Mono Basin Stream Restoration and Monitoring Program:

Synthesis of Instream Flow Recommendations to the State Water Resources Control Board

and the

Los Angeles Department of Water and Power

DRAFT REPORT FOR PUBLIC REVIEW

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Cover photo: Aerial photograph of Rush Creek watershed, showing Grant Lake reservoir in the upper left, Parker and Walker creeks, and the confluence of Rush Creek with Mono Lake (lower right). Image date: June 23, 2003

ACKNOWLEDGEMENTS

With release of this Draft Synthesis Report, the Mono Basin once again becomes a focus of attention in how best to balance water resources for ecological benefits as well as human needs. There is no clear answer, and never will be. In the 2010 Mono Lake Calendar (provided by the Mono Lake Committee), retired Senior Environmental Scientist Jim Canaday summarized the Mono Basin's challenge:

> "The main ingredient for Mono Lake's future is 'time', and continued dedication by those working for it. Mono Lake is a work in progress. It can take hundreds and in certain instances thousands of years for the present conditions to recover their past. Even with restoration efforts, some things will never be as they were. In the future, the environment of the streams and the lake will surely have changed. So too will there be new generations dedicated to the protection and recovery of Mono Lake. Where there was once little hope there is now optimism. Continued dedication to the present will ensure a very bright future for Mono Lake."

The Stream Scientists wish to acknowledge the leadership of the State Water Resources Control Board and their Staff in championing the Mono Basin program and managing its important water allocation issues. Equally importantly, the licensee – Los Angeles Department of Water and Power – has demonstrated a strong commitment to the recovery of Mono Lake and its tributary streams while seeking to ensure a water supply for the City of Los Angeles. The many individuals and their efforts are too numerous to list here, but supplies proof of their dedication to make this recovery program succeed.

Several groups ambiguously referred to as the "Interested Parties" have also played an invaluable role in helping this program succeed. Of course, the Mono Lake Committee and CalTrout, original litigants in the Mono Basin hearings, have stayed the course, and have provided a tremendous influence on the 'process', our understanding of the lake and stream ecosystems, and, perhaps most importantly, the relevance of achieving the best balance. We also wish to acknowledge the Department of Fish and Game, US Forest Service, and Southern California Edison, for their participation in the program.

GLOSSARY OF TERMS

af – Acre-feet. Measurement of water stored or diverted.

CalTrout – California Trout, Incorporated

CDFG – California Department of Fish and Game

cfs – Cubic Feet per Second. Measurement of streamflow.

D-1631 – Decision 1631. SWRCB decision adopted in 1994 that revised the conditions of LADWP Licenses #10191 and 10192.

GLOMP – Grant Lake Operations Management Plan. A management plan required by Order 98-05.

GLR – Grant Lake Reservoir

IFS – Instream Flow Study. The trout habitat-flow relationship studies conducted by the Stream Scientists on Rush Creek in 2008 and on Lee Vining Creek in 2009.

kg/ha – Kilograms per hectare. Measurement of trout standing crop or biomass in creeks.

LAASM – Los Angeles Aqueduct Simulation Model. A model used to predict GLR and Mono Lake levels under various flow release and export scenarios.

LADWP – Los Angeles Department of Water and Power

MGORD – Mono Gate One Return Ditch

MLC – Mono Lake Committee

MSL – Mean Sea Level

NGDs – Number of Good Days. A metric used to evaluate effects of flow recommendations.

RY – Runoff Year

SCE – Southern California Edison

SEF – Stream Ecosystem Flows. The instream flows recommended by the Stream Scientists that will replace the existing SRF flows.

SRF – Stream Restoration Flows

SWRCB – State Water Resources Control Board

USFS – United States Forest Service.

WR Order 98-05 – SWRCB Order that described the Mono Basin stream and waterfowl habitat restoration measures.

WR Order 98-07 - SWRCB Order that addressed termination of monitoring activities required by WR98-05.

WUA – Weighted Useable Area. An instream flow study estimate of fish habitat as related to streamflow used in the Instream Flow Incremental Methodology (IFIM).

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EXECUTIVE SUMMARY

The State Water Resources Control Board (SWRCB) appointed two ‘Stream Scientists’ oversight of a monitoring program funded by Los Angeles Department of Water and Power (LADWP) to evaluate whether the Stream Restoration Flows (SRFs) and baseflow provisions in Order WR 98-05 were achieving the Restoration Program goals of “functional and self-sustaining stream systems with healthy riparian ecosystem components” and “trout in good condition” for Rush Creek and Lee Vining Creek in the Mono Lake Basin, CA. Pending monitoring results and analyses, the SWRCB also tasked the Stream Scientists to recommend necessary changes. This Synthesis Report is the summary of the Stream Scientists’ 12-year monitoring program and analyses, including their recommended actions.

As twelve years of monitoring unfolded, the Stream Scientists, with assistance from LADWP, California Department of Fish and Game (CDFG), the Mono Lake Committee (MLC), and CalTrout, identified these primary ‘how to’ changes: (1) prescribe more reliable Lee Vining Creek diversions and eliminate potential negative impacts, (2) accelerate recovery of the Lee Vining Creek ecosystem by encouraging SCE’s assistance in releasing higher peak snowmelt runoff events, (3) reduce SCE’s elevated winter baseflows in Lee Vining Creek to improve winter trout holding habitat, (4) actively manage for a more reliably fuller Grant Lake Reservoir (GLR), by diverting Lee Vining Creek streamflow throughout most of the runoff year, to increase the magnitude, duration, and frequency of GLR spills and to provide cooler dam releases into Rush Creek from a deeper reservoir, (5) adjust the Rush Creek Order 98-05 SRF streamflows, based on previous and ongoing scientific investigations, to achieve more desired ecological outcomes and processes and to improve the reliability of their release, (6) accelerate recovery of the Rush Creek ecosystem by encouraging Southern California Edison (SCE) and United States Forest Service (USFS) to assist in releasing higher peak snowmelt runoff events that reservoir spills managed only by LADWP cannot re-create, (7) provide shallow groundwater during snowmelt runoff necessary to promote riparian vegetation recovery on contemporary floodplains, and (8) recommend baseflow changes to the SRFs that will shift the brown trout population for both creeks toward a more varied age-class structure that includes older and larger fish by increasing adult habitat and improving specific growth rates to the greatest extent feasible within an ecosystem context.

Revised instream flows called ‘Stream Ecosystem Flows’ (SEFs) are recommended to replace the present SRFs. For Lee Vining Creek, the revised SEF instream flows and operations are a significant departure from Order 98-05. During the spring snowmelt period from April 1 to September 30, daily diversion rates are prescribed based on the prevailing flow at Lee Vining above Intake. All streamflow above the specified diversion rate passes the Lee Vining Intake into lower Lee Vining Creek and eventually flows into Mono Lake. Two conditions must be met before diverting streamflows.
No diversion is allowed when streamflows are less than 30 cubic feet per second (cfs) to protect riparian vegetation vigor sustained by a shallow groundwater table. No diversions are allowed when

streamflows exceed 250 cfs. Most major geomorphic work is accomplished by peak streamflows greater than 250 cfs. Unregulated streamflows above this threshold already have been significantly reduced in magnitude, duration, and frequency by SCE operations. Assistance from SCE will be necessary to help restore geomorphic processes important to Lee Vining Creek's recovery.

Lee Vining Creek baseflows from October 1 to March 31 have prescribed daily average "bypass flows" released from the Lee Vining Creek Intake. Streamflows above the prescribed baseflows are diverted into the Lee Vining Creek conduit to Grant Lake Reservoir. From October 1 through November 30, the recommended bypass streamflows range from 16 to 30 cfs and provide water depths at riffle crests adequate to allow unrestricted adult movement during brown trout spawning. From December 1 through March 31, daily average bypass flows from 16 to 20 cfs will provide abundant trout holding habitat based on adult holding habitat rating curves developed specifically for Lee Vining Creek. Recommended winter baseflows are considerably lower than the currently prescribed winter baseflows, yet are much closer to estimated unimpaired winter baseflows. Potential effects from severe winter icing will be investigated during the first few seasons of implementing these winter baseflow recommendations.

In Rush Creek, instream flow prescriptions continue to rely on bypass flows, similar to the existing SRF flow release strategy, but with enhanced emphasis on a fuller GLR to improve summer water temperatures and to increase the probability of spills from GLR to achieve peak snowmelt flood magnitudes. In drier runoff years when GLR is drawn down, augmentation with cooler water delivered from Lee Vining Creek via the 5-Siphon Bypass may benefit Rush Creek thermal conditions under certain water availability and climatic conditions. Lower fall and winter baseflows, based on results of the Instream Flow Study (IFS) (Taylor et al. 2009), will increase available winter holding habitat for brown trout. Dry and Dry-Normal I runoff years prioritize stream productivity and riparian maintenance, with less emphasis placed on accomplishing geomorphic processes or riparian regeneration.

Attaining necessary snowmelt flood magnitudes for Rush Creek will require assistance by SCE and USFS to release greater peak floods, which then spill from GLR into Rush Creek. Improved coordination of Rush Creek flow releases with Parker and Walker creeks' hydrographs to augment flood peak magnitudes below the Narrows and to improve flood peak timing relative to annual woody riparian seed release is recommended.

A snowmelt recession limb replaces steady summer baseflows in wetter years. Summer baseflows were revised in all runoff year types based on recession rate requirements for riparian vegetation and to provide cooler water temperatures for better brown trout growth and condition factors. All these instream flow modifications should hasten and enhance Rush Creek ecosystem recovery, as well as produce older and larger trout.

Continued curtailment of diversions from Parker and Walker creeks are recommended. Their flow contributions to Rush Creek below the Narrows were incorporated into targeted SEF flow magnitudes below the Narrows. Consequently the MGORD flow release recommendations were reduced accordingly. We recognize that this strategy results in slightly lower flows in Upper Rush Creek, and less intra-annual flow variability.

Three storage thresholds are recommended to guide GLR management. First, the existing Order 98-05 specifies a minimum storage volume of 11,500 acre-feet (af), below which SRF flow releases are not required. The LADWP Mono Basin Implementation Plan (MoBIMP) specifies a similar storage threshold of 12,000 af as "the minimum operating level." This threshold volume should remain at 11,500 af. In addition to precluding SEF releases, exports to the Owens River also should be restricted , to protect Rush Creek from spring or summer flow releases with higher than usual turbidity and water temperatures. Second, a minimum GLR elevation of 7,100 ft (approximately 20,000 af storage volume) should be maintained during July, August, and September of all runoff years. Below this threshold GLR elevation, release temperatures to the MGORD are frequently above temperature range providing robust brown trout growth, and depending on climatic conditions, water temperatures may continue to increase in downstream. Finally, in Wet-Normal, Wet, and Extremely-Wet runoff years, GLR elevation should be at the spillway elevation (7,130 ft or 47,171 af) for at least a two week period to facilitate GLR spills.

The Stream Scientists suggest that the current termination criteria specified in Order 98-07 have served their purpose in guiding a quantitative assessment of stream ecosystem recover over the past 12 years, but have limited utility in the next phase of instream flow implementation and monitoring. Five specific areas of continued trend monitoring are recommended:

1. Grant Lake Reservoir elevation, storage volume, and water temperature;
2. Stream and groundwater hydrology and stream temperature monitoring;
3. Geomorphic monitoring (aerial and ground photography, riffle crest elevations, deep pool and run frequency, sediment bypass operations);
4. Riparian vegetation acreage;
5. Trout population metrics.

These monitoring components resemble many aspects of monitoring conducted the past 12 years. However, the monitoring intensity, data interpretation, and restoration program responses are meant as a departure from the most recent past. Neither the stream restoration program nor the restoration monitoring program will cease entirely in the foreseeable future; however, the Stream Scientists recommend that LADWP implement the monitoring program as recommended in this Report, overseen by the SWRCB, and with a diminished role for the SWRCB-appointed Stream Scientists.

CHAPTER 1. INTRODUCTION: THE MONO BASIN STREAM RESTORATION AND MONITORING PROGRAM

1.1. Ecological and Historical Setting

Four tributaries feeding Mono Lake – Lee Vining, Parker, Walker, and Rush creeks – are subject to appropriative water rights held by the Los Angeles Department of Water and Power (LADWP). The streamflow regimes in these creeks have been a topic of particular interest since the City of Los Angeles began diverting water from the Mono Basin over sixty years ago. The Mono Basin is a closed basin located east of the crest of the Sierra Nevada Mountains (Figure 1-1). The basin is widely recognized for its scenic qualities, with the most prominent feature being Mono Lake (Decision 1631). Mono Lake is a terminal lake in a watershed with no outlet. Historically, Mono Lake's elevation has fluctuated greatly in response to natural conditions (see Stine 1987). Since 1941, the salinity, alkalinity, and water surface elevation of Mono Lake have also been affected by the export of water to the Owens River and through the LADWP Aqueduct. As a result of water export, the elevation of Mono Lake fell from 6,417 ft in 1941 to a historic low of 6,372 ft in 1982. At its lowest recent elevation in 1982, the lake volume was reduced by approximately 50% while salinity nearly doubled (JSA FEIR 1994). Lake elevation has risen from 6,375 ft in 1994 to a recent high elevation of 6,384.4 ft in 1999 after several consecutive wet years, and now stands at 6,381.5 ft as of November 1, 2009.

The four Mono Lake tributaries are the subject of this report. Each creek emerges from glaciated valleys of the Eastern Sierra escarpment and traverses broad alluvial plains underlain mostly by deltaic gravels and young volcanic rocks (Lajoie 1968, Bailey 1989, from Kondolf and Vorster 1993). Each creek supported a riparian corridor of woody, herbaceous, and seasonal vegetation, marshlands, wet meadows, and abundant springs, partitioning the surrounding desert landscape. Each creek also sustained a native invertebrate and wildlife community, with non-native trout populations later introduced.

The history of land and water development in the Mono Basin, dating back at least to the 1860s, has been well documented in numerous sources (e.g., see the Mono Lake Committee's Mono Basin Clearinghouse at (http://www.monobasinresearch.org). Water was initially diverted for irrigation, milling, mining, hydropower generation, stockwatering, and domestic uses. Irrigation water was re-routed from many of the basin's streams by a system of ditches and canals. In many summers prior to 1941, the Rush Creek channel was dry from Grant Lake down to the Narrows because of irrigation withdrawals. Dams were constructed for hydropower generation in the upper Rush Creek basin beginning in 1916 at Waugh Lake, Gem Lake and Agnew Lake, and on Lee Vining Creek in 1924 at Tioga Lake, Ellery Lake, and Saddleback Lake. Hydropower systems in both basins are now operated by Southern California Edison (SCE). In 1915, a 10 ft high dam was constructed on Rush Creek to enlarge the capacity of Grant Lake, a natural lake formed by a glacial moraine (Kondolf and Vorster 1993). The height of the dam was increased to 20 feet in 1925 to provide additional storage. The current Grant Lake Dam was constructed in

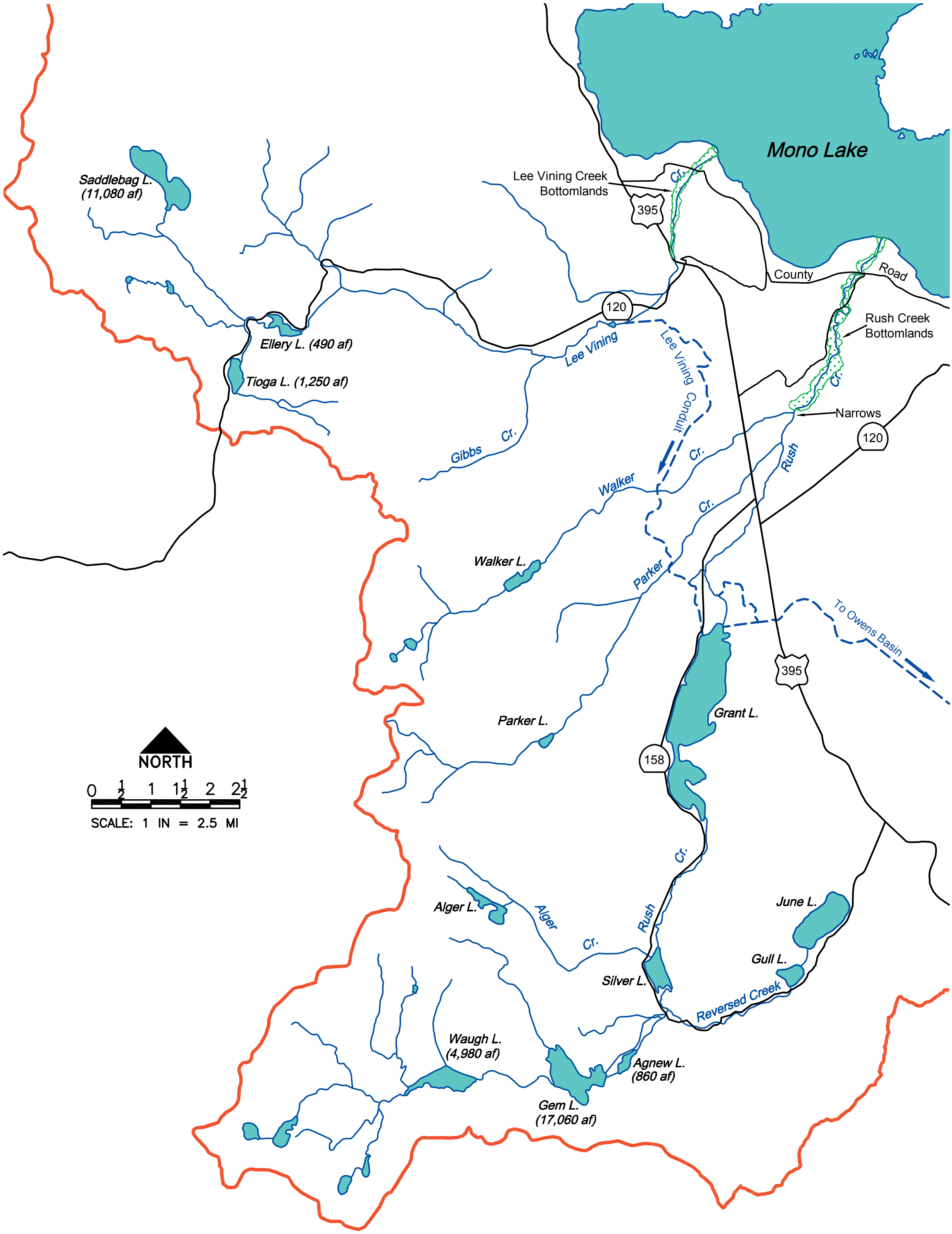


Figure 1-1. Major hydrologic features of the Mono Basin, CA and the location of Rush, Parker, Walker, and Lee Vining creeks.

1940 and has a storage capacity of 47,171 acre-feet (af) at the spillway elevation of 7,130 ft. (LADWP 1996). The crest elevation is 7,145 ft MSL.

Another chapter in the manipulation of Mono Lake tributaries by European settlers was the introduction of non-native trout species. Beginning in the 1880's, the streams were stocked with a variety of non-native trout species; including Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*), brown trout (*Salmo trutta*), steelhead/rainbow trout (*O. mykiss sp.*) and brook trout (*Salvelinus fontinalis*). Each species had varying degrees of success in maintaining self-sustaining populations. In the decade prior to 1941, the streams supported mostly self-sustaining brown trout populations with some rainbow and brook trout present; the fishery was also augmented by regular stocking of hatchery trout to meet rapidly increasing fishing pressure and declining catch rates.

1.2. The State Water Resources Control Board Order 98-05

Export of water from the Mono Basin by LADWP beginning in 1941 continued the legacy of land and water development. In the conclusion of its seminal Decision 1631 (D1631), the State Water Resources Control Board noted that "Los Angeles' export of water from the Mono Basin has provided a large amount of high quality water for municipal uses, but it has also caused extensive environmental damage. In 1983, the California Supreme Court ruled that the State Water Resources Control Board had the authority to re-examine past water allocation decisions and the responsibility to protect public trust resources where feasible." Based on that authority, in 1994 the SWRCB adopted Decision 1631 and amended LADWP's water right licenses to establish instream fishery flows and channel maintenance flows for Rush, Lee Vining, Walker, and Parker creeks. Water released to these streams was also intended to protect the public trust resources at Mono Lake. The four tributaries – Rush, Parker, Walker, and Lee Vining creeks – were permanently re-watered in June 1982, March 1987, October 1990, and October 1990, respectively.

Decision 1631 also required LADWP to prepare a Stream and Stream Channel Restoration Plan (Ridenhour et al. 1996), a Grant Lake Operations and Management Plan (GLOMP) (LADWP 1996), and a Waterfowl Habitat Restoration Plan (LADWP 1996). The subsequent SWRCB Order 98-05 revised the D1631 flows, and put in place minimum baseflow requirements and "Stream Restoration Flows" (SRFs) for each of the four streams. Order 98-05 also established a stream monitoring program under the supervision of two SWRCB-appointed Stream Scientists – William Trush and Chris Hunter. The monitoring program's principle mandate was to (1) "evaluate and make recommendations, based on the results of the monitoring program, regarding the magnitude, duration and frequency of the SRFs necessary for the restoration of Rush Creek; and the need for a Grant Lake bypass to reliably achieve the flows needed for restoration of Rush Creek below its confluence with the Rush Creek Return Ditch" and (2) "evaluate the effect on Lee Vining Creek of augmenting Rush Creek flows with up to 150 cubic feet per second (cfs) of water from Lee Vining Creek in order to provide SRFs." This evaluation was to take place "after two data gathering cycles (as defined in the stream monitoring plan), but at no less than 8 years nor more than 10 years after the monitoring program begins."

Extensive monitoring the past 12 years has been examining the efficacy of the SRF flows and baseflows in restoring and maintaining the Mono Lake tributaries. In general, stream and groundwater hydrology, geomorphology, and riparian ecology studies have been overseen by William Trush while trout population studies have been overseen by Chris Hunter and his successor Ross Taylor. Several projects and tasks have been planned and implemented cooperatively, including the analyses of existing SRF and baseflows and preparation of the revised streamflow recommendations in this report.

SWRCB Order 98-05 specifies a "Transition Period" and a "Post-Transition Period" to distinguish before and after Mono Lake reaches its target elevation of 6,391 ft, and assigned different SRFs, baseflows, and export allocations (Figure 1-2) for these two periods. Mono Lake has not reached the target elevation of 6,391 ft. The Stream Scientists recommend adopting the following flow regime to accelerate recovery and maintain stream ecosystem functions identified and studied in the monitoring program. To distinguish revised flow recommendations from the D1631 "Channel Maintenance Flows" and the Order 98-05 "Stream Restoration Flows, or SRFs, new streamflow recommendations provided in this report will be referred to as "Stream Ecosystem Flows" or SEFs.

This report to the SWRCB summarizes and references the Stream Scientists' findings, and recommends revising the SRF flows and baseflows. Existing SRF and baseflow regimes are described in SWRCB Order 98-05 and reviewed in Section 2.1 of this report. Revised flow recommendations are presented in Section 2.4. These revised SEF streamflow recommendations do not change water export allocations in pre- and post-transition periods (Figure 1-2), as specified in Order 98-05.

1.3. Stream Restoration and Monitoring Program Goals

The *stream restoration program* instituted by Order 98-05 established the overall goal of developing "functional and self-sustaining stream systems with healthy riparian ecosystem components." The program proposed to "restore the stream systems and their riparian habitats by providing proper flow management in a pattern that allows natural stream processes to develop functional, dynamic, and self-sustaining stream systems." The fisheries restoration program's overall goal was to have self-sustaining trout populations with fish in "good condition" that could support a "moderate level" of angler harvest.

The goal of the *stream monitoring program* directed by Order 98-05 has been to evaluate the performance of the existing flow regime and make adjustments where data and information warrant changes. In addition to recommending

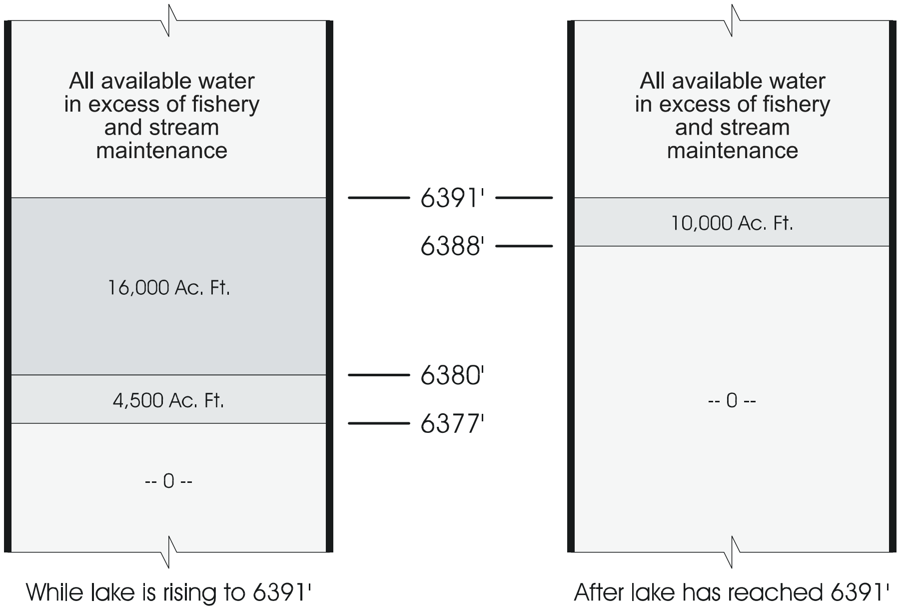


Figure 1-2. Export allocations and conditions specified in SWRCB Order 98-05 for pre-Transition and post-Transition periods while Mono Lake is filling to the target elevation of 6,391 ft.

changes to the magnitude, timing, duration, and frequency of specific hydrograph components to better achieve ecosystem recovery goals, improved operational reliability was an important objective.

The stream restoration goals established in the SWRCB Decision 1631 and Order 98-05 acknowledge that the four Mono Basin tributaries may never return to the same conditions prior to 1941. Those conditions resulted from their geologic histories, centuries of natural Mono Lake elevation fluctuations, different sediment and streamflow regimes, and decades of resource extraction and management activities by the initial settlers of European decent. Many of those conditions are permanently altered. However, healthy stream ecosystems are recovering, and will continue to mature under contemporary flow and sediment regimes and land use protections. The Order 98-05 SRF streamflows have provided a good initial impetus for recovery.

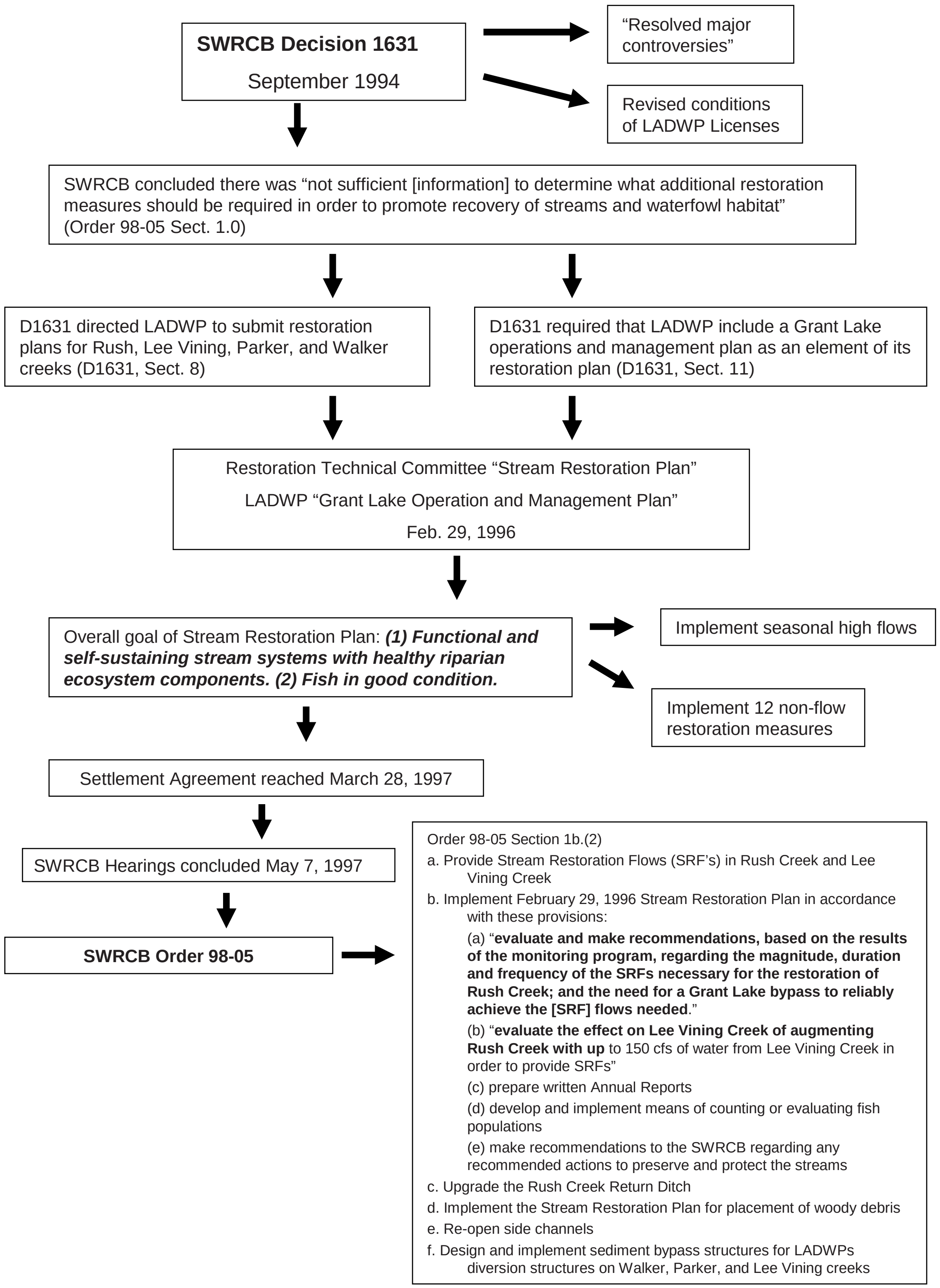
The monitoring program for the four tributaries was described in the Plan for Monitoring the Recovery of the Mono Basin Streams, colloquially known as the White Book and the Blue Book. The White Book listed the various monitoring activities for each of the streams, described their scope and duration, and established protocols for data gathering. The Blue Book established the methodology to be used in the analysis and evaluation of the data. The monitoring program has generally followed these protocols during the past 12 years, with revisions made as needed.

Monitoring Dry to Wet runoff years provided invaluable opportunities to evaluate specific annual hydrograph components and the ecological functions each provides. A runoff year (RY) begins April 1 and ends the following March 31. For example, during the Normal RY2005 SRF release, sediment transport and deposition rates were measured with a series of controlled Grant Lake Reservoir releases to evaluate the magnitude and duration of SRF releases. In RY1999, RY2004, and again in RY2009, the woody riparian vegetation along the Rush and Lee Vining stream corridors was mapped and quantified, then compared to pre-1941 estimated vegetation acreages. Trout populations have also been tracked through annual population estimates conducted in several representative stream monitoring reaches. The primary objective of annual fisheries monitoring was to collect baseline information about the trout fisheries in Rush and Lee Vining creeks to better understand the dynamics of the populations over a range of runoff year types and SRF releases. Additional studies were conducted to quantify trout habitat (habitat typing surveys), analyze thermal conditions, and study the movement patterns and seasonal habitat preferences of brown trout in Rush Creek, including:

- Rush and Lee Vining Creeks Instream Flow Study (Taylor et al. 2009a);
- Calibration of a Water Temperature Model for Predicting Summer Water Temperatures in Rush Creek below Grant Lake Reservoir (Shepard et al. 2009);
- Effects of Flow, Reservoir Storage, and Water Temperatures on Trout in Lower Rush and Lee Vining Creeks, Mono County, California (Shepard et al. 2009);
- Radio Telemetry-Movement Study of Brown Trout in Rush Creek (Taylor et al. 2009b)
- Pool and Habitat Studies on Rush and Lee Vining Creeks (Knudson et al. 2009);
- Comparison of snowmelt ascending limb ramping rates from unregulated hydrographs with regulated Grant Lake releases to Rush Creek (McBain and Trush 2002);
- Riparian Vegetation Atlas Mono Basin Tributaries: Rush, Parker, Walker, and Lee Vining creeks (McBain and Trush 2005);

This Synthesis Report references supporting documentation either by citing earlier reports or by providing relevant information in appendices.

The Mono Basin monitoring program has exemplified adaptive management. Interim streamflows and recovery goals were established in 1998. Monitoring approaches were specified in the Blue and White Books; results and



SWRCB Decision 1631

September 1994

"Resolved major controversies"

Revised conditions of LADWP Licenses

SWRCB concluded there was "not sufficient [information] to determine what additional restoration measures should be required in order to promote recovery of streams and waterfowl habitat" (Order 98-05 Sect. 1.0)

D1631 directed LADWP to submit restoration plans for Rush, Lee Vining, Parker, and Walker creeks (D1631, Sect. 8)

D1631 required that LADWP include a Grant Lake operations and management plan as an element of its restoration plan (D1631, Sect. 11)

Restoration Technical Committee "Stream Restoration Plan"

LADWP "Grant Lake Operation and Management Plan"

Feb. 29, 1996

Overall goal of Stream Restoration Plan: ***(1) Functional and self-sustaining stream systems with healthy riparian ecosystem components. (2) Fish in good condition.***

Implement seasonal high flows

Implement 12 non-flow restoration measures

Settlement Agreement reached March 28, 1997

SWRCB Hearings concluded May 7, 1997

SWRCB Order 98-05

Order 98-05 Section 1b.(2)

a. Provide Stream Restoration Flows (SRF's) in Rush Creek and Lee Vining Creek

b. Implement February 29, 1996 Stream Restoration Plan in accordance with these provisions:

  (a) "**evaluate and make recommendations, based on the results of the monitoring program, regarding the magnitude, duration and frequency of the SRFs necessary for the restoration of Rush Creek; and the need for a Grant Lake bypass to reliably achieve the [SRF] flows needed**."

  (b) "**evaluate the effect on Lee Vining Creek of augmenting Rush Creek with up** to 150 cfs of water from Lee Vining Creek in order to provide SRFs"

  (c) prepare written Annual Reports

  (d) develop and implement means of counting or evaluating fish populations

  (e) make recommendations to the SWRCB regarding any recommended actions to preserve and protect the streams

c. Upgrade the Rush Creek Return Ditch

d. Implement the Stream Restoration Plan for placement of woody debris

e. Re-open side channels

f. Design and implement sediment bypass structures for LADWPs diversion structures on Walker, Parker, and Lee Vining creeks

Figure 1-3. Summary of important steps in the State Water Resources Control Board (SWRCB) process outlining the Mono Basin Stream Restoration and Monitoring Programs and the directive to evaluate and revise SRF and Baseflow requirements.

analyses from the ensuing years of monitoring were reported in Annual Reports. With revised SEF streamflow recommendations presented in this Synthesis Report, the Mono Basin monitoring program will not cease, but a new phase of monitoring will begin.

Completion of this Synthesis Report marks the beginning of a process initially established in Order 98-05, in which the Stream Scientists were directed to evaluate and revise the SRF streamflows and baseflows (Figure 1-3). The first next step will entail LADWP's allotted 120 day period to review the SEF streamflow recommendations, and revise the Grant Lake Operations and Management Plan (GLOMP), to determine the feasibility of implementing the flow recommendations. Next, the SWRCB will solicit peer review comments from interested stakeholders and the public, and may direct the Stream Scientists to address peer comments and/or revise analyses. LADWP then plans to submit a request to the SWRCB for a 1-year temporary operating permit to implement the SEF flows. After this interim implementation year, presumably as early as 2011, the SWRCB may issue a new Order codifying an SEF flow regime and next phase of Mono Basin stream monitoring program.

1.4. What this Synthesis Report is Intended to Do

This Synthesis Report builds on results presented in Annual Reports, additional monitoring reports, and technical memoranda to (1) summarize the overall performance of the SRF and baseflow hydrographs, and (2) modify the Order 98-05 flow prescriptions deemed beneficial to stream ecosystem recovery and trout populations. Instream flow evaluations focused on the magnitude, duration, timing and frequency of flows required to achieve specific desired ecological objectives and the Restoration Program goal of "functional and self-sustaining stream systems with healthy riparian ecosystem components."

In this Synthesis Report, Chapters 1 and 2 summarize background information and contemporary stream, riparian, and fishery conditions as necessary context for presenting the flow recommendations. Section 2.4 presents the SEF flow recommendations and key operational requirements. Chapters 3 through 5 describe the analytical framework and primary analyses used to derive SEF flow recommendations. Those chapters present technical information to support the analyses, reference past monitoring reports, or reference appendices. The report concludes with discussions of GLR simulations, sediment bypass operations, potential effects of climate change to the Mono Basin, recommendations on the Termination Criteria established in Order 98-05, and the next phase of adaptive management and monitoring in the Mono Basin.

CHAPTER 2. STREAM ECOSYSTEM FLOW RECOMMENDATIONS

2.1. Summary of Mono Basin Hydrology, LADWP Operations, and Current Instream Flow Requirements

The Mono Basin is dominated by snowmelt runoff from the Sierra Nevada. Rush Creek and Lee Vining are the largest of the four tributaries to Mono Lake (Table 2-1). Parker and Walker creeks join Rush Creek mid-way down its course from Grant Lake to Mono Lake, at the downstream end of Rush Creek's steeper section just upstream of the Narrows (Figure 1-1). Below the Narrows, Rush Creek's valley widens into "the bottomlands", forming a 4.5 mile long meandering, braided stream course, then an alluvial Delta that joins Mono Lake. This section of Rush Creek receives perhaps the most attention of all the tributaries because of the lush riparian bottomlands and the pre-1941 trout fishery. Lee Vining Creek similarly has a steeper, relatively undisturbed upper canyon reach that extends from the Lee Vining Intake downstream below Hwy-395, before emerging into its valley bottomland.

Unimpaired annual hydrographs for Rush and Lee Vining creeks exist only in the upper elevations of each watershed. Snowmelt and year-round streamflow is captured by SCE storage reservoirs, sent to penstocks for hydropower generation, then released downstream. Streamflows arriving at LADWP storage and diversion facilities (GLR and Lee Vining Creek Intake) are thus already regulated by SCE hydropower operations. However, long-term annual yield (water volume) is not changed appreciably (Hasencamp 1994). The average annual unimpaired runoff from the four tributaries is in Table 2-1. Although

Table 2-1. Drainage area and annual yield for each of the four Mono Lake tributaries regulated by LADWP.

Watershed	Drainage Area (sq mi)	Elevation (ft)	Annual Yield RY1941 to 1990	Annual Yield RY1941 to 2008
Rush Creek at Damsite *	51.3	7,200	59,253	59,270
Lee Vining Creek above Intake *	34.9	7,400	46,738	46,543
Parker Creek above Conduit	13.7	7,136	8,104	8,285
Walker Creek above Conduit	15.7	7,143	5,991	5,571
Four Mono Lake Tributaries			122,124	121,695

*source:USGS

the operation of these reservoirs redistributes flow on a monthly basis, net storage change during the runoff year (April 1 to March 31) is negligible on both streams (LADWP 1996 p.13).

LADWP diverts water from Lee Vining, Walker, and Parker creeks via the Lee Vining Conduit (LVC) into Grant Lake Reservoir on Rush Creek (Figure 2-1). Water is then exported from the Mono Basin through the Mono Craters Tunnel, traveling down the Owens River before entering the Los Angeles Aqueduct south of Bishop, CA. Two operational facilities are the focal points of Mono Basin operations: the Lee Vining Intake and Grant Lake Reservoir. The Lee Vining Intake is the beginning of LADWP water diversion operations at the head of the LVC. The Intake receives streamflows regulated by SCE hydropower operations, diverts flow into the Conduit, and/or bypasses flow into lower Lee Vining Creek. Grant Lake Reservoir is the heart of LADWP's Mono Basin operations, and stores water delivered from Lee Vining Creek (and Parker and Walker creeks if diversions occur) and captured water from Rush Creek.

Estimated Unimpaired Flows. Unimpaired flows are reported by LADWP as 'Rush Creek Runoff' and 'Lee Vining Creek Runoff'. This report refers to these flows as 'estimated unimpaired', or simply 'unimpaired' flows. We refrain from the term 'natural flows' because these estimated unimpaired flows do not occur downstream of SCE reservoirs. Unimpaired daily average flow data were developed by obtaining the SCE reservoir storage data from RYs 1990 to 2008 published by USGS, converting the storage data to reservoir inflow rates, and adding this flow to measured flows at LADWP gaging station data. Unimpaired flows are thus synthetic (i.e., they are not measured flows). Hasencamp (1994) states "because measuring

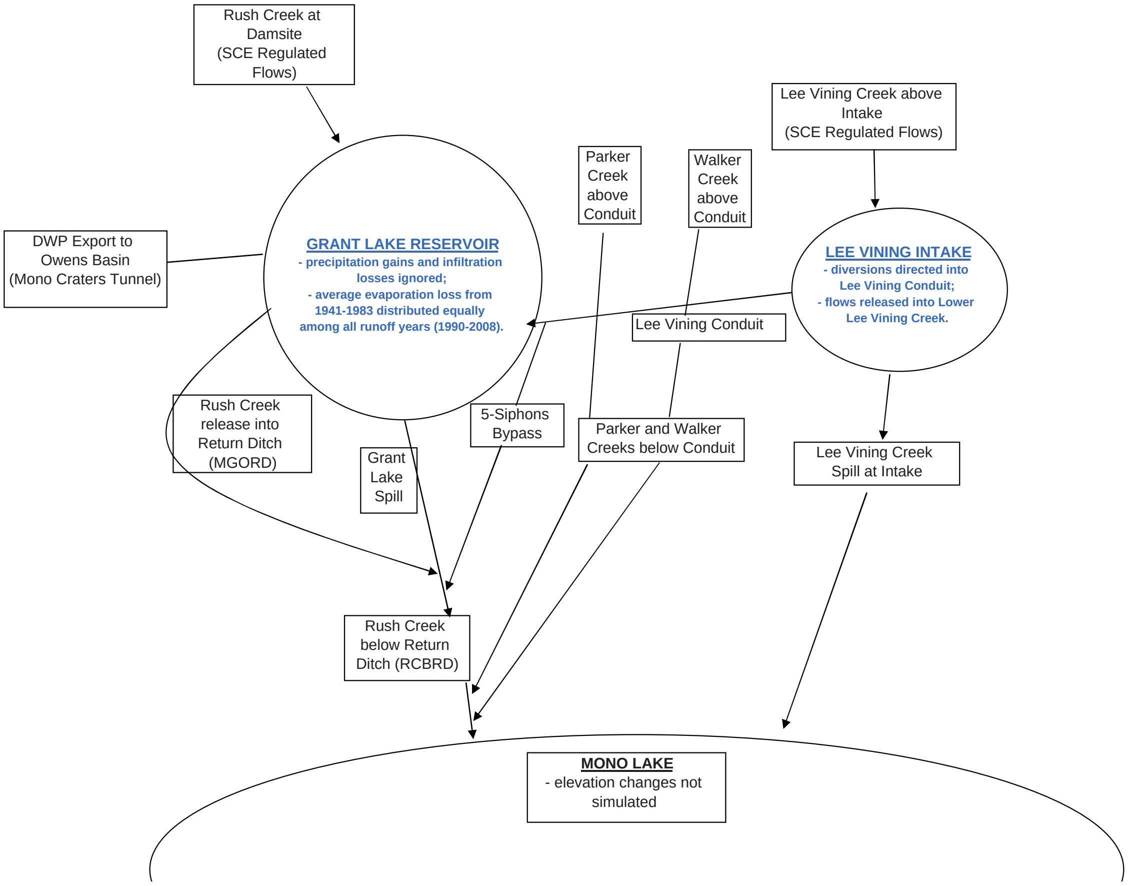


Figure 2-1. Diagram of LADWP's Mono Basin water export facilities, and flow release, diversion, and export pathways.

storage change is much less accurate than measuring flow rates, the natural (unimpaired) hydrograph is an approximation of natural flow, with ± 50 cfs uncertainty during higher flows." Hasencamp (1994) and the McBain and Trush RY2003 Annual Report describe the unimpaired hydrographs for Rush Creek (above Grant Lake Reservoir) and for Lee Vining Creek (at the LADWP Intake). Hasencamp estimated that 70% of the total annual runoff that reaches GLR flows through the SCE reservoirs; similarly on Lee Vining Creek several tributaries enter the creek below SCE's reservoirs. Adding the measured flow at the Rush Creek at Damsite and Lee Vining Creek above Intake gages accounts for flow from unregulated portions of the watershed. Unimpaired hydrographs were made available by LADWP (Hasencamp 1994) for RY1940 to RY1972 for the four month snowmelt period (May to August) and for RY1974 to RY1994 for the entire runoff year. Unimpaired data were extended through RY2008 for analyses in this Report. Estimated unimpaired flows are also computed below the Rush Creek Narrows by adding Parker and Walker creek flows above the Conduit to Rush Creek unimpaired flows. Data from nearby Buckeye Creek (USGS Stn 10291500) were also scaled to Rush Creek's watershed area to evaluate unimpaired hydrograph components. Analyses focus on the 19 year period of record for RY1990 to RY2008 (Table 2-2). The annual hydrographs, hydrograph component analyses, and flood frequency analyses are presented in Appendices A 1-4.

<u>SCE Regulated Flows.</u> Streamflows arriving at the Lee Vining Intake and Grant Lake Reservoir on Rush Creek are regulated by SCE. These regulated streamflows are gaged by LADWP and are referenced as 'Lee Vining above Intake (5008)' (Figure 2-2) and 'Rush Creek at Damsite (5013)' (Figure 2-3). These regulated hydrographs are referenced as "SCE

Table 2-2. Runoff year types and associated water yields from Runoff Year 1990 to 2008, including the most recent 12 years in which intensive monitoring has been conducted in the Mono Basin. The complete record of Mono Basin annual yields is provided in Appendix A.

Runoff Year	**Runoff Year Type**	**Percent of Average Runoff**	**Rush Creek at Damsite (af)**	**Lee Vining Creek above Intake (af)**	**Parker Creek above Conduit (af)**	**Walker Creek above Conduit (af)**	**Four Mono Lake Tributaries (af)**
1980	WET	139.2%	83,240	63,046	10,855	7,990	165,131
1981	DRY-NORMAL II	81.9%	48,657	36,625	6,967	4,518	96,767
1982	EXTREME-WET	173.8%	105,591	83,134	11,508	9,482	209,714
1983	EXTREME-WET	196.1%	118,178	90,865	15,350	12,132	236,525
1984	WET-NORMAL	121.0%	65,279	62,222	8,834	6,810	143,145
1985	NORMAL	88.3%	50,563	42,597	6,516	4,687	104,363
1986	WET	139.8%	80,627	67,517	10,867	7,793	166,803
1987	DRY	55.6%	34,441	24,485	4,662	3,129	66,716
1988	DRY	57.3%	31,677	26,625	4,576	3,232	66,110
1989	DRY-NORMAL I	73.5%	42,136	37,126	4,599	3,692	87,554
1990	DRY	49.0%	32,246	20,144	4,412	2,433	59,235
1991	DRY	63.8%	38,137	26,644	5,890	3,191	73,862
1992	DRY	59.6%	39,033	25,173	5,793	3,135	73,134
1993	WET-NORMAL	114.9%	73,320	50,313	7,346	5,225	136,205
1994	DRY	62.4%	36,619	28,308	5,448	3,509	73,884
1995	EXTREME-WET	176.3%	110,105	76,813	14,555	9,303	210,776
1996	WET-NORMAL	135.0%	78,862	65,295	10,776	7,491	162,423
1997	WET-NORMAL	117.4%	63,618	60,554	8,537	6,522	139,230
1998	WET	141.4%	86,259	64,044	11,546	8,320	170,169
1999	NORMAL	92.5%	51,755	46,773	7,332	5,061	110,920
2000	NORMAL	91.4%	57,064	41,236	7,760	4,524	110,584
2001	DRY-NORMAL II	75.8%	48,732	32,613	7,809	3,927	93,081
2002	DRY-NORMAL I	73.9%	41,264	37,463	6,343	3,779	88,848
2003	DRY-NORMAL II	81.9%	50,257	41,342	7,492	3,861	102,952
2004	DRY-NORMAL I	73.0%	44,533	34,779	6,118	3,671	89,101
2005	WET	145.8%	91,786	65,677	12,616	8,026	178,105
2006	WET	154.9%	93,909	74,558	12,463	8,227	189,157
2007	DRY	45.9%	22,122	24,097	5,020	2,330	53,569
2008	NORMAL	70.2%	40,380	32,302	6,031	3,329	82,042
2009	NORMAL	88% (Predicted)					
1941-2008 Average Runoff			**59,270**	**46,543**	**8,208**	**5,494**	**122,073**

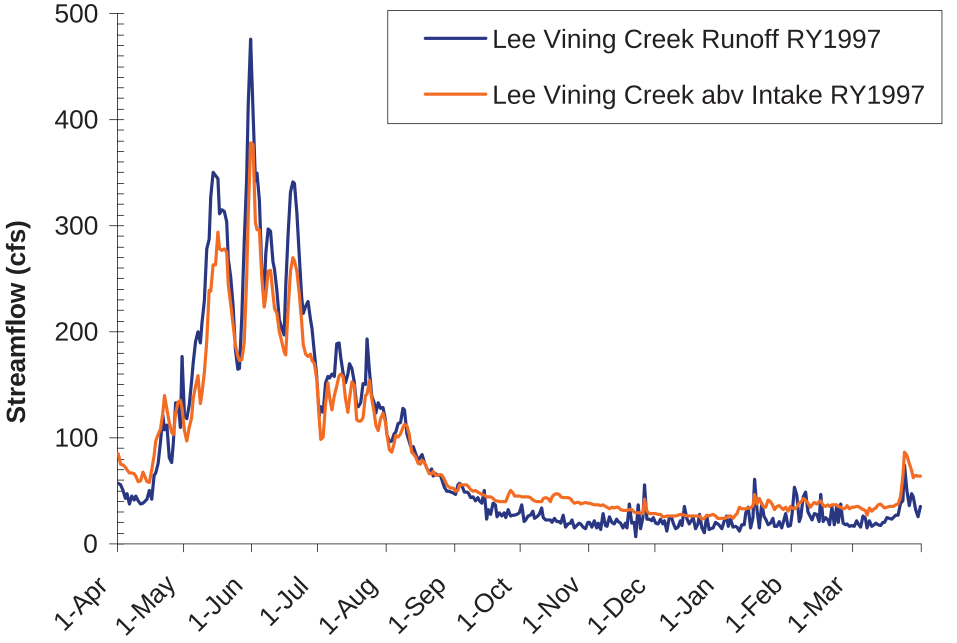


Figure 2-2. Annual hydrograph for Lee Vining Creek Runoff (unimpaired) and Lee Vining Creek above Intake (SCE regulated) for Wet-Normal RY1997.

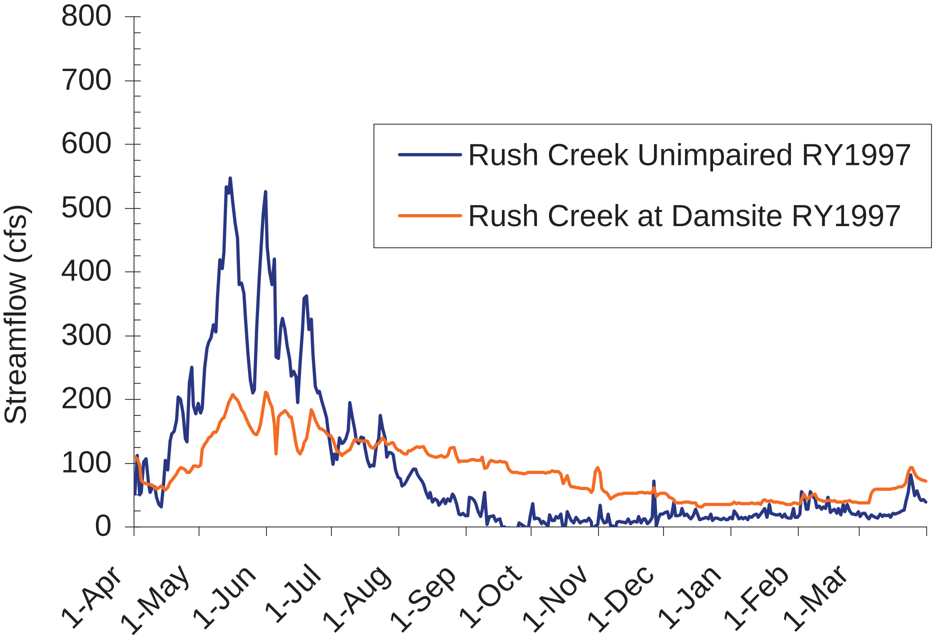


Figure 2-3. Annual hydrograph for Rush Creek Runoff (unimpaired) and Rush Creek at Damsite (SCE regulated) for Wet-Normal RY1997.

annual hydrographs". In general, peak flows are diminished while baseflows are inflated by SCE (Hasencamp 1994) as snowmelt is captured in SCE storage reservoirs in spring and slowly released through the following year for hydropower generation. Flood frequency analyses in the McBain and Trush RY2003 Annual Report were updated through RY2008 (Appendix A-4). Gaging records for Rush Creek at Damsite were available from RY1937 to present as daily average flow (RY1980 to RY1989 were available only as mean monthly flow). Lee Vining Creek above Intake flows were available for RY1978 to present, but RY1980 to RY1989 were similarly available only as mean monthly flow. With these data, a primary focus was on RYs 1990 to 2008. To demonstrate the extent of regulation from SCE operations, the unimpaired annual hydrographs were plotted with the SCE regulated flows for RY1990 to 2008 (Appendix A-1 and A-2). Flood frequency curves based on the peak daily average values for the entire period of record are in Appendix A-3.

Stream Restoration Flows (SRFs). The SRF flows and baseflows are minimum streamflows prescribed by Order 98-05 for release by LADWP below their storage and diversion facilities (Table 2-3). LADWP measures flows at the Lee Vining Creek Intake facility in two locations: at the Parshall flume immediately above the Intake ('Lee Vining Creek above Intake') and below the diversion structure ('Lee Vining Creek Spill at Intake'). The 'Lee Vining Creek Spill at Intake' flows are also referred to as 'Lee Vining Creek below Intake'; both describe flows bypassing the Intake and into Lower Lee Vining Creek. Flow is also measured after entering the Lee Vining Conduit at a site called Lee Vining *Conduit* Below Intake. At the diversion facility, flow can either be diverted into the conduit or spilled over the weir to continue down the creek. A radial gate regulates streamflow entering the conduit.

In Rush Creek, flows are released through the Mono Gate One Return Ditch (MGORD or Return Ditch) (Figure 1), and are gaged and reported as 'Rush Creek at Return Ditch' (5007). MGORD flow releases constitute the streamflows originating from upper Rush Creek. Parker and Walker creeks join Rush Creek below the MGORD but before the Narrows and thus augment the annual flow regime below the Narrows. Streamflows below the Narrows are not gaged, but are computed and referenced as 'Rush Creek below the Narrows'. A gaging station was established at the Rush Creek County Road for the monitoring program, but has not been continuously maintained.

Stream Ecosystem Flows (SEFs). To distinguish revised flow recommendations from existing SRF flows, and to emphasize the transition from stream restoration to ecosystem maintenance, the Stream Scientists refer to the revised flow regime as 'Stream Ecosystem Flows'. Recommended Stream Ecosystem Flows (SEFs) are presented for Rush and Lee Vining creeks in Section 2.4. Appendix A-1 presents simulated annual hydrographs for SEF flows plotted with the actual SRF flows for RY1990 to RY2008, for Lee Vining below the Intake and for Rush Creek below the Narrows.

Parker and Walker Creek Flows. Parker and Walker creeks contribute approximately 12 % of the average annual yield of the four Mono Lake tributaries (Table 2-1). More importantly, however, they provide a vital variable flow addition to lower Rush Creek, partially compensating for the year-round steady flows released from Grant Lake Reservoir. Unimpaired Parker and Walker creek flows are measured at the LADWP conduit (Figure 1-1), referenced as 'Parker or Walker Creek above the Conduit'. Gaged flows are released from small impoundments at the Conduit into the lower Parker and Walker creeks, where they flow to join Rush Creek above the Narrows. Parker Creek has two forks; South Parker Creek is also gaged by LADWP. SRF flows are prescribed by Order 98-05 for Parker and Walker creeks (Table 2-3). Since Order 98-05, LADWP has refrained from diverting from Parker and Walker creeks, except for rare occasions. Parker and Walker creek flows are summarized in Appendix A-5.

Table 2-3a. Current SWRCB Order 98-05 baseflow requirements for the four Mono Lake tributaries. All flows are in cfs.

Creek	Year-Type[1]	Apr	May	June	July	Aug	Sept	Oct-Mar
Rush	Dry	31	31	31	31	31	31	36
	Dry-Normal	47	47	47	47	47	47	44
	Normal	47	47	47	47	47	47	44
	Wet-Normal	47	47	47	47	47	47	44
	Wet	68	68	68	68	68	68	52
	Extreme	68	68	68	68	68	68	52
Lee Vining	Dry	37	37	37	37	37	37	25
	Normal & Wet	54	54	54	54	54	54	40
	Extreme	Flow through conditions for the entire year						
Parker	Dry	9	9	9	9	9	9	6
	Normal, Wet, & Extreme	Flow Through conditions for the entire year						
Walker	Dry	6	6	6	6	6	6	4.5
	Normal, Wet, & Extreme	Flow through conditions for the entire year						

Notes:

[1] Year Types are based on 1941-1990 average runoff of 122,124 acre-feet and are defined as follows:

Rush Creek

Dry	less than 68.5% of average runoff
Dry-Normal	between 68.5% and 82.5% of average runoff
Normal	between 82.5% and 107% of average runoff
Wet-Normal	between 107% and 136.5% of average runoff
Wet	between 136.5% and 160% of average runoff
Extreme	greater than 160% of average runoff

Lee Vining, Walker and Parker Creeks

Dry	less than 68.5% of average runoff
Normal	between 68.5% and 136.5% of average runoff
Wet	between 136.5% and 160% of average runoff
Extreme	greater than 160% of average runoff

[2] Adjustments to flows may occur during the runoff year.

Table 2-3b. Current SWRCB Order 98-05 Stream Restoration Flow (SRF) requirements for the four Mono Lake tributaries.

Creek	Year-Type[1]	Order 98-05
Rush	Dry	None
	Dry-Normal[5]	250 cfs for 5 days[3] 200 cfs for 7 days[4]
	Normal[5]	380 cfs for 5 days 300 cfs for 7 days
	Wet Normal	400 cfs for 5 days & 350 cfs for 10 days
	Wet	450 cfs for 5 days & 400 cfs for 10 days
	Extreme	500 cfs for 5 days & 400 cfs for 10 days
Lee Vining[2]	Dry	None
	Normal[5]	Allow peak to pass
	Wet	Allow peak to pass
	Extreme	Flow through conditions
Parker	Dry	None
	Normal, Wet, & Extreme[5]	Flow through conditions
Walker	Dry	None
	Normal, Wet, and Extreme[1]	Flow through conditions

Notes:

[1] Year Types are based on 1941-1990 average runoff of 122,124 acre-feet and are defined as follows:

Rush Creek

Dry	less than 68.5% of average runoff
Dry-Normal	between 68.5% and 82.5% of average runoff
Normal	between 82.5% and 107% of average runoff
Wet-Normal	between 107% and 136.5% of average runoff
Wet	between 136.5% and 160% of average runoff
Extreme	greater than 160% of average runoff

Lee Vining, Walker and Parker Creeks

Dry	less than 68.5% of average runoff
Normal	between 68.5% and 136.5% of average runoff
Wet	between 136.5% and 160% of average runoff
Extreme	greater than 160% of average runoff

[2] Restoration flows for Rush Creek will be augmented with Lee Vining Creek diversions in wet-normal, wet, and extreme years.

[3] During Dry-Normal years when the percentage of runoff is between 75% to 82.5% of normal.

[4] During Dry-Normal years when the percentage of runoff is between 68.5% to 75% of normal.

[5] Flows during Dry-Normal and Normal years may be reduced to the extent necessary to maintain exports.

Grant Lake Reservoir. Grant Lake Reservoir (GLR) is the primary storage facility for LADWP operations in the Mono Basin. The SWRCB Decision 1631 required LADWP to prepare a Grant Lake Operations and Management Plan to address four main operations: Grant Lake operations, Lee Vining Creek diversions, exports through the Mono Craters tunnel to Owens River, and streamflow releases to Lower Rush Creek. According to the LADWP 1996 Grant Lake Operations and Management Plan (GLOMP), the SWRCB Decision 1631 did not set specific requirements for operating Grant Lake. However, two sources specify target GLR storage volumes: (1) the GLOMP states that "LADWP has identified the concerns associated with the storage level of Grant Lake by conferring with parties and individuals who are impacted by changes to that [i.e. the storage level]. The LADWP proposal is to maintain storage in Grant Lake between approximately 30,000 af and 35,000 af" (LADWP 1996); and (2) Order 98-05 states that "In dry/normal and normal years, Licensee shall seek to have between 30,000 and 35,000 af of water in storage in Grant Lake at the beginning and the end of the run-off year. Licensee is not required to reduce storage in Grant Lake below 11,500 af to provide SRFs." Since at least RY1992, GLR storage volume and water surface elevation have been reported by LADWP. Daily average storage volumes were plotted for RY1992 to RY2008 (Figure 2-4). In Section 3 and Section 6, we describe a water balance model used to simulate GLR storage volumes and elevations for RY1990 to RY2008.

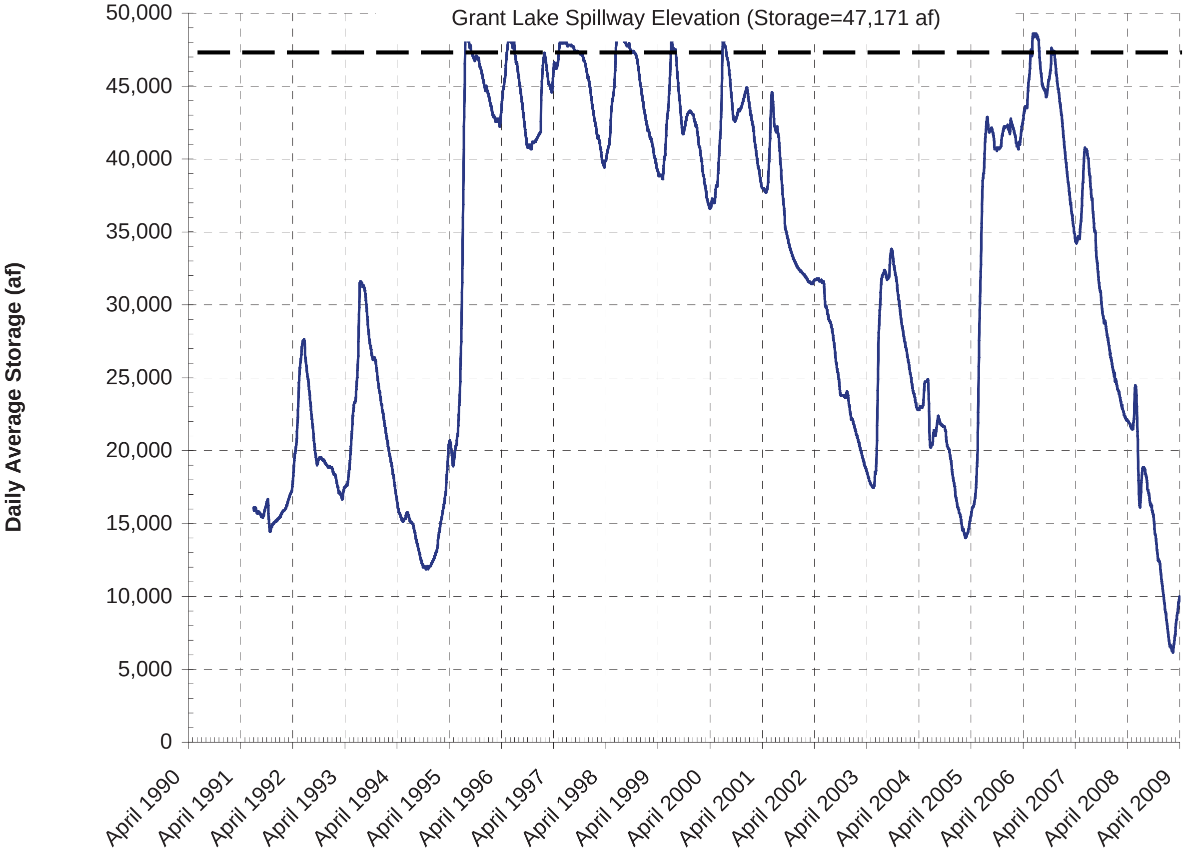


Figure 2-4. Fluctuations in Grant Lake Reservoir historic storage volume since July 1991, measured by LADWP. A full reservoir of 47,171 acre-feet corresponds to a spillway elevation of 7,130 ft.

2.2. The Status of Stream Ecosystem Recovery

2.2.1. *Evaluation of the existing SRFs and baseflows*

With the SRF streamflow regime in place the past 12 years, and extensive monitoring activities, controlled flow releases, and a wide range of runoff year types, the question is:

How well did the Stream Restoration Flows perform?

The four Mono Lake tributaries are recovering healthy stream ecosystems. Desired ecological functions targeted by the SRFs are influencing recovery within the mainstem channels and riparian corridors. Fish populations are reproducing naturally, including large brown and rainbow trout in some locations. Woody riparian trees are regenerating in many runoff year types, and tree growth during wetter cycles appears to be bridging the dry years without significant retraction. Several species of migrant songbirds have colonized the riparian forests. Grazing restrictions within the riparian corridors have allowed riparian vegetation and grasslands to flourish and eliminated those unnatural nutrient inputs into the streams. High flows intended to reshape the stream channels and floodplains are functioning well, creating more and deeper pools (Knudson et al. 2009), building floodplains, and reconfining channels. Figures 2-5 a-h provide several sequences of photographs taken over a 20 year period by Gary Smith of CDFG to show the extent of stream and riparian vegetation recovery.

Despite these successes, there are instream flow and operational changes that could further improve and accelerate stream ecosystem recovery. Water released from Grant Lake Reservoir can exceed thermal thresholds for good trout growth in hot summer periods, especially in Dry years when GLR elevation is lowered by exports and flow releases. The Rush Creek 3D Floodplain has only regenerated sparse riparian vegetation despite the extensive floodplain project implemented in RY2002. Medium and large in-channel wood utilized as cover by fish, and important for shaping channel morphology, is still generally lacking in most stream reaches. The Reach 5B from the Rush Creek 10 Channel Return downstream to the County Road crossing and farther to the Mono Lake delta, is still experiencing downcutting. On Lee Vining Creek, the A-3 and A-4 Channel entrances fluctuate annually and if cut off, could cause the loss of woody riparian vegetation. Many channel sections on Lee Vining Creek are still steep, coarse, and lack high quality brown trout holding and foraging habitat, particularly deep pools and runs providing refugia during winter baseflow periods and during peak snowmelt floods.

Although downstream, Mono Lake exerts its dominance up the stream valleys. Expanding and receding lake levels have altered the stream valley morphology over the centuries (Stine 1987). At the lake's fringe, a delta morphology forms with a network of multiple dominant stream channels. Fluctuating lake elevations from high stands to low stands leave this dominant imprint at successive elevations along the stream corridors, and the countering alluvial processes require even longer time-scales to undo this imprint. A dominant process altering the historical multi-channel delta morphology is migrating headcuts that abandon channel entrances.

Most examples of mechanical restoration have fulfilled their designed purpose. The big "Trihey" log weir in Upper Rush Creek undercut and washed out in RY2006, and all the constructed deep pools have deteriorated. The helicopter-placed rootwads randomly scattered throughout the channels have aggregated additional wood or influenced the formation of pool habitat in only a few locations. The "million-dollar bend" was abandoned by a headcut in RY1998 and has become encroached by willow and cattail. The blocking-off of vehicle trails has allowed abandoned roads to heal or remain as foot trails. The grade-control weirs constructed at the lower end of the MGORD and the introduced spawning substrate have persisted, and brown trout consistently use this area for spawning.

1987

1995

Figure 2-5a. Photographs of Upper Rush Creek taken from photopoint #6, looking upstream from the Old Highway 395 Bridge. Photos provided courtesy of retired CDFG biologist Gary Smith.

2002

2009

Figure 2-5a (continued). Photographs of Upper Rush Creek taken from photopoint #6, looking upstream from the Old Highway 395 Bridge. Photos provided courtesy of retired CDFG biologist Gary Smith.

1987

1995

Figure 2-5b. Photographs of Upper Rush Creek taken from photopoint #6, looking downstream from the Old Highway 395 Bridge. Photos provided courtesy of retired CDFG biologist Gary Smith.

2002

2009

Figure 2-5b (continued). Photographs of Upper Rush Creek taken from photopoint #6, looking downstream from the Old Highway 395 Bridge. Photos provided courtesy of retired CDFG biologist Gary Smith.

1987

1994

Figure 2-5c. Photographs of Lower Rush Creek taken from photopoint #13, looking downstream from the top of the left bank at the end of a short spur road. Photos provided courtesy of retired CDFG biologist Gary Smith.

2001

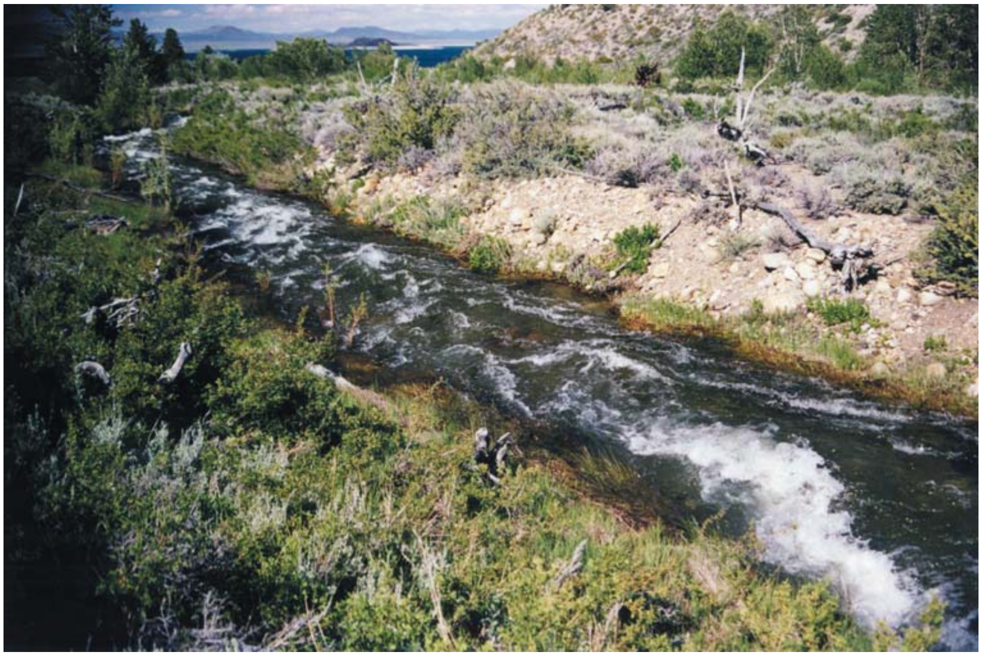
2009

Figure 2-5c (continued). Photographs of Lower Rush Creek taken from photopoint #13, looking downstream from the top of the left bank at the end of a short spur road. Photos provided courtesy of retired CDFG biologist Gary Smith.

1987

2009

Figure 2-5d. Photographs of Rush Creek taken from photopoint #17, at the Rush Creek delta looking toward Mono Lake. Photos provided courtesy of retired CDFG biologist Gary Smith.



1998

2009

Figure 2-5e. Photographs of Lee Vining Creek taken from photopoint #1, on left bank of B-1 Channel at XS 6+08 looking downstream (1998 discharge = 353 cfs).

1998

2009

Figure 2-5f. Photographs of Lee Vining Creek taken from photopoint #3, on left bank of A-4 Channel at XS 4+04 looking downstream (1998 discharge = 353 cfs).

1998

2009

Figure 2-5g. Photographs of Lee Vining Creek taken from photopoint #6, on the upper mainstem left bank floodplain near XS 10+44 and MLC Piezometer B-1.

1998

2009

Figure 2-5h. Photographs of Lee Vining Creek taken from photopoint #7, looking upstream on the upper mainstem left bank near XS 13+92.

The brown trout populations are healthy and self-sustaining, but they are not meeting the fisheries termination criteria (defined in Order 98-05) because of the relatively low numbers of fish longer than 14” (350 mm). Ten years of annual sampling has confirmed that larger brown trout (>12 inches) are relatively uncommon in Rush Creek below the MGORD (<1% of all brown trout captured) compared to the MGORD (29%) (Hunter et al. 2000-2009). Over the past 10 years of annual sampling, rainbow trout have comprised less than five percent of the fish captured in Rush Creek, often less than two percent (Hunter et al. 2000-2009). In contrast, rainbow trout comprised 10% to 40% of the total standing crop the past ten years in Lee Vining Creek (Hunter et al. 2000-2009). In Rush Creek, ample recruitment of age-0 brown trout has occurred the past 10 years; whereas in Lee Vining Creek recruitment of age-0 brown and rainbow trout has been more variable, and in some runoff year types, severely limited (Hunter et al. 2000-2009). In Rush Creek, water temperatures in late-July through mid-September often exceed thresholds for good brown trout growth, especially in drier runoff years or when Grant Lake Reservoir levels are lower. Water temperature and GLR storage levels have been correlated to Rush Creek brown trout condition factor (Shepard et al. 2009). Large diurnal fluctuations (up to 18°F) have also been documented in Rush Creek. In contrast, examination of the 10-year record of Lee Vining Creek summer water temperatures revealed no periods of excessive temperatures or wide diurnal fluctuations. Condition factors of age-1 and older brown trout in Lee Vining Creek have consistently exceeded 1.00 the past 10 years (Hunter et al. 2009).

Rush Creek downstream of the Narrows is either incapable of supporting large brown trout Order 98-05 desires, or this portion of Rush Creek is capable of supporting large brown trout, but contemporary flow regimes do not provide conditions compatible for fast enough growth and better winter survival for these resident trout to attain large size. Abundant age-0 brown trout indicate that a prey base is available for cannibalistic brown trout to shift to piscivory, if they reach sizes large enough to switch to a diet of fish (about 250 to 300 mm; Moyle 2002).,Brown trout biomasses estimated during the past 12 years represent a population near carrying capacity for the flow regime and physical habitat now present in lower Rush Creek. This population is fluctuating around a carrying capacity where no legal harvest of fish is allowed (CDFG regulations) and angler use is much lower than “put-and-take” sections of Rush Creek above GLR (CDFG creel surveys). Changes in biomass could be related to changes in flows (Shepard et al. 2009a and 2009b). Thus, that the best way to produce more large trout, and meet the intent of Order 98-05, is to shift the present size distribution from one dominated by younger, smaller trout to one dominated by larger trout, which will mean fewer trout in the population.

2.2.2. *Order 98-05 Stream Restoration Flows*

SWRCB D1631, Order 98-05, and several Annual Reports have discussed the ecological importance of high flow releases to mimic snowmelt floods for stream restoration and maintenance. In Order 98-05, the SWRCB concluded (Section 5.3.1): “…based on the evidence presented regarding the anticipated benefits of higher spring peaking flows for stream restoration purposes, and the willingness of Los Angeles to provide those flows, …it would be reasonable to provide the higher [SRF] flows called for in the settlement agreement on an interim basis subject to the provisions of this order. The subject of stream restoration flows can be reviewed by the SWRCB in the future with the benefit of the additional information developed through monitoring stream restoration and recovery in the Mono Basin.” Runoff years subsequent to Order 98-05 have provided a range of runoff year types for release and monitoring of high streamflows.

The monitoring program observed SRF flows for the 11 years on Lee Vining Creek (since RY1999) (Table 2-4). Three criteria were used to evaluate the success of Lee Vining Creek peak operations: (1) the percentage of the annual peak magnitude passed, (2) the daily average flow diversion on the day of the annual peak, and (3) comparison of annual hydrographs (Appendix A-1). Using these criteria, SRF peak requirements for Lee Vining Creek were met on 7 of 11 runoff years, but four runoff years' peaks were significantly impaired by diversion operations. SRF requirements for RY2007 were met because an SRF peak was not required below the Intake. Of the four years in which the SRF peaks were impaired, RYs 2003 and 2008 were the most significant, exemplifying operational challenges with the current peak operation and diversion requirements (Appendix A-1). In RY2009, despite comparable peak flood magnitudes above and below the Intake, each peak had different timing, and a portion of the primary peak was diverted.

On Rush Creek, two criteria were applied to evaluate the success of SRF release operations: (1) comparison of the annual peak magnitudes to Order 98-05 requirements, and (2) comparison of the peak durations to Order 98-05 requirements. During the first five runoff years following RY1998, SRF peak magnitude and duration requirements were not met because the MGORD did not have the capacity to convey the SRF peak discharge (Table 2-5). The SRF peaks have met the Order 98-05 prescriptions in four of the past six runoff years. In RYs 2007 and 2009, an SRF peak was not required below GLR due to Dry runoff year conditions or low GLR elevation. In RY2005, the SRF peak was lower than the Order 98-05 prescription because of SWRCB-approved experimental releases requested by the Stream Scientists for geomorphic experiments. Recalling that Order 98-05 recommended that "Licensee shall in all years attempt to maximize SRFs through coordination with Southern California Edison (SCE)", only one runoff year (RY 2004) significantly exceeded (i.e., maximized) the minimum SRF requirement. Requirements for SRF peak duration were met or exceeded in all runoff years since RY2004 except RY2008; in that year, the targeted peak releases of 380 cfs for 5 days was exceeded for three days, and

Table 2-4. Summary of peak flows on Lee Vining Creek for RYs 1990 to 2008 comparing the SRF peak releases to Order 98-05 requirements.

		Lee Vining Creek						
Runoff Year	Year-Type	Unimpaired (cfs)	Above Intake (cfs)	Below Intake (cfs)	Percentage of Peak Passed	Conduit on Date of Peak (cfs)	SRF MET?	Reason
1990	DRY	125	95	59.5		53	NA	pre Order 98-05
1991	DRY	280	186	164		30	NA	pre Order 98-05
1992	DRY	209	134	114		20	NA	pre Order 98-05
1993	WET/NORMAL	373	264	231		33	NA	pre Order 98-05
1994	DRY	216	139	125		14	NA	pre Order 98-05
1995	EXTREME WET	691	522	436		106	NA	pre Order 98-05
1996	WET/NORMAL	677	524	422		10	NA	pre Order 98-05
1997	WET/NORMAL	476	378	354		24	NA	pre Order 98-05
1998	WET	514	417	391		26	NA	pre Order 98-05
1999	NORMAL	367	285	274	96%	11	YES	
2000	NORMAL	355	264	258	98%	7	YES	
2001	DRY/NORMAL II	312	215	201	93%	14	YES	
2002	DRY/NORMAL I	311	238	233	98%	5	YES	
2003	DRY/NORMAL II	484	332	317	95%	50	NO	Conduit Diversions
2004	DRY/NORMAL I	203	152	141	93%	79	NO	Conduit Diversions
2005	WET	455	374	372	99%	2	YES	
2006	WET	515	444	457	103%	-13	YES	
2007	DRY	157	127	45	35%	86	NA	No SRF Required
2008	NORMAL	305	222	167	75%	146	NO	Conduit Diversions
2009		not available	230	232	101%	not available	NO	Conduit Diversions

Table 2-5. Summary of peak flows on Rush Creek for RYs 1990 to 2008 comparing the SRF peak releases to Order 98-05 requirements.

		Rush Creek						
Runoff Year	Year-Type	Unimpaired (cfs)	At Damsite (cfs)	Below GLR (cfs)	SRF Required (cfs)	SRF Peak Met?	SRF Duration Met?	Reason
1990	DRY	249	116	113	No Peak	NA	NA	pre Order 98-05
1991	DRY	506	150	101	No Peak	NA	NA	pre Order 98-05
1992	DRY	361	118	154	No Peak	NA	NA	pre Order 98-05
1993	WET/NORMAL	639	388	166	5 days/400	NA	NA	pre Order 98-05
1994	DRY	374	122	99	No Peak	NA	NA	pre Order 98-05
1995	EXTREME WET	1144	634	548	5 days/500	NA	NA	pre Order 98-05
1996	WET/NORMAL	874	306	333	5 days/400	NA	NA	pre Order 98-05
1997	WET/NORMAL	547	211	175	5 days/400	NA	NA	pre Order 98-05
1998	WET	726	495	538	5 days/450	NO	NO	Spill
1999	NORMAL	654	222	201	5 days/380	NO	NO	pre MGORD enlargement
2000	NORMAL	599	372	204	5 days/380	NO	NO	pre MGORD enlargement
2001	DRY/NORMAL II	588	231	161	5 days/250	NO	NO	pre MGORD enlargement
2002	DRY/NORMAL I	416	131	168	7 days/200	NO	NO	pre MGORD enlargement
2003	DRY/NORMAL II	742	311	203	5 days/250	NO	NO	pre MGORD enlargement
2004	DRY/NORMAL I	308	118	343	7 days/200	YES	YES (10 days)	MGORD Release
2005	WET	751	441	403	5 days/450	YES	YES (6 days>400)	*SWRCB-approved releases
2006	WET	644	483	477	5 days/450	YES	YES (18 days)	Spill
2007	DRY	302	148	45	No Peak	NA	NA	No SRF Required
2008	NORMAL	427	139	388	5 days/380	YES	NO (3 days)	MGORD Release
2009	NORMAL	not available	252	51	5 days/380	NA	NA	No SRF Required

* experimental releases were requested by Stream Scientists to test effects of peak duration on geomorphic processes

attained 360 and 370 cfs on two days. RY2009 was also an exception; despite a Normal runoff year, no SRF release was required because GLR storage fell below 11,500 af; the analysis in Chapter 6 demonstrates this was primarily because of RY2008 SRF releases that resulted from the difference between the April 1 forecast (86%) and the actual runoff (70%).

Acknowledging that the Rush Creek at Damsite (5013) flows are regulated by SCE, the SRF peak requirements often exceed the SCE regulated flows. An increase in peak magnitude below GLR occurred in four runoff years since RY1990 as a result of LADWP's MGORD releases (RYs 1992, 1998, 2002, 2004, and 2008). Two runoff years had slightly higher flows below GLR because of spills (Appendix A-1).

2.2.3. *Order 98-05 Baseflows*

The Order 98-05 baseflows for Rush and Lee Vining creeks were prescribed from studies by CDFG and other experts in the late-1980s and early-1990s (Smith and Aceituno 1987; CDFG 1991; CDFG 1993). These studies were conducted with the best available information using standard PHABSIM methodologies. However, in the ensuing years more information has become available and revised baseflows are needed for the following reasons:

(1) Winter baseflows in Rush and Lee Vining creeks are inflated by SCE's hydropower operations. Because SCE does not export water from the basin, the amount of flow held back (i.e. removed from the snowmelt peaks) must be released during other months of the year. The expression of these artificially-high winter baseflows is also evident in the flows presently prescribed by Order 98-05. Winter baseflows in both creeks were examined from annual hydrographs developed for estimated

unimpaired conditions, the SCE-regulated flows delivered to LADWP's facilities, and the flows released downstream by LADWP for RY's 1990 to 2008 (Figures 1-8 in Appendix A-2). These hydrographs provided the impetus to more closely examine the relationship between varying winter baseflows and the availability of suitable winter holding habitat for brown trout.

(2) The mainstem channels and riparian corridor have evolved so much that the original flow recommendations for brown trout habitat are no longer applicable. This eventuality was already being discussed at the 1993 Water Board hearings when only five years had passed between the instream flow studies and the initial instream flow recommendations (Appendix D-1). Comparisons of habitat typing and pool surveys between 1991 and 2008 (Trihey and Associates 1994; Knudson et al. 2009), and evidence from time-series photographs (Figures 2-5a-h), demonstrate significant riparian and channel evolution the past 17 years. The deep pools and dense riparian vegetation along the channel banks existing today are not the denuded stream banks and shallow/wide mainstem channel of the recent past.

(3) Development of habitat criteria curves for the CDFG instream flow studies was also an issue in the 1993 Water Board hearings (Appendix B-1). At the hearings, Dr. Hardy stated, "Primarily, the fundamental problem with suitability curves is that they are surrogate for what we know to be true fish behavior on selection of stream locations. They really select energetically favorable positions." We concur with Dr. Hardy's statement and have refined our understanding of habitat criteria by reevaluating several key assumptions used in developing the CDFG instream flow recommendations. During this study, brown trout observations were limited to daytime hours during the spring, summer, and fall (Smith and Aceituno 1987). The authors cautioned against relying on these data for night or winter flow recommendations; CDFG used these data for all seasons. Smith and Aceituno (1987) observed very few brown trout utilizing habitat deeper than 2 ft, probably because few pools had depths greater than 2 ft at that time. CDFG still applied these preference criteria to estimate juvenile and adult brown trout pool habitat as a function of baseflow.

(4) Habitat preference criteria utilized by CDFG to develop instream flows were based on mean water column velocities measured at 6/10th total water column depth (Smith and Aceituno 1987). The 12-yr study of brown trout biology on Rush and Lee Vining creeks, including extensive day and night snorkeling and three years of measuring habitat associated with relocated radio-tagged fish, clearly demonstrated that mean water column velocities were poor descriptors of brown trout habitat (Appendix B-2). Focal point velocity measurements during the Movement Study were consistent with those reported by Raleigh et al (1986),Clapp et al. (1990), Meyers et al. (1992), and Heggenes (2002).

(5) Unlike many other instream flow studies, fall and winter baseflow recommendations were developed with data generated from relocations of our radio-tagged brown trout during winter (December-March) and non-winter (April-November) periods. Site-specific habitat measurements were taken at each relocation site to develop holding habitat criteria for brown trout on Rush Creek and avoid extrapolating non-winter observations to winter conditions. Appendix B-2 addresses the importance of year-round holding habitat. More in-depth analyses of the Movement Study data in which the relocation data are presented by three size-classes of brown trout and by winter versus non-winter depths and focal point velocities. This additional analysis strengthens the binary habitat suitability criteria used in the study.

2.2.4. *Needed Changes to the Current SRF and Operational Requirements*

With the monitoring program's task of evaluating the existing Order 98-05 SRFs and baseflows, the initial step of our instream flow *synthesis* was to summarize needed changes to the SRFs, baseflows, and management operations. Those changes are summarized in this section.

- <u>Rush Creek Snowmelt.</u> Higher snowmelt floods are needed on Rush Creek than GLR can currently deliver without spills. Peak snowmelt flood magnitudes from GLR in wetter years reached maxima of 550 cfs below the MGORD and 650 cfs below the Narrows. The largest peak snowmelt flood magnitudes have been reduced nearly 50%, primarily by SCE hydropower operations above LADWP's facilities. More frequent, shorter duration flood peaks exceeding 450 cfs to 500 cfs are needed to help transport and deposit sediment, re-confine channels, and re-build floodplains. Other geomorphic processes provided by high peak flows are also critical to continue stream ecosystem recovery. However, augmentation of Rush Creek peaks from Lee Vining Creek (shunted through the 5-Siphons Bypass) is not ecologically sustainable. Spills are the best alternative for achieving the recommended high flow regime in Rush Creek below GLR. The operational strategy presented below, in coordination with other factors (GLR storage capacity, SCE operations, Lee Vining Creek diversion volumes, current water export allocations, post-transition water export restrictions tied to Mono Lake elevation) allows GLR to fill during spring or summer of most/all runoff years with an exceedence probability of 40% or less (Wet-Normal, Wet, Extreme-Wet runoff year types). The stage is therefore set for spill events of several days duration to meet or exceed recommended flood peak targets.
- <u>Lee Vining Creek Snowmelt.</u> Higher snowmelt floods and improved operational reliability are needed on Lee Vining Creek (also requiring SCE spills). Order 98-05 SRF requires LADWP to pass the snowmelt flood and release minimum baseflows. In addition, in Wet-Normal and wetter years, LADWP is required to divert water from Lee Vining Creek to augment Rush Creek's SRF peaks through the 5-Siphons bypass. These operational requirements, combined with the difficulty of reliably predicting the timing and magnitude of the Lee Vining Creek snowmelt peak, have hampered the ability of LADWP to reliably pass the peak snowmelt flood, then divert flows to augment Rush Creek SRF releases. These constraints have resulted in additional impairment to Lee Vining Creek snowmelt flood by diversion operations in several runoff years. Diversions after the snowmelt peak have also impaired the snowmelt recession. Finally, while augmentation was conducted in RY2005, RY2006, and RY2008, the premise of borrowing from Lee Vining Creek's snowmelt flood to augment Rush Creek's peak is questionable because Lee Vining Creek's channel morphology is much earlier in the recovery phase than Rush Creek. Diminishing the geomorphic work performed by Lee Vining Creek's snowmelt peak slows overall recovery. While reduction in snowmelt peaks from SCE hydropower operations above the LADWP facility on Lee Vining Creek is less than on Rush Creek, further impairment to the current Lee Vining snowmelt flood magnitudes would slow the rate of stream recovery. Snowmelt flood peaks higher than those SCE currently releases would benefit Lower Lee Vining Creek's recovery.
- <u>Lee Vining Diversion Volumes.</u> More reliable water diversion from Lee Vining is needed to better balance basin exports and increase GLR storage. A fuller GLR is essential to facilitate snowmelt spills to Rush Creek and to provide cooler summer water temperatures for trout. During the past 19 years (RY1990 to RY2008), LADWP exported an annual average of 3,500 af from Lee Vining, and has been exporting 16,000

af from the Mono Basin since RY1997. This imbalance, in turn, impacts GLR and Rush Creek. During wetter runoff year intervals, this diversion and export imbalance was less noticeable because GLR remained near or at full capacity. However, drier runoff year cycles, especially RY2007 to RY2009, have significantly lowered GLR storage. More water can be diverted from Lee Vining Creek without impairing the ecological role of its snowmelt hydrograph, and yet measurably improve baseflows for adult trout habitat. Water diverted from Lee Vining Creek triggers several positive benefits for GLR and Rush Creek, including a more scenic and likely better Grant Lake ecosystem, cooler summer water releases from GLR to Rush Creek, and higher magnitude and frequency of spills.

- <u>Rush Creek Water Temperatures.</u> Warm summer water temperatures on Rush Creek below the Narrows reduce trout habitat suitability, growth rates, and may reduce winter trout survival. Trout studies, water temperature modeling, and empirical water temperature data all indicate that water temperatures become unfavorable to trout during the hottest months of July and August regardless of the baseflow magnitude released because ambient air temperatures exert dominance on Rush Creek water temperatures. Not only do daily average and maximum temperatures exceed suitable trout rearing temperatures, but daily fluctuations are also too high. The lakes and storage reservoirs in the Rush Creek drainage increase water temperatures during years with warmer air temperatures and prevent cooler water from being released downstream. Our analyses confirmed those by Cullen and Railsback (1993) that the single most effective temperature management strategy for Rush Creek is to keep GLR full. The ability to transfer water from Lee Vining Creek to either GLR or Rush Creek is an option for managing Rush Creek streamflows.
- <u>Rush Creek Baseflows.</u> Fall and winter baseflows are too high on Rush and Lee Vining creeks, and likely contribute to low winter trout survival. Low suitability of winter holding habitat in pools and runs due to high water velocities may be causing low adult trout survival beyond two years. Age-0 recruitment of brown trout may be constrained in Lee Vining Creek by the coincidence of brown trout fry emergence timing with peak run-off events. Age-0 recruitment of rainbow trout may be constrained by spawning during peak snowmelt runoff.

2.3. Basin-wide Ecological and Operational Strategy

The stream ecosystems, riparian corridors, and fisheries are substantially different in Rush Creek and Lee Vining Creek. Operationally, the two systems also differ in significant ways. The annual hydrograph for Lee Vining above Intake (regulated by SCE) is moderately impaired. Lee Vining Creek lacks a LADWP storage facility to capture and release streamflows to Lower Lee Vining Creek. Additionally, Order 98-05 requirements to pass the Lee Vining Creek peak flow but otherwise divert during the snowmelt period to augment Rush Creek have reduced the reliability of achieving Lee Vining Creek flood peak releases, water exports, and Rush Creek peak augmentation. In contrast, Rush Creek streamflows are highly regulated above GLR. The reservoir captures and stores approximately 80% of the average annual yield, providing an opportunity to re-regulate downstream releases. Releases, however, are constrained by the 380 cfs maximum capacity of the MGORD. Spills are constrained by the inflow to GLR from SCE's hydropower releases. Water temperatures are warmer year-round in Rush Creek because of the numerous lakes and storage reservoirs upstream.

Several analytical pathways were taken in prescribing instream flows for Rush Creek and Lee Vining Creek. Four objectives dominated the analyses:

(1) provide annual hydrographs as similar to the unregulated annual hydrograph as possible given present-day SCE modifications, and provide greater reliability in protecting the Lee Vining Creek snowmelt flood (including the ascending limb, peak, and recession limb),

(2) make water diversions from Lee Vining Creek to Rush Creek as reliable as possible,

(3) meet desired ecological outcomes in Rush Creek by sustaining a reliably deeper GLR that will spill more frequently and release cooler summer water, and

(4) specifically identify where SCE could consider modifying their operations to improve snowmelt flood hydrographs.

Recommendations for Lee Vining Creek operations reflect an important shift in strategy for diversion operations and instream flows. Flows can be diverted from Lee Vining Creek two ways: divert a portion of the SCE flow according to a prescribed diversion rate, and allow the remaining flow to pass downstream, or, capture the SCE streamflow and release a bypass flow, typically to meet a minimum flow requirement. A hybrid diversion strategy is recommended: during the April 1 to September 30 snowmelt season, we recommend a variable diversion rate, calculated daily based on the magnitude of the ‘Lee Vining above Intake’ flow. During the baseflow period October 1 to March 31, we prescribe bypass flows for the fall and winter baseflow periods that vary only by runoff year type. Diversion rates during the snowmelt season require no ramping procedures; a diversion rate into the conduit is computed daily from April 1 through September 30 and the remaining streamflow passes downstream to Lower Lee Vining Creek and Mono Lake.

In Rush Creek, flow prescriptions continue to rely primarily on bypass flows, similar to the existing SRF flow release strategy, but with more emphasis on a fuller GLR to improve summer water temperatures and to increase the probability of spills from GLR. In drier runoff years when GLR is drawn down, augmentation with cooler water delivered from Lee Vining Creek via the 5-Siphon Bypass may benefit Rush Creek thermal conditions. Attaining snowmelt flood magnitudes recommended for Rush Creek will require participation by SCE to provide peak flows that spill from GLR. Changes to fall and winter baseflows are necessary, based on results of the baseflow habitat assessment (IFS Report), to increase available winter holding habitat for brown trout. The baseflow recommendations better mimic the estimated unimpaired baseflows than the currently prescribed baseflows. In Rush Creek, Dry and Dry-Normal I runoff years prioritize stream productivity and riparian maintenance, with less emphasis placed on accomplishing geomorphic processes or riparian regeneration. A snowmelt recession limb replaces steady summer baseflows in wetter years. Summer baseflows were revised in all runoff year types based on recession rate requirements for riparian vegetation and to provide more suitable water temperatures for brown trout growth and condition factor.For both Lee Vining Creek and Rush Creek, specific opportunities for SCE and the USFS to improve annual hydrographs by enhancing spill magnitudes are identified. Improved coordination of Rush Creek flow releases with Parker and Walker creeks’ hydrographs would also increase flood peak magnitudes below the Narrows and improve flood peak timing relative to annual seed release.

Parker and Walker creeks will remain unimpaired below the Lee Vining Conduit. Both tributaries and their trout populations have responded positively to the hands-off management practiced the past 12 years. Between RY2003 and RY2008, Walker Creek had the highest biomass (kg/ha) of brown trout of all Mono Basin sampling sites in five of six years, including greater than 300 kg/ha in four runoff years (Hunter et al. 2009). The Walker Creek study site has evolved into a single-thread, highly sinuous channel with abundant foraging and holding habitat in numerous pools with low focal-point velocities and extensive undercut banks. Streamflows from Parker and Walker creeks have been incorporated into SEF streamflow recommendations to (1) augment snowmelt peak flows below the Narrows, (2) provide cool water inputs in summer months at a key location on Rush Creek (just above the Narrows), and (3) add flow variability on daily and weekly time-scales to compensate for steady baseflow releases from the MGORD. For example, rather than recommending an 80 cfs GLR release to meet an 80 cfs threshold in Lower Rush Creek, the recommended release can be 70 cfs, knowing that Parker and Walker creek streamflow accretion will make-up the 10 cfs difference with high quality water. This strategy would result in slightly lower flows in Upper Rush Creek and less intra-annual flow variability.

A May 1 forecast, as opposed to only an April 1 forecast (necessary for LADWP's system-wide planning), would improve the accuracy of the runoff year forecast and year-type designation. The May 1 forecast may be necessary only during runoff years in which the percentage of average runoff is close to a boundary for runoff year type, and during runoff years in which April precipitation and snowpack accumulation diverge substantially from average values. All runoff year types except Dry years on Rush Creek have the same April bypass flow recommendations; thus a May 1 runoff year-type revision will not alter water release in April, nor export volumes.

Three storage thresholds for Grant Lake Reservoir management are also recommended. First, the existing Order 98-05 specifies a minimum storage volume of 11,500 af, below which SRF flow releases are not required. The LADWP Mono Basin Implementation Plan (MoBIMP) specifies a similar storage threshold of 12,000 af as "the minimum operating level." The threshold volume should remain 11,500 af, and in addition to precluding SEF releases, should also preclude exports to the Owens River, to prevent Grant Lake Reservoir from ever falling below this elevation. This threshold protects Rush Creek from spring or summer flow releases with higher than usual turbidity and water temperatures. Second, a minimum Grant Lake Reservoir elevation of 7,100 ft (20,000 af storage volume) should be maintained during July, August, and September of all runoff years. This threshold corresponds to the inflection in "maximum outflow temperatures" reported in Cullen and Railsback (1993); below this threshold GLR elevation, release temperatures to the MGORD are often above the threshold required for brown trout growth, and depending on climatic conditions, may continue to warm in a downstream direction. Finally, in Wet-Normal, Wet, and Extremely-Wet runoff years, GLR elevation must be at the spillway elevation (7,130 ft or 47,171 af) for at least a two week period between June 15 and July 15 to allow GLR to spill at the appropriate time ecologically (primarily for riparian vegetation regeneration targeting cottonwood seed release timing).

2.4. Stream Ecosystem Flow (SEF) Recommendations

This section of the Synthesis Report presents the Stream Scientists' recommendations for revised instream flows (baseflow and snowmelt periods) for Lee Vining Creek and Rush Creek. The revised instream flows are referred to as Stream Ecosystem Flows (SEFs) to differentiate them from Order 98-05 Stream Restoration Flows. Revised streamflows – magnitude, timing, duration, and rate of change - are presented in tables and figures; ecological functions of primary hydrograph components are described for each runoff year type. Subsequent chapters detail the analytical process used to derive SEF flow recommendations.

2.4.1. *Lee Vining Creek*

The Lee Vining Creek annual hydrograph is divided into a spring snowmelt period from April 1 to September 30, and a baseflow period from October 1 to March 31. Each period has flow allocated differently (Figure 2-6).

Spring Snowmelt Diversion Rates: The snowmelt period has fixed daily diversion rates that are determined by the daily average flow

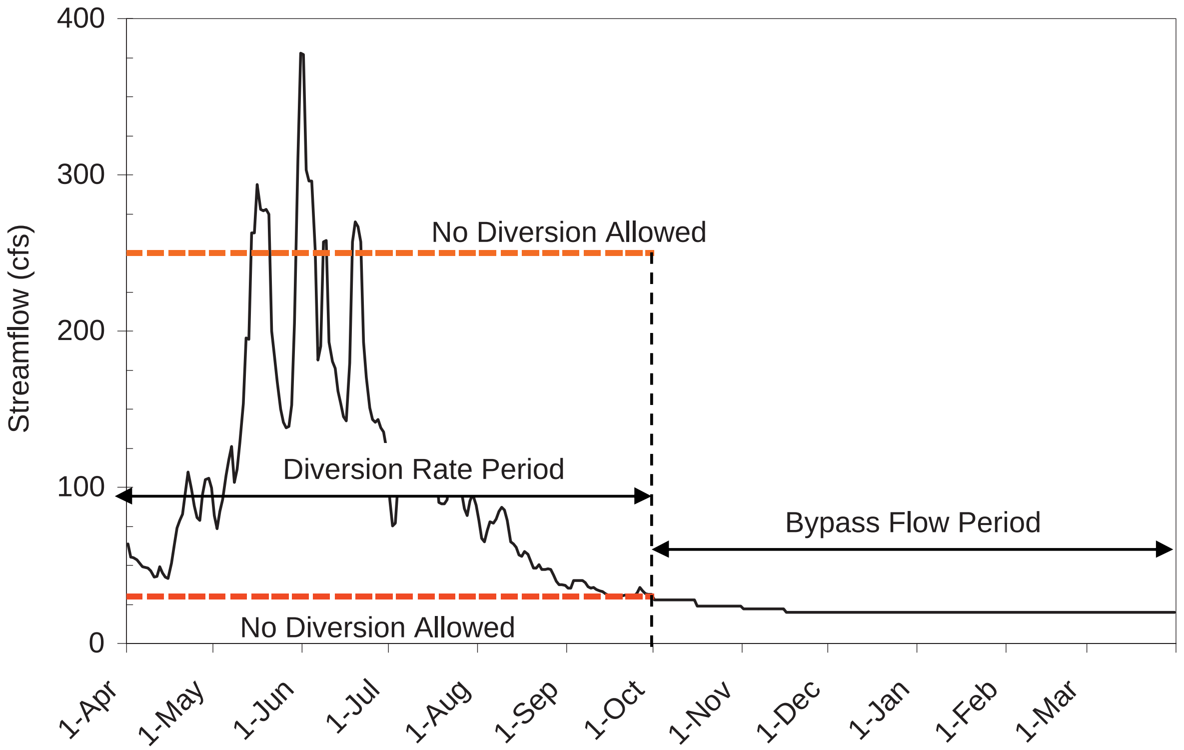


Figure 2-6. Lee Vining Creek proposed diversion strategy for recommended SEF streamflows. A 'hybrid' diversion strategy is recommended, with different diversion strategies proposed for different seasons: an April 1 to September 30 'diversion rate' period, and an October 1 to March 31 'bypass flow' period. Lower and upper diversion thresholds are represented by dashed red lines at 30 cfs and 250 cfs.

for the 'Lee Vining above Intake' streamflow gage. This gage operates in real-time; LADWP operators will access this information daily at approximately 9AM, and based on this flow, will determine the diversion rate for that day. The diverted flow is routed into the Lee Vining Conduit, and the remaining (undiverted) flow is allowed to pass downstream to Lower Lee Vining Creek. The effect is to provide the natural variability in daily discharge magnitude, duration, timing, and rate of change. Daily diversion rates were determined based on (1) a basic premise that the annual hydrograph for the period April 1 to September 30 for the SCE flows best preserves the intra- and inter-annual variability in daily average flow needed to perform desired ecological functions, and (2) a maximum allowable change in water surface stage height of 0.2 ft, determined at a representative Lower Lee Vining Creek cross section, would not significantly diminish desired ecological functions. All streamflows below 30 cfs and above 250 cfs (measured at Lee Vining above Intake) are allowed to pass the Intake, with no diversion allowed. A window of allowable diversion from 30 to 250 cfs thus results (Figure 2-6). Peak flows in Lee Vining Creek that exceed approximately 250 cfs will continue to limit recruitment of age-0 trout (primarily impacting rainbow trout). These short-term impacts are necessary for continued channel and floodplain recovery. Diversion rates for each 1.0 cfs increment between 30 and 250 cfs are presented in Table 2-6.

This diversion strategy ensures that peak events above 250 cfs are not regulated and that recession rates during the receding limb of the annual hydrograph are not significantly altered to the detriment of riparian regeneration. In addition, this strategy increases assurance of water diversion from Lee Vining to GLR.

Table 2-6. Lee Vining Creek recommended daily diversion rates for the April 1 to September 30 diversion period. An example diversion rate of 28 cfs is highlighted, and corresponds to a 'Lee Vining Creek above Intake' streamflow of 124 cfs.

Discharge at Lee Vining above Intake (cfs) (tens of cfs)	(cfs)									
	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
30	0	1	2	3	4	5	6	7	8	9
40	10	11	12	13	13	14	14	14	14	14
50	15	15	15	15	16	16	16	16	16	17
60	17	17	17	17	17	18	18	18	18	18
70	19	19	19	19	19	20	20	20	20	20
80	20	21	21	21	21	21	21	22	22	22
90	22	22	23	23	23	23	23	23	24	24
100	24	24	24	24	25	25	25	25	25	25
110	25	26	26	26	26	26	26	27	27	27
120	27	27	27	28	**28**	28	28	28	28	28
130	29	29	29	29	29	29	30	30	30	30
140	30	30	30	31	31	31	31	31	31	31
150	32	32	32	32	32	32	32	33	33	33
160	33	33	33	33	34	34	34	34	34	34
170	34	35	35	35	35	35	35	35	36	36
180	36	36	36	36	36	37	37	37	37	37
190	37	37	37	38	38	38	38	38	38	38
200	39	39	39	39	39	39	39	39	40	40
210	40	40	40	40	40	41	41	41	41	41
220	41	41	41	42	42	42	42	42	42	42
230	42	43	43	43	43	43	43	43	43	44
240	44	44	44	44	44	44	44	45	45	45
250	45	0	0	0	0	0	0	0	0	0
260	0	0	0	0	0	0	0	0	0	0
270	0	0	0	0	0	0	0	0	0	0
280	0	0	0	0	0	0	0	0	0	0
290	0	0	0	0	0	0	0	0	0	0
300	0	0	0	0	0	0	0	0	0	0

Diversion rates are independent of runoff year type and require no ramping rates. Additionally, during this period water temperatures are consistently within an optimal range for trout summer rearing; diversions are not expected to detrimentally affect water temperatures in Lower Lee Vining Creek.

Fall and Winter Baseflow Bypass Flow Rates: The fall and winter baseflow period reverses strategy from spring and summer, and instead relies on prescribed bypass flows for Lee Vining below Intake, with all Lee Vining above Intake streamflow above the bypass flow prescription subject to diversion into the Lee Vining Conduit. The effect is to provide a constant, steady, pre-determined flow for Lower Lee Vining Creek. Bypass flow rates were determined based on (1) results of the IFS which documented more suitable holding habitat at lower test flows, (2) a basic premise that the natural variability in the winter baseflow hydrograph was obscured by undesirable operational fluctuations caused by SCE's upstream hydropower operations, and (3) constant baseflows that provide abundant trout winter holding habitat would minimize stress to adult trout and thus improve winter survival.

Bypass flows are runoff year dependent: magnitudes range from 16 cfs in Dry, Dry-Normal I and II runoff years, 18 cfs in Normal years, to 20 cfs in Wet-Normal, Wet, and Extremely Wet runoff years. These baseflows are prescribed to meet late-summer rearing, fall brown trout spawning, and winter trout holding. Bypass flows are presented in Table 2-7.

A prescription allowing infrequent large winter floods to bypass the Intake (e.g., above 100 cfs at Lee Vining above Intake) was considered. However, there were no specific ecological objectives that would be met solely by a winter flood. Short-term impacts to trout include scouring or burying of brown trout redds and displacement of holding fish, including brown and rainbow trout, juveniles and adults. Fall and winter flood magnitudes are generally below geomorphic thresholds, and large magnitude events that do exceed geomorphic thresholds (such as the 524/422 cfs (above/below Lee Vining Intake) event of January 3, 1997) likely would bypass the Conduit. Example future annual hydrograph for Lower Lee Vining Creek are simulated for RYs 1990 to 2008. These hydrographs are presented in Appendix A-1.

Table 2-7. Lee Vining Creek recommended daily bypass flows for the October 1 to March 31 bypass period.

	Runoff Year Type						
	Extreme Wet	Wet	Wet-Normal	Normal	Dry-Normal II	Dry-Normal I	Dry
Fall Baseflow							
October 1-15	30	30	28	20	16	16	16
October 16-31	28	28	24	18	16	16	16
November 1-15	24	24	22	18	16	16	16
November 16-30	20	20	20	18	16	16	16
Winter Baseflow							
December 1-15	20	20	20	18	16	16	16
December 16-31	20	20	20	18	16	16	16
January 1-15	20	20	20	18	16	16	16
January 16-31	20	20	20	18	16	16	16
February 1-15	20	20	20	18	16	16	16
February 16-28	20	20	20	18	16	16	16
March 1-15	20	20	20	18	16	16	16
March 16-31	20	20	20	18	16	16	16

2.4.2. *Rush Creek*

Effects of SCE hydropower operations, including the larger SCE storage capacity (22,900 af), and the large storage capacity of Grant Lake Reservoir (47,100 af) precluded the option of a diversion rate strategy similar to Lee Vining Creek. The SRF and baseflows in Order 98-05 were prescribed as a common set of “annual hydrograph components” presented in the RY2003 Annual Report (M&T 2004).

Rush Creek SEF hydrographs follow a similar pattern through the runoff year, with increasing magnitudes and durations with progressively wetter runoff years (Figure 2-7). Spring baseflows of 40 cfs (30 cfs in Dry runoff years) persist through April, allowing a revision to the runoff year forecast with minimum or no water supply implications. Flows ascend on or soon after May 1 to a 80 cfs flow of extended duration (70 cfs in Dry runoff years), targeting stream productivity and groundwater maintenance to sustain riparian growth and vigor. Beginning mid-June in runoff years >70% exceedence (Dry-Normal II and wetter runoff years), flows ascend to a two-stage snowmelt flood. Stage-1 is a snowmelt bench with magnitude and duration that target ecological functions specific to each runoff year type. The snowmelt bench also provides a point of departure for ascension to the snowmelt flood. The snowmelt bench is designed to take advantage of Parker and Walker creek flows to preserve natural timing and daily fluctuations in the hydrograph, and to provide secondary peaks below the Narrows prior to the primary snowmelt flood release from GLR. Dry and Dry-Normal I runoff years remain at the snowmelt bench through the snowmelt period. Stage-2 is the snowmelt flood, which has specified ramping rates, and peak magnitude and duration, but the timing may vary within the period specified for the snowmelt bench. Flexible timing allows LADWP the operational flexibility to quickly ramp up to the snowmelt flood to piggyback on Parker and Walker creek peaks to maximize discharge below the Narrows. The snowmelt flood has fast ascension and recession rates that preserve operational flexibility and mimic natural rates. Prescribed peak releases are constrained by the 380 cfs maximum capacity of the MGORD. Prescribed snowmelt peak spills beyond the maximum capacity of the MGORD will require a full Grant Lake Reservoir and coordination with SCE operations to maximize spill magnitudes. The snowmelt bench ends at a recession node for each runoff year, with timing and magnitude of the node corresponding to the unimpaired hydrograph (this pattern can be observed in annual hydrographs presented in Appendices A-1 and A-2). The recession node signifies the start of the medium and slow snowmelt recession during which flows gradually descend to summer or fall baseflows. The snowmelt recession preserves the natural transition from snowmelt flood to baseflow periods, maintains higher soil moisture availability, and gradually increases water temperatures for trout acclimation. Summer and fall baseflows are 30 cfs in all runoff years but begin later with each wetter year-type. Winter baseflows are also 30 cfs. This 30 cfs value is the mid-point of a 28 to 32 cfs targeted range to accommodate operational feasibility. Depending on runoff year-type, fall and winter baseflow accretions from Parker and Walker creeks would contribute approximately 6 to 10 cfs additional flow to the Rush Creek bottomlands.

The following sections present the annual hydrographs for each runoff year type. Chapter 5.0 provides more detailed descriptions of analyses for Rush Creek SEF flow recommendations.

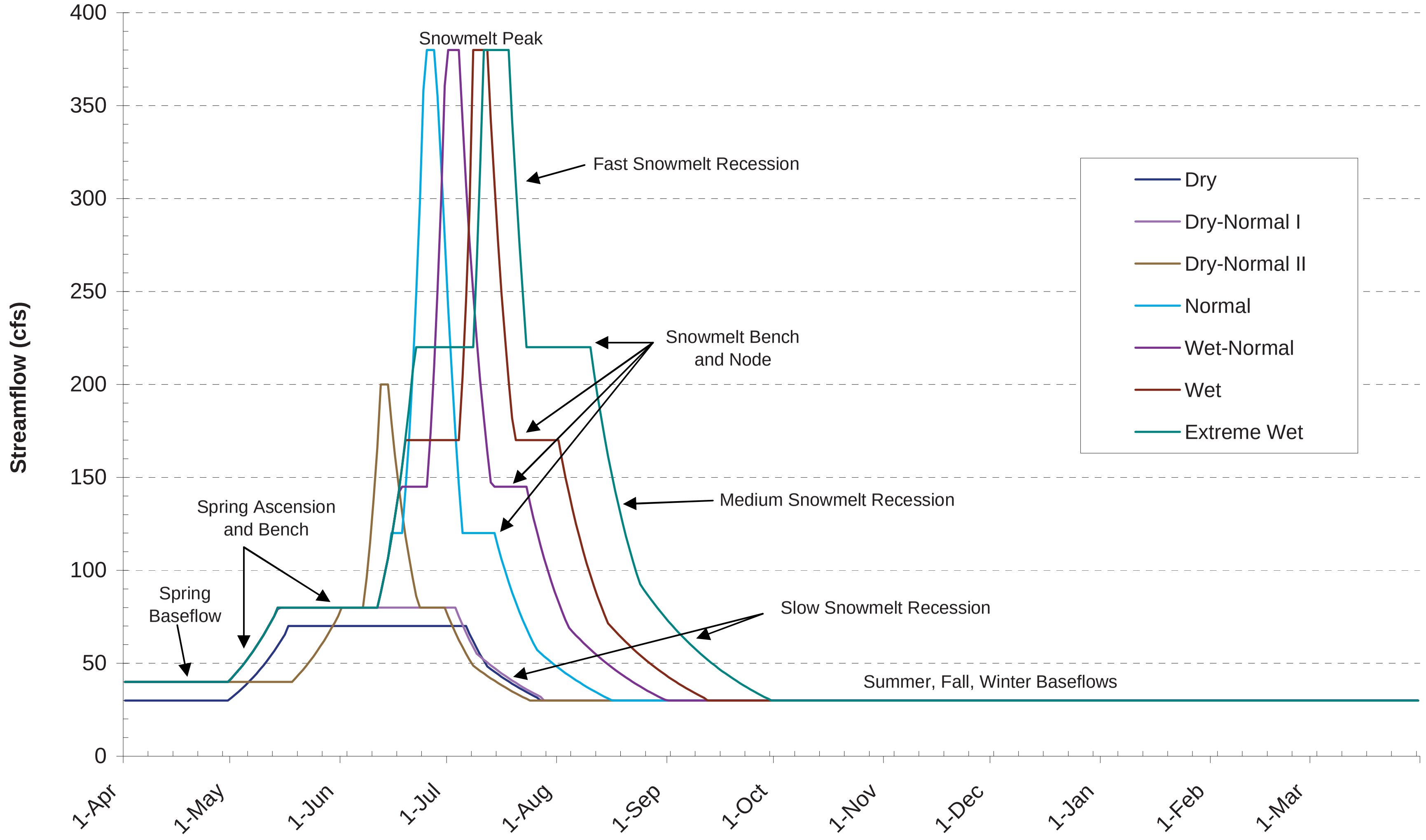


Figure 2-7. Rush Creek proposed SEF Annual Hydrographs (not including recommended spills) for seven runoff year types.

2.4.2.1. Dry Runoff Years

Runoff Year Type	Exceedence Probability	May 1 Forecast Runoff Volume (af)	Percent of Average Runoff
Dry	80-100%	<83,000	<68.5%

Current Baseflow and SRF Hydrograph: Current Dry runoff years require baseflows of 31 cfs from April 1 to September 30 and 36 cfs from October 1 to March 31. No snowmelt release is required.

Recommended SEF Hydrograph (Table 2-8; Figure 2-8): Recommended SEF flows provide baseflows of 30 cfs and a spring snowmelt bench of 70 cfs from May 17 through July 5 (51 day duration). Ramping rates of 5% maximum daily change are recommended for the snowmelt bench ascension and recession. If the storage level in Grant Lake Reservoir is below 25,000 af on July 1, we recommend that Lee Vining Creek diversions are directed into the 5-Siphons Bypass during July-September to lower Rush Creek water temperatures and increase potential growth of brown trout.

Primary Ecological Functions: Dry runoff years target maintenance of trout and riparian vegetation by minimizing, but not eliminating, stressful conditions during late spring and summer. The spring baseflow of 30 cfs prioritizes brown trout foraging and holding habitat over BMI habitat and thermal conditions. A 51 day snowmelt bench at 70 cfs extends from May 17 to July 5, and will provide cold water temperatures within the range identified as suitable for trout in simulated Dry runoff years. In addition to trout water temperature benefits, the snowmelt bench will maintain vigor of established riparian vegetation and prevent retraction of existing riparian vegetation acreage or conversion of riparian patch types to desert plant types in the Rush Creek bottomlands. In simulated Dry runoff years, flow releases from the MGORD combine with spring and summer flows from Parker and Walker creeks ranging from 10 to 40 cfs. The combined flows below the Narrows exceeded the 80 cfs threshold for maintaining riparian plant vigor. The 51 day release of 70 cfs from the MGORD provided an average of 53 days above the threshold 80 cfs below the Narrows in simulated Dry runoff years 1991, 1992, 1994, and 2007. The snowmelt recession begins on July 6, descending in two stages at maximum rates of 6% and 3% change per day, reaching summer baseflow of 30 cfs on July 24. The winter baseflow recommendation of a 28 to 32 cfs release at the top of the MGORD in concert with flow losses and tributary accretions should translate into a measured flow of approximately 19 to 23 cfs downstream of the Narrows. For the five Dry runoff years between 1990 and 2008, average Parker and Walker creek accretions equaled 5.0 cfs (Appendix A-5).

Table 2-8. Rush Creek recommended SEFs for DRY runoff year types.

DRY RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	April 30	30	30	
Spring Ascension	May 1	May 16	30-70	16	5%
Spring Bench					
Snowmelt Ascension					
Snowmelt Bench	May 17	July 6	70	51	
Snowmelt Flood					
Snowmelt Peak (release)					
Snowmelt Peak (spill)					
Fast Recession					
Medium Recession (Node)	July 7	July 12	70-45	6	6%
Slow Recession	July 13	July 26	45-30	14	3%
Summer Baseflow	July 27	September 30	30	66	
Fall Baseflow	October 1	November 30	30	61	
Winter Baseflow	December 1	March 31	30	121	

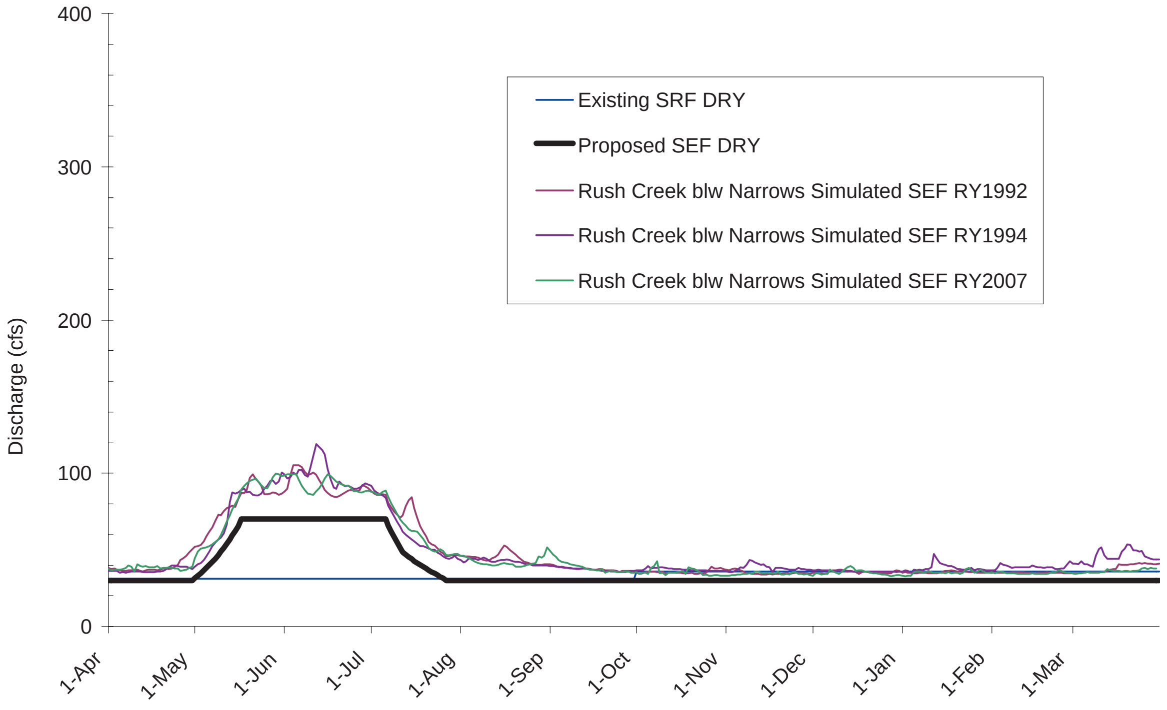


Figure 2-8. Rush Creek recommended SEF streamflows for DRY runoff years.

2.4.2.2. Dry-Normal I Runoff Years

Runoff Year Type	Exceedence Probability	May 1 Forecast Runoff Volume (af)	Percent of Average Runoff
Dry-Normal I	70-80%	83,655 - 92,207	68.5% - 75.5%

Current Baseflow and SRF Hydrograph: Current Dry runoff years require baseflows of 47 cfs from April 1 to September 30 and 44 cfs from October 1 to March 31. Peak SRF releases of 200 cfs for 7 days are required.

Recommended SEF Hydrograph (Table 2-9; Figure 2-9): Spring baseflows of 40 cfs from April 1 to 30, a spring snowmelt bench of 80 cfs for 51 days, a medium and slow recession totaling 19 days, descending in two stages at 6% and 3% maximum change per day, and summer, fall, and winter baseflows of 30 cfs. If the storage level in Grant Lake Reservoir is below 25,000 af on July 1, we recommend directing Lee Vining Creek diversions into the 5-Siphons Bypass during July-September to lower Rush Creek water temperatures and increase potential growth of brown trout.

Primary Ecological Functions: Dry-Normal I runoff years target stream productivity, riparian maintenance, and a balance between trout foraging habitat and thermal conditions. Baseflows of 40 cfs in April, combined with Parker and Walker creeks, provide flows below the Narrows in the 45 to 50 cfs range, and prioritize abundant benthic macroinvertebrate riffle habitat over adult trout foraging and holding habitat during spring. A peak release targeting geomorphic functions was unnecessary in this year type. A snowmelt bench of 80 cfs for 51 days, and 10 to 50 cfs flow augmentation from Parker and Walker creeks below the Narrows during May and June, balances thresholds for productive benthic macroinvertebrate habitat (40 to 110 cfs), maintenance of riparian plant vigor (>80 cfs), and off-channel spring and early-summer streamflow connectivity (>90 cfs). The spring snowmelt bench provides abundant productive BMI habitat in simulated Dry-Normal I runoff years 2002 and 2004. Thresholds for maintaining riparian plant vigor (>80 cfs) are exceeded an average of 54 days per year in simulated runoff years. The snowmelt bench exceeds 90 cfs below the Narrows for 60 days (approximately May 12 to July 10) in simulated runoff years. Simulated peak magnitudes of 142 and 132 cfs for RY2002 and 2004 will flush fine sediment and silt accumulated on the bed surface the previous winter and spring. The snowmelt recession begins July 1 and reaches summer baseflows by July 24. The winter baseflow recommendation of a 28 to 32 cfs release at the top of the MGORD in concert with flow losses and tributary accretions should translate into a measured flow of 19 to 23 cfs downstream of the Narrows. For the two Dry-Normal I runoff years between 1990 and 2008, average Parker and Walker creek accretions equaled 6.9 cfs (Appendix A-5).

Table 2-9. Rush Creek recommended SEFs for DRY-NORMAL I runoff year types.

DRY-NORMAL I RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	April 30	40	30	
Spring Ascension	May 1	May 13	30-70	13	5%
Spring Bench					
Snowmelt Ascension					
Snowmelt Bench	May 14	July 3	80	51	
Snowmelt Flood					
Snowmelt Peak (release)					
Snowmelt Peak (spill)					
Fast Recession					
Medium Recession (Node)	July 4	July 9	70-45	6	6%
Slow Recession	July 10	July 27	45-30	18	3%
Summer Baseflow	July 28	September 30	30	65	
Fall Baseflow	October 1	November 30	30	61	
Winter Baseflow	December 1	March 31	30	121	

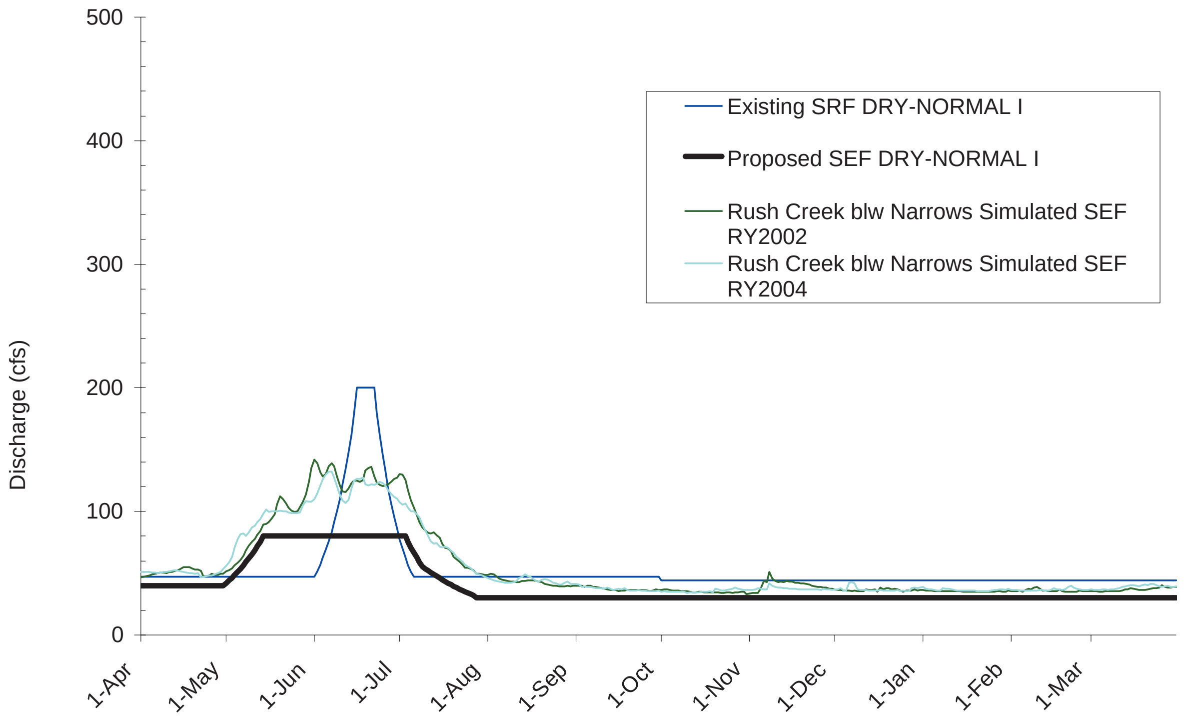


Figure 2-9. Rush Creek recommended SEF streamflows for DRY-NORMAL I runoff years.

2.4.2.3. Dry-Normal II Runoff Years

Runoff Year Type	Exceedence Probability	May 1 Forecast Volume of Runoff (af)	Percent of Average Runoff
Dry-Normal II	60-70%	92,207 - 100,750	75.5% - 82.5%

Current Baseflow and SRF Hydrograph: Current Dry-Normal II runoff years require baseflows of 47 cfs from April 1 to September 30 and 44 cfs from October 1 to March 31, and a 5 day peak SRF release of 250 cfs.

Recommended SEF Hydrograph (Table 2-10; Figure 2-10): Recommended SEF streamflows for Dry-Normal II runoff years include spring baseflows of 40 cfs, a spring snowmelt bench of 80 cfs, and a snowmelt peak release of 200 cfs for a minimum of three days. Streamflows descend in two stages at 6% and 3% maximum change per day, and summer, fall, and winter baseflows of 30 cfs.

Primary Ecological Functions: Dry-Normal II runoff years target stream productivity, riparian maintenance, fish growth, and add a moderate peak release initiating minor geomorphic functions. Baseflows in spring prioritize benthic macroinvertebrate productivity over adult trout foraging habitat: combined flows below the Narrows (45 to 60 cfs) are well within the range of good BMI habitat. Thresholds for off-channel streamflow connectivity (90 to 160 cfs) are exceeded throughout the snowmelt period, sustaining riparian growth and regeneration, and recharging shallow groundwater. Dry-Normal II snowmelt releases are specifically intended to take advantage of Parker and Walker creek augmentation below the Narrows to provide natural timing and daily fluctuations, and maximize the flow magnitude below the Narrows. The snowmelt bench provides operational flexibility to piggyback on Parker and Walker creek snowmelt peaks: combined Parker and Walker creek flows below the Narrows add an additional 35 to 65 cfs in simulated Dry-Normal II runoff years 2001 and 2003, peak flow magnitudes reached 242 and 265 cfs. These flows exceeded thresholds for spawning gravel mobilization in pool-tails and sediment deposition on the leading edge of point bars for at least 5 days for simulated runoff years. The snowmelt recession begins July 1 and slowly recedes to baseflow by July 23. The winter baseflow recommendation of a 28 to 32 cfs release at the top of the MGORD in concert with flow losses and tributary accretions should be 19 to 23 cfs downstream of the Narrows. For the two Dry-Normal II runoff years between 1990 and 2008, average Parker and Walker creek accretions equaled 6.6 cfs (Appendix A-5).

Table 2-10. Rush Creek recommended SEFs for DRY-NORMAL II runoff year types.

DRY-NORMAL II RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	May 18	40	48	
Spring Ascension	May 19	May 31	40-80	13	5%
Spring Bench					
Snowmelt Ascension					
Snowmelt Bench	June 1	June 30	80	15	
Snowmelt Flood	June 8	June 22	80-200-80	15	20%
Snowmelt Peak (release)	June 12	June 14	200	3	
Snowmelt Peak (spill)					
Fast Recession					10%
Medium Recession (Node)	July 1	July 8	80-48	8	6%
Slow Recession	July 9	July 23	48-30	15	3%
Summer Baseflow	July 24	September 30	30	69	
Fall Baseflow	October 1	November 30	30	61	
Winter Baseflow	December 1	March 31	30	121	

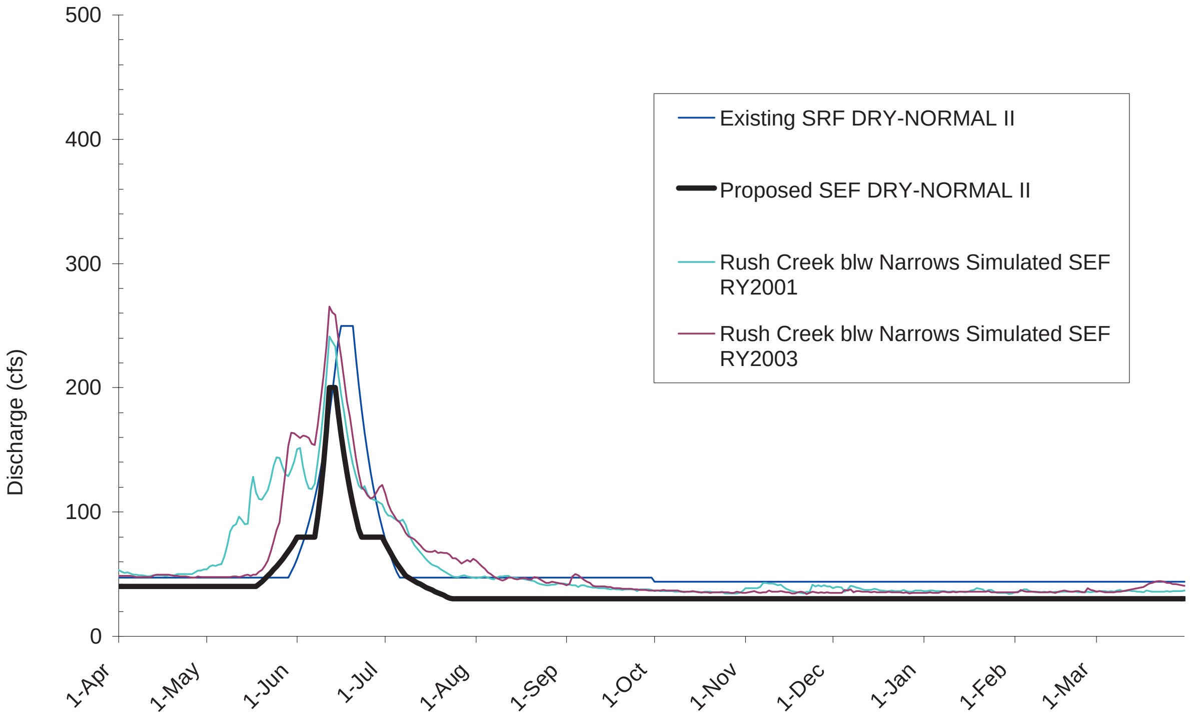


Figure 2-10. Rush Creek recommended SEF streamflows for DRY-NORMAL II runoff years.

2.4.2.4. Normal Runoff Years

Runoff Year Type	Exceedence Probability	May 1 Forecast Volume of Runoff (af)	Percent of Average Runoff
Normal	40-60%	100,750 - 130,670	82.5% - 107%

Current Baseflow and SRF Hydrograph: Current Normal runoff years require baseflows of 47 cfs from April 1 to September 30 and 44 cfs from October 1 to March 31, and a two-stage SRF peak release of 380 cfs for 5 days and 300 cfs for 8 days.

Recommended SEF Hydrograph (Table 2-11; Figure 2-11): Recommended SEF flows for Normal runoff years provide spring baseflows of 40 cfs during April. On May 1 baseflows ascend to an 80 cfs spring bench for 28 days, then ascend again from 80 to 120 cfs on June 12 to a snowmelt bench. A snowmelt flood peak of 380 cfs for 3 days is recommended, descending in three stages at 10%, 6% and 3% maximum change per day, reaching summer baseflows on August 16. Recommended summer, fall, and winter baseflows are 30 cfs.

Primary Ecological Functions: Normal runoff years should provide abundant trout and BMI habitat, sustain strong and vigorous riparian vegetation growth and regeneration, and achieve multiple geomorphic functions with peak snowmelt releases. Spring baseflow and pre-SEF peak streamflows ranging from 40 to 80 cfs are specifically intended to take advantage of Parker and Walker creek flows to provide more natural timing and daily fluctuations in the hydrograph, to provide pre-snowmelt secondary peaks of 125 to 175 cfs below the Narrows to recharge groundwater prior to the snowmelt flood. The snowmelt bench also provides operational flexibility to piggyback on Parker and Walker snowmelt peaks to maximize peak discharge below the Narrows. With 120 cfs MGORD releases and maximum ascending rates of 20% per day, seven days are required to reach the prescribed 380 cfs peak, and should allow frequent coincidence of Rush Creek peak releases with Parker and Walker peaks. Simulated snowmelt peaks for Normal runoff years 1999 and 2000 reached 458 and 452 cfs below the Narrows. These snowmelt flood peaks exceeded thresholds for spawning gravel mobilization and minor bar deposition (>250 cfs) for at least 4 days in simulated Normal runoff years 1999, 2000, and 2008, and exceeded thresholds for large wood mobilization and transport (>450 cfs) for at least one day in most simulated runoff years. The snowmelt bench allows a 30 day window for the 16 day snowmelt flood. Given this flexibility in peak flow release timing, the potential range of dates for the three day peak snowmelt flood is June 22 to July 6, corresponding to the peak seed release period for riparian vegetation. A GLR spill is not expected for Normal runoff years but may occur in some years prior above average runoff. The Normal year snowmelt recession has three stages of progressively slower recession rates. Moderately stressful daily average water temperatures may persist in late-August and into September of some runoff years. The winter baseflow recommendation of a 28 to 32 cfs release at the top of the MGORD in concert with flow losses and tributary accretions should translate into a measured flow of approximately 19 to 25 cfs downstream of the Narrows. For the three Normal runoff years between 1990 and 2008, average Parker and Walker creek accretions equaled 7.3 cfs (Appendix A-5).

Table 2-11. Rush Creek recommended SEFs for NORMAL runoff year types.

NORMAL RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	April 30	40	30	
Spring Ascension	May 1	May 14	40-80	14	5%
Spring Bench	May 15	June 11	80	28	
Snowmelt Ascension	June 12	June 14		3	10%
Snowmelt Bench	June 15	July 14	120	14	
Snowmelt Flood	June 19	July 4	120-380-120	16	20%
Snowmelt Peak (release)	June 25	June 27	380	3	
Snowmelt Peak (spill)					
Fast Recession					10%
Medium Recession (Node)	July 15	July 26	120-58	12	6%
Slow Recession	July 27	August 16	58-30	21	3%
Summer Baseflow	August 17	September 30	30	45	
Fall Baseflow	October 1	November 30	30	61	
Winter Baseflow	December 1	March 31	30	121	

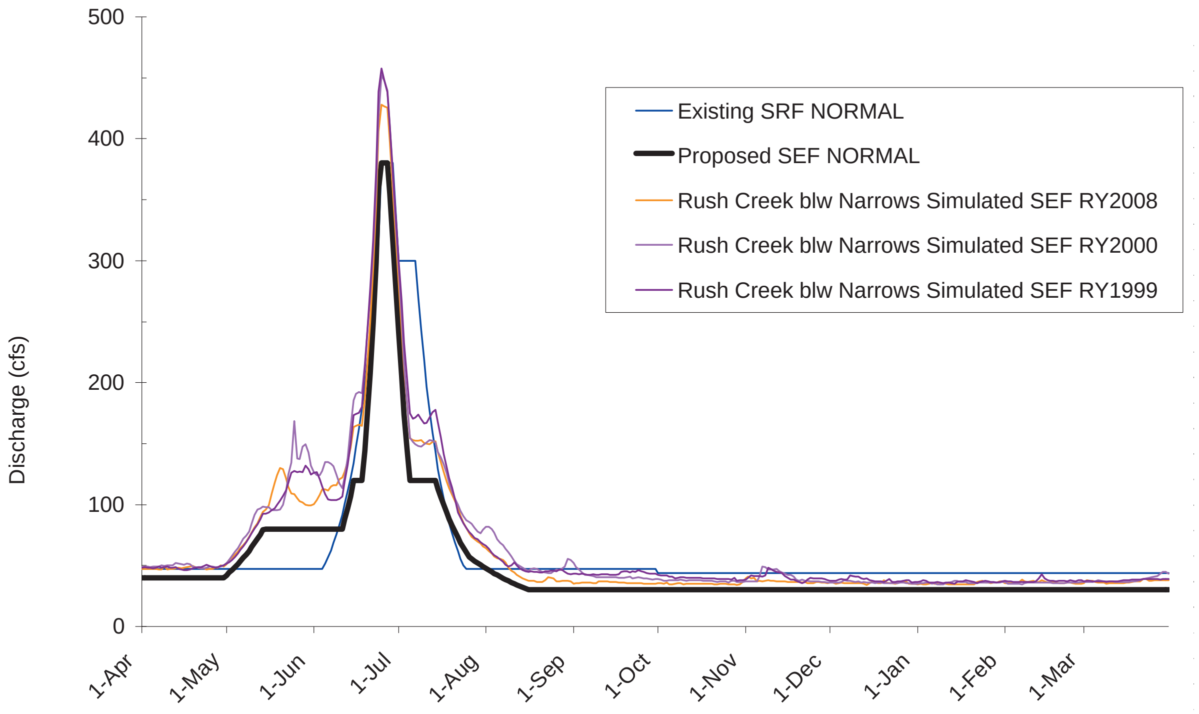


Figure 2-11. Rush Creek recommended SEF streamflows for NORMAL runoff years.

2.4.2.5. Wet-Normal Runoff Years

Runoff Year Type	Exceedence Probability	May 1 Forecast Volume of Runoff (af)	Percent of Average Runoff
Wet-Normal	20-40%	130,670 - 166,700	107% - 136.5%

Current Baseflow and SRF Hydrograph: Wet-Normal runoff years currently require baseflows of 47 cfs from April 1 to September 30 and 44 cfs from October 1 to March 31, and a two-stage SRF peak release of 400 cfs for 5 days and 350 cfs for 10 days.

Recommended SEF Hydrograph (Table 2-12; Figure 2-12): Wet-Normal SEF flows have the same spring hydrograph as Normal years, with 40 cfs spring baseflows, a spring ascension of 40 to 80 cfs, and a 28 day spring bench at 80 cfs. Flows then ascends to slightly higher bench of 145 cfs on June 12. Peak snowmelt releases are 380 cfs for 4 days. Recommended minimum flood peaks for spills are 3 days at 550 cfs. The snowmelt recession descends in three stages at 10%, 6% and 3% maximum change per day, reaching summer baseflows on September 1. Recommended summer, fall, and winter baseflows are 30 cfs.

Primary Ecological Functions: Wet-Normal years employ the same strategy as Normal years of a long-duration snowmelt bench at 145 cfs to to recharge groundwater prior to the snowmelt flood and provide operational flexibility needed to piggyback on Parker and Walker creek snowmelt peaks to maximize peak discharge below the Narrows (for geomorphic functions). The snowmelt bench extends from June 18 to July 23, with a flexibly-timed 18 day snowmelt flood within the 36 day snowmelt bench period. The potential timing of the snowmelt peak is therefore June 23 to July 14, corresponding to the peak seed release period for riparian vegetation.. Wet-Normal prescribed snowmelt releases are 380 cfs for four days; peak spills from GLR exceeding 550 cfs are recommended for a minimum of three days, and would exceed several geomorphic thresholds. The snowmelt recession limb also has three stages with progressively slower recession rates: a fast recession with maximum 10% change per day immediately following the snowmelt peak, a medium recession following the snowmelt recession node on July 23 with maximum 6% change per day, and a slow recession of 3% change per day extending the recession through August before reaching summer baseflow. The winter baseflow recommendation of a 28 to 32 cfs release at the top of the MGORD in concert with flow losses and tributary accretions should translate into a measured flow of approximately 19 to 25 cfs downstream of the Narrows. For two of the three Wet-Normal runoff years between 1990 and 2008, average Parker and Walker creek accretions equaled 7.6 cfs (Appendix A-5). RY1996 was excluded from calculating the average due to the January 1997 flood event which skewed the analysis with a mean monthly flow contribution from Parker and Walker creeks of 33.3 cfs (Appendix A-5).

Table 2-12. Rush Creek recommended SEFs for WET-NORMAL runoff year types.

WET-NORMAL RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	April 30	40	30	
Spring Ascension	May 1	May 14	40-80	14	5%
Spring Bench	May 15	June 11	80	28	
Snowmelt Ascension	June 12	June 17	80-145	6	10%
Snowmelt Bench	June 18	July 23	145	18	
Snowmelt Flood	June 26	July 13	145-380-145	18	20%
Snowmelt Peak (release)	July 1-4	July 4	380	4	
Snowmelt Peak (spill)			550	3	20%
Fast Recession					10%
Medium Recession (Node)	July 24	August 4	145-67	12	6%
Slow Recession	August 5	August 31	67-30	27	3%
Summer Baseflow	September 1	September 30	30	30	
Fall Baseflow	October 1	November 30	30	61	
Winter Baseflow	December 1	March 31	30	121	

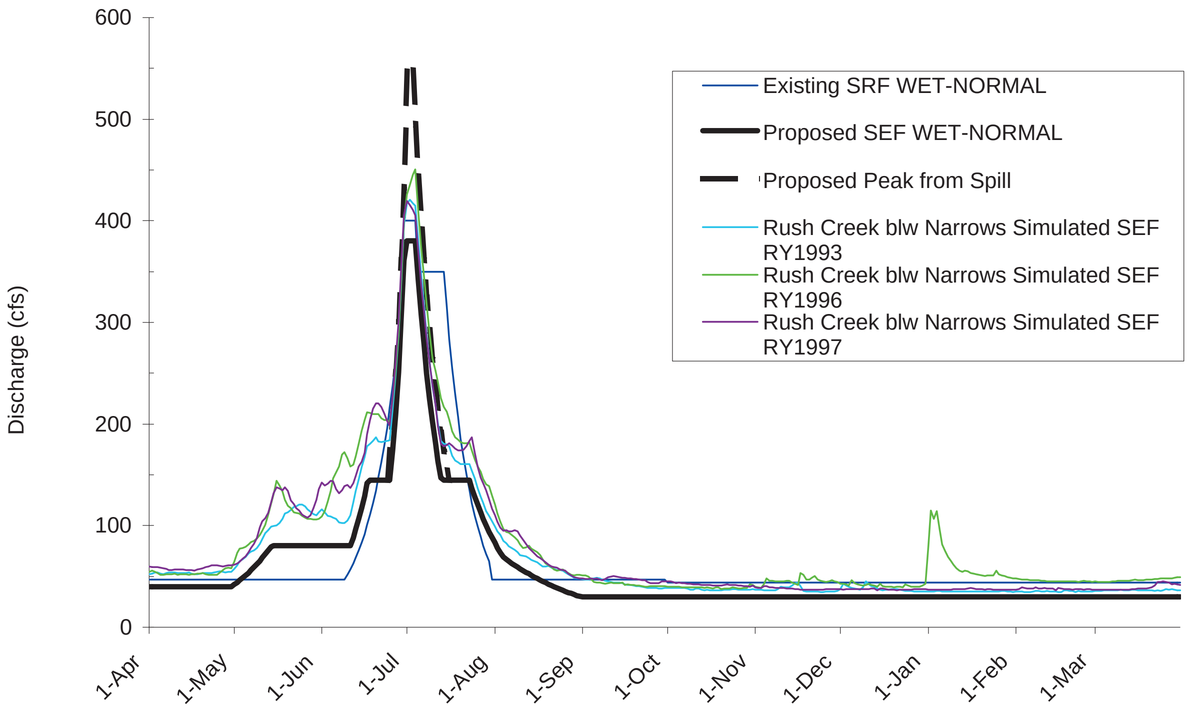


Figure 2-12. Rush Creek recommended SEF streamflows for WET-NORMAL runoff years.

2.4.2.6. Wet Runoff Years

Runoff Year Type	Exceedence Probability	May 1 Forecast Volume of Runoff (af)	Percent of Average Runoff
Wet	8-20%	166,700 - 195,400	136.5% - 160%

Current Baseflow and SRF Hydrograph: Wet runoff years currently require baseflows of 68 cfs from April 1 to September 30 and 52 cfs from October 1 to March 31, and a two-stage SRF peak release of 450 cfs for 5 days and 400 cfs for 10 days.

Recommended SEF Hydrograph (Table 2-13; Figure 2-13): The Wet runoff year SEF flows have a similar pattern to the Normal and Wet-Normal hydrographs, with 40 cfs spring baseflows in April, a 29 day spring bench at 80 cfs, followed by ascension to a snowmelt bench of 170 cfs. The snowmelt flood release has a peak release of 380 cfs for 5 days. Recommended minimum flood peaks for spills are 5 days at 650 cfs. The snowmelt recession descends in three stages at 10%, 6% and 3% maximum change per day, reaching summer baseflows on September 12. Recommended summer, fall, and winter baseflows are 30 cfs.

Primary Ecological Functions: Wet runoff years target major geomorphic functions, riparian regeneration, and high condition factor for 2+ and adult trout. The pre-snowmelt flood period targets abundant BMI habitat, wetting of off-channel features (such as gravel bars, side channels, and scour channels), and groundwater recharge. Beginning June 12, streamflows ascend to a snowmelt bench, where flows are maintained at 170 cfs from June 19 to August 1, punctuated by a 15 day snowmelt flood release. Snowmelt peak releases of 380 cfs for 5 days are prescribed for Wet runoff years, but these releases are intended to be replaced by spills from GLR. Spill magnitudes of 650 cfs for 5 days are recommended for Wet runoff years, to promote advanced floodplain deposition along channel margins and within the interior of floodplain surfaces, deposit gravel bars opposite eroding meander bends, alter side channel entrances, and form delta channels. The timing of the snowmelt flood can vary within the June 27 to July 13 window provided by the 170 cfs bench. Peak recession rates of 10% per day are recommended above the 170 cfs snowmelt bench, with a snowmelt recession node on August 1, followed by progressively slower recession rates of 6% and 3%. The recession extends through August and into September, balancing thresholds for abundant trout foraging habitat and maintenance of riparian vegetation. Summer baseflows of 28 to 32 cfs occur briefly from September 12 to 30. Fall and winter baseflows of 28 to 32 cfs at the top of the MGORD in concert with flow losses and tributary accretions should translate into a measured flow of 20 to 25 cfs downstream of the Narrows. For the three Wet runoff years between 1990 and 2008, average Parker and Walker creek accretions equaled 9.2 cfs (Appendix A-5).

Table 2-13. Rush Creek recommended SEFs for WET runoff year types.

WET RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	April 30	40	30	
Spring Ascension	May 1	May 13	40-80	13	5%
Spring Bench	May 14	June 11	80	29	
Snowmelt Ascension	June 12	June 18	80-170	7	10%
Snowmelt Bench	June 19	August 1	170	29	
Snowmelt Flood	July 5	July 19	170-380-170	15	20%
Snowmelt Peak (release)	July 8	July 12	380	5	
Snowmelt Peak (spill)			650	5	20%
Fast Recession					10%
Medium Recession (Node)	August 2	August 15	160-70	14	6%
Slow Recession	August 16	September 11	70-30	27	3%
Summer Baseflow	September 12	September 30	30	19	
Fall Baseflow	October 1	November 30	30	61	
Winter Baseflow	December 1	March 31	30	121	

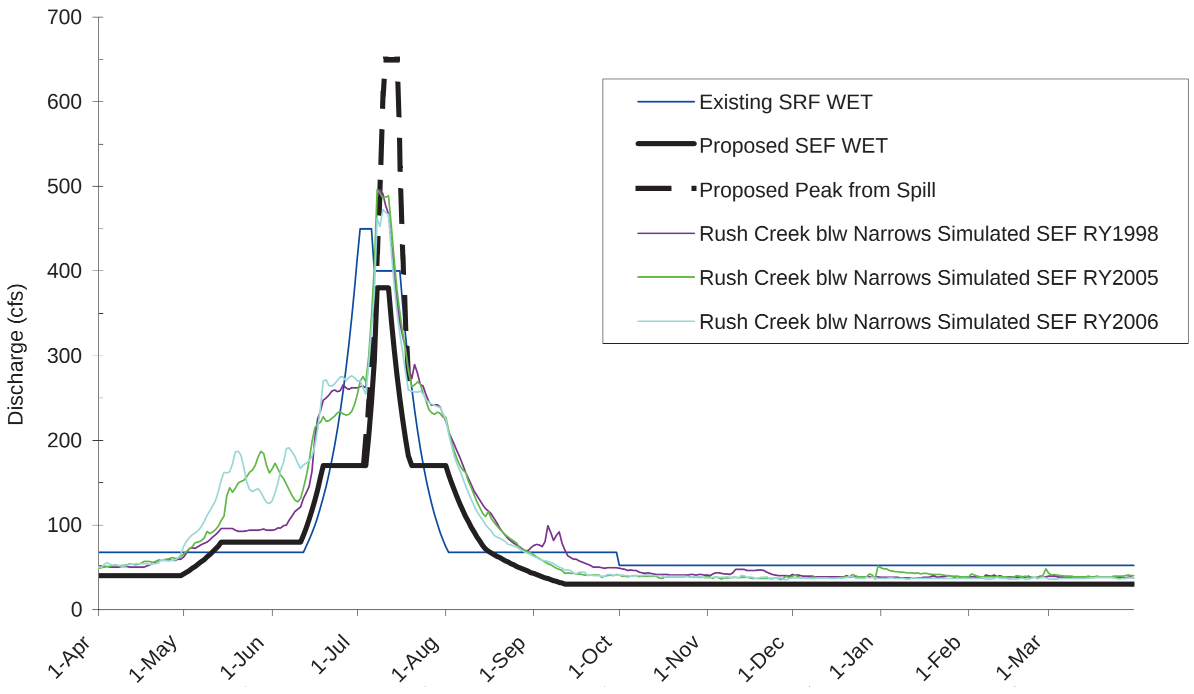


Figure 2-13. Rush Creek recommended SEF streamflows for WET runoff years.

2.4.2.7. Extremely-Wet Runoff Years

Runoff Year Type	Exceedence Probability	May 1 Forecast Volume of Runoff (af)	Percent of Average Runoff
Extreme Wet	<8%	>195,400	>160%

Current Baseflow and SRF Hydrograph: Extremely-Wet runoff years currently require baseflows of 68 cfs from April 1 to September 30 and 52 cfs from October 1 to March 31, and a two-stage SRF peak release of 500 cfs for 5 days and 400 cfs for 10 days.

Recommended SEF Hydrograph (Table 2-14; Figure 2-14): The Extremely-Wet runoff year SEF flows are similar to Wet runoff year hydrographs, with 40 cfs spring baseflows in April, a 29 day spring bench at 80 cfs, followed by ascension to a snowmelt bench of 220 cfs. The snowmelt flood release has a peak release of 380 cfs for 8 days. Recommended minimum flood peaks from GLR spills are 5 days at 750 cfs. Similar to other SEF hydrographs, the snowmelt recession descends in three stages at 10%, 6% and 3% maximum change per day, with a recession "node" on August 10, then descending to summer baseflows on September 12. Recommended summer, fall, and winter baseflows are 30 cfs.

Primary Ecological Functions: Peak magnitudes specified for Extremely-Wet runoff years (750 cfs) were not observed by our monitoring program, but are expected to promote significant geomorphic changes to mainstem and side-channel networks, cause channel avulsions over reaches longer than one or two meander wavelengths, cause rapid migration of headcuts, and provide the highest water surface stage heights for major floodplain aggradation and channel reconfinement.

The spring pre-snowmelt period provides similar ecological conditions as Wet-Normal and Wet runoff years, with abundant benthic macroinvertebrate habitat, significant wetting of off-channel features such as gravel bars, side channels, and scour channels, and significant groundwater recharge prior to the snowmelt flood. However, Extremely-Wet years may be subject to GLR spills beginning in April or May of some years. Beginning on June 12, SEF flows ascend to a snowmelt bench of 220 cfs in anticipation of large magnitude spills from GLR. A snowmelt peak of 380 cfs for 8 days may be released from the MGORD in conjunction with spills, or delayed to allow more rapid filling of GLR (if needed). The possible range in timing of the snowmelt peak if the snowmelt flood is released at the start or end of the snowmelt bench is June 28 to August 5. Peak snowmelt recession rates of 10% per day are recommended above the 220 cfs snowmelt bench, with a snowmelt recession node on August 10, followed by progressively slower recession rates of 6% and 3%. Extremely-Wet runoff years do not have summer baseflows. The slow recession extends through September and reaches fall baseflow on October 1. Fall and winter baseflow recommendations of a 28 to 32 cfs release at the top of the MGORD in concert with flow losses and tributary accretions should translate into a measured flow of approximately 23 to 30 cfs downstream of the Narrows. For the single Extremely-Wet runoff year between 1990 and 2008, average Parker and Walker creek accretions equaled 12.2 cfs (Appendix A-5).Average annual yields for each runoff year type provided by SRF and SEF streamflows are summarized in Table 2-15.

Table 2-14. Rush Creek recommended SEFs for EXTREME-WET runoff year types.

EXTREME-WET RUNOFF YEAR					
Hydrograph Component	Start Date	End Date	Streamflow (cfs)	Duration (days)	Rate of Change
Spring Baseflow	April 1	April 30	40	30	
Spring Ascension	May 1	May 13	40-80	13	5%
Spring Bench	May 14	June 11	80	29	
Snowmelt Ascension	June 12	June 21	80-220	10	10%
Snowmelt Bench	June 22	August 10	220	36	
Snowmelt Flood	July 9	July 22	220-380-220	14	20%
Snowmelt Peak (release)	July 11	July 18	380	8	
Snowmelt Peak (spill)			750	5	20%
Fast Recession					10%
Medium Recession (Node)	August 11	August 24	220-90	14	6%
Slow Recession	August 25	September 30	90-30	37	3%
Summer Baseflow					
Fall Baseflow	October 1	November 30	30	61	
Winter Baseflow	December 1	March 31	30	121	

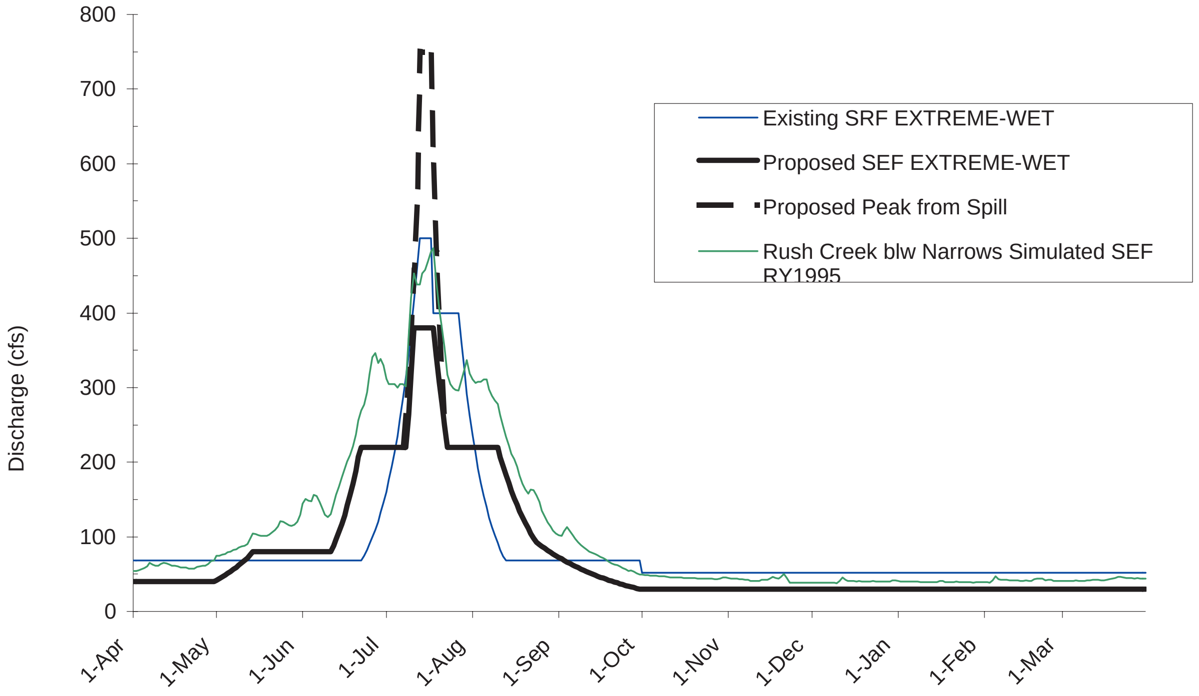


Figure 2-14. Rush Creek recommended SEF streamflows for EXTREME-WET runoff years.

Table 2-15. Summary of annual yield volumes for Rush Creek, for unimpaired runoff, Order 98-05 SRF streamflows, and recommended SEF streamflows for each runoff year type.

	Annual Yield (af)			
Runoff Year Type	Unimpaired	Existing SRFs	Proposed SEFs	SEFs with Spills
Dry	33,850	24,248	26,851	
Dry-Normal I	45,842	38,082	28,911	
Dry-Normal II	45,842	39,675	28,963	
Normal	54,296	47,226	38,063	
Wet-Normal	71,194	50,062	42,175	45,319
Wet	93,279	62,514	46,264	51,950
Extreme-Wet	93,279	63,783	55,265	60,649

2.5. SEF Annual Hydrographs and Diversion Rates are Templates

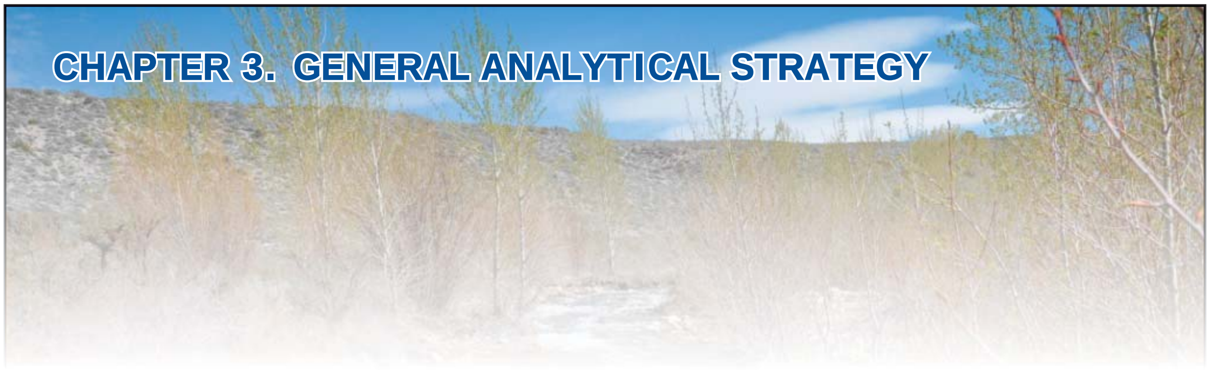
The SEF annual hydrographs in each runoff year type for Rush Creek must be considered templates, and not the final recommended annual hydrographs. Small-magnitude hydrograph transitions in the Rush Creek SEFs cannot all be feasibly reproduced in LADWP's releases. LADWP's task, as part of its 120 day review, will be to evaluate operational feasibility. Following LADWP's feasibility evaluation, the Stream Scientists will report to the SWRCB as to whether LADWP's proposed operational Rush Creek annual hydrographs meet the intent of the SEFs recommended. An upgraded diversion facility on Lee Vining Creek has made a daily diversion rate, rather than annual bypass flows strategize for Rush Creek, a viable alternative to present-day operations. However, the Lee Vining Creek facility still cannot be expected to divert streamflows within as narrow a margin of error as implied (i.e., within 1 cfs) in the SEF recommendations. Similar to Rush Creek, LADWP will have 120 days to evaluate how well the Stream Scientist's proposed daily diversion strategy for Lee Vining Creek can be implemented feasibly.

An acceptable margin of error ultimately must be traceable back to the affected streamflow's intended purpose. As a rule-of-thumb, no greater than a 5% change in stage bracketing the targeted stage would be an acceptable margin of error for a given flow release or flow diversion. For example, a targeted flow release of 40 cfs on Lee Vining Creek has a stage height of 1.69 ft (using a stage-discharge rating curve introduced in Chapter 4). A 5% total range bracketing 1.69 ft would equal an upper stage of 1.73 ft and a lower stage of 1.65 ft. Converting these upper/lower stage heights back to flow rates gives an upper flow release of approximately 43 cfs and a lower flow release of 37 cfs, for a 6 cfs acceptable range. LADWP would be expected to strive for releasing 40 cfs, but operationally, flow releases without a systematic bias between 37 cfs and 43 cfs would be acceptable. At higher streamflows, a 5% change gives a greater absolute stage change and a wider range in acceptable flow releases, both expected. For example, a 200 cfs on Lee Vining Creek has a stage height of 2.91 ft (using the same rating curve). A 5% total range bracketing 2.91 ft would equal an upper stage of 2.98 ft and a lower stage of 2.84 ft. Converting these upper/lower stage heights back to flow rates gives an upper flow release of approximately 218 cfs and a lower flow release of 188 cfs. LADWP would be expected to strive for releasing 200 cfs. Flow releases without a systematic bias between 218 cfs and 188 cfs would thus be acceptable. This rule provides LADWP a tool for evaluating operational feasibility.

2.6. Release of Excess Water During Pre-Transition Period

The SEF annual hydrographs for Rush Creek and Lee Vining Creek would allow LADWP to divert up to 35% and 23% of the average annual runoff from Rush and Lee Vining creeks, respectively, once Mono Lake reaches 6391 ft elevation. Until then, LADWP is limited to 16,000 af export to the Owens River. This leaves an 'extra' volume, watershed runoff not accounted for in the SEFs and exports to the Owens River, which must flow to and fill Mono Lake. This water can provide added ecological benefits to specific hydrograph components, when available. But absence of this excess streamflow in post-transition years with higher exports will not cause adverse conditions in Rush Creek. The late-fall through winter baseflow season provides no opportunity to release streamflows in excess of the recommended SEFs. The inflated SCE baseflows must be reduced to increase winter holding habitat for trout. This constraint leaves the snowmelt runoff period (April 1 through September 30) for releasing the extra streamflow. However, another SEF management objective is to make GLR spill frequently. Planned dam releases in excess of the SEFs during and after the snowmelt peak would be better than before the peak, to ensure a fuller reservoir when natural peak runoff occurs. Two hydrograph components would therefore be prime candidates for dam releases exceeding the SEF streamflows: longer duration of the snowmelt peak and longer duration of the snowmelt bench following the peak. Of the two, extending the snowmelt bench offers more ecological benefit. Water temperatures would be cooler later into the summer and early-fall, and woody riparian plant vigor would be sustained later as well. The greatest uncertainty with this amended release strategy concerns trout. Snowmelt bench streamflows in the SEFs (ranging from 70 cfs in a Dry runoff year to 220 in a Wet runoff year) are considerably higher than the range of streamflows offering abundant brown trout foraging and holding habitat (15 cfs to 35 cfs (Taylor et al. 2009)). Augmented benches would have even higher streamflows. However, the trout habitat rating curves do not extend above streamflows confined to the mainstem channel. Streamflows above 80 cfs to 100 cfs begin inundating off-channel features (such as alcoves) and emergent floodplains. The snowmelt bench streamflows would reach farther into backwater mainstem features and into emergent floodplains. These features would provide foraging and holding habitat for several age classes of trout. As the woody riparian vegetation matures, this habitat will likely improve. Elodea beds also would expand, offering more food and cover. Trout monitoring would provide the necessary feedback in adaptively managing these amended SEF streamflows. Monitoring in September of 2006 indicated that brown trout condition factors in Rush Creek were not compromised by extended periods of high runoff in RY2006 (Hunter et al. 2007).

CHAPTER 3. GENERAL ANALYTICAL STRATEGY



Instream flow recommendations for Rush Creek and Lee Vining Creek required analyzing the following ‘how to’ primary objectives: (1) prescribe more reliable Lee Vining Creek diversions and eliminate their potential negative impacts, (2) accelerate recovery of the Lee Vining Creek ecosystem by encouraging SCE’s assistance in releasing higher peak snowmelt runoff events, (3) reduce SCE’s elevated winter baseflows to improve winter trout holding habitat, (4) actively manage for a more reliably full GLR, by diverting Lee Vining Creek streamflow throughout most of the runoff year, to increase the magnitude, duration, and frequency of GLR spills and to provide colder dam releases into Rush Creek from a deeper, cooler reservoir, (5) adjust the Rush Creek SRF streamflows, based on previous and ongoing scientific investigations, to better achieve desired ecological outcomes and processes and to improve the reliability of their release, (6) accelerate recovery of the Rush Creek ecosystem by encouraging SCE’s and USFS’s assistance in releasing higher peak snowmelt runoff events that reservoir spills cannot create, (7) provide a shallow groundwater environment necessary to promote riparian vegetation recovery on contemporary floodplains, (8) recommend streamflow changes that will improve the brown trout population structure for both creeks by increasing adult habitat and improving specific growth rates to the greatest extent feasible, (9) inform the SWRCB how average annual diversion volumes ranging from 20,000 af up to 35,000 af, within the operational side-boards imposed by the recommendations, would affect key desired ecological outcomes and processes, and (10) eliminate the termination criteria and replace them with a long-term monitoring plan. Although each primary objective demanded unique analytical challenges, several fundamental analytical steps were precursors needed by all.

3.1. Specifying ‘Desired Ecological Outcomes’ with Streamflow Thresholds

The first step was to explicitly identify desired ecological outcomes for each creek using hydrograph components as guidelines. This process was initiated in the Stream Restoration Plan (Ridenhour et al. 1996). The RY2003 Annual Report describes the unimpaired hydrograph and specific hydrograph components, then identifies key ecological processes and conditions sustained by hydrograph components in different runoff year types. Since 2003, more data have been collected, analyzed, and synthesized. An understanding of the many past and present ecological roles each runoff year type performs also improved, though uncertainties remain.

Abrupt streamflow thresholds for biological or physical processes rarely exist in nature, always vary spatially, usually vary temporally, and almost always are highly interactive. Nevertheless, streamflow thresholds are extremely useful in prescribing instream flows to accomplish specific ecological tasks. Streamflow thresholds were kept broad in recognition of this spatial and temporal variability, but sufficiently narrow to be effective. The desired ecological outcomes and physical processes, and their accompanying streamflow thresholds (Table 3-1), reflect both considerations.

Without the opportunity to observe in the field what a 300 cfs streamflow looks like compared to a 400 cfs streamflow, the subtlety of these thresholds dominating how both streams work is difficult to appreciate. In Lower Rush Creek, the difference in flow depth (the same as 'stage height') at a riffle crest thalweg between a 300 cfs streamflow and a 400 cfs streamflow is approximately 0.5 ft. The difference in flow depth between a trout winter holding habitat threshold of 25 cfs and a streamflow threshold of 200 cfs for mobilizing spawning gravel is 1.7 ft. An historic 10-yr flood (800 cfs) is 0.25 ft deeper than a 5-yr flood (700 cfs). Although a threshold streamflow range of 600 cfs to 700 cfs for advanced floodplain deposition may seem too broad, the difference in depth between 600 cfs (~3.2 ft deep) and 700 cfs (~3.5 ft deep) is 0.3 ft. Yet the difference in stage between the upper threshold bound and lower threshold bound for abundant trout winter holding habitat (45 cfs and 25 cfs respectively) is approximately the same at 0.3 ft. The streamflow thresholds for desired ecological outcomes and physical processes therefore depend on, and are susceptible to, subtle changes in stage height. Many streamflow prescriptions in this report target a specific stage height.

Instream flow prescriptions must specify the magnitude, duration, frequency, timing, and sometimes rate of streamflow to be released. Difficulties in prescribing all five flow release parameters ranked from most difficult to least are: frequency, timing, duration, rate, and magnitude. By adopting a runoff year classification with seven runoff year types in SWRCB Order No.1631 and requiring annual releases to be patterned after their natural occurrence (i.e., when a Wet runoff year occurs in the Mono Basin, release a Wet runoff year instream flow), the two most difficult parameters (frequency and timing) have been incorporated into the overall instream flow prescription. This already was the SWRCB strategy. 'Rate' in the annual hydrograph refers to transitions (in cfs/day or ft of stage change/day) from low to high flow and vice versa. The two most important rates are the steeply rising limb of the snowmelt hydrograph and the less steep falling limb of the snowmelt hydrograph. To prescribe streamflow rates, the natural rate was recommended whenever analyses could not clearly mandate prescribing a steeper rate that would be ecologically equivalent.

3.2. Identifying Reference Conditions

Replicating the stream processes occurring before 1941 (i.e., prior to LADWP) will not lead to functional, dynamic, and self-sustaining stream ecosystems, even though some pre-1941 processes likely benefited trout (i.e., major spring-flow into lower Rush Creek). Replicating natural processes can restore stream ecosystems. However, the Stream Scientists' desire to recover natural processes is not a commensurate desire to return to pristine stream conditions that pre-dated hydropower production, water diversions, sheep grazing, and irrigation. Because there is no instruction manual on how Eastern Sierra Nevada stream ecosystems work, an understanding of how Mono Basin stream ecosystems likely functioned before disturbance is an objective and logical departure point. The first baseline for comparison is the computed unimpaired annual hydrograph, free from flow modifications by SCE. The second reference baseline is the hydrologic regime impaired by SCE. SCE has smoothed the annual hydrograph, dampening peaks and inflating baseflows to optimize hydropower production. Most streamflows that LADWP receives daily from SCE's upstream power operations on Rush Creek are significantly impaired. LADWP must manipulate these SCE annual hydrographs to begin achieving the SEFs and SWRCB's stream restoration goal, yet still meet its export goals. LADWP has internal operational constraints as well. The most serious is a maximum release capacity of 380 cfs to Lower Rush Creek via the MGORD. Many peak flood thresholds performing geomorphic work in Rush Creek's mainstem channel and floodplain are greater than 380 cfs. A third reference baseline is the

Table 3-1. Desired ecological outcomes for Rush and Lee Vining creeks, including the streamflow(s), time period, and duration (if appropriate) criteria used to define an NGD for each desired outcome. NGD was computed for each desired ecological outcome for unimpaired, SCE, SRF, and SEF annual hydrographs from RY1990 through RY2008.

Desired Ecological Outcomes	***Date Range for NGD Analysis***	***Flow Range (cfs)***	
		Lee Vining Creek	*Rush Creek*
Stream Productivity and Brown Trout Habitat			
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	16-22	25-45
Abundant Brown Trout Fry Habitat in Mainstem and along Channel Margin	May 20 to June 30	12-28; 80-150	40-60
Abundant Brown Trout Foraging and Holding Habitat	April 1 to September 30	15-30	15-35
Abundant Productive Benthic Macroinvertebrate Riffle Habitat	April 1 to September 30	20-38	40-110
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	55-80	90-160
Geomorphic Thresholds			
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	150-200	200-250
General LWD Transport and Debris Jam Formation	April 1 to September 30	>350	>450
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	250-300	400-450
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	300-400	450-600
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	400-500	600-700
Delta Building Event	April 1 to September 30	>350 for 5+ consec days	>500 for 5+ consec days
Mainstem Channel Avulsion	April 1 to September 30	500+	700-800
Riparian Growth and Maintenance			
Protect Vigor of Established Riparian Species along the Mainstem and Side-Channel Margins as well as on the Floodplain	May 1 to September 30	>30	>80
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces	June 15 to August 26	>80	120-275

stream processes resulting from the SRFs and minimum baseflows prescribed in SWRCB Order 98-05; recommended SEFs (and SEF implementation) should offer demonstrable improvement, given the SRFs were made prior to 12 years of monitoring.

For streamflow thresholds, the number of days at or above a threshold can be as important as the threshold itself. Streamflow duration, therefore, required multiple analytical strategies. A principal strategy, particularly for biological outcomes, was to determine duration of the unimpaired and regulated hydrographs first, then compare these to SEF hydrographs. For example, using the 30 cfs threshold for maintaining woody riparian growth on Lee Vining Creek floodplains, the number of days was tallied in unimpaired, the SCE regulated, and the SRF annual hydrographs when streamflows exceeded 30 cfs during the growing season (May 1 through September 30) as our reference duration. A good season for woody riparian vegetation would be a sufficient number of good days, i.e., when the 30 cfs threshold was exceeded. An improved SEF recommendation would maintain or increase the desired ecological outcome over the SCE and SRF flow regimes, and attempt to approach the unimpaired condition where feasible. The Stream Scientists ultimately must establish what 'a sufficient number' means (not always attaining the unimpaired annual hydrographs): in this example, 50% or more of the growing season's hydrograph is a duration threshold for sustaining vigorous woody riparian growth. For prescribing streamflow durations (e.g., for vigorous growth of established woody plants on Lee Vining Creek floodplains) there are nested thresholds: one threshold magnitude of 30 cfs and a nested threshold for duration (50% of the days between May 1 and September 30).

Even though it was ranked easiest among the five parameters, streamflow magnitude (generally as thresholds) was nevertheless challenging to prescribe given the significance of small stage changes already identified. Much of the fieldwork was dedicated to identifying and quantifying streamflow magnitude thresholds.

With desired ecological outcomes identified (Table 3-1), SEF streamflow recommendations were developed and evaluated using the following analytical approach. For Lee Vining Creek, alternative diversion rates were applied to Lee Vining above Intake, then the number of days quantified that streamflow thresholds (magnitude and duration) were met or exceeded for each simulated SEF hydrograph for RY1990 to RY2008. Days with daily average streamflows that meet or exceed a specified ecological threshold are termed "Good Days", hence the 'Number of Good Days' or 'NGD'. The NGD results were then examined relative to different reference baselines: unimpaired annual hydrographs, the SCE regulated annual hydrographs, and the SRF annual hydrographs. For Rush Creek, existing SRF flows were evaluated by computing NGDs for each simulated SEF hydrograph from RY1990 to RY2008. Annual thermograph simulations for selected representative runoff years also were evaluated by tallying NGDs in each reference baseline. Most analyses on Rush Creek focused below the Narrows with Parker and Walker creek assumed unimpaired. A simple spreadsheet model was developed that incorporated streamflow and diversion inputs and flow release outputs, simulated exports, and then predicted GLR elevation and storage volumes, spill frequencies and magnitudes.

The remainder of this Chapter describes this analytical framework: the NGD analysis and a water balance model used to evaluate GLR storage.

3.3. NGD Analyses

Two analytical strategies for evaluating instream flows on Rush and Lee Vining creek ecosystems were computed: (1) the number of good days (NGD) in a given year for a particular species/life stage or physical process and (2) the number of good years (NGY) for a particular species/life stage or physical process. For a trout or stonefly, a good day occurs when there is available physical habitat, favorable water temperatures, and abundant food. For a point bar in a cobble-bedded alluvial channel, a good day occurs when a peak streamflow threshold is exceeded that mobilizes and deposits cobbles onto large alluvial features. NGD's must be quantifiable and must be directly joined to the annual hydrograph. If the annual hydrograph is changed, the ecological consequence of those changes can be assessed objectively by evaluating the change in NGDs. NGDs rely on thresholds for streamflow magnitude and duration; NGD's rely on life history periodicity tables as well. For example, a good day for a yellow willow seed is landing on the moist surface of a shallow depression in a floodplain's interfluve. To compute NGD for yellow willow germination in this environmental setting, a streamflow threshold that will keep this floodplain surface moist (the capillary fringe of the shallow groundwater intersects the floodplain's surface) is needed as is the likely time period (also functioning as a threshold) when viable yellow willow seeds are dispersing.

Thresholds intentionally simplify complex processes for the purpose of identifying general cause-effect relationships of ecological importance. Even though simplification is intended, NGDs were extremely useful integrating physical and biological processes. The NGD for yellow willow germination integrates groundwater dynamics influenced by streamflow and integrates time periodicity of seed release. Streamflow and time are the X-axis and Y-axis of the annual hydrograph. An important objective of past monitoring was identifying and measuring thresholds for the NGD analyses.

NGDs were computed for annual hydrographs from RY1990 through RY2008 to capture a wide range in hydrological conditions. But NGDs can still have limited ecological perspectives. If a yellow willow seed successfully germinates (i.e., experiences good germination days), but dies 2 weeks later from desiccation, no regeneration has occurred (the seedling survives the first growing season, May 1 to September 30). A low or high number of germination NGDs could produce the same result. The number of good years (NGY) can widen an ecological perspective by assessing whether a particular runoff year is capable of successful germination *and* survival (=regeneration). To transition from NGD to NGY, another threshold typically is needed, usually a duration threshold. For yellow willow regeneration, saturated conditions were required for the first 21 days of a seedling's life. RYs that provided 21 continuous days of streamflows exceeding the threshold for sustaining saturated conditions were considered successful for yellow willow regeneration. NGY, therefore, was the number of good years between RY1990 and RY2008 achieving successful regeneration. NGY analyses also assessed the importance of runoff year type by noting which runoff year type(s) met with the most success.

NGD analyses for Lee Vining Creek and Rush Creek ecosystems can be portrayed collectively as a family of reference condition curves (Figure 3-1). The X-axis is a linear increase in diversion rate presented as a change in stage. The Y-axis is a ratio expressed as a percentage between NGD under unregulated and SCE reference conditions (the denominator) and NGD under a given diversion rate (the numerator) for any physical/biological process or ecological outcome under consideration. A value of 100% signifies no change relative to the reference condition. One reference condition is the unimpaired streamflows, but other reference conditions were considered including SCE-altered annual hydrographs and the currently prescribed SRFs. The management goal in using the unimpaired hydrograph as the reference condition is to prescribe the maximum diversion rate that results in only small negative and small positive deviations from unimpaired reference conditions while improving on the SCE and SRF regulated reference conditions. An increasing negative deviation, with greater stage diverted, signals a progressive impact to that biological/physical outcome or process. Less intuitively, positive deviations also signal impacts. A pertinent example for both creeks is the brown trout population where greater diversion rates can generate more available trout habitat based on

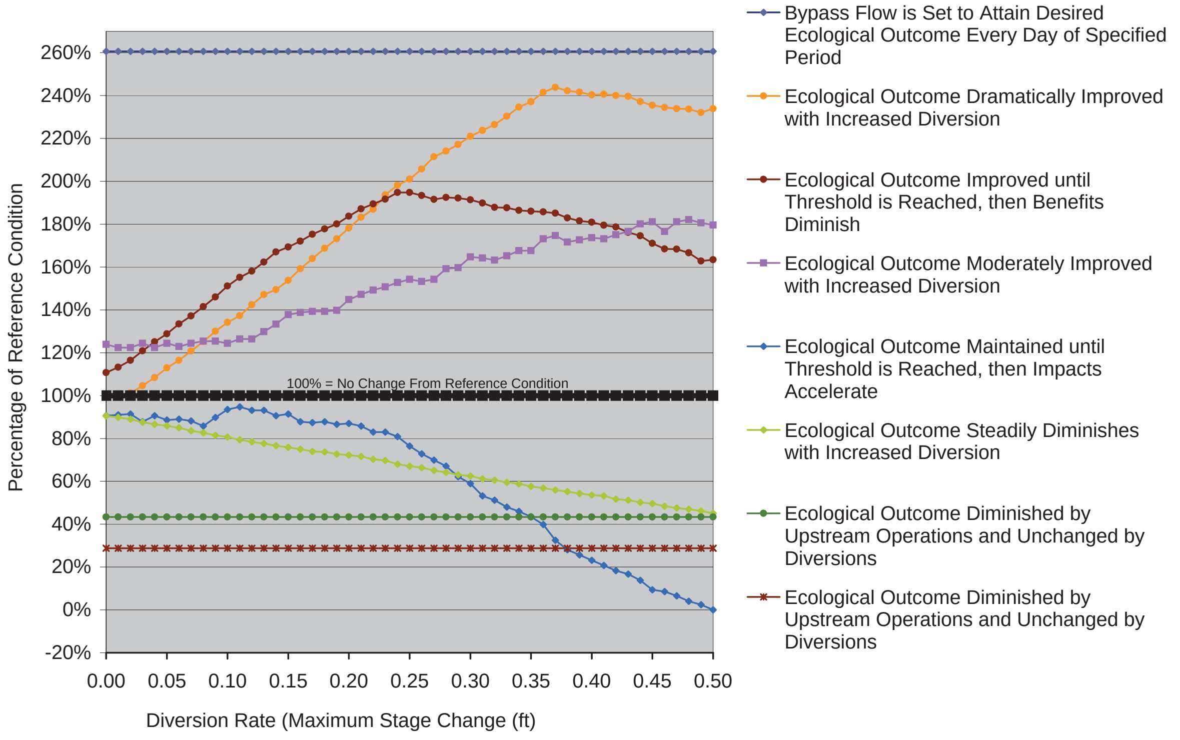


Figure 3-1. An idealized "family" of reference condition NGD curves. The relationships shown in the figure demonstrate the increasing 'effect' on NGDs for a family of Desired Ecological Outcomes with each incremental increase in diversion rate. Each curve is computed by quantifying the Number of Good Days (NGDs) as diversion rate increases from 0.0 to 0.5 ft allowable stage change, then dividing the resulting NGDs by the reference NGD (e.g., using either the unimpaired NGDs or the SCE regulated NGDs). The ratio of regulated-to-reference NGD is then plotted as a percentage. Increasing divergence from the neutral (baseline) of 100% of reference condition indicates increased effect of the diversion, either positive (>100%) or negative (<100%). The diversion rate in this analysis was determined by an allowable change in stage height using a rating curve from a representative cross section.

the habitat rating curves. However, the habitat that today's trout utilize has been created and maintained by past streamflow conditions that did not always favor abundant trout habitat or growth, but that were necessary to shape pools and floodplains. There is a balance in considering multiple desired ecological outcomes where the good of the individual may be jeopardized for the long-term good of the population.

3.4. A Spreadsheet Water Balance Model for Predicting Grant Lake Reservoir Elevations

A water balance model was developed to predict GLR elevations for individual and multiple runoff years. The model was used to evaluate implications of revised instream flow recommendations for Lee Vining and Rush creeks on GLR storage, probability of spills, and the potential for improved water temperatures released into Rush Creek. A more rigorous simulation model, the Los Angeles Aqueduct Simulation Model (LAASM), was developed by LADWP hydrographers to predict GLR and

Mono Lake elevations under different flow release and export scenarios. However, the present version of LAASM does not simulate runoff year sequences.

The model relies on input data for ‘Lee Vining Creek above Intake (5008)’ and ‘Rush Creek at Damsite (5013)’ streamflows. The model utilizes Lee Vining Creek SEF flows to compute water diversions from Lee Vining Creek as input to GLR. SEF flow releases into lower Rush Creek, and exports to the Owens Basin are both output variables from Grant Lake. The model was developed to simulate the 19-yr time-series from RY1990 to 2008 because there were complete records for daily average flows, GLR elevations, and exports. Also, this period provided a breadth of runoff conditions, beginning with an extended drought (RY1990 to RY1994), an extremely wet period (RY1995 to RY1998), a series of years with moderately dry to normal runoff conditions (RY 1999-2004), two Extremely-Wet runoff years (RY1995 and RY2006), an historic winter flood (January 3, 1997), and one of the driest years on record (RY2007). The historic low elevation of GLR occurred in June 2009, so the model was extended through August 2009 to evaluate the low GLR condition.

3.4.1. *Model calibration*

The model was developed to simulate GLR elevations for a 19-yr period of analysis using historic (real data) input and output values, with exception of GLR spills, and initially without an evaporation variable. The predicted GLR elevation was compared to historic elevations (Figure 3-2) to evaluate the model’s performance. Based on the initial poor fit of predicted to observed, an evaporation rate was added, and a GLR spillway rating curve (with constraint to outflow magnitude) was added. An average annual evaporation rate of 1,488 af/yr based on data from LADWP (1996) and Vorster (1985) resulted in a better fit.

3.4.2. *Model scenarios*

With a calibrated water balance model and refined SEF streamflow recommendations, different conditions and assumptions were simulated to evaluate the overall performance of the SEF flow recommendations and GLR in meeting the goals stated in Chapter 2. These scenarios are discussed in Section 6 after the Lee Vining Creek and Rush Creek analyses are presented.

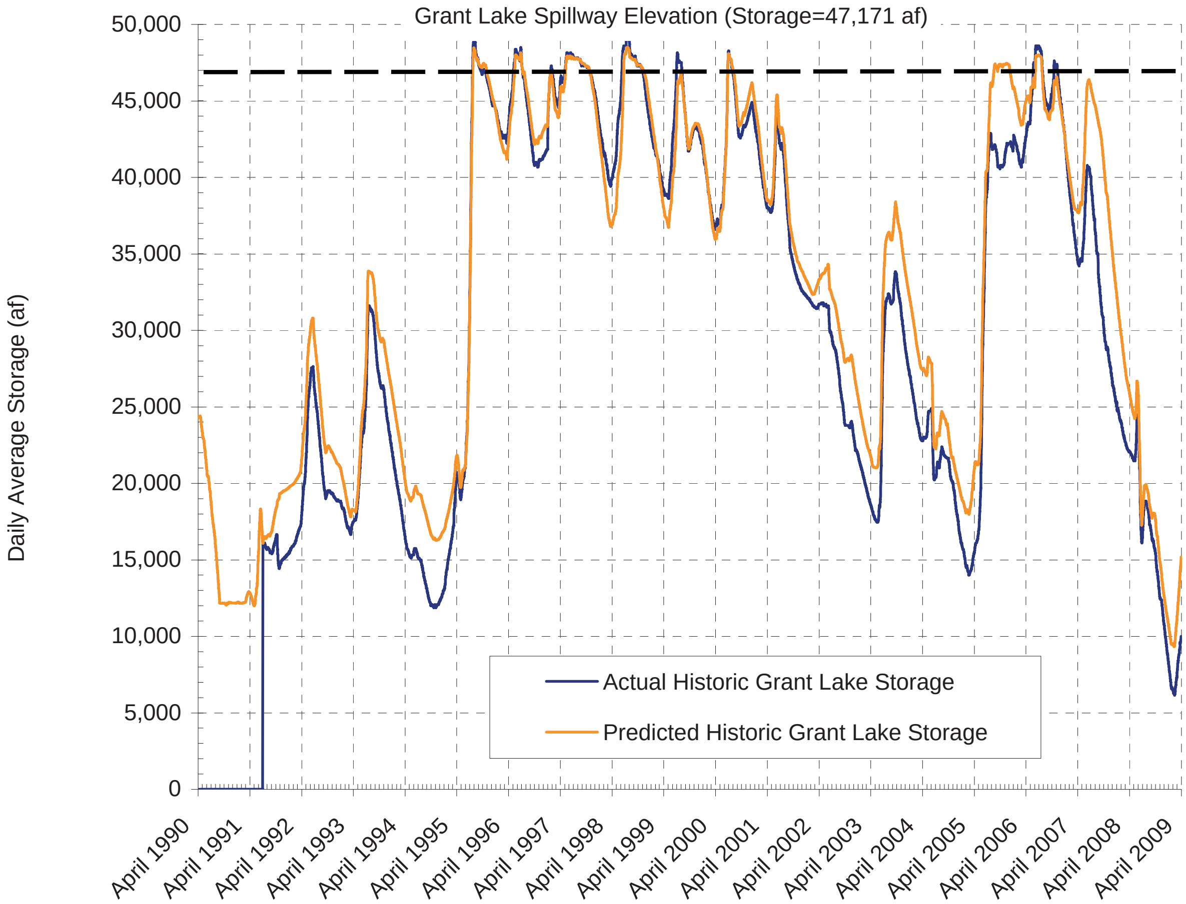


Figure 3-2. 'Actual Historic' vs 'Predicted Historic' Grant Lake Reservoir storage volume for the available period of record (RYs 1990 to 2008) used for hydrologic simulations. Once the model was calibrated to best predict GLR storage, the "predicted historic" storage volume was used as the basis for comparison in simulated diversion and export scenarios.

CHAPTER 4. LEE VINING CREEK ANALYSIS

4.1. Premises for the Analysis of Lee Vining Creek Hydrographs

Premises central to the analysis of Lee Vining Creek instream flows are:

- <u>Premise No.1.</u> Diversions from the Lee Vining Creek snowmelt flood to augment the Rush Creek snowmelt flood is not sustainable. The SWRCB Order 98-05 explicitly tasks the Stream Scientists with evaluating the augmentation of Rush Creek SRF snowmelt floods with 50 cfs, 100 cfs, and 150 cfs from Lee Vining during Wet-Normal, Wet, and Extremely-Wet runoff years. Future diversions are not recommended using this diversion protocol because of its well-documented unreliability and its impairment to the snowmelt recession limb even if reliably executed.
- <u>Premise No.2.</u> Annual snowmelt and baseflow hydrograph components for Lee Vining Creek above Intake (5008) are moderately regulated by SCE. Annual snowmelt flood peak magnitude and duration in the SCE annual hydrographs have been diminished compared to unregulated annual snowmelt peaks; fall and winter baseflows in the SCE annual hydrographs are elevated compared to unimpaired baseflows (Figure 4-1).
- <u>Premise No.3.</u> Some portions of the SCE regulated hydrographs can mimic unimpaired streamflows. SCE annual hydrographs selectively preserve the magnitude, duration, frequency, timing, and/or rate of a few unregulated annual hydrograph components. Most notably, the fast and slow snowmelt recession limbs in the SCE annual hydrographs are extremely similar to the fast and slow unregulated snowmelt recession limbs (Figure 4-1). Also, the timing of snowmelt peaks does not appear significantly altered by SCE operations.
- <u>Premise No.4.</u> Water temperatures in Lee Vining Creek are not impaired. Water temperature was not considered an issue for revising Lee Vining Creek instream flow needs. Water temperature monitoring clearly shows a healthy annual temperature regime typical of unregulated Eastern Sierra snowmelt streams, or the thermal regime typical of a regulated snowmelt stream with high-altitude storage reservoirs. In addition, no realistic management mechanism exists for significantly altering Lee Vining Creek water temperatures.
- <u>Premise No.5.</u> Large snowmelt floods impact trout recruitment. The timing, magnitude, and duration of snowmelt floods likely impair age-0 trout recruitment, particularly for rainbow trout. In balancing broader ecological objectives, short-term impairment to trout recruitment is outweighed by the need for snowmelt floods to restore mainstem channel morphology and build floodplains that eventually will promote more consistent age-0 recruitment.

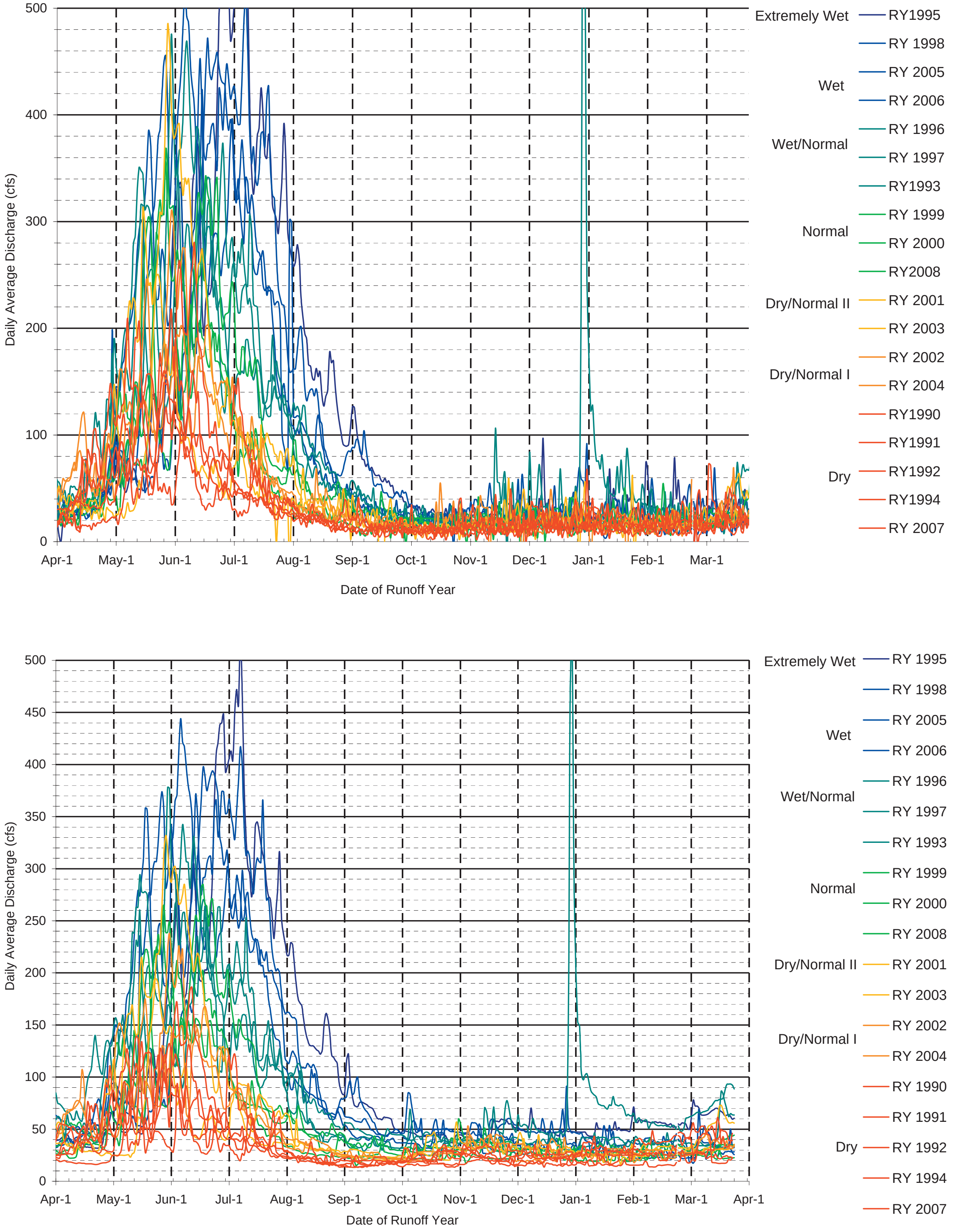


Figure 4-1. Annual hydrographs for Lee Vining Creek Runoff (computed unimpaired [above]) and for Lee Vining Creek above Intake (SCE regulated [below]) for RYs 1990 to 2008 showing patterns in annual hydrograph components and the range of variability in different runoff year types.

- Premise No.6. Winter baseflows are artificially high and as a result, diminish adult trout holding habitat quantity and quality. The Order 98-05 fall and winter baseflows generate unfavorably high velocities that consequently impair winter holding habitat availability for adult brown trout and rainbow trout. Lower fall and winter baseflows will provide more abundant high quality trout holding habitat. The potential for lower winter baseflow magnitudes mimicking unimpaired magnitudes to exacerbate winter icing effects on adult trout over-winter survival, relative to the Order 98-05 winter baseflows, will be investigated in RY2010.
- Premise No.7. More water can be reliably diverted from the Lee Vining Creek ecosystem. Total annual diversions from Lee Vining Creek via the Lee Vining Conduit and into GLR have frequently fallen below LADWP's targeted total annual diversion of 6,000 af (LADWP 2000). Less diversion from Lee Vining Creek places a higher burden on Rush Creek for providing LADWP's 16,000 af annual export allocation as Mono Lake fills, and an even greater burden with anticipated average annual exports up to approximately 30,000 af once Mono Lake does fill. More reliable Lee Vining Creek exports will also be instrumental in meeting desired ecological outcomes in Rush Creek by keeping GLR full to encourage more spills and improve GLR and Rush Creek water temperatures.

4.2. A Hybrid Diversion Rate and Bypass Flow Strategy

Given these basic premises, a hybrid instream flow management strategy for Lee Vining Creek, requiring diversion rates and bypass flows, met the desired ecological outcomes to the extent possible with the regulated SCE hydrographs.

4.2.1. *Diversion Rate Prescriptions:*

During the spring snowmelt period from April 1 to September 30, daily diversion rates are prescribed based on the prevailing flow at Lee Vining above Intake. All streamflow above the specified diversion rate passes the Lee Vining Intake. Two conditions must be met before diverting SCE streamflows. No diversions should be allowed when SCE streamflows exceed 250 cfs. Most major geomorphic work is accomplished by peak streamflows greater than 250 cfs (Appendix B). Unregulated streamflows above this threshold have already been reduced in magnitude, duration, and frequency by SCE operations. No diversion should be allowed when SCE streamflows are less than 30 cfs to maintain groundwater needed to sustain riparian vegetation vigor (Appendix C). However, there will be SCE flows less than 30 cfs during the summer months of drier runoff year types.

Given the lower bound (groundwater maintenance) and upper bound (geomorphic processes) to permissible diversions, the instream flow analysis evaluated diversion rates for SCE streamflows between 30 cfs and 250 cfs that could meet desired ecological outcomes and physical processes for the snowmelt hydrograph and provide water exports.

Diversion rates were developed iteratively in two stages: first, developing diversion rate rules based on a change in stage height that would have beneficial, minimal, or undetectable ecological effects; and second, assessing the number of days (NGDs) that flows regulated by those diversion rate rules met desired ecological outcomes, with the unimpaired, SCE regulated, and SRF annual hydrographs as reference conditions.

The analysis took the following steps:

Step 1: Select a representative stage-discharge rating curve for a model cross section in Lower Lee Vining Creek. This site needed cross section and planform morphology that resembled our desired future geomorphic conditions for the Lee Vining Creek mainstem. To compare several cross sections and stage-discharge rating curves, the water surface elevation data were normalized to the stage height above the downstream riffle crest thalweg elevation, which was assumed as the hydraulic control for the cross section. Among several cross sections and stage discharge rating curves assessed (Figure 4-2), XS 6+61 in the mainstem lower Lee Vining Creek best met our targeted future conditions. This mainstem channel segment has low-flow confinement formed by a right bank cobble bar and undercut left bank, a relatively unconfined bankfull channel width, high flow access to developing (right bank) and mature (left bank) floodplain, a scour pool and riffle, and recent riparian vegetation being recruited as large wood (the RY2006 snowmelt flood undercut a large cottonwood which fell into the channel) (Figure 4-3). A surveyed RY2006 flood peak stage height was also available (Figure 4-4), which was the highest peak flood recorded during the monitoring period. The baseflow range of the rating curve also had a slope similar to rating curves developed from field surveys during the May 2009 test flow releases.

Step 2: Using the stage-discharge rating curve from our model cross section (Discharge[Y] = $8.32*Stage[X]^{2.99}$), the “pre-diversion” Lee Vining Creek above Intake (5008) flow ($Q_{Reference}$) is converted to the normalized stage height above the riffle crest thalweg (Columns A and B in Table 4-1). A fixed stage change is subtracted from the stage height (Y-0.2 ft) (Column C in Table 4-1). Then the new stage height is converted back to a “diverted” Lee Vining Creek below Intake (5009) discharge (Column D). The difference between unregulated and regulated

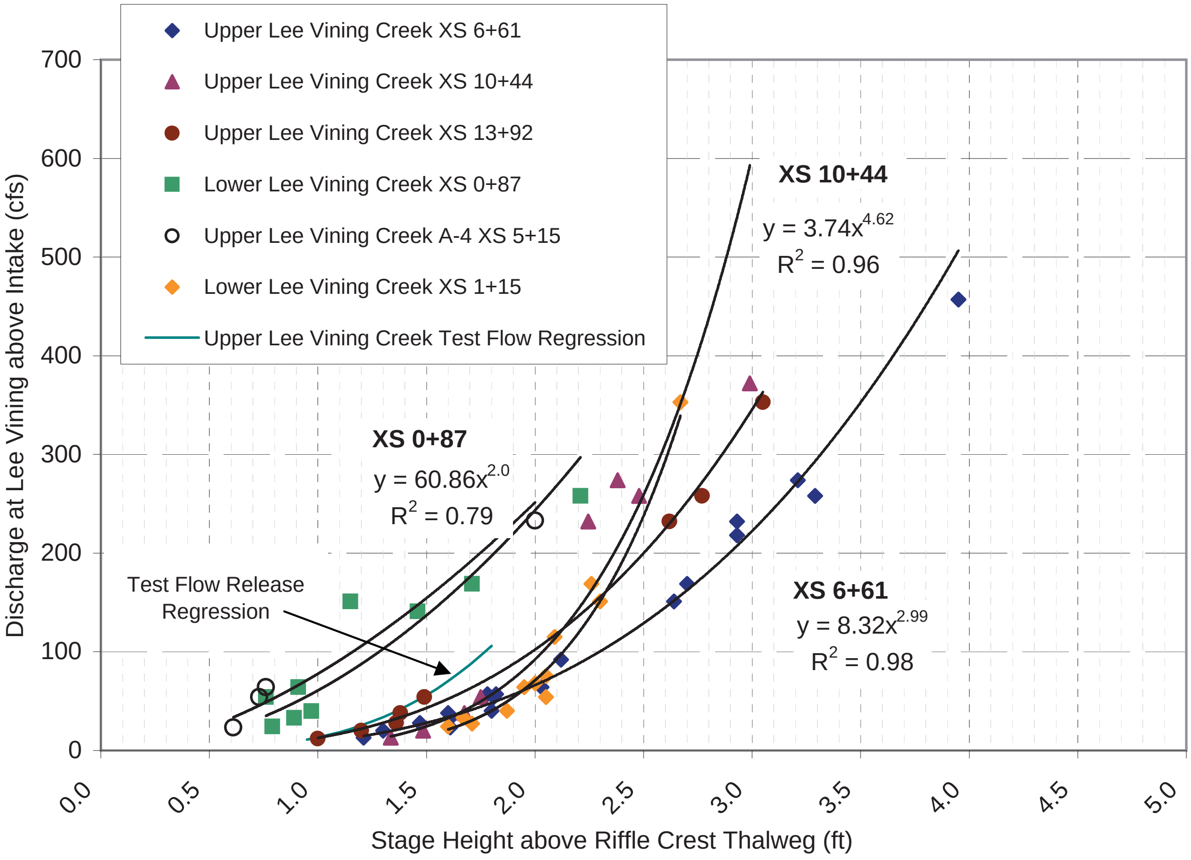


Figure 4-2. Stage discharge rating curves developed for representative cross sections in Lee Vining Creek. The x-axis is normalized by computing stage height above the riffle crest elevation at the hydraulic control downstream of each cross section.

Figure 4-3. Upper Lee Vining mainstem channel at cross section 6+61. The cross section traverses the mainstem just upstream of a cottonwood toppled into the stream in RY2006. The right bank cobble bar and left undercut bank are visible in the photo.

discharge is the diversion rate ($Q_{DiversionRate}$) for that specific Lee Vining Creek above Intake (5008) discharge and that specific "maximum stage change" (Column E). For example, using $Stage[X] = 8.32*Q[Y]^{2.99}$, the rating curve at XS 6+61, a 50 cfs streamflow has a computed stage height of 1.82 ft. If 0.2 ft of flow was diverted, the diverted stage height would equal 1.62 ft. Using the same rating equation, a 1.62 ft stage height is equivalent to a 35 cfs streamflow. Therefore, a diversion rate of 50 cfs – 35 cfs = 15 cfs would be required to change the stage height from 1.82 ft down to 1.62 ft. A change in stage height, therefore, is another way to express a diversion rate. Using XS 6+61 rating curve, a diversion rate was computed for each Lee Vining Creek above Intake (5008) streamflow between 30 to 250 cfs (Table 2-6).

Step 3: Diversion rates for a range of allowable stage changes were applied to Lee Vining above Intake annual hydrographs for RY1990 to RY2008, to simulate SEF hydrographs for Lee Vining Creek below Intake (5009). These annual hydrographs were then used to compute NGDs, i.e., the Number of Good Days the SEF flows met our desired ecological outcomes. Diversion rates and resulting NGDs were computed for each stage change ranging from 0.0 ft (no stage change) to 0.5 ft, in increments of 0.01 ft.
With a different set of RY1990 to 2008 annual snowmelt hydrographs and corresponding NGDs for each 0.01 ft of stage diverted, the next step was determining which sets of annual snowmelt hydrographs preserved desired ecological outcomes and physical processes as well as provided reliable water export to GLR. The corresponding diversion rate providing the best hydrograph set would become our recommended diversion rate from April 1 through September 30.

Step 4: Reference NGDs were computed for the Lee Vining Creek Runoff unimpaired, SCE regulated, and the SRF hydrographs for RY1990 to RY2008, and reference curves were plotted by dividing the regulated NGDs by the reference NGDs (Figure 4-5). A reference NGD of 100% means the desired ecological outcome is being met for the same Number of Days as the unimpaired or other reference conditions. Values under 100% mean fewer days relative to reference hydrographs; values over 100% mean more NGDs relative to reference hydrographs. Average NGDs for each desired ecological outcome were plotted for each runoff year type to assess the effects of different diversion rates on different year types. NGD figures (for different runoff year types) and tables are presented in Appendix E. Reference NGD curves with no change (flat-lined curves) through the range of increased diversion rates are consequences of winter bypass recommendations that maximize NGDs for trout habitat, and SCE flows that attenuate peak snowmelt magnitudes, durations, and

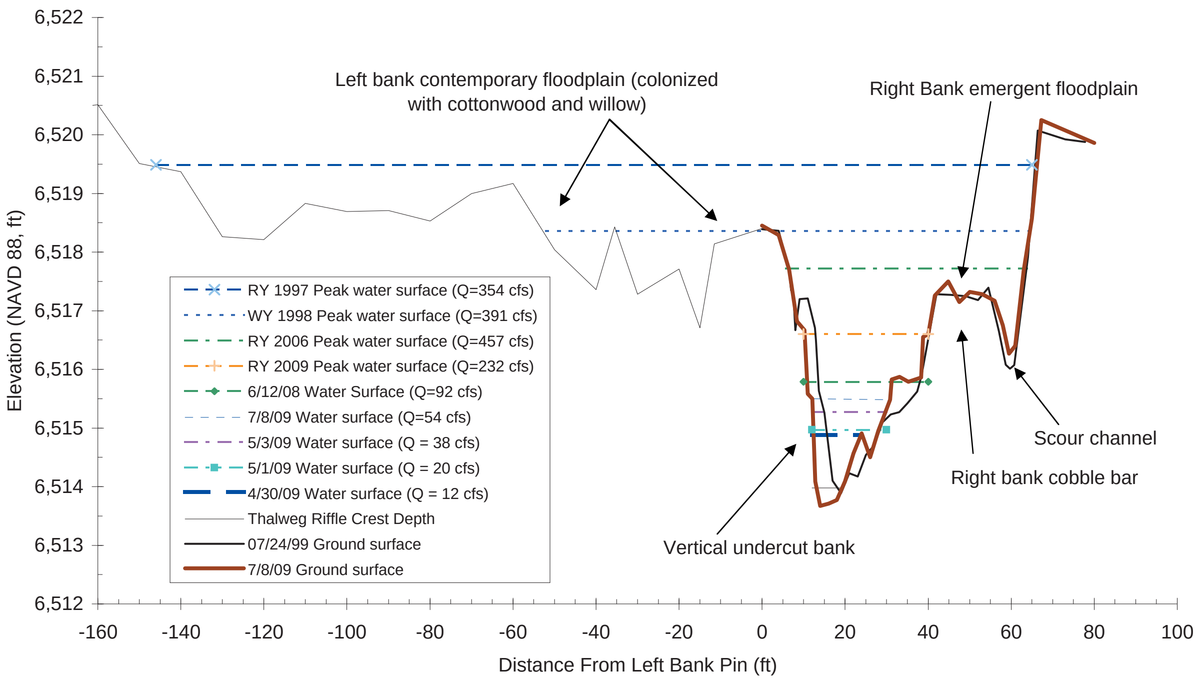


Figure 4-4. Cross section 6+61 in upper Lee Vining mainstem. Ground topography was surveyed in RYs 1999, 2004 (not shown), and 2009. Water surface elevations were surveyed during or after peak runoff events, or collected opportunistically based on field evidence.

frequencies coupled with the recommendation that no streamflows exceeding 250 cfs be diverted (Appendix E).

Step 5: No single cross section can entirely represent a stream's morphology. Consequently no single rating curve can entirely represent a stream's hydraulic relationship between streamflow and stage height. But an envelope of stage rating curves (Figure 4-2) can encompass most hydraulic settings. A sensitivity analysis was conducted to test different cross section stage discharge rating curves (from Figure 4-2). Three additional curves were tested: (1) the steeper-sloped stage-discharge rating curve from XS 10+44; (2) the lower stage-height curves resulting from A-4 XS 5+15 and B-1 XS 0+87; and (3) different diversion rates for different ranges of flows. From this sensitivity analysis, the steeper rating curve from XS 10+44 (with consequently higher diversion rates) impacted the NGDs more quickly through the MSC range of 0.0 to 0.5 ft, which resulted in selection of a lower allowable stage change and thus similar overall diversion rates. The low flow range (May 2009 test flow) rating curves and the side-channel cross section rating curves resulted in similar diversion rates and NGD calculations because the slopes of the rating curves were similar, and thus the magnitude of change from undiverted to diverted streamflow was similar.

Step 6: Conservatively select a single stage rating curve that defines the lower bound of this envelope (Figure 4-2) for computing a diversion rate. Balancing the NGD outcomes for different rating curves and diversion rates, XS 6+61 stage-discharge rating curve was selected as representative of contemporary and future desired channel morphology and a fixed stage change of 0.2 ft applied uniformly between 30 cfs and 250 cfs (Table 2-6). Reliance on this rating curve and fixed diversion rates is conservative in that it assigns a lower diversion rate than would a steeper rating curve.

Table Table 4-1. Spreadsheet computations used to estimate diversion rates for Lee Vining Creek above Intake (5008) flows in the diversion window of 30-250 cfs, the diversion season of April 1 to September 30, and a 0.2 ft maximum allowable stage change.

Discharge at Lee Vining above Intake (cfs)	*XS 6+61 Stage Height (ft) at corresponding Lee Vining Creek above Intake Discharge*	*Stage Height (ft) Reduced by "Allowable Stage Change"*	*Discharge at Lee Vining above Intake Corresponding to Lowered Stage (cfs)*	*Diversion Rate*
Column A	*Column B*	*Column C*	*Column D*	*Column E*
$Q_{reference}$	$\text{Stage}[X] = (Q_{reference}[Y]/8.32)^{(1/2.99)}$	Stage[Y] - 0.2 ft	$Q_{diverted}=8.32(\text{Stage}[Y]^{2.99})$	$Q_{DiversionRate} = Q_{reference} - Q_{diverted}$
1	0	0	0	*0.0*
		No Diversion Allowed below 30 cfs		
31	1.55	1.35	21	1.0
32	1.57	1.37	21	2.0
33	1.59	1.39	22	3.0
34	1.60	1.40	23	4.0
35	1.62	1.42	24	5.0
36	1.63	1.43	24	6.0
37	1.65	1.45	25	7.0
38	1.66	1.46	26	8.0
39	1.68	1.48	27	9.0
40	1.69	1.49	27	10.0
41	1.70	1.50	28	11.0
42	1.72	1.52	29	12.0
43	1.73	1.53	30	13.0
44	1.75	1.55	31	13.4
45	1.76	1.56	31	13.6
46	1.77	1.57	32	13.9
47	1.78	1.58	33	14.1
48	1.80	1.60	34	14.3
49	1.81	1.61	35	14.5
50	1.82	1.62	35	14.7
51	1.83	1.63	36	14.9
52	1.85	1.65	37	15.1
53	1.86	1.66	38	15.3
54	1.87	1.67	38	15.5
55	1.88	1.68	39	15.7
56	1.89	1.69	40	15.9
57	1.90	1.70	41	16.1
58	1.91	1.71	42	16.3
59	1.92	1.72	42	16.5
60	1.94	1.74	43	16.7
⋮				
241	3.08	2.88	197	43.8
242	3.09	2.89	198	44.0
243	3.09	2.89	199	44.1
244	3.09	2.89	200	44.2
245	3.10	2.90	201	44.3
246	3.10	2.90	202	44.5
247	3.11	2.91	202	44.6
248	3.11	2.91	203	44.7
249	3.12	2.92	204	44.8
250	3.12	2.92	205	44.9
251	0.00	0.00	0	0.0
		No Diversion Allowed Above 250 cfs		

4.2.2. Lee Vining Creek Snowmelt Hydrographs

To promote stream recovery to the greatest extent possible, no LADWP diversions will be allowed whenever daily average streamflows exceed 250 cfs at the 'Lee Vining Creek above Intake (5008)' gaging station. This condition preserves flood events with recurrence intervals of 2-years and above in SCE regulated hydrographs (Figure 4-6). SCE's cooperation for increasing annual snowmelt peak magnitude, duration, and frequency will be necessary to provide important geomorphic and riparian processes speeding recovery of the Lee Vining Creek ecosystem and trout fishery. For example, an unregulated 5-yr annual flood peak providing considerable geomorphic work (510 cfs) is

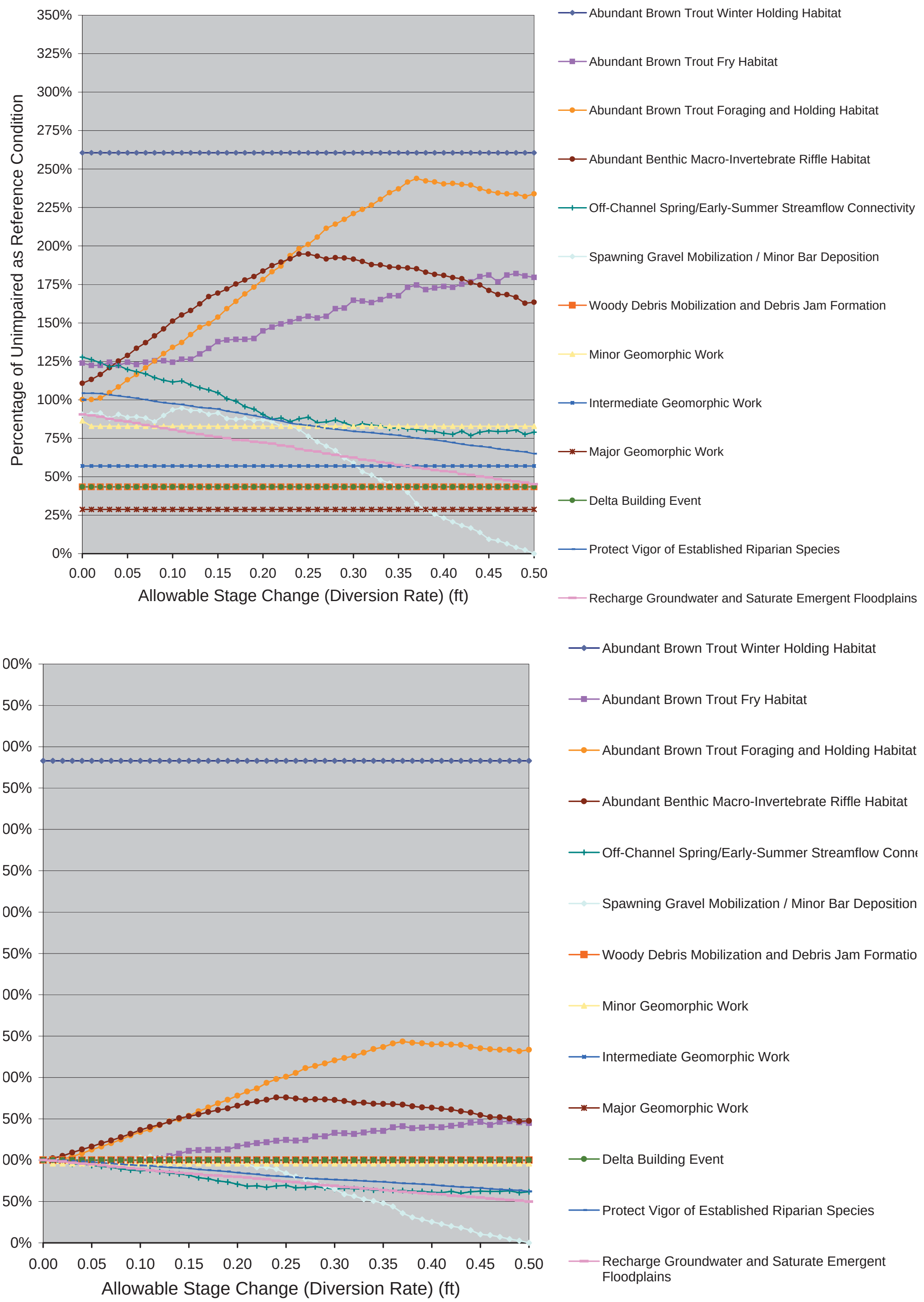


Figure 4-5. NGD analysis for Lee Vining Creek using the percent of unimpaired Lee Vining Creek flows as reference condition (above) and the percentage of SCE regulated Lee Vining Creek above Intake flows as reference condition (below). For each 'desired ecological outcome' the number of days thresholds were exceeded is computed, and then divided by the reference condition number of days. This computation is performed for each incrementally larger diversion rate, to produce a reference condition curve for each desired ecological outcome.

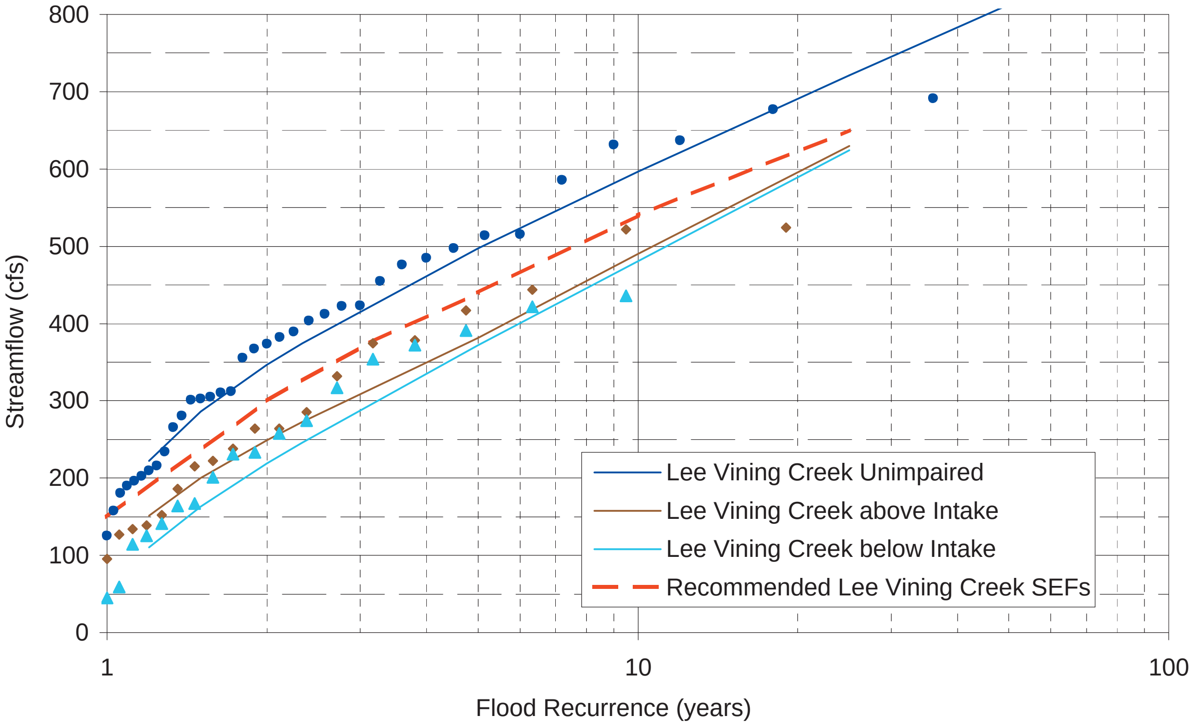


Figure 4-6. Lee Vining Creek flood frequency curves computed for RYs 1973-2008 (unimpaired), and RYs 1990 to 2008 (above and below Intake). The recommended SEF peaks increase SCE regulated peak flows, but would still remain partially impaired.

now approximately a 15-yr annual flood peak. Restoring the historic 5-yr flood magnitude of 500 cfs back to an approximate 8-yr flood is recommended, thereby doubling its frequency of occurrence. Targeted snowmelt peak flow magnitudes and recurrence intervals requiring cooperation from SCE are recommended in Table 4-2 and Figure 4-6.

The daily fixed diversion rates applied during the Lee Vining Creek snowmelt recession will preserve natural recession rates in the SCE regulated hydrographs. The primary effect of daily diversions during the snowmelt recession is to shift the timing of the recession forward (earlier) by one or several days, depending on the recession magnitudes and natural rates of change. Groundwater analyses indicated that the moderate daily stage changes accompanying the natural recession rates did not diminish groundwater and soil moisture availability for riparian vegetation.

4.2.3. *Minimum Baseflow of 30 cfs April 1-September 30*

Riparian vegetation is sustained by the shallow groundwater supplied by streamflow. Lee Vining Creek has several side-channels distributing streamflow broadly across the riparian corridor. Favorable groundwater conditions during the May 1 to September 30 growing season are necessary to maintain established riparian vegetation, to promote successful germination, initiation, and eventually, to recruit new riparian vegetation. Riparian vegetation and groundwater analyses (Appendix C) examined the relationship between different riparian vegetation patch types and distance to perennial groundwater by quantifying distance above the stream water surface for different vegetation patch types (Figures C-5 and C-6). The stream water surface elevation from the June 23, 2003 aerial photograph Digital Terrain Model was projected in a horizontal plane across the Lee Vining Creek riparian corridor, and the distance was measured above this

Table 4-2. Recommended flood peak magnitudes and recurrence intervals for Lee Vining Creek.

Recurrence Interval	Lee Vining Creek Unimpaired	Lee Vining Creek above Intake	Lee Vining Creek Recommended SEFs
(years)		(cfs)	
2	373	260	300
3	420	300	370
5	510	380	440
10	630	475	540
25	680	630	650

modeled groundwater elevation to the ground surface upon which riparian vegetation patch types mapped in RY2004 and RY2009. This analysis indicated that riparian patch types generally grow within approximately 4 ft of groundwater. On floodplain and terrace surfaces where groundwater depths exceed 3 ft deep, woody riparian vegetation transitions to desert vegetation (Figure 4-7). This groundwater threshold is intended to preserve and promote riparian vegetation (herbaceous or woody) on Lee Vining Creek. Groundwater elevation data collected seasonally by the Mono Lake Committee since RY1995 were then used to estimate a minimum streamflow capable of sustaining the groundwater table within 4 ft of the ground surfaces. Piezometer C-2, located in the interfluve between the mainstem and A-4 channels best represented targeted valley-wide morphology. The 14-year time-series indicates that mainstem streamflows below approximately 30 cfs during the riparian growing season result in a precipitous decline in shallow groundwater table to depths greater than 3 ft (Figure 4-8). A minimum streamflow of 30 cfs was thus adopted as a threshold for sustaining groundwater adequate to maintain woody riparian plant vigor on the Lee Vining Creek floodplain.

4.2.4. *Peak Emergence Timing of Brown Trout*

Peak emergence timing of brown trout was estimated for Lee Vining Creek to better evaluate how emergence timing coincided with the timing of higher streamflows during the snowmelt period in late-spring and early summer. Timing to peak emergence was estimated by using brown trout model 1b from Crisp (1981) to calculate the number of days required to reach 50% hatch at each daily average temperature. Appendix D-3 provides a detailed explanation of the methods used to estimate timing of peak emergence.

There was little information regarding the timing of brown trout spawning on Lee Vining Creek, so peak emergence timing was predicted for three dates to cover a range of likely spawning. These dates were November 1, November 15, and November 21 (Table 4-3). Peak emergence timing of brown trout was predicted for five spawning and incubation seasons (Table 4-3). Unfortunately, incomplete temperature data sets prevented an analysis of Wet runoff year types with large discharges. Compared to Rush Creek, colder winter water temperatures in Lee Vining Creek resulted in longer egg incubation durations. This difference was typically between 20 and 30 days (Appendix D-3). In Lee Vining Creek, the predicted peak emergence frequently occurred during, or soon after, the peak snowmelt period (Table 4-3), which may explain why the annual fish sampling documented variable, and sometimes very low, recruitment of age-0 brown trout in Lee Vining Creek (Appendix D-3).

Regardless of the negative effects of peak flows in Lee Vining Creek on recruitment of age-0 brown trout, no diversions were recommended from peak flows greater than 250 cfs. Riparian and groundwater needs are balanced with fish needs during the snowmelt peak and recession periods. Geomorphic and riparian functions provided by peak flows are essential to the continued recovery and maintenance of habitat in lower Lee Vining Creek. Ultimately, trout populations should benefit from improved habitat conditions created by peak flows. The recommended diversion rates during the Lee Vining Creek snowmelt recession may benefit newly emergent brown trout fry by reducing the risk of stranding.

No predictions were made of the emergence timing of rainbow trout in Lee Vining Creek due to the lack of spawning data. Because rainbow trout are spring spawners, spawning likely occurs during periods of peak discharges, probably on the receding limb of the hydrograph. For 12 years, recruitment of age-0 rainbow trout was variable, and in some years none were sampled (Hunter et al. 2009). Again, because rainbow trout spawning, incubation, and emergence occur during the snowmelt hydrograph, these functions are prioritized over the needs of a non-native fish species.

4.3. Bypass flows from October 1 to March 31

Baseflows from October 1 to March 31 have prescribed daily average flows released from the

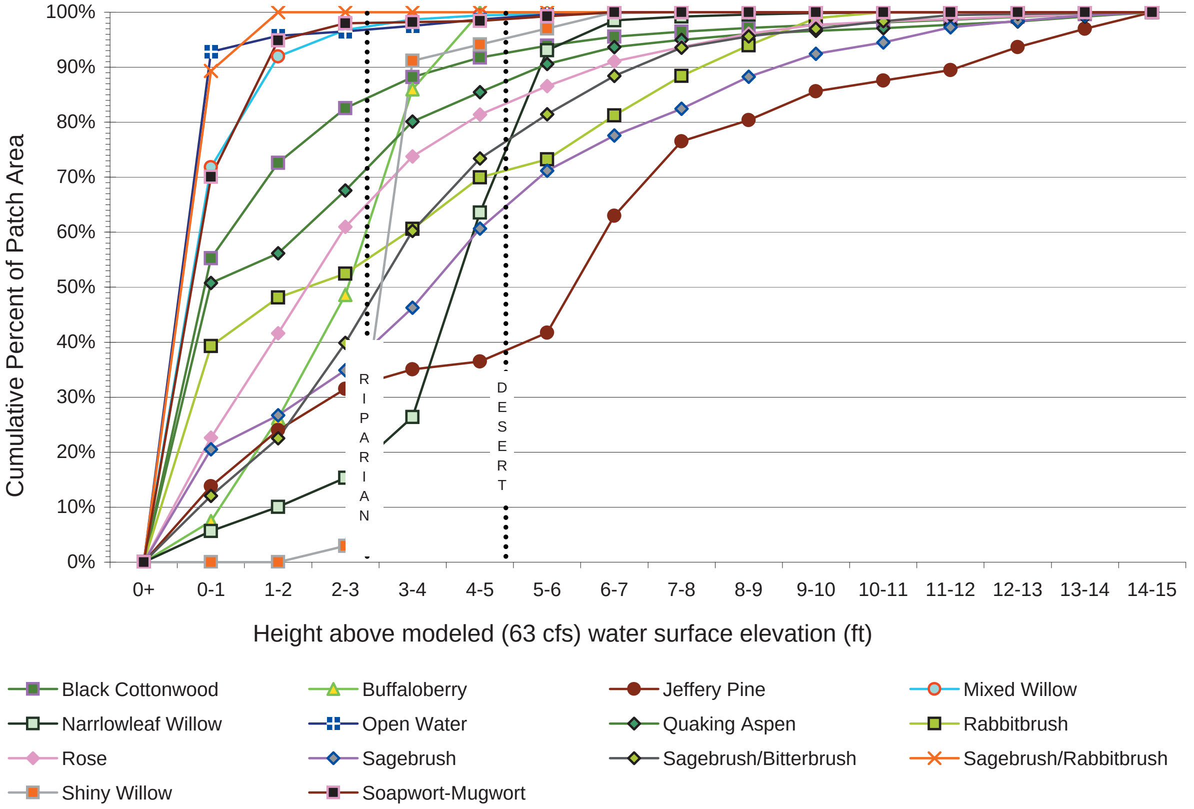


Figure 4-7. Zonal summary of vegetation cover types mapped in Lee Vining Creek Reach 3 (below Hwy 395) in RY2009. A digital terrain model developed from June 23, 2003 aerial photos was used to model groundwater elevation by projecting the stream water surface elevation as a horizontal plane across the Lee Vining Creek riparian corridor (at Lee Vining Creek below Intake discharge of 63 cfs). The height of above the 63 cfs modeled groundwater elevation was then computed for each plant stand mapped in RY2009. The cumulative percentage of patch areas were then computed for each vegetation stand type listed in the figure legend.

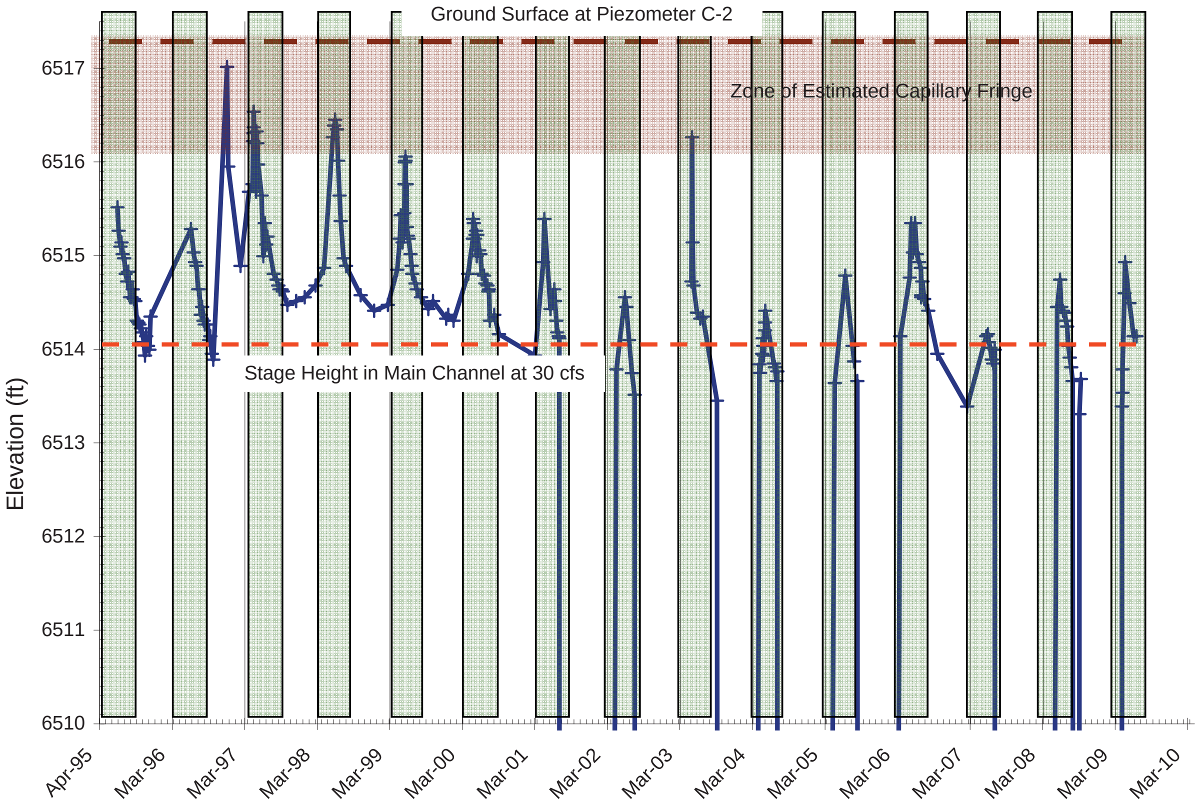


Figure 4-8. Groundwater elevation at Lee Vining Creek piezometer C-2 located in the interfluve between the upper mainstem and the A4 channels, for RYs 1995 to 2009. The water surface elevation is plotted as real elevation to show the relationship to ground surface and the stage height of the stream in the Lee Vining Creek mainstem adjacent to the piezometer. Stage height in the mainstem channel at 30 cfs indicated a threshold below which groundwater elevation declined precipitously. Groundwater data were measured and compiled by the Mono Lake Committee.

Lee Vining Creek Intake. Streamflows above the prescribed baseflows are diverted into the Lee Vining Creek conduit. From October 1 through November 30, the recommended bypass streamflows range from 16 to 30 cfs. As the creek cools and trout seek-out shelter, these baseflows will provide abundant adult holding habitat and ample depth at riffle crests for unrestricted adult movement during brown trout spawning (Appendix D). The Rush Creek trout movement study (Taylor et al. 2009) determined that adult brown trout exhibited minimal movement during post-spawning winter months, We assumed fish in Lee Vining Creek exhibit similar behavior. From December 1 through March 31, daily average bypass flows ranging from 16 cfs to 20 cfs will provide abundant trout holding habitat based on adult holding habitat rating curves (Appendix D).

Recommended winter bypass flows were similar to unregulated winter baseflows (remembering that the SCE regulated hydrographs have increased winter baseflows), but considerably lower than the Order 98-05 winter baseflows. Implications of a constant bypass flow for six months were weighed against potential benefits of maintaining some natural variability in the baseflow hydrograph. However, much of the daily baseflow variability in the SCE regulated hydrographs between October 1 and March 31 is attributable to SCE operations rather than natural variability. The unimpaired Lee Vining Runoff hydrographs, calculated from SCE reservoir storage changes, do not provide reliable streamflow estimates when the objective

Table 4-3. Predicted brown trout fry emergence times in Lee Vining Creek.

Spawning Season	*Presumed Date Peak Spawning*	*Predicted Peak Emergence (PPE)*	*Q at PPE (cfs)*	*Timing and Magnitude of Peak Discharge*
1999-2000	Nov 1st	May 18th	53	May 18th – 28th 55 to 258 cfs <100cfs on July 4th
	Nov 15th	May 28th	258	
	Nov 21st	May 31st	181	
2000-2001	Nov 1st	May 25th	192	May 5th – 17th 56 to 201 cfs <100 cfs on June 11th
	Nov 15th	May 29th	146	
	Nov 21st	May 31st	113	
2003-2004	Nov 1st	April 22nd	45	April 27th – May 19th 84 to 94 cfs* <100 cfs on June 18th
	Nov 15th	May 12th	69	
	Nov 21st	May 18th	83	
2006-2007	Nov 1st	May 15th	39	No peak discharge in Lee Vining Creek below the DWP diversion
	Nov 15th	May 23rd	39	
	Nov 21st	May 26th	41	
2007-2008	Nov 1st	May 26th	85	May 19th – 23rd 56 to 131 cfs** <100 cfs on July 2nd
	Nov 15th	June 3rd	117	
	Nov 21st	June 6th	70	

*other peaks: 114 cfs/June 2nd and 141 cfs/June 15th **other peaks: 167 cfs/June 4th; 149 cfs/June 17th, 22nd and 23rd

is to distinguish relatively small daily flow changes. The unregulated Buckeye Creek annual hydrographs (Appendix A) between October 1 through March 31 lack appreciable baseflow variability and help support the recommended constant bypass flow.

The winter bypass baseflow strategy greatly improves the reliability of diverting water from Lee Vining Creek to GLR. Elevated SCE winter baseflows were an obvious target for diversion, given the hydrograph analysis and baseflow trout habitat assessments. By diverting a moderate proportion of these baseflows daily from October to March (simulated for RY1990 to RY2008), an annual average of 5,200 af would be available for diversion. These diverted flows, stored in GLR, would contribute to achieving a fuller reservoir when peak Rush Creek snowmelt is imminent, thus increasing the likelihood of GLR spills to Rush Creek.

4.3.1. *Summer baseflows*

As reported in the IFS Report, the total area of mapped foraging habitat in Lee Vining Creek was highest at the lowest test flow release of 12 cfs (Taylor et al. 2009). Total area of mapped foraging habitat dropped by only 7% between the 12 and 20 cfs test flows; however the area of mapped foraging habitat in pocket pools increased nearly 75% (Figure 4-9). Development of flow recommendations for foraging habitat relied heavily on changes in pocket pool habitats because of the high occurrence of these individual foraging units in Lee Vining Creek (Taylor et al. 2009). For NGD analysis, a range of 15 to 25 cfs was selected to represent flows with abundant trout foraging habitat in primary pools and runs, as well as pocket pool habitats. This flow range provides 80 to 98% of the relative abundance of mapped foraging habitat and brackets the maximum mapped pocket pool habitat present at 20 cfs (Figure 4-9). At 20 cfs, not only were individual pocket pools most abundant, but the number of large individual units (areas >20 ft^2) was also highest (Taylor et al. 2009). More, and larger, individual pocket pool units create more individual territories for brown trout to occupy.

During the iterative process of NGD analyses with increasing diversion rates, days of abundant brown trout foraging habitat generally increased as diversion rates increased. NGDs for abundant trout foraging habitat were also greater in drier runoff years, regardless of the diversion rate. Purely from an adult trout habitat perspective, increasing the diversion rate to decrease flows in lower Lee Vining Creek would be the best strategy. However; this strategy reduces NGDs for other ecological processes. A diversion rate based on an allowable stage change of 0.2 ft increases the NGDs of foraging habitat above the unimpaired and SCE reference conditions in Dry and Dry-Normal runoff years, but leads to NGDs below reference conditions in Normal, Wet-Normal and Wet runoff years (Appendix E). A longer diversion season emphasizes protection of the snowmelt peak and recession periods, and associated geomorphic objectives. In Normal to Wet runoff years, higher streamflows in Lee Vining Creek may reduce preferred trout foraging and holding habitats, but should benefit long-term habitat recovery goals by producing more high-quality pool and deep-run habitats.

4.3.2. *October – March Baseflows*

Although winter holding habitats in Lee Vining Creek were most available at the lowest IFS test flow of 12 cfs, this discharge may inhibit fish migration during the fall spawning period or may result in icing conditions that could harm over-wintering trout (Taylor et al. 2009). To address potential migration issues for fall spawning brown trout, riffle crest thalweg depths measured during the IFS were examined to assist in determining October to December baseflows. At the 12 cfs test flow, nine riffle crest depths were measured within the BMI mapping reach and these had a range of 0.65 ft to 1.00 ft and an average of 0.90 ft. These riffle crest depths are well above the minimum passage depth of 0.5 ft as suggested in CDFG fish passage guidelines for resident salmonids (CDFG 2001). Because there is a lack of information regarding ice formation in Lee Vining Creek, the winter baseflow recommendations are 16 cfs in Dry through Dry Normal II runoff year types, 18 cfs in Normal runoff years, and 20 cfs in Wet-Normal through Extremely-Wet runoff years. Monitoring of icing conditions during the winter of 2009-2010 may provide information to either fine-tune winter baseflow recommendations to slightly lower flows or may direct keeping

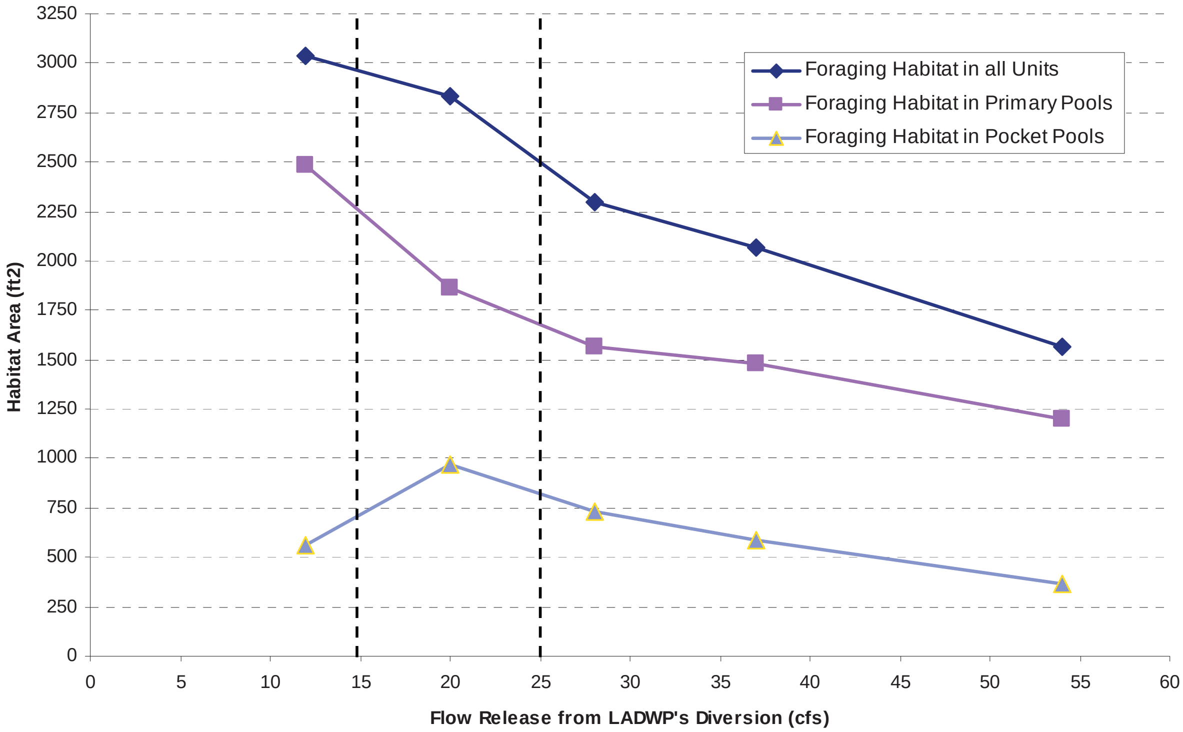


Figure 4-9. Lee Vining Creek brown trout foraging habitat-flow curves for all units, pools units, and pocket pool units, collected in April and May 2009.

the baseflows as initially proposed. In wetter runoff year types, duration of the unimpaired hydrograph's slow recession limb tailored low flow recommendations to mimic this hydrograph component. In Wet-Normal, Wet, and Extremely-Wet runoff years, the slow recession limb tapers down through October and mid-November, finally reaching the baseflow discharge on November 16. In the drier runoff years, the bypass flow of 16 cfs would start on October 1and last until March 31.

As mentioned previously, one premise behind the Lee Vining Creek flow recommendations was to improve winter baseflow conditions, yet consider retaining natural variability within the SCE-altered hydrograph. When the Lee Vining Creek hydrographs were examined, natural variations could not be discerned from the "noise" of SCE's operations in which the hydrographs fluctuate up-and-down throughout the winter low-flow period. Unimpaired annual hydrographs for Buckeye Creek were also examined to determine if this unregulated creek exhibited similar flow fluctuations as Lee Vining Creek's hydrographs. During most winters, Buckeye Creek's annual hydrographs did display a few minor fluctuations in discharge (Appendix A-1), but not to the degree of the Lee Vining Creek SCE regulated annual hydrographs.

Other than the January 1997 flood, there were no rain-on-snow events within the past 18 years large enough (> 250 cfs) to provide geomorphic benefits that were not met by the annual snowmelt flood, and thus there was no justification for preserving natural winter peak flow variations that outweighed the benefits of constant flows for maintaining trout winter holding habitat. The rare, extremely large, rain-on-snow events would most likely be passed to the lower Lee Vining Creek channel because of the inability of LADWP's diversion facility to capture these large peaks.

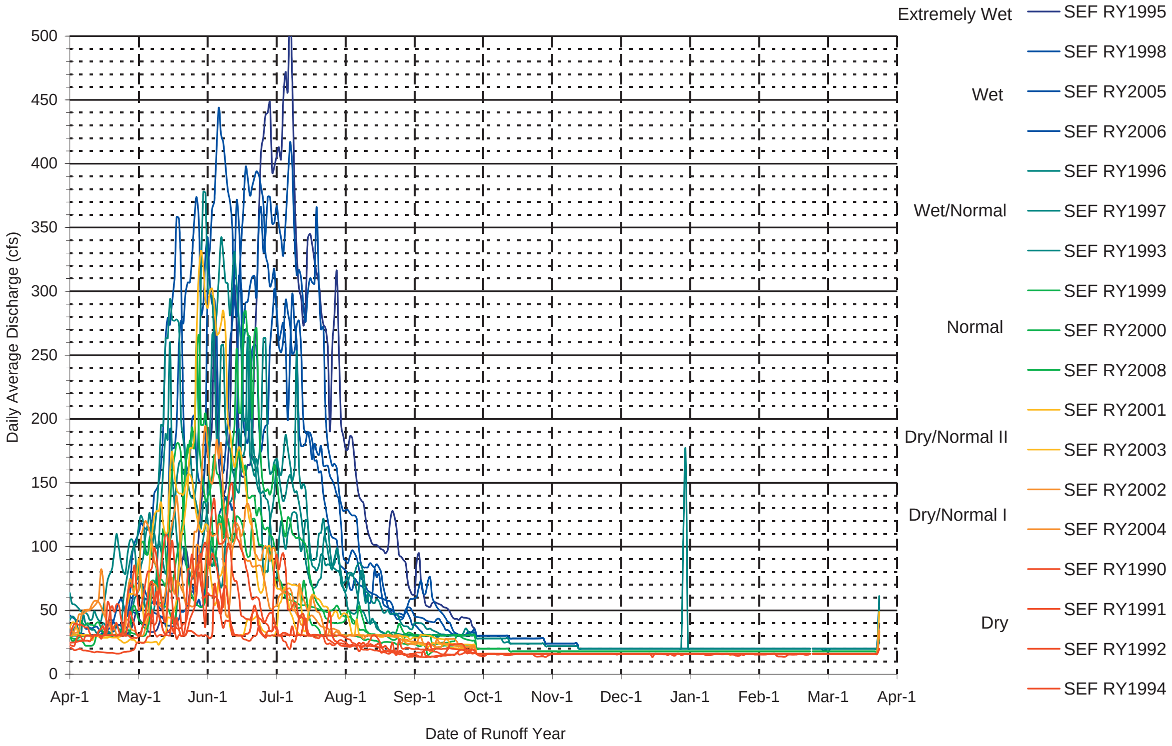


Figure 4-10. Lee Vining Creek SEF hydrographs simulated for RYs 1990 to 2008 using recommended diversion rates during the annual snowmelt period and bypass flows during the fall and winter baseflow period. See Figure 4-1 for a comparison to Lee Vining Creek unimpaired and SCE regulated (Lee Vining above Intake) hydrographs.

CHAPTER 5. RUSH CREEK ANALYSIS

5.1. Premises for the Analysis of Rush Creek Hydrographs

Premises central to analyzing Rush Creek instream flows are:

Premise No. 1. Annual snowmelt and baseflow hydrograph components for Rush Creek at Damsite (5013), heavily regulated by SCE, would prevent lower Rush Creek restoration and trout population recovery if there was no LADWP or Grant Lake Reservoir. Southern California Edison (SCE), as an operational goal, has attenuated natural snowmelt flood peaks and elevated seasonal baseflows entering Grant Lake Reservoir to optimize hydropower generation (Figure 5-1) (Appendix A-4, Table 3, and see Hasencamp 1994 for concise review). Snowmelt peak timing is also typically later than the unimpaired snowmelt peak (Figure 5-2). LADWP must export reservoir storage to the Owens River while managing these SCE annual hydrographs to propagate desired ecological outcomes and physical processes in Lower Rush Creek.

Premise No.2. No single optimal annual flow regime, including variable runoff year types, can restore Rush Creek back to pre-1941 conditions, not even the unregulated annual flow regime. Although there was no significant alteration in the annual runoff volume prior to 1941, streamflows were heavily regulated. Irrigation practices severely reduced streamflows above the Narrows and enhanced spring-flows below the Narrows. Livestock grazing likely contributed a moderate to high nutrient load to an otherwise borderline oligotrophic stream. In addition, in the decade prior to 1941, the self-sustaining trout population in Rush Creek was comprised mostly of brown trout with some rainbow and brook trout present; however the fishery was also augmented by regular stocking of hatchery trout to meet rapidly increasing fishing pressure and declining catch rates. The historic record also suggests that the self-sustaining brown trout population downstream of the Narrows benefited from effects of the irrigation practices as well as from the duck hunting ponds constructed near the Mono Lake delta

Premise No.3. A multiple channel network will not evolve upstream of the Rush Creek County Road. Streamflows don't make deltaic channel networks, deltas do. Fluctuating Mono Lake elevations and consequent delta formations are described in Stine (1987). High lake stands left their imprint of multiple channel networks in the Rush Creek bottomlands. Under deltaic conditions, saturation is the norm when many distributary channels with similar entrance elevations compete for surface flows. However farther upstream, beginning approximately 20 ft in elevation above the upper margin of the delta, equality among channels is unlikely to persist. As the stream morphology evolves from many competing deltaic channels to a few or only one mainstem channel, shallow groundwater dynamics will change accordingly. Additionally, downcutting precipitated by the downstream shift in delta (during periods of Mono Lake recession) also affects channels differentially: extent, duration, and eventually frequency of floodplain saturation will decline. This was likely happening under pre-1941 conditions.

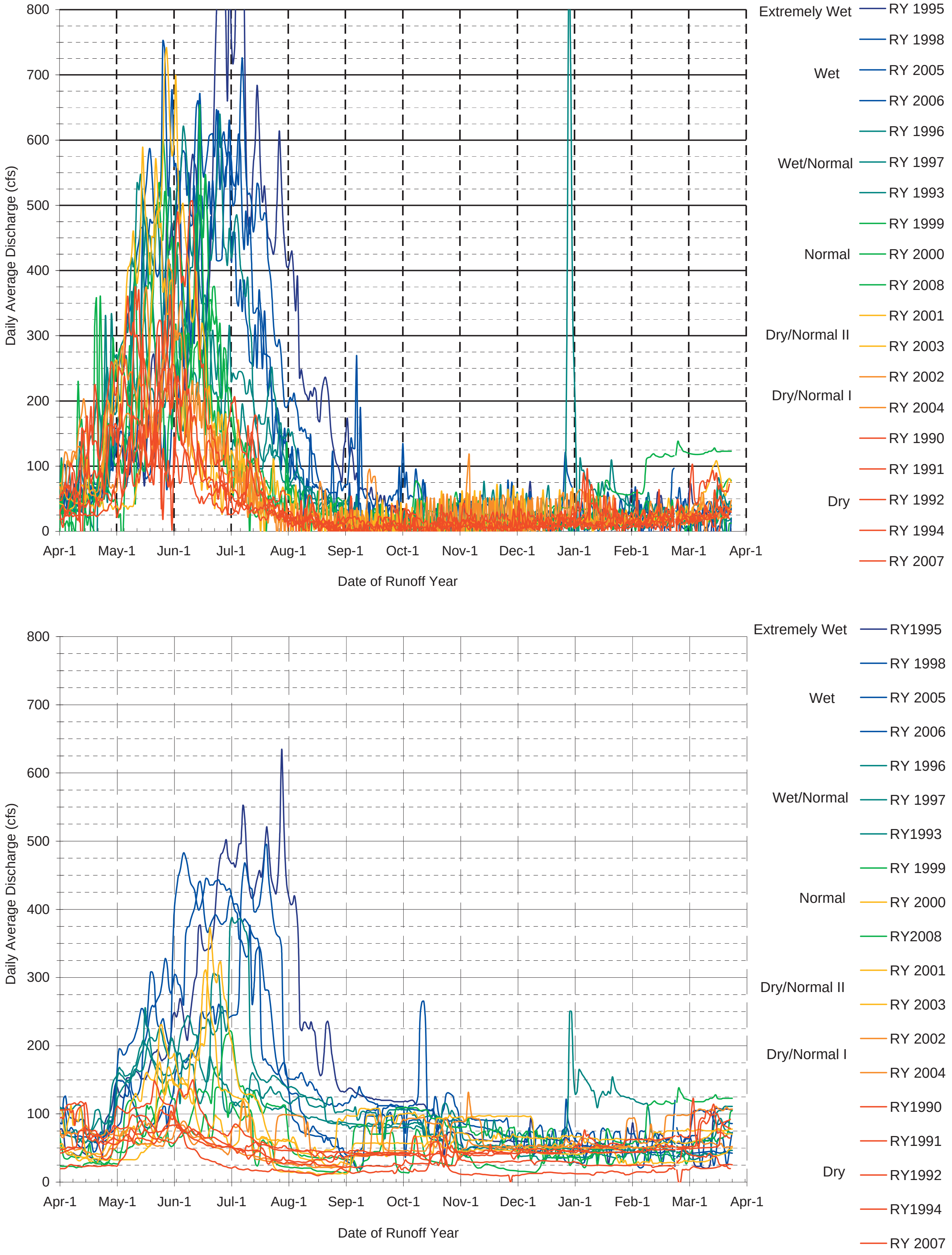


Figure 5-1. Annual hydrographs for Rush Creek Runoff (computed unimpaired) and Rush Creek at Damsite (SCE regulated) for RYs 1990 to 2008 showing patterns in annual hydrograph components and the range of variability in different runoff year types.

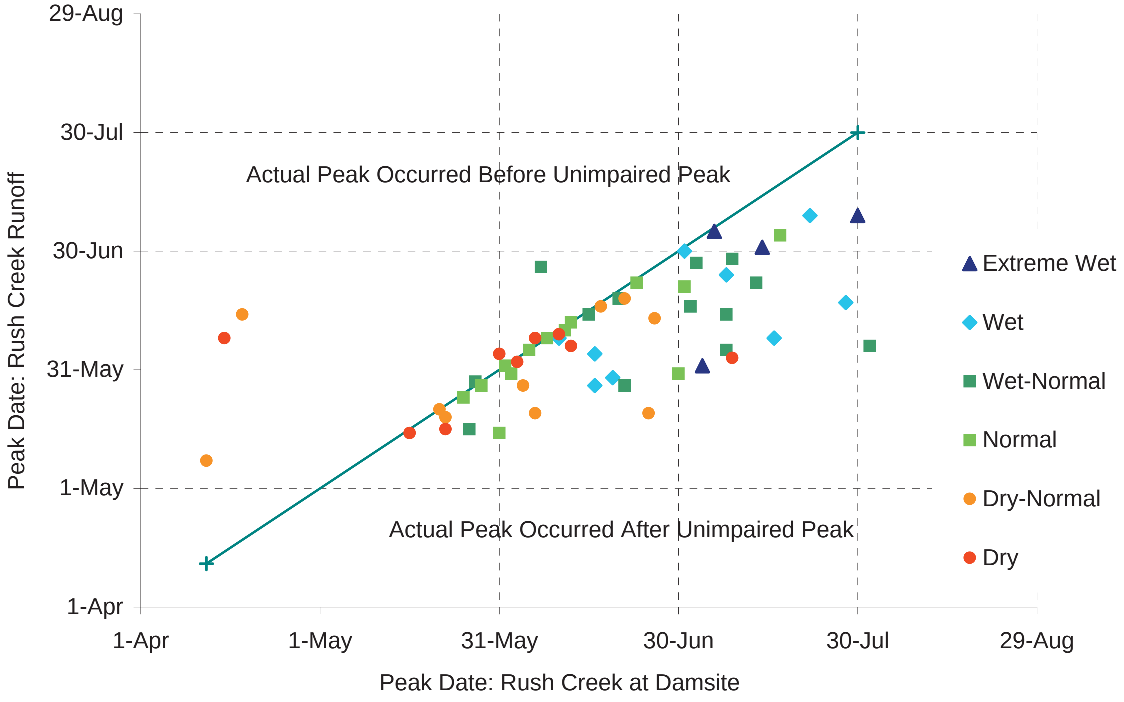


Figure 5-2. Comparison of the date of the annual snowmelt peak for Rush Creek unimpaired and Rush Creek at Damsite for RYs 1940 to 2008. The lag in the peak date for Rush Creek at Damsite results from SCE's flow regulation. The chart also demonstrates that wetter runoff year types tend to have later peaks.

Premise No. 4. Restoring hydraulic roughness, as woody riparian vegetation matures, will enhance flood peak functions. The Annual Report for RY1999 (McBain and Trush 2000) estimated a 0.5 ft gain in water surface elevation for the same flood peak magnitude generated by a modest increase in hydraulic roughness. As the mainstem channel narrows and deepens (hopefully more by floodplain surface aggradation than by channelbed downcutting) above its deltaic reach, flood peaks of the same magnitude will attain 0.4 ft up to 0.6 ft higher stage heights due to increased hydraulic roughness.

Premise No. 5. Some portions of the historic Lower Rush Creek floodplain will not sustain or regenerate woody riparian vegetation. Geomorphic surfaces (e.g., abandoned terraces) without access to water, even though within the riparian corridor, will remain in desert vegetation. As terrace surfaces are eroded and the floodplain rebuilt, desert patch types will be reclaimed to riparian vegetation.

Premise No.6. Side-channel entrance maintenance is still necessary in the short-term, but must have an exit strategy. Flow regulation reduces the frequency and duration of overbank flooding and floodplain inundation. This process can be partially recovered through maintenance of perennial side-channels to recharge shallow groundwater and promote regeneration/maintenance of riparian vegetation. Maintenance may only be required in a few discrete locations for the near-term (e.g., 10 to 20 years) until floodplain surfaces close to side-channels and capable of supporting riparian vegetation have time to develop mature riparian vegetation stands. However, side-channel shallow groundwater dynamics are not maintained if mainstem downcutting exceeds approximately 2.5 ft. With time, upstream change is inevitable, such that present side-channel flow conditions and floodplain groundwater dynamics may not be sustainable.

Premise No.7. Two main factors are limiting brown trout growth and survival in Rush Creek. The presently prescribed, artificially-high winter baseflows affect the availability of suitable winter holding habitat for larger trout, particularly microhabitats with low water column velocities near the stream bottom. Suitable winter holding habitat can be increased by recommending flows based on the results of the IFS. Elevated water temperatures often occur in Rush Creek from summer through early autumn, which stress the trout and lower growth rates and condition factors. Increased diversions from Lee Vining Creek into GLR will result in a consistently fuller reservoir and allow releases of cooler water down Rush Creek. An improved summer thermal regime should promote better growth (both metabolic rates of trout and productivity of benthic macroinvertebrates).

Premise No.8. Brown trout in Rush Creek exhibit two distinct life-history strategies. Few large brown trout inhabit Rush Creek downstream of the MGORD year-round, but some large brown trout from the MGORD use Rush Creek downstream of the MGORD seasonally, particularly for spawning (Taylor et al. 2009b). Numerous large brown trout that are likely piscivorous inhabit the MGORD. Age-0 brown trout abundance within the MGORD is very low, likely as a result of both poor spawning habitat and predation by large brown trout in the MGORD (Hunter et al. 2004). Longevity of brown trout in the MGORD is longer than in Rush Creek below the MGORD. Most brown trout that reside year-round in Rush Creek below the MGORD die before reaching age-4, while many more brown trout within the MGORD live longer, including several otolith-aged males in excess of 10 years (Hunter et al. 2004 and 2005). Two life histories are present within Rush Creek below Grant Lake Reservoir. One is a migratory life-history in which brown trout reside in the MGORD because of better thermal conditions. These migratory brown trout emigrate from the MGORD to lower Rush Creek to spawn and then return to the MGORD after spawning. The other is a resident life-history adopted by brown trout within lower Rush Creek. These resident brown trout appear to have shorter life-spans and spawn in lower Rush Creek, probably close to where they reside.

Premise No.9. The brown trout population in Rush Creek is at or near carrying capacity. Based on monitoring results collected the past 12 years, brown trout populations (in terms of biomass) are near carrying capacity for the flow regime and physical habitat present in lower Rush Creek. The rationale for this conclusion is that there is no legal harvest of fish allowed from this population (CDFG regulations), angler use is much lower than “put-and-take” sections of Rush Creek above Grant Lake Reservoir (CDFG creel surveys), and changes in biomass could be related to changes in flows (Shepard et al. 2009a and 2009b). Thus, the best way to produce more large trout in this population is to shift the present size distribution from a higher proportion of younger, smaller trout to larger trout. This size-class shift would retain similar biomass but provide fewer trout.

5.2. Bypass Flow Recommendations for Multiple Runoff Year Types

Given these basic premises, the analyses and instream flow recommendations for Rush Creek maintained the existing management strategy of bypass flows for each runoff year type, but identifies changes to the existing Order 98-05 SRF and baseflows that would improve ecological conditions and the trout fishery. Instream flow recommendations and their ecological justifications for Lower Rush Creek below the Narrows are presented by annual hydrograph component for each runoff year type.

5.3. The Annual Spring Break-Out Baseflow

As air temperatures begin to warm stream temperatures during late-March through mid-April, cold-water benthic macroinvertebrates (BMI) become more active. Hynes (1970) suggests that water temperatures of 42˚ to 44˚F initiate increased activity and that aquatic macroinvertebrates (i.e., mayflies, stoneflies, and caddis) may have a lower temperature threshold initiating growth than trout. An increase in early-spring streamflows, when temperatures favor BMI growth, will inundate more riffle habitat and stimulate high BMI production. Increased macroinvertebrate production should improve survival and growth for trout. Increased baseflows in early-spring, though not great when expressed as a percentage of winter baseflows, can significantly increase productive riffle BMI and trout foraging habitat availability. Healthy trout entering leaner times beginning in late-summer stand a better chance of surviving the next winter.

Unregulated annual hydrographs for Rush Creek (Appendix A-1 and A-2) show that April streamflows are not highly variable and are independent of the previous runoff year type. Normal runoff years exhibit the greatest April baseflows, presumably attributable to that April's weather (when there is a considerable snowpack that may melt relatively early).

A recommended Rush Creek 40 cfs baseflow beginning April 1 in all but Dry runoff years (30 cfs) provides abundant adult brown trout holding and foraging habitats as well as begins generating abundant and productive mainstem BMI riffle habitat (Taylor et al. 2009). April baseflows in Lower Rush Creek would range from 40 to 70 cfs, benefiting from gradual augmentation of the baseflow release by unregulated Parker and Walker creek runoff originating lower in the watershed. A much greater April baseflow release, though still within the unregulated range, could diminish adult trout habitat availability before the snowmelt pulse begins and potentially compromise early emerging trout fry. Although trout fry habitat was not mapped, the ratio of BMI habitat area to wetted riffle area converges at approximately 60 cfs (Taylor et al. 2009), indicating most of the shallow mainstem channel already is flowing too fast for trout fry above approximately 50 cfs. Streamflows narrowly ranging between 50 cfs and 80 cfs in Lower Rush Creek are too fast in the mainstem channel, but have barely begun inundating and/or backwatering off-channel habitats and the emergent floodplain where slow velocities favor trout fry.

5.4. The Annual Snowmelt Ascension

The overall ecological role of the annual snowmelt ascension is to prime the mainstem and floodplain for the peak snowmelt event soon to follow. In most years, snowmelt runoff builds gradually before peaking. First, the spring 'break-out' baseflows swell the mainstem channel in April. But beginning early-May, unregulated annual hydrographs diverge from the relative conformity of April's baseflows (Appendix A-1 and A-2). Warming weather soon accelerates snowmelt, giving most annual hydrographs a 'left shoulder' off their snowmelt peaks in May or June (Appendix A-1 and A-2). These streamflows are of sufficient magnitude to begin inundating portions of the emergent floodplain and margin habitats along the mainstem channel. With this pronounced increase in wetted channelbed, shallow groundwater dynamics are reinvigorated. Woody riparian vegetation launches into high growth and yellow willows begin setting seed.

Desired ecological outcomes for annual spring ascension streamflows are: (1) promote abundant trout foraging and holding habitat, and high specific growth rates, (2) accelerate mainstem and emergent floodplain inundation encouraging greater stream productivity than in April, (3) elevate the shallow groundwater table to improve response time when peak runoff follows, (4) provide vigorous growth for established floodplain riparian vegetation beginning May 1 or soon thereafter, (5) encourage yellow willow regeneration on bar features and within the emergent floodplain, and (6) incorporate unregulated Parker and Walker creek streamflows into exceeding flow thresholds and instilling natural variability into less variable dam releases. For prescribing instream flow releases, these desired outcomes should improve in successively wetter runoff years as would happen in an unregulated stream ecosystem ((Appendix A-1 and A-2).

Predicted peak emergence of brown trout generally occurred prior to snowmelt peaks, except RY2005 and RY2006 (Appendix D-3). The predicted peak emergence typically occurred two to five weeks prior to the peak snowmelt streamflows, depending on the presumed date of peak spawning. Regardless of the predicted emergence timing, fish sampling since 1999 has demonstrated that annual production of age-0 brown trout in Rush Creek has been more than adequate to fully seed the available habitat (Hunter et al. 2000-2009).

In Dry runoff years, April baseflow releases of 30 cfs are ramped gradually to 70 cfs by May 17 then continued through July 5, with no planned peak snowmelt bench or peak snowmelt release (Figure 2-8). The 70 cfs baseflow release, augmented by unregulated Parker and Walker creek streamflows, boosts streamflows above the 80 cfs threshold below the Narrows for maintaining shallow groundwater and riparian vegetation growth on floodplains and in interfluvs (Appendix C).

During the ascending limb of the hydrograph, shallow groundwater rises more quickly as snowmelt runoff accelerates if mainstem streamflows have been maintained at 80 cfs (Appendix C), and during the receding limb of the snowmelt hydrograph shallow groundwater recedes quickly when mainstem streamflows drop below 80 cfs (Figure 5-3). The mainstem channel can thus sustain shallow groundwater depths favoring maintenance of established woody riparian plants with streamflows

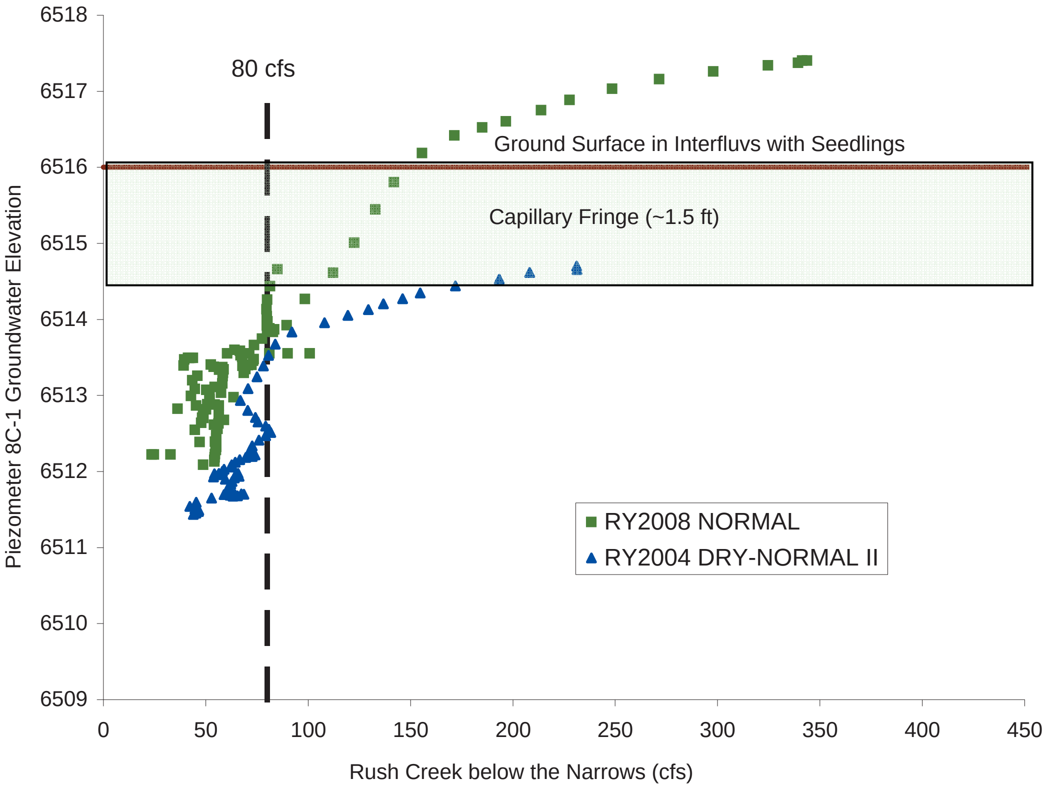


Figure 5-3. Groundwater elevations during the receding snowmelt limb at lower Rush Creek l piezometer 8C-1 in similar runoff years before (RY2004) and after (RY2008) the 8-Channel entrance was reconstructed for perennial flow.

exceeding 80 cfs below the Narrows (for a specified duration, discussed below). Releasing 80 cfs before the onset of snowmelt elevates the shallow groundwater, causing a more rapid rise and ultimately a higher maximum groundwater stage. If streamflows cannot be maintained above the 80 cfs threshold before the onset of peak snowmelt runoff, the groundwater table has farther to rise (Appendix C). Streamflows receding below 80 cfs allow a more rapid groundwater decline well before the end of the riparian growing season, thus diminishing the area of riparian vegetation the shallow groundwater is capable of maintaining. The 80 cfs streamflow threshold is thus a mechanism for attaining and sustaining the broadest area of riparian vegetation through mainstem groundwater maintenance, given annual regulation of the snowmelt peak and recession. With the snowmelt ascension streamflows lasting to July 5, potential specific growth rates for trout remain high before temperatures warm appreciably (Appendix D).

In Dry-Normal I runoff years, the April baseflow release of 40 cfs would be ramped up to 80 cfs by May 17 then continued through July 5, with no planned peak snowmelt bench or snowmelt peak (Figure 2-9). The additional 10 cfs release, compared to Dry runoff years, promotes vigorous growth of established woody riparian vegetation by exceeding the 80 cfs threshold longer, as well as begins to exceed the streamflow threshold of 90 cfs for promoting off-channel streamflow connectivity (Table 3-1). Parker and Walker creeks' accretions will typically keep daily streamflows above 90 cfs in Lower Rush Creek. The duration of the spring ascension and snowmelt bench bracket when peak streamflows naturally occurred in Dry and Dry-Normal I runoff year types (Figure 5-4).

The duration of streamflows during the snowmelt period required to maintain riparian vegetation (i.e., NGD > 80 cfs) was not explicit in the available data. The unimpaired reference condition (below the Narrows) provided 61 days and 76 days above 80 cfs for Dry and Dry-Normal I runoff years, respectively. The SCE regulated flows for Rush Creek at Damsite provided only 21 and 46 NGDs for these runoff year types. Our analysis assumed a minimum duration threshold of 77 days above 80 cfs (half of the May 1 to September 30 riparian growing season [n=153 days]) for a runoff year with favorable growth. However, these drier runoff year types (Dry and Dry-Normal I) did not meet the 77 day duration threshold in either reference condition (unimpaired or SCE-regulated), but instead sustained less than favorable conditions encountered in unregulated runoff years (Appendix A-1 and A-2). SEF recommendations simulated below the Narrows provide 53 and 61 NGDs for Dry and Dry-Normal I runoff years. Off-channel trout and BMI habitats are created, though not with the duration of wetter runoff year types.

In Dry-Normal II runoff years, the April baseflow release of 40 cfs is extended through May 18 before ramping to 80 cfs by June 1 and then extending the 80 cfs baseflow through June 30 (Figure 2-10). With greater streamflow augmentation by Parker and Walker creeks than in drier runoff years, Lower Rush Creek thresholds for vigorous woody riparian growth on the floodplain, streamflow connectivity, and yellow willow regeneration are generally met (Appendix E). Simulated Dry-Normal II runoff years averaged 78 NGDs. With streamflows exceeding 100 cfs, mainstem channel margin and emergent floodplain inundation provide backwater habitats for newly emerged brown trout fry, as well as allows benthic macroinvertebrates access to diverse habitats and a rich energy source of organic matter (last year's crop of fallen willow, alder, and cottonwood leaves). These areas will remain inundated well into summer.

Normal runoff years establish a release strategy adopted for Wet-Normal, Wet, and Extremely-Wet runoff years. Beginning May 1, the 40 cfs spring baseflow is gradually ramped to 80 by May 15 (just as in Dry-Normal II) then sustained through June 11. Although this ascension release is constant at 80 cfs, Parker and Walker creek streamflow accretion creates ascending streamflows as the peak runoff period approaches.

5.5. The Peak Snowmelt Bench

The Peak Snowmelt Bench keeps the stream corridor, including the mainstem margins, side-channels, and floodplains, primed for the snowmelt peak event. When the peak does occur, the shallow groundwater response is rapid and extensive.

In addition to addressing woody riparian vigor and regeneration on floodplains, the snowmelt bench operationally functions as a point of departure for managing annual snowmelt peaks in Dry-Normal II and wetter runoff year types (discussed under Snowmelt Peak). Each runoff year is unique. The timing of peak snowmelt runoff for any given runoff year type varies but generally occurs within a predictable 4 to 6 week period (Figure 5-4).

The duration of snowmelt bench inundation, lasting up to the snowmelt recession node of the unregulated hydrograph for a given runoff year type, will meet woody riparian vigor and regeneration thresholds expected of wetter runoff year types (Appendix C). The Peak Snowmelt Bench also provides a less abrupt transition for the peak snowmelt event. The end of the fast recession limb does not sharply dewater wetted margin and emergent floodplain habitats, for plants and animals, existing before the peak event. Rather, these habitats will be gradually dewatered during the slow recession limb.

In Dry, Dry-Normal I, and Dry-Normal II, the spring ascension releases also function as the Peak Snowmelt Bench. This prescription reduces opportunities for woody riparian regeneration, but mimics poor regeneration that

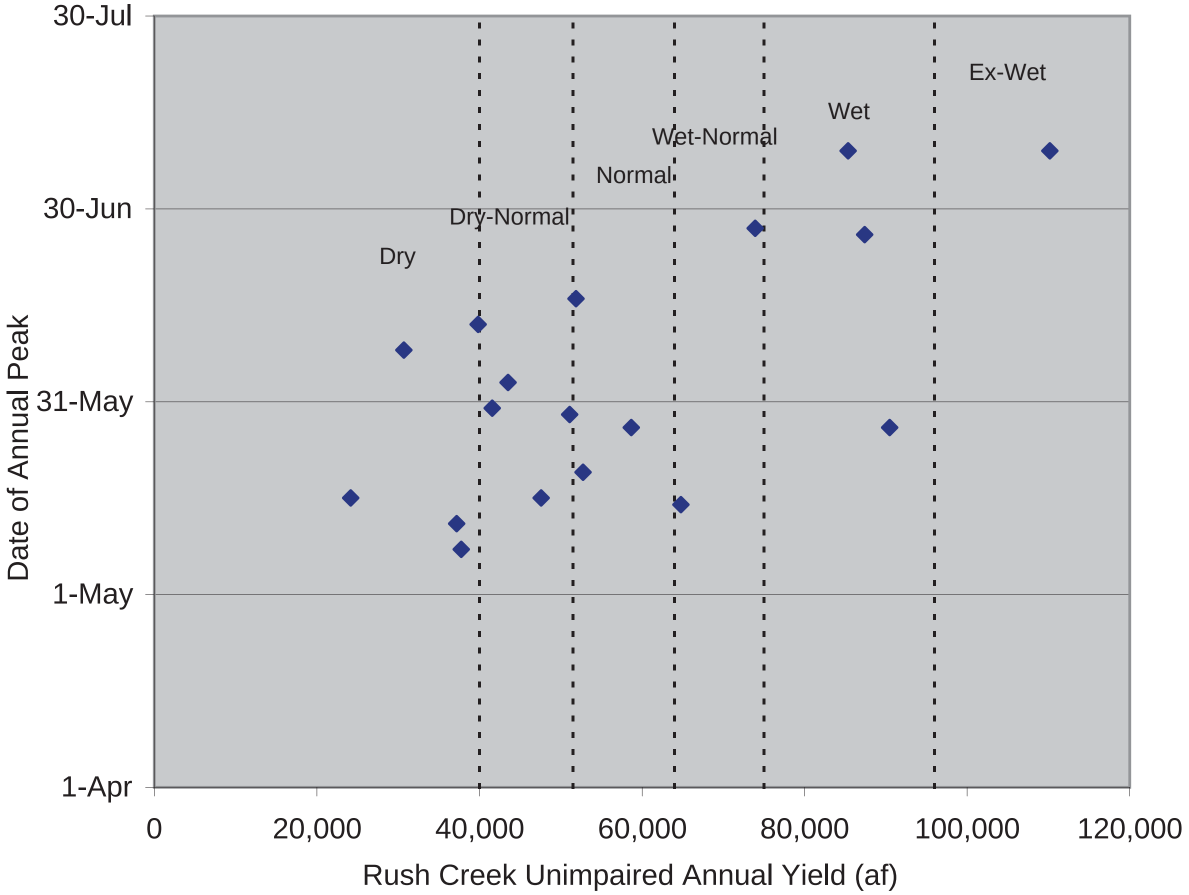


Figure 5-4. Date of the annual snowmelt peak for Rush Creek unimpaired for RYs 1990 to 2008, relative to the unimpaired annual yield and runoff year type.

occurred under unregulated annual hydrographs (Appendix A-1 and A-2). The natural woody riparian role of Dry and Dry Normal I runoff years during the peak snowmelt period was important to retain. Both these unregulated runoff year types in Lower Rush Creek rarely would have succeeded at regenerating willows and cottonwoods in floodplains based on the NGD analysis (Appendix E). Regeneration on floodplains was not an expected ecological outcome for Dry and Dry Normal I runoff years (Table 3-1), but both are expected to maintain woody riparian vigor (Appendix C) with similar success as would have occurred in unregulated Dry and Dry Normal I runoff years. Given the duration threshold of 77 days for streamflows exceeding 80 cfs to maintain plant vigor successfully (no dieback), success in unregulated Dry and Dry Normal I runoff years from RY1990 through RY2008 was uncertain (Appendix C). Die-back likely occurred in many Dry and Dry Normal I runoff years throughout Lower Rush Creek floodplains. To maintain vigor with similar success as in the unregulated RYs modeled, spring baseflows begin ramping up to 70 cfs on May 1 then extend through July 5, the snowmelt peak period for Dry and Dry Normal I runoff year types (Figures 2-8 and 2-9).

In Normal runoff years, the 80 cfs ascension streamflow would be rapidly ramped to 120 cfs by June 19 then extended to July 4. In sequentially wetter year types, bench releases would be greater and last longer as in the unregulated hydrograph. In Wet-Normal runoff years, the Snowmelt Peak Bench is 145 cfs and lasts until July 23; in Wet runoff years the release is 170 cfs lasting to August 1; in Extremely-Wet runoff years, the release has a bench release of 220 cfs lasting until August 10. Recommended releases in most Wet and Extremely-Wet runoff years will be difficult to regulate according to our recommended instream flow prescription, because of GLR spills.

A snowmelt bench release of 70 to 80 cfs, which reaches to > 90 cfs in the Bottomlands, reduces brown trout holding habitat to 52% of maximum availability and reduces foraging habitat to 47% of maximum availability. However, the loss of habitat area is offset by beneficial summer water temperatures promoting better trout growth rates.

5.6. The Annual Snowmelt Peak Rising Limb

Ascending limbs of unregulated snowmelt hydrographs are steep: daily average and maximum rates range from 12% to 39% (Appendix A-3, Table 1). A steep daily snowmelt ascension rate of 20% is recommended in all runoff year types requiring a snowmelt peak release (Dry-Normal II and wetter RYs). The 20% rate speeds LADWP's response time for coordinating GLR peak releases with unregulated Parker and Walker creek snowmelt peak runoff, without compromising ecological functions.

5.7. The Annual Snowmelt Peak

The snowmelt peak has many ecological functions vital to restoring and maintaining the Rush Creek ecosystem. Magnitude, duration, timing, and frequency of the annual snowmelt peaks all must be considered in meeting desired ecological outcomes.

Rush Creek peak floods provide the necessary physical and biological processes for the contemporary mainstem channel to narrow baseflow width to a range of 20 ft to 25 ft wide at the riffle crest thalwegs. A channel this narrow with 3.5 ft to 4 ft high banks has the pre-1941 mainstem morphology conducive to scouring deep pools and deep runs. The primary narrowing process is bar formation succeeded by woody riparian establishment along the bar's low flow margin. Flood peaks exceeding 500 cfs are necessary to create larger depositional features such as point bars and narrow lateral bars. If the colonizing willows, alders, and cottonwood saplings persist, these point bars and lateral bars begin to aggrade. Frequent peak floods between 350 cfs and 400 cfs will deposit finer bed material onto these depositional features. As a depositional feature grows, local channel morphology adjusts. The cross section at the bar apex becomes more asymmetrical, in turn encouraging even more bar deposition. As the bar builds, peak floods greater than 450 cfs continue the construction aided by maturing woody vegetation increasing hydraulic resistance (thus inducing more deposition). Mainstem narrowing therefore requires Dry, Normal, and Wet runoff years: the Wet years initiate bar formation, the Dry years favor successful woody riparian regeneration onto exposed bar surfaces, the Normal years begin depositing finer sediment onto the bar surfaces, and finally the Wet years complete bar aggradation by established riparian vegetation inducing coarse and fine sediment deposition. The margin of the emerging point bar eventually becomes the vertical channel bank thus effectively narrowing the mainstem channel.

In addition to channel narrowing, the annual snowmelt peaks also provide necessary physical and biological processes to build the channel vertically. The contemporary, migrating mainstem channel will need to build floodplain surfaces 3.5 ft to 4.0 ft above the riffle crest thalweg. Peak snowmelt floods between 350 cfs and 400 cfs attain an approximate stage height of 2.5 ft above the riffle crest thalweg in the contemporary mainstem channel (Figure 5-5). Peak floods of 600 cfs to 650 cfs attain an approximate 4.0 ft stage height above the RCT in the contemporary channel. Therefore, frequent peak annual floods greater than 350 cfs will be necessary to inundate contemporary floodplains; less frequent peak annual floods 600 cfs and greater will be necessary to aggrade newly formed and still forming floodplains. As the Lower Rush Creek mainstem channel narrows and deepens (hopefully more by

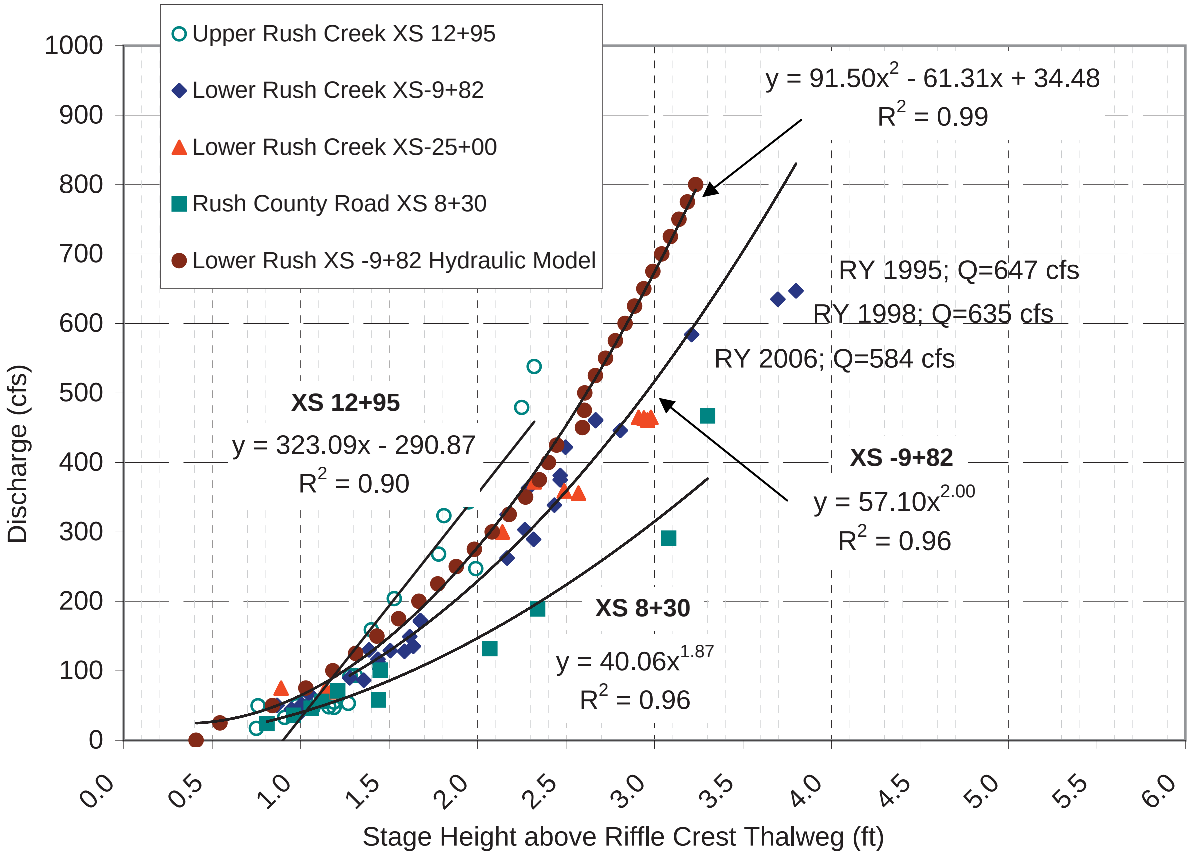


Figure 5-5. Stage discharge rating curves developed for representative cross sections in Rush Creek. The x-axis is normalized by computing stage height above the riffle crest elevation at the hydraulic control downstream of each cross section.

floodplain surface aggradation than by even more channelbed downcutting) above its contemporary deltaic reach, flood peaks of the same magnitude will attain higher stage heights due increasing hydraulic roughness. While this future positive feedback loop should accelerate future floodplain aggradation, near-term floodplain development and mainstem evolution primarily will be a function of woody riparian growth and the frequency of flood peaks exceeding 550 cfs to 600 cfs.

These snowmelt peak threshold magnitudes in the least driest runoff year type expected to accomplish a given level of geomorphic work performed the following geomorphic functions in Lower Rush Creek (Appendix B), and outlined in Table 3-1:

- Mainstem Channel Avulsion … > 800 cfs Extremely-Wet
- Advanced Floodplain Aggradation … 600 cfs to 750 cfs Wet
- Delta Construction … 550 cfs to 600 cfs Wet
- Point/Lateral Bar Formation … 500 cfs to 550 cfs Wet-Normal
- Coarse Riffle Mobilization … 450 cfs to 550 cfs Wet-Normal
- Deep Pool/Run Formation … 450 cfs to 550 cfs Wet-Normal
- Emergent Floodplain Aggradation … 400 cfs to 450 Normal
- Point Bar Accretion … 350 cfs to 400 cfs Normal
- LWD Transport and Jam Formation … 400 cfs to 450 cfs Normal
- Coarse Bedload Transport … 450 cfs to 500 cfs Normal
- Lateral Bar Accretion … 300 cfs to 350 cfs Dry-Normal II
- Fine Bedload Transport … 250 cfs to 300 cfs Dry-Normal I
- Spawning Gravel Scour/Replenishment … 200 to 250 cfs Dry

Given most unregulated annual runoff typically occurs as peak snowmelt runoff, tradeoffs between snowmelt function and snowmelt diversion are necessary in achieving the goals set out in SWRCB Decision 1631. Recommended annual hydrographs for each runoff year type for Rush Creek attempt to balance (1) desired ecological outcomes once provided by the natural snowmelt peak, (2) ways in which LADWP releases below Grant Lake Reservoir can reliably remedy the ecological functions that altered SCE annual hydrographs preclude, and (3) a targeted mean annual LADWP post-transition diversion volume of approximately 30,000 af.

The above thresholds for the SEF instream flow recommendations are targeted as follows for each minimal runoff year type (the driest runoff year type expected to accomplish a given level of geomorphic work):

- Episodic Channel Change … > 700 cfs Extremely-Wet
- Major Geomorphic Work … 550 to 700 cfs Wet
- Minor Geomorphic Work … 450 cfs to 550 cfs Wet-Normal
- Bankfull Channel Maintenance … 300 cfs to 450 cfs Normal
- Spawning Gravel Dynamics … 200 cfs to 300 cfs Dry-Normal II

5.7.1. *Annual Snowmelt Peaks in Dry and Dry Normal I Runoff Year Types*

Unregulated Dry and Dry-Normal I runoff years had annual peak snowmelt floods that frequently exceeded lower geomorphic thresholds (Table 2-4 and Appendix A-4 Table 1). Spawning gravel scour/replenishment was the most common physical task performed. Sand was deposited on advancing point bars and in the emergent floodplain, though to a minor extent compared to deposition during wetter RYs. Spawning gravel quality does not require annual scour/replenishment to maintain favorable trout egg survival, and wetter RYs should readily compensate for lost aggradation on emergent floodplains and point bars. The limited geomorphic role of the Dry and Dry-Normal I peak snowmelt hydrographs was scaled-back. Neither the Dry nor Dry-Normal I annual hydrographs were given snowmelt peak releases.

5.7.2. Annual Snowmelt Peaks in the Dry Normal II Runoff Year Type

Dry-Normal II runoff years bridge drier RYs when very minor geomorphic work is expected and Normal RYs when important channel maintenance occurs. A snowmelt peak of 200 cfs for 3 days was included in the Dry-Normal II annual hydrograph to begin mobilizing pool tail deposits and to help prevent sand accumulation in riffles. With Parker and Walker creek streamflow accretions, Lower Rush Creek would experience typical annual flood peaks of 230 cfs to 260 cfs. The June 1 through June 30 snowmelt bench should coincide with many Dry-Normal II runoff year peaks from Parker and Walker creeks (Figure 5-6).

5.7.3. Annual Snowmelt Peaks in Normal and Wetter Runoff Year Types

Our recommended snowmelt peak magnitudes and durations by runoff year type are:

Normal	380 cfs for 3 days
Wet-Normal	380 cfs for 3 days
Wet	380 cfs for 5 days
Extremely-Wet	380 cfs for 5 days

The 380 cfs peak release is not a geomorphic threshold for Normal and wetter runoff year types, rather the maximum release capacity through the MGORD. Snowmelt peak magnitudes in wetter years must be increased by coordinating the 380 cfs MGORD maximum release with Parker and Walker creek peak runoff, increasing the duration and frequency of GLR spills, and delaying Owens diversions until after the Rush Creek snowmelt peak. Coordination

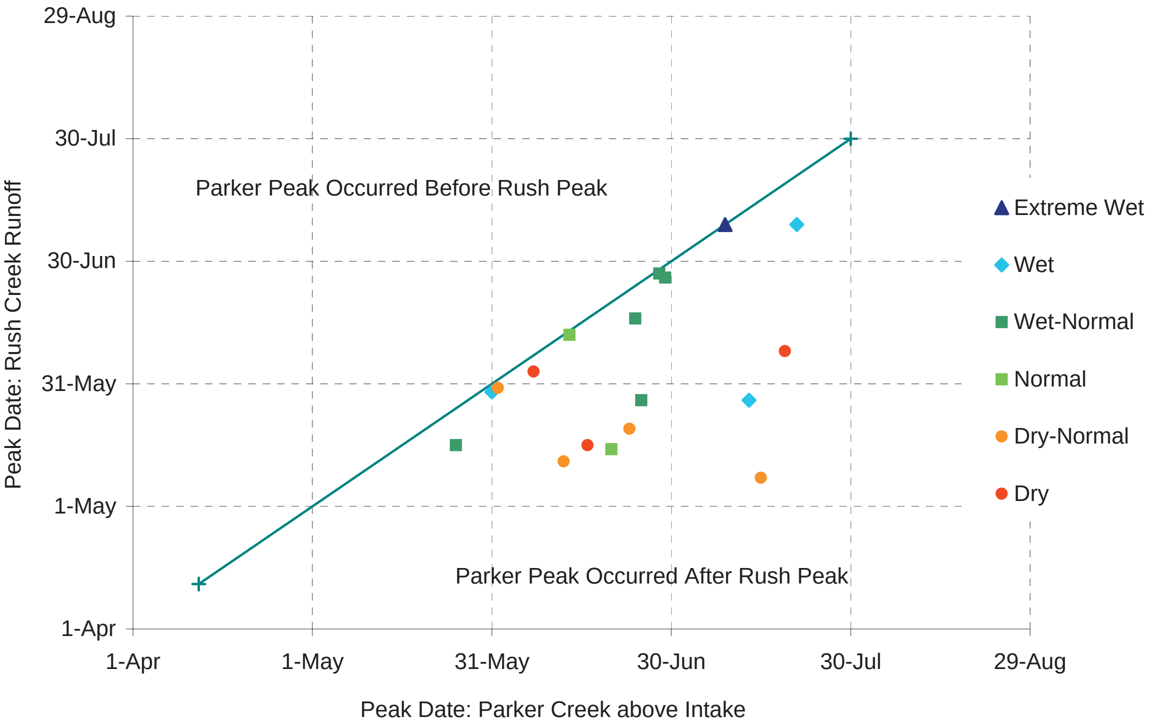


Figure 5-6. Peak timing for Rush Creek unimpaired compared to Parker Creek above Conduit for RYs 1990 to 2008. The Parker Creek snowmelt peak nearly always comes after the Rush Creek unimpaired peak, potentially allowing LADWP to manage peak releases to Rush Creek to coincide with Parker Creek.

of a GLR maximum release of 380 cfs with the unregulated peaks of Parker and Walker creeks infrequently can achieve the upper end of the targeted 450 cfs peak spill threshold in Normal RYs and not require a reservoir spill. Modeled snowmelt peak magnitudes by runoff year type from RY1990 to RY2008, after applying all these management tools, generated peak magnitudes listed in Table 5-1.

With the Owens diversion delay, only a slight increase in flood peak magnitudes was predicted (Appendix F). With all existing management tools applied, targeted snowmelt peak magnitudes in Wet-Normal, Wet, and Extremely-Wet RYs (Table 5-1) still cannot be met without SCE's cooperation and USFS's assistance in meeting these targeted peak snowmelt flood magnitudes and annual maximum recurrences (RI).

Historic floods initiating major geomorphic work likely ranged from a 3-yr 600 cfs flood peak up to a 5-yr 700 cfs flood peak. Historic floods initiating minor geomorphic work likely ranged from a 1.5-yr 400 cfs flood peak up to a 1.8-yr 500 cfs flood peak. From RY1990 through RY2008, a 600 cfs flood peak is now a 20-yr flood event and a 700 cfs flood peak is now a 35-yr flood event. The lack of more frequent big flood peaks will greatly constrain the rate, and likely quality, of long-term recovery. Management options are: (1) piggy-back Parker and Walker peak flows onto the maximum 380 cfs Mono Ditch release, (2) augment Grant Lake Reservoir releases with Lee Vining Creek streamflows via the LV Conduit, (3) keep Grant Lake Reservoir as full as possible to maximize spill opportunities, and (4) SCE and the USFS can improve peak flow releases going into Grant Lake Reservoir as LADWP keeps Grant Lake Reservoir full.

Option (1) has not been required and Option (2) has proven unreliable, with potentially significant impacts to juvenile and adult trout and woody riparian regeneration in Lee Vining Creek. Option (1) would improve the recurrence of smaller flood peaks (many of the Normal runoff year flood peaks) providing channel maintenance and minor geomorphic work. Option (3) would enhance a wider range of larger flood peaks than possible in Option (1), though not as easy to quantify or predict annually. Option (4) has been discussed, but not systematically explored. SCE and USFS can significantly improve flood peak magnitudes and flood peak frequencies entering Grant Lake Reservoir. Table 5-1 gives recommended SCE increases to specified flood peak magnitudes and recurrence intervals. Reviewing the flood frequency curves (Figure 5-7), a compromise between past and present could greatly enhance future recovery. One recovery 'signpost' would be converting the 600 cfs flood, that was a 3-yr unregulated flood but now is a 20-yr event, back to an 8-yr event or less.

5.8. The Fast Annual Snowmelt Peak Recession Limb

The fast descending limbs of unregulated snowmelt hydrographs are steep: daily average rates range from 9% to 18% (Appendix A-3

Table 5-1. Recommended flood peak magnitudes for Rush Creek.

Recurrence Interval	Rush Creek Unimpaired	Rush Creek at Damsite	Rush Creek Recommended SEFs
(years)	(cfs)		
2	550	225	380
3	600	280	450
5	715	380	550
10	800	480	650
25	100	640	750

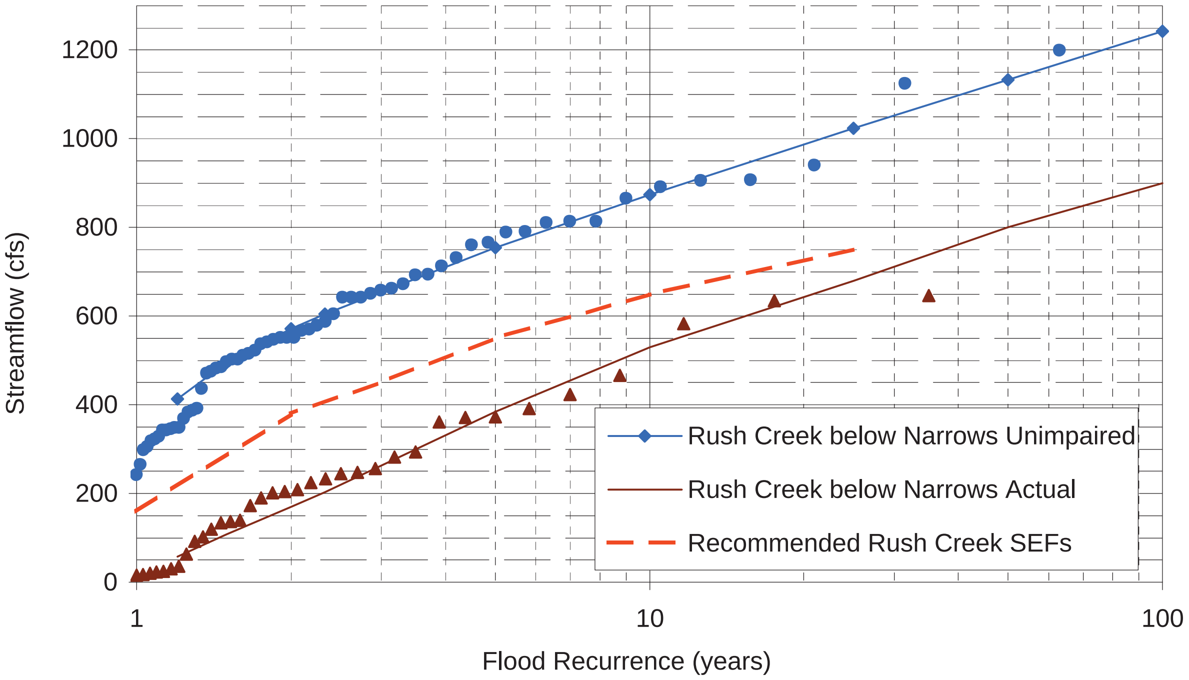


Figure 5-7. Flood frequency curves for Rush Creek below the Narrows for RYs 1941-2008 (unimpaired) and RYs 1990-2008 (Rush Creek at Damsite). The recommended SEF peaks increase SCE regulated peak flows, but would still remain partially impaired.

Table 1). A steep daily fast snowmelt recession rate of 10% is recommended in all runoff year types requiring a snowmelt peak release (Dry Normal II and wetter runoff years). The 10% daily rate approximates a conservative, fast snowmelt peak recession rate.

5.9. The Moderate/Slow Annual Snowmelt Recession Limb

Two broad ecological outcomes dominated moderate and slow snowmelt recession prescriptions: woody riparian germination and regeneration, and brown trout potential specific growth as a function of water temperature.

Woody riparian regeneration on the Rush Creek floodplain was an important desired outcome expected of the fast/slow snowmelt recession limb, dependent on runoff year type. The unregulated rate of streamflow decline past the recession node was nonlinear. The recommended moderate daily rate (6%) followed by a slow daily rate (3%) were patterned after natural snowmelt recession rates and shape of the unregulated slow recession limb (Appendix A-1 and A-2). Shallow groundwater and capillary fringe rate-of-change relative to seedling rooting capability was a principal concern, avoiding stage changes greater than 0.1 ft daily in shallow groundwater elevation. To evaluate how well prescribed rates performed, an NGD and NGY analysis was performed, using the unregulated annual hydrograph as the reference condition (Appendix A-1 and A-2). Three threshold streamflows were identified as necessary for successful germination and regeneration (a seedling survives its first growing season): (1) a 275 cfs streamflow for aggraded floodplains with no side-channels, (2) a 230 cfs streamflow for aggraded floodplain interfluves/depressions with no side-channel, and (3) a 120 cfs streamflow for emergent floodplains and aggraded floodplains with side-channels. Potentially successful regeneration required 21 continuous days beginning on the day of seed fall for 3 modeled species: black cottonwood, yellow willow, and narrow leaf willow. The NGD and NGY threshold magnitudes, durations, and time periods for germination and successful regeneration are as follows:

Aggraded Floodplains w/o a Side-Channel

- Number of Days that a black cottonwood seed could land on a moist surface and germinate (July 06 to July 27) > 275 cfs
- Number of Days that a yellow willow seed could land on a moist surface and germinate (June 14 to July 27) > 275 cfs
- Number of Days that a narrowleaf willow seed could land on a moist surface and germinate (July 15 to August 07) > 275 cfs
- A successful runoff year for black cottonwood regeneration is 21 continuous days > 275 cfs beginning July 06 and ending August 17
- A successful runoff year for yellow willow regeneration is 21 continuous days > 275 cfs beginning June 14 and ending August 17
- A successful runoff year for narrow leaf willow regeneration is 21 continuous days > 275 cfs beginning July 15 and ending August 26

Interfluves/Depressions within Aggraded Floodplains w/o a Side-Channel

- Number of Days that a yellow willow seed could land a moist surface and germinate (June 14 to July 26) > 230 cfs
- Number of Days that a black cottonwood seed could land on a moist surface and germinate (July 06 to July 27) > 230 cfs
- Number of Days that a narrowleaf willow seed could land on a moist surface and germinate (July 15 to August 07) > 230 cfs
- A successful for yellow willow regeneration is 21 continuous days > 230 cfs beginning June 14 and ending August 16
- A successful runoff year for black cottonwood regeneration is 21 continuous days > 230 cfs beginning July 06 and ending August 17
- A successful runoff year for narrow leaf willow regeneration is 21 continuous days > 230 cfs beginning July 15 and ending August 26

Emergent Floodplains and Aggraded Floodplains with Side-Channels

- Number of Days that a yellow willow seed could land on a moist surface and germinate (June 14 to July 26) > 120 cfs
- Number of Days that a black cottonwood seed could land on a moist surface and germinate (July 06 to July 27) > 120 cfs
- Number of Days that a narrow leaf willow seed could land on a moist surface and germinate (July 15 to August 07)

Table 5-2 Number of Good Year (NGY) estimates for Rush Creek woody riparian species.

	Date	Flow Range (cfs)	Rush Creek below Narrows Unimpaired	Rush Creek below Narrows Actual	Rush Creek below Narrows SRF	Rush Creek below Narrows SEF
Aggraded Floodplains without Side-Channels					(# DAYS)	
Number of Years of yellow willow germination	June 14 to July 26	>275	4	3	6	1
Number of Years of black cottonwood germination	July 6 to August 17	>275	2	3	0	1
Number of Years of narrowleaf willow germination	July 15 to August 26	>275	1	1	0	1
Interfluves/Depressions within Aggraded Floodplains without Side-Channels					0	
Number of Years of yellow willow germination	June 14 to July 26	>230	5	3	9	4
Number of Years of black cottonwood germination	July 6 to August 17	>230	3	4	0	4
Number of Years of narrowleaf willow germination	July 15 to August 26	>230	2	2	0	1
Emergent Floodplains and Aggraded Floodplains with Side-Channels					0	
Number of Years of yellow willow germination	June 14 to July 26	>120	11	8	10	10
Number of Years of black cottonwood germination	July 6 to August 17	>120	7	7	6	7
Number of Years of narrowleaf willow germination	July 15 to August 26	>120	5	7	1	4

- A successful runoff year for yellow willow regeneration is 21 continuous days > 120 cfs beginning June 14 and ending August 16
- A successful runoff year for black cottonwood regeneration is 21 continuous days > 120 cfs beginning July 06 and ending August 17
- A successful runoff year for narrow leaf willow regeneration is 21 continuous days > 120 cfs beginning July 15 and ending August 26

Results of these NGD analyses using unimpaired SCE annual hydrographs as reference conditions are in Appendix E.

A primary goal in prescribing slow recession streamflows was to achieve a level of successful regeneration commensurate with predicted success under unregulated hydrographs in different runoff year types. Success of the SEF annual hydrographs using NGY was comparable for the three riparian species on floodplain interfluves, within side-channels, and on emergent floodplains, but was not comparable on aggraded floodplains (Table 5-2). Threshold streamflows exceeding 275 cfs into mid-summer, without the aid of significant accretion from Parker and Walker creeks, were not extended sufficiently far into summer to achieve the minimum 21 continuous days.

5.10. Summer Baseflows and Temperature Simulations

5.10.1. *Evaluation of Changes in Foraging Habitat versus Temperature-related Flows*

Brown trout summer foraging and holding habitat will vary depending on runoff year type. In wetter years, higher receding flows extending further into the summer will reduce trout foraging and holding habitat area, but will provide more favorable thermal conditions and improve trout growth. In these cases, a thermal regime that promotes better trout growth and condition factor was prioritized over habitat availability.

In drier runoff year types, summer water temperatures will periodically be unfavorable for trout growth, even attaining stressful levels. During these dry runoff year types, abundant trout foraging and holding habitats will be available, but poor thermal conditions will most likely over-ride any potential gains in trout growth or condition factor attributable to physical habitat.

In addition to altering streamflow magnitudes delivered to Rush Creek from GLR, two other methods for mediating high temperatures in Rush Creek also were evaluated: (1) filling GLR, which Cullen and Railsback (1993) predicted would cool GLR outflows by 2˚C (3.6˚F); and (2) delivering cooler Lee Vining Creek water to upper Rush Creek via the 5-Siphon Bypass. Combinations of different flow, climate, GLR elevations, and delivery of 5-Siphon Bypass flows to upper Rush Creek were evaluated using a water temperature prediction model coupled with a brown trout growth model (Appendix D-4).

The stream network temperature model “StreamTemp” (version 1.0.4, Thomas R. Payne and Associates 2005) was selected by the Stream Scientists and CDFG (and supported by Mono Basin collaborators) for predicting stream temperatures in Rush Creek. This model is a Windows® operating system version of the DOS® operating system model SNTEMP (Theurer et al. 1984; Bartholow 1989; Bartholow 1991; Bartholow 2000). SNTEMP was originally developed by the U.S. Fish and Wildlife Service (now USGS) team in Fort Collins, Colorado. This model uses a stream network approach to track thermal fluxes throughout a stream network. One major advantage is the model’s ability to evaluate different flow and temperature scenarios and predict changes in temperatures throughout a networked system. This model was calibrated for Rush Creek using RY2000 to RY2008 data (Shepard et al. 2009c and Appendix D-4). Because the StreamTemp model better predicts average daily water temperatures than either minimum or maximum water temperatures (Bartholow 1989), average daily water temperature was used for evaluating model outputs for different flow scenarios from June 1 to September 30.

5.10.2. *Brown Trout Water Temperature Preferences and Thresholds*

Raleigh et al. (1986) report that the optimum water temperature range for the survival and growth of brown trout is from 12˚ to 19˚C (approximately 54 to 66˚F). Elliott and his colleagues developed and refined a series of growth models for brown trout that use water temperature as an independent variable to predict growth (Elliott 1975a; Elliott 1975b; Elliott et al. 1995; Elliott and Hurley 1999; Elliott and Hurley 2000). These studies found that brown trout fed an unlimited diet of invertebrates grew (had a positive weight gain) only when water temperatures ranged from 3˚ to 19˚C (37 to 67˚F), and had their highest growth rate at 14˚C (57˚F). When fish (sticklebacks) made up part of the diet, larger brown trout (300 g) increased their growth rates across a wider range of water temperatures (2 to >20˚C), and their maximum growth occurred at a higher temperature (~18˚C; Elliott and Hurley 2000). Ojanguren et al. (2001) found that the optimal temperature for growth of juvenile brown trout was 16.9˚C, the breadth of temperatures for 90% of maximum growth potential was between 13.8 and 19.6˚C, and the breadth of temperatures for positive growth was 1.2˚ to 24.7˚C. Wehrly et al. (2007) found that brook and brown trout had similar thermal tolerance limits. High mean and maximum water temperatures tolerated by both species depended on exposure times and declined rapidly from 25.3˚ to 22.5˚C and from 27.6˚ to 24.6˚C, respectively, for exposure times of one to 14 days. They reported a 7-day upper tolerance of 23.3˚C (74˚F) for mean and 25.4˚C (77.7˚F) for maximum temperatures.

Body condition and densities of brown trout in Rush Creek below GLR were higher at lower peak flows, moderate summer flows, and greater number of days that water temperatures were ideal for growth (52 to 67˚F). Brown trout growth modeling was based on water temperature thresholds developed by Elliott et al. (1995) and field-tested by Elliott (2009) to predict growth in weight (g) of juvenile brown trout from June 1 to September 30.

$$W_t = [W_0^b + bc(T - T_{\mathrm{LIM}})t/\{100(T_{\mathrm{M}} - T_{\mathrm{LIM}})\}]^{1/b}$$

Where, Wt = weight at the end of the period,

W0 = weight at the beginning of the period,

b = regression constant of 0.308 (Elliott et al. 1995),

c = regression constant of 2.803 (Elliott et al. 1995),

t = time-step (one day for our application),

T = temperature (˚C),

$$W_t = [W_0^b + bc(T - T_{\mathrm{LIM}})t/\{100(T_{\mathrm{M}} - T_{\mathrm{LIM}})\}]^{1/b},$$

where, TL and TU are the lower and upper temperature limits when growth equals zero and TM is the temperature at which optimum growth occurs.

TL = 3.56˚C (Elliott et al. 1995),

TU = 19.48˚C (Elliott et al. 1995),

TM = 13.11˚C (Elliott et al. 1995).

This equation results in a triangular relationship whereby predicted growth increases as temperature rises from TL to TM and then decreases as temperature increases further from TM to TU. This model was used to compute daily weights for the period June 1 through September 30 using starting weights on June 1 of 10 g (indicative of age-1 fish starting their second summer of life) and at 50 grams (indicative of age-2 fish starting their second summer) and grew the fish each day based on the predicted average daily water temperature. Total weight (Wt) at the end of the summer (September 30) was converted to weight gain (grams) by subtracting the initial weight (June 1) from the total weight.

The growth-prediction model of Elliott et al. (1995) was evaluated using data collected on weight gains from marked age-0 fish in Rush Creek. Preliminary field-evaluation indicated this model provided reasonable results for age-0 brown trout in Rush Creek from September 1 to August 31. Predicted growth provided the best way to evaluate the different flow scenarios. This growth model was initially developed for brown trout fed unlimited rations of food, so actual growth in the field could be lower. Predicted growth during the June 1 to September 30 summer period may represent only 60 to 70% of total annual growth predictions based on model tests ran for the Rush Creek temperature data. In spite of these discrepancies, this model provided the best index of temperature-mediated effects on brown trout.

5.10.3. *Evaluation of Air temperature, Initial Water Temperature, Streamflow, and Flow Addition Effects on Water Temperatures in Rush Creek*

Potential effects of air temperature, initial water temperature, streamflow, and additions of Lee Vining flows to upper Rush Creek via the 5-Siphon Bypass were evaluated by incrementally changing these values and observing how modeled stream water temperatures responded to changing each parameter. Based on these analyses, water temperatures in Rush Creek are regulated by a moderately complex interaction of water temperatures, flows released from GLR, flows and temperatures of water delivered to Rush Creek by Parker and Walker creeks and from Lee Vining Creek via the 5-Siphon Bypass, and climatic conditions (particularly air temperatures; Appendix D-4). When water temperatures released from GLR into the MGORD are cooler than average daily air temperatures a warming of this water occurs as it moves down Rush Creek and this warming becomes more pronounced at lower Rush Creek flow volumes. Conversely, when water temperatures released from GLR into the MGORD are warmer than average daily air temperatures a cooling of this water occurs as it moves down Rush Creek and this cooling also becomes more pronounced at lower flow volumes. The same relationships exist when water is added to Rush Creek from either the 5-Siphon Bypass or by flows from Parker and Walker creeks. If water temperatures in Rush Creek are warmer than input flow water temperatures, Rush Creek cools, with more cooling at lower Rush Creek streamflows.

5.10.4. *Comparisons of Predicted Water Temperatures and Fish Growth for SEF Versus the SRF Flows*

Predicted growth of 10 g and 50 g brown trout was always greater when GLR was full under all water availability and climate scenarios for the final recommended flows (Figures 5-8 through 5-11). Differences in growth between flows released during different water availability scenarios were not as pronounced under the average climate scenario as for hot and global warming climate scenarios. For these hotter summer scenarios growth was lower under drier water availability scenarios than for wetter scenarios. For wetter water availability scenarios (Wet and Extremely-Wet), more growth was predicted under hotter climate scenarios than the average climate scenario. This increase in predicted growth for wetter water availability scenarios under the hotter climate scenarios reflected the cooler water delivered under these high water and hotter temperature scenarios was warmed to a temperature that actually increased predicted growth, whereas the average climatic air temperatures did not warm this water. Under the average climate scenario, cool water released from GLR was not warmed and consequently was below temperatures ideal for growth and thus limited growth.

Predicted water temperatures based on our water management recommendations (flows, GLR full, and addition of 5-Siphon Bypass water to Rush Creek) were compared to the flows and temperatures actually experienced during a hot year (RY2008). Based on snowpack water availability forecasts, 2008 was a Normal water year, so we used the Normal water year

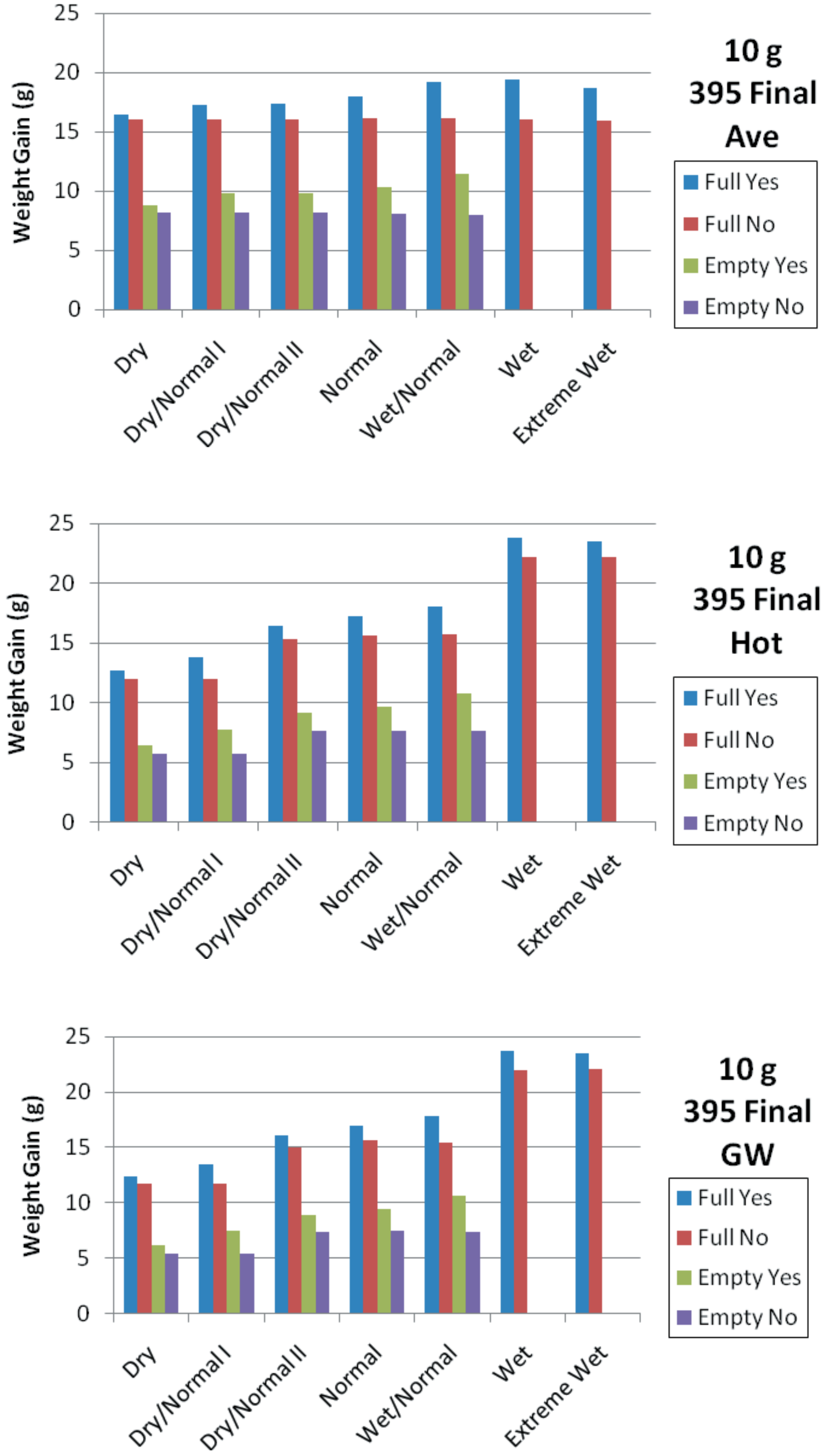


Figure 5-8. Predicted summer growth (g) of 10 g brown trout at Old 395 bridge site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), Grant Lake Reservoir full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

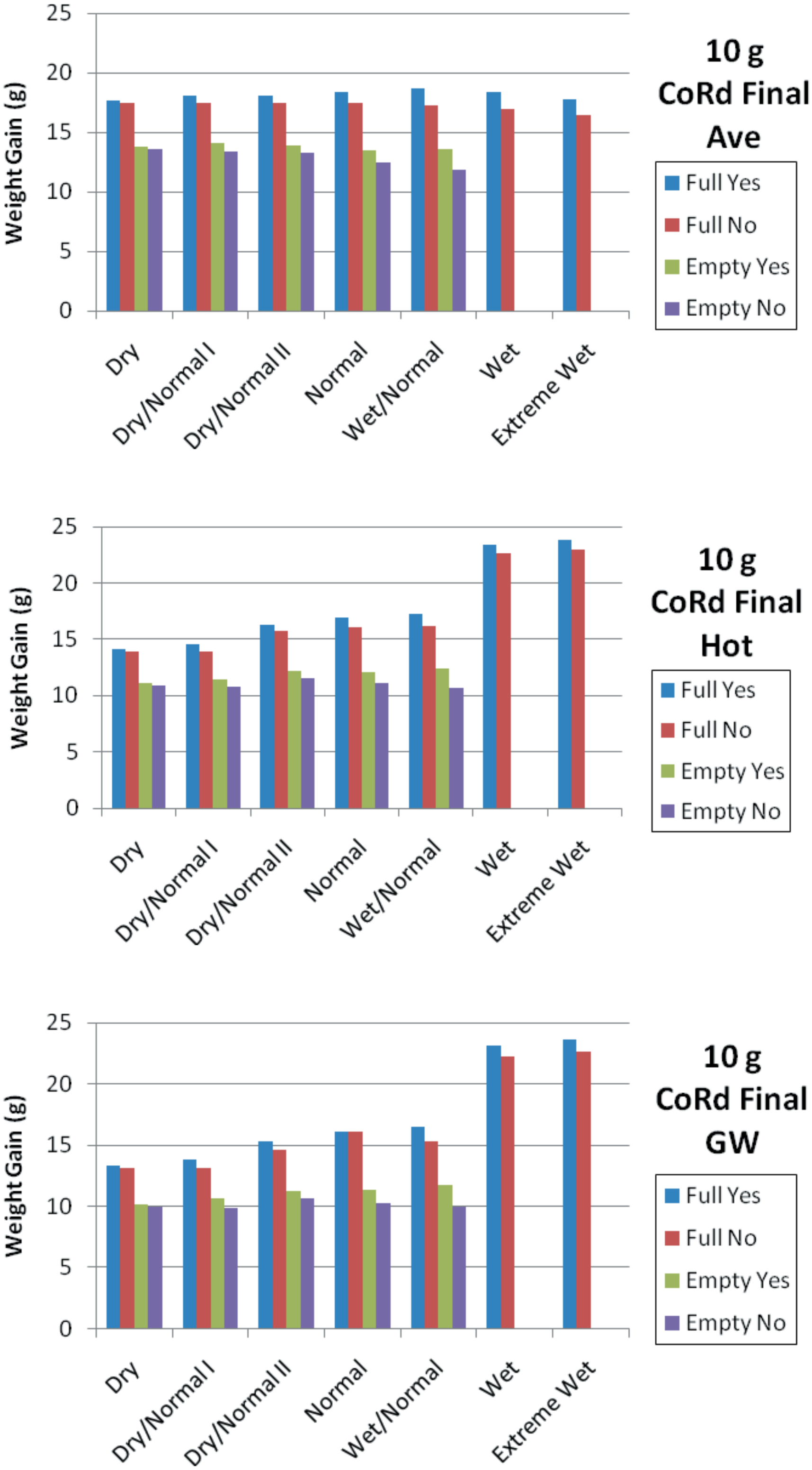


Figure 5-9. Predicted summer growth (g) of 10 g brown trout at the County Road site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), Grant Lake Reservoir full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

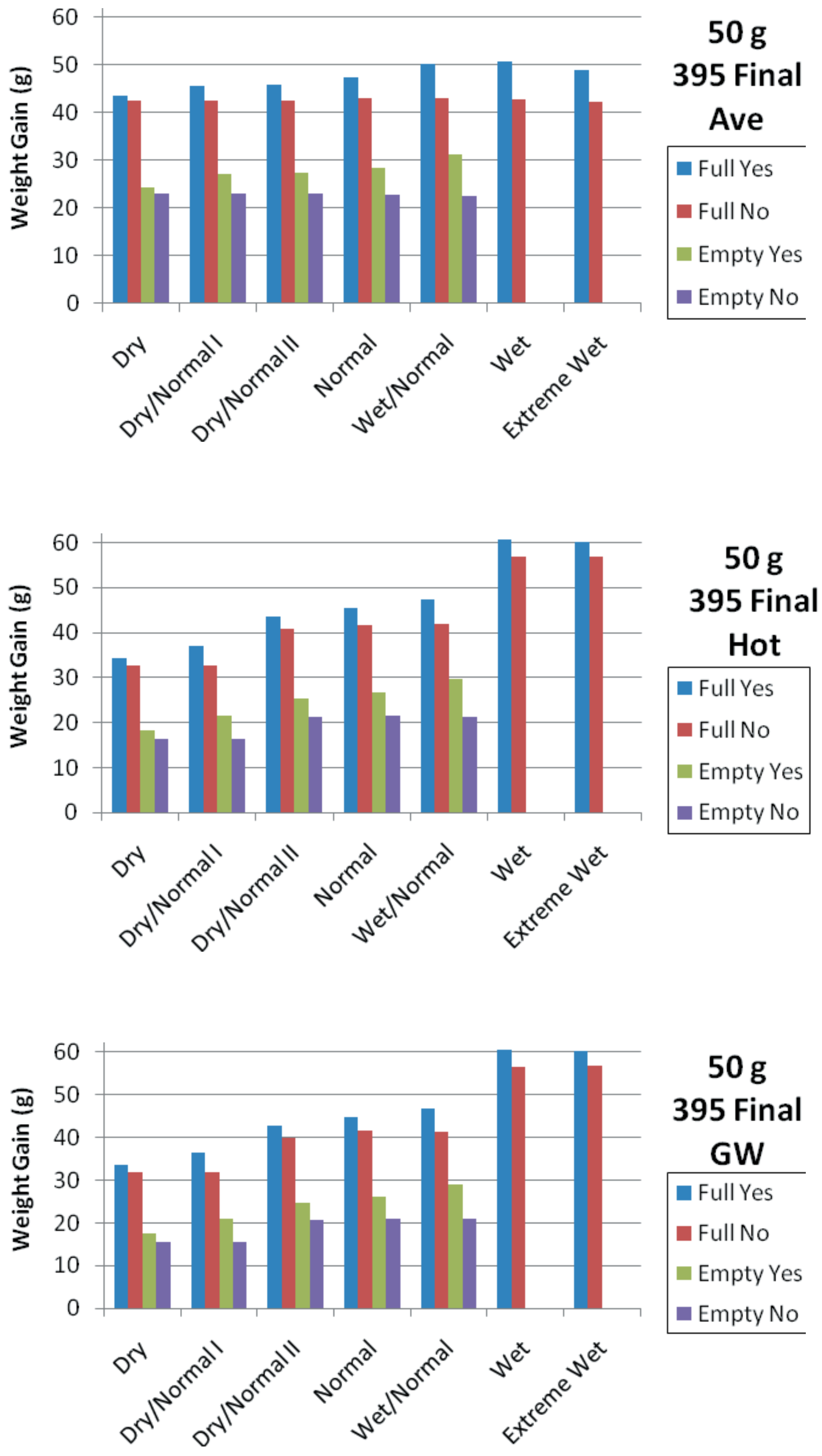


Figure 5-10. Predicted summer growth (g) of 50 g brown trout at Old 395 bridge site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), Grant Lake Reservoir full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

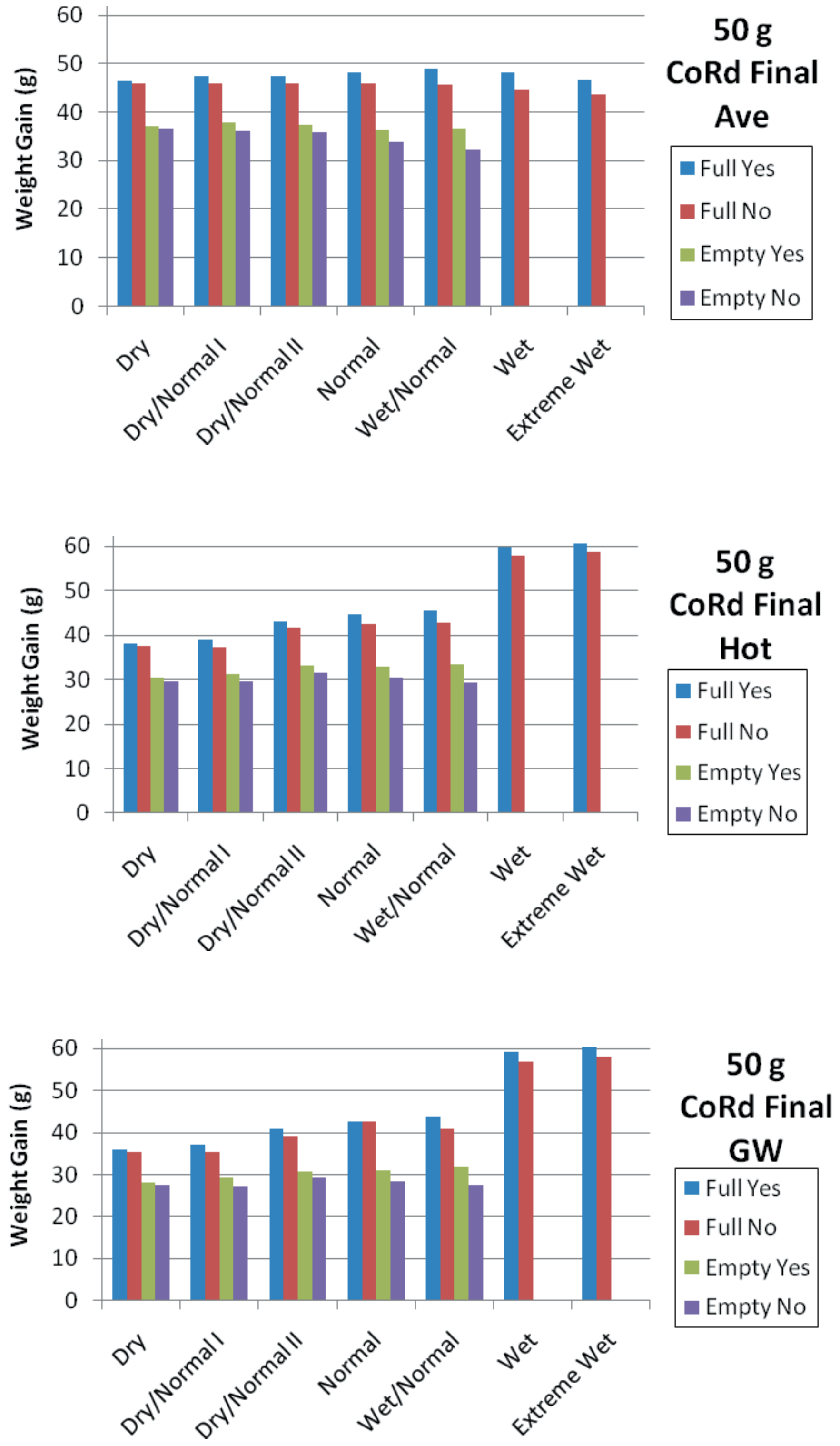


Figure 5-11. Predicted summer growth (g) of 50 g brown trout at County Road site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), Grant Lake Reservoir full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

recommended flows. This comparison illustrates how SEF recommendations might improve fish growth. Recommended flows under the Normal condition of water availability resulted in a later, but similar magnitude, peak flow than was actually released during 2008 with baseflows very similar to what was actually released during 2008 (Figure 5-12). When our recommendations of filling GLR, providing 5-Siphon Bypass flows to upper Rush Creek, and Rush Creek flows were included, the predicted summer growth of a brown trout that was 50 g on June 1 increased about 28 g at Old Hwy 395 and 16 g at the County Road based on the differences between water temperatures actually measured during 2008 and predicted water temperatures for these recommendations (Figure 5-13). More detailed discussion of the water temperature modeling and trout growth predictions is in Appendix D-4.

Temperature analyses suggest the primary management tool available for LADWP to control Rush Creek's summer thermal regime is to maintain GLR as full as feasible by mid-July when baseflows begin. A second management tool (or recommendation) is to release Lee Vining Creek's summer diversions (July-September) into Rush Creek via the 5-Siphons Bypass when GLR is relatively low (<25,000 af). Based on simulated GLR storage levels for RYs 1990 to 2008 under the SEF recommendations and a 16,000 af export, release of Lee Vining Creek diversions into the 5-Siphons Bypass would have occurred in only two (RY1991 and RY1992) of the 18 years simulated. In both these years, diversions from Lee Vining Creek would have been available only during July because flows in Lee Vining Creek dropped below the 30 cfs diversion threshold in August. In these rare instances, directing Lee Vining Creek's flow down the 5-Siphons Bypass would provide Rush Creek an important thermal benefit by reducing the number of thermally stressful days. In these drier years when storage in GLR is low, trout in Rush Creek would still be subjected to thermally stressful days during August and early September. SEF recommendations that result in more Lee Vining Creek diversions to GLR should result in higher GLR storage and consequently cooler water temperatures. Additional Lee Vining Creek water diverted into GLR may result in thermal benefits beyond the 3.6˚F temperature range of GLR full-versus-empty scenario as described in Cullen and Railsback (1993). Additional water temperature data collection in GLR is recommended as part of a future monitoring program.

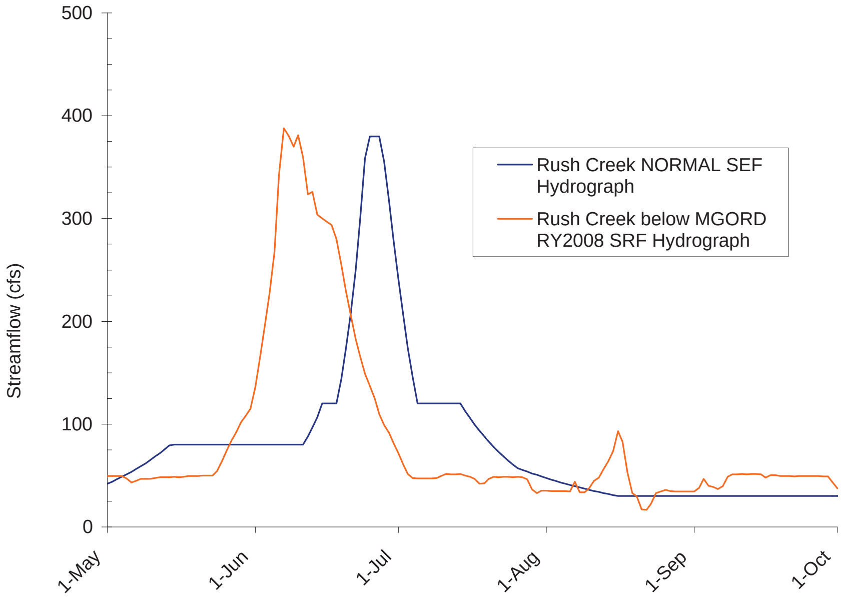


Figure 5-12. Comparison of Rush Creek SRF (Actual) and SEF (simulated) hydrograph for NORMAL RY2008.

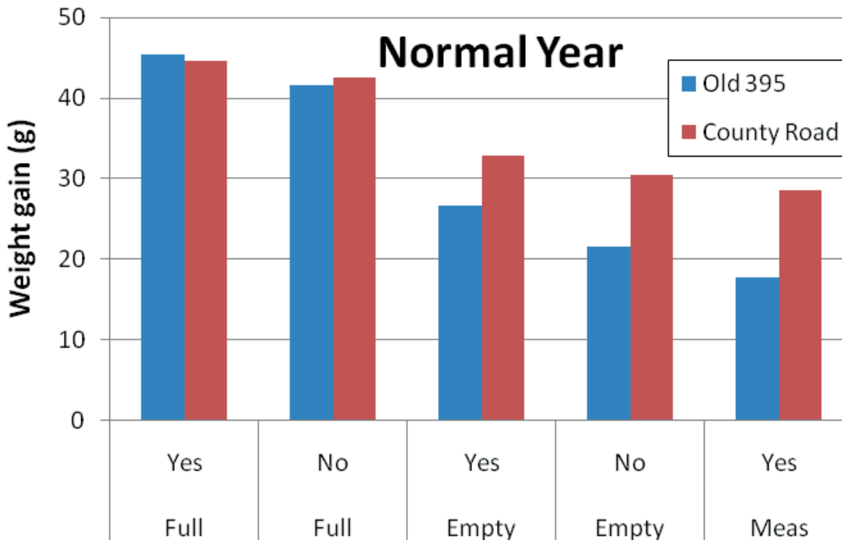


Figure 5-13. Comparison of predicted growth of a 50 g brown trout during the summer of 2008 (a year of Normal water availability and hot summer temperatures) at the Old Highway 395 and County Road sites in Rush Creek to predicted growth for recommended flows and GLR (Full or Empty) and 5-Siphon Bypass (Yes or No) scenarios and predicted growth from predicted water temperatures for the BASE model that included (Yes) and excluded (No) 5-Siphon Bypass flow additions to upper Rush Creek and for the actual measured water temperatures (Meas) that included the 5-Siphon Bypass flows that were actually released into upper Rush Creek.

5.11. Fall and Winter Baseflow

With the woody riparian growing season passed, baseflow allocation beginning October and lasting through March 31 is focused on brown trout habitat. Recommended fall and winter baseflows for Rush Creek in all runoff year types are 28 cfs to 32 cfs starting October 1 and ending March 31. Riffle crest thalweg depths were examined to determine that adult brown trout passage depths at riffle crests (riffle-pool connectivity) during spawning migration is adequate at these recommended baseflows (Appendix D). As documented during the Rush Creek Movement Study, brown trout spawning migration began mid- to late-October and ended mid-December (Taylor et al. 2009). Fall-winter baseflows during spawning season should be stable.

Fall and winter baseflow recommendations for brown trout in Rush Creek were developed from the IFS results (Taylor et al. 2009). Selection of mapping reaches emphasized Rush Creek below the Narrows because this reach supported clusters of high-quality pools with suitable habitat for larger brown trout and also has the greatest potential for additional channel evolution. Inclusion of the 10-Channel/Old Lower Mainstem split provided the opportunity to evaluate trout habitat in the relic mainstem channel at measured streamflows less than the lowest test flow released (Figure 8 in Taylor et al. 2009).

A winter baseflow (measured at the study reaches) from 19 cfs to 23 cfs provided the most brown trout holding habitat downstream of the Narrows, whereas baseflows of approximately 30 cfs provided the most holding habitat in Upper Rush Creek (Table 6 and Figure 8 in Taylor et al. 2009). To achieve 19 cfs to 23 cfs downstream of the Narrows, LADWP flow releases must range from 28 cfs to 32 cfs to account for streamflow losses

(Table 5-3). Depending on runoff year type, variable monthly accretion from Parker and Walker creeks, combined with variable flow losses, will increase the range of winter baseflows below the Narrows. These projected variations in winter baseflow will not appreciably reduce or impact winter holding habitat availability for brown trout in Rush Creek.

The SEF winter baseflow releases should increase preferred brown trout winter holding habitat compared to higher Order 98-05 winter baseflow requirements. Greater habitat availability will be most apparent in Wet and Extremely-Wet runoff years, which have a required SRF baseflow release of 52 cfs. Additional accretion from Parker and Walker creeks, particularly in wetter years and under less pronounced streamflow losses, generates unfavorably high winter baseflows in those wetter years. For example, streamflows in RY2006 below the Narrows varied between 58 cfs and 94 cfs from October to December, exceeding 65 cfs for 63 days of this 92-day period.

SEF hydrographs with recommended peak spills from GLR were simulated below the Narrows (with Parker and Walker unimpaired flows) for RYs 1990 to 2008 (Figure 5-14).

Table 5-3. Discharge values obtained from LADWP and synoptic field measurements during the Rush Creek IFS habitat study, August 12-22, 2009.

					Measured Flow at Sites (cfs)			
Dates	MGORD Targeted Release (cfs)	MGORD Actual Release (cfs) #	Parker+Walker Contributution (cfs) *	Rush Creek Below the Narrows (cfs)	Upper Rush	Lower Rush	10-Channel	Ford - County Road
12-Aug	45	47.3	4.9	52.2				45.7
13-Aug	45	52.8 **	4.9	57.7	43.3	8.6	32.2	
14-Aug	60	60.9	4.9	65.8	64.0			57.6
15-Aug	60	60.6	4.9	65.5		12.1	48.1	
16-Aug	90	89.8	4.9	94.7	94.1	19.2	62.0	77.3
17-Aug	90	89.4	4.9	94.3				
19-Aug	30	33	4.9	37.9	33.5		22.6	27.1
20-Aug	30	32.9	4.9	37.8		6.1		28.8
21-Aug	15	17.1	4.9	22	17.9		12.3	14.1
22-Aug	15	16.9	4.9	21.8		3.0		

represents the average of 15-minute MGORD data between 8AM and 4PM

* represents combined flow measured by DWP at tributary confluences on 8/12 and assumed steady through habitat flow study

** flow release remained 46.9 cfs until mid-day, when flows were ramped up prematurely

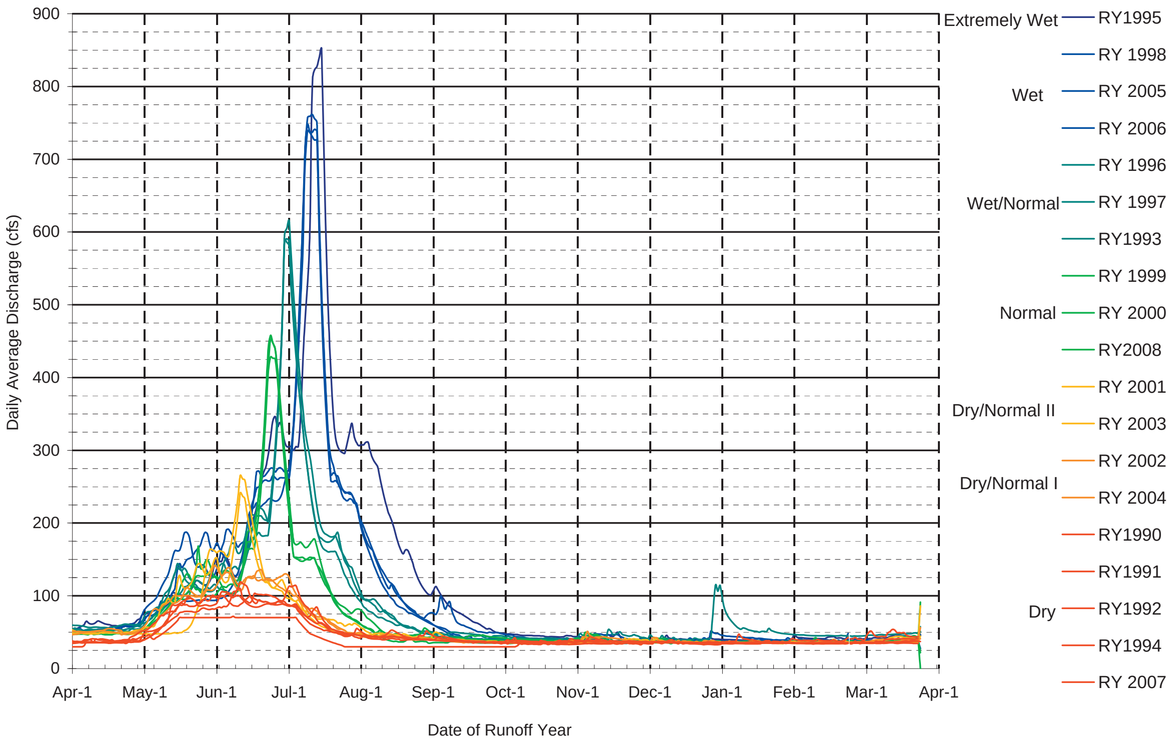


Figure 5-14. Rush Creek SEF hydrographs simulated Below the Narrows for RYs 1990 to 2008 using recommended bypass flows for each runoff year type and recommended SCE peak releases, combined with Parker and Walker creek above Conduit streamflows.

CHAPTER 6. GRANT LAKE RESERVOIR SIMULATIONS

The water balance model was needed to forecast whether proposed SEF recommendations would attain a higher GLR storage, increasing the magnitude, timing, and frequency of spills, and/or improve summer water temperature releases into Rush Creek. The overall water balance is presented in Section 3.4 and described in Figure 2-1. With the model calibrated, several scenarios were simulated in a step-wise fashion to demonstrate (1) the overall performance of SEF flow recommendations, and (2) the individual effect of each component (Lee Vining release and diversion volumes, Rush Creek releases, export volumes and annual export patterns). Each simulation included the 19-year period from RY1990 to RY2008 and into summer of RY2009. All streamflow values are daily averages. To compute GLR storage volume, the spreadsheet model uses:

Inflows to Lee Vining and GLR

- Lee Vining Creek above Intake (5008)
- Lee Vining Creek diversions
- Rush Creek at Damsite (5013) flow

Grant Lake Reservoir outflow data

- Rush Creek below MGORD
- GLR spills to Rush Creek
- GLR exports through Mono Craters Tunnel
- GLR annual evaporation (an annual constant)

Each scenario is described in the following section. All scenarios use the gaged data for Lee Vining Creek above Intake (5008) and Rush Creek at Damsite as the model input. Charts for each scenario showing GLR storage volume are presented in Appendix F. To quantify changes in GLR storage, NGDs were calculated for the number of days the reservoir exceeded storage volume thresholds for each runoff year from RY1990 to 2008 (Table 6-1). The most important factor for this evaluation was the total number of days, and the specific period, that GLR was full (i.e., at maximum storage volume of 47, 171 af). The NGD for full GLR was thus computed for each runoff year, and averaged for each runoff year type (Table 6-1). Charts of GLR storage are presented in Appendix F.

6.1. Grant Lake Reservoir Model Scenarios

Scenario-1: Using historical SRF flow releases and historical export data, Scenario-1 predicted GLR storage volume for RY1990 to 2008 and compared the predicted storage to historic storage volume to evaluate the overall model performance. Once the model was calibrated as best it could with the available data (including a factor for average annual evaporation), the *predicted* Grant Lake Reservoir storage volume was used for all subsequent scenarios. Using the predicted GLR storage instead of historical thus avoided the error between the predicted and observed GLR storage being included in, and thus confounding, interpretation of subsequent scenarios. The calibrated fit of predicted historic GLR storage to the actual historic was not perfect. Daily average GLR storage data were not available prior to June 1, 1991. Predicted storage fluctuates with the actual storage for the subsequent runoff years, primarily over-predicting the actual value, and remaining within approximately 4,000 af of historic storage. During several intermediate wetter runoff

Table 6-1. NGD calculations for Grant Lake Reservoir storage for modeling scenarios evaluated with the water balance model.

	Scenario 1a: Actual Historical Conditions						Scenario 1b: Predicted Historical Conditions						Scenario 2: Historical Rush Creek and Exports; Lee Vining Creek SEF						Scenario 3: Historical Exports; Rush and Lee Vining SEFs						Scenario 4: Rush and Lee Vining SEFs; 16K Export; NO Curtailment					
	Average NDGs												Average NDGs						Average NDGs						Average NDGs					
	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
Number of Days Grant Lake Elevation is below 7,090 ft	94	0	45	0	0	32							73	0	0	0	0	19	73	0	21	0	0	22	73	0	30	0	0	24
Number of Days Grant Lake Elevation is above 7,090 ft	271	365	320	365	365	333							292	365	365	365	365	346	292	365	344	365	365	343	292	365	335	365	365	341
Number of Days Grant Lake Elevation is above 7,100 ft	121	310	268	341	353	268							274	365	314	365	365	333	365	365	274	365	365	351	216	365	274	354	365	310
Number of Days Grant Lake Elevation is above 7,110 ft	49	172	243	270	330	200							172	365	256	352	365	295	355	365	243	365	365	343	141	365	243	342	365	283
Number of Days Grant Lake Elevation is above 7,120 ft	15	37	232	243	312	152							66	365	243	317	365	260	244	365	243	365	365	314	111	365	243	313	365	271
Number of Days Grant Lake Elevation is above 7,130 ft (Spillway Elevation)	0	0	13	51	47	20	0	0	8	49	41	18	2	6	24	86	96	39	42	49	43	202	208	104	6	35	49	103	187	72
Peak Discharge below MGORD	0	0	68	119	255	83							128	233	297	231	485	268	112	192	392	421	489	301	82	170	387	409	472	283

years (RY1998 to RY2000), the model storage predictions were lower than the actual storage volume. The poorest predicted fit was in October 2005 when the predicted value deviated by more than 7,000 af for a short time. Using the NGD computations, the actual historic GLR was full an average of 83 days per runoff year, but never filled during Dry RYs (Table 6-1). The predicted historical scenario had NGD values similar to actual historical storage.

<u>Scenario-2:</u> Using historical Rush Creek SRF flow releases and historical export data as in Scenario-1, Scenario-2 then substituted the Lee Vining Creek SEF flow recommendations. This scenario thus demonstrates the net effect on GLR of just the increased diversions from Lee Vining resulting from SEF recommendations. The Grant Lake Reservoir storage chart shows that after the succession of Dry runoff years in 1990 to 1992, GLR storage fills by RY1995 and remains above approximately 37,000 af (78% of full storage) in all runoff years until RY2007. The reservoir also fills in all RYs between 1995 and 2007 except for Dry-Normal I RY2002 and RY2004. Following the extremely Dry RY2007 and the miss-forecast Normal RY2008, GLR storage dropped to an historic low storage below 10,000 af in February 2009. The NGDs increase from an average of 20 full reservoir days per year to 39 days per year, just with increased water diversions from Lee Vining Creek. Wetter runoff years also significantly increase the number of full reservoir days (Table 6-1). Scenario-2 had the overall effect of eliminating nearly all reservoir draw-downs below approximately 35,000 af, with lower storage volumes only during Dry runoff years (RY1994 and RY2007).

<u>Scenario-3</u>: This scenario takes Scenario-2 one step further and adds the Rush Creek SEF flow recommendations to the modeled GLR output. The model continues to use historical exports. The overall response is to maintain a full GLR storage in all runoff years after the reservoir fills in RY1992. NGDs for Scenario-3 indicate a full GLR for an average of 104 days per year, with wetter years exceeding 200 full days each year. Dry, Dry-Normal, and Normal runoff year

Table 6-1. (Continued)

Scenario 5: Rush and Lee Vining SEFs; 16K Export; 3 Month curtailment						Scenario 6: Rush and Lee Vining SEFs; 16K Export; Change RY2008 to DN-I						Scenario 7: Rush and Lee Vining SEFs; 16K Export; No Curtailment [BASELINE]						Scenario 10: BASELINE + Export Excess from Each Runoff Year (~30,000 af)						Scenario 11: Baseline + Export Excess from Each Runoff Year (~30,000 af); RY1995 10,000 af export					
Average NDGs						Average NDGs						Average NDGs						Average NDGs						Average NDGs					
Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
73	0	28	0	0	24	73	0	0	0	0	19	73	0	0	0	0	19	73	0	0	0	0	19	73	0	0	0	0	19
292	365	337	365	365	341	292	365	365	365	365	346	292	365	365	365	365	346	292	365	365	365	365	346	292	365	365	365	365	346
243	365	279	354	365	318	239	365	365	353	365	330	216	365	365	354	365	324	283	317	365	309	349	321	283	365	365	359	365	342
154	365	243	344	365	287	152	365	246	343	365	287	141	365	246	342	365	284	80	34	332	109	251	151	80	361	365	277	349	272
117	365	243	324	365	274	116	365	243	324	365	274	111	365	243	313	365	271	6	0	0	0	60	14	7	51	229	203	293	142
5	42	42	93	169	67	5	35	42	93	169	65	6	35	49	103	187	72	0	0	0	0	0	0	0	0	0	22	65	17
91	191	392	405	492	294	89	188	292	405	492	277	82	170	287	409	472	267	70	140	280	380	381	232	70	140	320	380	417	246

types remain full more than 40 days each year. Scenario-3, demonstrating the net increase in GLR storage by changing the Lee Vining Creek and Rush Creek SEF flows and diversions from Lee Vining, had the most dramatic effect on increasing GLR storage of all subsequent scenarios and recommended actions, and demonstrates the feasibility of managing Grant Lake Reservoir at a consistently high storage volume while still releasing desired SEF flows and exporting water.

Scenario-4: This scenario continues with Rush Creek and Lee Vining Creek SEF flow recommendations, but simulates a 16,000 af per year export allocation, replacing the historical export data in which no exports occurred until RY1995 while Mono Lake filled above 6,381 ft. The primary effect of this scenario is that filling GLR after the drought years ending in RY1994 is delayed as water is exported during these years: Scenario-3 with historic exports filled GLR by April 1992; Scenario-4 with simulated exports filled GLR by June 1995Scenario-5: This scenario simulates the same conditions as in Scenario-4 (16,000 af export), but has exports curtailed May, June, and July to forecast if this delayed export rule would enhance GLR storage volume.

Scenario-6: This scenario maintains the three month export curtailment simulated in Scenario-5, and changes RY2008 from a Normal to Dry-Normal I runoff year to demonstrate the best-case scenario for simulated RY1990 to RY2008. The RY2008 runoff year type was changed for the following reason: despite the obvious benefits of simulated SEF flows to GLR storage, RY2007 and RY2008 brought Grant Lake to an historic low elevation, and no previous scenario showed improvement in GLR storage in these runoff years. RY2007 ranked as the third driest runoff year in the period of record since 1941, with an annual yield of 46% of the long-term average. Beginning in June of 2007, GLR storage fell from a seasonal high of 40,700 af to under 22,000 af in approximately 10 months, as outputs from GLR (exports and flow releases) were more than twice as much as inputs (LVC diversions; Rush Creek at Damsite). No SRF release was required in RY2007. Following this critically Dry runoff year, RY2008 had a promising April 1 forecast of 86.1 % equating to a Normal runoff year, but precipitation in April was considerably below average and the runoff year ended with only 70.2% of the long-term average yield. The runoff year type was not revised on May 1, and RY2008 had a Normal year SRF peak release of 380 for 5 days and 300 cfs for 8 days. Following a brief rise in GLR storage in spring 2008, storage again fell sharply through the end of 2008 and into spring 2009. Finally, SCE delayed releasing water from the upstream Gem Lake Reservoir because of operational changes, and only began emptying Gem Lake reservoir in February 2009 instead of the previous October. This delay affected the GLR level by an additional 6,000 af (MLC 2009). The combination of extremely dry conditions in RY2007 followed by the sharp deviation from the RY2008 predicted vs. observed runoff thus led to an unusually steep decline in GLR storage. A change in runoff year type for RY2008 equated to a reduction of 9,000 af in simulated Rush Creek releases, which translates directly into increased GLR storage in Scenario-6. This scenario demonstrates that runoff year forecasts require high accuracy, and have implications for instream flow releases and GLR storage. Under the simulated Scenario-6, with 16,000 af annual exports and higher SEF flow releases in Dry runoff years, GLR storage would not have fallen below 20,000 af in spring of 2009. Additionally, input and output data were added to the model through August 2009; the predicted GLR storage rebounded to full reservoir by July 2009.

Conditions simulated in Scenario-6 (SEF flow releases and diversions, 16,000 af annual export, export curtailment during May, June, and July) demonstrate that GLR storage goals are met through SEF streamflow recommendations, during the pre-Transition period before Mono Lake reaches 6,391 ft.

Scenarios 10 and 11: The final two scenarios simulated an increase in exports from GLR to the Owens River in the post-Transition period after Mono Lake reaches the target elevation of 6,391 ft. The key factor under this scenario is whether GLR fills and spills in Wet-Normal, Wet, and Extremely-Wet runoff years that require GLR spills to achieve SEF snowmelt peaks. To determine the export volume, the maximum sustainable export volume available would be the mathematical difference between the combined annual yields for Lee Vining Creek above Intake (5008) and Rush Creek at Damsite (inputs), and the total annual volume released to Lee Vining Creek and to Rush Creek (outputs). This annual volume averaged 30,600 af (Table 6-2). The simulated future annual diversions were thus input into the model for each runoff year in the 19 year time-series. No export curtailment occurred in spring months. Under Scenario-10, storage in GLR never reached the spillway and fluctuated between approximately 15,000 af and 35,000 af. Annual export volumes averaged 30,600 af. Following RY1994 in which 3 of the previous 4 years were Dry runoff years, Mono Lake elevation would likely have fallen below 6,391 ft at least by RY1995. The RY1995 export allocation was thus modified to allow only the 10,000 af export specified in Order 98-05. With this modeled assumption, the simulated GLR storage filled to capacity in RY1995, fluctuated at a much higher overall storage volume between 35,000 af and 47,57171 af (top of spillway), and spilled in all Wet-Normal and above runoff years.

6.2. Grant Lake Reservoir Spill Magnitudes

Our water balance model was constructed to include all primary water inputs and outputs to GLR. Only local precipitation and runoff were excluded. Including predicting GLR storage volume (and therefore lake elevation), the model predicts the magnitude of spills to Rush Creek. The GLR spillway functions as a hydraulic control limiting spill magnitude; this control is expressed in a spillway rating curve. However, the model could not accurately predict spill magnitude and will require more sophisticated modeling by LADWP to accurately predict flood peak magnitudes during spills.

Table 6-2. Summary of simulated Rush Creek and Lee Vining Creek combined annual diversions for each runoff year, used to simulate post-Transition SEF streamflows and Grant Lake Reservoir storage.

Runoff Year	Runoff Year Type	Simulated RC+LVC Diversions (af)	Percent of Annual Mono Basin Yield Diverted
1990	Dry	9,009	15%
1991	Dry	17,900	23%
1992	Dry	18,732	26%
1993	Wet Normal	41,197	29%
1994	Dry	18,526	24%
1995	Ext Wet	66,386	31%
1996	Wet Normal	55,690	34%
1997	Wet Normal	31,820	22%
1998	Wet	45,443	26%
1999	Normal	25,008	22%
2000	Normal	29,270	26%
2001	Dry Normal	28,552	31%
2002	Dry Normal	22,237	25%
2003	Dry Normal	31,223	31%
2004	Dry Normal	25,525	29%
2005	Wet	52,281	29%
2006	Wet	54,081	29%
2007	Dry	367	1%
2008	Normal	8,918	8%
Average:		30,640	24%
Maximum:		66,386	34%

6.3. Annual Yield, SEF Releases, and Export Volumes

The final data output from revised SEF streamflows and water balance modeling is a summary of annual water yields for each major flow component, including flow releases, water diversions, and export volumes. Modeling simulated these volumes for RY1990 to RY2008. With the historical data as a reference, changes to water volumes were compared resulting from the recommended SEF streamflows.

First, the average annual yield for the 19-year simulation period (for the four Mono Lake tributaries) was 118,331 af, which indicates slightly drier conditions during the 19 simulated years compared to the long-term (RY1941 to RY2008) average yield of 121,981 af. Twelve of the 19 simulation runoff years were below the average annual yield. The analysis period also contained the second wettest (RY1995) and third driest (RY2007) runoff years.

<u>Lee Vining Creek Annual Yield.</u> The average annual Lee Vining Creek above Intake (5008) yield was 44,600 af, representing 38% of Rush, Parker, Walker , and Lee Vining creek total annual yield. As reported previously, average annual diversions from Lee Vining to GLR were only 3,500 af (8% of unimpaired yield), with 41,000 af released below the Intake. The

recommended (and simulated) SEF streamflows resulted in more dependable flow diversions from Lee Vining Creek, with an average annual diversion of 10,500 af and the balance of 34,100 af released to lower Lee Vining Creek. The percent of unimpaired yield released to instream flows (i.e., below the Intake) was thus reduced from 92% to 77% by the SEF flow recommendations. The 23% diversion represents a substantial increase in annual diversions.

Rush Creek Annual Yield. Rush Creek's average yield of 57,900 af represented 49% of the total basin yield. An average of 37,000 af are prescribed for release to Rush Creek, representing 65% of the unimpaired annual yield. The 35% of Rush Creek flow available for diversion (i.e., captured in storage in GLR) is substantially higher than Lee Vining Creek's diversions (23%).

For simulated RYs 1990 to 2008, the Lee Vining and Rush creek combined annual yields provide an average of 30,640 af annual water volume available for diversion (Table 6-3). This diversion volume represents approximately 24% of the total average yield from the four Mono Basin tributaries.

Table 6-3. Annual Yield summaries for simulated runoff year, for Lee Vining Creek and Rush Creek.

Runoff Year	*Runoff Year Type*	*Mono Basin Yield (Rush, Parker, Walker, Lee Vining) (af)*	*Lee Vining Creek above Intake (af)*	*Simulated Lee Vining Creek below Intake (af)*	*Simulated Lee Vining Creek Diversions (af)*	*Rush Creek at Damsite (af)*	*Simulated Rush Creek below MGORD (af)*	*Simulated Rush Creek Diversions (af)*
1990	Dry	59,782	20,144	16,530	3,614	32,246	26,851	5,395
1991	Dry	77,935	26,571	19,956	6,614	38,137	26,851	11,286
1992	Dry	72,766	25,174	18,623	6,551	39,033	26,851	12,182
1993	Wet Normal	140,291	50,313	37,178	13,135	73,320	45,259	28,062
1994	Dry	76,218	28,308	19,549	8,758	36,619	26,851	9,768
1995	Ext Wet	215,252	76,704	59,773	16,930	110,105	60,649	49,456
1996	Wet Normal	164,817	65,295	43,208	22,087	78,862	45,259	33,603
1997	Wet Normal	143,433	60,554	47,093	13,461	63,618	45,259	18,359
1998	Wet	172,744	64,044	52,910	11,134	86,259	51,950	34,309
1999	Normal	112,946	46,713	35,397	11,316	51,755	38,063	13,692
2000	Normal	111,621	41,236	30,967	10,269	57,064	38,063	19,001
2001	Dry Normal II	92,630	32,613	23,830	8,784	48,732	28,963	19,769
2002	Dry Normal I	90,227	37,463	27,299	10,164	41,264	29,191	12,073
2003	Dry Normal II	100,000	41,282	31,353	9,929	50,257	28,963	21,294
2004	Dry Normal I	89,101	34,779	24,596	10,183	44,533	29,191	15,342
2005	Wet	178,105	65,677	53,233	12,444	91,786	51,950	39,836
2006	Wet	189,157	74,558	62,436	12,122	93,909	51,950	41,960
2007	Dry	56,069	24,067	18,972	5,095	22,122	26,851	-4,729
2008	Normal	105,200	32,322	25,721	6,600	40,380	38,063	2,317
	Average:	118,331	44,622	34,138	10,484	57,895	37,738	20,157
	Maximum:	215,252	76,704	62,436	22,087	110,105	60,649	49,456
	Minimum:	56,069	20,144	16,530	3,614	22,122	26,851	-4,729

CHAPTER 7. TERMINATION CRITERIA AND MONITORING

The basis for monitoring is to measure change and to assess uncertainty. Extensive monitoring and analyses the past 12 years have significantly improved an understanding of how Rush Creek and Lee Vining Creek ecosystems work. The proposed SEF streamflows should meet the SWRCB D1631 and Order 98-05 recovery program goal: functional and self-sustaining stream systems with healthy riparian ecosystem components and self-sustaining trout populations with fish in good condition able to support a moderate level of angler harvest. The SRF streamflows, SEF's predecessor, were developed under considerably greater uncertainty. Consequently, SWRCB Order 98-07 established termination criteria to "address the subject of when the stream restoration program and stream restoration monitoring required by Order 98-05 may eventually be terminated." The termination criteria offered presumed pre-1941 stream channel, riparian vegetation, and fisheries conditions for Rush Creek and Lee Vining Creek set forth in Ridenhour et al. 1996 to chart stream ecosystem recovery, guide scientific studies, and ultimately to signal an end to extensive monitoring. The termination criteria (TC) targeted several geomorphic metrics, riparian vegetation acreages for sub-reaches of Rush and Lee Vining creeks, and trout population metrics. The SRFs were expected to change. Order 98-07 anticipated this by stating: "revising the termination criteria when existing conditions make it infeasible to restore a pre-project condition or when new information provides a better understanding of how to evaluate stream restoration progress."

In 2006, the Stream Scientists summarized the status of the termination criteria, the feasibility and ability to predict if and when they would be met, and submitted two separate memoranda to the SWRCB that recommended specific revisions to the termination. The Technical Memorandum (Trush 2006) to the SWRCB regarding geomorphic criteria states:

> "Application of the Rush Creek and Lee Vining Creek termination criteria as standards by which to document/verify recovery assumes today's stream corridor has the same potential to grow and sustain woody riparian vegetation as the 1929 stream corridor. Unfortunately, some acreages within Rush Creek and Lee Vining Creek corridors that were woody riparian in 1929 cannot be restored to woody riparian vegetation, either through natural processes by the year 2100 or by planting cottonwoods/Jeffrey pine. Extensive channel downcutting, being more pronounced closer to the Mono Lake shoreline, has isolated many former floodplain and terrace surfaces from the mainstems' influence by peak flow releases on surface inundation/saturation and shallow groundwater dynamics. In other valley bottom locations, burial of former floodplain surfaces by 3 ft to 6 ft of coarse bedload material has made woody riparian initiation difficult, if not highly improbable, by distancing pioneer seedlings from a reliable water source."

> "We have monitored and assessed, and have ascertained that the prognosis (i.e., recovery by 2100) is good for many 1929 riparian areas, fair for others, and poor or futile for some."

The Technical Memorandum (Hunter 2007) to the SWRCB analyzed the basis of the Order 98-07 termination criteria for fish and proposed new metrics to replace the existing numerical targets:

> "The rationale for replacing the current termination criteria is to evaluate brown trout populations in a more quantifiable and relevant fashion. As stated in past annual reports, no data were available that provided a scientifically quantitative picture of trout populations that these streams supported on a self-sustaining basis prior to 1941."

The Fisheries Stream Scientists recommend that the termination criteria metrics in the Hunter (2007) memorandum continue to be annually computed, using data collected at each established electrofishing section on Rush and Lee Vining creeks, to evaluate trout population dynamics and assess the outcome of SEF flow recommendations. The five reproducible and quantifiable metrics to be used are: trout biomass, density, condition factor, relative stock density (RSD) of catchable trout >225 mm (>9" aka RSD-225), and RSD-300 (>12").

The present termination criteria specified in Order 98-07 have guided quantitative assessment of stream ecosystem recovery, but now have limited utility in the next phase of SEF implementation and monitoring. For example, adoption of the 1929 acreages as guideposts was an excellent strategy in drafting the Orders, but research subsequently indicates slightly less floodplain capacity for riparian vegetation. This conclusion is based on the following:

- The existing geomorphic termination criteria (main channel length, channel gradient, channel sinuosity) no longer describe environmental conditions that the Stream Scientists consider key monitoring metrics;
- Recovery of all woody riparian vegetation acreages by designated stream reaches stipulated in the termination criteria is unattainable in an ecologically sustainable or defensible way (i.e., without extensive planting and irrigation efforts, and/or mechanical manipulation of abandoned floodplains and terraces). Some 1929 floodplain and low terrace surfaces that once supported woody riparian vegetation are now too high, relative to shallow groundwater, to sustain riparian vegetation. As of RY2008 (the latest woody riparian inventory) Rush Creek has 204 acres of riparian vegetation (Reaches 2 to 6 below the MGORD), with a 38 acre deficit relative to the Order 98-07 termination criteria; Lee Vining Creek has 60 acres of riparian vegetation (in Reach 3 below Hwy 395), and a deficit of 23.5 acres relative to the termination criteria.
- Hunter (2007) proposed four repeatable and quantifiable metrics to evaluate the brown trout populations in Rush Creek and Lee Vining Creek – biomass, density, condition factor, and relative stock density (RSD) of catchable trout ≥225 mm (≥9") in the population. These metrics were not formally adopted, but currently these metrics are used to evaluate fish population data collected annually, and should be continued to gauge trout population dynamics and assess the outcome of SEF flow recommendations.

The stream restoration and monitoring program must not cease entirely in the foreseeable future. However LADWP can implement less intensive monitoring as outlined in this Chapter, overseen by the SWRCB but with a diminished role for the SWRCB-appointed Stream Scientists.

7.1. Future Monitoring

A guiding principle has been to promote an ecologically sustainable restoration program and to make ecologically defensible recommendations. The primary impetus on Rush and Lee Vining Creeks will be continued monitoring of selected desired ecological outcomes. This monitoring must also advance our scientific understanding of how Rush Creek and Lee Vining Creek ecosystems work. Five specific areas warrant this effort:

1. Grant Lake Reservoir elevation, storage volume, and water temperature;
2. Stream and groundwater hydrology and stream temperature monitoring;
3. Geomorphic monitoring (aerial and ground photography, riffle crest elevations, deep pool and run frequency, sediment bypass operations);
4. Riparian vegetation acreage;
5. Trout population metrics.

These monitoring components resemble many aspects of monitoring conducted the past 12 years. However, monitoring intensity and frequency, data interpretation, and restoration program responses depart from the most recent past. These monitoring components are described in the following sections.

7.1.1. *Grant Lake Reservoir*

The importance of GLR storage volume and water temperature profiles to the overall management strategy cannot be overstated. LADWP already monitors Grant Lake Reservoir storage and will continue to do so. The purpose for including it in this monitoring list is threefold: first to highlight its importance to overall management recommendations; second, to recommend that additional analyses and simulations be conducted by LADWP with an updated LAASM model with GLR and Mono Lake elevation as the basis for analysis; and third, to provide an avenue for experimentation and evaluation of future SCE peak flow releases that stimulate GLR spills to Rush Creek. The simple analyses outlined in Section 6 required important assumptions regarding Mono Lake elevations; these assumptions should be investigated to confirm anticipated outcomes (i.e., specifically evaluating post-Transition GLR storage and spill frequency). The LAASM model should better analyze GLR spill magnitudes relative to SEF targeted spill magnitudes. Regarding SCE activities that result in GLR spills, no specific monitoring actions are being recommended to coordinate SCE-LADWP peak operations, but this topic must be addressed by SWRCB.

7.1.2. *Hydrology and Water Temperature*

Nearly all the recommended streamflow, groundwater, and water temperature monitoring infrastructure is in place. Three exceptions are important: GLR water temperature monitoring, installation of six new water temperature dataloggers on Rush Creek and the 5-Siphons Bypass, and re-operation of streamflow gaging in the lower Rush Creek County Road site. Long-term monitoring of water temperatures should continue on Rush and Lee Vining creeks. Water temperatures should be measured at one-hour intervals throughout the year at the already established thermograph locations, as well as several new locations listed below that were recommended in Shepard et al. (2009a) to provide data to refine the StreamTemp model for future model runs.

During the one-year temporary implementation period, the following data should be collected to clarify outstanding issues concerning water temperature analyses prior the SWRBC making a final determination of the flow recommendations:

- Temperature of Lee Vining Creek diversions through the 5-Siphons Bypass. A 1°F heating of water was assumed diverted through the six mile long Lee Vining Conduit. No warming of this diversion once the water left the Conduit and flowed into Rush Creek also was assumed. Data collected from new thermograph locations will allow an assessment of any temperature changes;
- Flow losses in the 5-Siphons Bypass channel. For StreamTemp modeling, no flow loss in the Bypass channel was assumed; however flow losses likely occur. Synoptic flow measurements or installation of temporary flume structures are required to measure flow losses. In late-July to mid-

August of 2010 an experimental release from the 5-Siphons Bypass would evaluate temperature and flow assumptions used in StreamTemp modeling scenarios that included 5-Siphons bypass inputs;

- GLR release temperatures relative to storage volume and input temperatures from upper Rush Creek and Lee Vining Creek diversions. Current information describing GLR thermal conditions is limited to the Cullen and Railsback (1993) study which reports a 2°C (3.6°F) gradient between a full and near-empty reservoir. Preliminary water temperature data collected by CalTrout in July 2009 above GLR suggest that Rush Creek may be thermally impaired before reaching GLR. The July 2009 water temperature data from the upper MGORD indicated another 2°F warming through GLR. Increased Lee Vining Creek diversions to GLR may help cool GLR, resulting in cooler release temperatures in the MGORD than were used in the StreamTemp analyses. Data collected from new thermograph locations and existing locations will help clarify GLR thermal characteristics relative to Lee Vining Creek diversions. These data should be collected as part of the long-term temperature monitoring program. To better define GLR water temperature regime and trophic status, water temperature and dissolved oxygen concentrations should be measured at one-meter depth intervals at the deepest part of the reservoir and adjacent to the MGORD's intake pipe. These depth-profile samples should be collected at least monthly during the summer and once during late winter. This monitoring should take place for at least three years, or until enough new data are collected to update the Cullen and Railsback (1993) thermal gradient profiles and our Stream Temp model scenarios.
- Diurnal fluctuations in lower Rush Creek. In many past years, summer water temperatures in Rush Creek have exhibited wide diurnal fluctuations, especially downstream of Highway 395. Potential effects of these diurnal fluctuations on brown trout growth and condition factor in the 2004 Annual Report (Hunter et al. 2005). The StreamTemp analyses focused on daily average temperatures generated by various flow, climate, and GLR storage scenarios, but did not predict diurnal fluctuations associated with Rush Creek summer flow recommendations. Managing for a fuller GLR and judicial use of 5-Siphons Bypass accretions in specific situations will result in cooler releases that will be more resistant to warming from solar input. The existing water temperature monitoring infrastructure will allow evaluation of changes in diurnal water temperature fluctuations.

With these final components, the overall hydrology monitoring component should include:

Streamflow Gaging. The current (and future) LADWP streamflow gaging sites on Rush, Parker, Walker, and Lee Vining creeks, should continue reporting daily average flows and lake elevation metrics on a real-time basis on the LADWP website, and made available in annual summary format (e.g., published in Annual Compliance Reports). Synoptic stream discharge measurements should continue to be conducted on Rush Creek to determine the extent of groundwater recharge or discharge downstream of the Narrows during different seasons and stream flow periods.

Groundwater Monitoring. The Rush Creek 8 Channel piezometers 8C-2 and 8C-8 should continue to be monitored annually with dataloggers recording at hourly intervals. For Rush and Lee Vining creeks, the piezometers monitored since RY1995 by the Mono Lake Committee provide excellent long-term data sets, and if the MLC discontinues their seasonal groundwater monitoring, then LADWP should equip at least one (preferably more) piezometer in the Rush Creek 10-Channel array and one piezometer in the Lee Vining Creek 'C' piezometer array with a continuously recording datalogger. Data should be reported annually in tabular and graphic formats.

Stream Temperatures. Water temperature loggers (and duplicate backup loggers) are currently deployed at six locations along Rush Creek below GLR, and at two locations on each Parker, Walker, and Lee Vining creeks One logger was recently deployed on upper Rush Creek at the ‘Rush Creek at Damsite (5013)’ LADWP gage, for a total of 12 water temperature dataloggers. New dataloggers should be installed at these locations:

- In the Lee Vining Conduit at the head of the 5-Siphons Bypass.
- At the confluence of the 5-Siphons Bypass with Rush Creek.
- Rush Creek immediately upstream of Parker Creek.

Continued use of the Onset ProV2 ® dataloggers is recommended, set at one hour recording intervals. Data should be reported annually in tabular and graphic formats.

Rush Creek County Road Gage. The infrastructure remains in place for a gaging station at the Rush Creek County Road crossing. LADWP hydrographers are not satisfied with the pool riffle crest control at the outlet of the County Road culvert. Installation of a physical infrastructure (e.g., a flume or hardened grade control structure) may be warranted. However, streamflow data from this site, or at a more feasible location very near this site, will be essential for assessing groundwater recharge dynamics during snowmelt peak releases and for assessing implications of streamflow accretions and losses during baseflow periods.

7.1.3. *Geomorphic monitoring*

Future monitoring of geomorphic attributes should include the following:

Aerial photography. Obtain high resolution, orthorectified aerial photographs of the Rush and Lee Vining creek corridors from Grant Lake to Mono Lake (Rush Creek), from Hwy 395 to Mono Lake (Lee Vining Creek), and from the Conduit to Rush Creek for Parker and Walker creeks. Photographs should be true color images (four bands, including Near InfraRed), attain 3.5 cm pixel resolution, and use airborne GPS/IMU). Photographs should be obtained at 5-yr intervals or after all Wet and Extremely-Wet runoff years.

Ground photography. Continue photo-monitoring at all monumented photopoints established by Gary Smith (retired CDFG biologist) and McBain & Trush, on Rush Creek and Lee Vining Creek, at approximately 5-year intervals (less frequency may be required depending on the scale of change from year to year). Photo-monitoring points established along riparian band transects should also be reoccupied at the same 5-year interval, as a means of tracking changes in riparian vegetation structure.

Riffle Crest elevations. Survey riffle crest thalweg elevations from the Narrows downstream to Mono Lake along Rush Creek and from top of A4 side-channel downstream to Mono Lake along Lee Vining Creek. Survey riffle crest thalweg elevation along Rush Creek side-channels 3D, and Lee Vining Creek A-3 and A-4 side-channels. This information should be collected at 5-yr intervals or after all Wet and Extremely-Wet runoff years (along with aerial photography) and will provide the basis for determining the efficacy of maintaining side-channel openings for riparian vegetation recovery.

Sediment bypass operations. As stated in SWRCB Order 98-05, all sediment should bypass LADWP diversion structures on Parker and Walker creeks. Sediment storage occurs within the forebay pools (for finer bed material transported) and within each creek’s delta (for the coarser bed material transported). LADWP’s pilot operation using sluice pipes to transport sediment passing into the forebays shows promise. Effectiveness of the sluice pipes in passing all new fine sediment deposited will depend on the sequence of runoff year types encountered during pilot operations. LADWP must demonstrate that the sluice pipes effectively transport the fine sediment transported in Wet as well as Dry runoff years.

Coarse sediment (gravel and larger) is more likely to deposit in the delta (where each creek enters its forebay) during sediment mobilizing flood flows rather than farther downstream into the forebay. Significant transport will occur in the wettest years when the chance of having a 5-yr flood peak and greater is likely, though even drier runoff years can still generate relatively big flood peaks. We recommend surveying the bed topography of both deltas in 2010 as done for the forebays, then resurveying following the first 5-yr or greater flood peak. The most difficult operational guideline is specifying a threshold increase in stored deltaic coarse sediment that would require excavation. Real-time sediment bypass (passing coarse sediment the same year it is deposited) does not appear warranted. However, delaying excavation until a large volume accumulates will likely create problems re-introducing this coarse sediment back into the mainstem channel downstream.

Trout habitat surveys. Future habitat typing and pool surveys should occur on Rush and Lee Vining creeks to monitor pool and deep-run habitats for brown trout. This information should be collected at 5-yr intervals or after all Wet and Extremely-Wet runoff years. Because minimal changes in pool frequency occurred from RY2002 to RY2008 in Rush Creek between the bottom of the MGORD and the Narrows, we recommend that future surveys begin at the base of the Narrows and downstream to the Mono Lake delta. All future Lee Vining Creek habitat typing and pool surveys should cover the 10,000 ft of channel originally surveyed in RY2008 and RY2009 (Knudson et al. 2009). Future surveys should classify pools using the Platts et al. (1987) methods and measure maximum pool depths and thalweg riffle crest depths and elevations so that residual pool depths can be computed and compared to previous surveys.

A large increase in the number of high-quality (Class 4 and 5) pools occurred in Rush Creek below the Narrows between the RY2002 and RY2008 surveys. Future wet runoff years will not appreciably continue this trend of increasing pool frequency. Instead, future improvements to Rush Creek pool and deep run habitats will likely be expressed as increases in residual depths and more abundant undercut bank habitat. As undercut bank habitat increases along with input and accumulation of wood in the channel, brown trout holding and foraging habitat (defined by the IFS mapping criteria) should also increase.

Given the scarcity of pools and runs in Lee Vining Creek, there is potential for appreciable increases in the number of pool and run habitat units. The steeper and less-confined Lee Vining Creek channel should produce more deep runs with undercut banks than pools. As riparian vegetation matures, undercut bank habitat should increase in pools and runs.

7.1.4. *Riparian Vegetation Acreage*

Riparian vegetation in some locations along the Mono Lake tributaries is beginning to resemble a forest, with multiple age-classes of trees, a stratified canopy with understory and herbaceous layers, and abundant soil-forming leaf-litter. In other locations, desert patch types are still in early stages of transition to riparian vegetation (though most of those transitional patches are included in contemporary riparian acreage estimates). However as discussed above, based on the proximity of many floodplain surfaces to groundwater, the trajectory of riparian vegetation recovery will not likely reach the pre-diversion acreages, at least in the foreseeable future.

The riparian vegetation has received more attention than perhaps any other topic, with the possible exception of adult brown trout recovery. The patch types, boundaries, and underlying geomorphic surfaces were mapped on more than 260 acres of the Rush and Lee Vining creek corridors in RY1999, RY2004, and again in RY2009. Plant species composition and plant stand structure was assessed in detail at multiple randomly placed transects and at several valley-wide cross sections. The original 1929 aerial photographs archived in the Fairchild collection were completely redigitized, geo-corrected, and the woody riparian vegetation remapped to refine estimated pre-1941 riparian acreages. This effort produced a riparian atlas. Several strategies were considered for recovering more acreage, including dry and irrigated planting efforts, and mechanical manipulation of terrace surfaces. Finally, revised SEF flow recommendations have several hydrograph components for maintenance and regeneration of riparian vegetation.

In the short-term, a modest increase in riparian acreage over the quantity mapped in RY2009 is possible. Presently there are locations where woody riparian plants have established that were not mapped as woody riparian patches because the establishing plants were not visible in the aerial photographs used in mapping. Beyond the modest increase in riparian acreage attributable to the maturation of establishing woody plants, riparian vegetation area, quality, and structure will be maintained similar to that mapped in RY2009. This most recent mapping acreage (Table 7-1) is the strongest indication of what the streams, with their regulated magnitudes and duration, peak timing, and overall volumes, are capable of sustaining through natural processes. Riparian vegetation will not fluctuate more than 10% around the area mapped in RY2009 (Figure 7-1). SEF flows should provide abundant groundwater for maintenance of riparian vegetation in Dry and Dry-Normal runoff year types, and regeneration of riparian vegetation in Normal, Wet-Normal, and Wet runoff year types. Some short-term increases in acreage may occur where side-channels are maintained and riparian vegetation is still recovering. Long-term recoverable acreage (to RY2100) will result from: (1) changing shallow groundwater dynamics as increasing channel roughness increases flood stage and increases the extent and duration of floodplain saturation, (2) better seedling success as adjacent areas already with maturing woody riparian vegetation favorably change the microclimate, (3) main channel avulsions, and (4) slow cottonwood and willow suckering that will require infrequent wetter years combined with other favorable factors (e.g., no late-season cold snap that can kill catkins).

Riparian vegetation can be mapped remotely in 2015 and in RY2020 on 0.5 ft pixel resolution aerial photographs. Additionally, riparian vegetation mapped remotely in RY2020 would be compared with a riparian vegetation maps developed in the field the same year. In RY2020, field and remotely developed riparian maps will be evaluated for accuracy.

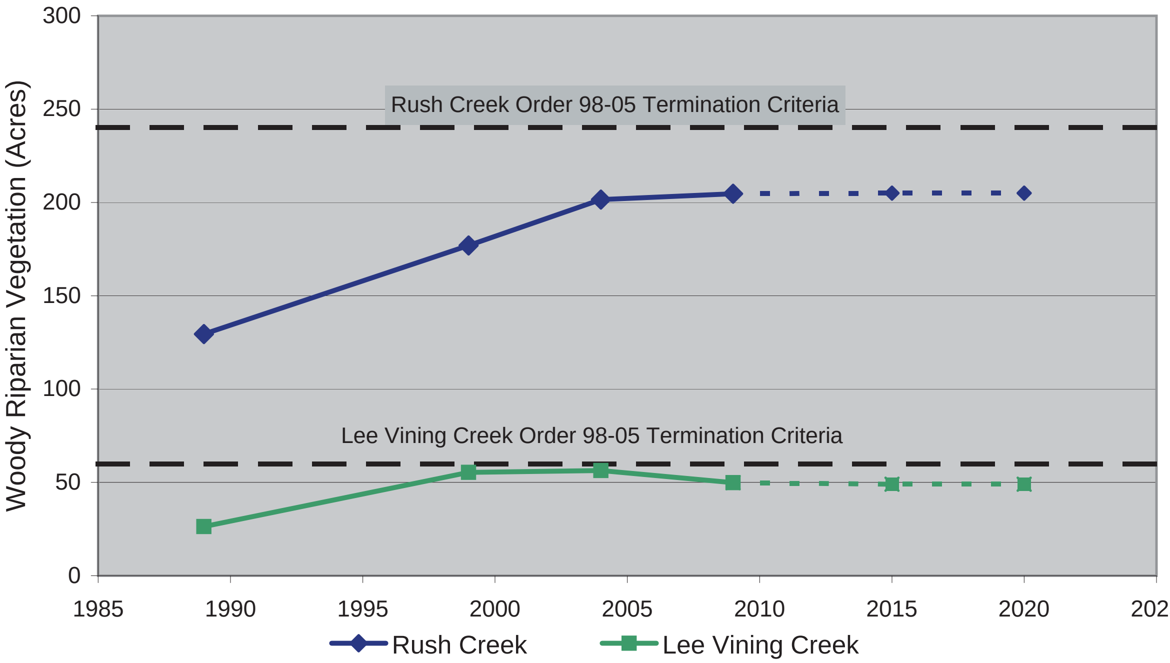


Figure 7-1. Recovery of woody riparian vegetation acreage in Rush Creek and Lee Vining Creek relative to the Order 98-05 termination criteria.

The riparian response to 30 cfs (LVC) and 80 cfs (RC) maintenance streamflows should be qualitatively assessed in dry years. Shoot lengths are a direct reflection of a woody plant's vigor. In good years where abundant water is available, woody plants can grow long woody shoots. In dry years where minimal water is available, a woody plant may grow short shoots or even dieback. The 30 and 80 cfs thresholds are intended to maintain shoots and provide adequate water to prevent dieback. In dry years, a qualitative visual survey should be of riparian vegetation along streams where piezometers are located to determine whether riparian vigor has been maintained.

Additional study may be warranted to quantify how the patterns of wet and dry years have affected growth rates and vigor in locations where groundwater data were collected. Comparison of growth rates in RY2007 contrasted against growth rates in RY2009 would provide valuable insight into the specific effects that 30 and 80 cfs would have in a dry year (RY2007 did not have the thresholds met, RY2009 did).

7.1.5. *Side-channel maintenance.*

Continued side-channel entrance maintenance is recommended for Lower Rush Creek 4 and 8 side-channel entrances in Lower Rush Creek to encourage perennial flow. Maintenance

Table 7-1. Rush Creek and Lee Vining Creek woody riparian vegetation coverage established in the Termination Criteria compared to 1989 acreages quantified by JSA, and 1999, 2004, and 2009 acreages quantified by McBain and Trush.

RUSH CREEK							
Reach	*Termination Criteria (Order 98-07)*		*1989 Vegetation JSA*	*1999 Vegetation McBain & Trush*		*2004 Vegetation McBain & Trush*	
				Woody Riparian Vegetation (Acres)			
1	6.2		1.7	N/A		1.9	
2	5.0		5.9	5.6		6.5	
3a	21.5		12.7	13.2		14.3	
3b	2.9		0.1	1.3		2.8	
3c	11.2		4.1	8.4		9.7	
3d	10.0		4.0	4.0		5.2	
4a	26.3	145.2	90.0	22.5	113.4	26.2	124.3
4b	80.2			61.4		66.8	
4c	38.7			29.5		31.3	
5a	37.8		11.0	26.4		29.3	
5b	N/A		*combined with 5a*	4.6		7.7	

LEE VINING CREEK				
Reach	*Termination Criteria (Order 98-07)*	*1989 Vegetation JSA*	*1999 Vegetation McBain & Trush*	*2004 Vegetation McBain & Trush*
			Woody Riparian Vegetation (Acres)	
1	20.0	19.8	N/A	27.9
2a	30.0	13.4	N/A	16.7
2b	*Combined with 2a*	10.9	10.6	10.2
3a	22.2	6.9	12.5	12.5
3b	32.9	7.5	24.6	25.0
3c	4.0	3.3	5.5	5.7
3d	N/A	8.6	12.8	13.2

at the 3D entrance to encourage perennial flow is also recommended. Woody riparian establishment in the 3D floodplain has lagged behind expectations, given the sharp plunge in shallow groundwater elevation whenever surface flows into the 3D side-channel ceases. Quickly establishing woody riparian vegetation in the 3D Floodplain is the best insurance policy against catastrophic bedload mobilization by the next big flood (as occurred in the 1960's). The alternative remedy is to increase hydraulic roughness and establish physical hydraulic controls in the present mainstem channel that will slightly backwater mainstem streamflows and better divide baseflows between the mainstem channel and the 3D side-channel.

Table 7-1. (Continued)

2009 Vegetation McBain & Trush		*2009-TC difference*
Not Mapped		
6.9		1.9
17.4		-4.1
5.0		2.1
10.8		-0.4
6.3		-3.7
25.1	122.0	-1.2
67.7		-12.5
29.1		-9.6
27.0		-10.8
9.2		

2009 Vegetation McBain & Trush	*2009-TC difference*
Not Mapped	
Not Mapped	
10.4	
9.5	-12.7
20.8	-12.1
5.3	1.3
14.3	-

Entrance maintenance should not continue indefinitely, but have an exit strategy. More than a 2 ft drop in riffle crest thalweg (RCT) elevation between the mainstem channel and side-channel entrance creates an inhospitable environment for woody riparian regeneration in the Lower Rush Creek floodplain. Side-channels, often former mainstem channels, become the future regeneration sites where the floodplain surface is frequently moist whenever seeds are falling and sufficiently moist to germinate and sustain cottonwood and willow seedlings.

The difference in RCT elevation between the top of the historic 14 Side-Channel (formerly the mainstem channel) and present mainstem channel is 4.2 ft. At the 8 side-channel entrance, the difference is 0.8 ft to 1.2 ft, though another mainstem headcut appears to be advancing adjacent to the 8 Floodplain. Although new riparian regeneration (other than suckering) in the 14 Floodplain is extremely unlikely, regeneration in the 8 Floodplain is still feasible. We recommend a guideline for terminating side-channel entrances when the adjacent mainstem RCT profile has dropped more than 2.0 ft. Although measuring future mainstem RCT elevation change is not difficult, measuring how much RCT elevation change already has occurred is. This can be accomplished by surveying RCT elevations down the entire side-channel and adjacent mainstem channel.

On Lee Vining Creek, the following actions are recommended: (1) maintaining surface streamflow into the A4 Side-Channel entrance whenever mainstem streamflows exceed 30 cfs and (2) maintaining the present pattern of streamflow inundation at the A3 entrance. The minimum baseflow that just inundates the A3 entrance has not yet been determined. An exit strategy (similar to that proposed in Lower Rush Creek) for the A3 entrance is tentatively set at a 1.5 ft difference between RCT elevations of the adjacent mainstem channel the entrance RCT.

7.1.6. Fisheries Population Monitoring

Once the SEF flows are implemented, annual monitoring of trout populations is recommended to capture population fluctuations that result from the relatively short lifespan of individual trout, and to provide data to assess long-term population trends and annual variations resulting from different runoff year types. Sampling less frequently than annually may preclude opportunities to evaluate the fishery's response to the SEF flows.

The fieldwork for long-term monitoring is similar to the existing annual population sampling occurring in September, including:

- Conducting mark-recapture electrofishing in Rush Creek sections and the Lee Vining Creek mainstem section. Continue to implant PIT tags and recapture previously tagged fish for specific growth rate information.
- Conducting multiple-pass depletion electrofishing on Walker Creek and the Lee Vining Creek side-channel. Continue to implant PIT tags and recapture previously tagged fish for specific growth rate information.
- Sample the MGORD in even years with mark-recapture electrofishing to generate a population estimate, calculate RSD values, implant PIT tags, and recapture previously tagged fish for specific growth rate information. In odd years, conducting a single electrofishing pass to generate RSD (relative stock density) values, implant PIT tags, and recapture previously tagged fish for specific growth rate information.

Annual electrofishing data should still be used to generate population estimates, length-frequency histograms, density estimates, biomass estimates, condition factors, and RSD values. Length and weights measured from recaptured PIT tagged fish will be used to calculate specific growth rates so that actual growth rates may be compared to predicted growth rates. Because individual fish are uniquely identified, growth (length and weight) for each fish can be computed. Annual growth can then be averaged over all fish of a similar age.

Rush Creek SEF recommendations revise fall and winter baseflows to improve winter holding habitat for brown trout to increase over-winter survival. Increased diversions from Lee Vining Creek should result in a fuller GLR, which should translate into more favorable summer water temperature regimes in Rush Creek. Because these changes are expected to result in more brown trout growing older and maintaining better condition factors throughout the summer, SEF flow recommendations should produce larger brown trout. To monitor trends in larger brown trout, changes in RSD values (Figures 7-2 and 7-3) should be tracked. The horizontal dashed line in these figures represents the RSD values developed by the Fisheries Scientists (Hunter 2007). The RY2000 to RY2008 values are actual data; values for RY2009 to RY2020 are hypothetical and are intended to show expected increases in RSD values resulting from SEF recommendations. A similar trend could be monitored to evaluate changes in the condition factor of brown trout (Figure 7-4).

Sustained shifts in population structure should be accompanied by a decrease in total fish numbers. Long-term population and density estimates should decrease, whereas estimates of total standing crop should remain relatively steady.

7.1.7. Predicting Water Temperature and Brown Trout Growth

The StreamTemp model predicted water temperatures and with these water temperature predictions, annual growth of brown trout in Rush Creek was predicted for different flows. While the brown trout growth predictions are better applied as growth indices, monitoring growth of brown trout is important for determining if relative weight gains estimated in the field have the same relative values as weight gains predicted using the temperature and growth models. This field monitoring must

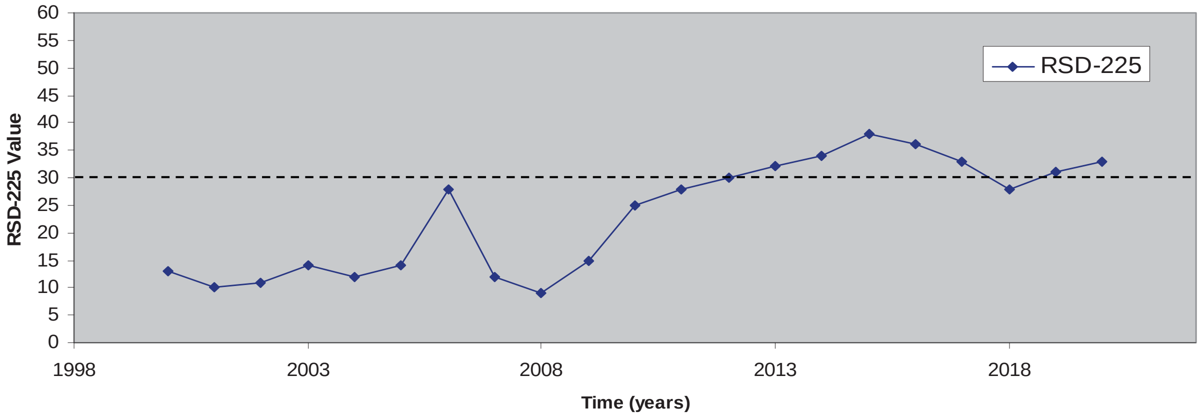


Figure 7-2. RSD-225 values of brown trout sampled from the County Road section of Rush Creek between 2000 and 2020. The values presented from 2000-2008 are actual data, whereas values presented for 2009-2020 are hypothetical.

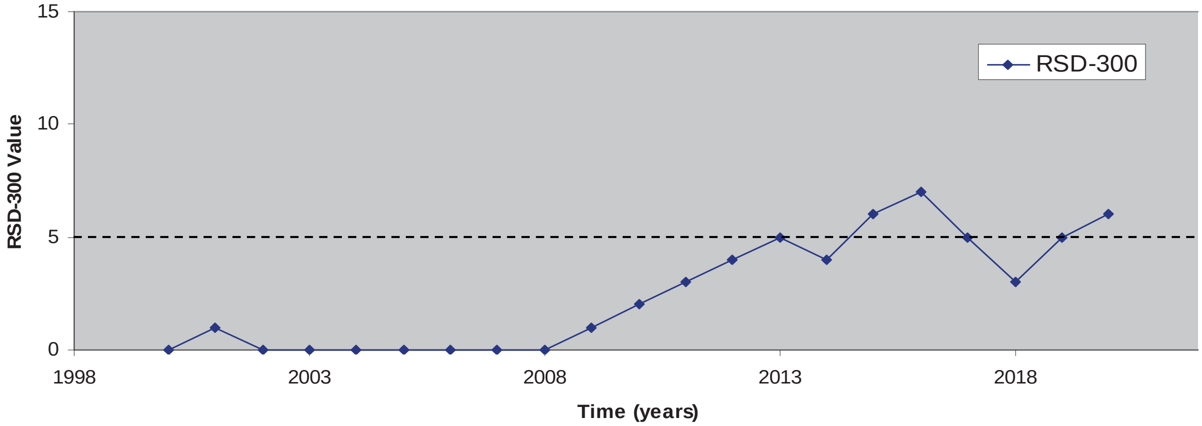


Figure 7-3. RSD-300 values of brown trout sampled from the County Road section of Rush Creek between 2000 and 2020. The values presented from 2000-2008 are actual data, whereas values presented for 2009-2020 are hypothetical.

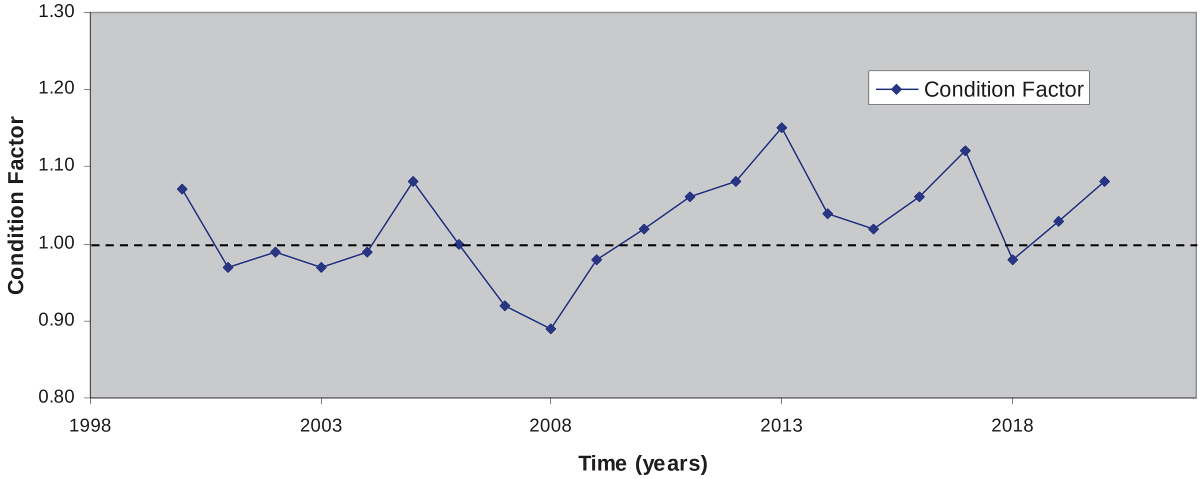


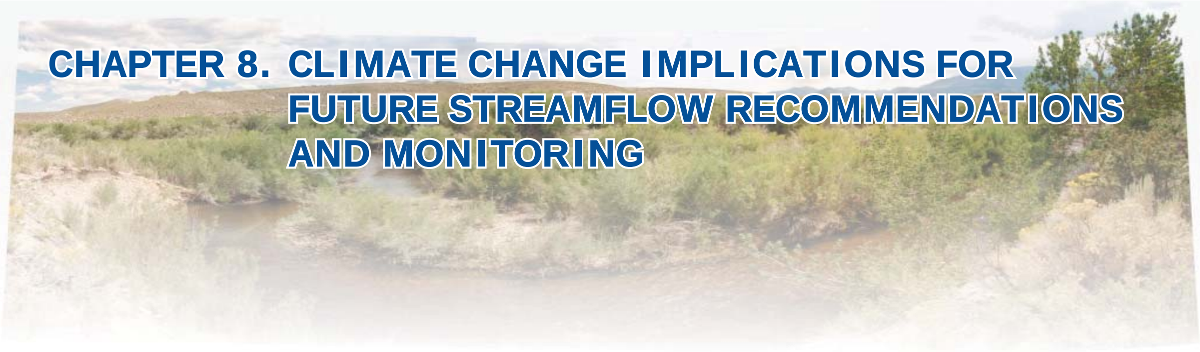
Figure 7-4. Condition factors of brown trout sampled from the County Road section of Rush Creek between 2000 and 2020. The values presented from 2000-2008 are actual data, whereas values presented for 2009-2020 are hypothetical.

be a two-stage approach. The first stage will be validating annual StreamTemp predictions of average daily water temperatures by measuring daily water temperatures at several locations in Rush Creek. The second stage will be to compare predicted weight gains to estimated annual weight gains for brown trout in Rush Creek.

Data from thermographs can be used in two ways. First, measured temperatures can validate the daily average temperature predictions of the "StreamTemp" model. Second, measured temperatures can predict brown trout growth using the Elliott et al. (1995) growth model. Growth predictions using measured water temperatures and predicted water temperatures can be compared to estimates of actual annual growth. Relative growth estimates and predictions can be compared among years to determine if flows released during a given year result in the same relative growth (i.e., are predictions and measurements of growth strongly correlated). Differences between actual and predicted growth rates may provide better information regarding ration amounts available for foraging trout or insights regarding energetic efficiency of trout during growth periods. Over time, measured growth rates of recaptured PIT tagged fish should provide information regarding how much growth must occur for fish to maintain good condition factors (>1.00).

7.2. Adaptive Management

New monitoring to replace the current program must provide information in years to come that would allow specific responses to unmet desired ecological outcomes (i.e., adaptive management). However, the Stream Scientists were not directed in Order 98-05 to recommend specific actions beyond the current SEF flow recommendations and specific monitoring metrics designed to track their outcome. The adaptive management process begun in Orders 98-05 and 98-07 should continue, but without the termination criteria. However; an adaptive management plan should not be developed before SWRCB's determination of the future flow regimes. For an adaptive management process to succeed, LADWP, the SWRCB, and stakeholders should be involved in developing responses if the SEF recommendations diverge from predicted outcomes.



CHAPTER 8. CLIMATE CHANGE IMPLICATIONS FOR FUTURE STREAMFLOW RECOMMENDATIONS AND MONITORING

8.1. General Description of Anticipated Climate Change in Eastern Sierra Streams

Changes observed over the past several decades have shown the Earth is warming, and there is irrefutable scientific evidence that increasing greenhouse gas emissions are changing the Earth's climate (Moser et al. 2009). Accumulating greenhouse gas concentrations in the Earth's atmosphere have been linked to global warming, and projected future trends of increasing atmospheric greenhouse gas concentrations suggest global warming will continue (National Research Council 2001).

Large scale climate models, such as general circulation models (or GCM's), predict global trends, but are generally too coarse to provide regional information. GCM's are unable to capture local climatic effects arising from topographic, coastal, and land-surface processes that contribute to hydrologic impacts (Wilby and Dettinger 2000). More focused modeling techniques, called "downscaling", develop connections between the GCM predictions with regional and watershed-scale (< 1,000 km^2) hydrologic models. Downscaling allows for topographic and regional hydrologic processes to be included that are not captured by the GCM, and these techniques have been used to gain a more focused understanding of potential climate changes to specific areas in the western United States such as for California (Cayan et al. 2008, Dettinger et al. 2009) and even more specifically for the Sierra Nevada (Wilby and Dettinger 2000, Dettinger et al. 2004).

Observations and modeling indicate that the western United States is experiencing warmer winter storms, more rain, less snow, and earlier snowmelt (Cayan et al. 2008). In an investigation of trends in recorded rainfall and snowfall across the western United States over the last half century, Knowles et al. (2006) conclude that: (1) projected global warming impacts in the western United States include reducing snowpack volume and persistence by reducing the amount of precipitation that falls as snow (rather than rain), (2) this warming will hasten the start of snowmelt from the snowpacks that do form, and (3) if warming trends across the western United States continue as projected in response to increasing atmospheric greenhouse gas concentrations, the snowfall fraction of precipitation will likely continue to decline. These conclusions are corroborated by modeling efforts, which have predicted the same trends continuing in the western United States through the 21st century. For California, Cayan et al. (2008) conclude increased warming will produce a trend toward more rain and less snow, diminishing snow accumulations, and an earlier snowmelt, especially in lower to middle elevations of mountain catchments as snowlines retreat to higher elevations.

The combined effects of more rain, less snow, and an earlier spring snowmelt will affect the primary components of many California annual hydrographs, particularly those in the Sierra Nevada. Winter floods may increase in magnitude and frequency as: (a) rainfall catchment areas expand in response to diminishing snowpacks and/or (b) the frequency of storms where rainfall runoff volumes are large and the frequency of rain-on-snow events increases (Dettinger et al. 2009). Earlier spring snowmelt coupled with a reduced winter snowpack may result in decreased snowmelt hydrograph magnitude, duration, and volume; some modeling projections show the snowmelt hydrograph occurring one month earlier by 2100 (Dettinger et al. 2004). Summer and fall baseflows are also affected by the timing shift of the snowmelt hydrograph. Resulting changes include reduced summer and fall baseflows and less summertime soil moisture, which could lead to the depletion of shallow groundwater storage and create stresses on basin vegetation and ecosystems (Dettinger et al 2004).

Although there appears to be general consensus on the projected climatic trend of California (more rain, less snow, and an earlier spring snowmelt), how these changes will manifest themselves as hydrologic processes and annual hydrographs will vary by basin. For example, Wilby and Dettinger (2000) and later Dettinger et al. (2004) modeled runoff scenarios for three Sierra Nevada rivers: the American River, the Merced River, and the Carson River. Model projections for each river showed similar results of increased precipitation totals, increased annual runoff volume, and earlier runoff timing; however, and differences in the timing and magnitude.

There is consensus among many climatologists that continued warming in California will have uneven effects on the landscape. Safe assumptions are: (1) the same climatic shifts documented in the western United States and in California have also occurred in the Mono Basin, and (2) the same projected future trends will occur (i.e., warmer, wetter, and earlier snowmelt). However, research has demonstrated local topography of individual basins strongly influences precipitation and runoff characteristics. Therefore watershed-specific investigations should help estimate future Mono Basin flow regimes under projected climatic conditions. This is especially important for reservoir management because the predicted trend of more rain, less snow, and an earlier spring snowmelt could result in competing flood control and water storage management strategies, potentially resulting in reduced runoff that could be stored for use later in the season (Moser et al. 2009; Brekke et al. 2009). For Mono Lake tributaries (e.g., Rush Creek), this means current reservoir operations should be reviewed and simulated to evaluate what potential operations changes may be warranted under larger winter flood and earlier snowmelt scenarios so flood control, water storage, and SEF objectives can continue to be met.

8.2. Implications for Mono Basin Hydrographs

Section 5.10.4 applied the StreamTemp model to evaluate effects of global climate change on predicted water temperatures and brown trout growth rates. In modeled scenarios with warmer summer ambient temperatures, brown trout growth was lower under drier runoff year scenarios than during wetter runoff years. However, during wetter water availability scenarios (Wet and Extreme-Wet runoff years), more growth was predicted under hotter climate scenarios than the average climate scenario (Figures 5-8 through 5-10). This increase in predicted growth for wetter water availability scenarios under the hotter climate scenarios presumably resulted from cooler water delivered under these high water and hotter temperature scenarios and then warmed (in GLR and lower Rush Creek) to a temperature that actually increased predicted growth.

Another way to appreciate the range of potential responses, and to suspect that the number of plausible scenarios border on infinite, is to consider effects on timing and volume of snowmelt (Figure 8-1). If the area under the snowpack curve does not change for a given runoff year type (e.g., the 1982-1983 wettest year’s total annual precipitation does not change), then the shape of the curve must change. Several annual hydrograph responses can be anticipated. Note that the slope of snowmelt storage loss is similar among the driest, average, and wettest years (but not the averaged year, which does not exist in nature). If the peak occurs earlier, as many predict peak snowmelt runoff occurring a month earlier, then the recession limb could simply be displaced forward the same month (i.e., no change in recession slope). With small changes, snowmelt recession could be over by May 1 in more than half the years (roughly distinguishing the median from the average). This change alone would greatly diminish the NGDs for woody riparian regeneration and affect the growth of established floodplain plants if soil moisture storage cannot meet the demand for water an additional month or longer. Rather than having 10% to 30% dry years, 50% or even 60% dry years would reduce the corridor width capable of sustaining riparian vegetation. Relatively small episodes of mainstem channel downcutting, insignificant in the past, would become more significant for woody riparian maintenance and regeneration.

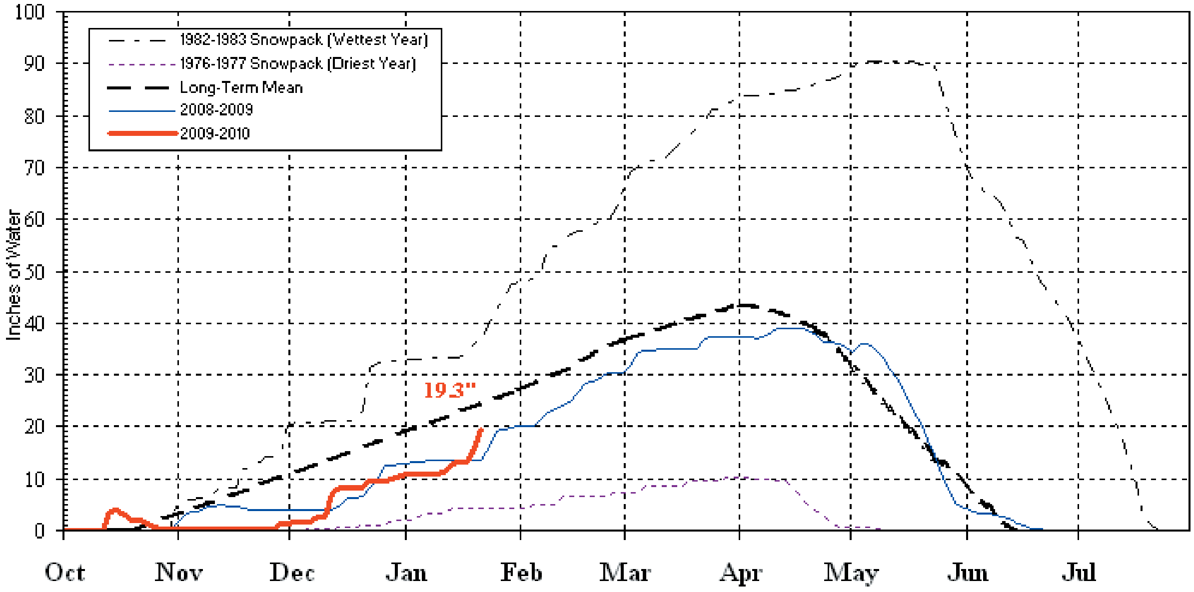


Figure 8-1. Eastern Sierra precipitation conditions represented by Mammoth Pass Snowpack, as of January 22, 2010.

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