | 319 | 129 | 55 | 28 | 28 | 23,121 |
| 1974 | 80 | 911 | 3,977 | 3,845 | 605 | 3,716 | 3,759 | 525 | 199 | 104 | 37 | 15 | 17,775 |
| 1975 | 49 | 89 | 273 | 552 | 6,678 | 7,390 | 2,065 | 519 | 178 | 95 | 58 | 46 | 17,993 |
| 1976 | 61 | 71 | 83 | 74 | 83 | 206 | 83 | 37 | 15 | 9 | 9 | 9 | 740 |
| 1977 | 28 | 28 | 31 | 138 | 58 | 123 | 61 | 43 | 18 | 6 | 6 | 6 | 546 |
| 1978 | 6 | 15 | 347 | 6,402 | 3,673 | 4,570 | 1,854 | 439 | 169 | 58 | 31 | 28 | 17,591 |
| 1979 | 28 | 49 | 71 | 1,252 | 3,364 | 1,808 | 589 | 209 | 61 | 28 | 15 | 12 | 7,485 |
| 1980 | 34 | 101 | 847 | 5,659 | 10,870 | 2,311 | 868 | 344 | 141 | 68 | 34 | 21 | 21,298 |
| 1981 | 25 | 34 | 98 | 2,808 | 546 | 2,516 | 473 | 175 | 58 | 15 | 9 | 6 | 6,764 |
| 1982 | 12 | 651 | 1,356 | 6,773 | 4,091 | 3,023 | 9,477 | 1,280 | 175 | 77 | 40 | 28 | 26,982 |
| 1983 | 37 | 586 | 2,750 | 8,749 | 10,477 | 16,106 | 3,716 | 2,474 | 264 | 123 | 61 | 43 | 45,386 |
| 1984 | 86 | 1,286 | 5,573 | 875 | 491 | 543 | 479 | 411 | 101 | 37 | 21 | 15 | 9,919 |
| 1985 | 31 | 850 | 430 | 212 | 887 | 1,059 | 153 | 160 | 68 | 25 | 15 | 12 | 3,901 |
| 1986 | 12 | 49 | 138 | 132 | 12,454 | 7,034 | 1,206 | 396 | 147 | 61 | 34 | 15 | 21,679 |
| 1987 | 21 | 25 | 74 | 129 | 399 | 353 | 120 | 40 | 25 | 9 | 6 | 6 | 1,206 |
| 1988 | 9 | 25 | 264 | 509 | 117 | 83 | 104 | 46 | 25 | 9 | 6 | 6 | 1,203 |
| 1989 | 9 | 15 | 114 | 126 | 110 | 424 | 114 | 34 | 25 | 9 | 6 | 6 | 991 |
| 1990 | 9 | 114 | 89 | 285 | 335 | 193 | 95 | 71 | 28 | 12 | 9 | 6 | 1,246 |
| 1991 | 6 | 28 | 92 | 83 | 77 | 2,750 | 439 | 147 | 40 | 21 | 9 | 6 | 3,698 |
| 1992 | 12 | 15 | 144 | 209 | 4,628 | 1,151 | 451 | 153 | 77 | 25 | 15 | 12 | 6,893 |
| 1993 | 15 | 15 | 513 | 6,503 | 5,644 | 2,434 | 706 | 460 | 123 | 49 | 28 | 18 | 16,508 |
| 1994 | 34 | 49 | 242 | 187 | 1,805 | 325 | 236 | 209 | 43 | 15 | 9 | 9 | 3,164 |
| 1995 | 6 | 52 | 150 | 10,164 | 1,304 | 11,456 | 1,525 | 697 | 344 | 172 | 74 | 49 | 25,994 |
| 1996 | 49 | 46 | 608 | 4,514 | 8,357 | 3,983 | 672 | 473 | 209 | 77 | 37 | 34 | 19,058 |
| 1997 | 49 | 1,470 | 6,831 | 13,021 | 1,320 | 534 | 304 | 169 | 95 | 49 | 31 | 34 | 23,907 |
| 1998 | 40 | 227 | 776 | 6,718 | 17,557 | 3,330 | 3,069 | 1,203 | 574 | 279 | 132 | 83 | 33,988 |
| 1999 | 104 | 138 | 344 | 1,605 | 4,054 | 1,491 | 2,228 | 580 | 279 | 95 | 61 | 28 | 11,008 |
| 2000 | 34 | 71 | 89 | 1,182 | 5,806 | 3,397 | 485 | 249 | 117 | 61 | 28 | 37 | 11,554 |
| 2001 | 46 | 61 | 104 | 454 | 2,615 | 2,173 | 516 | 163 | 55 | 25 | 15 | 12 | 6,239 |
| 2002 | 12 | 61 | 1,630 | 1,037 | 555 | 1,317 | 344 | 160 | 64 | 15 | 9 | 6 | 5,211 |
| Avg (21-02) | 26 | 206 | 1,154 | 2,528 | 3,303 | 2,353 | 1,270 | 397 | 102 | 43 | 23 | 17 | 11,421 |
| Max (21-02) | 104 | 2,231 | 10,692 | 13,021 | 17,557 | 16,106 | 10,594 | 2,474 | 574 | 279 | 132 | 83 | 45,386 |
| Min (21-02) | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 |

**Table 4.1.2.10-1**
**Inflow to San Andreas Reservoir from Watershed (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 6 | 68 | 1,163 | 1,648 | 878 | 242 | 104 | 68 | 21 | 12 | 6 | 6 | 4,223 |
| 1922 | 6 | 9 | 663 | 405 | 3,403 | 1,587 | 555 | 153 | 37 | 18 | 9 | 6 | 6,853 |
| 1923 | 12 | 74 | 1,719 | 911 | 770 | 160 | 503 | 71 | 34 | 12 | 6 | 6 | 4,278 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1925 | 3 | 6 | 144 | 135 | 1,261 | 86 | 187 | 196 | 21 | 6 | 3 | 3 | 2,053 |
| 1926 | 6 | 6 | 12 | 141 | 2,504 | 190 | 703 | 49 | 31 | 12 | 6 | 6 | 3,667 |
| 1927 | 6 | 568 | 187 | 491 | 2,335 | 638 | 804 | 98 | 40 | 15 | 9 | 6 | 5,199 |
| 1928 | 9 | 9 | 365 | 187 | 350 | 2,240 | 856 | 86 | 3 | 12 | 6 | 6 | 4,131 |
| 1929 | 6 | 9 | 328 | 252 | 255 | 362 | 153 | 43 | 21 | 6 | 3 | 3 | 1,442 |
| 1930 | 3 | 6 | 12 | 331 | 331 | 1,369 | 110 | 52 | 12 | 6 | 6 | 3 | 2,243 |
| 1931 | 9 | 9 | 21 | 141 | 58 | 74 | 25 | 18 | 9 | 3 | 3 | 3 | 374 |
| 1932 | 3 | 6 | 1,126 | 602 | 1,086 | 135 | 95 | 46 | 28 | 9 | 6 | 3 | 3,146 |
| 1933 | 9 | 9 | 15 | 319 | 110 | 157 | 107 | 71 | 15 | 6 | 3 | 3 | 826 |
| 1934 | 3 | 6 | 374 | 506 | 516 | 169 | 52 | 25 | 18 | 6 | 3 | 3 | 1,682 |
| 1935 | 6 | 21 | 43 | 1,243 | 114 | 457 | 1,034 | 212 | 37 | 12 | 6 | 6 | 3,192 |
| 1936 | 9 | 9 | 46 | 307 | 2,081 | 341 | 344 | 126 | 37 | 12 | 6 | 6 | 3,324 |
| 1937 | 9 | 9 | 31 | 138 | 1,614 | 2,167 | 651 | 178 | 43 | 15 | 9 | 6 | 4,870 |
| 1938 | 9 | 15 | 697 | 746 | 4,269 | 2,863 | 779 | 215 | 61 | 28 | 15 | 9 | 9,707 |
| 1939 | 25 | 46 | 196 | 138 | 298 | 258 | 83 | 37 | 21 | 9 | 6 | 3 | 1,120 |
| 1940 | 3 | 6 | 12 | 1,255 | 3,047 | 1,869 | 908 | 178 | 52 | 21 | 12 | 9 | 7,375 |
| 1941 | 12 | 18 | 651 | 1,421 | 3,170 | 2,354 | 2,943 | 528 | 71 | 31 | 15 | 12 | 11,226 |
| 1942 | 18 | 40 | 801 | 2,329 | 2,099 | 835 | 1,255 | 439 | 55 | 25 | 12 | 9 | 7,918 |
| 1943 | 15 | 141 | 135 | 2,541 | 942 | 1,080 | 371 | 166 | 46 | 18 | 9 | 6 | 5,472 |
| 1944 | 12 | 28 | 55 | 104 | 819 | 666 | 178 | 104 | 28 | 9 | 6 | 3 | 2,013 |
| 1945 | 6 | 40 | 92 | 221 | 1,884 | 568 | 233 | 178 | 37 | 12 | 6 | 6 | 3,284 |
| 1946 | 6 | 52 | 1,700 | 875 | 420 | 255 | 209 | 132 | 37 | 12 | 6 | 6 | 3,710 |
| 1947 | 12 | 89 | 126 | 129 | 227 | 316 | 212 | 83 | 28 | 9 | 6 | 6 | 1,243 |
| 1948 | 6 | 15 | 46 | 43 | 61 | 224 | 374 | 169 | 21 | 9 | 6 | 3 | 979 |
| 1949 | 6 | 6 | 61 | 68 | 172 | 1,906 | 215 | 150 | 37 | 12 | 6 | 6 | 2,645 |
| 1950 | 6 | 6 | 37 | 672 | 740 | 175 | 141 | 71 | 21 | 6 | 3 | 3 | 1,881 |
| 1951 | 6 | 856 | 2,102 | 973 | 810 | 970 | 199 | 166 | 49 | 18 | 12 | 6 | 6,168 |
| 1952 | 9 | 25 | 976 | 3,977 | 1,565 | 2,381 | 583 | 184 | 61 | 28 | 15 | 9 | 9,814 |
| 1953 | 18 | 25 | 1,132 | 1,660 | 362 | 470 | 181 | 184 | 37 | 12 | 9 | 6 | 4,097 |
| 1954 | 9 | 61 | 37 | 393 | 709 | 598 | 249 | 101 | 31 | 9 | 6 | 6 | 2,210 |
| 1955 | 6 | 21 | 414 | 641 | 193 | 209 | 150 | 104 | 25 | 9 | 6 | 3 | 1,783 |
| 1956 | 3 | 9 | 4,103 | 2,630 | 1,894 | 715 | 258 | 141 | 61 | 28 | 15 | 9 | 9,867 |
| 1957 | 21 | 25 | 37 | 110 | 872 | 230 | 153 | 218 | 25 | 9 | 6 | 3 | 1,709 |
| 1958 | 3 | 21 | 126 | 654 | 3,124 | 2,756 | 4,066 | 433 | 74 | 31 | 15 | 12 | 11,315 |
| 1959 | 18 | 18 | 40 | 414 | 1,203 | 181 | 98 | 58 | 21 | 6 | 6 | 3 | 2,068 |
| 1960 | 6 | 6 | 15 | 117 | 644 | 77 | 58 | 46 | 12 | 6 | 3 | 3 | 994 |
| 1961 | 6 | 37 | 34 | 80 | 61 | 184 | 43 | 31 | 12 | 6 | 3 | 3 | 500 |
| 1962 | 3 | 6 | 31 | 37 | 1,706 | 687 | 141 | 107 | 31 | 9 | 6 | 3 | 2,768 |
| 1963 | 6 | 15 | 107 | 1,798 | 2,584 | 730 | 1,458 | 681 | 58 | 25 | 12 | 9 | 7,485 |
| 1964 | 15 | 175 | 86 | 623 | 107 | 120 | 95 | 61 | 18 | 6 | 3 | 3 | 1,313 |
| 1965 | 3 | 49 | 1,851 | 3,327 | 549 | 193 | 1,117 | 187 | 52 | 21 | 12 | 9 | 7,371 |
| 1966 | 12 | 184 | 445 | 377 | 506 | 187 | 37 | 40 | 21 | 6 | 6 | 3 | 1,826 |
| 1967 | 6 | 40 | 574 | 2,108 | 838 | 1,706 | 1,691 | 715 | 55 | 25 | 12 | 9 | 7,780 |
| 1968 | 15 | 21 | 89 | 865 | 463 | 368 | 181 | 101 | 28 | 9 | 6 | 3 | 2,151 |
| 1969 | 6 | 28 | 282 | 3,219 | 3,640 | 1,277 | 408 | 135 | 64 | 21 | 12 | 9 | 9,102 |
| 1970 | 18 | 21 | 114 | 1,998 | 442 | 1,194 | 147 | 77 | 31 | 12 | 9 | 6 | 4,069 |
| 1971 | 6 | 187 | 1,442 | 718 | 129 | 359 | 206 | 92 | 40 | 12 | 6 | 6 | 3,204 |
| 1972 | 9 | 12 | 377 | 132 | 249 | 55 | 40 | 18 | 12 | 3 | 0 | 3 | 911 |
| 1973 | 6 | 562 | 282 | 2,093 | 3,652 | 1,734 | 328 | 123 | 49 | 21 | 12 | 9 | 8,872 |
| 1974 | 31 | 350 | 1,525 | 1,476 | 233 | 1,427 | 1,442 | 203 | 77 | 40 | 15 | 6 | 6,825 |
| 1975 | 18 | 34 | 104 | 212 | 2,563 | 2,836 | 792 | 199 | 68 | 37 | 21 | 18 | 6,902 |
| 1976 | 25 | 28 | 31 | 28 | 31 | 80 | 31 | 15 | 6 | 3 | 3 | 3 | 282 |
| 1977 | 9 | 12 | 12 | 52 | 21 | 46 | 25 | 18 | 6 | 3 | 3 | 3 | 212 |
| 1978 | 3 | 6 | 135 | 2,458 | 1,409 | 1,752 | 712 | 169 | 64 | 21 | 12 | 9 | 6,752 |
| 1979 | 9 | 18 | 28 | 482 | 1,292 | 694 | 227 | 80 | 25 | 12 | 6 | 6 | 2,879 |
| 1980 | 12 | 40 | 325 | 2,173 | 4,171 | 887 | 335 | 132 | 55 | 25 | 12 | 9 | 8,176 |
| 1981 | 9 | 12 | 37 | 1,077 | 209 | 967 | 181 | 68 | 21 | 6 | 3 | 3 | 2,593 |
| 1982 | 3 | 249 | 519 | 2,599 | 1,571 | 1,160 | 3,637 | 491 | 68 | 31 | 15 | 9 | 10,351 |
| 1983 | 15 | 224 | 1,056 | 3,357 | 4,020 | 6,181 | 1,427 | 948 | 101 | 46 | 25 | 15 | 17,416 |
| 1984 | 34 | 494 | 2,139 | 335 | 187 | 209 | 184 | 157 | 40 | 15 | 9 | 6 | 3,809 |
| 1985 | 12 | 325 | 166 | 80 | 341 | 405 | 58 | 61 | 28 | 9 | 6 | 6 | 1,498 |
| 1986 | 3 | 18 | 52 | 49 | 4,778 | 2,698 | 463 | 153 | 55 | 25 | 12 | 6 | 8,314 |
| 1987 | 9 | 9 | 28 | 49 | 153 | 135 | 46 | 15 | 9 | 3 | 3 | 3 | 463 |
| 1988 | 3 | 9 | 101 | 196 | 43 | 31 | 40 | 18 | 9 | 3 | 3 | 3 | 460 |
| 1989 | 3 | 6 | 43 | 49 | 43 | 163 | 43 | 12 | 9 | 3 | 3 | 3 | 381 |
| 1990 | 3 | 43 | 34 | 110 | 129 | 74 | 37 | 28 | 9 | 3 | 3 | 3 | 476 |
| 1991 | 3 | 12 | 34 | 31 | 31 | 1,056 | 169 | 58 | 15 | 9 | 3 | 3 | 1,424 |
| 1992 | 6 | 6 | 55 | 80 | 1,771 | 442 | 172 | 58 | 31 | 9 | 6 | 3 | 2,639 |
| 1993 | 6 | 6 | 196 | 2,489 | 2,161 | 930 | 270 | 178 | 46 | 18 | 9 | 6 | 6,316 |
| 1994 | 12 | 18 | 92 | 71 | 691 | 126 | 92 | 80 | 15 | 6 | 3 | 3 | 1,209 |
| 1995 | 3 | 18 | 58 | 3,891 | 500 | 4,385 | 583 | 267 | 132 | 68 | 28 | 18 | 9,952 |
| 1996 | 18 | 18 | 233 | 1,728 | 3,198 | 1,525 | 258 | 181 | 80 | 31 | 12 | 12 | 7,295 |
| 1997 | 18 | 562 | 2,615 | 4,984 | 506 | 206 | 117 | 64 | 37 | 18 | 12 | 12 | 9,151 |
| 1998 | 15 | 86 | 298 | 2,572 | 6,721 | 1,274 | 1,175 | 460 | 218 | 107 | 52 | 34 | 13,012 |
| 1999 | 40 | 52 | 132 | 614 | 1,553 | 571 | 853 | 221 | 107 | 37 | 25 | 9 | 4,214 |
| 2000 | 12 | 28 | 34 | 451 | 2,222 | 1,301 | 184 | 95 | 43 | 25 | 9 | 15 | 4,419 |
| 2001 | 18 | 25 | 40 | 175 | 1,000 | 832 | 196 | 61 | 21 | 9 | 6 | 3 | 2,388 |
| 2002 | 6 | 25 | 623 | 399 | 212 | 503 | 132 | 61 | 25 | 6 | 3 | 3 | 1,998 |
| Avg (21-02) | 10 | 79 | 443 | 970 | 1,267 | 903 | 487 | 152 | 39 | 16 | 9 | 7 | 4,381 |
| Max (21-02) | 40 | 856 | 4,103 | 4,984 | 6,721 | 6,181 | 4,066 | 948 | 218 | 107 | 52 | 34 | 17,416 |
| Min (21-02) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 4.1.2.11-1**
**Inflow to Pilarcitos Reservoir (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 3 | 61 | 1,059 | 1,498 | 798 | 221 | 95 | 61 | 18 | 12 | 6 | 6 | 3,839 |
| 1922 | 6 | 6 | 602 | 368 | 3,093 | 1,439 | 503 | 141 | 34 | 18 | 9 | 6 | 6,227 |
| 1923 | 9 | 64 | 1,562 | 829 | 700 | 144 | 457 | 64 | 31 | 12 | 6 | 6 | 3,885 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1925 | 3 | 6 | 132 | 123 | 1,148 | 80 | 172 | 178 | 18 | 6 | 3 | 3 | 1,872 |
| 1926 | 6 | 6 | 9 | 129 | 2,274 | 172 | 638 | 46 | 28 | 9 | 6 | 3 | 3,327 |
| 1927 | 6 | 516 | 169 | 445 | 2,121 | 580 | 730 | 89 | 37 | 12 | 6 | 6 | 4,717 |
| 1928 | 9 | 9 | 331 | 169 | 319 | 2,035 | 779 | 80 | 3 | 12 | 6 | 6 | 3,759 |
| 1929 | 6 | 6 | 298 | 227 | 230 | 331 | 138 | 40 | 18 | 6 | 3 | 3 | 1,307 |
| 1930 | 3 | 6 | 12 | 301 | 301 | 1,246 | 101 | 46 | 9 | 6 | 3 | 3 | 2,038 |
| 1931 | 6 | 9 | 18 | 126 | 55 | 64 | 21 | 15 | 9 | 3 | 3 | 3 | 335 |
| 1932 | 3 | 6 | 1,022 | 546 | 988 | 123 | 86 | 43 | 25 | 9 | 6 | 3 | 2,860 |
| 1933 | 9 | 9 | 15 | 292 | 98 | 144 | 98 | 64 | 12 | 6 | 3 | 3 | 755 |
| 1934 | 3 | 6 | 341 | 460 | 466 | 153 | 46 | 21 | 18 | 6 | 3 | 3 | 1,528 |
| 1935 | 6 | 18 | 40 | 1,129 | 104 | 414 | 939 | 190 | 31 | 12 | 6 | 6 | 2,897 |
| 1936 | 6 | 9 | 40 | 279 | 1,890 | 310 | 313 | 117 | 31 | 12 | 6 | 6 | 3,020 |
| 1937 | 6 | 6 | 28 | 126 | 1,467 | 1,970 | 592 | 163 | 40 | 15 | 9 | 6 | 4,428 |
| 1938 | 6 | 12 | 632 | 678 | 3,879 | 2,599 | 709 | 196 | 55 | 25 | 12 | 9 | 8,814 |
| 1939 | 21 | 43 | 178 | 126 | 270 | 236 | 77 | 34 | 18 | 6 | 6 | 3 | 1,019 |
| 1940 | 3 | 6 | 9 | 1,139 | 2,768 | 1,700 | 826 | 163 | 46 | 18 | 9 | 6 | 6,693 |
| 1941 | 9 | 15 | 589 | 1,292 | 2,882 | 2,139 | 2,673 | 479 | 64 | 28 | 15 | 9 | 10,195 |
| 1942 | 15 | 37 | 727 | 2,118 | 1,906 | 758 | 1,139 | 399 | 49 | 21 | 12 | 9 | 7,190 |
| 1943 | 12 | 129 | 123 | 2,308 | 856 | 982 | 338 | 150 | 43 | 15 | 9 | 6 | 4,972 |
| 1944 | 12 | 25 | 49 | 95 | 746 | 605 | 163 | 95 | 25 | 9 | 6 | 3 | 1,832 |
| 1945 | 6 | 37 | 83 | 199 | 1,712 | 516 | 212 | 160 | 34 | 12 | 6 | 6 | 2,983 |
| 1946 | 6 | 46 | 1,547 | 795 | 381 | 230 | 190 | 120 | 34 | 12 | 6 | 6 | 3,373 |
| 1947 | 12 | 83 | 114 | 117 | 206 | 285 | 193 | 74 | 25 | 9 | 6 | 6 | 1,129 |
| 1948 | 6 | 12 | 43 | 40 | 55 | 206 | 341 | 153 | 18 | 6 | 6 | 3 | 890 |
| 1949 | 6 | 6 | 55 | 61 | 157 | 1,731 | 196 | 138 | 31 | 9 | 6 | 6 | 2,403 |
| 1950 | 6 | 6 | 34 | 611 | 672 | 160 | 129 | 64 | 18 | 6 | 3 | 3 | 1,712 |
| 1951 | 6 | 779 | 1,909 | 884 | 737 | 881 | 181 | 150 | 46 | 18 | 9 | 6 | 5,607 |
| 1952 | 9 | 21 | 887 | 3,612 | 1,424 | 2,164 | 531 | 169 | 55 | 25 | 12 | 9 | 8,918 |
| 1953 | 15 | 21 | 1,028 | 1,507 | 328 | 427 | 166 | 166 | 34 | 12 | 6 | 6 | 3,716 |
| 1954 | 9 | 55 | 34 | 359 | 641 | 543 | 224 | 92 | 28 | 9 | 6 | 3 | 2,004 |
| 1955 | 6 | 21 | 377 | 583 | 175 | 187 | 135 | 95 | 21 | 6 | 6 | 3 | 1,617 |
| 1956 | 3 | 9 | 3,729 | 2,388 | 1,722 | 648 | 236 | 126 | 55 | 25 | 12 | 9 | 8,961 |
| 1957 | 18 | 21 | 34 | 101 | 792 | 212 | 138 | 196 | 25 | 9 | 6 | 3 | 1,556 |
| 1958 | 3 | 18 | 114 | 592 | 2,839 | 2,504 | 3,695 | 393 | 64 | 31 | 15 | 9 | 10,278 |
| 1959 | 18 | 18 | 37 | 377 | 1,093 | 163 | 89 | 52 | 21 | 6 | 3 | 3 | 1,881 |
| 1960 | 6 | 6 | 15 | 107 | 586 | 68 | 52 | 40 | 12 | 6 | 3 | 3 | 905 |
| 1961 | 6 | 34 | 31 | 74 | 55 | 169 | 37 | 28 | 12 | 6 | 3 | 3 | 457 |
| 1962 | 3 | 6 | 28 | 34 | 1,550 | 626 | 129 | 98 | 28 | 9 | 6 | 3 | 2,520 |
| 1963 | 6 | 15 | 98 | 1,636 | 2,348 | 663 | 1,323 | 617 | 55 | 21 | 12 | 9 | 6,804 |
| 1964 | 15 | 160 | 80 | 568 | 98 | 110 | 86 | 55 | 18 | 6 | 3 | 3 | 1,203 |
| 1965 | 3 | 43 | 1,682 | 3,023 | 497 | 175 | 1,016 | 169 | 46 | 18 | 9 | 6 | 6,687 |
| 1966 | 12 | 166 | 402 | 344 | 460 | 169 | 34 | 37 | 21 | 6 | 3 | 3 | 1,657 |
| 1967 | 3 | 37 | 522 | 1,915 | 761 | 1,550 | 1,538 | 651 | 52 | 21 | 12 | 9 | 7,071 |
| 1968 | 12 | 21 | 80 | 786 | 420 | 335 | 166 | 92 | 25 | 9 | 6 | 3 | 1,955 |
| 1969 | 6 | 25 | 255 | 2,928 | 3,308 | 1,160 | 371 | 123 | 58 | 21 | 9 | 9 | 8,274 |
| 1970 | 15 | 21 | 104 | 1,817 | 402 | 1,086 | 132 | 68 | 28 | 12 | 6 | 6 | 3,698 |
| 1971 | 6 | 172 | 1,310 | 654 | 117 | 325 | 187 | 83 | 34 | 12 | 6 | 3 | 2,909 |
| 1972 | 6 | 12 | 344 | 120 | 224 | 49 | 34 | 15 | 9 | 3 | 0 | 3 | 819 |
| 1973 | 6 | 509 | 258 | 1,903 | 3,321 | 1,577 | 298 | 110 | 46 | 18 | 9 | 9 | 8,065 |
| 1974 | 28 | 316 | 1,387 | 1,341 | 212 | 1,295 | 1,310 | 184 | 71 | 37 | 12 | 6 | 6,199 |
| 1975 | 18 | 31 | 95 | 193 | 2,329 | 2,578 | 721 | 181 | 61 | 34 | 21 | 15 | 6,279 |
| 1976 | 21 | 25 | 28 | 25 | 28 | 71 | 28 | 12 | 6 | 3 | 3 | 3 | 252 |
| 1977 | 9 | 9 | 12 | 49 | 21 | 43 | 21 | 15 | 6 | 3 | 3 | 3 | 196 |
| 1978 | 3 | 6 | 123 | 2,231 | 1,280 | 1,593 | 648 | 153 | 58 | 21 | 9 | 9 | 6,135 |
| 1979 | 9 | 15 | 25 | 436 | 1,172 | 629 | 206 | 74 | 21 | 9 | 6 | 3 | 2,605 |
| 1980 | 12 | 34 | 295 | 1,973 | 3,790 | 807 | 304 | 120 | 49 | 25 | 12 | 6 | 7,427 |
| 1981 | 9 | 12 | 34 | 979 | 190 | 878 | 166 | 61 | 21 | 6 | 3 | 3 | 2,363 |
| 1982 | 3 | 227 | 473 | 2,360 | 1,427 | 1,056 | 3,305 | 448 | 61 | 28 | 15 | 9 | 9,412 |
| 1983 | 12 | 206 | 957 | 3,050 | 3,655 | 5,616 | 1,295 | 862 | 92 | 43 | 21 | 15 | 15,826 |
| 1984 | 31 | 448 | 1,943 | 304 | 172 | 190 | 166 | 144 | 37 | 12 | 6 | 6 | 3,459 |
| 1985 | 9 | 295 | 150 | 74 | 310 | 368 | 55 | 55 | 25 | 9 | 6 | 3 | 1,360 |
| 1986 | 3 | 18 | 49 | 46 | 4,342 | 2,452 | 420 | 138 | 52 | 21 | 12 | 6 | 7,562 |
| 1987 | 6 | 9 | 25 | 46 | 138 | 123 | 40 | 12 | 9 | 3 | 3 | 3 | 417 |
| 1988 | 3 | 9 | 92 | 178 | 40 | 31 | 37 | 15 | 9 | 3 | 3 | 3 | 424 |
| 1989 | 3 | 6 | 40 | 43 | 40 | 147 | 40 | 12 | 9 | 3 | 3 | 3 | 350 |
| 1990 | 3 | 40 | 31 | 98 | 117 | 68 | 34 | 25 | 9 | 3 | 3 | 3 | 433 |
| 1991 | 3 | 9 | 31 | 31 | 28 | 957 | 153 | 52 | 15 | 6 | 3 | 3 | 1,292 |
| 1992 | 3 | 6 | 49 | 74 | 1,608 | 399 | 157 | 52 | 28 | 9 | 6 | 3 | 2,394 |
| 1993 | 6 | 6 | 178 | 2,259 | 1,961 | 844 | 246 | 160 | 43 | 18 | 9 | 6 | 5,736 |
| 1994 | 12 | 18 | 83 | 64 | 626 | 114 | 83 | 74 | 15 | 6 | 3 | 3 | 1,102 |
| 1995 | 3 | 18 | 52 | 3,532 | 454 | 3,980 | 531 | 242 | 120 | 61 | 25 | 18 | 9,038 |
| 1996 | 15 | 15 | 212 | 1,568 | 2,903 | 1,384 | 233 | 163 | 74 | 28 | 12 | 12 | 6,620 |
| 1997 | 18 | 509 | 2,372 | 4,524 | 457 | 187 | 104 | 58 | 34 | 15 | 9 | 12 | 8,301 |
| 1998 | 15 | 80 | 270 | 2,332 | 6,101 | 1,157 | 1,065 | 417 | 199 | 95 | 46 | 31 | 11,809 |
| 1999 | 37 | 49 | 120 | 559 | 1,409 | 519 | 773 | 203 | 95 | 34 | 21 | 9 | 3,827 |
| 2000 | 12 | 25 | 31 | 411 | 2,016 | 1,182 | 169 | 86 | 40 | 21 | 9 | 12 | 4,014 |
| 2001 | 15 | 21 | 37 | 157 | 908 | 755 | 178 | 55 | 18 | 9 | 6 | 3 | 2,164 |
| 2002 | 6 | 21 | 565 | 362 | 193 | 457 | 120 | 55 | 21 | 6 | 3 | 3 | 1,814 |
| Avg (21-02) | 9 | 72 | 402 | 881 | 1,151 | 820 | 443 | 138 | 36 | 15 | 8 | 6 | 3,980 |
| Max (21-02) | 37 | 779 | 3,729 | 4,524 | 6,101 | 5,616 | 3,695 | 862 | 199 | 95 | 46 | 31 | 15,826 |
| Min (21-02) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 4.1.2.12-1**
**Unregulated Runoff below Pilarcitos Reservoir (Acre-feet)**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | WY Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 0 | 28 | 491 | 697 | 371 | 101 | 43 | 28 | 9 | 6 | 3 | 3 | 1,780 |
| 1922 | 3 | 3 | 279 | 172 | 1,439 | 669 | 233 | 64 | 15 | 9 | 3 | 3 | 2,894 |
| 1923 | 3 | 31 | 727 | 387 | 325 | 68 | 212 | 31 | 15 | 6 | 3 | 3 | 1,811 |
| 1924 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1925 | 0 | 3 | 61 | 58 | 534 | 37 | 80 | 83 | 9 | 3 | 0 | 0 | 868 |
| 1926 | 3 | 3 | 3 | 61 | 1,059 | 80 | 298 | 21 | 12 | 3 | 3 | 0 | 1,547 |
| 1927 | 3 | 239 | 80 | 206 | 985 | 270 | 341 | 40 | 18 | 6 | 3 | 3 | 2,194 |
| 1928 | 3 | 3 | 153 | 80 | 147 | 945 | 362 | 37 | 0 | 6 | 3 | 3 | 1,743 |
| 1929 | 3 | 3 | 138 | 104 | 107 | 153 | 64 | 18 | 9 | 3 | 0 | 0 | 605 |
| 1930 | 0 | 3 | 6 | 141 | 141 | 580 | 46 | 21 | 3 | 3 | 0 | 0 | 945 |
| 1931 | 3 | 3 | 9 | 58 | 25 | 31 | 9 | 6 | 3 | 0 | 0 | 0 | 147 |
| 1932 | 0 | 3 | 476 | 255 | 460 | 58 | 40 | 21 | 12 | 3 | 3 | 0 | 1,332 |
| 1933 | 3 | 3 | 6 | 135 | 46 | 68 | 46 | 31 | 6 | 3 | 0 | 0 | 347 |
| 1934 | 0 | 3 | 160 | 215 | 218 | 71 | 21 | 9 | 9 | 3 | 0 | 0 | 709 |
| 1935 | 3 | 9 | 18 | 525 | 49 | 193 | 436 | 89 | 15 | 6 | 3 | 3 | 1,350 |
| 1936 | 3 | 3 | 18 | 129 | 878 | 144 | 144 | 55 | 15 | 6 | 3 | 3 | 1,402 |
| 1937 | 3 | 3 | 12 | 58 | 681 | 918 | 276 | 77 | 18 | 6 | 3 | 3 | 2,059 |
| 1938 | 3 | 6 | 295 | 316 | 1,805 | 1,209 | 328 | 92 | 25 | 12 | 6 | 3 | 4,100 |
| 1939 | 9 | 21 | 83 | 58 | 126 | 110 | 37 | 15 | 9 | 3 | 3 | 0 | 476 |
| 1940 | 0 | 3 | 3 | 531 | 1,286 | 792 | 384 | 77 | 21 | 9 | 3 | 3 | 3,112 |
| 1941 | 3 | 6 | 273 | 602 | 1,341 | 994 | 1,243 | 224 | 31 | 12 | 6 | 3 | 4,738 |
| 1942 | 6 | 18 | 338 | 985 | 887 | 353 | 531 | 184 | 21 | 9 | 6 | 3 | 3,342 |
| 1943 | 6 | 61 | 58 | 1,074 | 399 | 457 | 157 | 71 | 21 | 6 | 3 | 3 | 2,317 |
| 1944 | 6 | 12 | 21 | 43 | 347 | 282 | 77 | 43 | 12 | 3 | 3 | 0 | 850 |
| 1945 | 3 | 18 | 40 | 92 | 795 | 239 | 98 | 74 | 15 | 6 | 3 | 3 | 1,387 |
| 1946 | 3 | 21 | 718 | 368 | 178 | 107 | 89 | 55 | 15 | 6 | 3 | 3 | 1,568 |
| 1947 | 6 | 40 | 52 | 55 | 95 | 132 | 89 | 34 | 12 | 3 | 3 | 3 | 525 |
| 1948 | 3 | 6 | 21 | 18 | 25 | 95 | 160 | 71 | 9 | 3 | 3 | 0 | 414 |
| 1949 | 3 | 3 | 25 | 28 | 74 | 804 | 92 | 64 | 15 | 3 | 3 | 3 | 1,117 |
| 1950 | 3 | 3 | 15 | 285 | 313 | 74 | 61 | 31 | 9 | 3 | 0 | 0 | 798 |
| 1951 | 3 | 362 | 887 | 411 | 344 | 408 | 83 | 71 | 21 | 9 | 3 | 3 | 2,605 |
| 1952 | 3 | 9 | 411 | 1,679 | 663 | 1,007 | 246 | 80 | 25 | 12 | 6 | 3 | 4,143 |
| 1953 | 6 | 9 | 479 | 700 | 153 | 199 | 77 | 77 | 15 | 6 | 3 | 3 | 1,728 |
| 1954 | 3 | 25 | 15 | 166 | 298 | 252 | 104 | 43 | 12 | 3 | 3 | 0 | 924 |
| 1955 | 3 | 9 | 175 | 270 | 83 | 86 | 61 | 43 | 9 | 3 | 3 | 0 | 746 |
| 1956 | 0 | 3 | 1,734 | 1,111 | 801 | 301 | 110 | 58 | 25 | 12 | 6 | 3 | 4,164 |
| 1957 | 9 | 9 | 15 | 46 | 368 | 98 | 64 | 92 | 12 | 3 | 3 | 0 | 721 |
| 1958 | 0 | 9 | 52 | 276 | 1,320 | 1,163 | 1,719 | 184 | 31 | 15 | 6 | 3 | 4,778 |
| 1959 | 9 | 9 | 18 | 175 | 509 | 77 | 40 | 25 | 9 | 3 | 0 | 0 | 875 |
| 1960 | 3 | 3 | 6 | 49 | 273 | 31 | 25 | 18 | 6 | 3 | 0 | 0 | 417 |
| 1961 | 3 | 15 | 15 | 34 | 25 | 80 | 18 | 12 | 6 | 3 | 0 | 0 | 212 |
| 1962 | 0 | 3 | 12 | 15 | 721 | 292 | 61 | 46 | 12 | 3 | 3 | 0 | 1,169 |
| 1963 | 3 | 6 | 46 | 761 | 1,093 | 307 | 614 | 285 | 25 | 9 | 6 | 3 | 3,158 |
| 1964 | 6 | 74 | 37 | 264 | 46 | 52 | 40 | 25 | 9 | 3 | 0 | 0 | 555 |
| 1965 | 0 | 21 | 783 | 1,406 | 230 | 83 | 473 | 80 | 21 | 9 | 3 | 3 | 3,112 |
| 1966 | 6 | 77 | 187 | 160 | 215 | 80 | 15 | 18 | 9 | 3 | 0 | 0 | 770 |
| 1967 | 0 | 18 | 242 | 890 | 353 | 721 | 715 | 304 | 25 | 9 | 6 | 3 | 3,287 |
| 1968 | 6 | 9 | 37 | 365 | 196 | 157 | 77 | 43 | 12 | 3 | 3 | 0 | 908 |
| 1969 | 3 | 12 | 120 | 1,363 | 1,538 | 540 | 172 | 58 | 28 | 9 | 3 | 3 | 3,848 |
| 1970 | 6 | 9 | 49 | 844 | 187 | 506 | 61 | 31 | 12 | 6 | 3 | 3 | 1,719 |
| 1971 | 3 | 80 | 611 | 304 | 55 | 150 | 86 | 40 | 15 | 6 | 3 | 0 | 1,353 |
| 1972 | 3 | 6 | 160 | 55 | 104 | 21 | 15 | 6 | 3 | 0 | 0 | 0 | 374 |
| 1973 | 3 | 236 | 120 | 884 | 1,544 | 733 | 138 | 52 | 21 | 9 | 3 | 3 | 3,747 |
| 1974 | 12 | 147 | 644 | 623 | 98 | 602 | 611 | 86 | 34 | 18 | 6 | 3 | 2,885 |
| 1975 | 9 | 15 | 43 | 89 | 1,083 | 1,200 | 335 | 83 | 28 | 15 | 9 | 6 | 2,915 |
| 1976 | 9 | 12 | 12 | 12 | 12 | 34 | 12 | 6 | 3 | 0 | 0 | 0 | 114 |
| 1977 | 3 | 3 | 6 | 21 | 9 | 21 | 9 | 6 | 3 | 0 | 0 | 0 | 83 |
| 1978 | 0 | 3 | 58 | 1,037 | 595 | 740 | 301 | 71 | 28 | 9 | 3 | 3 | 2,848 |
| 1979 | 3 | 6 | 12 | 203 | 546 | 292 | 95 | 34 | 9 | 3 | 3 | 0 | 1,206 |
| 1980 | 6 | 15 | 138 | 918 | 1,762 | 374 | 141 | 55 | 21 | 12 | 6 | 3 | 3,453 |
| 1981 | 3 | 6 | 15 | 454 | 89 | 408 | 77 | 28 | 9 | 3 | 0 | 0 | 1,093 |
| 1982 | 0 | 104 | 221 | 1,099 | 663 | 491 | 1,538 | 209 | 28 | 12 | 6 | 3 | 4,373 |
| 1983 | 6 | 95 | 445 | 1,418 | 1,700 | 2,612 | 602 | 402 | 43 | 21 | 9 | 6 | 7,359 |
| 1984 | 15 | 209 | 902 | 141 | 80 | 89 | 77 | 68 | 18 | 6 | 3 | 3 | 1,611 |
| 1985 | 3 | 138 | 71 | 34 | 144 | 172 | 25 | 25 | 12 | 3 | 3 | 0 | 629 |
| 1986 | 0 | 9 | 21 | 21 | 2,019 | 1,142 | 196 | 64 | 25 | 9 | 6 | 3 | 3,517 |
| 1987 | 3 | 3 | 12 | 21 | 64 | 58 | 18 | 6 | 3 | 0 | 0 | 0 | 190 |
| 1988 | 0 | 3 | 43 | 83 | 18 | 15 | 18 | 6 | 3 | 0 | 0 | 0 | 190 |
| 1989 | 0 | 3 | 18 | 21 | 18 | 68 | 18 | 6 | 3 | 0 | 0 | 0 | 157 |
| 1990 | 0 | 18 | 15 | 46 | 55 | 31 | 15 | 12 | 3 | 0 | 0 | 0 | 196 |
| 1991 | 0 | 3 | 15 | 15 | 12 | 445 | 71 | 25 | 6 | 3 | 0 | 0 | 595 |
| 1992 | 3 | 3 | 25 | 34 | 749 | 187 | 74 | 25 | 12 | 3 | 3 | 3 | 1,120 |
| 1993 | 3 | 3 | 83 | 1,050 | 911 | 393 | 114 | 74 | 18 | 9 | 3 | 3 | 2,664 |
| 1994 | 6 | 9 | 40 | 31 | 292 | 52 | 37 | 34 | 6 | 3 | 3 | 0 | 513 |
| 1995 | 0 | 9 | 25 | 1,642 | 212 | 1,851 | 246 | 114 | 55 | 28 | 12 | 9 | 4,201 |
| 1996 | 9 | 6 | 98 | 730 | 1,350 | 644 | 107 | 77 | 34 | 12 | 6 | 6 | 3,081 |
| 1997 | 9 | 236 | 1,105 | 2,102 | 215 | 86 | 49 | 28 | 15 | 9 | 6 | 6 | 3,867 |
| 1998 | 6 | 37 | 126 | 1,086 | 2,836 | 537 | 497 | 193 | 92 | 46 | 21 | 12 | 5,490 |
| 1999 | 15 | 21 | 55 | 258 | 654 | 242 | 359 | 95 | 46 | 15 | 9 | 3 | 1,774 |
| 2000 | 6 | 12 | 15 | 190 | 939 | 549 | 77 | 40 | 18 | 9 | 3 | 6 | 1,866 |
| 2001 | 6 | 9 | 18 | 74 | 424 | 350 | 83 | 28 | 9 | 3 | 3 | 3 | 1,010 |
| 2002 | 3 | 9 | 264 | 169 | 89 | 212 | 55 | 25 | 9 | 3 | 0 | 0 | 838 |
| Avg (21-02) | 4 | 33 | 187 | 410 | 535 | 381 | 206 | 64 | 16 | 7 | 3 | 2 | 1,849 |
| Max (21-02) | 15 | 362 | 1,734 | 2,102 | 2,836 | 2,612 | 1,719 | 402 | 92 | 46 | 21 | 12 | 7,359 |
| Min (21-02) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### *4.1.3 Evaporation*

Water added to or dissipated from reservoirs due to net evaporation and precipitation is determined dynamically within a study based on the operation of the reservoirs. The underlying net evaporation and precipitation at the reservoirs is represented by 12 monthly factors, constant for each year of the simulation.

For Hetch Hetchy Reservoir, Lake Lloyd, and Lake Eleanor, a set of monthly net evaporation and precipitation factors is used. These factors have been agreed to by San Francisco and the Districts, and are currently used for Tuolumne River flow accounting by the two entities. Table 4.1.3-1 depicts the evaporation factors for SFPUC reservoirs. Also shown are the daily net evaporation factors used for Don Pedro Reservoir. Net evaporation values from Burlingame have been assumed for the Peninusula reservoirs, and net evaporation values for Del Valle Reservoir have been assumed for the Alameda system reservoirs. These values are also shown in Table 4.1.3-1

**Table 4.1.3-1**
**Net Evaporation Factors for Reservoirs**

| | Hetch Hetchy Reservoir<br>Lake Lloyd<br>Lake Eleanor | Don Pedro Reservoir | Crystal Springs Reservoir<br>San Andreas Reservoir<br>Pilarcitos Reservoir | Calaveras Reservoir<br>San Antonio Reservoir |
|---|---|---|---|---|
| | cfs/[acre*day] | cfs/[acre*day] | Inches | Inches |
| October | 0.00325269 | 0.00639480 | 2.88 | 4.10 |
| November | 0 | 0.00178105 | 1.50 | 2.08 |
| December | 0 | -0.00013449 | 1.00 | 1.20 |
| January | -0.00325269 | -0.00088458 | 1.03 | 1.02 |
| February | -0.00360119 | -0.00025777 | 1.41 | 1.29 |
| March | 0 | 0.00113491 | 2.74 | 2.22 |
| April | 0 | 0.00308124 | 3.97 | 3.41 |
| May | 0.00325269 | 0.00796822 | 5.15 | 5.15 |
| June | 0.00672222 | 0.01094715 | 5.89 | 6.37 |
| July | 0.00975807 | 0.01397570 | 6.30 | 7.75 |
| August | 0.00975807 | 0.01410893 | 5.53 | 7.32 |
| September | 0.00672222 | 0.01072018 | 4.30 | 6.16 |

Sample computation of reservoir evaporation:

<u>Tuolumne River Reservoirs</u>
Average Evaporation (cfs/day) = Evaporation Rate x Surface Area (acres)
Evaporation (acre-feet) = Average Evaporation (cfs/day) x number of days x 1.98347
<u>Bay Area Reservoirs</u>
Evaporation (acre-feet) = Evaporation (inches) x Surface Area x Conversion

## 4.2 Facilities

This section describes the facilities modeled by HH/LSM. The facilities are grouped into subsections: Reservoirs, Pipelines and Conveyance Facilities, Power Facilities, and Treatment Facilities.

### *4.2.1 Reservoirs*

As described above, San Francisco manages three major reservoirs in the Tuolumne River Basin and five Bay Area reservoirs. San Francisco also utilizes the Water Bank Account in Don Pedro Reservoir to enhance San Francisco’s operations within the Tuolumne River Basin. Table 4.2.1-1 shows the modeled maximum storage of San Francisco’s major storage reservoirs, and Don Pedro Reservoir which is operated by the Districts.

**Table 4.2.1-1**
**Modeled Major Reservoir Storage**

| Reservoir/Facility | Maximum Storage (acre-feet) |
|---|---|
| Hetch Hetchy Reservoir | 360,400 |
| Lake Lloyd | 273,300 |
| Lake Eleanor | 27,100 |
| New Don Pedro Water Bank (Exchange Storage Space) | 570,000 (Not including 170,000 acre-feet of conditional storage) |
| Calaveras Reservoir | 96,800 [1] |
| San Antonio Reservoir | 50,600 |
| Crystal Springs Reservoir | 69,360 [2] |
| San Andreas Reservoir | 19,000 |
| Pilarcitos Reservoir | 2,980 |
| Don Pedro Reservoir (MID/TID) | 2,030,000 |

[1] Currently 37,800 acre-feet interim conditions as required by Division of Safety of Dams
[2] Currently 58,300 acre-feet interim conditions as required by Division of Safety of Dams

### 4.2.1.1 Tuolumne River Reservoirs

A physical relationship exists between a reservoir's storage and surface area, and is based on the topographical characteristics of the reservoir's site. Within the simulation of reservoir operation, the surface area of a reservoir is required for the determination of net evaporation. The surface area-storage relationship for each reservoir is defined by a series of paired values. The model interpolates an area for a computed reservoir storage using these paired values. Table 4.2.1.1-1 depicts the storage and surface area relationship for Hetch Hetchy Reservoir, Lake Lloyd, Lake Eleanor and Don Pedro Reservoir. The computed area is used by the model in estimating the net evaporation of each reservoir for each month of the simulation.

The Hetch Hetchy reservoirs are constrained by maximum storage levels which sometimes vary from month to month. For Hetch Hetchy Reservoir, the maximum storage level is 360,400 acre-feet and is associated with a reservoir level at the top of the spillway drum gates. For the October through March period, a reservoir regulation buffer is modeled. During this period the model attempts to maintain no more than 330,000 acre-feet in storage to reflect a reservoir operation that can regulate most winter-time storms without spill releases below Hetch Hetchy Reservoir.

Cherry Reservoir maximum storage is assumed to vary between 248,000 acre-feet and 273,300 acre-feet. The higher value is allowed to occur during the months of April through June (an assumption that the spillway flash boards are installed). During July, August and September, the maximum storage is modeled to decrease by 10,000 acre-feet per month to draw the reservoir down to 248,000 acre-feet by the end of September. This level of maximum storage is assumed to continue through the end of March. The lower storage is provided as a regulation buffer for winter-time storms. It is assumed that the spillway flash boards are removed during this period of time. Similarly, the maximum allowed storage at Lake Eleanor varies between 21,500 acre-feet (with spillway flash boards removed) and 27,100 acre-feet (with spillway flash boards installed). The spillway flash boards are assumed to be removed during the October through March period.

The maximum amount of available storage in the Water Bank Account varies between a minimum of 570,000 acre-feet (during the flood control season) and a maximum of 740,000 acre-feet. The SFPUC's use of available storage above 570,000 acre-feet is dependent on the Districts' operation of Don Pedro Reservoir. Modeled Water Bank Account storage is normally incidental to upstream operations; however, during drought the model requires specific releases from upstream reservoirs to maintain a greater than zero balance in the account.

Minimum operable or dead storage at Hetch Hetchy Reservoir is assumed to equal 26,100 acre-feet; Lake Lloyd, 1,000 acre-feet; and Lake Eleanor, empty.

**Table 4.2.1.1-1**
**Reservoir Area – Reservoir Storage Relationship for Tuolumne River Reservoirs**

| Hetch Hetchy Res | | Lake Lloyd | | Lake Eleanor | | Don Pedro Reservoir | | | |
|---|---|---|---|---|---|---|---|---|---|
| Storage Acre-feet | Area Acres | Storage Acre-feet | Area Acres | Storage Acre-feet | Area Acres | Storage Acre-feet | Area Acres | Storage Acre-feet | Area Acres |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 308,960 | 3,520 |
| 410 | 124 | 75 | 8 | 39 | 403 | 35 | 7 | 345,310 | 3,750 |
| 3,300 | 454 | 250 | 16 | 52 | 413 | 120 | 10 | 384,060 | 4,000 |
| 8,700 | 634 | 675 | 38 | 82 | 423 | 229 | 12 | 425,510 | 4,290 |
| 15,400 | 704 | 1,530 | 99 | 130 | 429 | 383 | 19 | 469,910 | 4,590 |
| 22,900 | 793 | 3,025 | 243 | 183 | 431 | 617 | 28 | 517,450 | 4,920 |
| 31,000 | 834 | 6,030 | 473 | 211 | 432 | 916 | 32 | 568,150 | 5,220 |
| 39,500 | 867 | 11,745 | 737 | 550 | 446 | 1,280 | 41 | 621,950 | 5,540 |
| 48,300 | 899 | 19,740 | 883 | 996 | 460 | 1,759 | 55 | 678,950 | 5,840 |
| 57,400 | 926 | 28,885 | 973 | 2,450 | 511 | 2,401 | 74 | 738,950 | 6,180 |
| 66,900 | 952 | 38,886 | 1,047 | 5,296 | 617 | 3,268 | 100 | 802,500 | 6,530 |
| 76,500 | 979 | 49,751 | 1,125 | 8,707 | 758 | 4,481 | 144 | 869,700 | 6,900 |
| 86,500 | 1,010 | 60,836 | 1,154 | 12,682 | 832 | 6,283 | 219 | 940,700 | 7,300 |
| 97,000 | 1,066 | 72,701 | 1,211 | 16,984 | 889 | 8,906 | 308 | 1,015,700 | 7,710 |
| 108,200 | 1,142 | 85,131 | 1,265 | 21,495 | 915 | 12,393 | 391 | 1,094,900 | 8,130 |
| 119,900 | 1,224 | 98,111 | 1,315 | 27,113 | 952 | 16,706 | 473 | 1,178,300 | 8,570 |
| 132,700 | 1,311 | 111,811 | 1,364 | | | 21,899 | 567 | 1,266,400 | 9,030 |
| 146,200 | 1,391 | 125,681 | 1,402 | | | 28,101 | 675 | 1,359,200 | 9,530 |
| 160,200 | 1,453 | 139,921 | 1,439 | | | 35,404 | 787 | 1,457,100 | 10,050 |
| 175,000 | 1,505 | 154,586 | 1,476 | | | 44,037 | 942 | 1,560,300 | 10,590 |
| 190,200 | 1,553 | 169,691 | 1,515 | | | 54,237 | 1,100 | 1,669,000 | 11,150 |
| 206,000 | 1,596 | 185,196 | 1,554 | | | 66,110 | 1,250 | 1,783,300 | 11,720 |
| 222,200 | 1,642 | 201,096 | 1,597 | | | 79,744 | 1,480 | 1,903,600 | 12,330 |
| 238,900 | 1,690 | 217,371 | 1,640 | | | 95,337 | 1,640 | 2,030,000 | 12,960 |
| 256,090 | 1,740 | 234,076 | 1,682 | | | 113,313 | 1,960 | | |
| 273,700 | 1,792 | 251,231 | 1,721 | | | 134,591 | 2,300 | | |
| 291,840 | 1,835 | 268,811 | 1,765 | | | 158,731 | 2,530 | | |
| 310,380 | 1,873 | 277,879 | 1,792 | | | 184,827 | 2,690 | | |
| 329,300 | 1,911 | | | | | 212,870 | 2,920 | | |
| 348,600 | 1,949 | | | | | 242,866 | 3,080 | | |
| 360,360 | 1,972 | | | | | 274,760 | 3,300 | | |
| Value may exceed modeled maximum storage for interpolaton purposes. | | | | | | | | | |

4.2.1.2 Bay Area Reservoirs

A physical relationship also exists between each of the Bay Area reservoir's storage and surface area. The surface area-storage relationship for each reservoir is defined by a series of paired storage values and area equations. The model determines the area for a computed reservoir storage using the area equations. The computed reservoir area is used by the model to estimate net evaporation for each month of the simulation.

The modeled operation of each of the Bay Area reservoirs considers a monthly preferred storage level. This storage level serves as a trigger to initiate modeled actions regarding the transference of water between reservoirs, drafting of local inflow or stored water through treatment facilities, or the release of water for flood control purposes. The storage level for each reservoir does not serve as absolute targets which drive reservoir operations. Rather, the value serves as a trigger to initiate water movement among the Bay Area reservoirs and into the distribution system. As a result of the water movement decisions, reservoir storage may ultimately be higher or lower than the preferred storage level. The preferred storage levels for Bay Area reservoirs are shown in Table 4.2.1.2-1. These values are representative of a system configuration and operation with Calaveras Reservoir being fully operable prior to the DSOD operational constraint.

**Table 4.2.1.2-1**
**Bay Area Reservoir Modeled Preferred Storage Levels (end-of-month)**

| | Reservoir Storage - mg | | | | |
|---|---|---|---|---|---|
| Month | Calaveras [1] | San Antonio | Crystal Springs [2] | San Andreas | Pilarictos |
| July | 31,500 | 16,500 | 19,000 | 6,200 | 970 |
| August | 31,500 | 16,500 | 18,000 | 6,200 | 970 |
| September | 30,000 | 15,900 | 17,000 | 5,600 | 890 |
| October | 28,500 | 15,900 | 17,000 | 5,600 | 810 |
| November | 27,000 | 15,900 | 17,000 | 5,600 | 720 |
| December | 27,000 | 15,900 | 17,000 | 5,600 | 720 |
| January | 28,500 | 15,900 | 17,000 | 5,600 | 720 |
| February | 30,000 | 15,900 | 17,000 | 5,600 | 900 |
| March | 31,500 | 16,500 | 17,000 | 5,600 | 970 |
| April | 31,500 | 16,500 | 19,000 | 6,200 | 970 |
| May | 31,500 | 16,500 | 19,000 | 6,200 | 970 |
| June | 31,500 | 16,500 | 19,000 | 6,200 | 970 |

[1] As designed and constructed.
[2] Since 1983, the DSOD has placed operational restrictions on Lower Crystal Springs Dam

Winter storage levels were based on SFPUC historical operation experience and iterative analysis that attempted to maximize the utilization of local watershed runoff, minimize spill and maximize May 1 storage within the Bay Area system for drought protection. The analysis was based on the historical record of hydrologic variance. Various modeled system actions occur at various levels for each reservoir.

The operation of the local system is generally driven by local inflow in a month and the monthly preferred storage levels. For the purpose of planning studies, the model assumes perfect knowledge of reservoir inflows for the current month. Diversions from the Tuolumne River are used to minimize Bay Area storage fluctuations during drought, i.e., maintain preferred Bay Area storage for reserves.

### *4.2.2 Pipelines and Conveyance Facilities*

HH/LSM performs the system simulation with a monthly time step, with water balances typically occurring in terms of monthly volumes of water. However, the model adheres to several overarching capacity constraints that occur hydraulically within the system. Salient capacity constraints incorporated into HH/LSM are described below.

Water is conveyed through the Hetch Hetchy and Bay Area systems via a series of tunnels and pipelines. From Hetch Hetchy Reservoir, water is conveyed through the Canyon Power Tunnel up to a rate that is dependent upon the head developed at Hetch Hetchy Reservoir, with a maximum rate approximately 1,400 cfs. Mountain Tunnel can convey approximately 660 cfs (currently constrained) and any flow through Canyon Power Tunnel in excess of this rate is modeled to be released back to the Tuolumne River at Early Intake. The Foothill Tunnel, which originates at Moccasin Reservoir and connects to the San Joaquin Pipelines is not capacity constrained in HH/LSM. This segment of conveyance is connected to the San Joaquin Pipelines which were designed to have a combined capacity of approximately 465 cfs (300 mgd). Cherry Power Tunnel is modeled to convey water up to a flow rate of approximately 970 cfs.

The San Joaquin Pipelines are currently a bottleneck in San Francisco’s conveyance capacity between the Tuolumne River and the Bay Area systems. HH/LSM models the SJPL to operate at several levels of flow, which are dependent on assumptions for the number of pipes in service and valve settings. Under the current configuration of the system, the model assumes 11 discrete flow rates, ranging from a minimum of 70 mgd to a maximum of 290 mgd. Up to 19 discrete flow rate settings have been incorporated into HH/LSM, with seasonal over-riding capacity limits capable of being identified (for purposes of mimicking maintenance outages).

The Coast Range Tunnel is not capacity constrained in the model. Between the Alameda East Portal and the Alameda West Portal, several facilities manage waters from Hetch Hetchy with waters from the San

Antonio and Calaveras reservoirs. At times water can be imported to San Antonio Reservoir from either Hetch Hetchy or Calaveras Reservoir. The model limits pumping to San Antonio Reservoir from Calaveras Reservoir to 60 mgd, and from Hetch Hetchy to 125 mgd. Water can be released from Calaveras Reservoir to Sunol Valley WTP up to a rate of 90 mgd. Water can be released from San Antonio to Sunol Valley WTP up to a rate of 140 mgd if pumping at San Antonio Pump Station is provided.

HH/LSM does not incorporate the Irvington Tunnel as a capacity constrained facility with the current configuration of the Bay Division Pipelines. The pipelines are modeled to constrain the conveyance of water from the East Bay system to the South Bay and Peninsula areas. Seasonal capacity limits are provided to the model. For the current configuration of the system, maximum capacity into the pipelines is assumed to be 340 mgd June through September, 320 mgd April, May and October, and 290 mgd November through March. Maintenance can be modeled with seasonal over-riding capacity limits.

Pumping of water from Crystal Springs Reservoir into San Andreas Reservoir through the Crystal Springs Pump Station is model constrained between 75-90 mgd, dependent on the calculated head differential between the two reservoirs. Modeled conveyance of water from Pilarictos Creek to the San Mateo system is capacity constrained to no more than 40 mgd from Pilarcitos Reservoir and another 40 mgd from Stone Dam.

### *4.2.3 Power Facilities*

Hetch Hetchy facilities provide incidental power generation. Water released from Lake Lloyd and Lake Eleanor (via the Cherry-Eleanor Tunnel) primarily flows through Holm Powerhouse. A significant portion of the water released from Hetch Hetchy Reservoir flows through Kirkwood Powerhouse and subsequently through Moccasin Powerhouse. A small amount of water flows through the Moccasin Low Head Powerhouse to Moccasin Creek. Hydroelectric generation is modeled in HH/LSM from Holm Powerhouse (two units up to approximately 167 MW total), Kirkwood Powerhouse (three units up to approximately 115 MW total), and Moccasin Powerhouse (two units up to approximately 110 MW total). Modeled generation at the facilities considers flow rate and head calculated by the model. The Moccasin Low Head Powerhouse is not modeled in HH/LSM, and there are currently no hydroelectric generation facilities in the Bay Area system.

### *4.2.4 Treatment Facilities*

The Sunol Valley WTP is used primarily to filter water from the East Bay reservoirs, although it can incorporate water from Hetch Hetchy. The model has the functionality to incorporate water into Sunol Valley WTP released from Calaveras Reservoir, San Antonio Reservoir, Hetch Hetchy, and water released from Calaveras Reservoir and recaptured from Alameda Creek. The sustainable capacity of the plant is 160 mgd. The plant is operated on an ongoing basis at a minimal level of about 20 MGD because treatment problems are more likely to occur when plants initiate operations or ramp up quickly in rate. HH/LSM allows input of a seasonal (monthly) maximum rate of treatment capacity and a minimum required treatment capacity for the plant. For the current configuration, HH/LSM constrains the plant to a maximum of 120 mgd of treatment capacity during a month, and a minimum production of no less than 20 mgd during a month.

The Harry Tracy WTP filters water from San Andreas Reservoir. Identical to the Sunol Valley WTP, HH/LSM constrains the modeled range of operation for the plant. The maximum production rate of the plant is 160 mgd, with a sustainable capacity of 140 mgd if turbidity is less than 5 NTU and 120 mgd when turbidity is greater than 5 NTU. HH/LSM allows input of a seasonal (monthly) maximum rate of treatment capacity and a minimum required treatment capacity for the plant. For the current configuration, HH/LSM constrains the plant to a maximum of 120 mgd of treatment capacity during a month, and a minimum production of no less than 20 mgd during month.

## 4.3 Operations

A summary of the general procedures and parameters used by HH/LSM in modeling the SFPUC Regional Water System follows.

### *4.3.1 Tuolumne System Operations*

HH/LSM integrates the operation of the SFPUC's three major Tuolumne River reservoirs, Hetch Hetchy Reservoir, Lake Lloyd, and Lake Eleanor with the operation of the Don Pedro Water Bank Account, and is responsive to the modeled need for water from the Bay Area system. In general each reservoir is a balancing mechanism for watershed inflows, minimum release requirements, and releases for water demands. Incidentally and opportunistically, hydroelectric generation also occurs. The Don Pedro Project is also modeled by HH/LSM.

#### 4.3.1.1 Hetch Hetchy Reservoir

Hetch Hetchy Reservoir is modeled to regulate the reservoir's watershed runoff with minimum stream releases, releases to Canyon Tunnel, and releases below the reservoir which are in excess of minimum requirements.

As described later, minimum stream releases below Hetch Hetchy Reservoir are determined by precipitation and runoff indicators, and are also dependent upon the operation of Canyon Tunnel. These releases become an absolute obligation of the reservoir. Diversions to Canyon Tunnel are dependent first upon the call for water from the Bay Area system (described below in Section 4.3.1.4, San Joaquin Pipelines). Diversions to San Francisco from Hetch Hetchy for domestic use normally originate from Hetch Hetchy Reservoir. Additional diversions to Canyon Tunnel may occur for an enhanced power operation if appropriate hydrologic conditions occur (described below in Section 4.3.1.6, Hetch Hetchy Power Operations).

In anticipation of snowmelt runoff, HH/LSM will model Hetch Hetchy Reservoir being lowered by releases through Canyon Tunnel. This reduction in storage normally begins in early winter as the model's forecast of snowmelt runoff indicates anticipated spill around SFPUC powerhouses. Drawdown of reservoir storage is limited first by releases necessary for diversion to the Bay Area system and minimum downstream flow requirements, and secondly by the capacity of Kirkwood Powerhouse. The primary objective of Hetch Hetchy Reservoir's operation is to develop maximum reservoir carryover storage into the summer season, and maintain reservoir storage for as long as possible.

After the snowmelt season, Hetch Hetchy Reservoir storage levels will begin to decline as water diversions to the Bay Area system increase and inflow subsides. In circumstances when inflow to Hetch Hetchy Reservoir and water demands of the SFPUC are such that Hetch Hetchy Reservoir remains essentially full into the fall (a rare event following an extremely wet year), the model will lower reservoir storage by November 1, to provide the buffer reservoir space below the spillway sill. This additional release is made though Canyon Tunnel and ultimately spills from Moccasin Reservoir.

#### 4.3.1.2 Lake Lloyd and Lake Eleanor

Similar to the Hetch Hetchy Reservoir operation, the Lake Lloyd and Lake Eleanor system is also modeled to conserve reservoir inflow for both water supply and hydroelectric generation. Winter and spring operations rely on the occurrence and forecast of runoff which at times allows drawdown of reservoir storage. This drawdown of storage allows greater utilization of Holm Powerhouse. Water transfer capability from Lake Eleanor to Lake Lloyd through the Eleanor-Cherry Tunnel and Pumping Plant allows the utilization of runoff from the Eleanor Creek watershed through Holm Powerhouse; thus, the operation of the two watersheds is integrally linked. Like Hetch Hetchy Reservoir, maximum carry-over storage into the summer-time season (which is potentially the beginning of an extended drought) is the primary objective for modeled reservoir operations.

Minimum stream releases from Lake Lloyd and Lake Eleanor are determined by criteria described in Section 4.4. Lake Lloyd minimum stream releases are the same every year, while Lake Eleanor minimum stream releases depend upon the use or non-use of the Cherry-Eleanor Pump Station for transference of water between the two reservoirs. Releases to the streams in excess of minimum requirements below the impoundments are modeled only when there is no reservoir space available to regulate inflow and conveyance or generation capacity is modeled at maximum. Releases through Holm Powerhouse are governed by the model’s attempt to avoid spills to the stream below Lake Lloyd and Lake Eleanor. After the snowmelt season, diversions to Holm Powerhouse are determined by the releases needed to draw Lake Lloyd down to the preferred storage level indicated for each month. These releases are comprised of the evacuated storage and the inflow to the reservoir from its watershed and from Lake Eleanor not released for minimum stream flows. The Lake Lloyd summer-time drawdown associated with the preferred storage levels along with the diversion of an amount of the reservoir’s inflow coincidentally provides for desired recreational flows downstream of Holm Powerhouse.

Transference of water from Lake Eleanor to Lake Lloyd occurs when, in consideration of the preferred storage levels at Lake Eleanor, releases in excess of minimum stream flow requirements occur or are forecasted to occur below Lake Eleanor. The model determines if this transference occurs as gravity flow or if it requires pumping, based on the reservoir condition of both reservoirs.

The Water Bank Account in Don Pedro Reservoir will typically not vary from full significantly during many years. However, during periods of drought the Water Bank Account will be significantly debited as the model’s reservoir operation logic attempts to retain storage in SFPUC upstream reservoirs. In order to maintain a positive balance in the Water Bank Account, the model has the functionality to call for releases from both Hetch Hetchy Reservoir and Lake Lloyd. The amount of water released from each reservoir is defined by model input that indicates the percentage desired from each of the reservoirs and constraints for the release based on each reservoir’s storage. The Lake Lloyd and Lake Eleanor system is typically used to provide releases to the Districts.

4.3.1.3 Water Bank Account

The operation of San Francisco’s Water Bank Account in Don Pedro Reservoir is normally incidental to San Francisco’s upstream operations. With the objective to maintain as much water as possible within the reservoirs and account of the SFPUC, under normal circumstances the balance of the Water Bank Account will vary up and down within a year. Significant drawdown of the Water Bank Account occurs early during drought as runoff is held in upstream SFPUC reservoirs. Within a year, the balance will vary as San Francisco uses available space in the Water Bank Account to enhance power operations. The Water Bank Account balance is not allowed to be less than zero in HH/LSM; however, logic has been incorporated into HH/LSM to provide transfers of water into the Water Bank Account.

The Districts' Raker Act entitlements and Fourth Agreement rights to inflow to Don Pedro Reservoir are required for the determination of the balance of the Water Bank Account. A monthly time series for these values has been determined from an analysis of historical daily runoff of the Tuolumne River. For modeling purposes, the values are used in the comparison of regulated inflow to Don Pedro Reservoir to the unimpaired flow of the Tuolumne River to determine the change in Water Bank Account balance.

4.3.1.4 San Joaquin Pipelines

The operation of the San Joaquin Pipelines is primarily dependent on the supplemental needs of San Francisco’s Bay Area system operations to meet water demands. The seasonal level of the San Joaquin Pipelines diversion is consistent with one of the combinations of pipeline operation configurations described previously. Maintenance to the pipelines is modeled as an over-riding seasonal capacity limit. Also, maintenance is modeled to occur annually and on less than annual cycles. Additionally, month to month changes to the flow in the pipelines are constrained.

For each month, HH/LSM determines the need for supplemental water from Hetch Hetchy. This need is determined by the simulated operation of the Bay Area system. The need for Hetch Hetchy water is the residual amount of demand from the Bay Area system after all of the Bay Area system-alone operational protocols have been applied. These protocols include the consideration of the Bay Area reservoir preferred storage levels, water demands, and conveyance and treatment plant capacities. The residual need from Hetch Hetchy incorporates the system water demand net of the amount of water needed for the consideration of the preferred storage levels.

The identified need for Hetch Hetchy water through the pipelines mathematically can be any value. However, HH/LSM embodies practicable operational considerations that require the flow rate to match a flow that can exist with established valve settings and pipeline configurations. The model also considers the previous month’s pipeline flow rate and further constrains the number of times the flow rate can change during a year. After this conditioning of the flow rate there is typically a difference between the originally established need for Hetch Hetchy water and the pipeline flow rate. A positive difference (more water transferred that requested) is balanced within the Bay Area system by storing water, and a negative difference (less water transferred than requested) is balanced by depleting the Bay Area reservoirs. Although the San Joaquin Pipelines are defined to have a minimum rate of operation (the current configuration assumes 70 mgd), HH/LSM over-rides this constraint and minimizes flow from Hetch Hetchy during periods when the Bay Area system is modeled to be in an extreme spill condition.

#### 4.3.1.5 Lower Cherry Aqueduct

HH/LSM has functionality to simulate the use of the Lower Cherry Aqueduct (LCA) to transfer water from the Cherry-Eleanor watersheds to Early Intake for transport to the Bay Area system. The model can trigger the use of the LCA in two different conditions: one reacting to drought conditions, which triggers on specified reservoir storage levels at Lake Lloyd and Hetch Hetchy Reservoir, and the other triggering an increased conservation of runoff from the Cherry-Eleanor watersheds during times when Hetch Hetchy Reservoir has available reservoir space. Under the current configuration setting the modeled use of the LCA is not occurring.

#### 4.3.1.6 Hetch Hetchy Power Operations

HH/LSM can model reservoir operations to maximize water supply at the risk of less than optimal operations for other purposes such as power generation. The most conservative water supply operation suggests holding water in storage until spilled. However, there are circumstances that warrant early additional releases from reservoirs in anticipation of releases that otherwise could result in spills around San Francisco’s hydroelectric facilities.

The model forecasts anticipated runoff to the San Francisco Tuolumne River reservoirs using a forecasting procedure that is nearly identical to the procedure used by system operators. Based on a database of historical snow course and watershed runoff information, a statistically-based procedure has been developed that provides a temporal runoff forecast for each basin which is dependent upon the modeler’s desire for confidence in the forecast. By increasing the risk factor associated with the forecast the operation of the reservoirs can become less conservative and thus increase hydroelectric generation. The resultant reservoir operation involves the early release (when available hydroelectric generation capability exists) of reservoir inflow and storage before such time that the hydroelectric facilities operate at maximum and releases must bypass the facilities.

The forecasting routine projects the amount of runoff that can be expected to occur to each San Francisco reservoir, Don Pedro Reservoir and the Water Bank Account. The amount of certainty concerning precipitation yet to come and procedural error assumed in the forecast is prescribed by the modeler. Once the amount of anticipated runoff is projected, the runoff is compared to the availability of reservoir storage to capture the runoff and the anticipated releases required from the reservoir for downstream requirements and diversions to San Francisco. If the reservoir is projected to spill during the month or in aggregate by July 1, discretionary releases (up to the amount of anticipated spill) are allowed in order to enhance power generation from the project. This forecasting and decision process occurs continuously each month of the period being modeled.

The currently used criteria for the anticipatory release of water for power generation enhancement have been established through iterative refinement of the long-term HH/LSM studies. In order to not affect the amount of water delivered resulting from the most conservative water supply analysis, it has been determined that seasonal operations based on risk assumption should not be modified for power enhancement during the months of July through November, i.e., Hetch Hetchy should be operated in a conservative mode. However, during December through June the forecast can be “relaxed.” This relaxation equates to increasing the forecast risk from 99 percent exceedence (during the July through November period) to 98 percent in December, 90 percent in January and February, 75 percent in March, and 50 percent during April through June. These factors are adjustable within the input to HH/LSM.

4.3.1.7 Don Pedro Project

HH/LSM models the operation of the Don Pedro Project. Don Pedro Reservoir is modeled to regulate inflow with the requirements for stream flow below La Grange Dam, diversions to the Districts' canals, and flood control. Canal diversions are determined by a procedure that is based on the assumed consumptive use needs of the Districts and a water balance for the diversion canals, regulating reservoirs and other supply resources of the Districts in their service areas. Flow requirements below La Grange, as specified by the Federal Energy Regulatory Commission (FERC) license, are met with releases from Don Pedro Reservoir, and flood control reservation space in Don Pedro Reservoir cannot be encroached. If designated in HH/LSM, Don Pedro Reservoir will only release water necessary to satisfy minimum stream flows below La Grange Dam, canal diversions, or to maintain required flood control reservation space. HH/LSM contains logic to provide early releases in excess of minimum stream requirements in order to reduce spill past the powerhouse during seasons of high inflow and constrained storage.

The following describes the modeling of operations of the Don Pedro Project with respect to serving the demand of the Districts and meeting downstream minimum release requirements. Minimum release requirements below La Grange, as specified by the Don Pedro FERC license, are additionally described in Section 4.4.

The methodology used to determine the diversion requirement for the Districts uses a water budget approach. The water budget develops a canal diversion demand based upon estimates of the consumptive use of applied water (CUAW), non-recoverable losses and inferred deep percolation, District and private groundwater pumping, system losses, operational spills, and regulating reservoir operation. The CUAW numbers are generated by the Department of Water Resources-United States Bureau of Reclamation consumptive use model which estimates the CUAW based on precipitation, crop ET and crop acreage. These monthly data were generated for the simulation period. MID’s diversion demand includes municipal use drawn from Modesto Lake.

Don Pedro Reservoir is modeled to not exceed a pre-defined maximum allowable end-of-month storage. These values represent the historic or simulated flood control storage limit provided by the Corps of Engineers. Table 4.3.1.7-1 depicts the monthly values for this maximum storage. Although there is not a required reservation of space during the summer, HH/LSM has the functionality to provide a preferred storage level for each month which serves as an over-ride to values shown in the table. This capability provides a surrogate method to make stream releases in excess of minimum stream requirements, which will draw Don Pedro Reservoir down to flood control levels systematically during wetter years when substantial releases in the early fall would otherwise occur.

HH/LSM also incorporates procedures that evaluate the condition of Don Pedro Reservoir storage in the context of diversions to the Districts’ canals. A water supply index is determined each year based on projected spring-time storage in Don Pedro Reservoir. If drought is occurring the model will reduce the demand being served by the Districts to prolong the availability of storage in the reservoir. A demand served–water supply index relationship has been developed based on iterative analysis of District operation simulations. This relationship currently provides for the demand being served to range between 50 percent and 100 percent. The lower end of the range usually occurs only within sequences of dry years. Most model parameters affecting the Districts’ operation of their canal systems can be modified through user-defined input.

**Table 4.3.1.7-1**
**Don Pedro Reservoir Maximum Allowable Storage**

| Water Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1921 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,970,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1922 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1923 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1924 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1925 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,780,000 | 1,935,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1926 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1927 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,870,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1928 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,960,000 | 2,015,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1929 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1930 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,990,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1931 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1932 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,980,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1933 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,990,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1934 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1935 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,895,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1936 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,960,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1937 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,990,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1938 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,730,000 | 2,025,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1939 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1940 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,990,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1941 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,830,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1942 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,765,000 | 2,027,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1943 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,970,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1944 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,990,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1945 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,975,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1946 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,975,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1947 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1948 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,950,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1949 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1950 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1951 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,955,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1952 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,895,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1953 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,990,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1954 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1955 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1956 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,915,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1957 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,975,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1958 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,910,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1959 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1960 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1961 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1962 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1963 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,980,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1964 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1965 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 1,900,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1966 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1967 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,880,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1968 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1969 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,930,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1970 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,713,000 | 2,002,000 | 2,030,000 | 2,030,000 | 2,030,000 | 1,773,000 |
| 1971 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1972 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1973 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1974 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1975 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1976 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1977 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1978 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 1,580,000 | 1,761,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1979 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1980 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 1,890,400 | 1,960,200 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1981 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1982 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 1,876,400 | 2,002,900 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1983 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,294,700 | 1,264,000 | 1,270,800 | 1,851,400 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1984 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1985 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1986 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 1,888,300 | 2,001,400 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1987 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1988 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1989 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1990 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1991 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1992 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1993 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1994 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1995 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 1,629,700 | 1,982,800 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1996 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1997 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1998 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 1,714,000 | 1,987,500 | 2,030,000 | 2,030,000 | 1,772,100 |
| 1999 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 2000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 2001 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |
| 2002 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,690,000 | 1,717,600 | 2,002,400 | 2,030,000 | 2,030,000 | 2,030,000 | 1,772,100 |

### *4.3.2 Bay Area System Operations*

The Bay Area system provides regulation between water demands, local watershed runoff and imported water from Hetch Hetchy. The primary objectives of the system are to conserve local watershed runoff for delivery, and to satisfy system water demands. Modeling of the Bay Area system involves many pieces of logic (algorithms) that make decisions concerning how water demands are met and how water in the system is routed and balanced between the reservoirs. The decisions are made sequentially, with the results sometimes conflicting with a later recognized constraint. An earlier decision is at times revisited by the model, or subsequent decisions occur to remedy the conflict. The following provides a summary of the flow of algorithms that has been developed to simulate the operation of the Bay Area system.

#### 4.3.2.1 Water Demands and Deliveries

As described earlier, HH/LSM is provided a water demand (purchase request) to satisfy. This annual average annual demand is disaggregated into the demand centers in terms of volume and monthly distribution. The volume and shape of the demand is also identified for pre-established levels of delivery shortages. During the April time step of each year the model forecasts the total reservoir storage of the system for the end of June and initially establishes the level of water delivery shortage or water supply action necessary for the current year. This information is updated during the July time step, with the resulting action applied to operations for the July through following June time period.

#### 4.3.2.2 Pilarcitos Reservoir and Coastside CWD

The modeled objective of Pilarcitos Reservoir operation is the conservation of runoff for 1) Coastside CWD deliveries, and 2) transference to the remainder of the SFPUC system. Consistent with the ending of the rainy season, the model attempts to fill the reservoir (and all of the Bay Area system reservoirs) by the end of April. Releases from the reservoir to Pilarcitos Creek only occur to the extent that accretion flow below the dam does not satisfy Coastside CWD demand, unless the reservoir is full (or at its preferred storage level) and the transference of water to San Andreas Reservoir is already maximized. Water in excess of Coastside CWD needs will be released for 1) transference to Crystal Springs Reservoir (at Stone Dam) and 2) spill past Stone Dam. San Andreas and Crystal Springs reservoirs may reject transferences from the Pilarcitos system if their storage condition warrants. After filling, Pilarcitos Reservoir is drawn down by the need to satisfy the portion of Coastside CWD's demand not met from accretion flow occurring between Pilarcitos Dam and Stone Dam. HH/LSM allows the draw from Pilarcitos Reservoir to occur until a specified storage is reached (typically the invert elevation of the outlet works). At that time any Coastside CWD delivery not met at Stone Dam is drawn from Crystal Springs Reservoir.

#### 4.3.2.3 San Andreas Reservoir and Crystal Springs Reservoir

The Crystal Springs Reservoir operation and San Andreas Reservoir operation is very intertwined. Both reservoirs are modeled to be drawn down in the fall and maintained at preferred reservoir levels during winter, either by demands exceeding inflows, or by explicit evacuation of storage by additional production at Harry Tracy WTP. The maintenance of available reservoir storage space facilitates the conservation of watershed runoff during the winter and spring. Part of this reservoir operation occurs through explicit use of Harry Tracy WTP draft from San Andreas Reservoir. If storage at Crystal Springs Reservoir exceeds preferred storage levels, water is transferred to San Andreas Reservoir by the Crystal Springs Pumping Plant. This transference may contribute to or cause San Andreas Reservoir storage to exceed its preferred storage level. Production at Harry Tracy WTP attempts to deliver the volume in excess of the preferred storage level, but is limited by the amount of system water demand potentially met with its production. If the Crystal Springs Reservoir transference to San Andreas Reservoir causes San Andreas Reservoir storage, after draft to Harry Tracy WTP, to be greater than the preferred storage level, the Crystal Springs Reservoir transference will be reduced so as not cause the conflict. If Crystal Springs Reservoir exceeds its preferred storage level, plus a user-specified allowance, releases up to 250 cfs will be made from Crystal Springs Dam to San Mateo Creek.

When the storage at San Andreas Reservoir is less than its preferred storage level, transfers from Crystal Springs Reservoir to San Andreas Reservoir will occur to achieve the preferred storage level. Similarly, the model uses the transfer of water from the East Bay system (including Hetch Hetchy supplies) to achieve the preferred storage level in Crystal Springs Reservoir.

4.3.2.4 San Antonio Reservoir and Calaveras Reservoir

The San Antonio Reservoir operation and Calaveras Reservoir operation are dependent upon operation goals to conserve their watersheds' runoff, and also upon the operational priority given to the Peninsula system operation.

Similar to the operation described for the Peninsula reservoirs, San Antonio and Calaveras reservoirs' fall and winter operation is guided by preferred storage levels that provide reservoir space to regulate rainfall runoff. Sunol Valley WTP is utilized to maintain preferred storage levels in the reservoirs. The amount of water that can be drafted to Sunol Valley WTP can at times be constrained by system water deliveries and the need to draft water from the Peninsula reservoirs. During those constrained instances, flows to the Peninsula will be rejected. In instances when Calaveras Reservoir exceeds its preferred storage level and Sunol Valley WTP is constrained, the model will transfer Calaveras Reservoir water to San Antonio Reservoir if reservoir space is available in the reservoir. Spills will be modeled from the reservoirs when inflow exceeds reservoir storage availability and draft to Sunol Valley WTP.

Calaveras Reservoir operations also affect the operation of Alameda Creek diversions at the Alameda Creek Diversion Dam. HH/LSM provides a diversion of flow at the diversion dam to Calaveras Reservoir whenever Calaveras Reservoir is below its preferred storage level. Water not diverted to Calaveras Reservoir continues past the diversion dam and contributes to flow that reaches the Alameda Creek and Calaveras Creek confluence.

HH/LSM has the functionality to model a minimum release requirement at the Calaveras Creek and Alameda Creek confluence. The logic is consistent with the principals specified by the Memorandum of Understanding (MOU) between the SFPUC and the California Department of Fish and Game. The MOU specifies minimum flow requirements in Alameda Creek at the confluence with Calaveras Creek. The stream flow requirement is met through releases at Calaveras Dam as needed to supplement unregulated flows that occur at the confluence. In the HH/LSM model, these supplemental releases are assumed to be recaptured by a downstream facility and transferred into the water supply system at Sunol Valley WTP.

## 4.4 Minimum Stream Release Requirements

### *4.4.1 Hetch Hetchy Reservoir*

Fishery releases to the Tuolumne River below O'Shaughnessy Dam are governed by several stipulated agreements between San Francisco and the Department of Interior. The regime of release is defined within three year-type classifications, coined as year types A, B & C. The classification of a year is dependent on the occurrence of precipitation and runoff at Hetch Hetchy Reservoir. Table 4.4.1-1 set forth the criteria that determine the year type classification and required monthly releases to the Tuolumne River below O'Shaughnessy Dam.

In addition to the basic release schedules shown in Table 4.4.1-1, the U.S. Fish and Wildlife Service has discretion to require supplemental releases of additional water from Hetch Hetchy Reservoir. These releases amount to 15,000, 6,500 and 4,400 acre-feet during year types A, B and C, respectively. Also, during year types A and B, an additional 64 cubic feet per second release below Hetch Hetchy Reservoir can be required whenever Canyon Tunnel flow exceeds 920 cubic feet per second. The release of 4,400 acre-feet during a year type C can be required only if Hetch Hetchy Reservoir storage is greater than 210,000 acre-feet on July 1 of that year.

Releases to the Tuolumne River below O'Shaughnessy Dam as applied in the model are summarized in Table 4.4.1-2.

**Table 4.4.1-1**
**Average Daily Required Fishery Release Schedule Below O'Shaughnessy Dam**

| | Year Type A | | Year Type B | | Year Type C |
|---|---|---|---|---|---|
| Month | Release (cfs) | Criteria[a, b] | Release (cfs) | Criteria[a, b] | Release (cfs) |
| January | 50 | 8.80" | 40 | 6.10" | 35 |
| February | 60 | 14.00" | 50 | 9.50" | 35 |
| March | 60 | 18.60" | 50 | 14.20" | 35 |
| April | 75 | 23.00" | 65 | 18.00" | 35 |
| May | 100 | 26.60" | 80 | 19.50" | 50 |
| June | 125 | 28.45" | 110 | 21.25" | 75 |
| July | 125 | 575,000 acre-feet | 110 | 390,000 acre-feet | 75 |
| August | 125 | 640,000 acre-feet | 110 | 400,000 acre-feet | 75 |
| September 1-14 | 100 | | 80 | | 75 |
| September 15-30 | 80 | | 65 | | 50 |
| October | 60 | | 50 | | 35 |
| November | 60 | | 50 | | 35 |
| December | 50 | | 40 | | 35 |

[a] Precipitation indicator in inches is cumulative, measured at Hetch Hetchy Reservoir, starting October 1.
[b] Runoff indicator in acre-feet is the calculated inflow into Hetch Hetchy Reservoir commencing on the previous October 1.

**Table 4.4.1-2**
**Modeled Monthly Minimum Release Below O'Shaughnessy Dam – Acre-feet**

| | Type A | | | Type B | | | Type C | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | F&W Release | Discre-tionary Release | Total Release | F&W Release | Discre-tionary Release | Total Release | F&W Release | Discre-tionary Release[a] | Total Release |
| October | 3,689 | 0 | 3,689 | 3,074 | 0 | 3,074 | 2,152 | 0 | 2,152 |
| November | 3,570 | 0 | 3,570 | 2,975 | 0 | 2,975 | 2,083 | 0 | 2,083 |
| December | 3,074 | 0 | 3,074 | 2,460 | 0 | 2,460 | 2,152 | 0 | 2,152 |
| January | 3,074 | 0 | 3,074 | 2,460 | 0 | 2,460 | 2,152 | 0 | 2,152 |
| February | 3,362 | 0 | 3,362 | 2,802 | 0 | 2,802 | 1,961 | 0 | 1,961 |
| March | 3,689 | 0 | 3,689 | 3,074 | 0 | 3,074 | 2,152 | 0 | 2,152 |
| April | 4,463 | 0 | 4,463 | 3,868 | 0 | 3,868 | 2,083 | 0 | 2,083 |
| May | 6,149 | 0 | 6,149 | 4,919 | 0 | 4,919 | 3,074 | 0 | 3,074 |
| June | 7,438 | 0 | 7,438 | 6,545 | 0 | 6,545 | 4,463 | 0 | 4,463 |
| July | 7,686 | 6,000 | 13,686 | 6,764 | 2,600 | 9,364 | 4,612 | 1,800 | 6,412 |
| August | 7,686 | 6,000 | 13,686 | 6,764 | 2,500 | 9,264 | 4,612 | 1,800 | 6,412 |
| September | 5,316 | 3,000 | 8,316 | 4,284 | 1,400 | 5,684 | 3,669 | 800 | 4,469 |
| Total | 59,196 | 15,000 | 74,196 | 49,989 | 6,500 | 56,489 | 35,165 | 4,400 | 39,565 |

[a] If July first-of-month storage at Hetch Hetchy Reservoir is less than 210,000 acre-feet program will not make the discretionary release.

### *4.4.2 Lake Lloyd and Lake Eleanor*

Fishery releases below Lake Lloyd to Cherry Creek are maintained in all years. Table 4.4.2-1 describes these releases that vary monthly between 5 cubic feet per second and 15.5 cubic feet per second. Releases below Lake Lloyd as applied in the model are also summarized in Table 4.4.2-1.

**Table 4.4.2-1**
**Modeled Monthly Minimum Release Below Lake Lloyd**

| | Release to Stream | |
|---|---|---|
| Month | (cfs) | (acre-feet) |
| October | 5 | 307 |
| November | 5 | 298 |
| December | 5 | 307 |
| January | 5 | 307 |
| February | 5 | 278 |
| March | 5 | 307 |
| April | 5 | 298 |
| May | 5 | 307 |
| June | 5 | 298 |
| July | 15.5 | 953 |
| August | 15.5 | 953 |
| September | 15.5 | 922 |
| Total | | 5,535 |

Fishery releases below Lake Eleanor to Eleanor Creek are dependent on the operation of the Eleanor-Cherry Diversion Tunnel. Table 4.4.2-2 depicts the releases made to Eleanor Creek under both a pumping mode and gravity flow mode. Releases below Lake Eleanor as applied in the model are also summarized in Table 4.4.2-2.

**Table 4.4.2-2**
**Modeled Monthly Minimum Release Below Lake Eleanor**

| | With Pumping [a] | | Gravity Flow Without Pumping [a] | |
|---|---|---|---|---|
| Month | (cfs) | (acre-feet) | (cfs) | (acre-feet) |
| October | 10 | 615 | 5 | 307 |
| November | 5 | 298 | 5 | 298 |
| December | 5 | 307 | 5 | 307 |
| January | 5 | 307 | 5 | 307 |
| February | 5 | 278 | 5 | 278 |
| March | 10 | 615 | 5 | 307 |
| April 1-14 | 10 | 278 | 5 | 139 |
| April 15-30 | 20 | 635 | 5 | 159 |
| May | 20 | 1,230 | 5 | 307 |
| June | 20 | 1,190 | 5 | 298 |
| July | 20 | 1,230 | 16 | 953 |
| August | 20 | 1,230 | 16 | 953 |
| September 1-15 | 20 | 595 | 16 | 461 |
| September 16-30 | 10 | 298 | 16 | 461 |
| Total | | 9,106 | | 5,535 |

[a] The agreement for the operation of the Eleanor-Cherry Tunnel and Pumping Plant calls for different fishery release schedules below Eleanor Dam depending on whether or not the pumping plant is used.

### *4.4.3 Don Pedro Reservoir*

Minimum flows for the Tuolumne River below La Grange Dam are required by the FERC license for the New Don Pedro Project. The FERC license identifies ten year-type classifications for the Tuolumne River, of which only seven have distinctly different minimum flow schedules. Table 4.4.3-1 illustrates the determination of the year-type classification as indexed to the State Water Resources Control Board San Joaquin Valley Water Year Hydrologic Classification.

**Table 4.4.3-1**
**Tuolumne River FERC Flow Requirement Year-Type Classification**

| FERC Year Type Classification | San Joaquin Valley Hydrologic Classification 60-20-20 Index (1,000 AF) |
|---|---|
| Critical and Below | <1,500 |
| Median Critical | 1,500 |
| Intermediate Critical / Dry | 2,000 |
| Median Dry | 2,200 |
| Intermediate Dry / Below Normal | 2,400 |
| Median Below Normal | 2,700 |
| Intermediate Below Normal / Above Normal | 3,100 |
| Median Above Normal | 3,100 |
| Intermediate Above Normal / Wet | 3,100 |
| Median Wet / Maximum | 3,100 |

For each year-type classification, a basic schedule of flows is identified for the break point for the year type (Table 4.4.3-2). For example, if the San Joaquin Valley Hydrologic Classification index is 1,550 thousand acre-feet (TAF) the year is classified as Median Critical and its basic schedule is a volume of 103,000 AF. The FERC license requires an interpolation of schedules within year type classifications. Therefore, the annual FERC requirement for this example is a linearly interpolated volume between the Median Critical schedule (103,000 AF) and the Intermediate Critical / Dry schedule (117,016 AF). HH/LSM assumes the amount of water determined by the interpolation is added to the basic schedule during the out migration pulse flow period.

**Table 4.4.3-2**
**Tuolumne River FERC Flow Requirement Requirements**

| | FERC Year Type Classificatoin | | | | | | |
|---|---|---|---|---|---|---|---|
| Period | Critical and Below | Median Critical | Intermed Critical / Dry | Median Dry | Intermed Dry / Below Normal | Median Below Normal | Intermed Below Normal / Above Normal and Above |
| Annual Volume (acre-feet) | 94,000 | 103,000 | 117,016 | 127,507 | 142,502 | 165,002 | 300,923 |
| October 1 – 15 | 100 | 100 | 150 | 150 | 180 | 200 | 300 |
| Attraction Pulse Flow (acre-feet) | None | None | None | None | 1,676 | 1,736 | 5,950 |
| October 16 - May 31 | 150 | 150 | 150 | 150 | 180 | 175 | 300 |
| Out migration Pulse Flow (acre-feet) | 11,091 | 20,091 | 32,619 | 37,060 | 35,920 | 60,027 | 89,882 |
| June 1 – September 30 | 50 | 50 | 50 | 75 | 75 | 75 | 250 |
| Units: cfs unless otherwise noted. | | | | | | | |

### *4.4.4 Calaveras Reservoir*

Minimum release requirements below Calaveras Reservoir are specified by the MOU between SFPUC and the California Department of Fish and Game. The MOU specifies minimum flow requirements in Alameda Creek at the confluence with Calaveras Creek. The stream flow requirement is met through releases at Calaveras Dam as needed to supplement unregulated flows that occur at the confluence. The total annual obligation is up to 6,300 acre-feet/year. The monthly flow requirements at the confluence as modeled by HH/LSM are presented in Table 4.4.4-1. These requirements are assumed not in effect while the Calaveras Dam is operating at a reduced capacity due to DSOD requirements.

**Table 4.4.4-1**
**Alameda Creek MOU Flow Requirement Requirements**

| | Average Monthly (cfs) | Volume (acre-feet) |
|---|---|---|
| October | 7 | 430 |
| November | 5 | 298 |
| December | 5 | 307 |
| January | 13 | 799 |
| February | 20 | 1121 |
| March | 13 | 799 |
| April | 7 | 417 |
| May | 7 | 430 |
| June | 7 | 417 |
| July | 7 | 430 |
| August | 7 | 430 |
| September | 7 | 417 |

### *4.4.5 San Antonio Reservoir*

There are no minimum release requirements below San Antonio Reservoir.

### *4.4.6 Peninsula Reservoirs*

There are no minimum release requirements below the Peninsula reservoirs.

# 5. Modifications to HH/LSM for WSIP Analyses

Several modifications were made to the model to evaluate projects and operations considered in the evaluation and development of the Water System Improvement Program (WSIP). These modifications enhanced the functionality of the model. The following provides a brief description of various water supply and management options that are additionally available for evaluation by the model.

## 5.1 Retail Customer Recycled Water/Groundwater/Conservation

The “City Gradient” water demands can be offset to incorporate an assumed level of water demand reduction attributed to implementation of recycled water, groundwater or conservation. The amount of offset is defined by month and is applied each year of the simulation.

## 5.2 Wholesale Customer Recycled Water/Groundwater/Conservation

Each of the wholesale customer “gradients” water demand can be offset to incorporate an assumed level of water demand reduction attributed to implementation of recycled water, groundwater or conservation. The amount of offset is defined by month and is applied each year of the simulation.

## 5.3 Westside Basin Conjunctive Use Program

The Westside Basin Conjunctive Use Program is modeled as a water demand modifier to the San Andreas and Crystal Springs water delivery gradients. The functionality of the program is defined by the storage capacity (volume) of the underground reservoir, the rate at which increased Regional Water System deliveries can “store” water, and the rate at which increased groundwater pumping by the participants can “extract” water. The extraction mode of the program is triggered when the drought response is at a level of 1 or greater. Replenishment occurs whenever the storage is less than maximum and extraction is not occurring.

## 5.4 Tuolumne River Water Transfer

A water transfer to the SFPUC from the Districts can occur via the Water Bank Account in Don Pedro Reservoir. The transfer can be defined by month for each year of the simulation. The assumed transfer modifies the SFPUC’s account balance and the system will subsequently react to the modified balance.

## 5.5 Regional Dry-year Desalination

Regional dry-year desalination is modeled as a supplemental stream of water entering the Regional Water System through Sunol Valley conveyance. The stream of water is defined as a rate of production for each month of the year. The project’s production can be triggered by drought response level.

## 5.6 Oceanside Desalination

The production rate of the Oceanside Desalination Project is defined for each month of a year and is utilized in all years when this feature is applied. The production offsets the water demand of the “City Gradient”.

## 5.7 Lower Tuolumne River Diversion

This feature shifts a portion of the SFPUC’s Tuolumne River diversion to the lower Tuolumne River below La Grange Dam. The feature also triggers additional stream releases from O’Shaughnessy Dam coincident with the diversion from the lower Tuolumne River. A rate of potential diversion from the lower Tuolumne River is defined for the project. Whenever the Bay Area system requires Tuolumne River diversions in excess of the available capacity of the San Joaquin Pipelines a supplemental release from Hetch Hetchy Reservoir occurs which then is bypassed through Don Pedro Reservoir and La Grange Dam for diversion by the SFPUC from the lower Tuolumne River.

### 5.8 Delta Diversion

A source of supply originating from the Sacramento-San Joaquin Delta can be defined by a monthly and yearly array. The stream of water can be entered into the Regional Water System at two different locations: 1) inflow to San Antonio Reservoir, and 2) supplementing flow into Sunol Valley conveyance.

# 6. Model Verification

The HH/LSM was originally developed in 1988 and has undergone a continuous process of improvement. The model was used in support of an application to amend the license for the Don Pedro Project, which was submitted to the Federal Energy Regulatory Commission (FERC) in 1993 and 1994. FERC approved the use and results of the model for purposes of the amendment.

## 6.1 Parsons/CH2MHill Review

The model was reviewed again in 2005, as part of the Water Supply Improvement Program Assessment conducted by Parsons/CH2MHill. The purpose of this review was to determine if:

- the model adequately represents the SFPUC system;
- the fundamental assumptions of the model are reasonable based on the available data;
- the model has been applied in an appropriate manner; and,
- the model results have been incorporated into the decision/planning process.

The model review was conducted by looking at each element of HH/LSM to see if the model input data, assumptions, operational criteria, and results were within the expected range of practice for this type of model application. The review included brief checks of input hydrology, system demands, reservoir target storage levels and capacities, transmission system flow capacities, general operations criteria, and simulation procedure logic. Model Fortran source was not reviewed as part of the evaluation.

### *6.1.1 Conclusions*

The following conclusions regarding the model were presented in the Parsons/CH2MHill report:

- The review of model input hydrology, system demands, representation of system facilities, operating criteria, and procedural simulation logic indicates that the model representation of the existing SFPUC system is reasonable as applied to the general types of planning purposes for which the model is designed. The monthly time step limits the model’s intended use for planning applications, and it is not designed for analyzing power generation or system operations that require a weekly, daily, or even hourly assessment.

- The comparison of HH/LSM results with historical operations for the period 1986 through 1995 shows that the model provides a reasonable simulation of system deliveries and reservoir storage values for the existing SFPUC regional water system.

- HH/LSM provides a valuable planning tool that the SFPUC can use to evaluate drought periods to establish system firm yield, levels of required rationing, water transfer needs, and reservoir storage requirements. It can also be used to assess benefits and impacts to SFPUC regional water system long-term delivery reliability based on different mixes of water supply sources, levels of conservation, operations criteria, new transmission and storage facilities, and changing hydrologic conditions such as global climate warming.

- The SFPUC’s drought planning methodology using HH/LSM provides a logical, defensible, and repeatable analytical process that can be used to develop yearly sequences of simulated design drought operations of SFPUC facilities to meet operational and delivery targets.

- The computer simulation of the SFPUC regional water system requires a fairly high level model code to allow adequate representation of the large number of transmission and storage facilities, regulatory requirements, and operational complexities of the system. The proper application of the model and interpretation of model results requires a person with a high level understanding of system operations and of HH/LSM to effectively apply the model and provide meaningful interpretation of model results.

### *6.1.2 Recommendations*

The following recommendations regarding the model were presented in the Parsons/CH2MHill report:

- Develop consistent standards and protocols for HH/LSM analyses of WSIP projects and water supply options to allow proper model application, ensure comparable simulation results, and facilitate consistent sizing of new transmission and storage facilities (i.e., specification of maintenance windows and specific definitions of proposed future facilities).

- Conduct an HH/LSM workshop with WSIP staff to improve understanding of the capabilities and limitations of the model and allow for more effective assessment of how to incorporate the application of the model into projects at the planning, feasibility, and design levels.

- Improve coordination with analyses conducted with the hydraulic transmission system model by developing a procedure for iterating between the models to evaluate system operations, sizing of future facilities, and impacts on design drought operations and system yield. In some cases, it appears there may be inconsistencies between the assumptions in HH/LSM and the transmission model with regard to demands, conveyance capacities, and operational/maintenance strategies .

- The LOTUS preprocessor spreadsheets are outdated, and development of a new user interface should be considered to make model application more efficient and reduce potential data input errors.

## 6.2 Comparison of Model Results with Current Operations

It is the policy of the SFPUC to operate its water system in a prudent manner that maximizes the reliability and quality of water deliveries. These operations are grounded on numerous specific requirements described in several legal agreements, authorizing legislation, and regulatory requirements. Operations are also guided by judgment, strategies and historical experience. In total, formal and informal “rules” combine into the current operation of San Francisco’s Regional Water System. The operation of the San Francisco Regional Water System is a matter of historical record, an operation evidenced with an evolution that has been caused by natural events, changes in facilities and regulatory constraints, and changes in planning perspective and objectives. Because of this historically changing operation and physical regime, the historical record of operations does not depict a consistent operational philosophy. Also, due to the dynamic nature of actual operating conditions, including facility maintenance that affects short-term operations, and the limited hydrologic period that incorporates current operation objectives, the recent historical record of operations cannot fully describe system operation. Conclusions drawn from the review of the historical record must recognize and consider these changes and special circumstances.

Monthly water planning simulation models such as HH/LSM are difficult to validate against historical operations since these systems are complex and there are multiple variables associated with system facilities, operational strategies, and demands that affect year-to-year operations. Historical operations of the Hetch Hetchy and Bay Area facilities in earlier years of the system are a reflection of operating needs at that time. Since then, regulatory requirements, available system transmission and storage facilities, sources of supply, and demand levels have all changed. Therefore, simulation results for current system facilities, operating conditions, and 265 mgd of demand are not expected to validate against earlier years from the historical record. Historical data from more recent years with existing facilities in place and similar demand levels can be expected to more closely correlate with current model results. Simulated results for system deliveries, local reservoir storages, Hetch Hetchy upstream reservoirs, Don Pedro Water Bank Account, and Sunol Valley WTP operations track reasonably well with historic data over the most recent period, providing confidence in model performance. Overall, the simulation capabilities of the model appear to be appropriate for water supply planning based on the review of model input data, operating rules, simulation results, and available comparisons with historical operations data.

## 7. References and Sources of Additional Information

Federal Energy Regulatory Commission (FERC), 1995. New Don Pedro Proceeding P-2299-024 Settlement Agreement. Dated 1995.

SFPUC 1996. Hetch Hetchy Water & Power Tuolumne River Water Supply Forecasting Model, Volume 1 – Manual and Volume 2 – Operation Manual. Prepared by Hannaford Consulting, Inc., October 10, 1996.

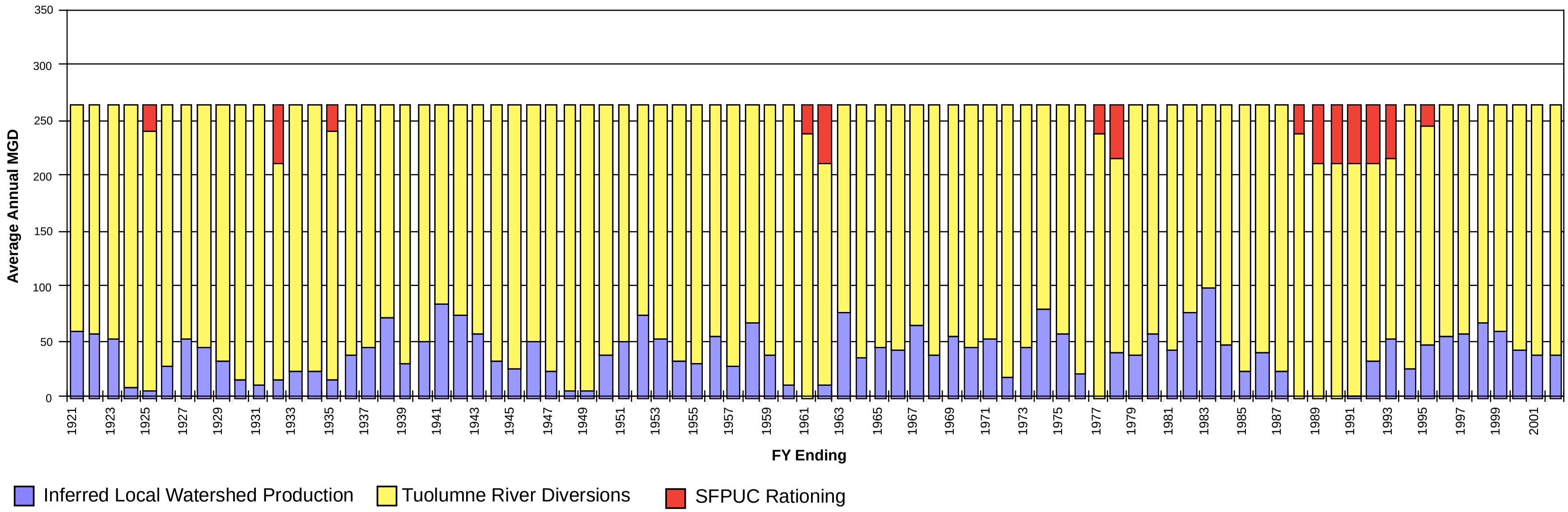
SFPUC 1997. Memorandum of Understanding Between the City and County of San Francisco Public Utilities Commission and the California Department of Fish and Game Regarding Water Release and Recapture Facilities for Purposes of Improving Native Fisheries on Alameda Creek and Calaveras Creeks. August, 1997.

SFPUC 2005. Regional Water System Operations Plan. CDM, April 2005.

SFPUC 2006. Regional Water System Hetch Hetchy Water & Power Operations Plan. URS, August 2006.

State Water Resources Control Board. Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary, 95-1WR, May 1995.

Steiner, Daniel B., Consulting Engineer. Unimpaired Flow Estimates for HH/LSM System – East Bay Locales. Draft, August 2006.




This figure illustrates what combination of supply sources the regional system would use year to year under existing conditions to meet the existing system delivery demand of 265 mgd if it were operated over a long series of years similar in terms of climate conditions to those that occurred between 1920 and 2002. This 82-year simulation illustrates how the relative contribution of water supply sources available to the SFPUC would vary year to year and shows the frequency and extent of supply shortages and rationing that would occur if there were dry years and drought periods similar to those that occurred during this historic period.

NOTES: (1) This figure illustrates a conceptual breakdown of water sources available to the SFPUC regional system. Local Watershed Production (inferred) is estimated as the difference between the amount of water delivered to system customers and the amount of water provided by the San Joaquin pipeline (Tuolumne River) and extracted from the Westside Basin groundwater aquifer. This estimate does not account for the source of Bay Area system reservoir storage used to serve deliveries or the partial use of San Joaquin pipeline deliveries for replenishment of Bay Area system reservoirs.

SOURCE: SFPUC, HH/LSM (see Appendix H)

SFPUC Water System Improvement Program . 203287

**Figure 5.1-4**
Water Supply Sources and Shortages – Existing Conditions (265 mgd Delivery)

**Dan Steiner Direct Testimony, Table 1 Computation Sheet**

| | **SFPUC Water Supply Outlook** | | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 |
|---|---|---|---|---|---|---|---|---|
| | Projected Year | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| | Recurring Year | | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
| a | Existing System Delivery Shortage (%) | 1 | 10 | 20 | 20 | 20 | 20 | 20 |
| b | Existing Delivery (MGD) | 2 | 239 | 212 | 212 | 212 | 212 | 212 |
| c | Existing Delivery (Acre-feet/year) | 3 | 267,700 | 237,500 | 237,500 | 237,500 | 237,500 | 237,500 |
| d | Additional Reduction (Acre-feet) | 4 | 99,300 | 99,300 | 99,300 | 99,300 | 99,300 | 99,300 |
| e | Remaining Delivery (Acre-feet) | 5 | 168,400 | 138,200 | 138,200 | 138,200 | 138,200 | 138,200 |
| f | Remaining Delivery (MGD) | 6 | 150 | 123 | 123 | 123 | 123 | 123 |
| g | Remaining Delivery (%) | 7 | 57 | 47 | 47 | 47 | 47 | 47 |
| h | Shortage after Additional Release (%) | 8 | 43 | 53 | 53 | 53 | 53 | 53 |

1. Shortage as a percentage of current delivery of average annual 265 MGD.
   Assumes sequence of 2010 - 2015 runoff is equal to runoff experienced during 1987 - 1992.
2. Average annual delivery after reduction. Full current delivery is an average annual 265 MGD.
3. Average annual delivery after reduction, converted to acre-feet per year.
4. Average annual reduction in SFPUC water supply, illustrated as approximately 52% of the incremental difference in required flow schedule.
   The reduction calculation assumes that CCSF provides 51.7121% of the difference between the USFWS May 1, 2008 proposal and the existing Article 37 fish flow requirements. While CCSF and the Districts have agreed on the use of this assumption for purposes of modeling in this proceeding, CCSF contends that this assumption is not dictated by the Fourth Agreement and the Districts contend that it is. Neither CCSF nor the Districts waive their respective rights to challenge whether this assumption is required by the Fourth Agreement. Further, this modeling assumption shall not be used as evidence in any proceeding relating to and shall not act as precedence for any allocation of Tuolumne River water between CCSF and the Districts for any purpose.
6. Remaining delivery converted to MGD.
7. Remaining delivery after additional reduction, as a percentage of full current delivery (265 MGD).
8. Shortage as a percentage of current delivery of average annual 265 MGD.

Computation/Source

a From PEIR (June 2007) for the WSIP, existing conditions with current 1996 FERC Settelement.

b Average annual delivery to SFPUC customers after imposed shortage. Current demand is 265 mgd.
Example of delivery after shortage: 265 mgd (full delivery) x 90% (10% shortage) = 239 mgd

c Average annual delivery in mgd converted to acre-feet per year.
Example: (239 mgd x 1,000,000 gallons x 365 days/year ) / 325,850 gallons/acre-foot = 267,700 acre-feet

d Difference between existing 1996 FERC Settlement flow requirement below La Grange Dam and proposed agency flow requirement (described by Mr. Monier, TID), 307,000 acre-feet/year minus 115,000 acre-feet per year, assuming an assignment of approximately 52% to be provided by the SFPUC.
307,000 - 115,000 = 192,000 192,000 x .517121 = 99,300

e Remaining delivery after existing shortage and additional reduction due to SFPUC incremental flow release.
Example: 267,700 (delivery after existing shortage) minus 99,300 (additional shortage) = 168,400 acre-feet

f Remaining delivery in acre-feet converted to average annual delivery in mgd.
Example: (168,400 acre-feet/year x 325,850 gallons/acre-foot) / (1,000,000 gallons x 365 days/year) = 150 mgd

g Remaining delivery as a percentage of full demand.
Example: 150 mgd (remaining delivery after shortage) x 100 / 265 mgd (full demand)

h Water delivery shortage as a percentage of full demand.
Example: 100 percent minus 57 percent (delivery) = 43 percent shortage

September 14, 2009

# AFFIDAVIT

STATE OF CALIFORNIA )
) ss:
COUNTY OF PLACER )

Daniel B. Steiner, being first duly sworn, deposes and says that he is the same Daniel B. Steiner whose testimony on behalf of City and County of San Francisco, California accompanies this affidavit; that he has read the foregoing questions and answers constituting that testimony, and that if asked such questions his answers in response would be as shown; that the facts set forth therein are true and correct to the best of his knowledge, information and belief; and that he does adopt the same as his sworn testimony in this proceeding.

Daniel B. Steiner

Subscribed and sworn to before me, the undersigned notary public, this 12th day of September, 2009.

DENISE RENEE PIEPLOW
COMM. # 1776135
NOTARY PUBLIC-CALIFORNIA
PLACER COUNTY
MY COMM. EXP. OCT. 26, 2011

Denise Renee Pieplow
Notary Public

**MY COMMISSION EXPIRES:** 10/26/11

Exhibit No. CSF-20

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

| | | |
|---|---|---|
| Turlock Irrigation District and Modesto Irrigation District | | Project Nos. 2299-065 2299-053 |

**ANSWERING TESTIMONY OF**
**DAVID L. SUNDING ON BEHALF OF**
**SAN FRANCISCO PUBLIC UTILITIES COMMISSION**

**Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.**

**A.** My name is David L. Sunding, Berkeley Economic Consulting, Inc., 2531 Ninth Street, Berkeley, CA 94710.

**Q. WHAT IS YOUR OCCUPATION?**

**A.** I am a director of Berkeley Economic Consulting, Inc. (BEC), an independent economic research firm. I am an economist specializing in natural resource and environmental economics, including water resource economics.

**Q. ON WHOSE BEHALF DO YOU APPEAR IN THIS PROCEEDING?**

**A.** I am appearing on behalf of the San Francisco Public Utilities Commission (SFPUC).

**Q. PLEASE SUMMARIZE YOUR BACKGROUND AND EXPERIENCE.**

**A.** I completed a Ph.D. in natural resource economics from the University of California, Berkeley (UC Berkeley). I earned a bachelor’s degree in economics from Claremont McKenna College. My CV is attached hereto as Exhibit CSF-21. I have over 20 years of experience as a water resource economist and have held several prominent academic appointments. I currently hold the Thomas J. Graff Chair in Natural Resource Economics and Policy at UC Berkeley and am co-director of the Berkeley Water Center. I have served on panels of the National Academy of Sciences and the U.S. EPA Science Advisory Board. Prior to joining the Berkeley faculty, I taught at Boston College in the Department of Economics and the School of Law. During the Clinton Administration, I was a senior economist at the President's Council of Economic Advisors.

**Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?**

**A.** I have been asked to present my estimates of the economic impacts that would result from water rationing in the SFPUC service area if the SFPUC Regional Water System is required to provide flows from its water system to the Turlock and Modesto Irrigation Districts (Districts) for release to the lower Tuolumne River below LaGrange Dam, as recommended by National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) in their direct testimony submitted on September 14, 2009 (Exh. NMF-1), which USFWS witness Michelle Workman supports in her direct testimony (Exh. No. FWS-2).[1]

**Q. PLEASE DESCRIBE BRIEFLY HOW ECONOMISTS EVALUATE THE ECONOMIC IMPACTS OF WATER RATIONING ON THE RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL SECTORS OF THE BAY AREA ECONOMY.**

**A.** Economists measure economic impacts in terms of changes to consumer and producer surplus. Consumer surplus refers to the difference between what a

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[1] Exhibit No. NMF-1 is the interim protection measures newly recommended by NMFS and USFWS in their September 14, 2009 direct testimony, and it does not appear to be sponsored by any single NMFS or USFWS witness. As stated by NMFS witness Strange in Exhibit No. NMF-2, page 16 of 25, lines 7-8, different experts support the different elements of Exhibit No. NMF-1. I understand that six witnesses from NMFS (Steven Lindley (Exh. NMF-6), Erin Strange (Exh. NMF-2), Craig Anderson (Exh. NMF-4)), USFWS (Michelle Workman (Exh. FWS-2) (referring to identical Exhibit No. FWS-1), and the California Department of Fish and Game (CDFG) (Timothy Heyne (Exh. DFG-2), Andrew Gordus (Exh. DFG-4) (referring to identical Exhibit No. DFG-1)), all filed direct testimony stating that they support the Exhibit No. NMF-1 Interim Measure Elements.

consumer is willing to pay for a good or service and what a consumer actually pays. Producer surplus is a similar measure; it is defined by the difference between revenues and variable costs, and is a measure of economic profit. Producer surplus reflects the benefit of an activity to business owners by measuring revenues in excess of levels adequate to keep producing goods or services.

While consumer and producer surplus measures are preferred by economists since they are grounded in modern concepts of welfare economics and public finance, we are often asked to calculate changes in other measures such as employment and sales. Economists typically estimate these impacts by using an empirical relationship between variables of interest, referred to as elasticity.

**Q. PLEASE DESCRIBE BRIEFLY THE PRIOR STUDIES THAT HAVE BEEN CONDUCTED ON THE IMPORTANCE OF THE BAY AREA REGIONAL WATER SYSTEM TO THE ECONOMY OF THE SFPUC SERVICE AREA, INCLUDING ANY PRIOR STUDIES IN WHICH YOU PARTICIPATED.**

A. Several studies have been conducted to measure the impacts of water supply shortages in the San Francisco Bay area over the past 15 years. Exhibit CSF-22 lists four of them, including one that I collaborated on in 2007 on behalf of SFPUC and one that I directed in 2002 for the Bay Area Economic Forum. Dr. William Wade conducted a drought impact study on behalf of the Bay Area Water Supply and Conservation Agency (BAWSCA) in 2005. Just over 10 years earlier, Dr. Philip McCleod conducted a study on behalf of SFPUC. All three studies found that even a 10% water shortage results in substantial losses in industrial output (sales or shipments). The most recent study found that a 10% shortage would reduce industrial output by over $0.5 billion and create job losses of over 1,300. The previous study estimated that industrial output would fall by $2.5 billion. (Employment impacts were not addressed). Larger losses may be explained in part by changes in industrial composition over time. Many water "intensive" industries have left the region since the late 1990s thereby reducing the impact of water shortages.

According to all three studies, economic losses increase relative to increased water shortages. Doubling the water shortage from 10% to 20% roughly doubles the industrial losses ($0.5 billion to $1.1 billion) according to the most recent study and more than triples the industrial losses ($2.5 billion to $7.66 billion) according to the 2005 study. The earlier study showed an even more dramatic increase. Doubling the water shortage from 15% to 30% resulted in a five-fold increase in industrial losses ($0.4 billion to $2.1 billion). The most recent study found that a 30% water shortage would result in industrial losses totaling $3.6 billion with job losses exceeding 8,000.

I also conducted a study in 2002 with funding from the Bay Area Economic Forum to calculate the economic impacts of a Hetch Hetchy system failure caused by an earthquake or other catastrophic event. In such events, water supplies would be unavailable or severely rationed for 10 to 30 days and possibly as long as 60 days. This study, which was published in *Water Resources Research*, concluded that this type of supply interruption occurring along the San Andreas Fault would result in economic losses in excess of $28.7 billion in the Bay Area. Commercial and industrial losses alone would be at least $14.2 billion.

**Q. WHAT IS THE IMPORTANCE TO THE BAY AREA ECONOMY OF THE SFPUC REGIONAL WATER SYSTEM?**

The SFPUC Regional Water System is comprised of the SFPUC retail agency and the member agencies of BAWSCA. The retail agencies serve residential, commercial, industrial, and government customers across four counties – San Francisco, Alameda, San Mateo, and Santa Clara counties.

Across the agencies receiving water from the Regional Water System, residential demand represents 60% of FY 04-05 demand, industrial demand represents 7%, commercial demand accounts for 19%, and government and other sectors account for the remaining 14% of demand.

Six agencies—SFPUC retail, Alameda County Water District (Alameda CWD), California Water Service Company (CWS),[2] Santa Clara, Sunnyvale, and Hayward—account for about two-thirds of total water demand. Six agencies, including SFPUC retail, Alameda CWD, Sunnyvale, Hayward, CWS - Mid Peninsula, and CWS - Bear Gulch account for roughly two-thirds of residential demand. Santa Clara, Alameda CWD, and Hayward account for nearly two-thirds of industrial water demand.

The SFPUC provides retail water delivery service within the City and County of San Francisco to over 147,800 residential accounts and 21,600 non-residential

[2] CWS is broken down into its three jurisdictions in the area: CWS - Bear Gulch, CWS – Mid-Peninsula, and CWS – South San Francisco.

accounts and to 27 wholesale agencies. BAWSCA is composed of the 24 cities and water districts and two private utilities, Stanford University and California Water Service Company, that are wholesale customers of SFPUC. Member agencies of BAWSCA service a population of nearly 1.7 million, with over 370,000 residential accounts, 5,500 industrial accounts, and 25,800 commercial accounts. In FY 04-05, SFPUC water accounted for roughly 68% of total water supply for BAWSCA members; the remaining 32% of water supply is from other sources.

The area served by the SFPUC Regional Water System is one of the largest centers of employment and economic activity in the United States. There are over 1.6 million jobs located in the service area. Firms located in the service area produce over $280 billion in goods and services each year. Because of the Bay Area’s arid climate, this economic activity is dependent on the importation of water from other areas.

**Q. HAVE YOU REVIEWED THE TESTIMONY OF DAN STEINER REGARDING POTENTIAL LEVELS OF RATIONING FOR THE REGIONAL WATER SYSTEM AND ELLEN LEVIN'S TESTIMONY ON STRATEGIES FOR REDUCING THE IMPACTS OF RATIONING?**

A. Yes, I have.

**Q WHAT STEPS DID YOU UNDERTAKE TO ANALYZE THE IMPACTS OF THESE LEVELS OF RATIONING IN THE SAN FRANCISCO BAY AREA?**

A I developed an economic model of agency-level water allocation that reflects the demand for water for various customer classes. The model incorporates all retail agencies receiving water from the SFPUC Regional Water Supply System. The technical report attached to this testimony as Exhibit CSF-24 describes the specification of the model.

In developing the impact model, I estimated a detailed statistical demand relationship for residential water use in the Regional Water System. The data used in the estimation capture a number of important factors that influence demand, including income, climate variables, residential density, water rates, and adoption of the Best Management Practices described in Ms. Levin's direct testimony. As she notes, retail agencies receiving water from SFPUC have made good progress in encouraging efficient water use practices. Residential water use accounts for over 60% of total water consumption in the SFPUC Regional Water System. The econometric model I developed for this customer class greatly enhances my ability to make accurate predictions about the economic ramifications of water supply disruptions.

For each customer class in each agency, the economic impact model calculates the rationing levels that minimize economic surplus losses while still achieving necessary levels of conservation. Actual surplus losses may be larger than those calculated here to the extent that agencies use other factors to determine mandated levels of conservation for different groups of consumers. Even with this conservative assumption in place, the economic losses resulting from the levels of rationing described by Mr. Steiner and Ms. Levin are extraordinarily large and would have a devastating effect on the economy of the Bay Area.

**Q. PLEASE SUMMARIZE YOUR CONCLUSIONS ON THE ECONOMIC IMPACTS OF THE POTENTIAL LEVELS OF RATIONING IDENTIFIED BY MR. STEINER AND HOW SUCH RATIONING MIGHT BE IMPLEMENTED BETWEEN THE WHOLESALE AND RETAIL CUSTOMERS AS DESCRIBED BY MS. LEVIN.**

**A.** I calculated economic impacts for several levels of rationing: 10%, 20%, 41%, and 51%. While the first two scenarios do not represent the maximum potential impacts of the proposed instream flow requirements, these lower rationing levels will occur with much greater frequency than at present, and with much greater frequency than the maximum rationing scenarios. The results of my analysis of these four scenarios are presented in Exhibit CSF-23.

With respect to lost consumer and producer surplus, the potential rationing losses will result in significant impacts, which I calculate at $471 million annually in the 51% rationing scenario. Losses in the other scenarios are $324 million (41% Rationing), $119 million (20% Rationing), and $53 million (10% Rationing).

Rationing in the range of 40% - 50% is extreme, and it is more reminiscent of the effects of a major earthquake than the effects of typical environmental regulation. To understand some of the practical difficulties associated with conservation of this magnitude, consider that residential consumption accounts for around 60% of all water use in the Regional Water System. The United Nations recommends that a minimum level of water to maintain human survival with basic levels of sanitation is 13.7 gallons of water per person per day (gcd). Multiplying this basic human water requirement across the population served by the Regional Water System (and accounting for the proportion of supply from non-SFPUC sources), it follows that roughly 34 mgd is needed to meet this basic level. Thirty-four mgd is close to 13% of the total water delivered by the SFPUC, meaning that this quantity is absolutely off-limits to conservation, and conservation must come from remaining uses.

More realistic levels of residential indoor uses can be determined by looking across retail agencies in the Bay Area. A level of 50 gcd is below that of any retail agency in the Regional Water System, is below the level currently attained in East Palo Alto, a severely depressed city, and 13% below the current level of residential consumption in the City of San Francisco, which has one of the lowest levels of per capita water use of any major city in California. At a level of 50 gcd, residential consumption across the Regional Water System would account for nearly 125 mgd in total. In this instance, all required conservation would need to be met by reductions in other demands such as outdoor use, commercial and industrial uses. In addition, some agencies can turn to alternative supplies to replace some portion of lost SFPUC deliveries as described in Exhibit CSF-24

**Q. PLEASE DESCRIBE THE IMPACT OF THE POTENTIAL WATER RATIONING LEVELS ON EMPLOYMENT AND SALES IN THE SAN FRANCISCO BAY AREA.**

**A.** The impact of the potential rationing levels on employment is severe. In the 51% rationing scenario, I estimate that the Bay Area would lose more than 188,000 jobs as industrial and commercial output is reduced to meet conservation requirements. Such losses account for over one-tenth of all payroll in the SFPUC Regional Water System service area. Job losses in the other scenarios are 139,146 (41% Rationing), 6,562 (20% Rationing), and 3,922 (10% Rationing). Note that job losses increase dramatically in the event of larger rationing as firms run out of ways to reduce water consumption that do not require shutting down.

Lost sales of firms in the SFPUC Regional Water System area are in excess of $49 billion annually in the event of 51% rationing. This figure corresponds to roughly 20% of all economic activity in the region. Sales losses in the other scenarios are $37 billion (41% Rationing), $3.1 billion (20% Rationing), and $1.8 billion (10% Rationing).

**Q. DOES THIS CONCLUDE YOUR TESTIMONY?**

**A.** Yes, it does.

**UNITED STATES OF AMERICA**
**BEFORE THE**
**FEDERAL ENERGY REGULATORY COMMISSION**

| | | |
|---|---|---|
| **Turlock Irrigation District and** | ) | **Project Nos. 2299-065** |
| **Modesto Irrigation District** | ) | **2299-053** |

**DIRECT TESTIMONY OF F. WESLEY MONIER**
**ON BEHALF OF TURLOCK AND MODESTO**
**IRRIGATION DISTRICTS**

**Q. Please state your name, title, and present affiliation.**

A. My name is F. Wesley Monier and I am the Strategic Issues and Planning Department Manager for Turlock Irrigation District ("TID"). I am testifying on behalf of TID and Modesto Irrigation District ("MID") (collectively, the "Districts").

**Q. Please summarize your professional and educational qualifications, as well as your current responsibilities.**

A. I have over twenty years of experience in calculating flow requirements for the Tuolumne River in accordance with FERC license requirements for the Don Pedro Project ("Project"). This has included forecasting full natural flow for the Tuolumne River watershed, monitoring actual runoff, and the accounting of shares and entitlements to water of the respective parties. I am responsible for coordinating reservoir release requirements for in-stream flows and meeting the diversion demands for irrigation and municipal and industrial purposes. I hold a BA degree in Physics from California State University, Stanislaus. A copy of my resume is included as Exhibit DIS-12.

**Q. Are you familiar with the flow levels being requested by the National Marine Fisheries Service ("NMFS") and the United States Fish and Wildlife Service ("USFWS") in this proceeding?**

A. I understand that these two agencies and the other parties to this proceeding have not yet disclosed what flow levels they are requesting be imposed through this proceeding. However, on August 14, 2009, both NMFS and the USFWS provided to the parties their last published flow proposals. According to the USFWS' August 14, 2009 submittal, its last flow proposals were included in its May 2, 2008 request for rehearing. Those flow proposals were: pulse flows of 1,330 cubic-feet-per-second ("cfs") for 45 days during April and May; fall pulse flows of 1,500 cfs for 10 days in mid-October; and year round base flows of 235 cfs. NMFS indicated in its August 14, 2009 submittal that its last flow proposals, as reflected in its May 2, 2008 request for rehearing and in a May 19, 2008 letter to the Districts, were the same as those of the USFWS referenced above. Subsequent references herein to the USFWS' or agencies' "flows," "fish flows," "flow levels," or "flow proposal" are to the flows set out in the USFWS' May 2, 2008 request for rehearing as referenced above.

**Q. Have you done any analysis to determine what impact the USFWS' flow proposal would have on the Districts' water supply?**

A. Yes, I have calculated the impact to the water supply of the USFWS' flow levels. The results are in Exhibit DIS-13.

**Q. How did you go about making your calculation?**

A. Droughts are unfortunately a common occurrence in California and within the Tuolumne River watershed. Therefore, all water agencies must employ a dry-year water supply planning criteria. The Districts' primary dry-planning criterion is the 1987-1992 drought. The 1987-92 drought represents the "drought of record," *i.e.*, the longest consecutive number of dry water years experienced on the Tuolumne River since record keeping began over 100 years ago. *See* Exhibit DIS-14. Other possible drought periods that may be used are the 1976-77 drought, the most severe two-year drought of record over that 100 year+ time period, and the 1929-1934 drought. For comparison purposes, utilizing the official California Department of Water Resources' published numbers for the San Joaquin River Basin Hydrologic Index, the average index number for each year of the 1929-1934 drought was 2.09, for the 1976-77 drought was 1.21, and for the 1987-1992 drought was 1.72. It is a standard industry practice to gauge water supply system exposure to risk by comparing available resources against expected demands, including requested increased instream flows, under previously experienced drought conditions. While using the 1987-1992 drought is a prudent water supply planning method, it was not the most severe drought of record.

**Q. Please describe how you made your calculation.**

A. First, I assumed that the hydrology of the 1987-92 drought repeated over the next six water years, which start on October 1, 2009. I assumed for purposes of this analysis that the City and County of San Francisco ("CCSF") would provide 51.7121% of the difference between the USFWS fish flow proposal and the existing Article 37 fish flow requirement. For each of the next six water years, I took the total amount of Don Pedro storage starting with the estimated storage for October 1, 2009, added to that sum the calculated inflow based upon the historical hydrologic records plus CCSF's water contribution and subtracted from that total the USFWS flow proposal. From that value, I then subtracted the Districts' respective normal water supply diversions to the extent that water would be available for each of those years, excluding water in dead storage. Don Pedro Reservoir dead storage is the bottom 309,000 acre-feet ("AF") of the reservoir, which is below the elevation of the Project's power tunnel and which is inaccessible for water supply purposes.

**Q. What did your calculation show?**

A. If the proposed USFWS flows were in place during the next six water years, 2010 (commencing October 1, 2009) through 2015 (ending September 30, 2016), and there is a repeat of the 1987-92 drought over those same six years, Don Pedro would be out of water in the second year. During water years 2011 through 2015, the Districts would have an average shortage of 35% from the water they would normally divert to meet their customers' water supply needs. By the end of September 2011, Don Pedro Reservoir would be empty all the way down to dead storage. For the remaining four years of drought, the Districts would receive substantially less water each year and the reservoir would be down to dead storage by September 30 of each year, except for September 30, 2012, when there would be 45 AF in active storage.

**Q. Did the Districts receive full allotments of water during the 1987-92 drought of record?**

A. No, they did not.

**Q. So, with the proposed USFWS flows the Districts would receive even less water. Is that correct?**

A. Yes, that is true.

**Q. How did you determine how much water would be required under the USFWS proposal?**

A. I took the daily requested cfs flow and multiplied it by 1.983471 to calculate the number of acre feet that would be required each day. That sum was multiplied by the number of days in a month and then I totaled the sum of the months to arrive at the base flow. A five percent (5%) buffer flow was then added to the required minimum instream flow to compensate for any potential problems with the U.S. Geological Service gage below La Grange Dam that measures the Districts' compliance with the FERC minimum instream flow requirement.

**Q. How much water would that require on an annual basis?**

A. It would require 292,959 AF annually without a buffer added and 307,607 AF if a 5% buffer is added.

**Q. Did you contrast the proposed flow to the existing requirements under Article 37 of the Districts' license?**

A. Yes, I did. If a repeat of the 1987-1992 drought occurred during the next six water years, 2010 through 2015, the USFWS proposal would increase the instream flow requirement by approximately 176,000 to 190,000 AF each year. In other words, the USFWS proposal results in up to a tripling of the existing Article 37 fish flow requirement for the 50% drier water years when the other water demands of the Tuolumne system are already significantly stressed.

**Q. Does this conclude your testimony?**

A. Yes.

DC:615565.3

**AFFIDAVIT**

I, F. Wesley Monier, being first duly sworn, hereby declares under penalty of perjury that he is the same F. Wesley Monier whose Direct Testimony on behalf of Turlock and Modesto Irrigation Districts accompanies this affidavit; that he has read the foregoing questions and answers constituting that testimony, and that if asked such questions, his answers in response would be as shown; that the facts set forth therein are true and correct to the best of his knowledge, information and belief; and that he does adopt the same as his sworn testimony in this proceeding.

F. Wesley Monier

Subscribed and sworn to before me, the undersigned notary public, this 14 day of September 2009.

Notary Public

MY COMMISSION EXPIRES:

DAVE FALKENBERG
Commission # 1847131
Notary Public - California
Stanislaus County
My Comm. Expires May 28, 2013

DC:615380.1

# EXHBIT DIS-12

**EXHIBIT DIS-12**

**Statement of Qualifications**

Fred Wesley Monier
*Position:* Strategic Issues and Planning Department Manager
*Employer:* Turlock Irrigation District, P.O. Box 949, Turlock, CA 95381
*Phone:* 209-883-8321; FAX 209-656-2143

RESPONSIBILITIES

Mr. Monier has been employed in the planning and resource development category since January 1989. His current responsibility includes: 1) a variety of executive level administrative and analytical support in the strategic planning and direction of the District's operations as directed by the Assistant General Manager; 2) manage special projects, as directed, that cross administration lines, supervise retail and wholesale rate preparation and analysis as well as risk measurement and reporting; 3) develop long-range strategic plans for the District's water and electrical resources; 4) provide research and analysis on internal and external industry-related issues, including renewable energy and regional water policy.

Activities include:

- Supervise water and generation resource planning and development as well as operations planning and implementation for the District's multipurpose system. This system consists of water supply, power supply, flood control, recreation, and fishery and wildlife requirements.
- Develop hydrologic analysis and runoff forecasts and use them with other data to develop electrical and water supply and demand forecasts.
- Analysis of operation for modeling and operational plan development.
- Coordination of the District's river release operations for the Vernalis Adaptive Management Program.
- Supervise and participate in the preparation of annual adjustments to the wholesale and retail electric rate schedules to reflect revenue requirements.
- Provide assistance in the negotiation of wholesale contract rate changes and necessary customer contract changes.
- Supervise the data acquisition and maintenance of the customer load research program and associated database.
- Supervise the District's water database and data acquisition system.
- Supervise and direct the preparation of mark-to-market and net-forward position reports required under the District's risk management activities.
- Provide risk management analysis for long-term water supplies and hydroelectric production, including drought and conjunctive groundwater management impacts and practices.
- Interpret prevailing river flow requirements and devise release schedules to comply with regulatory requirements.
- Develop models depicting the District's water rights and potential impacts to those rights.
- Supervise and coordinate river and reservoir operation schedules with other operators within the watershed as well as with state and federal agencies as appropriate.

ACCOMPLISHMENTS:

- Developed and coded the District's current Tuolumne River System Model in MathWorks Simulink program.
- Developed and Implemented the 1995 settlement and 1996 FERC order governing minimum flow requirements in the Tuolumne River.
- Implemented the Vernalis Adaptive Management Program's release criteria.
- Developed model to study pump-hydro potential for the District.
- Developed current models of District's water rights.
- Introduced and developed processes to use District HFAM hourly model of watershed runoff.

EDUCATION:

Bachelor of Arts in Physics, California State University, Stanislaus, 1994
12 classes completed in Humphreys College Jurist Doctorate Program

# EXHIBIT DIS-13

**EXHIBIT DIS-13**

USFWS' May 2, 2008 Request for Rehearing

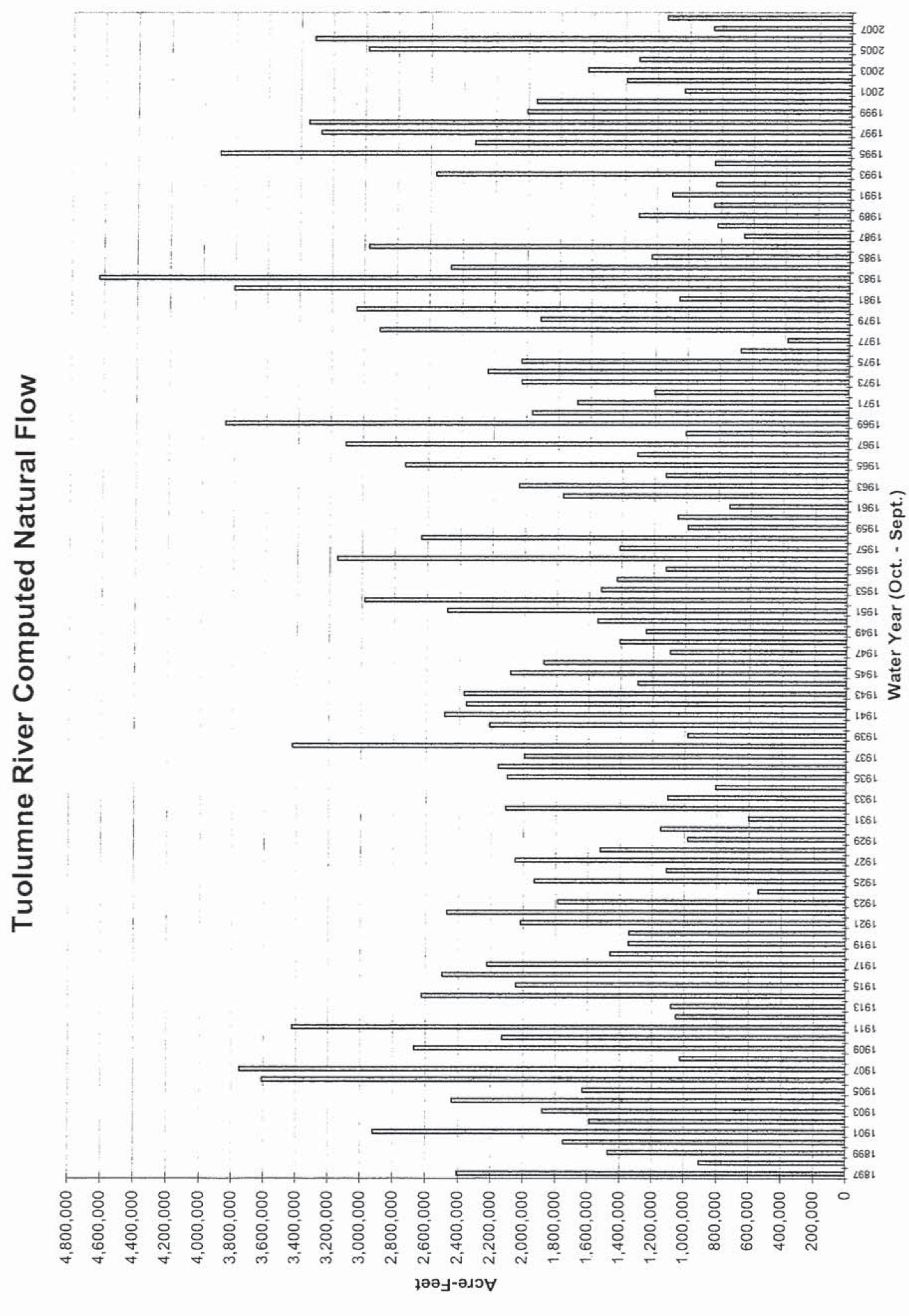
| | 10/1/2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| **I.** Input (hydrologic years represented) | | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
| Full Natural Flow^[1] | | 655,767 | 820,881 | 1,311,955 | 842,622 | 1,103,363 | 832,590 |
| Percentage of Average | | 34% | 42% | 67% | 43% | 57% | 43% |
| **II.** Don Pedro | | | | | | | |
| Don Pedro Inflow^[4] | | 326,757 | 680,089 | 1,027,768 | 892,231 | 920,385 | 873,965 |
| River^[3,9] | | 307,607 | 307,607 | 307,607 | 307,607 | 307,607 | 307,607 |
| TID Canal^[6,5] | | 648,729 | ***350,895*** | ***467,141*** | ***371,803*** | ***398,099*** | ***361,988*** |
| Percent Reduction From Average^[7] | | | 42% | 22% | 38% | 34% | 40% |
| MID Canal^[5] | | 329,066 | ***167,837*** | ***233,862*** | ***193,753*** | ***195,565*** | ***185,256*** |
| Percent Reduction From Average^[7] | | | 44% | 22% | 35% | 35% | 38% |
| Total Don Pedro Releases | | 1,285,402 | 826,339 | 1,008,610 | 873,163 | 901,272 | 854,851 |
| System Evaporation^[8] | | 19,113 | 19,113 | 19,113 | 19,113 | 19,113 | 19,113 |
| Total Don Pedro Active Storage^[2] | 1,143,122 | 165,363 | 0 | 45 | 0 | 0 | 0 |

Notes:

1 Full Natural Flow is Actual Amounts from 1987 through 1992
2 Starting Active Storage Values are estimated for 2009; does not include 309,000 AF of dead storage; values are as of each September 30
3 USFWS' May 2, 2008 Request for Rehearing
4 The Don Pedro Inflow calculation assumes that CCSF provides 51.7121% of the difference between the USFWS' May 2, 2008 Request for Rehearing and the existing Article 37 fish flow requirements. While CCSF and the Districts have agreed on the use of this assumption for purposes of modeling Don Pedro inflow in this proceeding, CCSF contends that this assumption is not dictated by the Fourth Agreement and the Districts contend that it is. Neither CCSF nor the Districts waive their respective rights to challenge whether this assumption is required by the Fourth Agreement. Further, this modeling assumption shall not be used as evidence in any proceeding relating to and shall not act as precedence for any allocation of Tuolumne River water between CCSF and the Districts for any purpose.
5 Diversion amounts are reduced from average annual diversions due to lack of water (italic bold values)
6 TID Diversions adjusted for current limitation on pumping capacity of 101,000 AF
7 Assumes 600,000 AF average for TID and 300,000 AF average for MID
8 6 Year Average
9 5% buffer added to USFWS' May 2, 2008 Request for Rehearing (292,959 AF)

# EXHIBIT DIS-14

**EXHIBIT DIS-14**




Source: TID data