DRAFT Technical Memorandum

Operation Guidelines for Implementing Restoration Flows

SAN JOAQUIN RIVER
RESTORATION PROGRAM

April 2008

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List of Abbreviations and Acronyms

cfs	cubic feet per second
CVP	Central Valley Project
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
FWUA	Friant Water Users Authority
NRDC	Natural Resources Defense Council
RA	Restoration Administrator
Reclamation	United States Department of the Interior, Bureau of Reclamation
RWA	Recovered Water Account
Settlement	San Joaquin River Settlement
SJRRP	San Joaquin River Restoration Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TM	Technical Memorandum

This Draft Technical Memorandum (TM) was prepared by the San Joaquin River Restoration Program (SJRRP) Team as a draft document in support of preparing a Program Environmental Impact Statement/Report (PEIS/R). The purpose for circulating this document at this time is to facilitate early coordination regarding initial concepts and approaches currently under consideration by the Program Team with the Settling Parties, the Third Parties, other stakeholders, and interested members of the public. As such, the content of this document may not necessarily be included in the PEIS/R.

This Draft TM does not present findings, decisions, or policy statements of any of the Implementing Agencies. Additionally, all information presented in this document is intended to be consistent with the Settlement. To the extent inconsistencies exist, the Settlement should be the controlling document and the information in this document will be revised prior to its inclusion in future documents. While the Program Team is not requesting formal comments on this document, all comments received will be considered in refining the concepts and approaches described herein to the extent possible. Responses to comments will not be provided and this document will not be finalized; however, refinements will likely be reflected in subsequent program documents.

1.0 Introduction

This Operation Guidelines for Implementing Restoration Flows Technical Memorandum (TM) was prepared in support of the San Joaquin River Restoration Program (SJRRP). This TM provides an interpretation of the Stipulation of Settlement (Settlement) that includes details on releasing Restoration Flows from Friant Dam in accordance with hydrographs attached to the Settlement as Exhibit B. It is intended that this TM be used to supplement the existing Friant Operations Guidelines, and also used to guide default operations during periods when specific recommendations have not been provided to the Secretary by the Restoration Administrator (RA), or during periods of conflict.

1.1 Background

In 1988, a coalition of environmental groups, led by the Natural Resources Defense Council (NRDC), filed a lawsuit challenging the renewal of long-term water service contracts between the United States and the Central Valley Project (CVP) Friant Division contractors. After more than 18 years of litigation of this lawsuit, known as *NRDC et al. v. Kirk Rodgers et al.*, a Settlement was reached. On September 13, 2006, the “Settling Parties” agreed on the terms and conditions of the Settlement, which was subsequently approved by the Court on October 23, 2006. The “Settling Parties” include NRDC, Friant Water Users Authority (FWUA), and the United States Departments of the Interior and Commerce.

The Settlement identified two goals, the Restoration Goal and the Water Management Goal:

- Restoration Goal – Restore and maintain fish populations in "good condition" in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.

- Water Management Goal – Reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows.

The SJRRP will implement the San Joaquin River litigation Settlement by meeting these two identified goals. The "Implementing Agencies" responsible for management of the SJRRP include the United States Department of the Interior, through the Bureau of Reclamation (Reclamation) and the Fish and Wildlife Service; United States Department of Commerce through the National Marine Fisheries Service; and the State of California through the Department of Water Resources (DWR) and the Department of Fish and Game.

1.2 Related Settlement Language

This TM covers default operation guidelines for implementing Restoration Flows. The procedures for establishing a Recovered Water Account (RWA) required in the Settlement is a related topic that must be considered at the same time and is also discussed herein. Language in the Settlement related to the default operation guidelines and RWA is given below.

1.2.1 Restoration Flow Guidelines

Paragraph 13 of the Settlement describes implementing Restoration Flows. Some subsections are especially relevant to this TM, and are included in the following:

Line 24, Page 10

> 13. In addition to the channel and structural improvements identified in Paragraph 11, releases of water from Friant Dam to the confluence of the Merced River shall be made to achieve the Restoration Goal as follows:
>
> (a) All such additional releases from Friant Dam shall be in accordance with the hydrographs attached hereto collectively as Exhibit B (the "Base Flow"), plus releases of up to an additional ten percent (10 percent) of the applicable hydrograph flows (the "Buffer Flows") may be made by the Secretary [of the Interior] based upon the recommendation of the Restoration Administrator to the Secretary, as provided in Paragraph 18 and Exhibit B. The Base Flows, the Buffer Flows and any additional water acquired by the Secretary from willing

sellers to meet the Restoration Goal are collectively referred to as the "Restoration Flow." Additional water acquired by the Secretary may be carried over or stored provided that doing so shall not increase the water delivery reductions to any Friant Division long-term contractor beyond that caused by releases made in accordance with the hydrographs (Exhibit B) and the Buffer Flows.

(b) The Restoration Flows identified in Exhibit B include releases from Friant Dam for downstream riparian interests between Friant Dam and Gravelly Ford and assume the current level of downstream diversions and seepage losses downstream of Gravelly Ford.

Line 19, Page 13

(d) Notwithstanding Paragraphs 13(a), (b), and (c), the Parties acknowledge that flood control is a primary authorized purpose of Friant Dam, that flood flows may accomplish some or all of the Restoration Flow purposes to the extent consistent with the hydrographs in Exhibit B and the guidelines developed pursuant to Paragraph 13(j), and further acknowledge that there may be times when the flows called for in the hydrographs in Exhibit B may be exceeded as a result of operation of Friant Dam for flood control purposes. Nothing in this Settlement shall be construed to limit, affect, or interfere with the Secretary's ability to carry out such flood control operations.

(e) Notwithstanding Paragraphs 13(a), (b), and (c), the Secretary may temporarily increase, reduce, or discontinue the release of water called for in the hydrographs shown in Exhibit B for the purpose of investigating, inspecting, maintaining, repairing, or replacing any of the facilities, or parts of facilities, of the Friant Division of the Central Valley Project (the "CVP"), necessary for the release of such Restoration Flows; however, except in cases of emergency, prior to taking any such action, the Secretary shall consult with the Restoration Administrator regarding the timing and implementation of any such action to avoid adverse effects on fish to the extent possible. The Secretary shall use reasonable efforts to avoid any such increase, reduction, or discontinuance of release. Upon resumption of service after any such reduction or discontinuance, the Secretary, in consultation with the Restoration Administrator, shall release, to the extent reasonably practicable, the quantity of water which would have been released in the absence of such discontinuance or reduction when doing so will not increase the water delivery reductions to any Friant Division long-term contractors beyond what would have been caused by releases made in accordance with the hydrographs (Exhibit B) and Buffer Flows.

Line 25, Page 16

(j) Prior to the commencement of the Restoration Flows as provided in this Paragraph 13, the Secretary, in consultation with the Plaintiffs and Friant Parties, shall develop guidelines, which shall include, but not be limited to: (i) procedures for determining water-year types and the timing of the Restoration Flows consistent with the hydrograph releases (Exhibit B); (ii) procedures for the measurement, monitoring and reporting of the daily releases of the Restoration Flows and the rate of flow at the locations listed in Paragraph 13(g) to assess compliance with the hydrographs (Exhibit B) and any other applicable releases (e.g., Buffer Flows); (iii) procedures for determining and accounting for reductions in water deliveries to Friant Division long-term contractors caused by the Interim Flows and Restoration Flows; (iv) developing a methodology to determine whether seepage losses and/or downstream surface or underground diversions increase beyond current levels assumed in Exhibit B; (v) procedures for making real-time changes to the actual releases from Friant Dam necessitated by unforeseen or extraordinary circumstances; and (vi) procedures for determining the extent to which flood releases meet the Restoration Flow hydrograph releases made in accordance with Exhibit B. Such guidelines shall also establish the procedures to be followed to make amendments or changes to the guidelines.

Line 5, Page 23

18. The selection and duties of the Restoration Administrator and the Technical Advisory Committee are set forth in this Settlement and Exhibit D. Consistent with Exhibit B, the Restoration Administrator shall make recommendations to the Secretary concerning the manner in which the hydrographs shall be implemented and when the Buffer Flows are needed to help in meeting the Restoration Goal. In making such recommendations, the Restoration Administrator shall consult with the Technical Advisory Committee, provided that members of the Technical Advisory Committee are timely available for such consultation. The Secretary shall consider and implement these recommendations to the extent consistent with applicable law, operational criteria (including flood control, safety of dams, and operations and maintenance), and the terms of this Settlement. Except as specifically provided in Exhibit B, the Restoration Administrator shall not recommend changes in specific release schedules within an applicable hydrograph that change the total amount of water otherwise required to be released pursuant to the applicable hydrograph (Exhibit B) or which increase the water delivery reductions to any Friant Division long-term contractors.

Exhibit B presents hydrographs that constitute the Base Flows referenced in Paragraph 13 of the Settlement. In addition, the exhibit contains specifics of the following subjects:

- Buffer Flows[1]
- Restoration year types for applying the six hydrographs
- Intent to transform the annual allocation methodology from Exhibit B's stair-step hydrograph approach to more continuous approach
- Flexibility in timing of releases in selected periods
- Flushing flows (a block of water averaging 4,000 (cubic feet per second (cfs)) from April 16 through 30 in normal-wet and wet years
- Riparian recruitment flows (a block of water averaging 2,000 cfs) from May 1 through June 30 in wet years[2]

1.2.2 Recovered Water Account

Page 20, Line 9

> 16. In order to achieve the Water Management Goal, immediately upon the Effective Date of this Settlement, the Secretary, in consultation with the Plaintiffs and Friant Parties, shall commence activities pursuant to applicable law and provisions of this Settlement to develop and implement the following:
>
> (b) A Recovered Water Account (the "Account") and program to make water available to all of the Friant Division long-term contractors who provide water to meet Interim Flows or Restoration Flows for the purpose of reducing or avoiding the impact of the Interim Flows and Restoration Flows on such contractors. In implementing this Account, the Secretary shall:
>
> (1) Monitor and record reductions in water deliveries to Friant Division long-term contractors occurring as a direct result of the Interim Flows and Restoration Flows that have not been replaced by recirculation, recapture, reuse, exchange or transfer of Interim Flows and Restoration Flows or replaced or offset by other water programs or projects undertaken or funded by the Secretary or other Federal Agency or agency of the State of California specifically to mitigate the water delivery impacts caused by the Interim Flows and Restoration Flows ("Reduction in Water Deliveries"). For purposes of this Account, water voluntarily sold to the Secretary either to mitigate Unexpected Seepage Looses or to augment Base Flows by any Friant Division long-term contractor shall not be considered a Reduction in Water Delivery caused by this Settlement. The Account shall establish

[1] In Exhibit B, the term "Restoration Flows" was defined as Base Flows plus Buffer Flows.
[2] See Exhibit B, Table 1F, Proposed Restoration Flow Release Schedule and Accounting for Wet Year Type on the San Joaquin River, Footnote 9.

a baseline condition as of the Effective Date of this Settlement with respect to water deliveries for the purpose of determining such reductions. The balance of any Friant Division long-term contractor in the Account shall be annually adjusted in accordance with the provisions of this Paragraph 16(b)(1) and of Paragraph 16(b)(2). Each Friant Division long-term contractor's account shall accrue one acre foot of water for each acre foot of Reduction in Water Deliveries. In those years when, pursuant to Paragraphs 13(a) and 19, the Secretary, in consultation with the Restoration Administrator, determines to increase releases to include some or all of the Buffer Flows, Friant Division long-term contractors shall accrue into their account one and one quarter acre foot for each acre foot of Reduction in Water Deliveries;

(2) Make water available as herein provided to all of the Friant Division long-term contractors who experience a Reduction in Water Deliveries as a direct result of the release of Interim Flows and Restoration Flows as reflected in their Account maintained pursuant to Paragraph 16(b)(1). Water shall be made available only in wet hydrologic conditions when water is not needed for the Interim Flows and Restoration Flows as provided for in this Settlement, to meet obligations of the Secretary existing on the Effective Date of this Settlement, as determined by the Secretary;

(3) Make water available to the Friant Division long-term contractors pursuant to Paragraph 17(b)(2) at the total cost of $10.00 per acre foot, which amounts shall be deposited into the Restoration Fund to be established by the legislation authorizing implementation of the Settlement;

(4) Ensure that recovery of the cost of any new CVP facilities for storage or conveyance of CVP water is not determined according to the provisions of this Paragraph 16; and

(5) Implement the Account and program developed pursuant to this Paragraph in accordance with all applicable laws, regulations and standards.

1.3 Purpose and Scope of this Technical Memorandum

As previously mentioned, this TM covers the default operation guidelines for implementing Restoration Flows under the Settlement. The RWA, an account to record associated water supply impacts from implementing the Restoration Flows, is a related subject and thus is discussed herein. This TM focuses on the following topics associated with Restoration Flows:

- Restoration year type classification and application [Paragraph 13(j)(i)]
- Interannual interpretation of hydrographs [Paragraphs13(a), 13(b) and Exhibit B]
- Default Friant Dam operation with obligation of releasing Restoration Flows [Paragraphs 13(j)(iii), 13(j)(v), and 13(j)(vi)]
- Procedures for making real-time changes to actual releases from Friant Dam necessitated by hydrologic uncertainties and other real-time operation considerations [Paragraphs 13(j)(v) and 18]
- Procedures for determining the extent to which flood releases meet Restoration Flow hydrograph releases made in accordance with Exhibit B [Paragraphs 13(d) and 13(j)(vi)]
- Procedures for RWA accounting [Paragraph 16(b)]

The guidelines described in this TM may ultimately be incorporated into a definitive policy document separate from or amended to the Operational Guidelines for Water Service – Friant Division Central Valley Project, which is currently used for Friant Division operation (Reclamation, 2005).

1.4 Related Topics Covered by Future Refinements and/or Other Technical Memoranda

The following topics included in Paragraph 13 and Exhibit B of the Settlement will not be addressed in this TM, but in future refinement or other TMs:

- Procedures and protocols for implementing Buffer flows and hydrograph flexibility that may be recommended by the RA and/or other advisory parties are considered part of real-time operations [Exhibit B]
- Intermonthly hydrograph smoothing based on flushing flows for fishery and riparian vegetation, or riparian recruitment flows [Exhibit B]
- Measurement procedures and monitoring requirements [Paragraph 13(j)(ii)]
- Development of methodology and procedures for seepage evaluation [Paragraph 13(j)(iv)]
- Framework for developing a plan to achieve the Water Management Goal and details of plan components [Paragraph 16]

Some of the topics above would also be incorporated in the above-mentioned policy document separate from or amended to the Operational Guidelines for Water Service – Friant Division Central Valley Project (Reclamation, 2005).

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2.0 Restoration Flow Year Types

This section provides the derivation of the Restoration year type classification and its application in real-life operations with use of forecast hydrological information.

2.1 Settlement Specification and Required Refinements

Exhibit B of the Settlement identifies a set of six hydrographs (see Figure 2-1) that vary in shape and volume according to the annual unimpaired runoff of the San Joaquin River at Friant Dam for a water year (October 1 through September 30). The six year types (referred to as Restoration Flow year types in this TM) are “critical-low,” “critical-high,” “dry,” “normal-dry,” “normal-wet,” and “wet.”

Based on the historical record of unimpaired flow for water years 1922 through 2004, Exhibit B includes a Restoration year type classification system based on percentage of occurrence in this 83-year period. The wettest 20 percent of these years are classified as “wet.” In order of descending wetness, the next 30 percent of the years are classified as “normal-wet,” the next 30 percent of the years are classified as “normal-dry,” and the next 15 percent of the years are classified as “dry.” The remaining 5 percent of the years are classified as “critical.” A subset of the critical years, with less than 400,000 acre-feet of unimpaired runoff (i.e., water years 1924 and 1977), are classified as “critical-low”; the remaining critical years are classified as “critical-high.”

The Settlement defines year types based on their occurrence in an 83-year period, from 1922 through 2004, without using a conventional threshold approach. While the associated year type for each year within the 83-year period is clear, the extrapolation of such a Restoration year type definition for years outside this period is not. The refinements of Restoration year type classification for the SJRRP are discussion below in three parts:

- Classification thresholds
- Beginning date for year type application and corresponding Restoration Flows schedule
- Incorporation of hydrologic forecast uncertainties

The first two items are discussed in this section, and hydrologic forecast uncertainties are discussed in detail in Section 4.

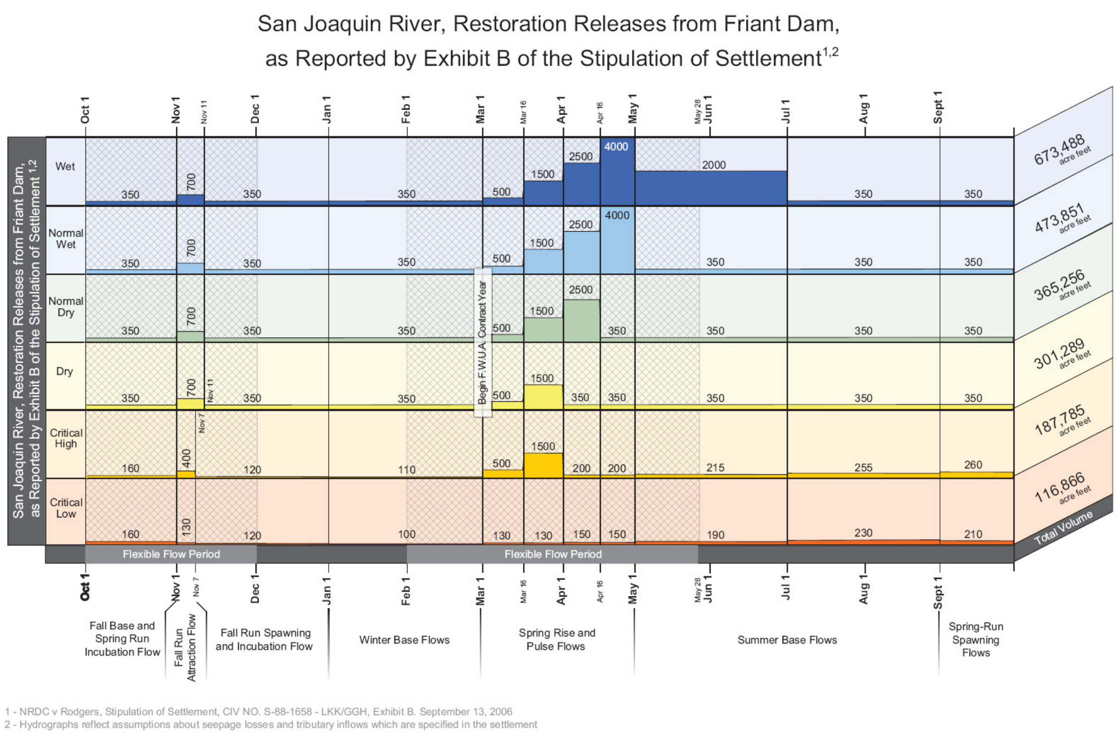


Figure 2-1.
Restoration Flow Hydrographs, by Restoration Year Type: Presentation Depicts the Stair-Step Hydrograph Allocation Method, as in Exhibit B

2.2 Classification Thresholds

The Settlement defines Restoration year types using annual unimpaired inflow below Friant Dam, for water years 1922 through 2004. Table 2-1 compares the Restoration year type classification with the San Joaquin Valley Water Year Types,[3] which is referenced in other management activities throughout the San Joaquin River basin. Table 2-2 shows the Restoration year type classification of the referenced period, sorted by annual unimpaired inflow below Friant Dam.

As previously mentioned, the Restoration year type classification was not based on a set of statistical thresholds, but instead by using the percentage of occurrences for annual inflows over the 83-year period of record; this is equivalent to the *n*-plotting position method without any hypothesis for the underlying statistical distribution. For Restoration year type classification purposes, the question is: at what point within the difference between these two volumes does the Restoration year type classification change?

[3] State Water Resources Control Board (SWRCB), Water Right Decision 1641.

Table 2-1.
Restoration Year Type Classification
Compared with San Joaquin Valley Water Year Types

Water Year	October-through-September San Joaquin River Unimpaired Flow at Friant Dam (TAF)	Restoration Year Type*	San Joaquin Valley Water Year Types*
1922	2,355.1	Normal-Wet	Wet
1923	1,654.3	Normal-Wet	Above Normal
1924	444.1	Critical High	Critical
1925	1,438.7	Normal-Dry	Below Normal
1926	1,161.4	Normal-Dry	Dry
1927	2,001.3	Normal-Wet	Above Normal
1928	1,153.7	Normal-Dry	Below Normal
1929	862.4	Dry	Critical
1930	859.1	Dry	Critical
1931	480.2	Critical High	Critical
1932	2,047.4	Normal-Wet	Above Normal
1933	1,111.4	Normal-Dry	Dry
1934	691.5	Dry	Critical
1935	1,923.2	Normal-Wet	Above Normal
1936	1,853.3	Normal-Wet	Above Normal
1937	2,208.0	Normal-Wet	Wet
1938	3,688.4	Wet	Wet
1939	920.8	Dry	Dry
1940	1,880.6	Normal-Wet	Above Normal
1941	2,652.5	Wet	Wet
1942	2,254.0	Normal-Wet	Wet
1943	2,053.7	Normal-Wet	Wet
1944	1,265.4	Normal-Dry	Below Normal
1945	2,138.1	Normal-Wet	Above Normal
1946	1,729.6	Normal-Wet	Above Normal
1947	1,125.5	Normal-Dry	Dry
1948	1,214.8	Normal-Dry	Below Normal
1949	1,164.1	Normal-Dry	Below Normal
1950	1,310.5	Normal-Dry	Below Normal
1951	1,859.0	Normal-Wet	Above Normal
1952	2,840.1	Wet	Wet
1953	1,226.7	Normal-Dry	Below Normal
1954	1,313.8	Normal-Dry	Below Normal
1955	1,161.0	Normal-Dry	Dry
1956	2,960.1	Wet	Wet
1957	1,326.6	Normal-Dry	Below Normal
1958	2,631.0	Wet	Wet
1959	949.3	Normal-Dry	Dry
1960	828.6	Dry	Critical
1961	646.9	Critical High	Critical
1962	1,923.6	Normal-Wet	Below Normal
1963	1,944.9	Normal-Wet	Above Normal
1964	922.2	Dry	Dry
1965	2,272.2	Normal-Wet	Wet
1966	1,298.6	Normal-Dry	Below Normal
1967	3,232.2	Wet	Wet
1968	862.1	Dry	Dry
1969	4,040.3	Wet	Wet
1970	1,445.6	Normal-Dry	Above Normal
1971	1,417.5	Normal-Dry	Below Normal
1972	1,039.0	Normal-Dry	Dry
1973	2,047.0	Normal-Wet	Above Normal
1974	2,190.5	Normal-Wet	Wet
1975	1,795.7	Normal-Wet	Wet
1976	629.2	Critical High	Critical
1977	361.6	Critical Low	Critical
1978	3,401.9	Wet	Wet
1979	1,830.3	Normal-Wet	Above Normal
1980	2,972.7	Wet	Wet
1981	1,068.0	Normal-Dry	Dry
1982	3,316.1	Wet	Wet
1983	4,641.9	Wet	Wet
1984	2,048.9	Normal-Wet	Above Normal
1985	1,129.0	Normal-Dry	Dry
1986	3,031.4	Wet	Wet
1987	757.6	Dry	Critical
1988	862.1	Dry	Critical
1989	939.2	Normal-Dry	Critical
1990	742.5	Dry	Critical
1991	1,034.1	Normal-Dry	Critical
1992	808.5	Dry	Critical
1993	2,672.9	Wet	Wet
1994	826.4	Dry	Critical
1995	3,877.7	Wet	Wet
1996	2,202.8	Normal-Wet	Wet
1997	2,781.5	Wet	Wet
1998	3,159.8	Wet	Wet
1999	1,527.1	Normal-Wet	Above Normal
2000	1,741.9	Normal-Wet	Above Normal
2001	1,065.1	Normal-Dry	Dry
2002	1,170.9	Normal-Dry	Dry
2003	1,449.9	Normal-Wet	Below Normal
2004	1,130.7	Normal-Dry	Dry

*Based on D-1641

Key: TAF = thousand acre-feet

San Joaquin River Settlement Restoration Year Type	San Joaquin Valley Water Year Types: Wet	Above Normal	Below Normal	Dry	Critical
Wet	16				
Normal-Wet	8	15	2		
Normal-Dry		1	11	11	2
Dry				3	9
Critical High					4
Critical Low					1

San Joaquin River Restoration Year Types:

The total annual unimpaired runoff at Friant Dam for the water year (October through September) is the index by which the water year type is determined.

In order of descending wetness, the wettest 20 percent of the years are classified as Wet, the next 30 percent of the year are classified as Normal-Wet, the next 30 percent of the year are classified as Normal-Dry, the next 15 percent of the years are classified as Dry, and the remaining 5 percent of the year are classified as Critical. A subset of the Critial years, those with less than 400 TAF of unimparied runoff, are identified as Critical Low.

San Joaquin Valley Water Year Types:

The San Joaquin Valley Water Year Type is determined through the use of an index. The index is based upon Stanislaus River inflows to New Melones Lake, Tuolumne River inflows to New Don Pedro Reservoir, Merced River inflows to Lake McClure, and San Joaquin River inflows to Millerton Lake, in million acre-feet (MAF).

San Joaquin Valley Water Year Index
= 0.6 * Current Apr-Jul Runoff Forecast (MAF)
+ 0.2 * Current Oct-Mar Runoff in (MAF)
+ 0.2 * Previous Water Year's Index (if the Previous Water Year's Index exceeds 4.5, then 4.5 is used).

Wet Equal to or greater than 3.8 MAF;
Above-Normal Greater than 3.1, and less than 3.8;
Below-Normal Greater than 2.5, and equal to or less than 3.1;
Dry Greater than 2.1, and equal to or less than 2.5; and
Critical Equal to or less than 2.1

This index, originally specified in the 1995 SWRCB Water Quality Control Plan, is used to determine the San Joaquin Valley water year type as implemented in SWRCB D-1641. Water year types are set by first of month forecasts beginning in February. Final determination for San Joaquin River flow objectives is based on the May 1st 75% exceedence forecast.

Table 2-2. Restoration Year Type Classification, Sorted by Annual Unimpaired Inflow Below Friant Dam

Water Year	October-through-September San Joaquin River Unimpaired Flow at Friant Dam (TAF)	Restoration Year Type
1,983.0	4,641.9	Wet
1969	4,040.3	Wet
1995	3,877.7	Wet
1938	3,688.4	Wet
1978	3,401.9	Wet
1982	3,316.1	Wet
1967	3,232.2	Wet
1998	3,159.8	Wet
1986	3,031.4	Wet
1980	2,972.7	Wet
1956	2,960.1	Wet
1952	2,840.1	Wet
1997	2,781.5	Wet
1993	2,672.9	Wet
1941	2,652.5	Wet
1958	2,631.0	Wet
1922	2,355.1	Normal-Wet
1965	2,272.2	Normal-Wet
1942	2,254.0	Normal-Wet
1937	2,208.0	Normal-Wet
1996	2,202.8	Normal-Wet
1974	2,190.5	Normal-Wet
1945	2,138.1	Normal-Wet
1943	2,053.7	Normal-Wet
1984	2,048.9	Normal-Wet
1932	2,047.4	Normal-Wet
1973	2,047.0	Normal-Wet
1927	2,001.3	Normal-Wet
1963	1,944.9	Normal-Wet
1962	1,923.6	Normal-Wet
1935	1,923.2	Normal-Wet
1940	1,880.6	Normal-Wet
1951	1,859.0	Normal-Wet
1936	1,853.3	Normal-Wet
1979	1,830.3	Normal-Wet
1975	1,795.7	Normal-Wet
2000	1,741.9	Normal-Wet
1946	1,729.6	Normal-Wet
1923	1,654.3	Normal-Wet
1999	1,527.1	Normal-Wet
2003	1,449.9	Normal-Wet
1970	1,445.6	Normal-Dry
1925	1,438.7	Normal-Dry
1971	1,417.5	Normal-Dry
1957	1,326.6	Normal-Dry
1954	1,313.8	Normal-Dry
1950	1,310.5	Normal-Dry
1966	1,298.6	Normal-Dry
1944	1,265.4	Normal-Dry
1953	1,226.7	Normal-Dry
1948	1,214.8	Normal-Dry
2002	1,170.9	Normal-Dry
1949	1,164.1	Normal-Dry
1926	1,161.4	Normal-Dry
1955	1,161.0	Normal-Dry
1928	1,153.7	Normal-Dry
2004	1,130.7	Normal-Dry
1985	1,129.0	Normal-Dry
1947	1,125.5	Normal-Dry
1933	1,111.4	Normal-Dry
1981	1,068.0	Normal-Dry
2001	1,065.1	Normal-Dry
1972	1,039.0	Normal-Dry
1991	1,034.1	Normal-Dry
1959	949.3	Normal-Dry
1989	939.2	Normal-Dry
1964	922.2	Dry
1939	920.8	Dry
1929	862.4	Dry
1988	862.1	Dry
1968	862.1	Dry
1930	859.1	Dry
1960	828.6	Dry
1994	826.4	Dry
1992	808.5	Dry
1987	757.6	Dry
1990	742.5	Dry
1934	691.5	Dry
1961	646.9	Critical High
1976	629.2	Critical High
1931	480.2	Critical High
1924	444.1	Critical High
1977	361.6	Critical Low

Key: TAF = thousand acre-feet

For example, the Restoration year type classification changes from a normal-wet year type to a wet year type between the historical runoff volumes associated with 1922 (2,355,000 acre-feet and 1958 (2,631,000 acre-feet). Because hydrological conditions in the years after 2004 are not likely to repeat those in the 1922 through 2004 period, it is necessary to define a set of thresholds for Restoration year type classification that is consistent with the Restoration year type classification.

To be consistent with Exhibit B, a threshold was defined using a practical point near the average of the unimpaired runoff amounts of 2 years that bracket the transition. Therefore, the following classification of Restoration year types is recommended (based on annual October-through-September unimpaired flow below Friant Dam):

- Wet equal to or greater than 2,500,000 acre-feet
- Normal-wet equal to or greater than 1,450,000 acre-feet
- Normal-dry equal to or greater than 930,000 acre-feet
- Dry equal to or greater than 670,000 acre-feet
- Critical-high equal to or greater than 400,000 acre-feet
- Critical-low less than 400,000 acre-feet

Based on the Settlement, the designation of year type is for the period of October through September that is consistent with the water year definition. For water years 2005, 2006, and 2007, the annual unimpaired flows of the San Joaquin River below Friant Dam are 2,830, 3,181, and 684 thousand acre-feet (TAF), respectively (DWR, 2007). Therefore, based on this set of thresholds for Restoration year type classification, water years 2005, 2006, and 2007 would be classified as wet, wet, and dry years, respectively.

2.3 Beginning Date for Hydrograph Application

While the above Restoration year type classification is applicable for a water year from October through September, October 1 may not be a good beginning date for applying a corresponding hydrograph because of the following hydrologic and biological considerations, and existing contract allocation practices.

2.3.1 Availability and Quality of Hydrologic Forecasts

Forecasts of annual unimpaired flow below Friant Dam, while imperfect, will be a necessary tool for Restoration year type designations. Making the current year's Restoration flow hydrograph representative of the current year's runoff requires a forecast of a portion of the entire year's runoff. These forecasts combine estimates of snow accumulation, antecedent precipitation, and a statistical range of precipitation predictions. More than one forecast of runoff is made for the San Joaquin River basin, including forecasts from Southern California Edison Company, Reclamation, and DWR.

For establishing Restoration year types, it is recommended that the California Cooperative Snow Survey forecast, prepared by DWR (provided periodically in Bulletin

120 – Water Conditions in California) be used to forecast unimpaired flow of the San Joaquin River below Friant. Reclamation currently operates Friant Dam using Bulletin 120 forecast information. In addition, Reclamation and DWR rely on the Bulletin 120 forecasts to make water allocations for the CVP and State Water Project (SWP). Therefore, using Bulletin 120 forecast information for the SJRRP would be consistent with statewide water management practices.

DWR publishes Bulletin 120 four times a year, generally during the second week of February, March, April, and May. Bulletin 120 contains forecasts of the volume of seasonal runoff from the State's major watersheds (including unimpaired flow of the San Joaquin River below Friant Dam), including values for different forecast confidence intervals. The earliest available forecast information is in February.

Additional information contained in Bulletin 120 includes summaries of precipitation, snowpack, reservoir storage, and runoff in various regions of the State (see http://cdec.water.ca.gov/snow/bulletin120/). Supplementing the published report are periodic updates to the forecasts during the primary runoff season.

As with all forecasts, the accuracy of projections increases as the year progresses, with more and more of the predictive element of the forecast being eliminated with the passage of time. As a result, allocations to Restoration flow hydrograph will need to consider the potential inaccuracy of runoff forecasts to prevent overcommitting water supplies before their availability, or undercommitting water and thus frustrating either goal in the Settlement. Section 4 contains more discussion on balancing forecast uncertainties and practical operation of Friant Dam.

2.3.2 Consideration of Chinook

SJRRP is considering both spring-run and fall-run Chinook salmon in the current planning process; other fishery species may also be considered. However, the discussion on Chinook herein as a surrogate for biological considerations used to determine the beginning date for Restoration flow hydrograph application.

Spring-Run Life Cycle Timing

In the Sacramento River watershed (the closest population of spring-run Chinook salmon to the San Joaquin River), adult spring-run Chinook salmon historically returned to fresh water between late March and early July (DFG 1998). After they arrive in their natal streams in the spring, they hold in deep pools through the summer, conserving energy until the fall when their gonads ripen and they spawn, between August and October (DFG 1998, McReynolds et al. 2005). In the Sacramento River, the egg incubation period for spring-run Chinook salmon extends from August to March (Fisher 1994, Ward and McReynolds 2001).

After hatching, fry may move downstream to the estuary and rear, or may take up residence in the stream for a period of time from weeks to a year (Healey 1991). The Butte Creek fry primarily disperse downstream from mid-December through February whereas the subyearling smolts primarily migrate between late-March and mid-June.

Spring-run yearlings in Butte Creek migrate from September through March (Hill and Webber 1999, Ward and McReynolds 2001, Ward et al. 2002).

Fall-Run Life Cycle Timing

Adult fall-run Chinook salmon in the San Joaquin River basin typically migrate into the upper rivers between late September and mid-November (S.P. Cramer and Associates 2004, 2005; Cramer Fish Sciences 2006, 2007). Spawning in the San Joaquin River takes place between October and December (DFG 2001-2005), and the incubation period extends from late October through February. Fall-run juveniles will rear and migrate between January and June (Fishbio Environmental, LLC. Unpublished Data)

In noncritical years, Restoration flow hydrographs (see Figure 2-1) schedule the same flow rates between the months of August and February, with only minor differences in fall-run attraction flows in the first week of November. The scale of flow change during August through February across the various Restoration year types is significantly less than that of the period from March through July. In other words, Restoration year type classification is a more meaningful consideration for Restoration flow hydrograph implementation after February.

The period exhibiting the most significant differences, among the Restoration flow hydrographs is during the months of March and April. Restoration years classified as Wet are additionally unique in scheduling additional flow for the months of May and June. However, the Settlement allows for flexibility in the release of Restoration flow hydrographs within some periods. Specifically,[4]

> … releases allocated during the period from March 1 through May 1 ("Spring Period") in any year may be shifted up to four weeks earlier and later than what is depicted in the hydrograph for that year, and managed flexibly within that range (i.e. February 1 through May 28), so long as the total volume … allocated for the Spring Period is not changed.

Accommodating this intended flexibility suggests that the Restoration year type classification could recognize year-specific differences in Restoration flow hydrograph shaping as early as February if necessary.

2.3.3 Existing Contract Allocation Practice

Friant Division long-term contractors are currently given initial allocations in mid-February of each year, after the first forecast of unimpaired inflow to Millerton Lake becomes available (i.e., in February).

This declaration of allocation to long-term contractors and temporary contractors is periodically revised as changing water supply conditions evolve; typically, the revision continues through June. As confidence in the forecast hydrology increases over time, the revision is generally for increased allocation as opposed to retracting a previously

[4] Refer to the Settlement, Exhibit B, Paragraph 4(b)

declared water allocation. More details on hydrologic forecast uncertainties are contained in Section 4.

2.3.4 March 1 as Beginning Date for Restoration Flow Hydrographs

March 1 is recommended as the beginning date for Restoration year type classification and, more importantly, the beginning date for the resulting Restoration flow hydrograph application. This recommendation was based on the above discussion, summarized herein.

- From a practical viewpoint, the first determination of Restoration year type and flow hydrographs could be in mid-February, when Bulletin 120 forecast information becomes available. Before the February forecast, there is insufficient information for a determination.

- Based on the review of historical forecast, February forecast is subject to a much greater margin of error, resulting in a greater risk of misclassification of year type. From fisheries management viewpoint, it is common to maintain established flow in the river to March for avoiding risk of dewatering redds. Reviewing the Restoration flow hydrographs in Figure 2-1, March Restoration flow of all year types (except for critical-low years) are higher than 350 cfs, the maximum of February Restoration flows for all year types. Therefore, the risk of dewatering the redds due to misclassification of year type using early forecast information can be avoided completely by delaying the beginning point of the new year until March.

- While the flexibility of shifting Restoration flow hydrograph to start as early as February 1 is provided in the Settlement, due to the risk of redd dewatering, such flexibility would be better provided through real-time adjustments based on monitoring information.

It is anticipated that the Restoration year type classification would be revised, if necessary, as subsequent Bulletin 120 forecasts become available in April and May. There are years that an additional forecast in June is available (although not necessarily published officially in Bulletin 120 format); in these years, additional revisions of Restoration year type classification may be made. It would not be meaningful to modify the designation after June because the associated flow hydrographs return to a more uniform schedule for all year types.

The Restoration flow hydrograph for months before the March 1 date would follow the Restoration year type designation of the prior year. This practice is commonly applied to river management in California watersheds.

Additional considerations and recommendations for Restoration flow hydrograph implementation with consideration of forecast uncertainties are discussed in Section 4.

3.0 Developing Continuous Hydrographs

This section presents the process recommended for developing continuous hydrographs per the requirements in the Settlement.

3.1 Need for Continuous Hydrographs

Exhibit B of the Settlement identifies a set of six Restoration flow hydrographs, which present a schedule for flow rates throughout the year. These flow hydrographs vary in shape and annual cumulative volume according to wetness in the San Joaquin River basin. The method producing a single flow hydrograph for each Restoration year type is referred to as the "stair-step hydrographs" within the Settlement. The Settlement indicates that transforming the stair-step hydrograph method into a continuously increasing hydrograph method is desired:

> The Parties agree to transform the stair step hydrographs to more continuous hydrographs prior to December 31, 2008 to ensure completion before the initiation of Restoration Flows, provided that the Parties shall mutually-agree that transforming the hydrographs will not materially impact the Restoration or Water Management Goal.

The stair-step hydrograph method, as summarized in Table 3-1, is relatively easy to apply, and the ranges of wetness indices associated with a year type provide some level of buffer against hydrologic uncertainties. However, challenges could regularly arise when a year's projected wetness is borderline between two Restoration year type classifications, especially when hydrologic forecast uncertainties are considered. The resulting differences in annual allocations between the two borderline year type classifications could be subject to disagreement; the disagreement could become even greater as availability and quality of hydrologic forecasts are also considered.

Table 3-1.
Stair-Step Restoration Flow Hydrographs as in Settlement Exhibit B (TAF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Wet	21.5	27.8	21.5	21.5	19.4	62.5	193.4	123.0	119.0	21.5	21.5	20.8	673.5
Normal-Wet	21.5	27.8	21.5	21.5	19.4	62.5	193.4	21.5	20.8	21.5	21.5	20.8	473.9
Normal-Dry	21.5	27.8	21.5	21.5	19.4	62.5	84.8	21.5	20.8	21.5	21.5	20.8	365.3
Dry	21.5	27.8	21.5	21.5	19.4	62.5	20.8	21.5	20.8	21.5	21.5	20.8	301.3
Critical-High	9.8	9.9	7.4	6.8	6.1	62.5	11.9	13.2	12.8	15.7	15.7	15.5	187.2
Critical-Low	9.8	7.2	7.4	6.1	5.6	8.0	8.9	11.7	11.3	14.1	14.1	12.5	116.8

Key: TAF = thousand acre-feet

Figure 3-1 shows the classification system developed in Section 2, the associated annual flow volume, as defined in Exhibit B stair-step hydrographs, and corresponding historical records for the 1922 through 2004 period. The potential for disagreement on Restoration year type classification and associated hydrograph volume is evident in borderline years using forecast hydrology. For example, for a year with approximately 1,400,000 acre-feet of unimpaired runoff, an additional 1 acre-foot of runoff would lead to the year type being changed in the classification from normal-dry to normal-wet, and require more than 100,000 acre-feet of additional release for Restoration Flows. This could create unexpected challenges in real-time water management and fishery management.

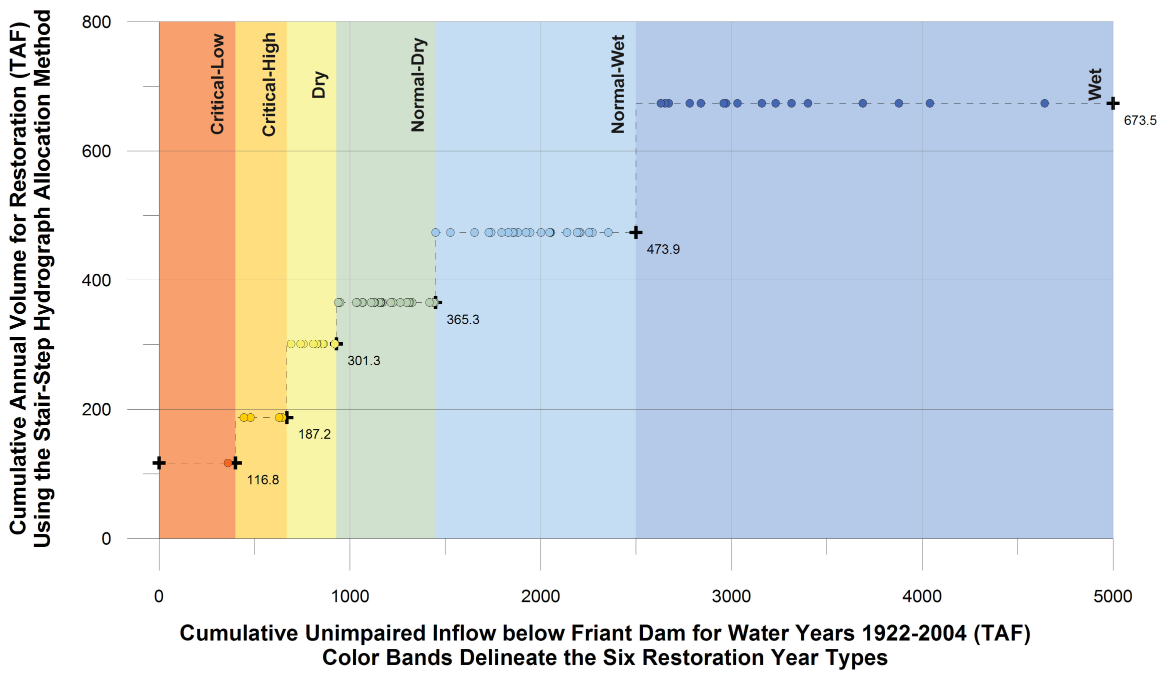


Figure 3-1.
Annual Restoration Flow Volume (TAF) for the 1922-2004 Period of Record Resulting from the Settlement's Stair-Step Hydrographs

Developing a continuous function to determine annual Restoration hydrograph allocations reduces such potential challenges. The continuous function responds to the need for a systematic methodology to distribute the resulting Restoration hydrograph allocation into a Restoration flow hydrograph.

3.2 Determining Continuous Restoration Flow Hydrographs

As described in Exhibit B, the six Restoration flow hydrographs were developed for fishery management purposes and, in wet years only, additional specific considerations for vegetation recruitment purposes. The annual cumulative volumes were estimated to have a certain impact on CVP Friant Division long-term contractors' water supply. Therefore, the transformation from stair-step hydrographs to a continuous hydrograph method needs to be consistent with these premises in the Settlement.

3.2.1 Annual Restoration Flow Volume

The major concern over stair-step approach is the potential for abrupt changes in allocated Restoration flow hydrograph volumes with small changes in unimpaired flow conditions.

A straightforward approach is recommended to form a continuous function where the six stair-step hydrographs from Exhibit B occur at the midpoint of the Restoration year type's range of indexed inflows.

- The approach is simple and easy to implement.
- The approach could automatically preserve the long-term average (by Restoration year type) for both the Restoration Flow volume, and the associated water supply impacts. Maintaining these averages provides consistency with the Settlement.

The following are details for developing a piece-wise linear function for annual Restoration flow hydrograph volume:

1. The Restoration Flow volume for critical-low years is the existing release from Friant Dam for downstream riparian water right diversions; and can be used as the starting point for developing the piece-wise linear function for annual volume.
2. The critical-low year type was classified to be any year when unimpaired San Joaquin River flow below Friant Dam is less than 400,000 acre-feet (see Section 2). A critical-high year was classified to be any year when unimpaired San Joaquin River flow below Friant Dam is between 400,000 acre-feet and 670,000 acre-feet, with a midpoint unimpaired inflow of 535,000 acre-feet. Considering that the midpoint unimpaired inflow of 535,000 acre-feet is the representative condition for critical-high years, it is assumed that the corresponding volume of Restoration Flows would be the volume of 187,000 acre-feet, as prescribed by the stair-step hydrograph for the critical-high years.

3. A line can be drawn through the following two points:

   - The point corresponding to the critical-high midpoint unimpaired inflow (535,000 acre-feet) and Restoration Flow volume of 187,000 acre-feet

   - The boundary condition for critical-low years with unimpaired flow of 400,000 acre-feet and Restoration Flow requirements of 117,000 acre-feet

The linear function for determining Restoration Flow volume by unimpaired San Joaquin River flow below Friant Dam can be completed by extending the line to the maximum of unimpaired inflow volume for critical-high years (670,000 acre-feet). The resulting Restoration Flow requirement is 257,000 acre-feet.

1. This mathematical procedure continues for the dry, normal-dry, and normal-wet year type ranges.

2. For wet years, no median reference point exists for the above linear process. Therefore, it is recommended that the original stair-step hydrograph volume of 673,000 acre-feet be used whenever unimpaired inflow is estimated to equal or exceed 2,500 TAF. This would result in an abrupt change in hydrograph volume, at a much reduced scale, when the annual unimpaired flow forecast suggests a change from a normal-wet to a wet Restoration year type. However, the associated concerns over the abrupt change in Restoration Flow volume for water supply and fishery management are less in years of high runoff.

Figure 3-2 illustrates the piece-wise linear function of the recommended approach. Figure 3-3 shows the application of this concept to the period from 1922 through 2004, which was referenced in the Settlement for Restoration year type definition. The piece-wise linear function for annual Restoration Flow volume runs through the midpoint of each Restoration year type's range of indexed flows, with the continuous flow requirement being less than the explicit Restoration Flow volume for the lower half of the range, and higher than the explicit Restoration Flow volume for the higher half of the range.

Using the midpoint-driven volumes as connecting points between Restoration year types closely approximates the average Restoration Flow volume and potential water supply impacts within each classification, thereby maintaining consistency with the Settlement. The transformation should alleviate the concerns over abrupt changes in the volume requirement for Restoration Flows, and enhance the correspondence between volumes of Restoration Flows and annual unimpaired flow.

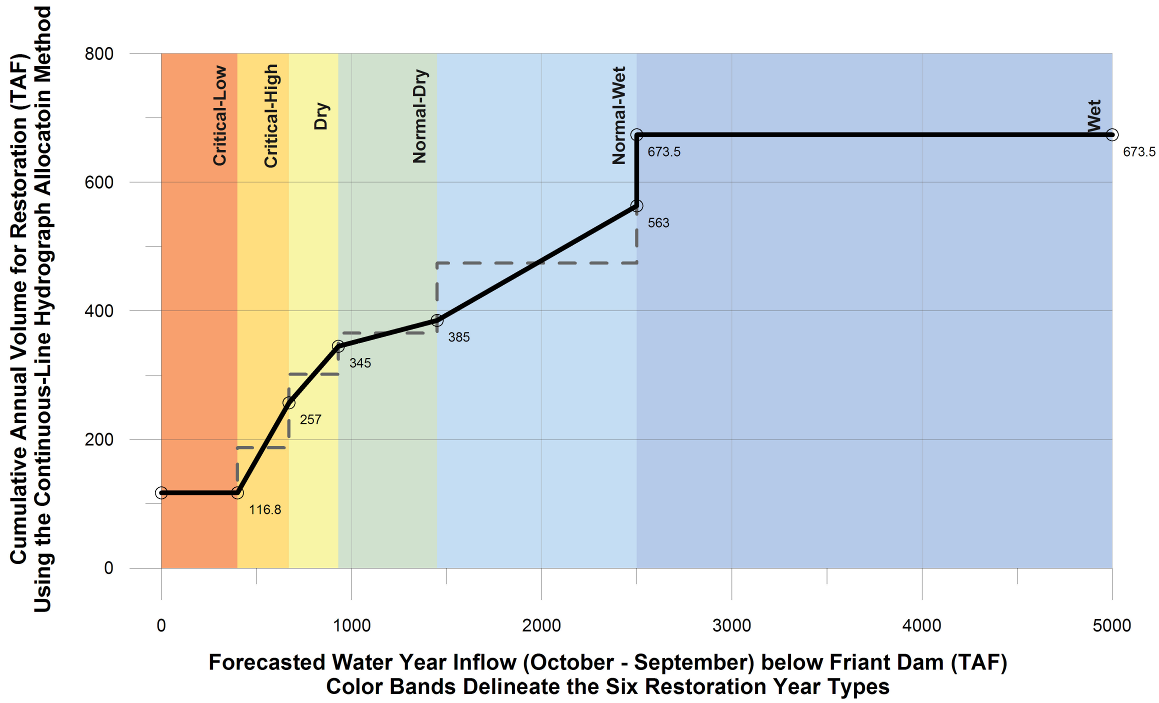


Figure 3-2.
Proposed Concept of a Continuous Hydrograph Method for Determining Annual Restoration Flow Volume (TAF)

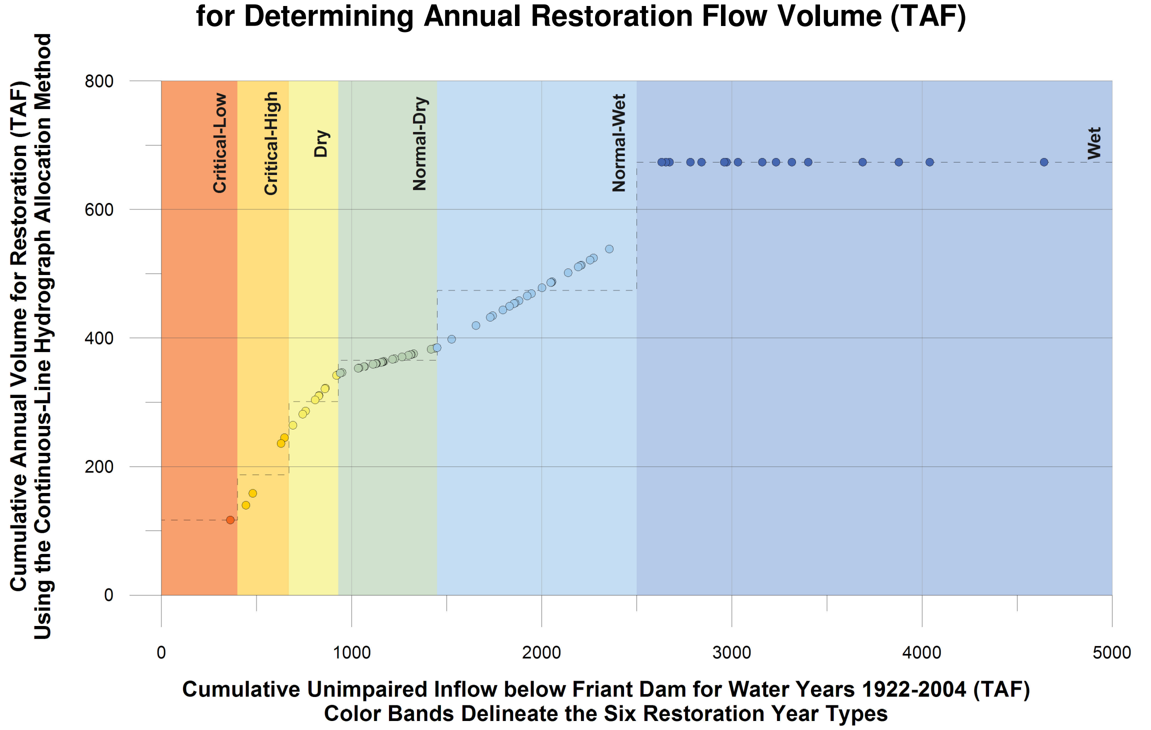


Figure 3-3.
Annual Restoration Flow Volume (TAF) for the 1922-2004 Period of Record Resulting from the Continuous Hydrograph Method

3.2.2 Monthly Pattern

Table 3-1 illustrates the monthly release requirement by year type, as presented by the Settlement's six stair-step Restoration flow hydrographs. The above development of a continuous function for the annual flow requirement necessitates development of a method to distribute monthly the resulting annual flow volume that is not described by one of the six stair-step Restoration flow hydrographs.

The stair-step hydrographs shown in Figure 2-1 also display the progression in monthly patterns for six hydrographs: as the annual volume of Restoration Flows increases, the monthly volume increases - ultimately the period of high flow in spring is extended for wet years. In other words, the monthly hydrograph release rates for wetter year types are always equal to or higher than those of any drier year type; the increase in release occurs only in selected months in November and in the spring months. To be consistent with the Settlement, the method for distributing the above-determined annual amount (see Section 3.2.1) should be consistent with the progressive characteristics in the original stair-step hydrographs.

The continuous hydrograph approach outlined in Section 3.2.1 produces a series of key reference hydrographs that can be used for defining monthly patterns for all Restoration Flow volumes. Table 3-2 shows these key reference hydrographs. The referenced unimpaired inflow amounts are either boundaries (for critical-low, normal-wet (max), and wet years), or midpoints (for critical-high, dry, normal-dry, and normal-wet years). The monthly distribution pattern for each referenced unimpaired inflow amount is consistent with that of the stair-step hydrograph method in the Settlement. These key reference hydrograph monthly patterns can be used with interpolation, for any given annual unimpaired inflow below Millerton Lake, to produce a corresponding hydrograph.

For instance, for a year that requires 500,000 acre-feet of Restoration Flow volume, 473,900 acre-feet would be distributed according to the normal-wet reference hydrograph and the remaining 26,100 acre-feet would be proportionately distributed in May and June (the 2 months that show an increase in flow when adjusting from the normal-wet Restoration flow hydrograph to the normal-wet (max) reference hydrograph).

Although they are not discussed by this TM, the specifications for daily flow operations (e.g., ramping rate restrictions for ecological purposes and recommendations to the Secretary) will further refine the default release patterns presented in this section.

Table 3-2.
Reference Hydrographs for Transformation to Continuous Hydrograph

Year Type		Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Normal-Wet (max)	Wet
Forecasted Inflow (TAF)*		400	537	801	1,193	1,974	2,500	2,500
Allocation Volume (TAF)*		117	188	301	365	474	563	673
Month	Day	Hydrograph (cfs)	Hydrograph (cfs)	Hydrograph (cfs)	Hydrograph (cfs)	Hydrograph (cfs)	Hydrograph (cfs)	Hydrograph (cfs)
10	1	160	160	350	350	350	350	350
10	16	160	160	350	350	350	350	350
11	1	124	232	583	583	583	583	583
11	16	120	120	350	350	350	350	350
12	1	120	120	350	350	350	350	350
12	16	120	120	350	350	350	350	350
1	1	100	110	350	350	350	350	350
1	16	100	110	350	350	350	350	350
2	1	100	110	350	350	350	350	350
2	16	100	110	350	350	350	350	350
3	1	130	500	500	500	500	500	500
3	16	130	1,500	1,500	1,500	1,500	1,500	1,500
4	1	150	200	350	2,500	2,500	2,500	2,500
4	16	150	200	350	350	4,000	4,000	4,000
5	1	190	215	350	350	350	1,087	2,000
5	16	190	215	350	350	350	1,087	2,000
6	1	190	215	350	350	350	1,087	2,000
6	16	190	215	350	350	350	1,087	2,000
7	1	230	255	350	350	350	350	350
7	16	230	255	350	350	350	350	350
8	1	230	255	350	350	350	350	350
8	16	230	255	350	350	350	350	350
9	1	210	260	350	350	350	350	350
9	16	210	260	350	350	350	350	350

* Forecasted inflow and allocation volume are defined in Section 3.2.1 as boundary conditions (critical-low, normal-wet(max) and wet), or midpoint conditions (critical-high, dry, normal-dry and normal-wet)

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

3.2.3 Validation for Settlement Consistency

The period from 1922 through 2004 was used in negotiating the Settlement; therefore, the same period was used in the validation process to verify that the resulting Restoration Flow releases and canal deliveries are consistent with the Settlement. Overall, consistency with the Settlement was confirmed through the validation process.

Figure 3-3 shows the annual Restoration Flow volumes for water years 1922 through 2004 using the above-mentioned continuous hydrograph concept. The monthly pattern proposed in Section 3.2.2 was used to further delineate the annual amount into a corresponding monthly distribution. The Settlement spreadsheet model was used to also eliminate potential differences, if any, that may be created by using different analytical tools.

Tables 3-3 and 3-4 summarize the simulated average annual releases from Friant Dam and average annual canal deliveries to Friant Division long-term contractors using the continuous hydrograph, the Settlement compared to stair-step hydrographs, and existing conditions without Settlement releases.

The average annual release requirements of two Restoration hydrograph scenarios are essentially the same, consistent with the intent of the proposed approach to derive the continuous hydrograph. There is a slightly higher average release requirement under the continuous hydrograph scenario in dry and critical-high years, resulting in a slightly conservative, but not significant practice. Similarly, the difference in canal deliveries derived from stair-step hydrographs and continuous hydrographs is not significant. Appendix C shows detailed results for canal deliveries. The largest difference, in critical-low years (approximately 25,000 acre-feet), shows 1977 to be the only year in the average, and the effect is due to the carryover operation from 1976.

Table 3-3.
Simulated Average Restoration Flow Volumes by Restoration Year Type for Contract Years 1922 Through 2003

Restoration Year Type	Average Annual Release from Friant Dam (TAF)			
	Without Restoration (Existing Condition)	With Restoration Releases		
		Continuous Hydrograph Method	Stair-Step Hydrograph Method	Difference Between Methods
Wet	117	674	673	0
Normal-Wet	117	471	474	-3
Normal-Dry	117	365	365	0
Dry	117	311	301	10
Critical-High	117	195	187	8
Critical-Low	117	117	117	0
All Years	117	438	437	1

Key: TAF = thousand acre-feet

Table 3-4.
Simulated Average Canal Delivery Volumes by Restoration Year Type for Contract Years 1922 Through 2003

Restoration Year Type (Mar - Feb)	Average Canal Delivery to Friant Division Long-Term Contractors (TAF)			
	Without Restoration (Existing Condition)	With Restoration Releases		
		Continuous Hydrograph Method	Stair-Step Hydrograph Method	Difference Between Methods
Wet	1,967	1,802	1,802	0
Normal-Wet	1,627	1,343	1,339	3
Normal-Dry	1,095	892	892	1
Dry	778	615	627	-13
Critical-High	525	401	389	12
Critical-Low	322	289	320	-31
All Years	1,344	1,135	1,136	0

Key: TAF = thousand acre-feet

Tables 3-5 and 3-6 show the annual amounts for Tables 3-3 and 3-4, respectively. Within each year type's range of forecasted inflow, the continuous method reduces canal diversions on wetter end of the range, and increases them on the drier end of each range, relative to the stair-step hydrographs. This corresponds with increases and decreases to the Restoration Flow requirement on the high and low end of each range, respectively.

Table 3-5.
Simulated Restoration Flow Releases for Contract Years 1922 Through 2004

Total River Release Requirement (TAF)												
Chronological Listing						Descending Order of Wetness						
Year	Without Restoration (Existing Condition)	Continuous Hydrograph Method	Stair-Step Hydrograph Method	Difference Between Methods	Difference Continuous Function and Existing Conditions	Year		Without Restoration (Existing Condition)	Continuous Hydrograph Method	Stair-Step Hydrograph Method	Difference Between Methods	Difference Continuous Function and Existing Conditions
1922	117	538	474	65	421	1983		117	674	673	1	557
1923	117	420	474	-54	303	1969		117	673	673	0	556
1924	117	140	187	-47	23	1995		117	674	673	1	557
1925	117	384	365	19	267	1938		117	673	673	0	556
1926	117	363	365	-2	246	1978		117	673	673	0	556
1927	117	479	474	5	362	1982		117	673	673	0	556
1928	117	362	365	-3	245	1967		117	674	673	1	557
1929	117	322	301	21	205	1998	Wet	117	673	673	0	556
1930	117	321	301	20	204	1986		117	673	673	0	556
1931	117	159	187	-29	42	1980		117	673	673	0	556
1932	117	486	474	12	369	1956		117	673	673	0	556
1933	117	359	365	-6	242	1952		117	673	673	0	556
1934	117	264	301	-37	147	1997		117	673	673	0	556
1935	117	466	474	-8	349	1993		117	673	673	0	556
1936	117	453	474	-20	336	1941		117	673	673	0	556
1937	117	513	474	40	396	1958		117	673	673	0	556
1938	117	673	673	0	556	1922		117	538	474	65	421
1939	117	343	301	41	226	1965		117	524	474	51	407
1940	117	458	474	-16	341	1942		117	521	474	47	404
1941	117	673	673	0	556	1937		117	513	474	40	396
1942	117	521	474	47	404	1996		117	513	474	39	396
1943	117	488	474	14	371	1974		117	511	474	37	394
1944	117	371	365	6	254	1945		117	502	474	28	385
1945	117	502	474	28	385	1943		117	488	474	14	371
1946	117	432	474	-41	315	1984		117	487	474	13	370
1947	117	361	365	-5	244	1932		117	486	474	12	369
1948	117	367	365	2	250	1973		117	486	474	12	369
1949	117	363	365	-2	246	1927		117	479	474	5	362
1950	117	374	365	9	257	1963	Normal-wet	117	470	474	-4	353
1951	117	455	474	-19	338	1962		117	465	474	-9	348
1952	117	673	673	0	556	1935		117	466	474	-8	349
1953	117	368	365	3	251	1940		117	458	474	-16	341
1954	117	375	365	9	258	1951		117	455	474	-19	338
1955	117	363	365	-2	246	1936		117	453	474	-20	336
1956	117	673	673	0	556	1979		117	450	474	-24	333
1957	117	376	365	10	259	1975		117	444	474	-30	327
1958	117	673	673	0	556	2000		117	434	474	-39	317
1959	117	347	365	-18	230	1946		117	432	474	-41	315
1960	117	311	301	9	194	1923		117	420	474	-54	303
1961	117	245	187	58	128	1999		117	399	474	-75	282
1962	117	465	474	-9	348	2003		117	386	474	-88	269
1963	117	470	474	-4	353	1970		117	385	365	19	268
1964	117	342	301	41	225	1925		117	384	365	19	267
1965	117	524	474	51	407	1971		117	383	365	18	266
1966	117	373	365	8	256	1957		117	376	365	10	259
1967	117	674	673	1	557	1954		117	375	365	9	258
1968	117	322	301	21	205	1950		117	374	365	9	257
1969	117	673	673	0	556	1966		117	373	365	8	256
1970	117	385	365	19	268	1944		117	371	365	6	254
1971	117	383	365	18	266	1953		117	368	365	3	251
1972	117	353	365	-12	236	1948		117	367	365	2	250
1973	117	486	474	12	369	2002		117	364	365	-2	247
1974	117	511	474	37	394	1949		117	363	365	-2	246
1975	117	444	474	-30	327	1926		117	363	365	-2	246
1976	117	236	187	49	119	1955		117	363	365	-2	246
1977	117	117	117	0	0	1928		117	362	365	-3	245
1978	117	673	673	0	556	2004		Partial Year				
1979	117	450	474	-24	333	1985		117	360	365	-5	243
1980	117	673	673	0	556	1947		117	361	365	-5	244
1981	117	356	365	-10	239	1933		117	359	365	-6	242
1982	117	673	673	0	556	1981		117	356	365	-10	239
1983	117	674	673	1	557	2001		117	355	365	-10	238
1984	117	487	474	13	370	1972		117	353	365	-12	236
1985	117	360	365	-5	243	1991		117	354	365	-12	237
1986	117	673	673	0	556	1959		117	347	365	-18	230
1987	117	287	301	-14	170	1989		117	346	365	-20	229
1988	117	322	301	21	205	1964		117	342	301	41	225
1989	117	346	365	-20	229	1939		117	343	301	41	226
1990	117	282	301	-20	165	1929		117	322	301	21	205
1991	117	354	365	-12	237	1988		117	322	301	21	205
1992	117	304	301	3	187	1968		117	322	301	21	205
1993	117	673	673	0	556	1930	Dry	117	321	301	20	204
1994	117	310	301	9	193	1960		117	311	301	9	194
1995	117	674	673	1	557	1994		117	310	301	9	193
1996	117	513	474	39	396	1992		117	304	301	3	187
1997	117	673	673	0	556	1987		117	287	301	-14	170
1998	117	673	673	0	556	1990		117	282	301	-20	165
1999	117	399	474	-75	282	1934		117	264	301	-37	147
2000	117	434	474	-39	317	1961		117	245	187	58	128
2001	117	355	365	-10	238	1976	CH	117	236	187	49	119
2002	117	364	365	-2	247	1931		117	159	187	-29	42
2003	117	386	474	-88	269	1924		117	140	187	-47	23
2004	Partial Year					1977	CL	117	117	117	0	0
Avg	117	438	437	1	321	Wet Avg		117	674	673	0	557
Max	117	674	673			Normal-Wet Avg		117	471	474	-3	354
Min	117	117	117			Normal-Dry Avg		117	365	365	0	248
						Dry Avg		117	311	301	10	194
Driest 20% of Water Years on Record						Critical-High Avg		117	195	187	8	78
Driest Avg	117	272	264	9	155	Critical-Low Avg		117	117	117	0	0

Note: Values are summed over Contract Years (March-February)

Note: Wetness based on water year unimpaired inflow below Friant Dam

Key: TAF = thousand acre-feet

Table 3-6.
Simulated Annual Canal Delivery to Friant Division Long-Term Contractors for Contract Years 1922 Through 2004

Total Canal Diversions (TAF)													
Chronological Listing						Descending Order of Wetness							
Year	Without Restoration (Existing Condition)	Continuous Hydrograph Method	Stair-Step Hydrograph Method	Difference Between Methods	Difference Continuous Function and Existing Conditions	Year		Without Restoration (Existing Condition)	Continuous Hydrograph Method	Stair-Step Hydrograph Method	Difference Between Methods	Difference Continuous Function and Existing Conditions
1922	1,962	1,713	1,799	-86	-248	1983		2,010	1,972	1,973	-1	-38
1923	1,373	1,247	1,152	96	-126	1969		1,843	1,822	1,822	0	-21
1924	506	408	365	43	-97	1995		2,236	2,138	2,138	-1	-98
1925	1,130	938	955	-17	-192	1938		1,952	1,880	1,878	2	-72
1926	1,144	847	845	3	-297	1978		2,056	1,981	1,981	0	-76
1927	1,701	1,363	1,368	-5	-338	1982		2,088	2,005	2,005	0	-83
1928	1,202	988	985	3	-214	1967		2,067	1,942	1,942	0	-125
1929	707	536	557	-21	-172	1998	Wet	1,853	1,768	1,768	0	-85
1930	727	525	544	-19	-201	1986		1,938	1,797	1,797	0	-142
1931	394	278	250	28	-116	1980		2,063	1,720	1,720	0	-343
1932	1,651	1,373	1,385	-12	-278	1956		2,027	1,581	1,581	0	-446
1933	1,104	860	854	6	-243	1952		1,833	1,742	1,742	0	-91
1934	649	480	466	14	-169	1997		1,597	1,329	1,329	0	-268
1935	1,573	1,234	1,202	32	-340	1993		2,066	1,736	1,736	0	-331
1936	1,578	1,316	1,305	10	-263	1941		2,022	1,763	1,763	0	-258
1937	1,675	1,501	1,519	-18	-174	1958		1,818	1,654	1,654	0	-164
1938	1,952	1,880	1,878	2	-72	1922		1,962	1,713	1,799	-86	-248
1939	848	646	687	-41	-202	1965		1,777	1,392	1,442	-50	-385
1940	1,538	1,267	1,252	15	-272	1942		1,983	1,595	1,635	-40	-388
1941	2,022	1,763	1,763	0	-258	1937		1,675	1,501	1,519	-18	-174
1942	1,983	1,595	1,635	-40	-388	1996		1,786	1,592	1,631	-39	-193
1943	1,545	1,298	1,306	-9	-247	1974		1,818	1,493	1,570	-77	-325
1944	1,102	990	1,000	-11	-112	1945		1,873	1,548	1,575	-27	-325
1945	1,873	1,548	1,575	-27	-325	1943		1,545	1,298	1,306	-9	-247
1946	1,475	1,208	1,167	41	-268	1984		1,539	1,225	1,238	-13	-313
1947	1,073	885	880	5	-188	1932		1,651	1,373	1,385	-12	-278
1948	920	694	696	-2	-226	1973		1,733	1,416	1,416	0	-317
1949	1,048	804	802	2	-244	1927		1,701	1,363	1,368	-5	-338
1950	1,383	1,127	1,136	-9	-256	1963	Normal-wet	1,707	1,408	1,403	5	-299
1951	1,265	978	959	19	-288	1962		1,649	1,326	1,354	-27	-323
1952	1,833	1,742	1,742	0	-91	1935		1,573	1,234	1,202	32	-340
1953	1,066	877	879	-3	-190	1940		1,538	1,267	1,252	15	-272
1954	1,130	866	875	-9	-264	1951		1,265	978	959	19	-288
1955	1,125	1,062	1,059	3	-63	1936		1,578	1,316	1,305	10	-263
1956	2,027	1,581	1,581	0	-446	1979		1,653	1,327	1,315	12	-327
1957	1,226	1,084	1,094	-10	-143	1975		1,606	1,343	1,294	49	-262
1958	1,818	1,654	1,654	0	-164	2000		1,615	1,255	1,218	37	-360
1959	855	822	804	19	-33	1946		1,475	1,208	1,167	41	-268
1960	704	510	520	-10	-194	1923		1,373	1,247	1,152	96	-126
1961	518	357	379	-21	-161	1999		1,321	1,134	1,058	76	-187
1962	1,649	1,326	1,354	-27	-323	2003		1,274	1,012	923	89	-263
1963	1,707	1,408	1,403	5	-299	1970		1,306	1,038	1,058	-20	-268
1964	1,101	906	947	-42	-195	1925		1,130	938	955	-17	-192
1965	1,777	1,392	1,442	-50	-385	1971		1,208	980	997	-17	-228
1966	1,346	1,108	1,116	-8	-238	1957		1,226	1,084	1,094	-10	-143
1967	2,067	1,942	1,942	0	-125	1954		1,130	866	875	-9	-264
1968	988	842	863	-21	-146	1950		1,383	1,127	1,136	-9	-256
1969	1,843	1,822	1,822	0	-21	1966		1,346	1,108	1,116	-8	-238
1970	1,306	1,038	1,058	-20	-268	1944		1,102	990	1,000	-11	-112
1971	1,208	980	997	-17	-228	1953		1,066	877	879	-3	-190
1972	1,056	789	777	11	-267	1948		920	694	696	-2	-226
1973	1,733	1,416	1,416	0	-317	2002		1,030	785	784	2	-245
1974	1,818	1,493	1,570	-77	-325	1949		1,048	804	802	2	-244
1975	1,606	1,343	1,294	49	-262	1926	Normal-dry	1,144	847	845	3	-297
1976	684	562	563	-2	-122	1955		1,125	1,062	1,059	3	-63
1977	322	289	320	-31	-33	1928		1,202	988	985	3	-214
1978	2,056	1,981	1,981	0	-76	2004				Partial Year		
1979	1,653	1,327	1,315	12	-327	1985		1,127	893	888	5	-233
1980	2,063	1,720	1,720	0	-343	1947		1,073	885	880	5	-188
1981	1,114	1,039	1,029	10	-75	1933		1,104	860	854	6	-243
1982	2,088	2,005	2,005	0	-83	1981		1,114	1,039	1,029	10	-75
1983	2,010	1,972	1,973	-1	-38	2001		955	748	738	10	-208
1984	1,539	1,225	1,238	-13	-313	1972		1,056	789	777	11	-267
1985	1,127	893	888	5	-233	1991		845	624	600	24	-221
1986	1,938	1,797	1,797	0	-142	1959		855	822	804	19	-33
1987	589	586	580	5	-3	1989		797	570	551	20	-227
1988	732	536	548	-12	-196	1964		1,101	906	947	-42	-195
1989	797	570	551	20	-227	1939		848	646	687	-41	-202
1990	620	445	438	7	-175	1929		707	536	557	-21	-172
1991	845	624	600	24	-221	1988		732	536	548	-12	-196
1992	794	553	557	-4	-241	1968		988	842	863	-21	-146
1993	2,066	1,736	1,736	0	-331	1930	Dry	727	525	544	-19	-201
1994	878	812	820	-9	-67	1960		704	510	520	-10	-194
1995	2,236	2,138	2,138	-1	-98	1994		878	812	820	-9	-67
1996	1,786	1,592	1,631	-39	-193	1992		794	553	557	-4	-241
1997	1,597	1,329	1,329	0	-268	1987		589	586	580	5	-3
1998	1,853	1,768	1,768	0	-85	1990		620	445	438	7	-175
1999	1,321	1,134	1,058	76	-187	1934		649	480	466	14	-169
2000	1,615	1,255	1,218	37	-360	1961		518	357	379	-21	-161
2001	955	748	738	10	-208	1976	CH	684	562	563	-2	-122
2002	1,030	785	784	2	-245	1931		394	278	250	28	-116
2003	1,274	1,012	923	89	-263	1924		506	408	365	43	-97
2004			Partial Year			1977	CL	322	289	320	-31	-33
Avg	1,344	1,135	1,136	0	-209	Wet Avg		1,967	1,802	1,802	0	-165
Max	2,236	2,138	2,138			Normal-Wet Avg		1,627	1,343	1,339	3	-284
Min	322	278	250			Normal-Dry Avg		1,095	892	892	1	-203
						Dry Avg		778	615	627	-13	-163
		Driest 20% of Water Years on Record				Critical-High Avg		525	401	389	12	-124
Driest Avg	692	545	553	-8	-147	Critical-Low Avg		322	289	320	-31	-33

Note: Values are summed over Contract Years (March-February)

Note: Wetness based on water year unimpaired inflow below Friant Dam

Key: TAF = thousand acre-fee

4.0 Incorporation of Hydrologic Forecast Uncertainties

The major challenge in using a hydrologic forecast in water operations is the uncertainties associated with the forecast (i.e., the risks of not meeting anticipated operational objectives). For the SJRRP, these uncertainties could raise concerns over equity in operation guidelines for fishery protection and water supply reliability. This section discusses hydrologic uncertainties, and a proposal for incorporating this consideration into water operations.

4.1 Quality of Bulletin 120 Hydrologic Forecast

DWR uses a composite approach to produce 10-, 50- and 90-percent forecasts. The 50-percent forecast is produced from snow survey data, using correlations between historic flows and snow survey data. However, the 90- and 10-percent forecasts are produced by imposing an envelope of likely inflows around the 50-percent forecast.

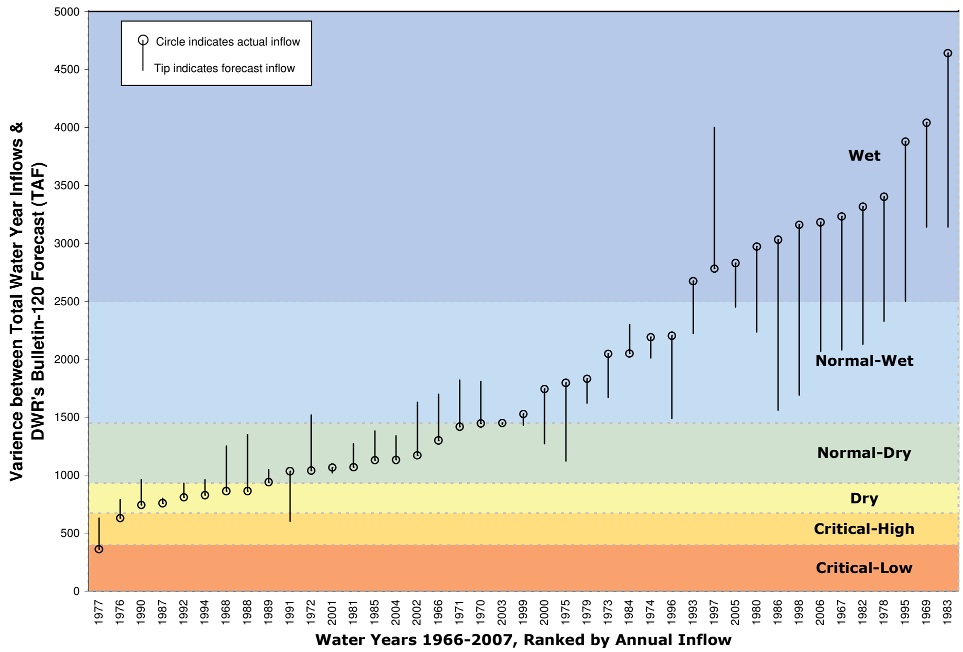
The envelope is defined with data from the previous 50 years, and reflects the 10- and 90-percent deviations from the 50-percent forecast which have occurred during the remaining portions of the year. The timing and volumes of the 90th and 10th percentile forecasts are distributed across the months of forecast based on historical patterns and professional judgment. Thus, the 50-percent forecasts are based directly upon snow survey data (i.e., antecedent conditions), whereas the 10- and 90-percent exceedences are based upon the spread of inflows over the previous 50 years about the 50-percent forecast, and professional judgment. (Rizzardo, 2007) [5]

Figures 4-1 through 4-4 compare the historical annual unimpaired flow of 1966 through 2007[6] with corresponding February, March, April, and May forecasts. Comparison plots for both 50-percent and 90-percent forecasts are shown. Several observations on forecast quality are summarized as follows:

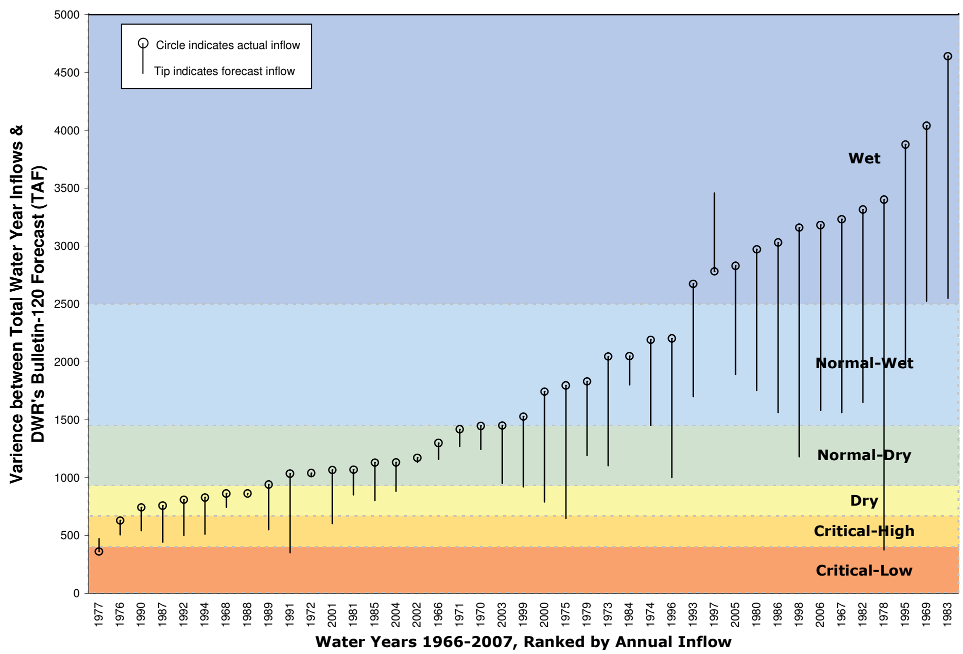
- In general, the forecast quality is not ideal, and has a significant variation of error.
- The quality of the February forecast is low for both 50-percent and 90-percent exceedence forecasts; more forecast errors in quantity occur in wetter years.
- The quality of the forecast improves significantly for May; however, the forecast for wetter years has greater error.
- By definition, the 90-percent exceedence forecast would be more likely to underestimate the annual unimpaired flow than the 50-percent exceedence

[5] Details of Bulletin 120 forecast methodology are beyond the scope of this TM. While relevant, the more important consideration herein is the adequate application of such forecast data.
[6] The common period for available 50-percent and 90-percent forecast data by DWR.

forecast; however, the actual quantity difference between these two forecasts gradually diminishes in later months.

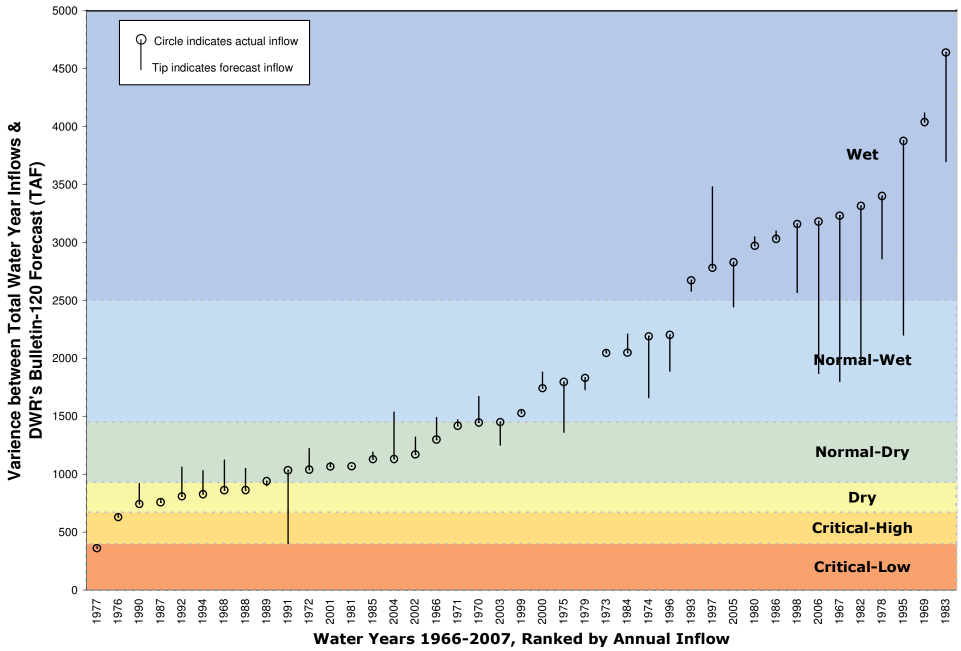


(a) 50-Percent Exceedence Forecast

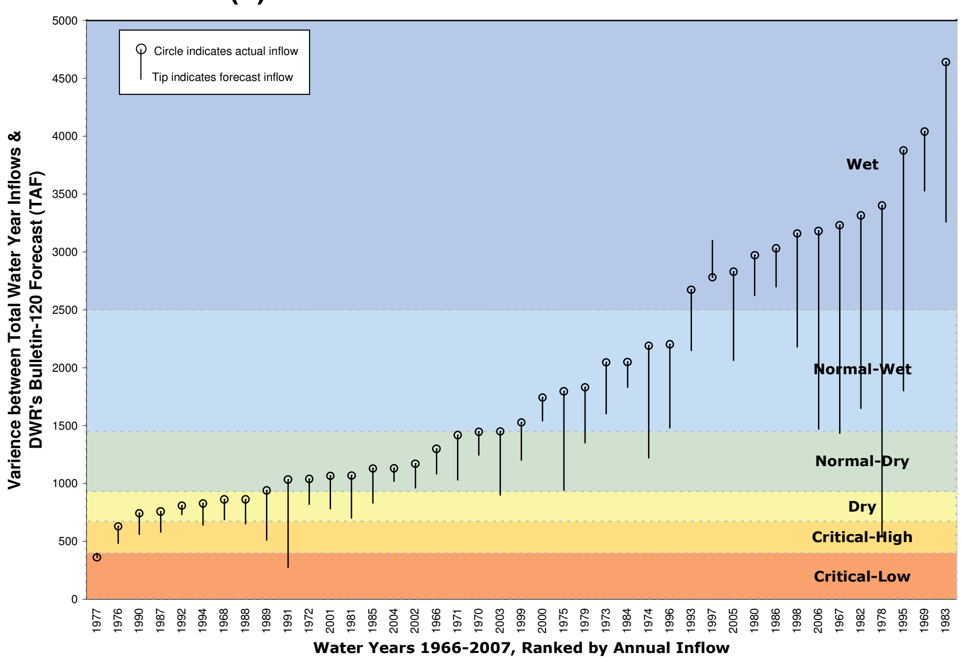


(b) 90-Percent Exceedence Forecast

Figure 4-1.
Comparison of Actual Annual Unimpaired Flow and February Forecast from Bulletin 120, for Water Years 1966-2007

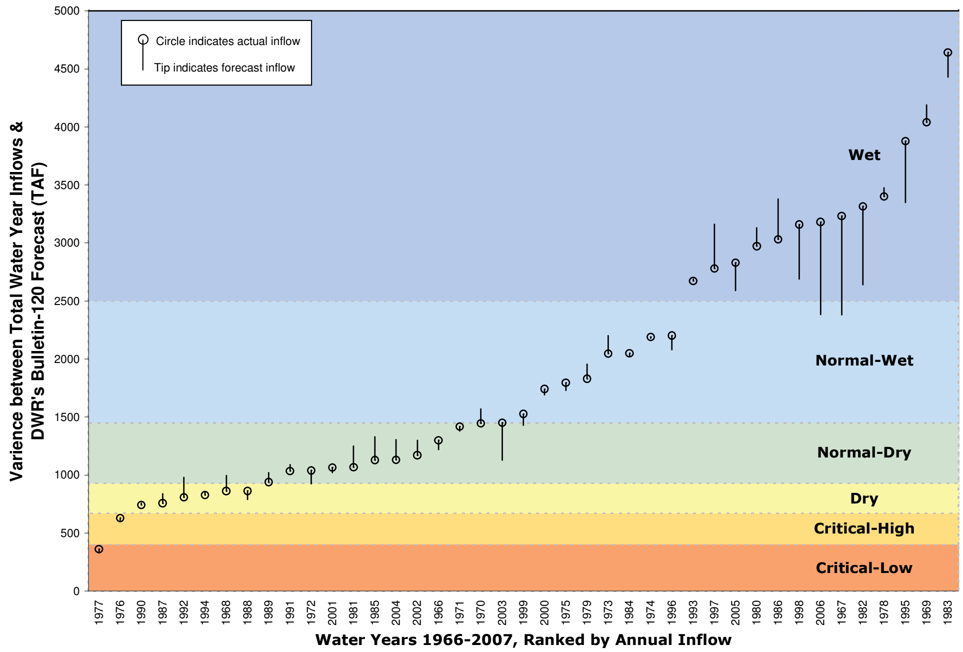


(a) 50-Percent Exceedence Forecast

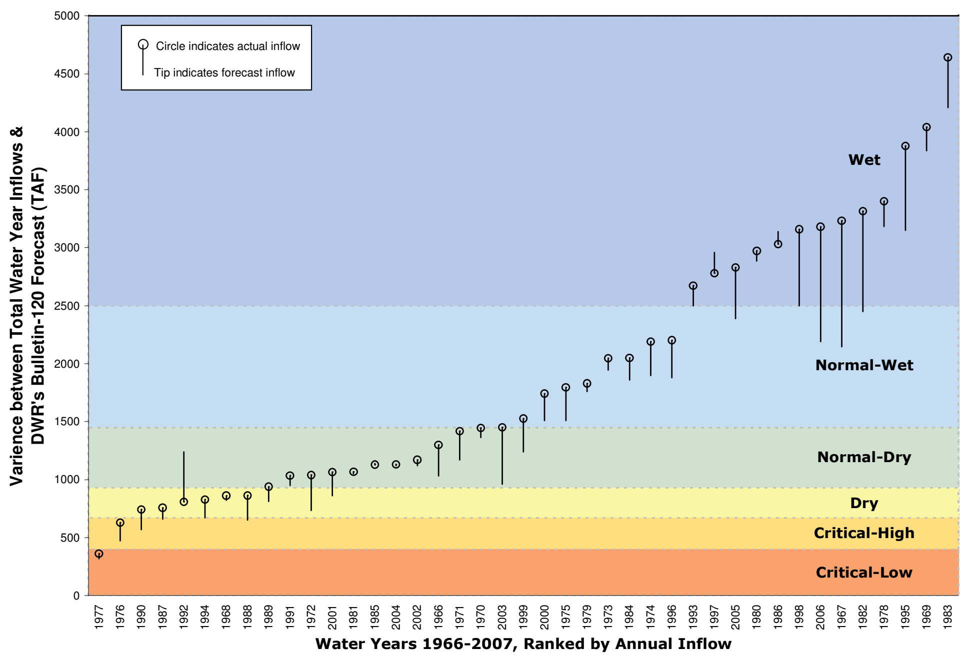


(b) 90-Percent Exceedence Forecast

Figure 4-2.
Comparison of Actual Annual Unimpaired Flow and March Forecast from Bulletin 120, for Water Years 1966-2007

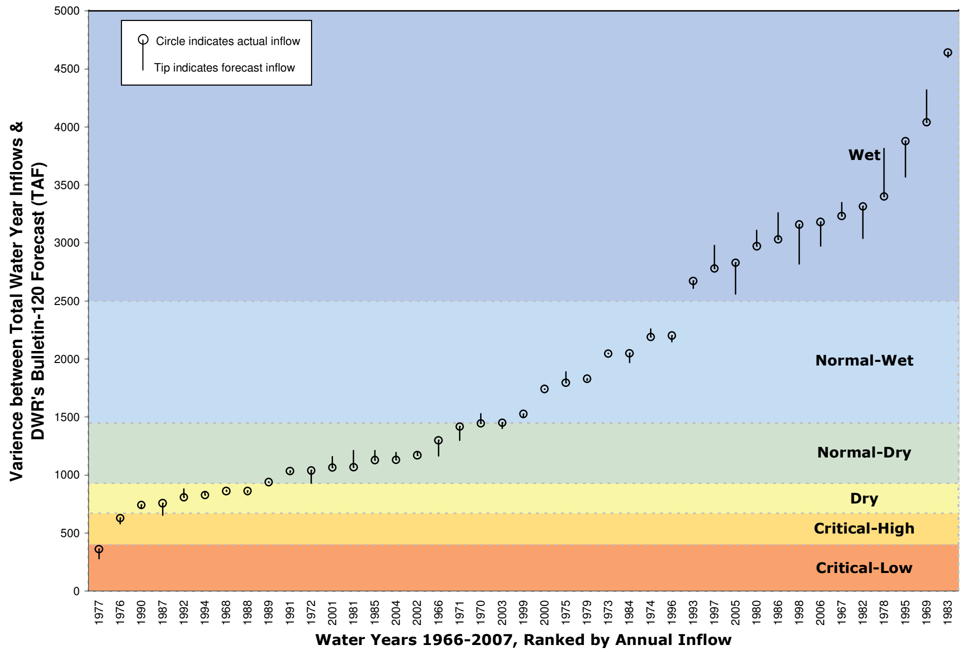


(a) 50-Percent Exceedence Forecast

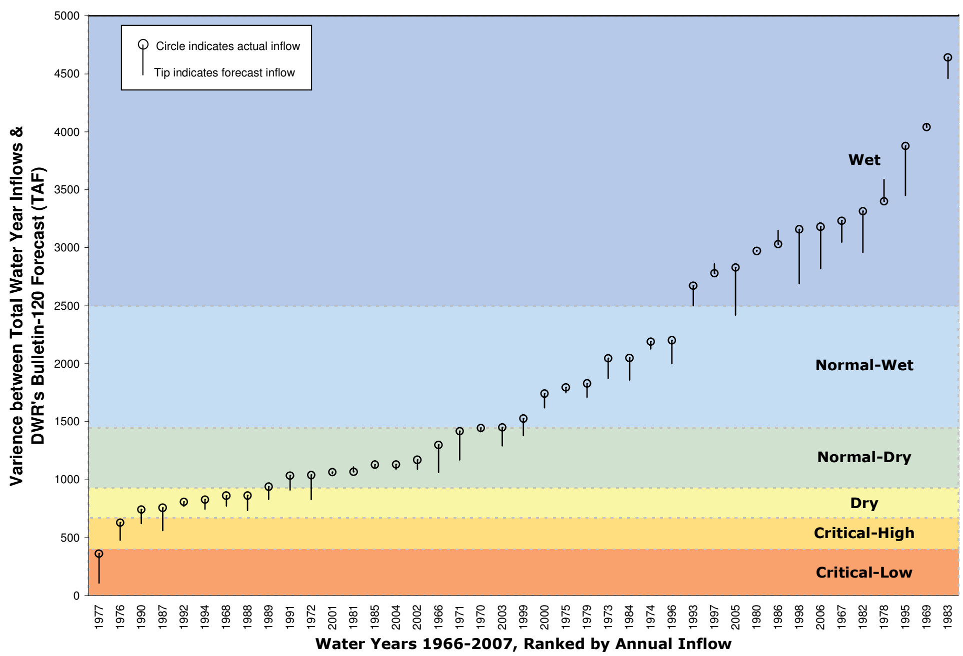


(b) 90-Percent Exceedence Forecast

Figure 4-3.
Comparison of Actual Annual Unimpaired Flow and April Forecast from Bulletin 120, for Water Years 1966-2007



(a) 50-Percent Exceedence Forecast



(b) 90-Percent Exceedence Forecast

Figure 4-4.
Comparison of Actual Annual Unimpaired Flow and May Forecast from Bulletin 120, for Water Years 1966-2007

Table 4-1 shows another Bulletin 120 forecast summary for assessing associated forecast quality. Because the unimpaired flow largely originates from snowmelt, the period forecast (i.e., April through July) may be more reliable than the forecasts for individual months. However, 2006 is a good example of a forecast that cannot capture the associated year type until much later in spring because of the late storms that occurred in that year. The volatility associated with a hydrologic forecast is a great challenge for real-time operations and a water year definition and associated operations hinged upon the total annual unimpaired flow amount, as required in the Settlement.

Table 4-1.
Summary of Bulletin 120 Forecast for San Joaquin River Unimpaired Inflow to Millerton Lake from 2001 Through 2006 (in TAF)

Year	Forecast Month	Forecast Period															
		Apr-Jul	% Error	Feb	% Error	Mar	% Error	Apr	% Error	May	% Error	Jun	% Error	Jul	% Error	Aug-Sept	% Error
2001	Feb	730	-8%	65	55%	105	-17%	190	1%	300	-33%	180	57%	60	28%	40	74%
	Mar	830	4%			110	-13%	200	6%	350	-21%	220	91%	60	28%	40	74%
	Apr	740	-7%							310	-30%	180	57%	60	28%	35	52%
	May	870	9%							370	-17%	230	100%	80	70%	45	96%
	Actual	**795**		**42**		**126**		**188**		**445**		**115**		**47**		**23**	
2002	Feb	1,190	41%	100	75%	140	49%	240	-3%	450	39%	380	70%	120	126%	45	114%
	Mar	960	13%			105	12%	200	-19%	380	18%	280	26%	100	89%	45	114%
	Apr	950	12%					210	-15%	380	18%	270	21%	90	70%	45	114%
	May	860	2%							355	10%	200	-10%	60	13%	35	67%
	Actual	**846**		**57**		**94**		**247**		**323**		**223**		**53**		**21**	
2003	Feb	1,030	-3%	70	17%	130	19%	250	58%	400	-8%	290	-23%	90	1%	35	-24%
	Mar	880	-17%			110	1%	240	52%	340	-22%	240	-36%	60	-33%	25	-46%
	Apr	760	-28%					240	52%	290	-33%	180	-52%	50	-44%	25	-46%
	May	1,020	-4%							420	-4%	330	-12%	110	24%	35	-24%
	Actual	**1,058**		**60**		**109**		**158**		**436**		**375**		**89**		**46**	
2004	Feb	1,050	43%	45	-35%	85	-56%	200	-10%	420	48%	310	79%	120	118%	45	125%
	Mar	1,170	59%			130	-32%	240	8%	480	69%	350	102%	100	82%	50	150%
	Apr	880	20%					210	-6%	350	23%	240	39%	80	45%	50	150%
	May	780	6%							295	4%	200	16%	60	9%	40	100%
	Actual	**735**		**69**		**192**		**223**		**284**		**173**		**55**		**20**	
2005	Feb	1,730	-17%	150	13%	180	-20%	325	26%	590	-28%	565	-15%	250	-27%	90	0%
	Mar	1,720	-17%			200	-12%	310	21%	610	-25%	565	-15%	235	-31%	90	0%
	Apr	1,840	-12%					370	44%	650	-21%	585	-12%	235	-31%	90	0%
	May	1,810	-13%							685	-16%	620	-6%	250	-27%	90	0%
	Actual	**2,080**		**133**		**226**		**257**		**818**		**662**		**343**		**90**	
2006	Feb	1,460	-41%	95	-16%	140	-29%	270	-46%	525	-41%	470	-38%	195	-40%	60	-31%
	Mar	1,270	-49%			115	-42%	230	-54%	460	-48%	410	-46%	170	-48%	60	-31%
	Apr	1,700	-31%					300	-40%	550	-38%	580	-24%	270	-17%	60	-31%
	May	2,180	-12%							680	-23%	660	-13%	345	6%	170	95%
	Actual	**2,471**		**113**		**198**		**498**		**884**		**763**		**326**		**87**	

4.2 Existing Operation Guidelines Associated with Hydrologic Uncertainties

The Friant Division uses a contract year of March through February to be consistent with allocation practices. The existing contract allocation practices for the Friant Division allow Reclamation to exercise its discretion in using a forecast within the range of 50 to 90 percent of exceedence (Reclamation, 2005). Contract allocations are based on the review of several forecasts, which combine estimates of snow accumulation, antecedent conditions, and a statistical range of precipitation predictions.

Using discretion, Reclamation tends to establish initial allocations in February by using higher probability forecasts (i.e., an expectancy that forecasted runoff would have a 90 percent of exceedence) early in the year and when dry conditions have prevailed. In years with wet conditions, with surplus water or possible flood control releases, an initial forecast might favor a lower percent of exceedence because the negative consequences of overestimating runoff and allocations are potentially great.

As additional forecast information becomes available in subsequent months, water contract allocations are amended to reflect the increasing confidence in hydrologic forecasts. Allocations may also increase during this period if inflows are projected to be greater than previously forecasted.

The majority of snow in the Sierra typically melts by the end of June, causing the forecast of unimpaired runoff for the remainder of the year to become more certain. After June, inflow to Millerton Lake depends highly on releases from upstream storage. At this point, allocations are set mostly by the projected operation of upstream projects and end-of-year carryover targets. Allocations are generally held constant from July through the following February (i.e., the end of the contract year).

4.3 Incorporating Hydrologic Forecast Uncertainties in Restoration Flow Accounting

While Reclamation may, at its discretion, use any exceedence forecast between 50 and 90 percent for contract allocations, it is recognized that additional resolutions are necessary for managing Restoration Flow releases because of potential differences in hydrographs in the spring period. The continuous hydrograph in Section 3 would help alleviate concern over forecast uncertainties; however, forecast uncertainties remain a very critical issue for real-time water operations.

4.3.1 Considerations in Using Exceedence Forecast

Concern over hydrologic forecast uncertainties in Settlement implementation is due to the resulting water-year classification, and potential undefined risks associated with overestimated or underestimated Restoration Flow requirements. The actual impacts of misclassification of year type and associated flow requirements are significantly reduced when hydrographs are transformed into a continuous format, as recommended in Section 3, to alleviate abrupt changes in flow requirements.

Within a Restoration Flow year, from March through February, Restoration Flow releases would be accounted for and compared with the volumes determined by procedures outlined in Section 3. Because of a changing annual allocation of flow due to revised forecasts (through June) of unimpaired runoff, diligent management and planning of the release of Restoration Flows is necessary.

In principle, when an allocation is revised as a result of a changed forecast, the total volume of Restoration Flows for the entire Restoration Flow year (March through February) would be reevaluated and modifications to the remaining portion of the Restoration flow hydrographs would be implemented. When the revised forecast of unimpaired inflow below Millerton Lake becomes available each month, a balance of flow to-date would be calculated as the difference between annual Restoration Flow allocations under the previous determination and the current determination. The balance would then add to or subtract from the releases in the remaining year in a manner proportional to the Restoration flow hydrographs.

Note that many options of this adjustment protocol are based on fishery management preferences and risk management, the use of other provisions in the Settlement on Buffer Flows and Flexible Flows described in Exhibit B, and the management structure that would be established for SJRRP implementation. Therefore, further coordination and development of a final protocol is necessary in continued SJRRP development.

4.3.2 Consideration of Flood Releases

The adjustment mentioned above accounts for forecast uncertainties; further adjustment is required for incorporating consideration of flood releases.

The Settlement allows using flood releases to meet Restoration Flow requirements. Therefore, the obligation to release water from Millerton Lake for restoration purposes will be met when required flood control releases at Friant Dam are above Restoration flow hydrographs under the default, or subsequently modified Restoration Flow requirements. Releases in excess of Restoration Flow requirements are considered flood releases in Restoration Flow accounting.

For illustrative purposes, consider the following scenario:

- an April 1st forecast which establishes a Normal-Dry restoration year type.
- an intense rain event causes uncontrolled releases from Friant Dam of
  - 2,800 cfs from April 1st through 15th, and
  - 3,000 cfs from April 16th through April 30th.

Table 4-2 depicts an example where the following May 1st forecast establishes the year type as Dry, which retroactively decreases the Restoration Flow volume provided for April. In this example, regulations throughout the entire month of April are being determined by flood control (uncontrolled releases) and all scheduled releases are below the actual uncontrolled releases. So long as the scheduled releases are below actual uncontrolled release rates, and so long as the releases were made as part of uncontrolled operations, the revised scheduled release will be charged against Restoration flow allocations. This approach is not expected to incur a water supply impact above the quantities assessed for the Settlement.

Table 4-2.
Example of Charges to Restoration Flows Resulting from Decreasing Forecasts During Periods of Uncontrolled Release

Period of Release	Scheduled Release using April Forecast (cfs)	Actual Uncontrolled Releases (cfs)	Revised Scheduled Release using May Forecast (cfs)	Charges against Restoration Flow Allocations (TAF)
April 1-15	2,500	2,800	350	**10.4**
April 16- 30	350	3,000	350	**10.4**

Table 4-3 depicts an example where the following May 1st forecast establishes the year type as Normal-Wet, which retroactively increases the Restoration Flow volume provided for April. However, releases have been made for April when May forecast becomes available. Therefore, the lesser of scheduled release based on April forecast and actual release is charged to Restoration flow account.

In this example, regulations throughout the entire month of April are being determined by flood control (uncontrolled releases). For the first period, the Restoration flow volume is unchanged by the revised schedule: the charge for this period equal to 2,500 cfs held over the full 15 days, even though the uncontrolled releases were in addition to this quantity. This is an example where the uncontrolled releases are used toward Restoration flow, as prescribed in the Settlement.

Table 4-3.
Example of Charges to Restoration Flows Resulting from Increasing Forecast During Periods of Uncontrolled Release

Period of Release	Scheduled Release using April Forecast (cfs)	Actual Uncontrolled Releases (cfs)	Revised Scheduled Release using May Forecast (cfs)	Charges against Restoration Flow Allocations (TAF)
April 1-15	2,500	2,800	2,500	**74.4**
April 16- 30	350	3,000	4,000	**89.3**

However, the revised schedule for releases exceeds the uncontrolled releases made during the April 16-30 period. Thus, the change in forecast calls for more water than was provided by either the previous scheduled amount or the uncontrolled release. Therefore, the full uncontrolled release will be charged against the Restoration flow allocation. However, the Restoration flow allocation was not fully met for this period: the shortfall equals 1000 cfs for 15 days. This difference is available to subsequent Restoration flow releases within the current Restoration year.

4.3.3 Recommendation for Forecast Use

It is necessary to use a higher percent exceedence forecast in early months to avoid overcommitment of Restoration Flow designations and also water supply allocation. This will result in additional adjustment problems for river and water management, and in a greater level of risk of depleting Millerton Lake without an additional remedy for water supply and river management in place. As the accuracy of forecast improves in later months, a lower percent exceedence forecast should be used. However, as previously mentioned, the difference between 50- and 90-percent exceedence forecasts is gradually diminishing as time progresses. Therefore, the use of 50- or 90-percent exceedence forecasts may not result in significant differences:

Based on the review of forecast quality and the above-mentioned considerations, the following schedule is proposed for use as a reference in allocating both Restoration Flows and contract deliveries.

- March 90-percent exceedence forecast
- April 75-percent exceedence forecast
- May 75-percent exceedence forecast
- June 50-percent exceedence forecast

The above sequence of exceedence percentages for estimating Restoration Flows and contract allocations is intended for default operations, which are further subject to real-time adjustments recommended by advisory parties. Bulletin-120 forecasts are generally available within the first ten days of each month. Because they may not be available on the 1st of each month, real-time adjustments may be required in advance of available forecast information. (See Section 5 for additional discussion on real-time considerations.)

4.3.4 Validation of Recommended Forecast Use

Forecast-based operation is a true real-time operation challenge. Therefore, the validation presented herein provides additional information to support the above-recommended forecast exceedence sequence in the beginning months of a Restoration Flow year. More importantly, this validation establishes the reasonableness of such a recommendation, rather than presenting a definite procedure or process for real-time adjustments and management.

Major concerns over the sequence of choice for forecast exceedence are the balance between aggressive operation to realize potential restoration benefits (and water deliveries) in early months, and subsequent risk in fishery management and water supply if the hydrology is drier than predicted. The risks of managing Restoration Flows and concurrent water contract allocations are critical to Settlement implementation. While expectations were established in the Settlement, the details of balancing these risks were the focus herein.

Scenarios were used to demonstrate that (1) the recommended forecast exceedence sequence is acceptable and (2) there are no apparent benefits in using other sequences if the equity of Restoration Flows could be accomplished. Table 4-4 shows four scenarios of exceedence sequence for the February-through-June forecast. The period of analysis is from 1966 through 2004 to better facilitate comparison and discussion because (1) historical 50-percent and 90-percent forecast data in the February-through-May period are available after 1966, and (2) the Settlement model and analysis were for the period of 1922 through 2004.

A set of procedures was used in these scenarios to demonstrate the possibility of using a continuous forecast-and-adjustment method to maintain the equity of Restoration Flow accounting. These procedures are for illustrative purposes. There is no further assumption in adopting these procedures for implementation; however, it is a viable approach. It is important that the equity of Restoration Flow accounting can be demonstrated to allow for later proposed procedures for RWA accounting (see Section 4.4). In other words, the strategy herein is to decouple the equity issues associated with the accountings for Restoration Flows and for water allocation.

Table 4-4.
Scenarios of Forecast Exceedence Sequence

Scenario	Forecast Exceedence Level			
	March	April	May	June**
1	90	90	90	50
2	90	75*	75*	50
3	75*	75*	75*	50
4	50	50	50	50

* Historical 75% forecast is not available; for illustrative purposes, an average between 90% and 50% forecast was used.

** Historical June forecast is not available; for illustrative purposes, the 50% May forecast was used.

The adjustment for changing the forecast used in the analysis is outlined below:

1. Based on the new forecast, a new annual Restoration Flow requirement is established per the procedure in Section 3.2.1.

2. The resulting Restoration Flow requirement from Step 1 is distributed among months per the procedure in Section 3.2.2. The verification in Section 3 suggests that no additional inconsistency would be introduced in these two steps.

3. The to-date balance calculated from the to-date releases, established by using the previous month's forecast, and the new hydrograph, established by using the current forecast, are added to the Restoration Flow requirement volume in Step 1.

4. The adjusted Restoration Flow requirement volume from Step 3 is distributed into a Restoration flow hydrograph, per the procedure in Section 3.2.2. If uncontrolled releases are made, charges are assessed against the Restoration flow allocation, as described in section 4.3.2.[7]

5. At the end of October, if the to-date balance is positive, the balance is allocated to November flow to augment fall pulse flows, with a cap of 700 cfs, described as the highest fall pulse flow rate. If the to-date balance is negative, no adjustments are made.

6. No further adjustments are made for the remaining balance.

The above approach was not designed to provide detailed accounting of Restoration Flow releases to resolve all equity issues. However, it is considered adequate for illustrative purposes that equity issues could be resolved through adjusting flood release credits, augmenting fall pulse flow implementation, and current unspecified real-time adjustments being made by the Secretary in consultation with advising parties.

Figures 4-5 and 4-6 show, for four scenarios, the end-of-June Restoration Flow account balance, and the end-of-January account balance, based on the procedure prescribed above.

[7] Flood release credits herein do not refer to the conversion of flood releases under existing operations to Restoration Flow releases under the Settlement (see discussion in Section 4.4.2). The credits refer to flood releases under the Settlement that can be used to offset the difference in hydrograph releases created by changes in forecast.

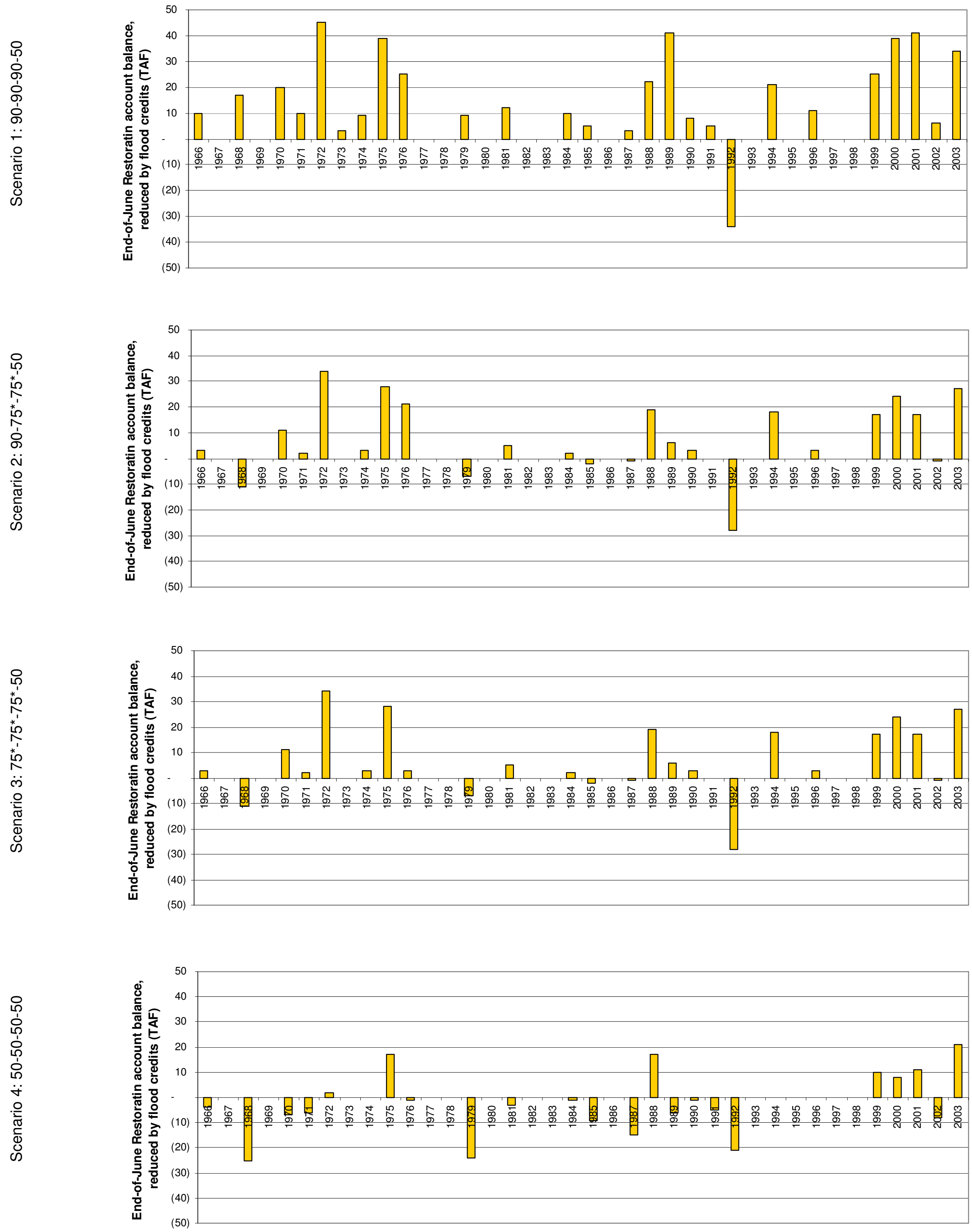


Figure 4-5.
End-of-June Restoration Flow Account Balance by Scenario Adjusted for Flood Release Credits

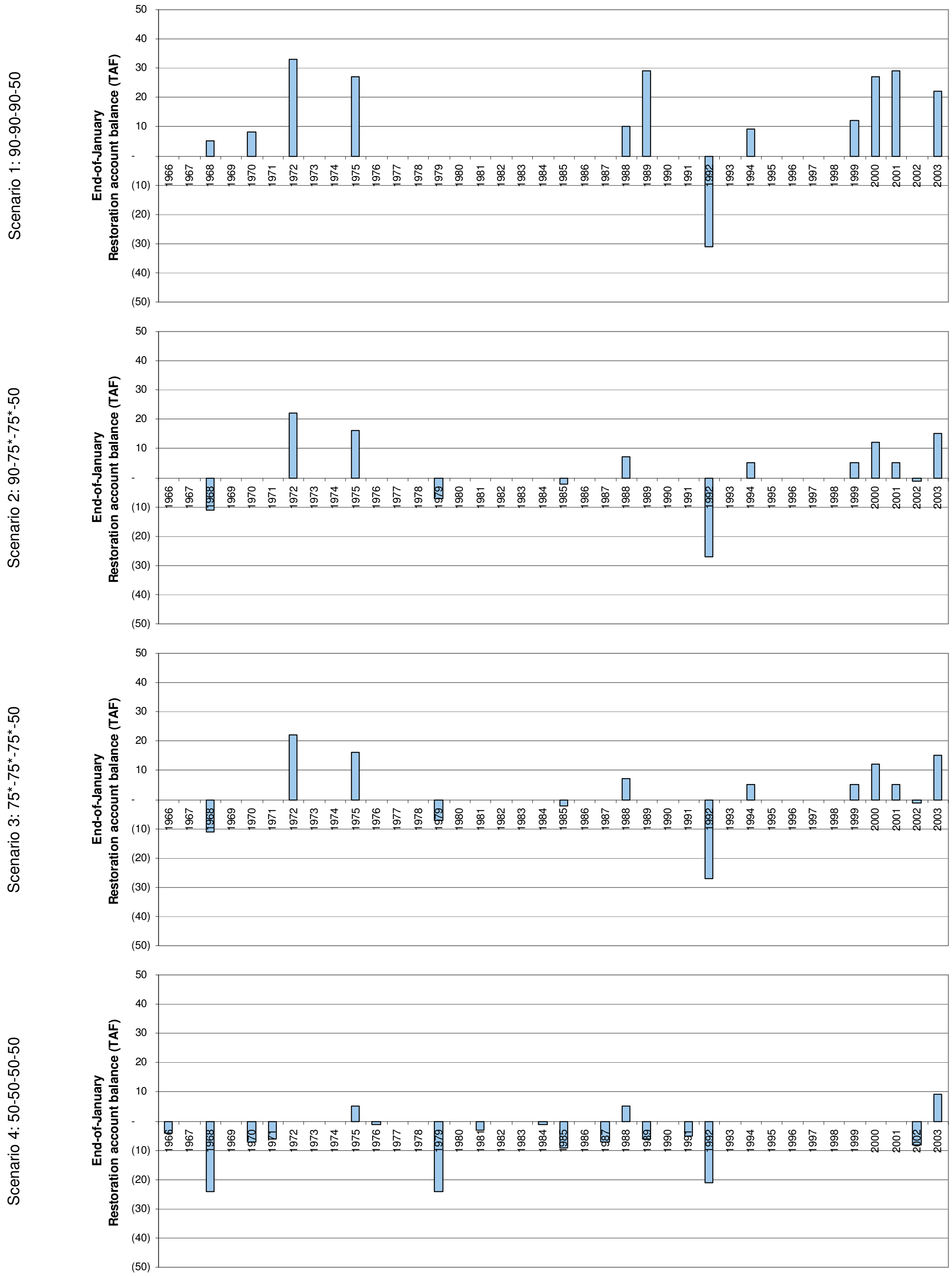


Figure 4-6.
End-of-February Restoration Flow Account Balance by Scenario Adjusted for Flood Release Credits and Fall Augmentation Flows

The results of this analysis suggest the following:

- A two-part answer is required to answer the question outlined in Settlement Paragraph 13(j)(v) in evaluating flood releases for Restoration Flow purposes:

    1. Under Settlement operations, the flood releases that occurred in existing operations could be transformed into Restoration Flow releases, as shown in Figure 4-7.

    2. Additional flood release credits may offset the Restoration Flow account balance created by forecast uncertainties; however, this occurrence is infrequent and its effects are not significant. This observation is consistent with all scenarios of exceedence sequences. This suggests that the corrective measure used in the analysis to reconcile the Restoration Flow account through changes in forecast is functioning reasonably well.

- More aggressive operation using lower exceedences in early months would increase the chance of a negative Restoration Flow balance at the end of June. Considering equity for Restoration Flow releases and water supply, subject to further discussion, the negative Restoration Flow balance could potentially impact implementation of fall pulse flows under the equity consideration. Similar risks would be reflected in water contract delivery reliability.

- The positive end-of-June Restoration Flow balance could be used to augment fall pulse flows and resolve much of the balance.

- The balance at the end of February (being, the end of the Restoration flow year) is generally relatively small, and likely to be resolved with additional real-time adjustments that the Secretary may implement in consultation with advising parties.

- The use of a different forecast exceedence level in early months such as March would not result in major differences in the Restoration Flow account balance. Therefore, from the risk management viewpoint, it is reasonable to maintain a high exceedence level use in early months because this would not impact Restoration Flow implementation, but would provide conservative allocations for water supply, as then currently being implemented. The limited differences in flow schedule in March across the six stair-step Restoration flow hydrographs would also alleviate concerns over using the forecast of a higher exceedence level.

Overall, the analysis above confirms the reasonableness of using the proposed 90-90-75-75-50 sequence of forecast exceedence for Restoration Flow implementation. Equity issues associated with the Restoration Flow account can be largely resolved by in-year adjustments, as demonstrated as an example in the above analysis. The remaining end-of-January balance is small and could be further resolved through real-time adjustments by the Secretary in consultation with advising parties.

The above validation demonstrates that the equity associated Restoration Flow accounting could be achieved; thus, RWA accounting can be decoupled.

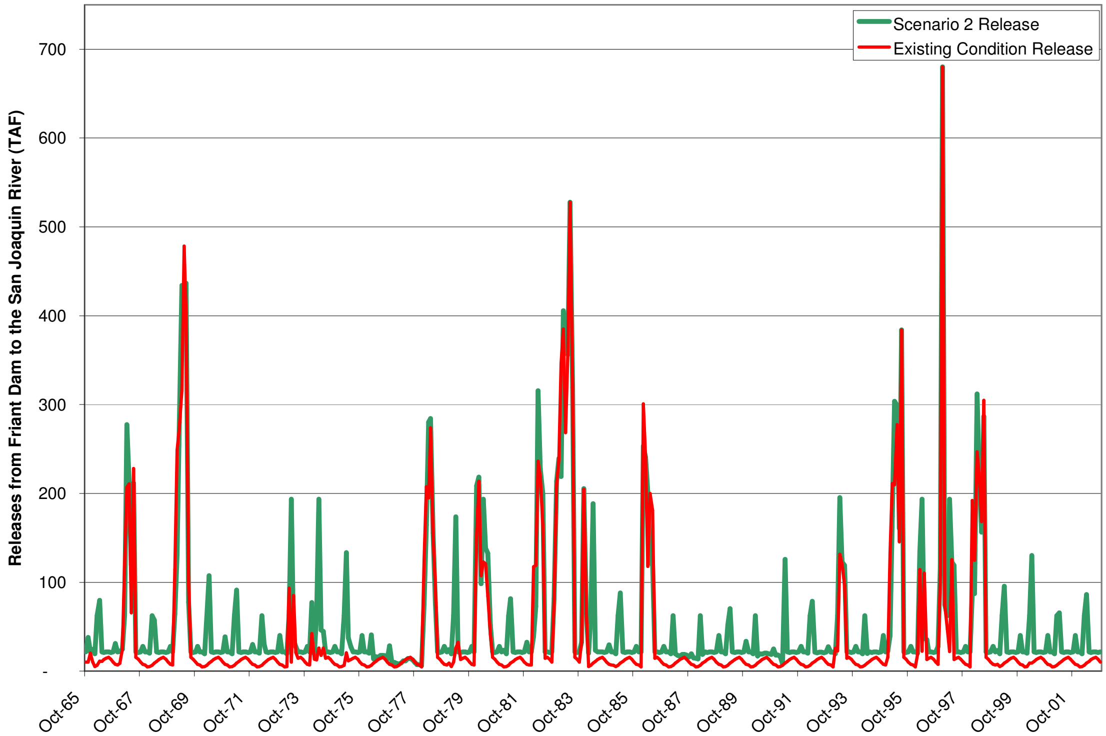


Figure 4-7.
Comparison of Flood Releases Under the Existing Operation with Releases Under Scenario 2.

5.0 Real-Time Operational Considerations

Additional real-time operational considerations may be considered as part of Friant Division operations. While some of the considerations are not stipulated in the Settlement, they could still relate to Restoration Flow management as part of overall water management practices of the Friant Division. Following is a list of additional real-time operational considerations that would be addressed at the appropriate level in the SJRRP Program Environmental Impact Statement/Report.

- Formal protocol for real-time adjustments that the Secretary may use for equity issues, in consultation with advising parties. The organization of advising parties and associated responsibilities is expected to be formalized through a policy document and through continued discussion with the RA, Settling Parties, and potential advising parties.

- Ramping rates that consider operational constraints at Friant Dam and downstream channels and levees, and constraints in fishery management for the Restoration Goal.

- Implementation of the flexible flow periods in spring and fall.

- Regular maintenance of facilities, which may require rescheduling Restoration Flow releases.

- Power operations as part of the release mechanism for providing Restoration Flows.

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