Mono Basin Stream Restoration and Monitoring Program:

Appendices to the 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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APPENDIX A. HYDROLOGY

Hydrology of the Mono Basin has been a subject of numerous reports and analyses. Technical Appendix A summarizes hydrologic information relevant to the revised Stream Ecosystem Flow recommendations. For additional background information refer to the Grant Lake Operations and Management Plan (LALADWP 1996), Hasencamp (1994), Vorster (1985), and the Mono Basin EIR (Jones and Stokes 1993).

LADWP Mono Basin operations are governed by Runoff Year (RY), with each runoff year beginning April 1 and ending the next March 31 (e.g., RY2009 began April 1, 2009). Runoff Year forecasts are determined on April 1, and may be updated on May 1 each year. LADWP developed a Grant Lake Operations and Management Plan (LADWP 1996) to address four operational aspects of water management in Mono Basin: Grant Lake Reservoir (GLR) operations, Lee Vining Conduit diversions, water exports through the East Portal into the Owens Basin, and instream flow requirements for Rush, Parker, Walker, and Lee Vining creeks. LADWP also submits an annual Operations Plan to the SWRCB at the start of each runoff year.

The foundation of hydrologic analyses is the daily average annual hydrograph measured at specific locations within Mono Basin over many runoff years. Primary gaging locations are:

- Rush Creek Runoff (estimated unimpaired);
- Rush Creek at Damsite (LADWP station 5013);
- Rush Creek below the MGORD (LADWP station 5007);
- Rush Creek below the Narrows (estimated unimpaired and computed [additive] flow);
- Walker Creek above (LADWP station 5016) and below (LADWP station 5002) the Lee Vining Conduit;
- Parker Creek above (LADWP station 5017) and below (LADWP station 5003) the Lee Vining Conduit;
- Lee Vining Creek Runoff (estimated unimpaired);
- Lee Vining Creek above Intake (LADWP station 5008);
- Lee Vining Creek Spill at Intake (LADWP station 5009).

With exception of the estimated unimpaired data (described below), the daily average discharge data for these gaging sites are collected and published by LADWP, and can be found online at http://www.ladwp.com/ladwp/aqueduct. At some gaging locations the 15-minute streamflow data have also been acquired from LADWP for analysis.

Most analyses in this Synthesis Report used the 19-year period of record from RY1990 to RY2008 in which daily average flow data were available for all LADWP Mono Basin gaging stations. Analyses such as the flood frequency curves and annual yield summaries use the period of record back to RY1941 when LADWP began exporting.

The “estimated unimpaired” data are not measured streamflows, but are computed by estimating the inflow to SCE reservoirs from daily reservoir storage change, and then adding this inflow to the measured flow at the downstream LADWP gaging station. For Rush Creek, SCE reservoirs include Waugh, Gem, and Agnew lakes; the downstream station is the Rush Creek at Damsite gage (reported as 5013). For Lee Vining Creek, SCE reservoirs include Saddleback, Ellery, and Tioga lakes; the downstream gaging station is Lee Vining above Intake (reported as 5008). The estimated unimpaired flow is thus computed by summing the daily average streamflow captured in storage reservoirs and streamflow not captured, i.e., measured at the downstream gaging station. Estimated unimpaired data and annual hydrographs are referred to as “Rush Creek Runoff” and “Lee Vining Creek Runoff”, and represent unimpaired flows at the downstream measurement station if SCE reservoirs and operations did not exist.

Archived records for daily reservoir storage change from SCE are not published prior to 1990, but unimpaired flows were computed for May 1 through August 31 for RY1941 to RY1994 by Hasencamp (1994). The analyses updated the unimpaired data using the published SCE reservoir storage changes for RY1990 to RY2008. Only the RY1990 to RY2008 data are presented in this Appendix. There can be considerable error in converting daily storage change in acre-feet (af) to a discharge inflow rate (in cubic feet per second, or cfs) particularly for low baseflows. However, this conversion works reasonably well for estimating unimpaired streamflows for the spring snowmelt hydrograph, including the annual maximum daily flood peak during the snowmelt runoff, the timing and duration of snowmelt peaks, and the snowmelt recession period (discussed below).

An alternative modeling approach was estimating unimpaired annual hydrographs for Rush Creek from USGS streamflow records measured in a nearby watershed – Buckeye Creek near Bridgeport – and scaling up to Rush Creek based on the ratio of annual water yields. Thus each modeled unimpaired runoff year from Buckeye Creek had the identical annual yield as the Rush Creek estimated unimpaired annual hydrograph. The modeled unimpaired data had slightly lower annual snowmelt peaks compared to the estimated unimpaired, but were a good representation of annual runoff, peak timing, and especially baseflows.

In this Appendix, the following data are presented:

A-1: Annual Hydrographs

- Annual hydrographs for Rush Creek Runoff (estimated unimpaired) and Rush Creek at Damsite (measured) daily average flows, for RY1990 to RY2008;
- Annual hydrographs for Rush Creek Runoff (estimated unimpaired) and Buckeye Creek (modeled unimpaired), for RY1990 to RY2008;
- Annual hydrographs for Parker and Walker creeks above Intake (measured unimpaired) daily average flows, for RY1990 to RY2008;
- Annual hydrographs for Lee Vining Creek Runoff (estimated unimpaired) and Lee Vining Creek above Intake (measured) daily average flows, for RY1990 to RY2008;
- Annual hydrographs for Rush Creek below Narrows Actual and Rush Creek Recommended SEF below Narrows with spills simulated for RY1990 to RY2008;
- Annual hydrographs for Lee Vining Creek above Intake and Lee Vining Creek SEF simulated for RY1990 to RY2008;

A-2: Composite Hydrographs (aka "Spaghetti Graphs") for RY1990 to RY2008

- Rush Creek Unimpaired;
- Rush Creek at Damsite;
- Rush Creek below Narrows Unimpaired;
- Rush Creek below Narrows simulating full GLR;
- Rush Creek below Narrows actual (additive) flow;
- Lee Vining Creek estimated unimpaired;
- Lee Vining Creek above Intake;
- Lee Vining Creek "spill" at Intake;
- Rush Creek SEF (Stream Ecosystem Flow) Recommendations;
- Lee Vining Creeks SEF (Stream Ecosystem Flow) Recommendations.

A-3: Hydrograph Component Analysis

The hydrograph component analysis presented in this Appendix includes summary tables of hydrograph components for Rush and Lee Vining creek estimated unimpaired streamflows. The hydrograph component analysis was reported in RY2003 Annual Report (M&T 2004) and updated through RY2008 for this Appendix. RY2003 Annual Report explains the analytical steps used to develop the summary information.

Charts of peak timing are presented for Rush Creek estimated unimpaired and at Damsite, and for Parker Creek.

A-4: Flood Frequency Analysis

A flood frequency analysis was presented in the RY2003 Annual Report (M&T 2004) for the available period of record and was updated through RY2008. This Appendix presents:

- Summary tables of annual peak discharge (daily average flow) for Rush Creek and Lee Vining Creek;
- Summary table of flood recurrences for Rush Creek and Lee Vining Creek;
- Flood frequency curves for Rush Creek estimated unimpaired and Rush Creek at Damsite, and for Rush Creek estimated unimpaired and actual below the Narrows;
- Flood frequency curves for Lee Vining Creek estimated unimpaired and Lee Vining Creek above Intake;

A-5: Summary Information

- Mono Basin and Tributary annual yields for RY1941 to RY2008;
- Mono Basin April 1 forecast vs. actual runoff;
- Rush Creek synoptic measurements of longitudinal flow gains and losses;

A-6: Ramping rate analysis and memorandum presented in RY2002

A-7: Literature Cited

LADWP. 1996. Grant Lake Operations and Management Plan: Mono Basin. Report prepared by Los Angeles Department of Water and Power. Prepared for the State Water Resources Control Board in response to Mono Lake Water Right Decision 1631. February 1996.

Hasencamp, B. 1994. Lower Rush Creek Flow Analysis. Los Angeles Department of Water and Power. 11 p.

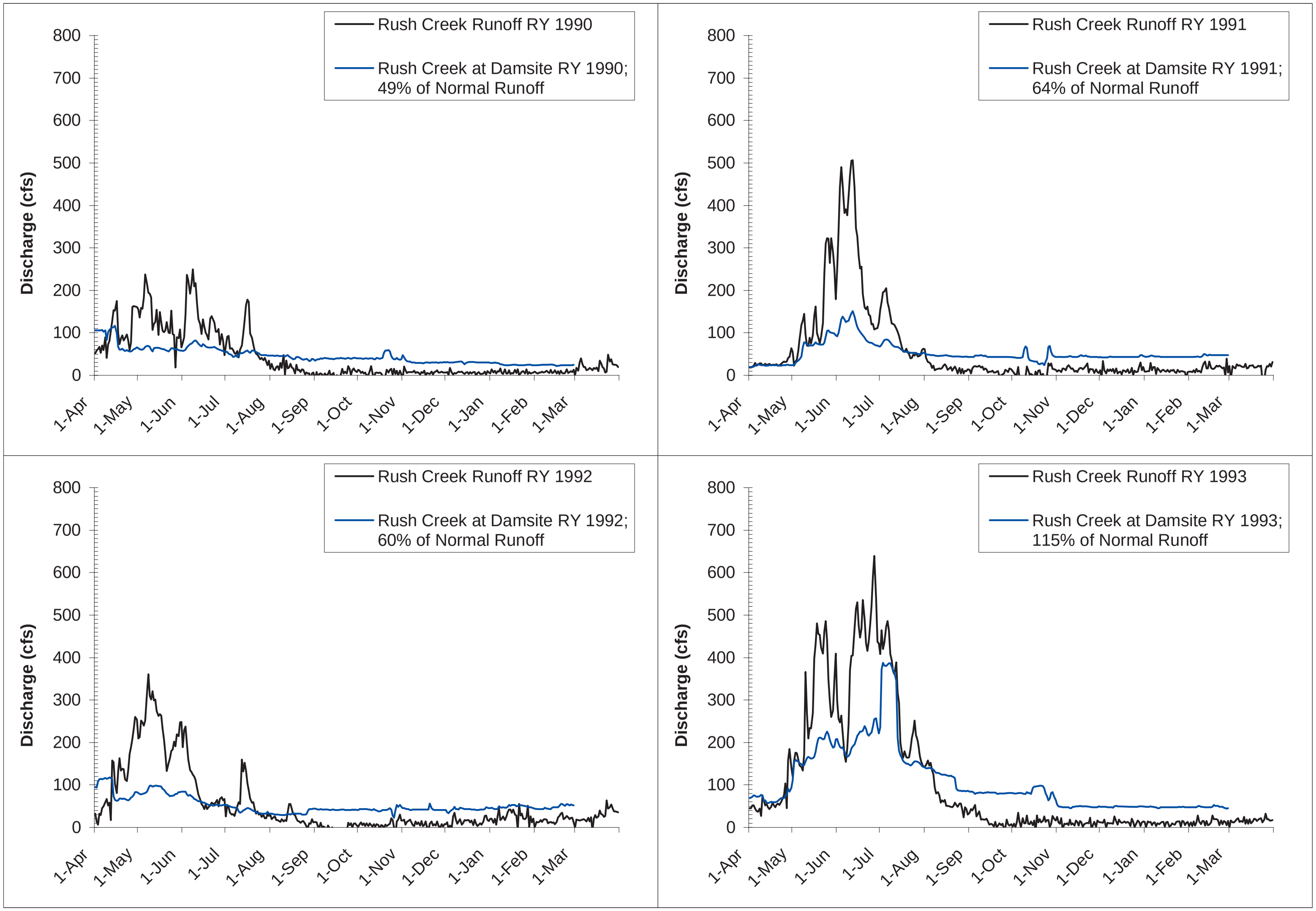
Jones and Stokes, Inc. 1993. Draft environmental impact report for the review of the Mono Basin Water Rights of the City of Los Angeles, Volumes 1 and 2 and Appendices, Los Angeles Department of Water and Power, Sacramento, CA.

McBain & Trush, Inc. 2004. Runoff Year 2003 Annual Report. Prepared for the Los Angeles Department of Water and Power, Los Angeles, CA.

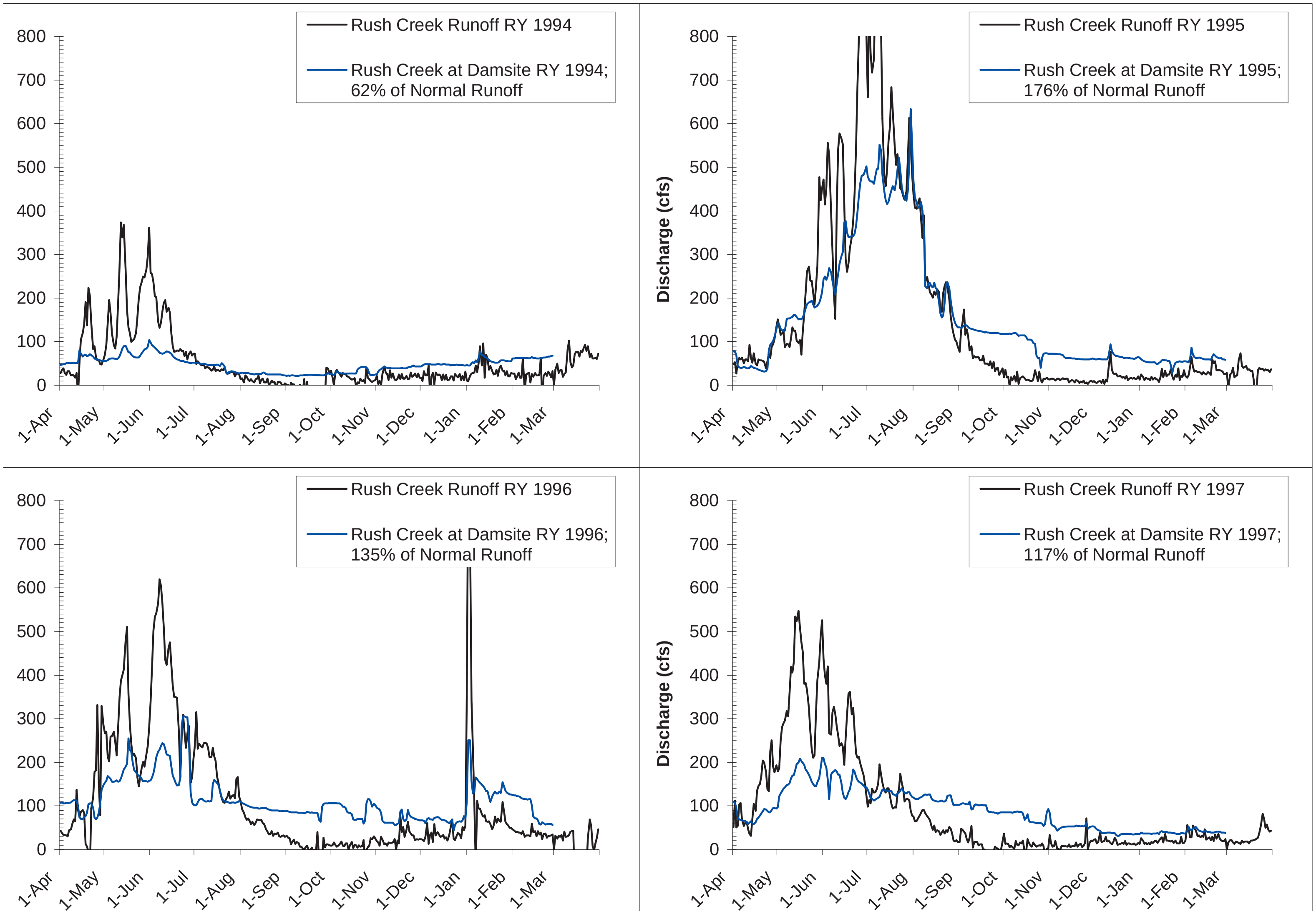
Ridenhour, R.L., C. Hunter, and B. Trush. 1995. Mono Basin Stream Restoration Work Plan. Los Angeles Department of Water and Power.

Vorster, P. 1985. A water balance forecast model for Mono Lake, California. California State University, Hayward. 341 p.

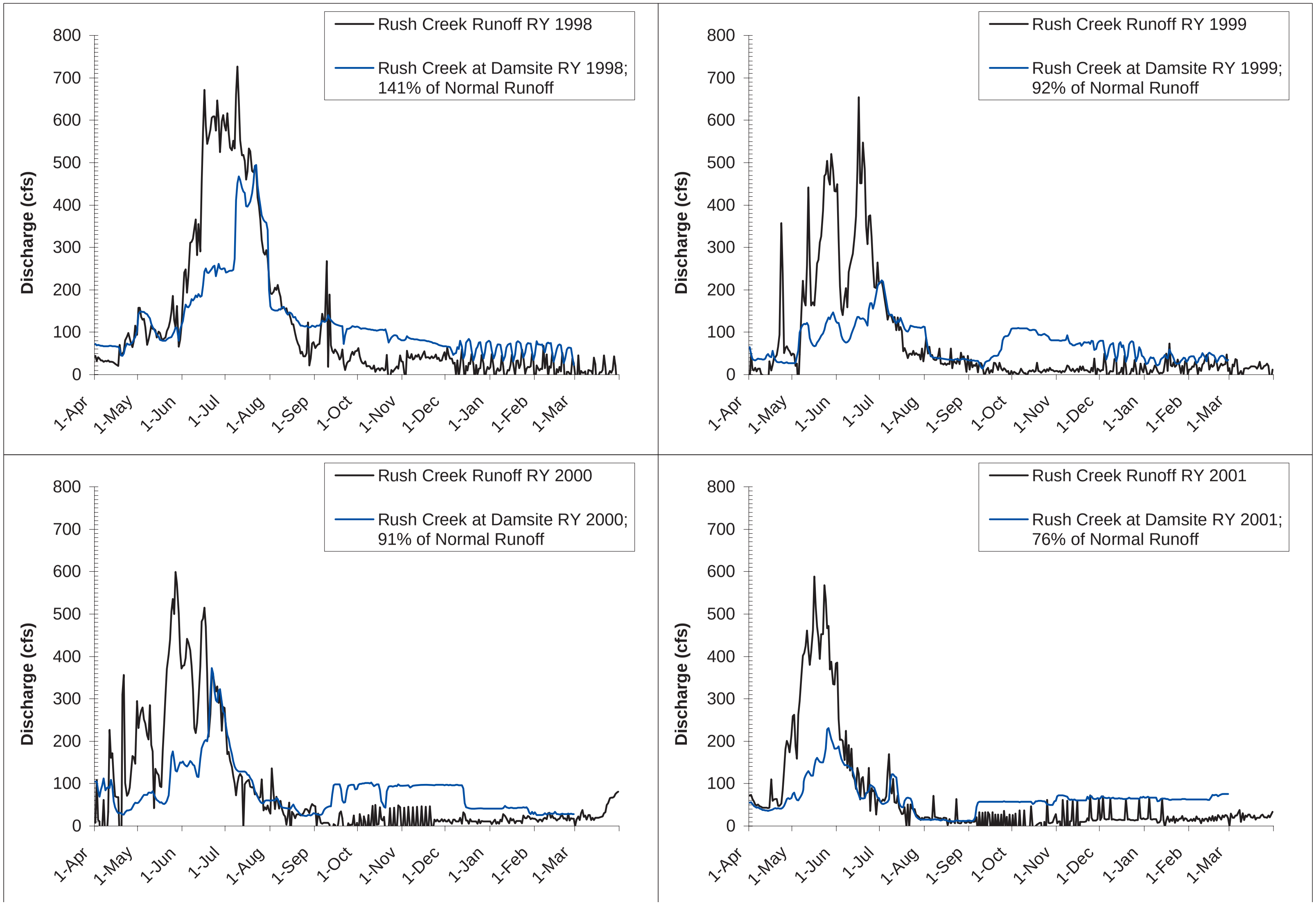
APPENDIX A-1. ANNUAL HYDROGRAPHS



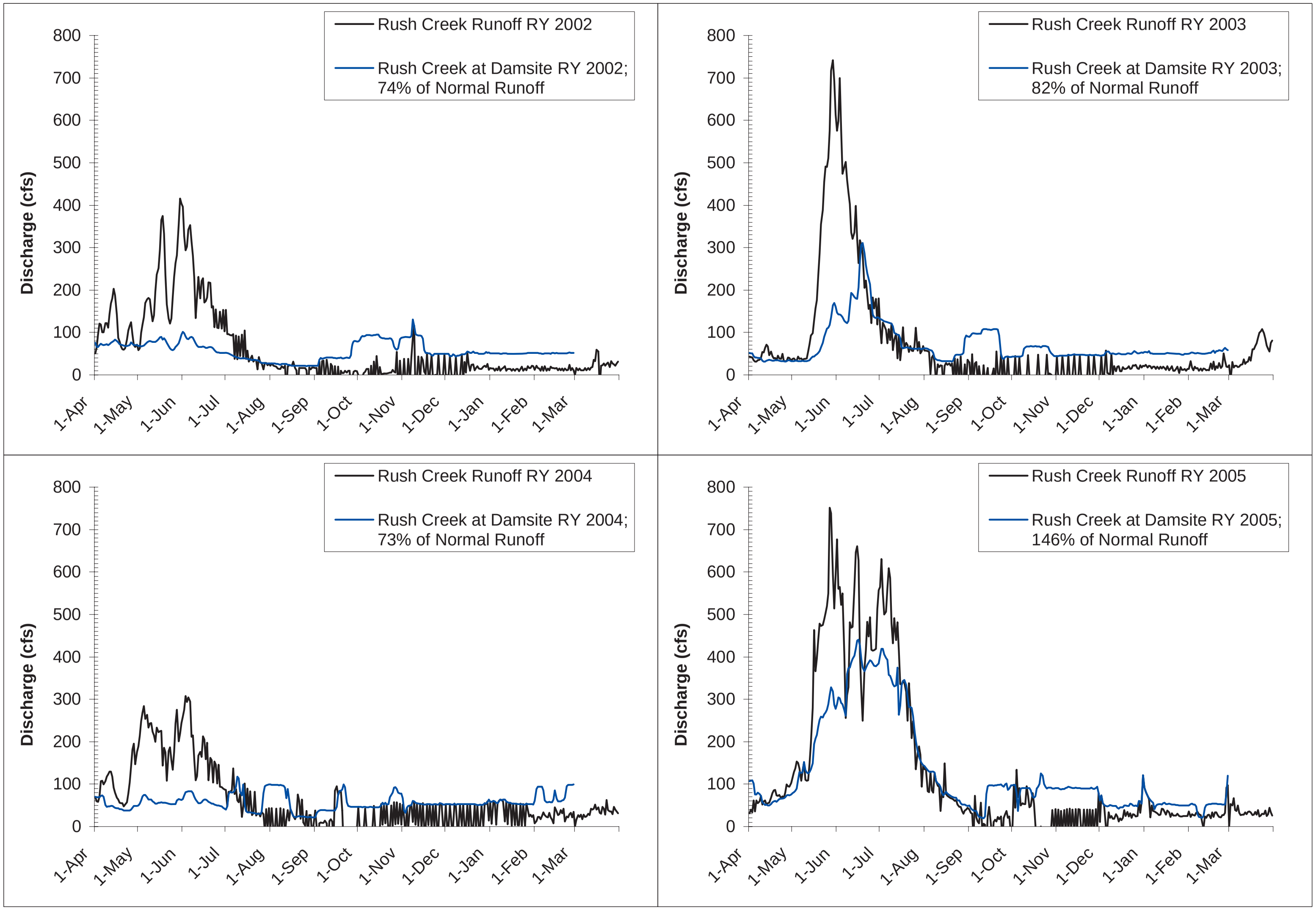
Appendix A-1. Figure 1A. Rush Creek Runoff (estimated unimpaired) and Rush Creek at Damsite (SCE impaired) annual hydrographs for 1990-1993.



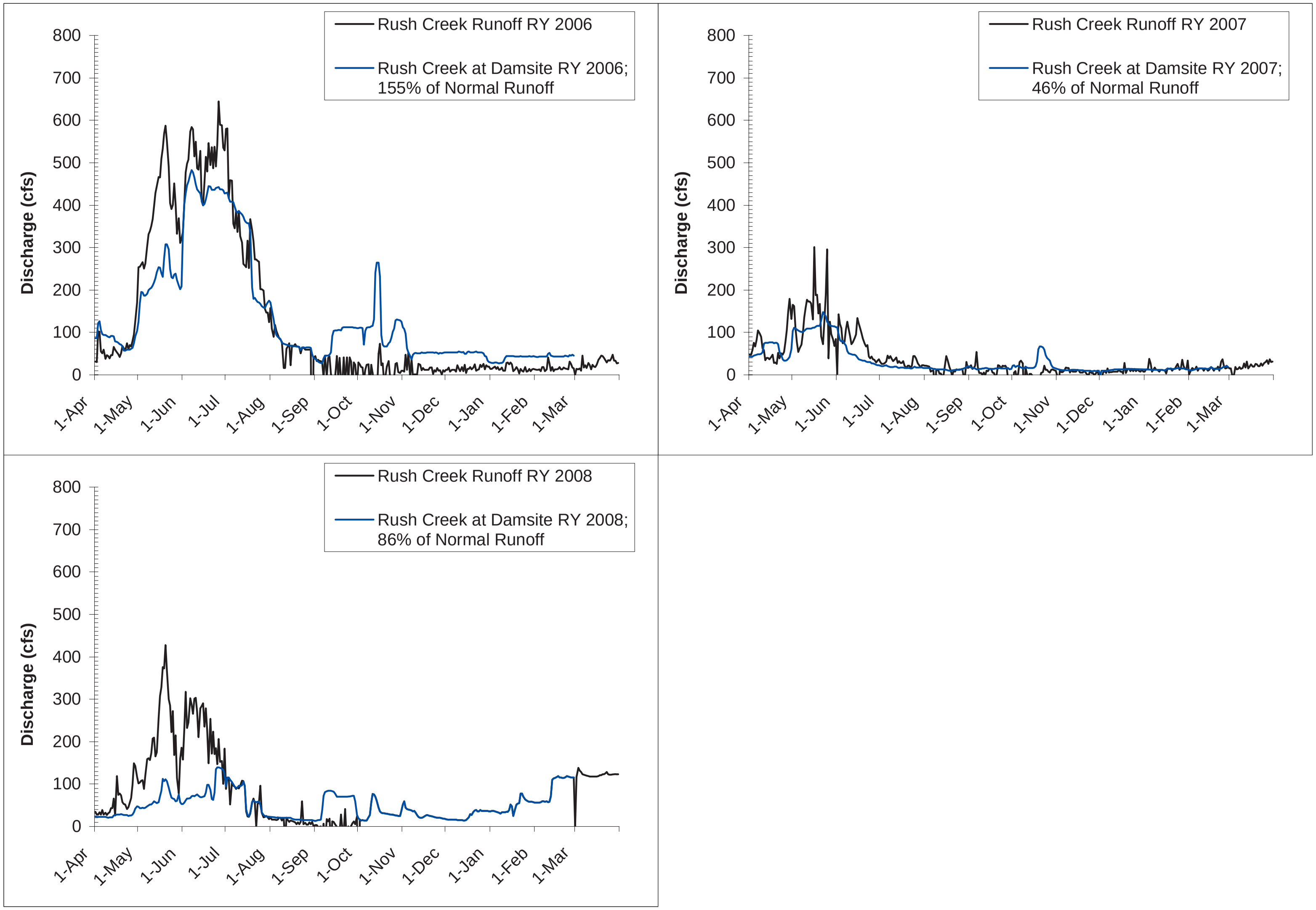
Appendix A-1. Figure 1B. Rush Creek Runoff (estimated unimpaired) and Rush Creek at Damsite (SCE impaired) annual hydrographs for 1994-1997.



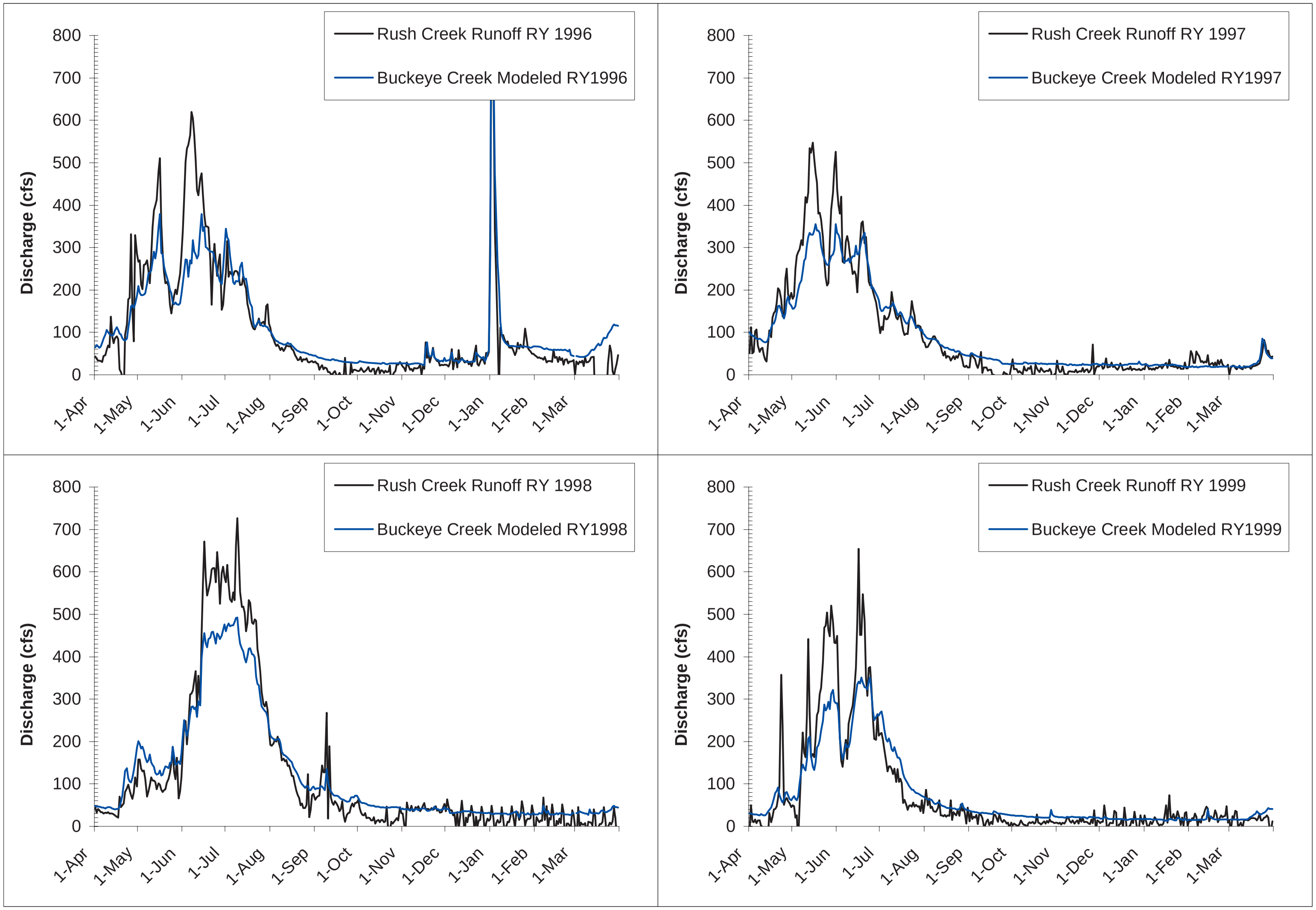
Appendix A-1. Figure 1C. Rush Creek Runoff (estimated unimpaired) and Rush Creek at Damsite (SCE impaired) annual hydrographs for 1998-2001.



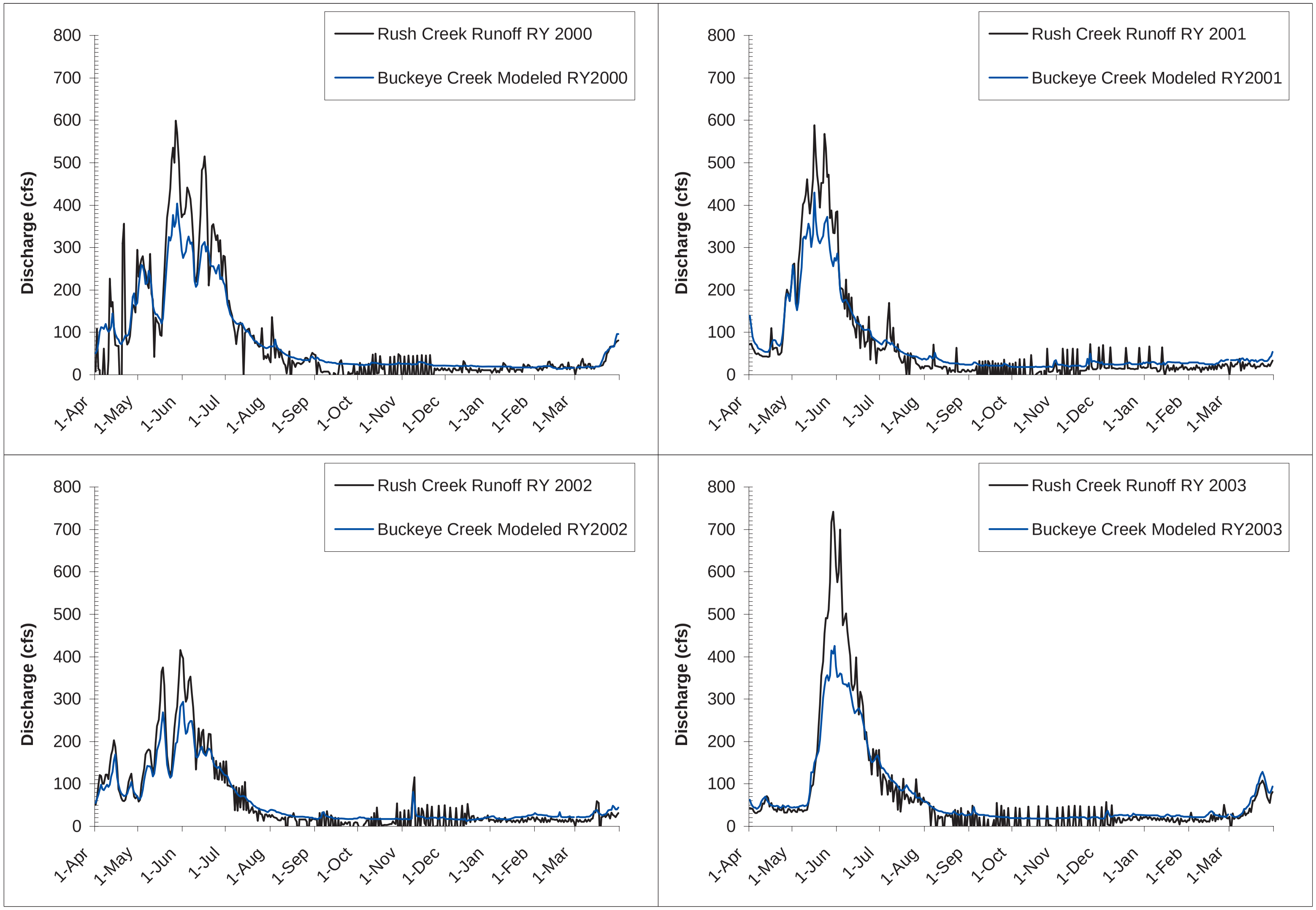
Appendix A-1. Figure 1D. Rush Creek Runoff (estimated unimpaired) and Rush Creek at Damsite (SCE impaired) annual hydrographs for 2002-2005.



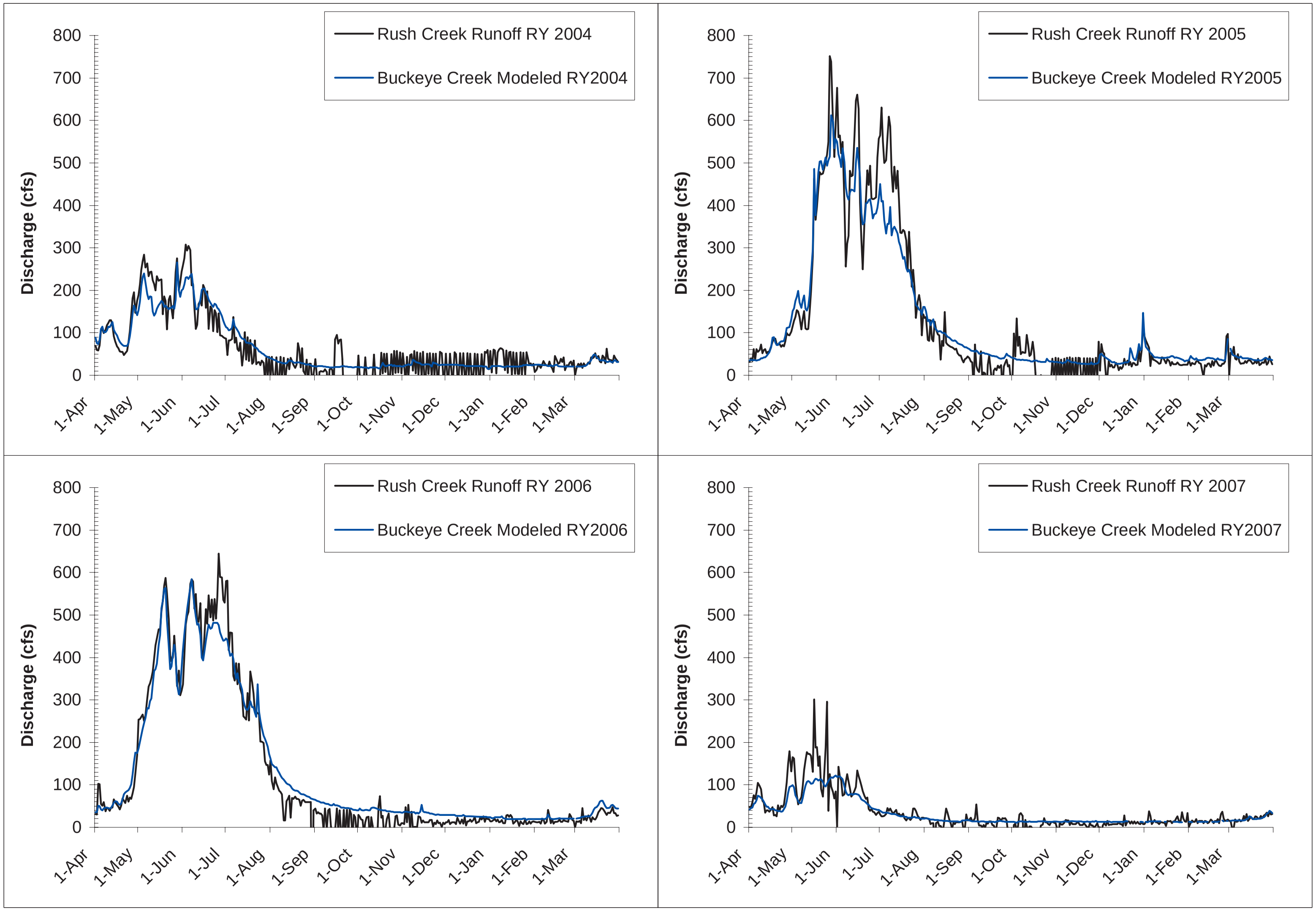
Appendix A-1. Figure 1E. Rush Creek Runoff (estimated unimpaired) and Rush Creek at Damsite (SCE impaired) annual hydrographs for 2006-2008.



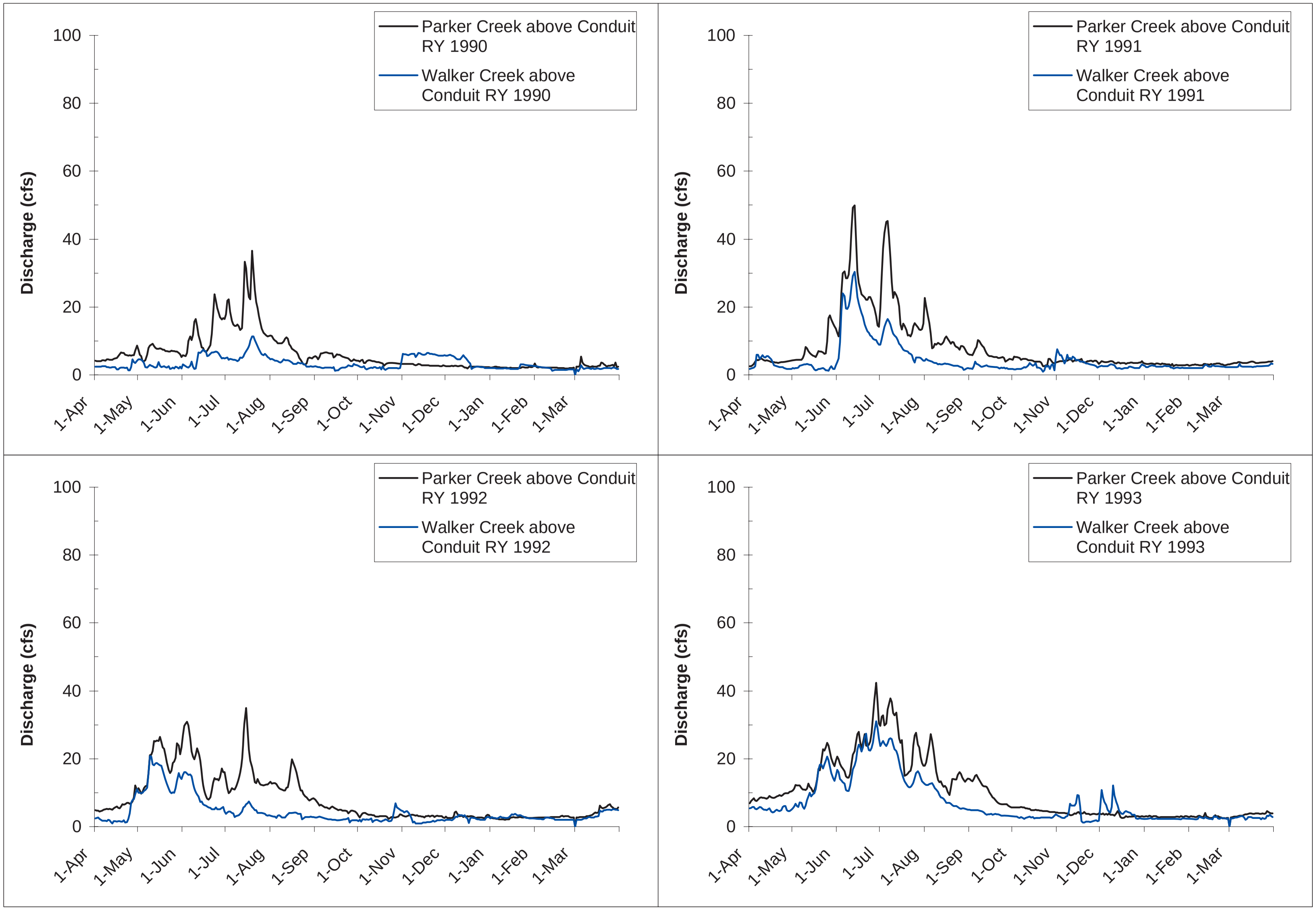
Appendix A-1. Figure 2A. Rush Creek Runoff (estimated unimpaired) and Buckeye Creek (modeled unimpaired) annual hydrographs for 1996-1999.



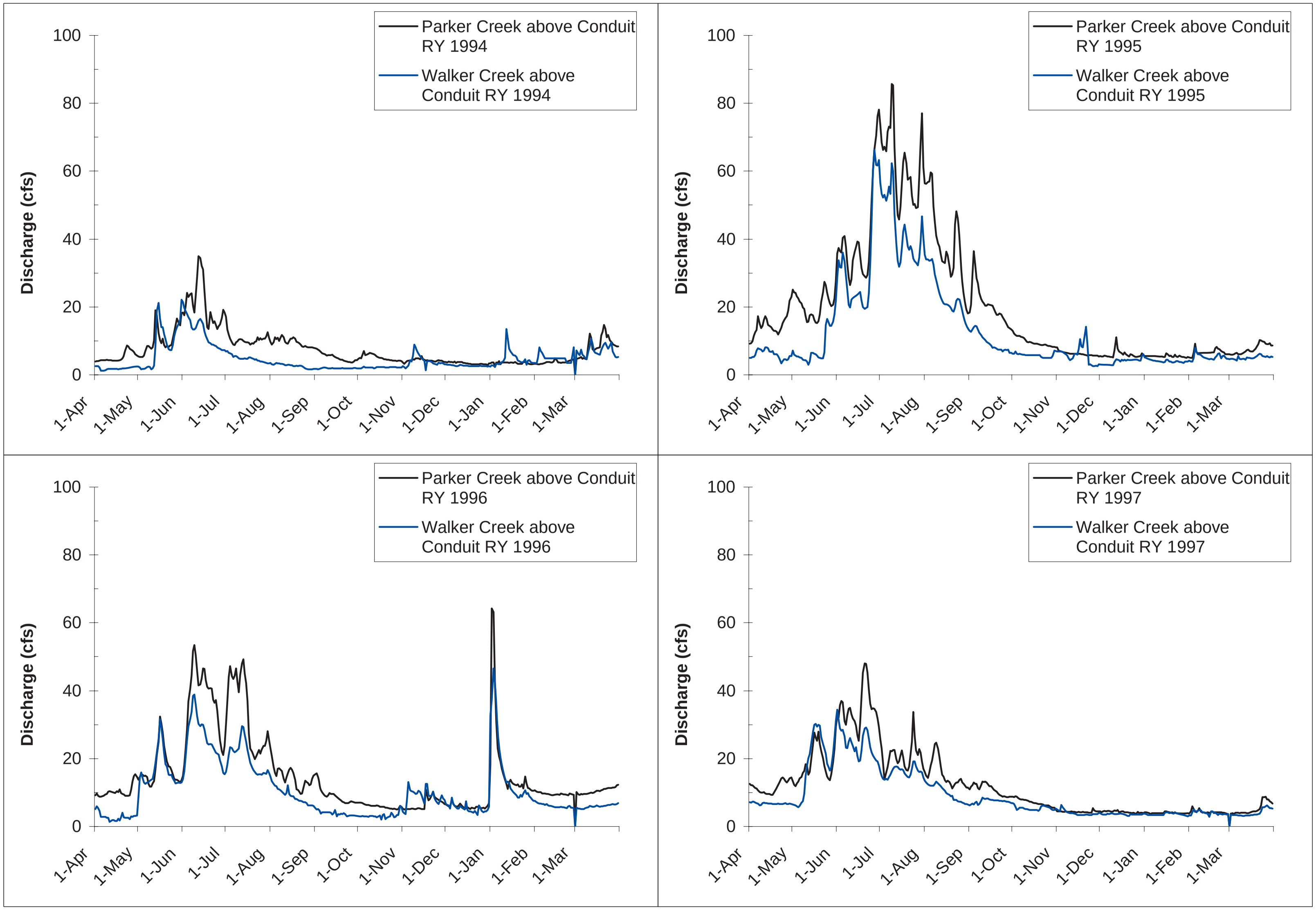
Appendix A-1. Figure 2B. Rush Creek Runoff (estimated unimpaired) and Buckeye Creek (modeled unimpaired) annual hydrographs for 2000-2003.



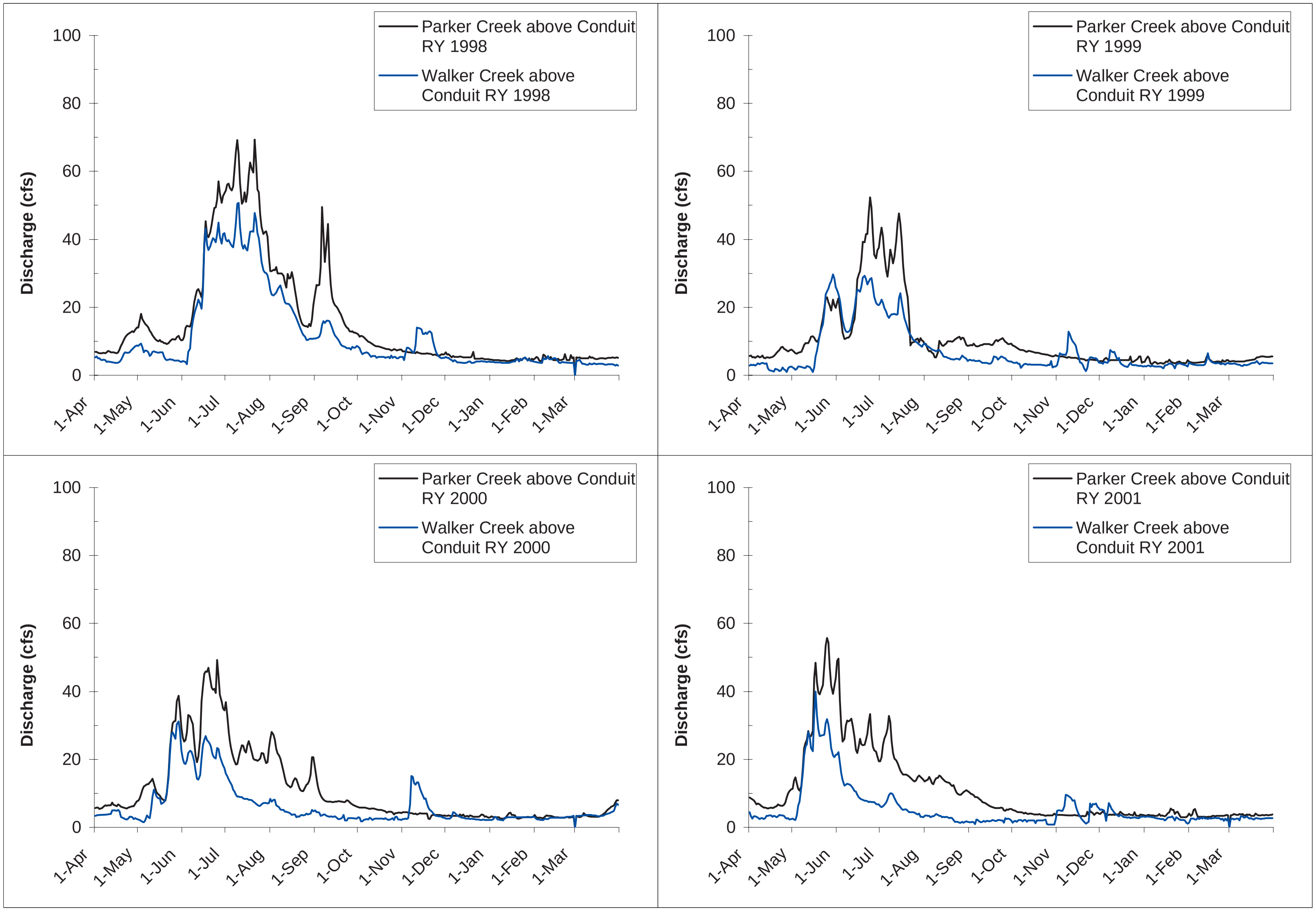
Appendix A-1. Figure 2C. Rush Creek Runoff (estimated unimpaired) and Buckeye Creek (modeled unimpaired) annual hydrographs for 2004-2007.



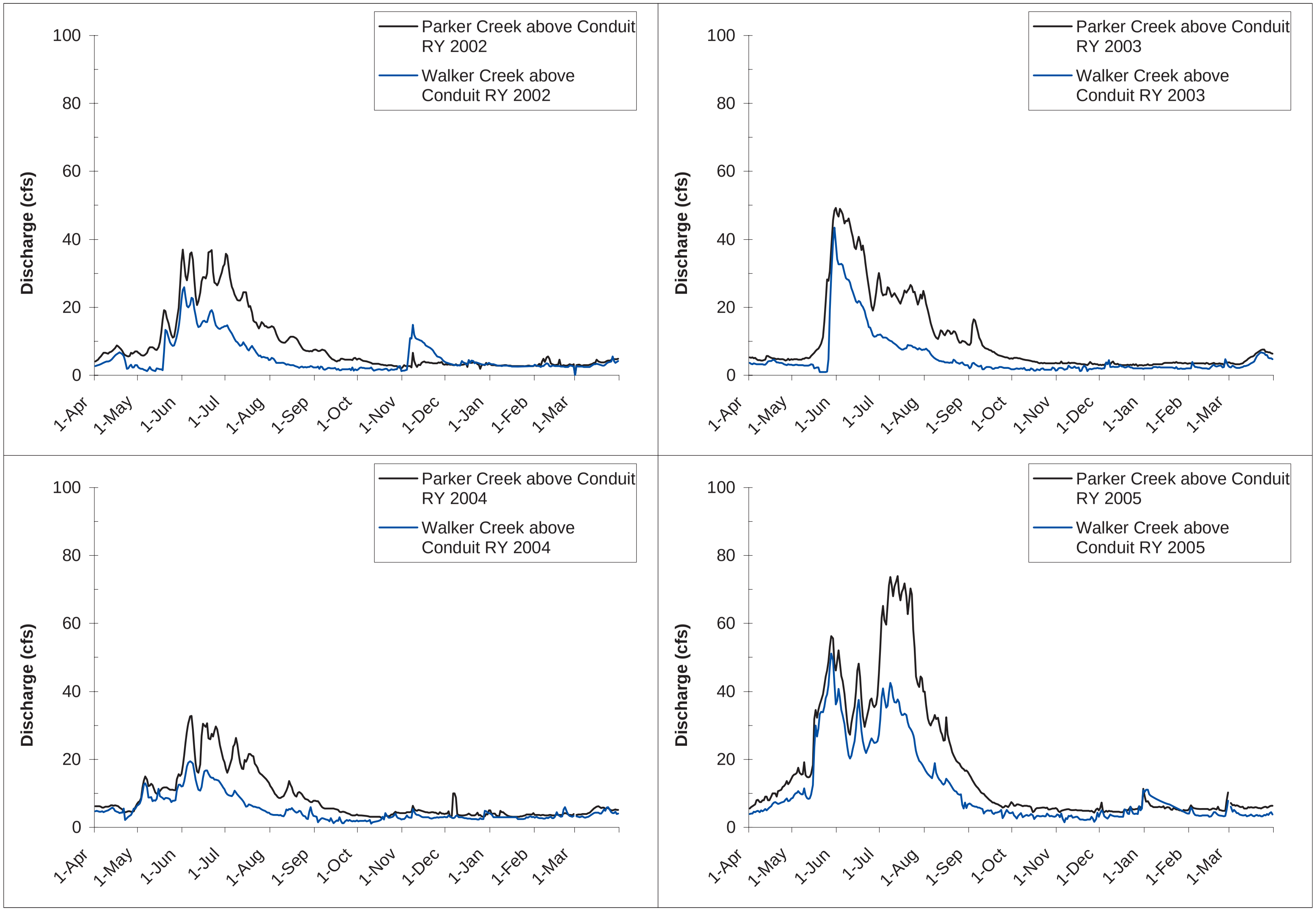
Appendix A-1. Figure 3A. Parker and Walker Creeks above Conduit (unimpaired) annual hydrographs for 1990-1993.



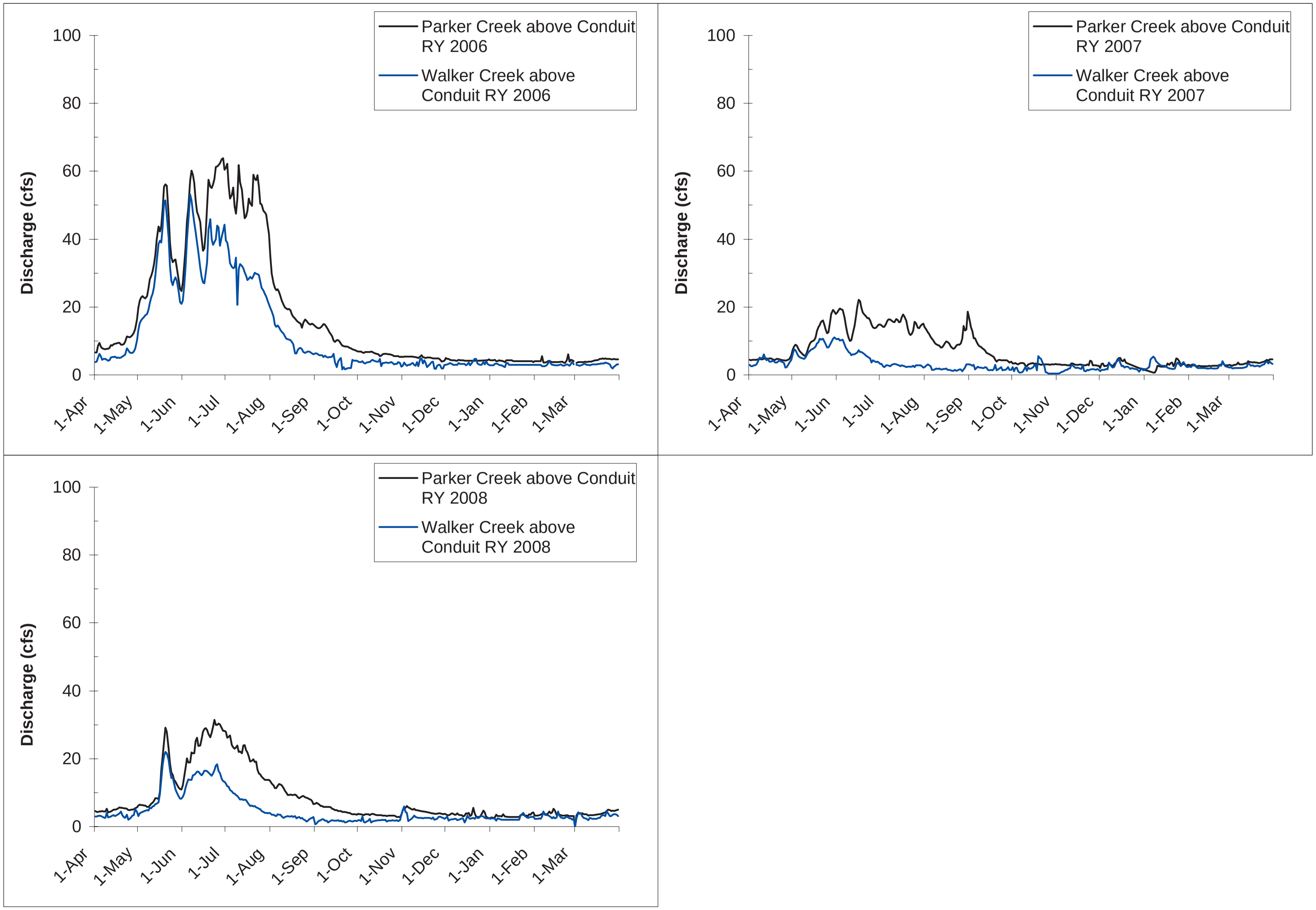
Appendix A-1. Figure 3B. Parker and Walker Creeks above Conduit (unimpaired) annual hydrographs for 1994-1997.



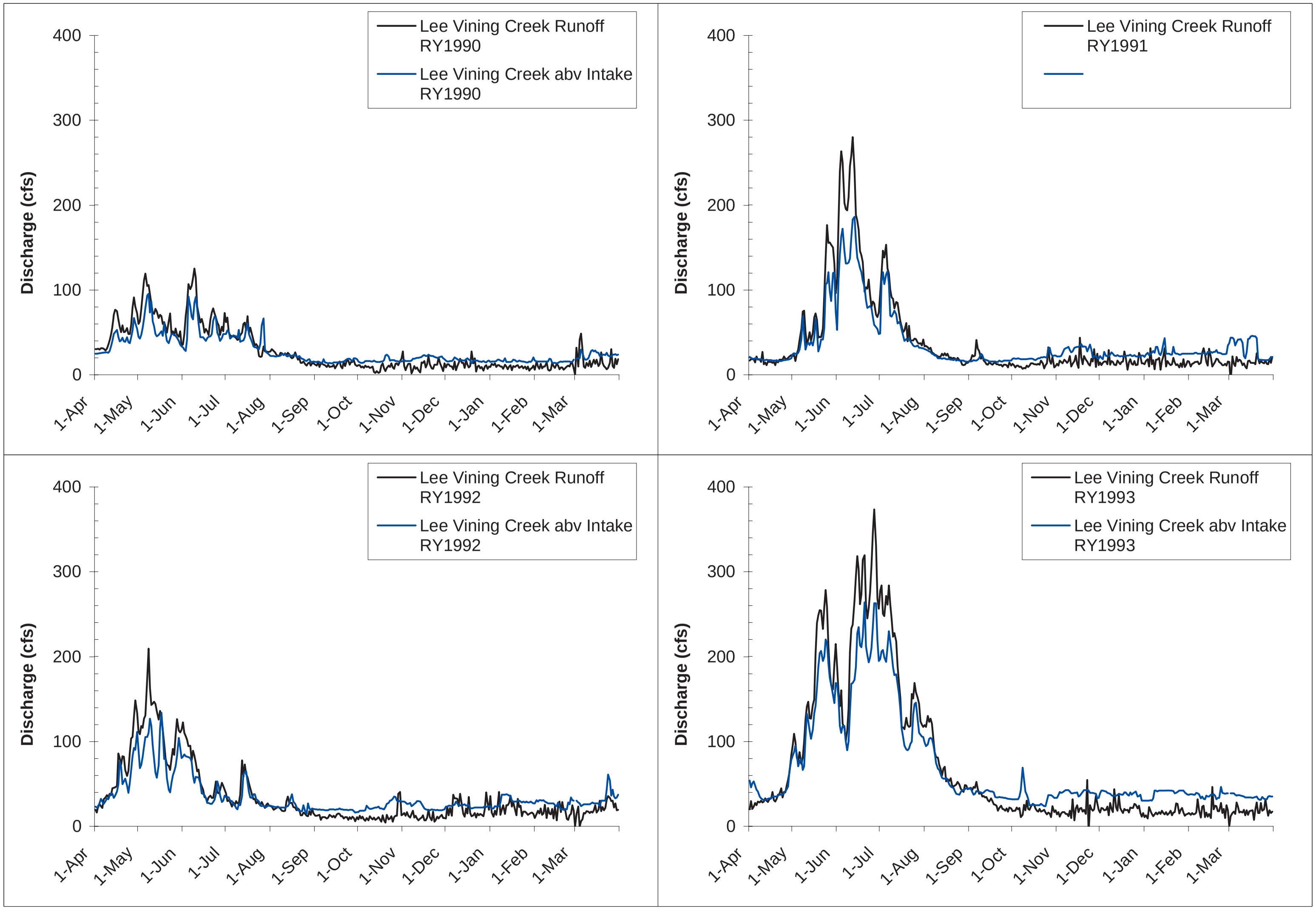
Appendix A-1. Figure 3C. Parker and Walker Creeks above Conduit (unimpaired) annual hydrographs for 1998-2001.



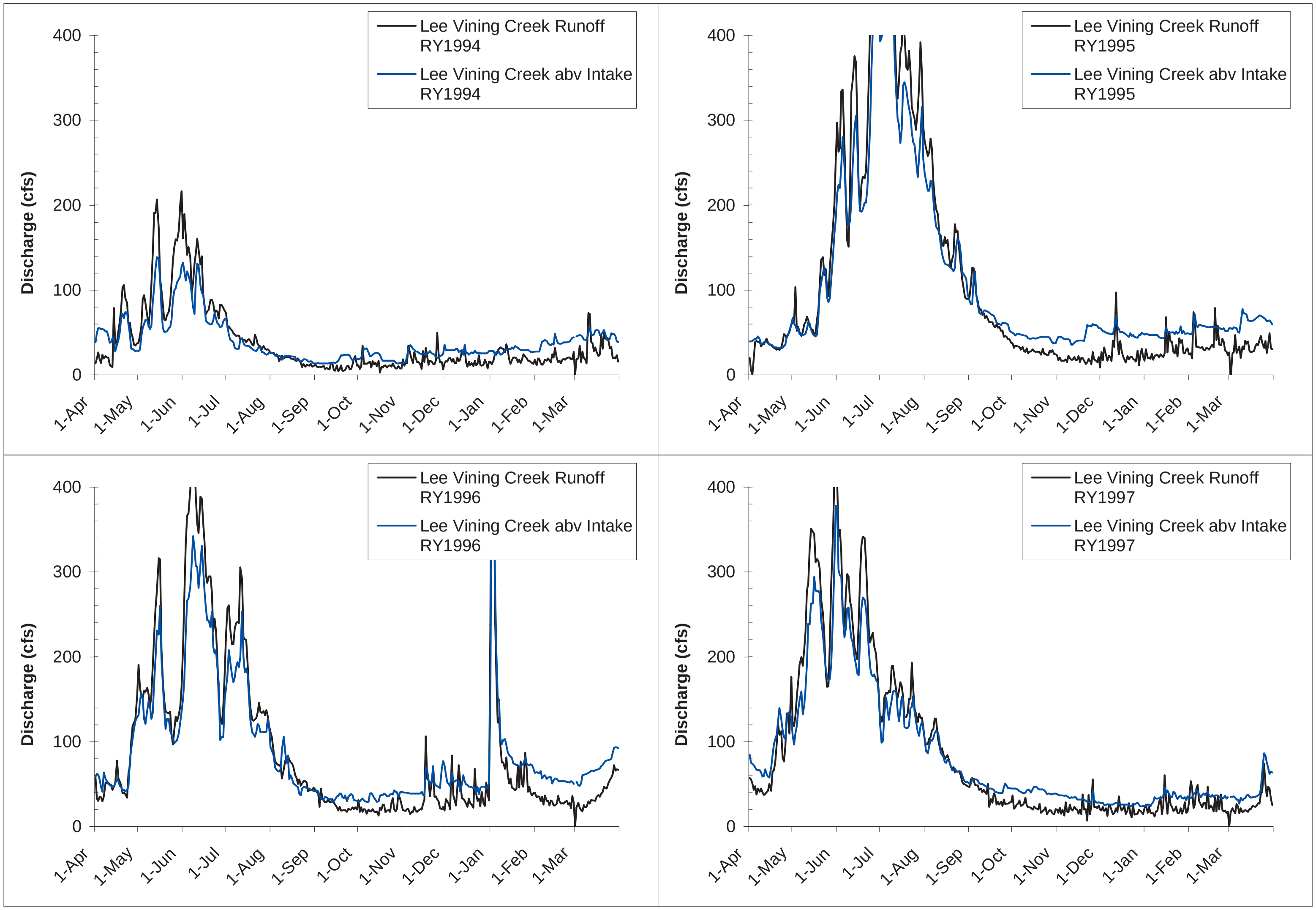
Appendix A-1. Figure 3D. Parker and Walker Creeks above Conduit (unimpaired) annual hydrographs for 2002-2005.



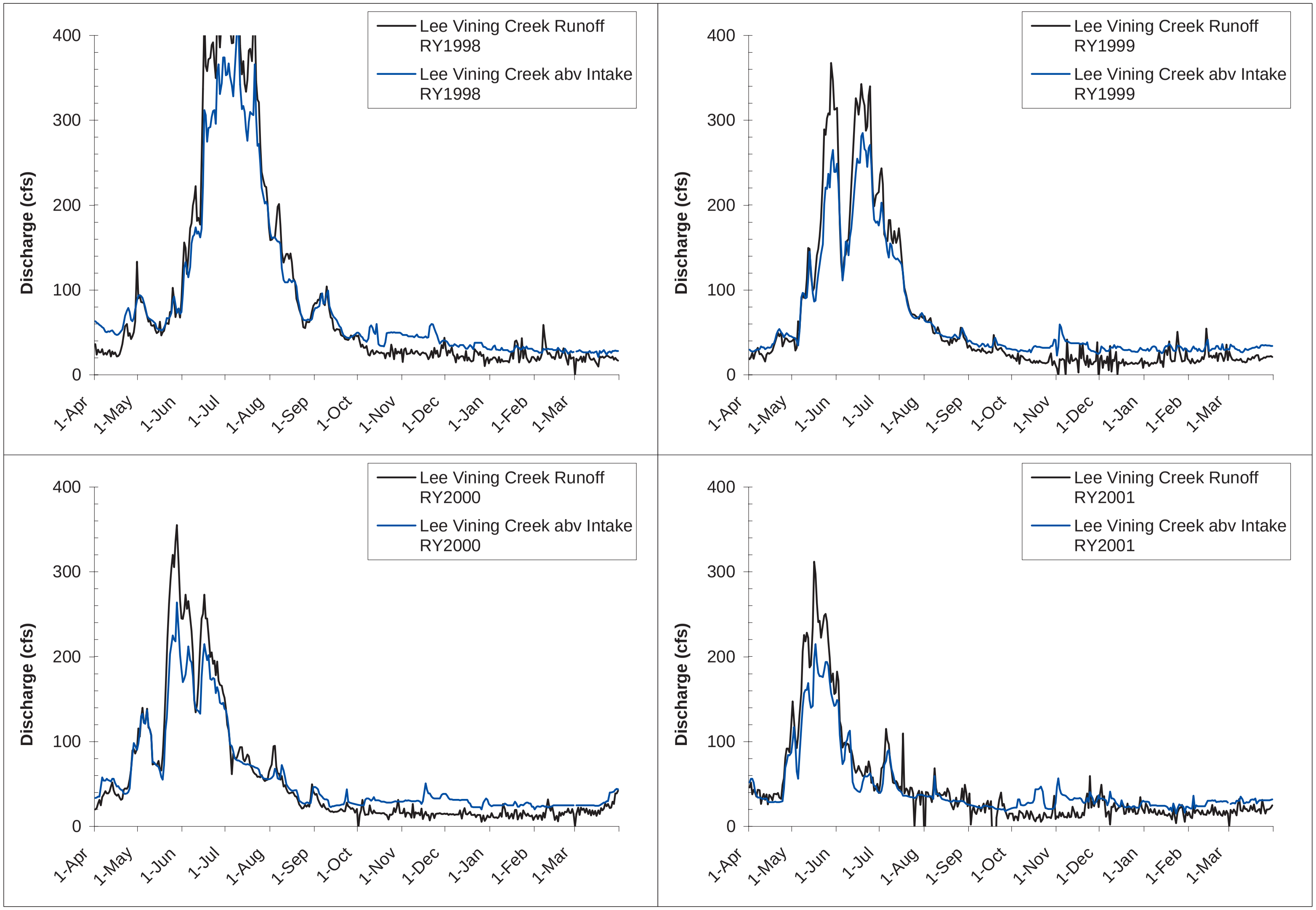
Appendix A-1. Figure 3E. Parker and Walker Creeks above Conduit (unimpaired) annual hydrographs for 2006-2008.



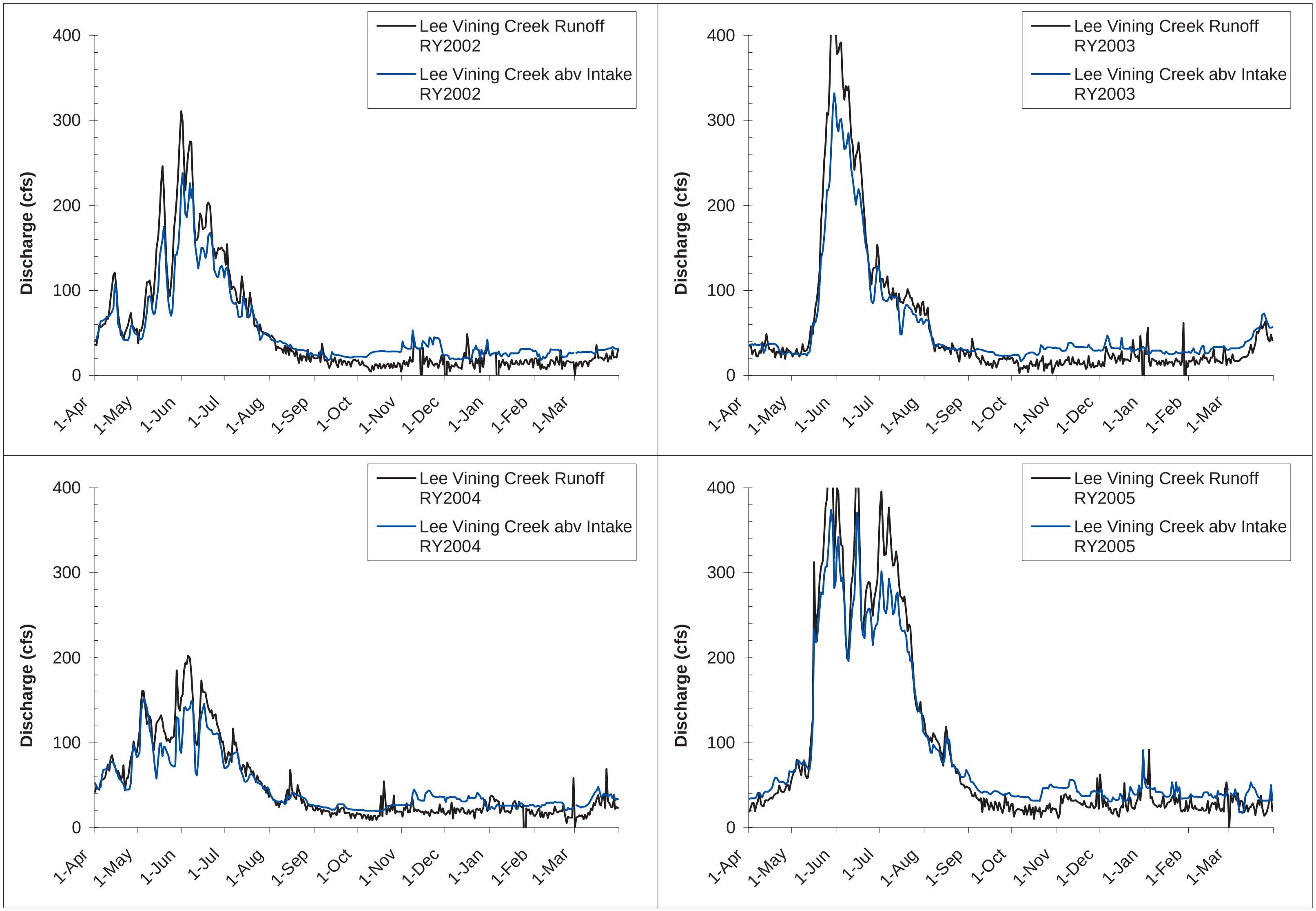
Appendix A-1. Figure 4A. Lee Vining Creek Runoff (estimated unimpaired) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 1990-1993.



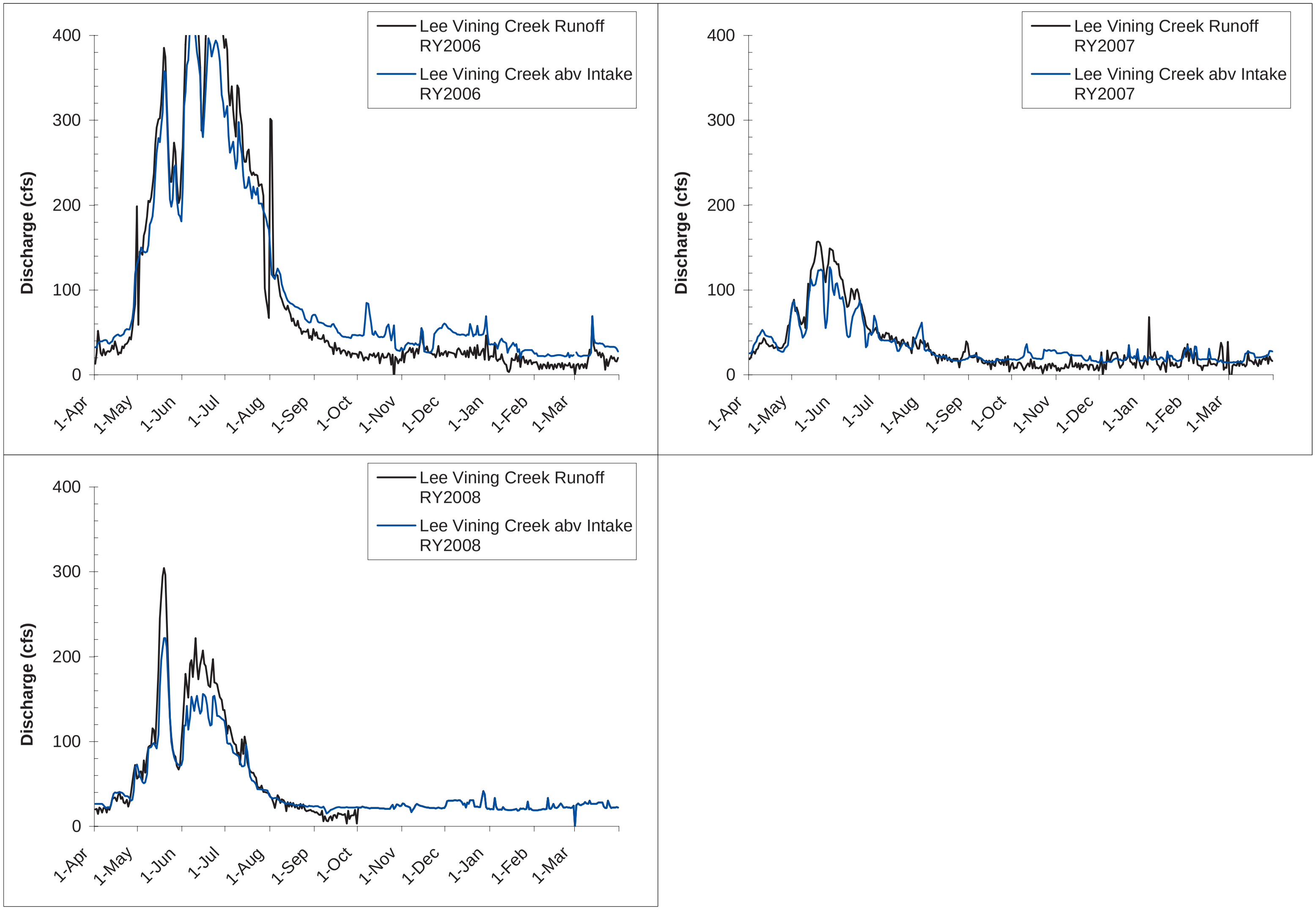
Appendix A-1. Figure 4B. Lee Vining Creek Runoff (estimated unimpaired) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 1994-1997.



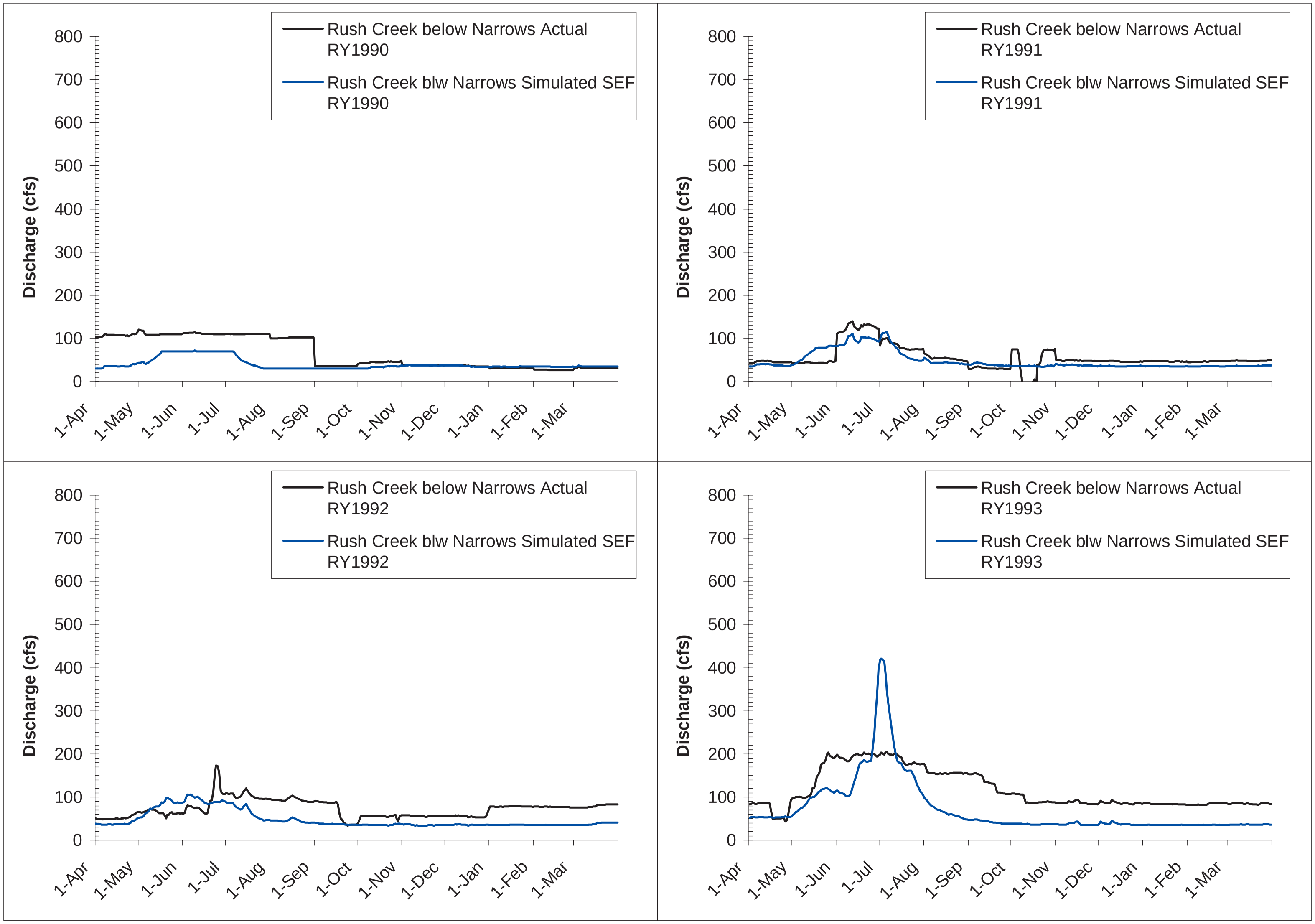
Appendix A-1. Figure 4C. Lee Vining Creek Runoff (estimated unimpaired) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 1998-2001.



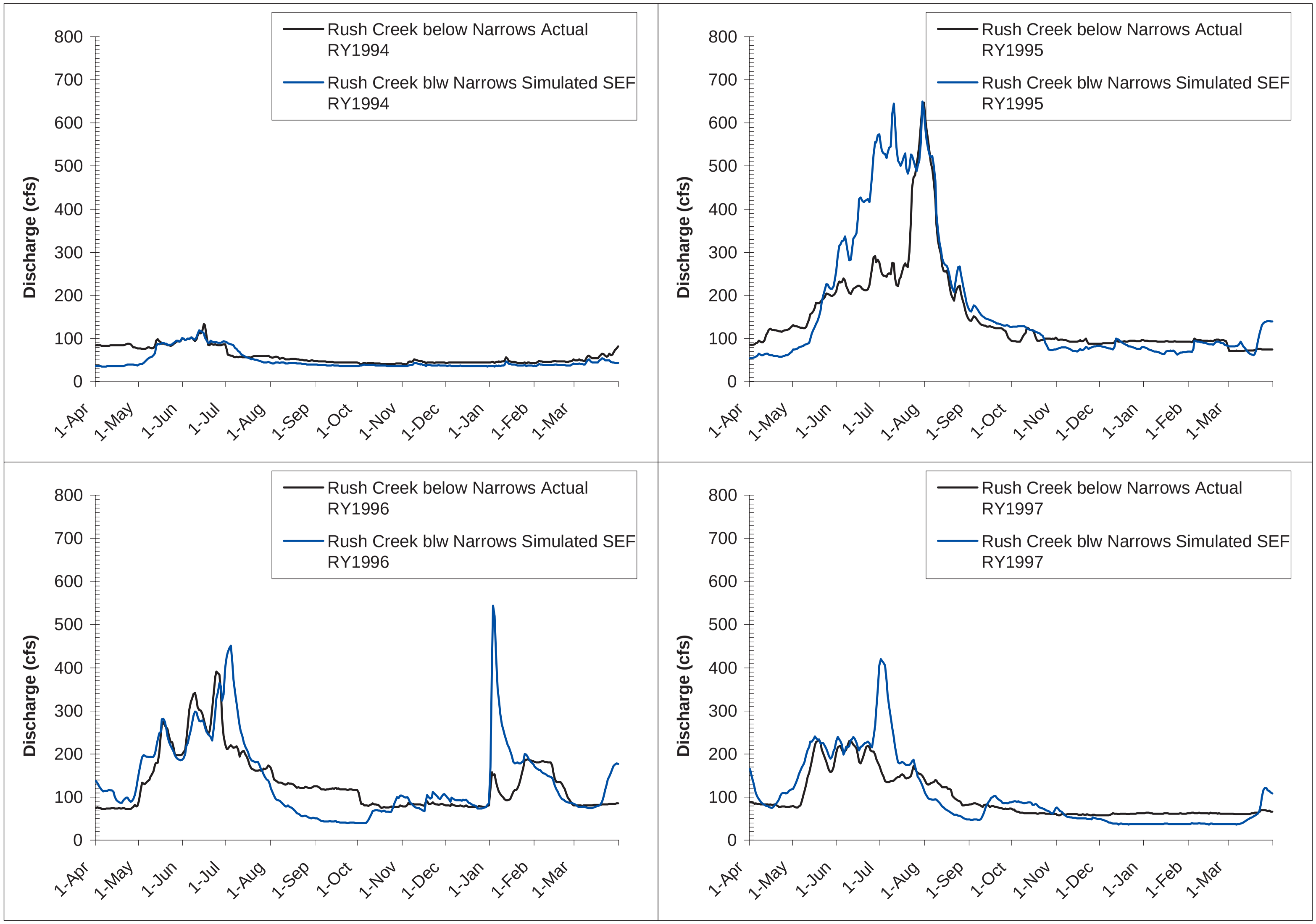
Appendix A-1. Figure 4D. Lee Vining Creek Runoff (estimated unimpaired) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 2002-2005.



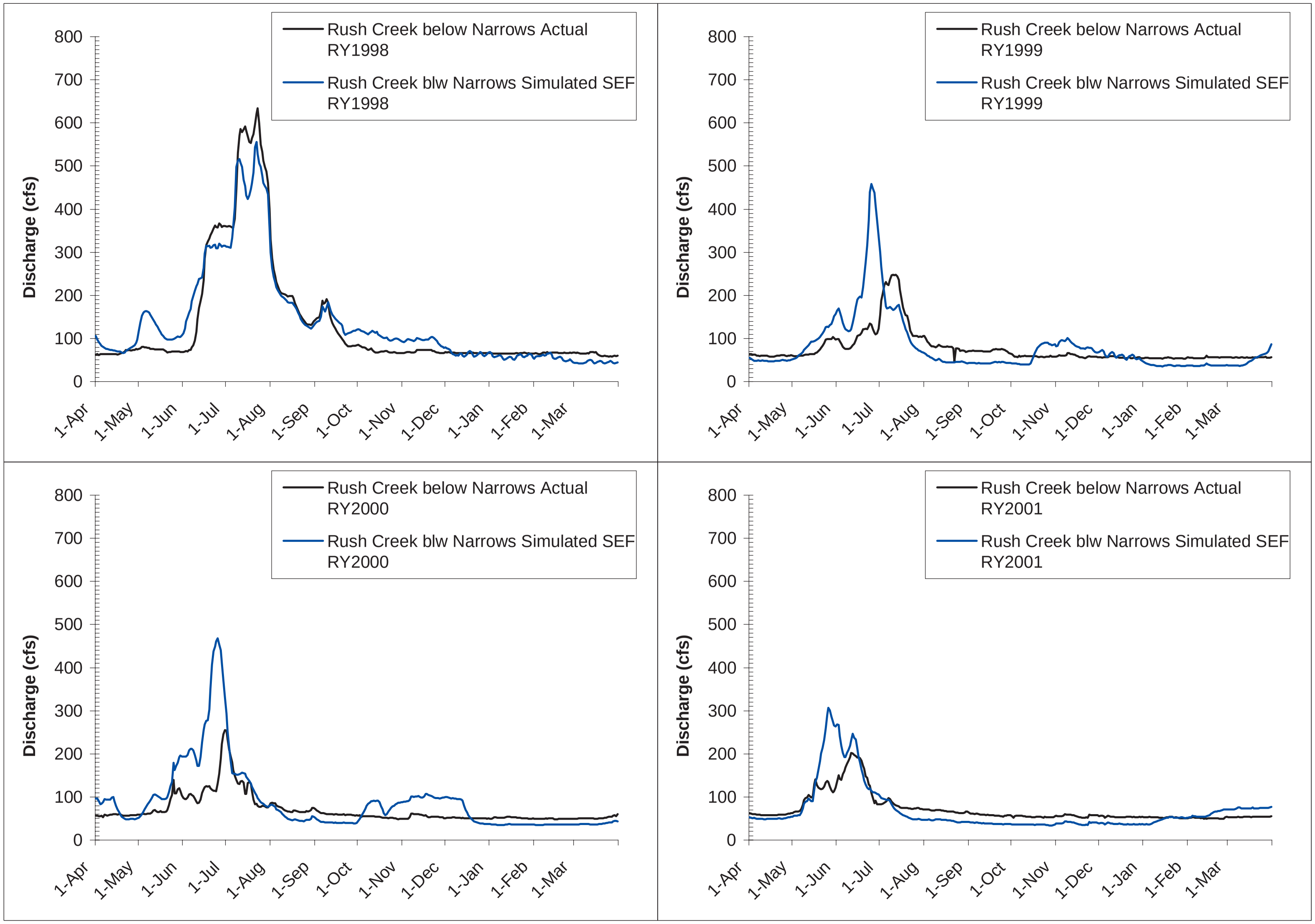
Appendix A-1. Figure 4E. Lee Vining Creek Runoff (estimated unimpaired) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 2006-2008.



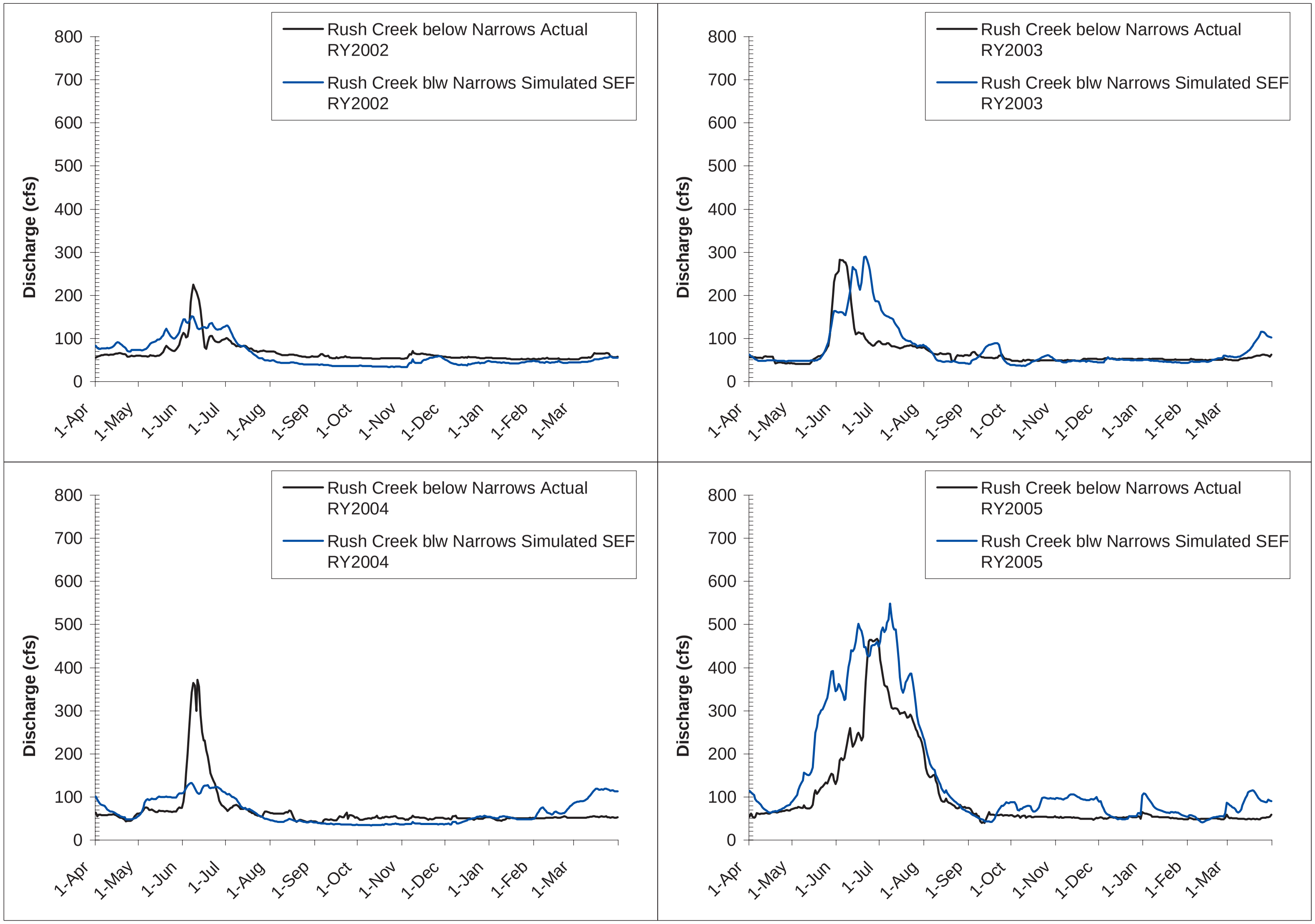
Appendix A-1. Figure 5A. Rush Creek below Narrows (Actual) and Rush Creek below Narrows (Simulated SEF) annual hydrographs for 1990-1993.



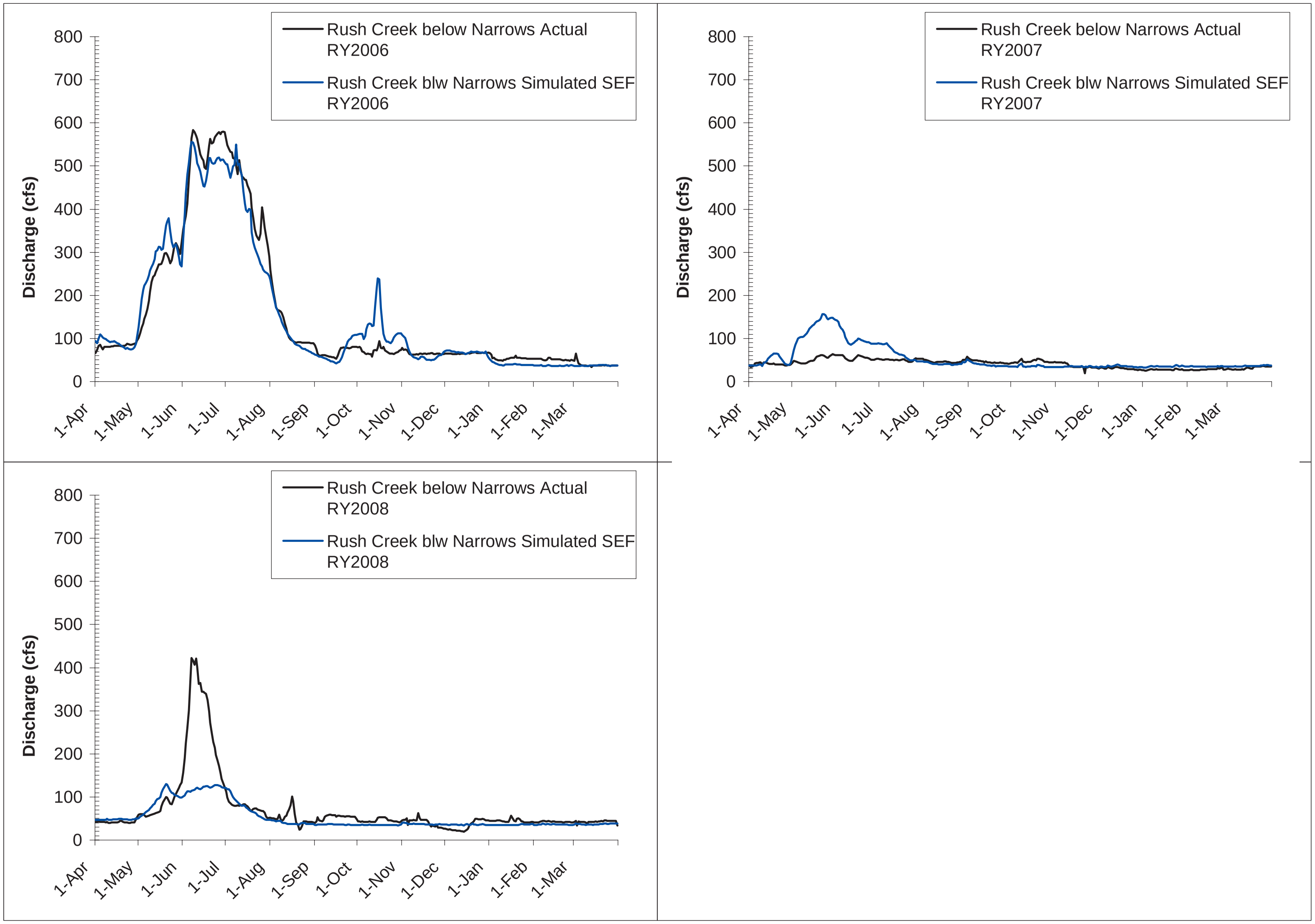
Appendix A-1. Figure 5B. Rush Creek below Narrows (Actual) and Rush Creek below Narrows (Simulated SEF) annual hydrographs for 1994-1997.



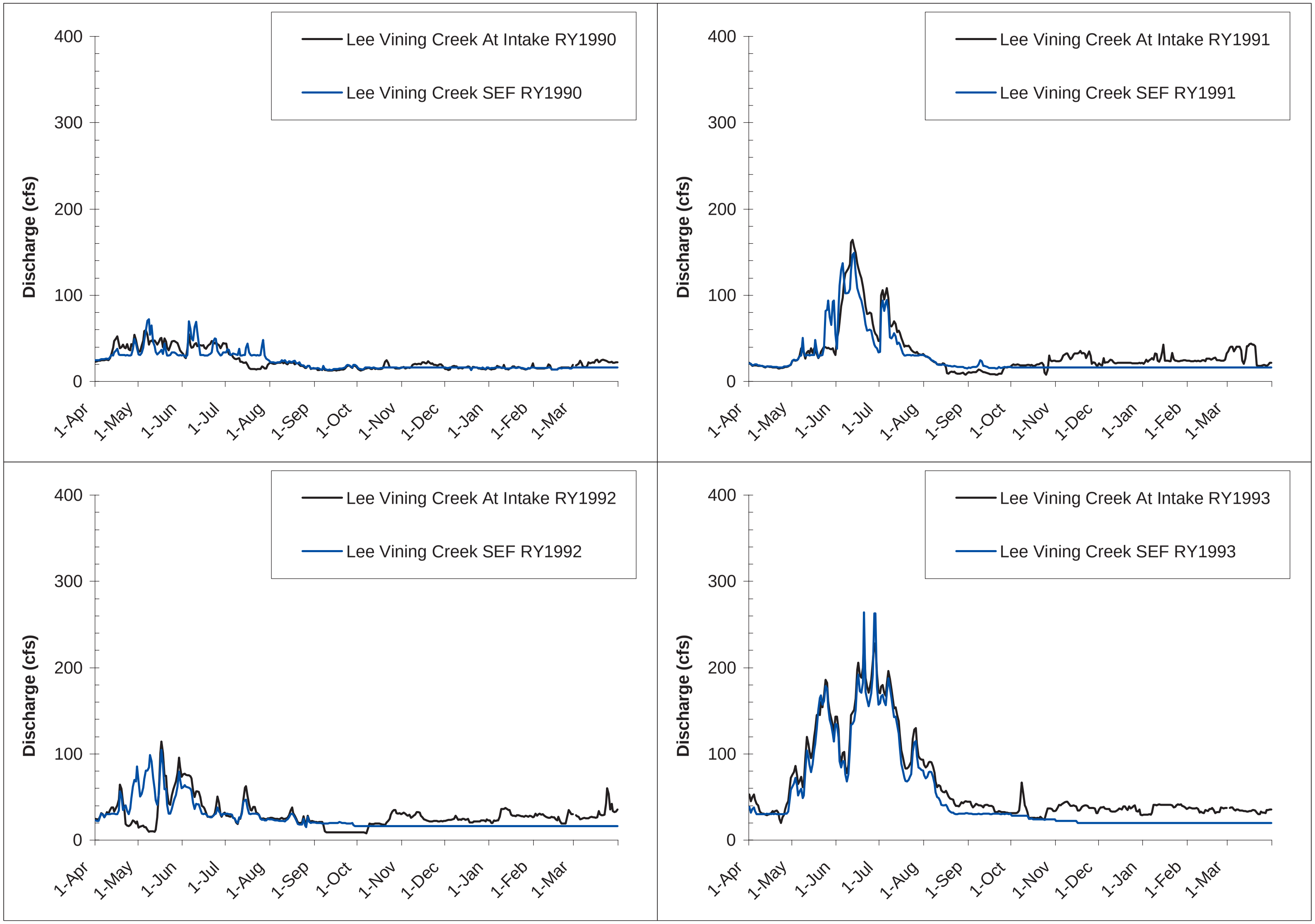
Appendix A-1. Figure 5C. Rush Creek below Narrows (Actual) and Rush Creek below Narrows (Simulated SEF) annual hydrographs for 1998-2001.



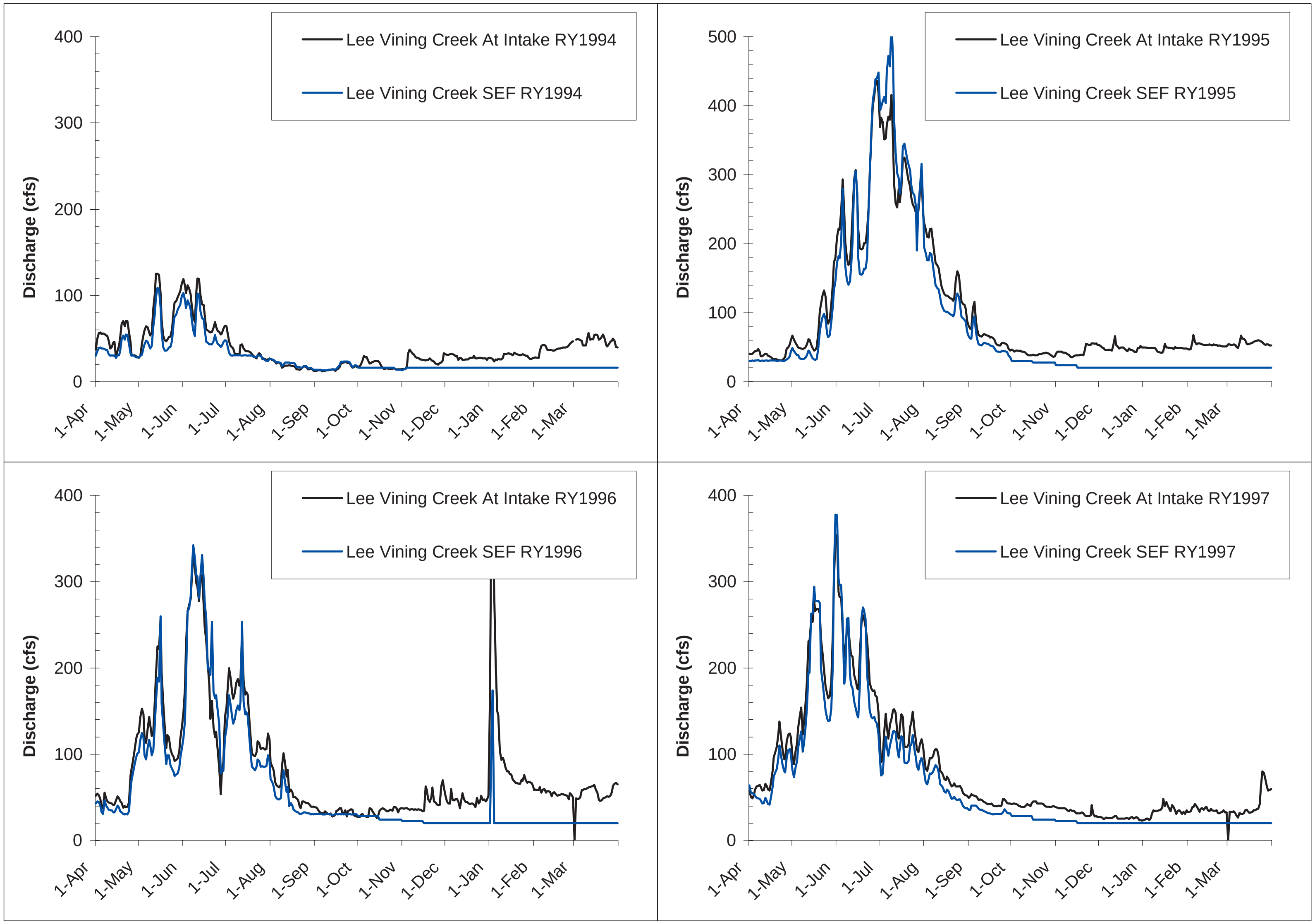
Appendix A-1. Figure 5D. Rush Creek below Narrows (Actual) and Rush Creek below Narrows (Simulated SEF) annual hydrographs for 2002-2005.



Appendix A-1. Figure 5E. Rush Creek below Narrows (Actual) and Rush Creek below Narrows (Simulated SEF) annual hydrographs for 2006-2008.



Appendix A-1. Figure 6A. Lee Vining Creek (SEF) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 1990-1993.



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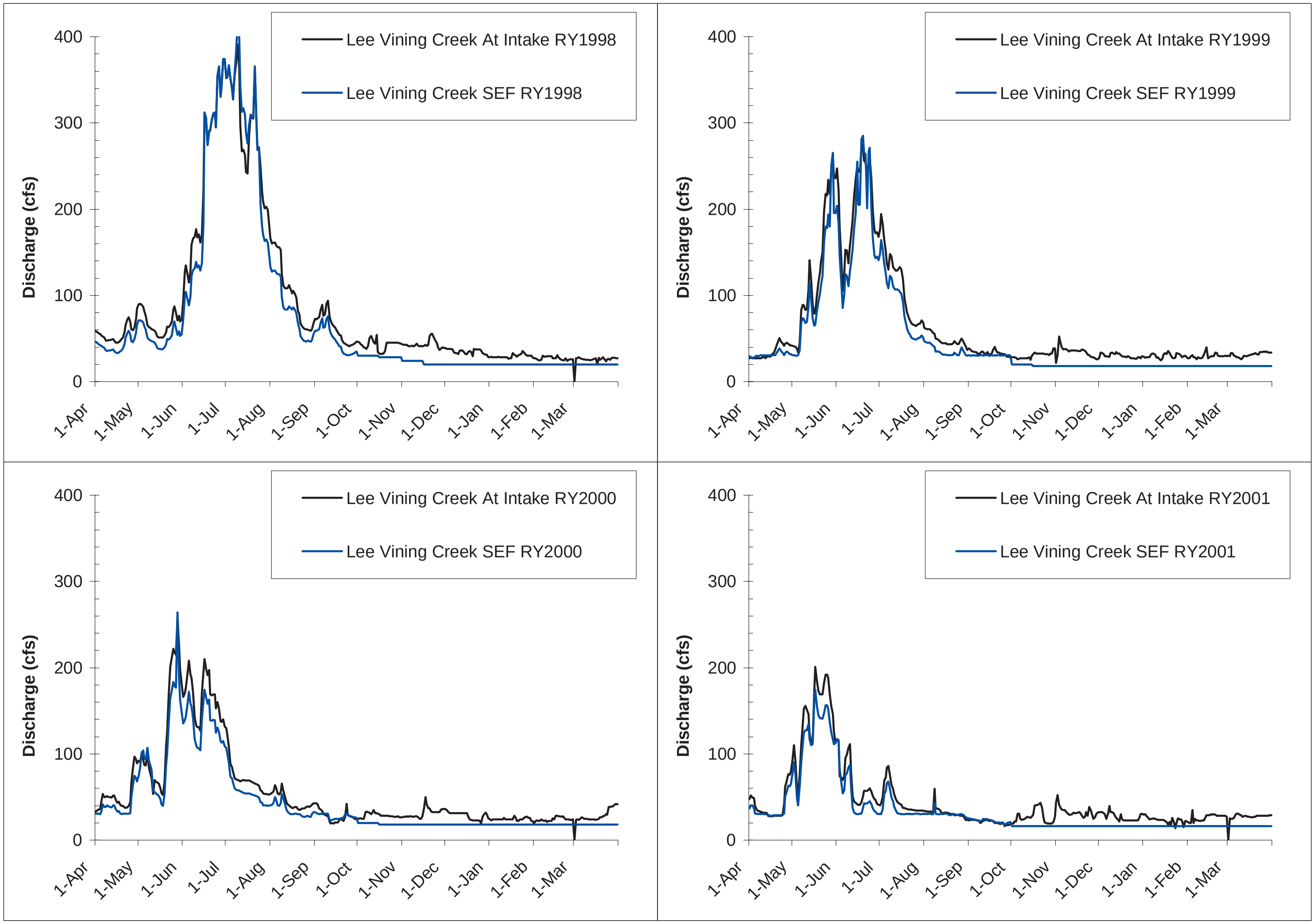
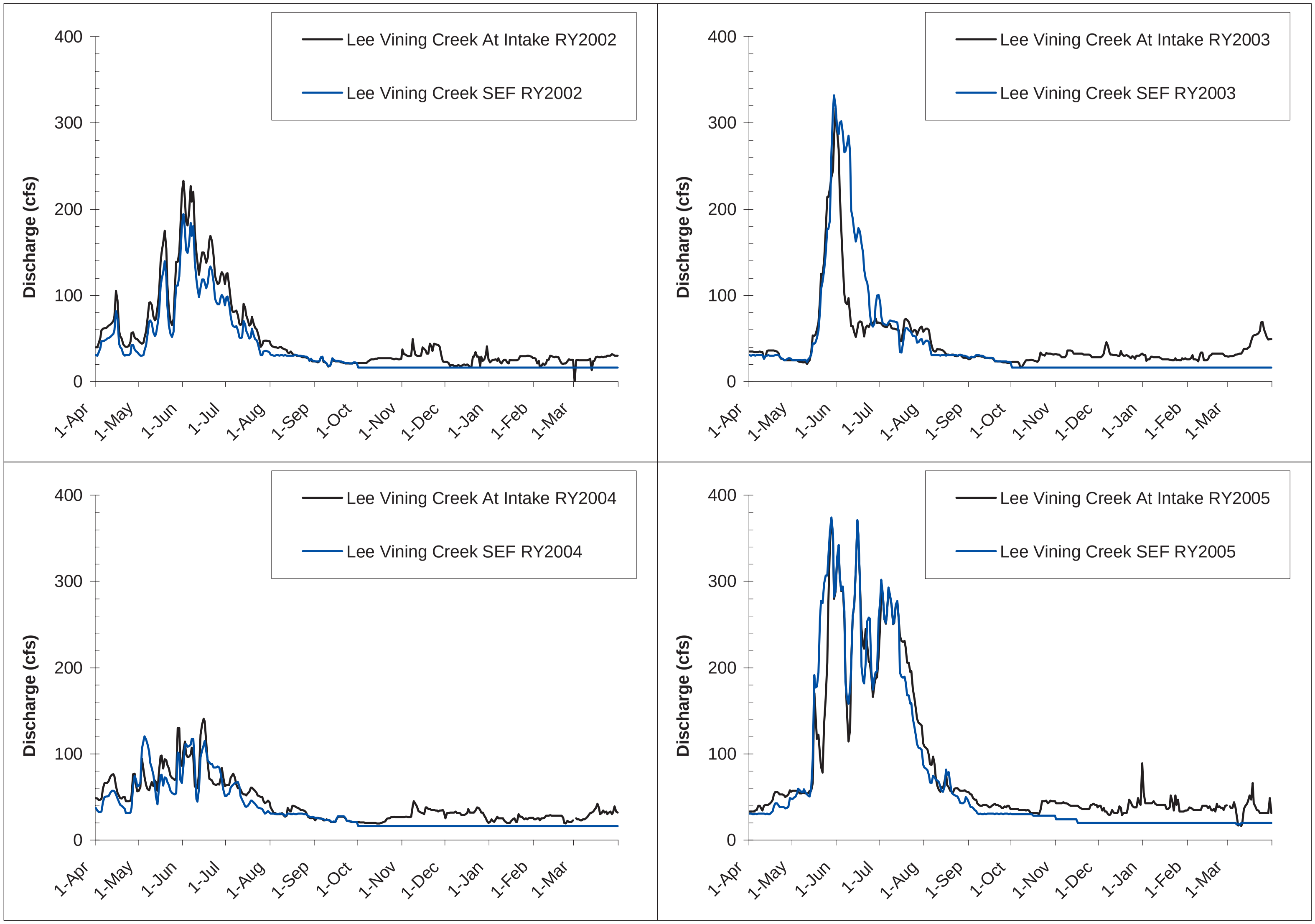
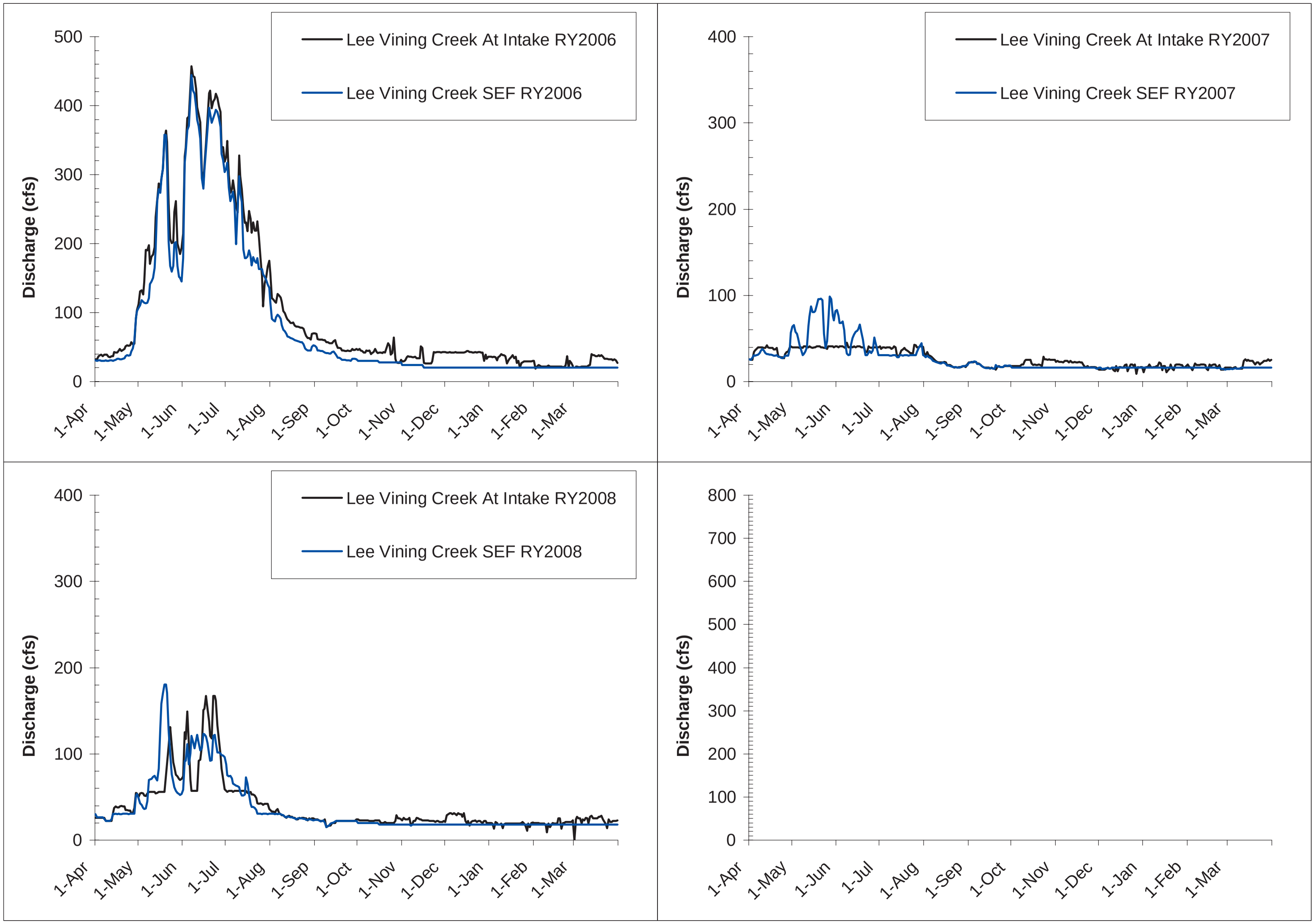


Appendix A-1. Figure 6C. Lee Vining Creek (SEF) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 1998-2001.

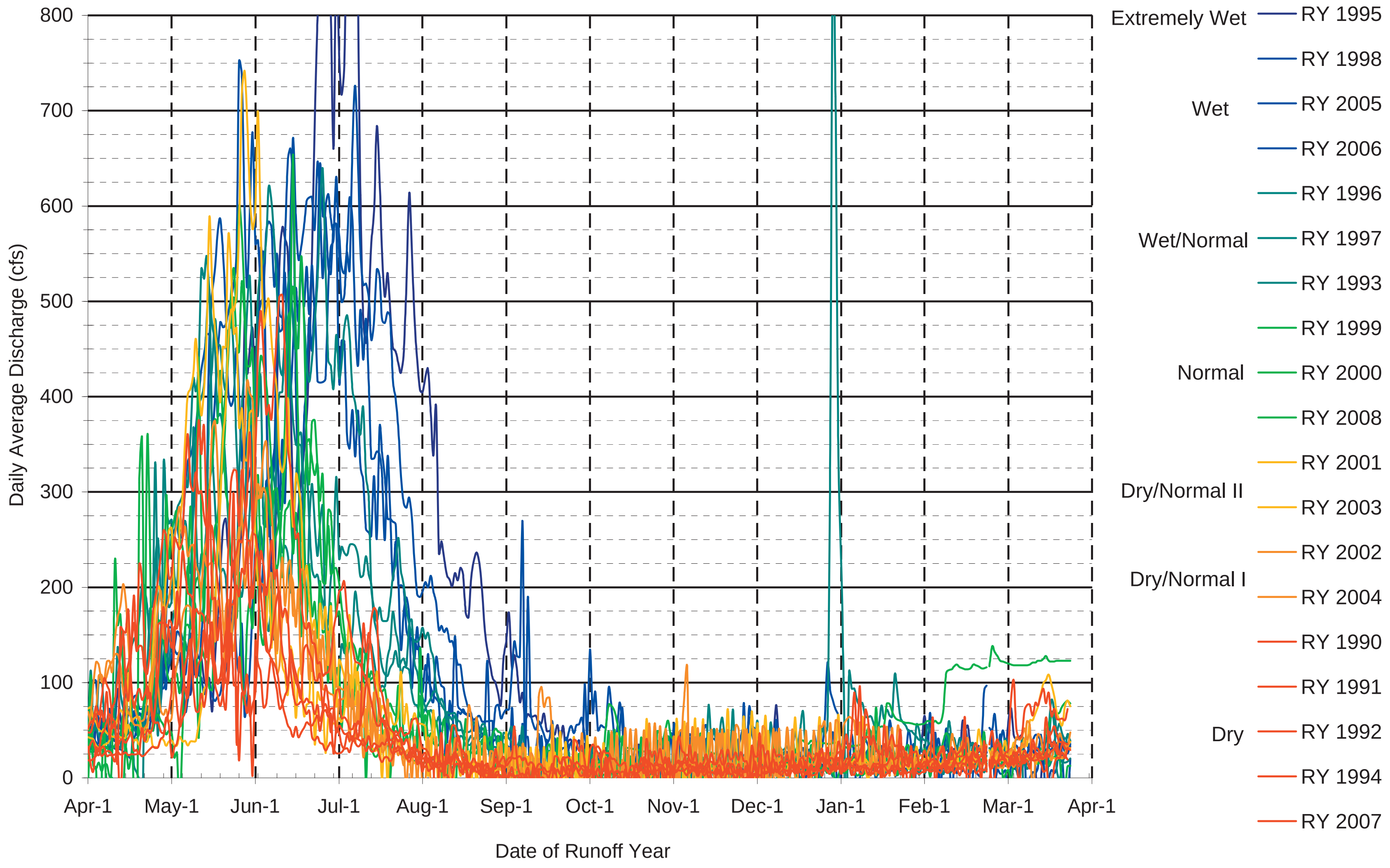


Appendix A-1. Figure 6D. Lee Vining Creek (SEF) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 2002-2005.

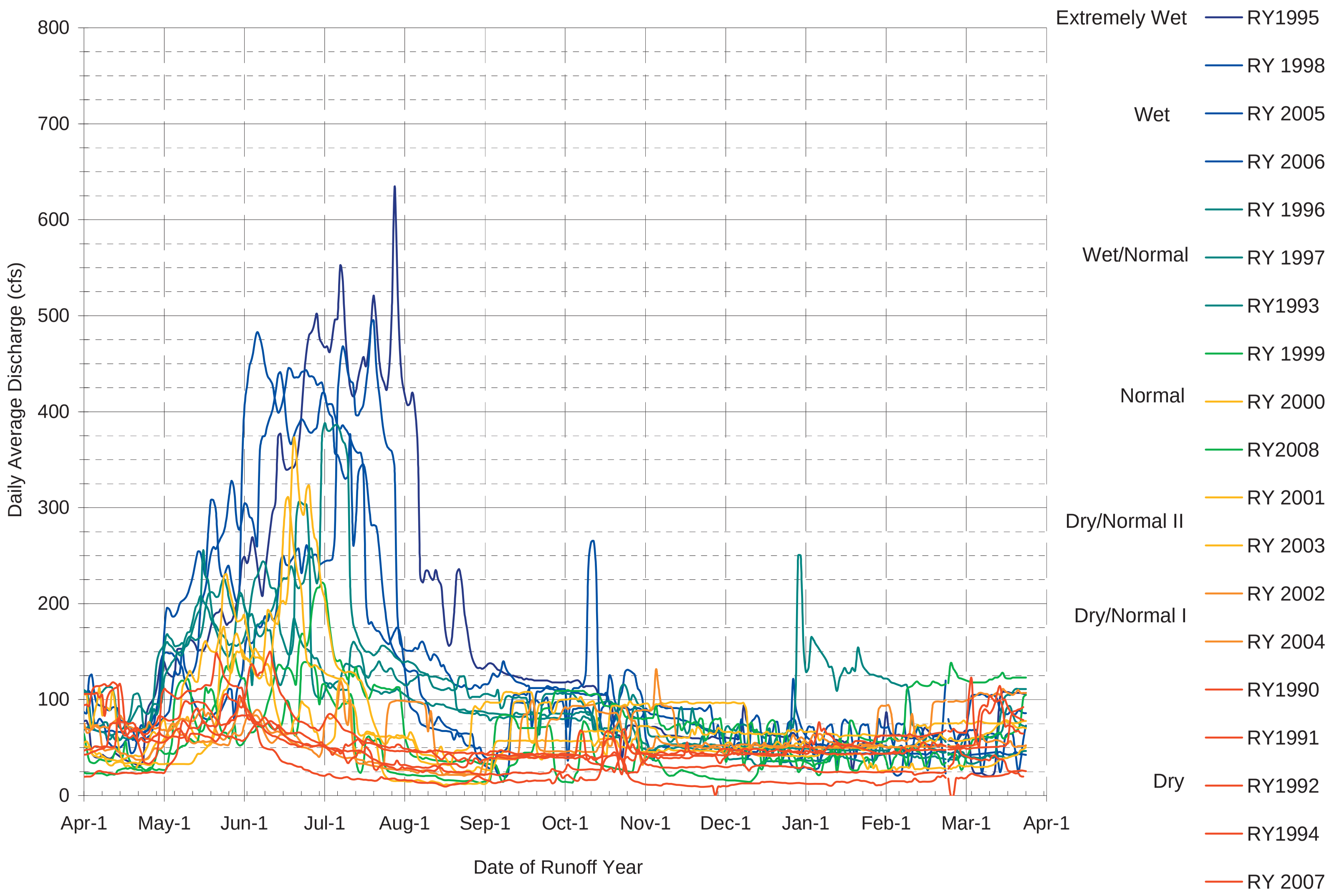


Appendix A-1. Figure 6E. Lee Vining Creek (SEF) and Lee Vining Creek above Intake (SCE impaired) annual hydrographs for 2006-2008.

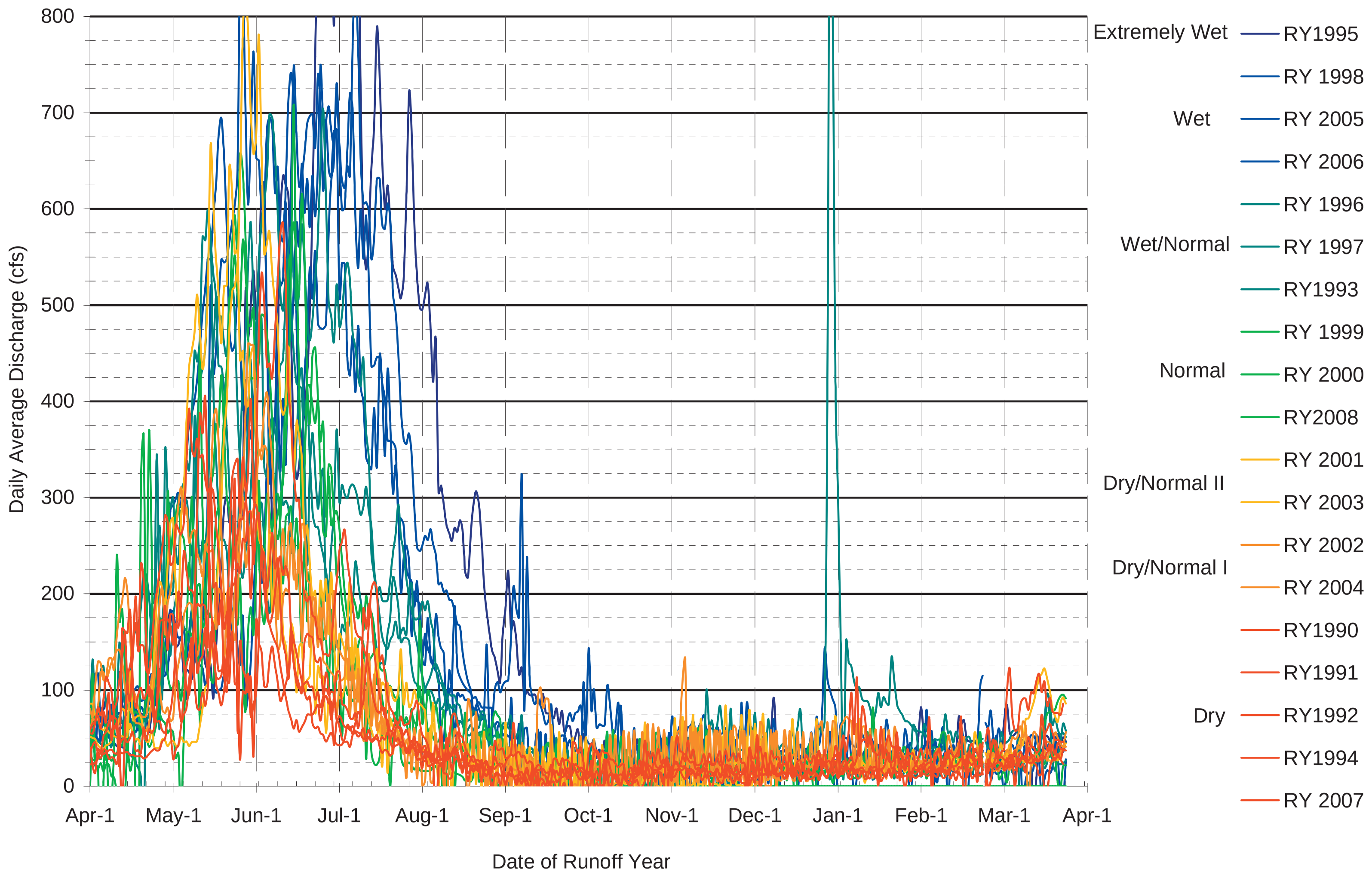
APPENDIX A-2. COMPOSITE HYDROGRAPHS (AKA “SPAGHETTI GRAPHS”) FOR RY 1990-2008



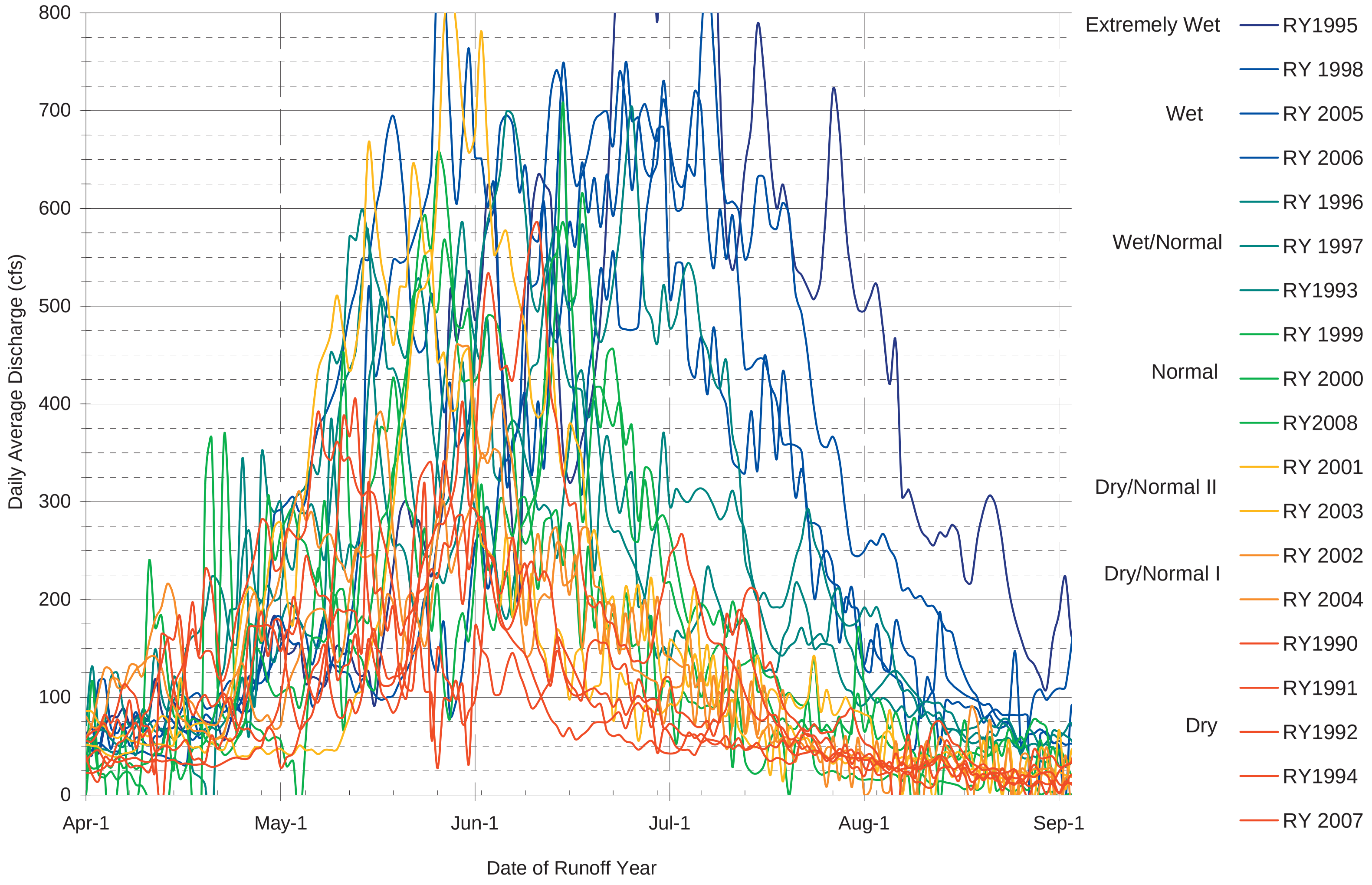
Appendix A-2. Figure 1. Rush Creek Unimpaired composite hydrographs for Runoff Years 1990-2008.



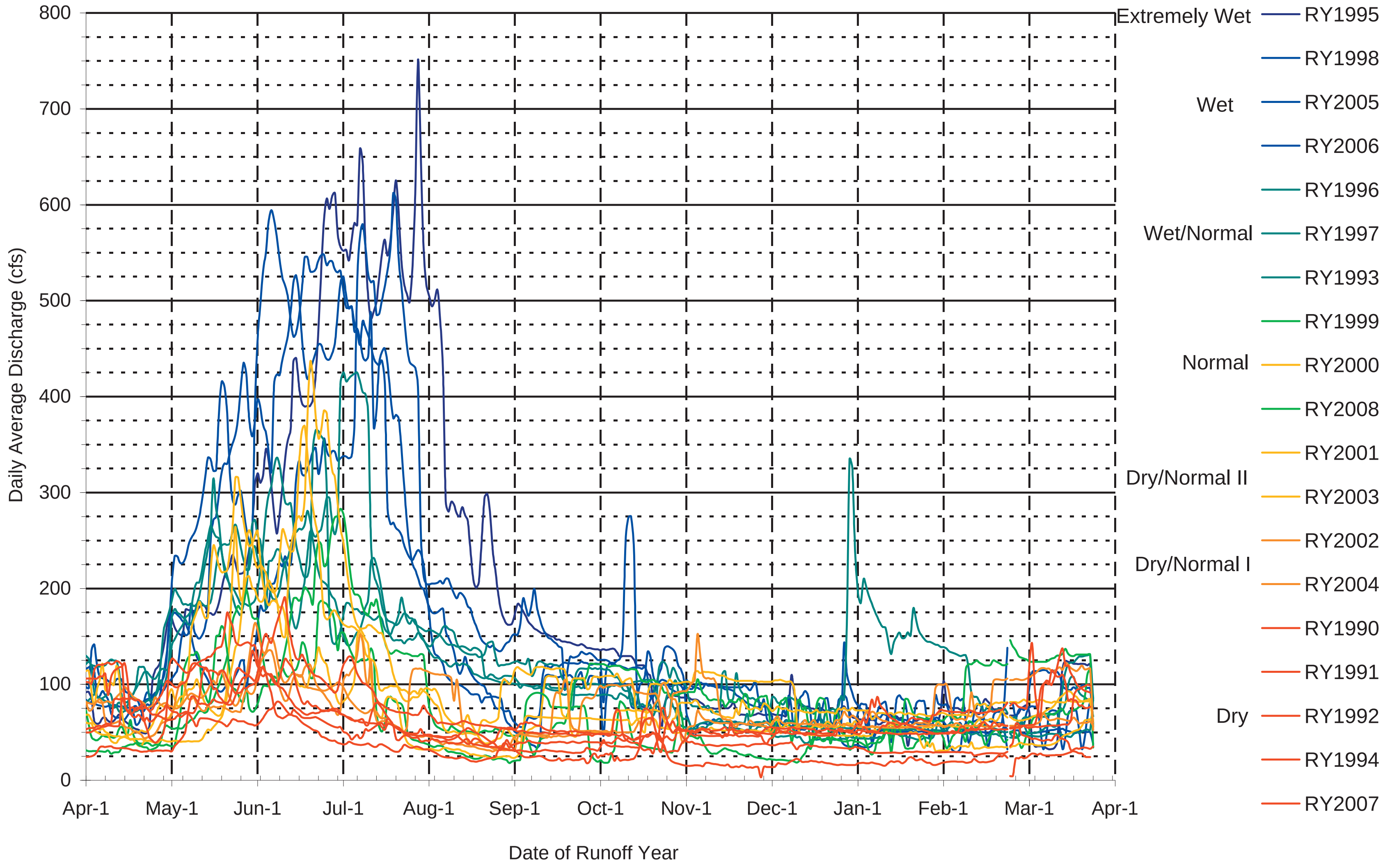
Appendix A-2. Figure 2. Rush Creek at Damsite composite hydrographs for Runoff Years 1990-2008.



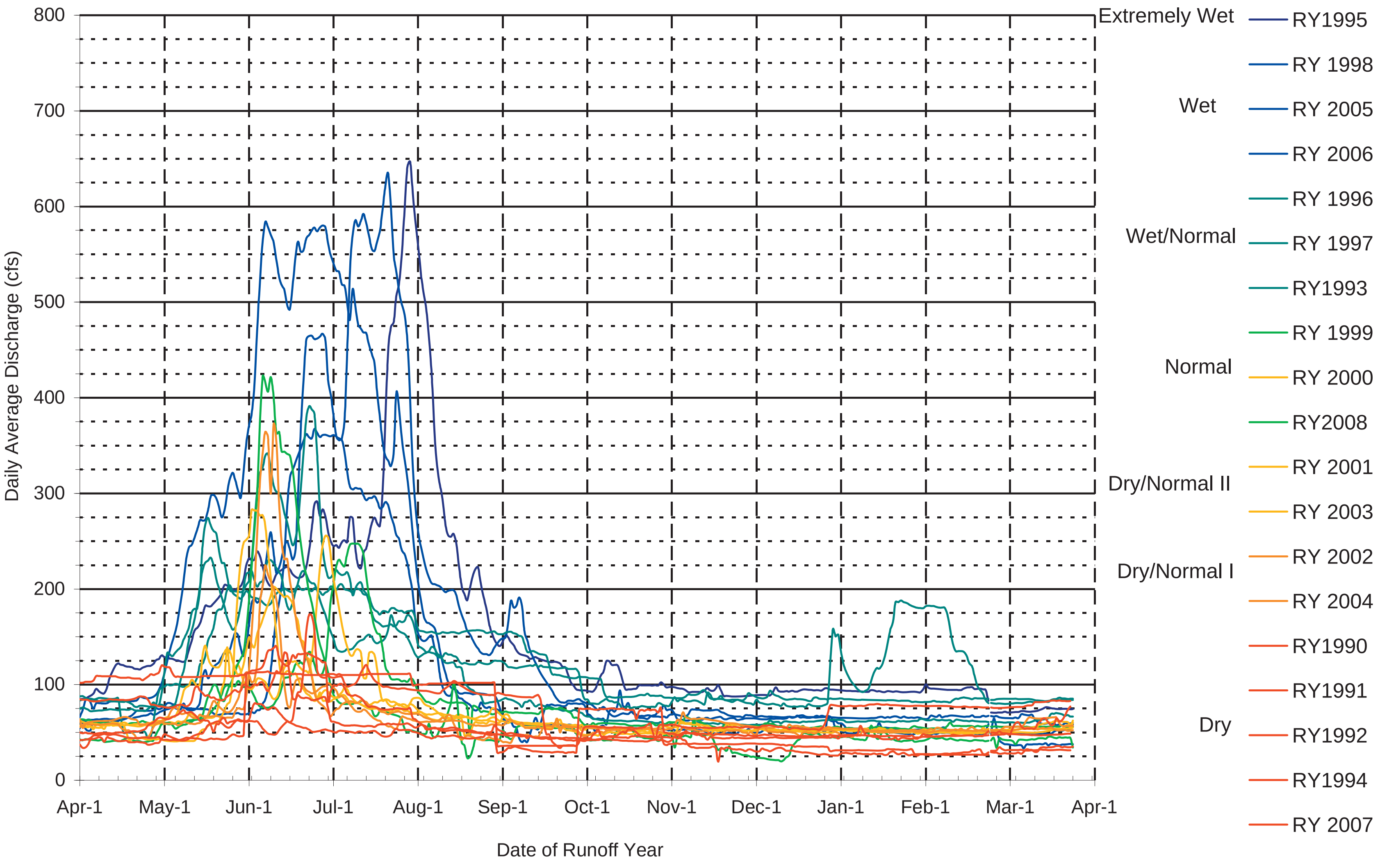
Appendix A-2. Figure 3a. Rush Creek below Narrows Estimated Unimpaired composite hydrographs for Runoff Years 1990-2008.



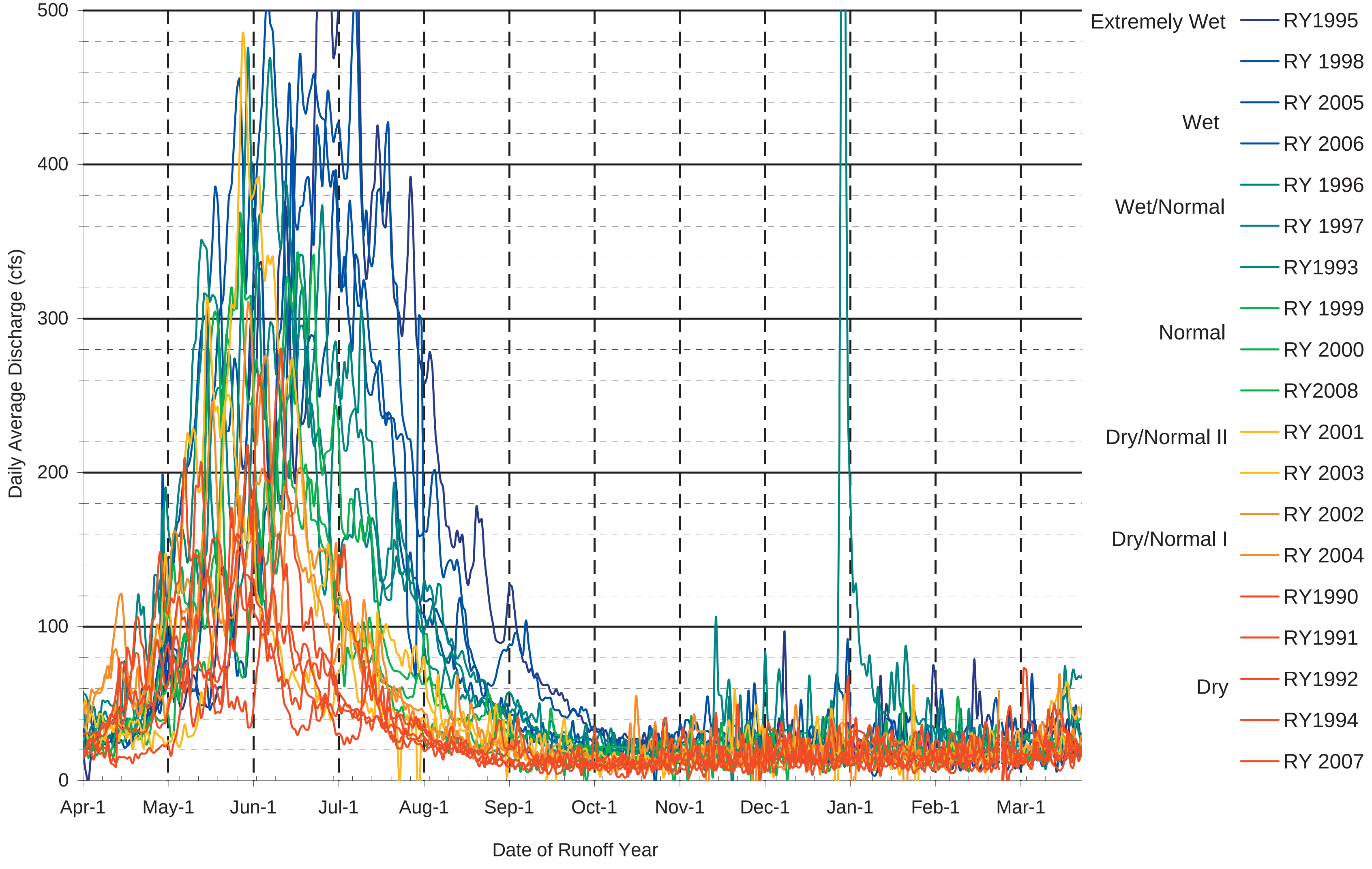
Appendix A-2. Figure 3b. Rush Creek below Narrows Estimated Unimpaired composite hydrographs for Runoff Years 1990-2008, enlarged to show flows from April to September of each runoff year.



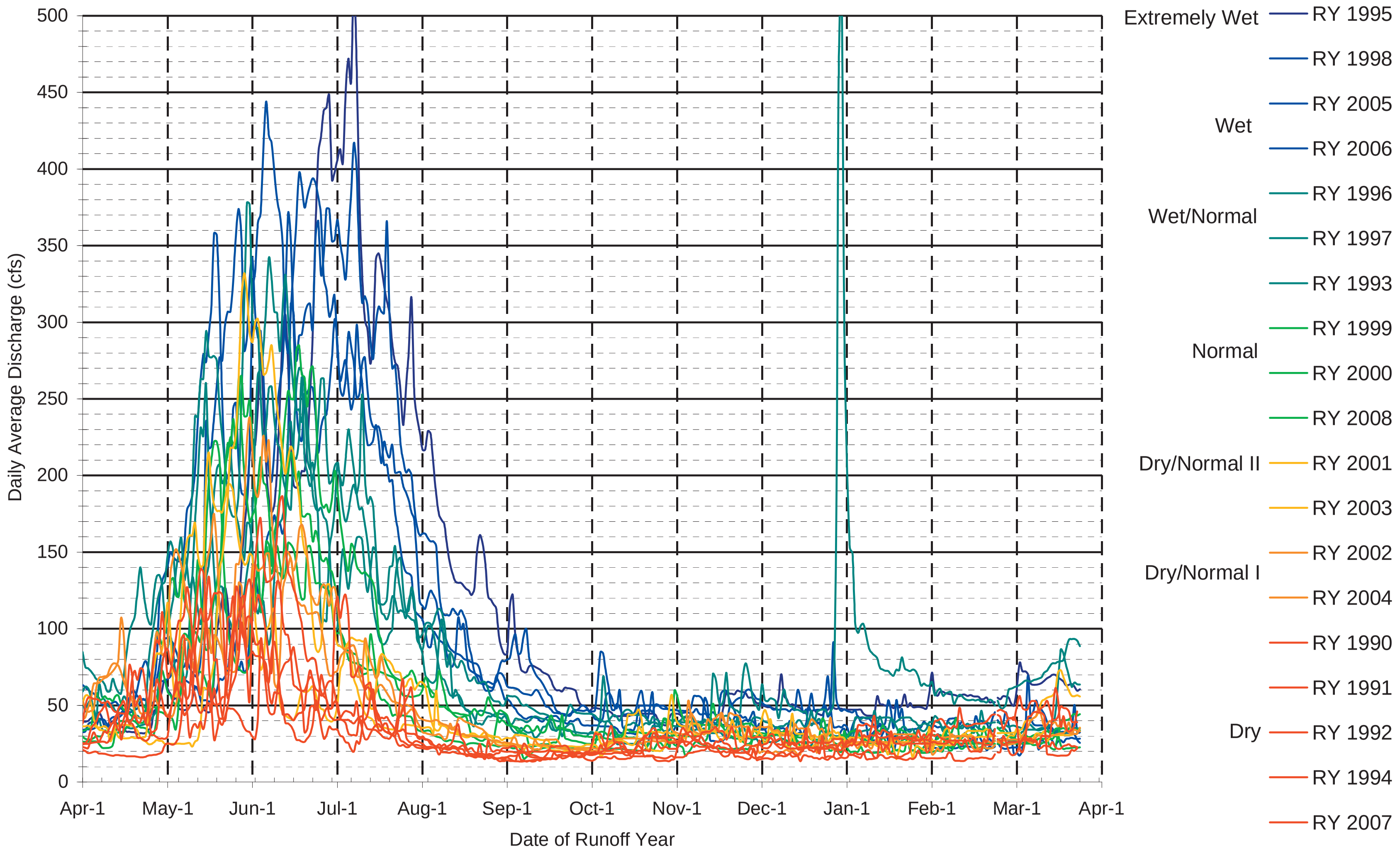
Appendix A-2. Figure 4. Rush Creek below Narrows simulated full GLR composite hydrographs for Runoff Years 1990-2008.



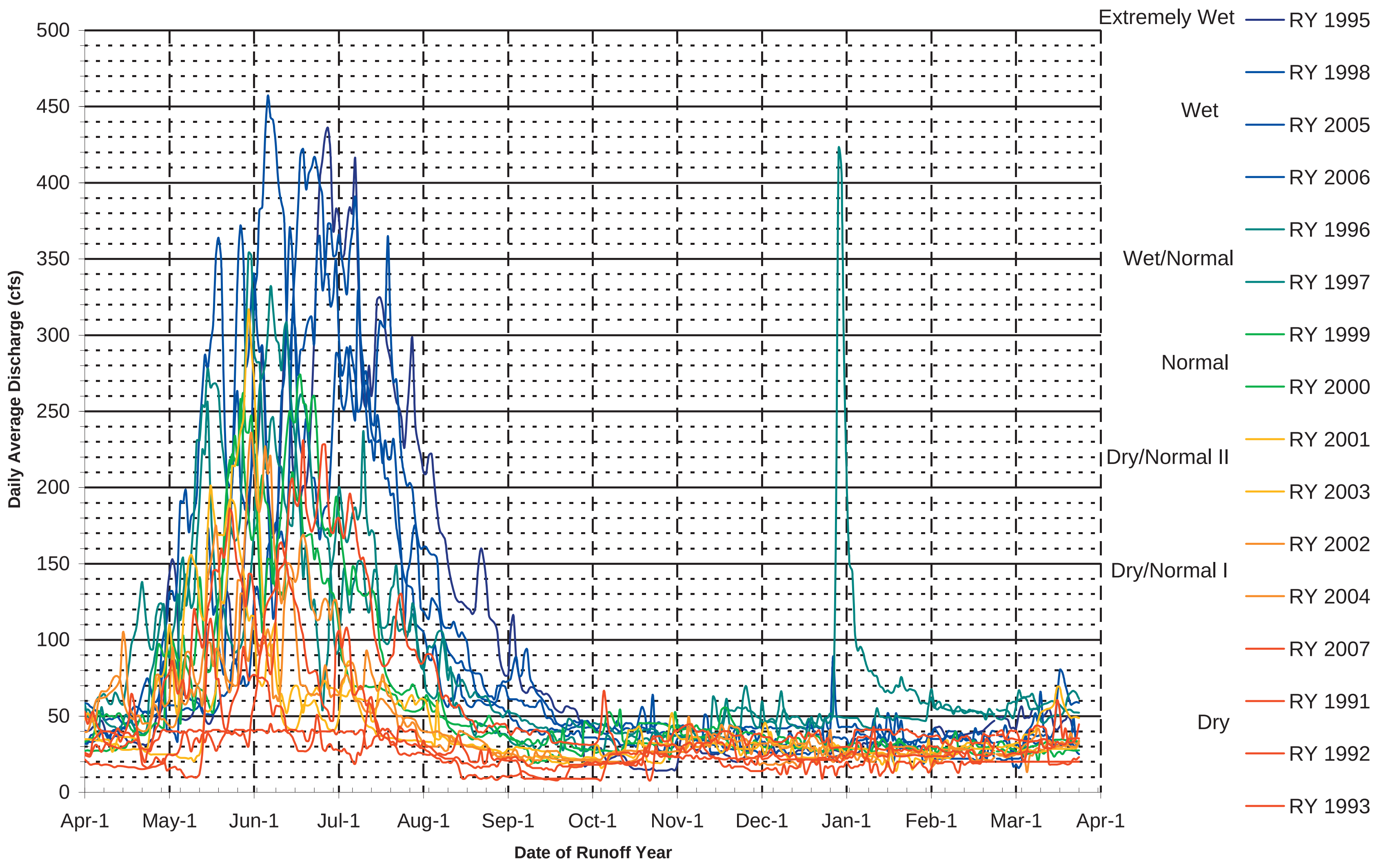
Appendix A-2. Figure 5. Rush Creek below Narrows Actual composite hydrographs for Runoff Years 1990-2008.



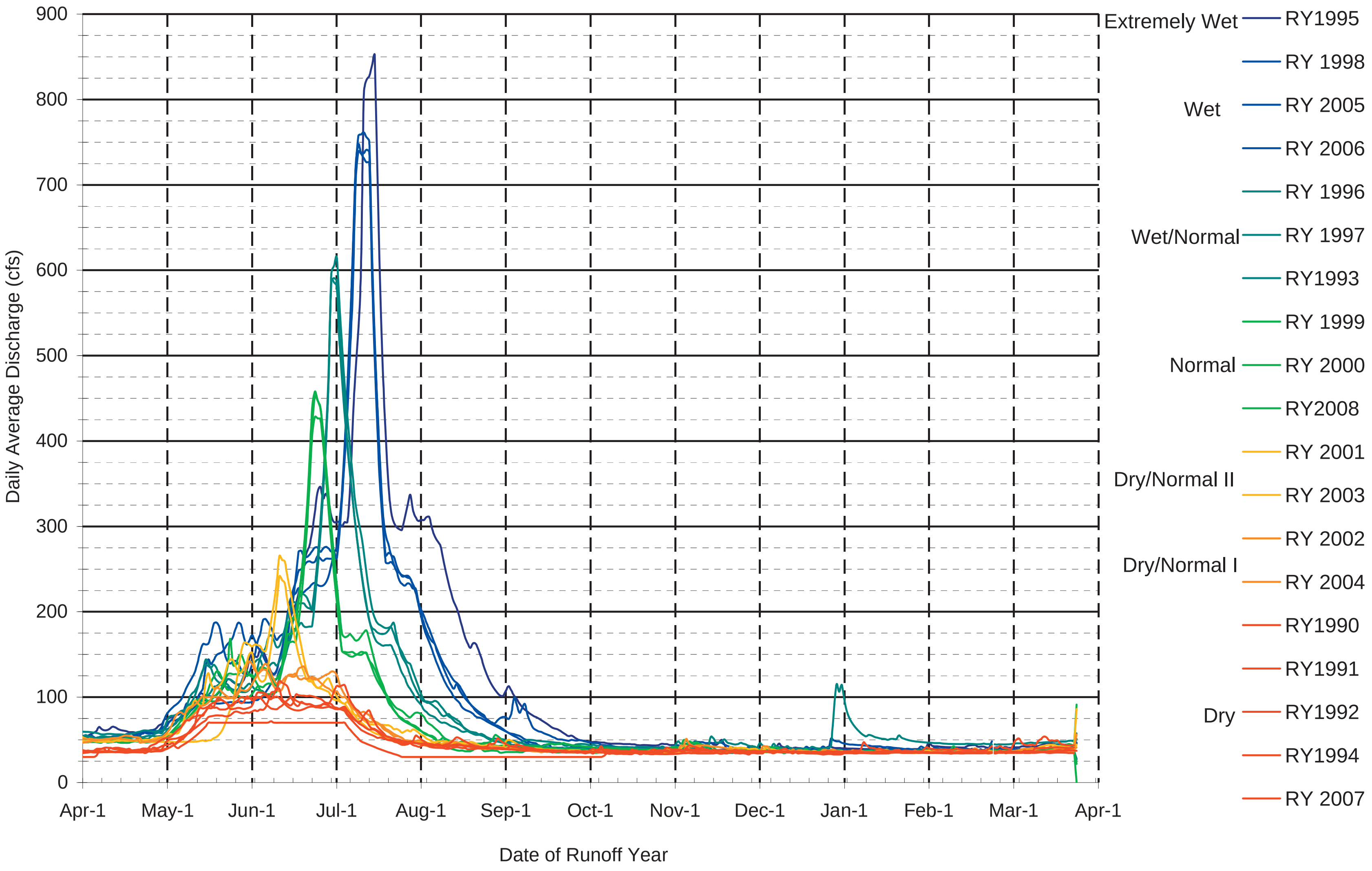
Appendix A-2. Figure 6. Lee Vining Creek Unimpaired composite hydrographs for Runoff Years 1990-2008.



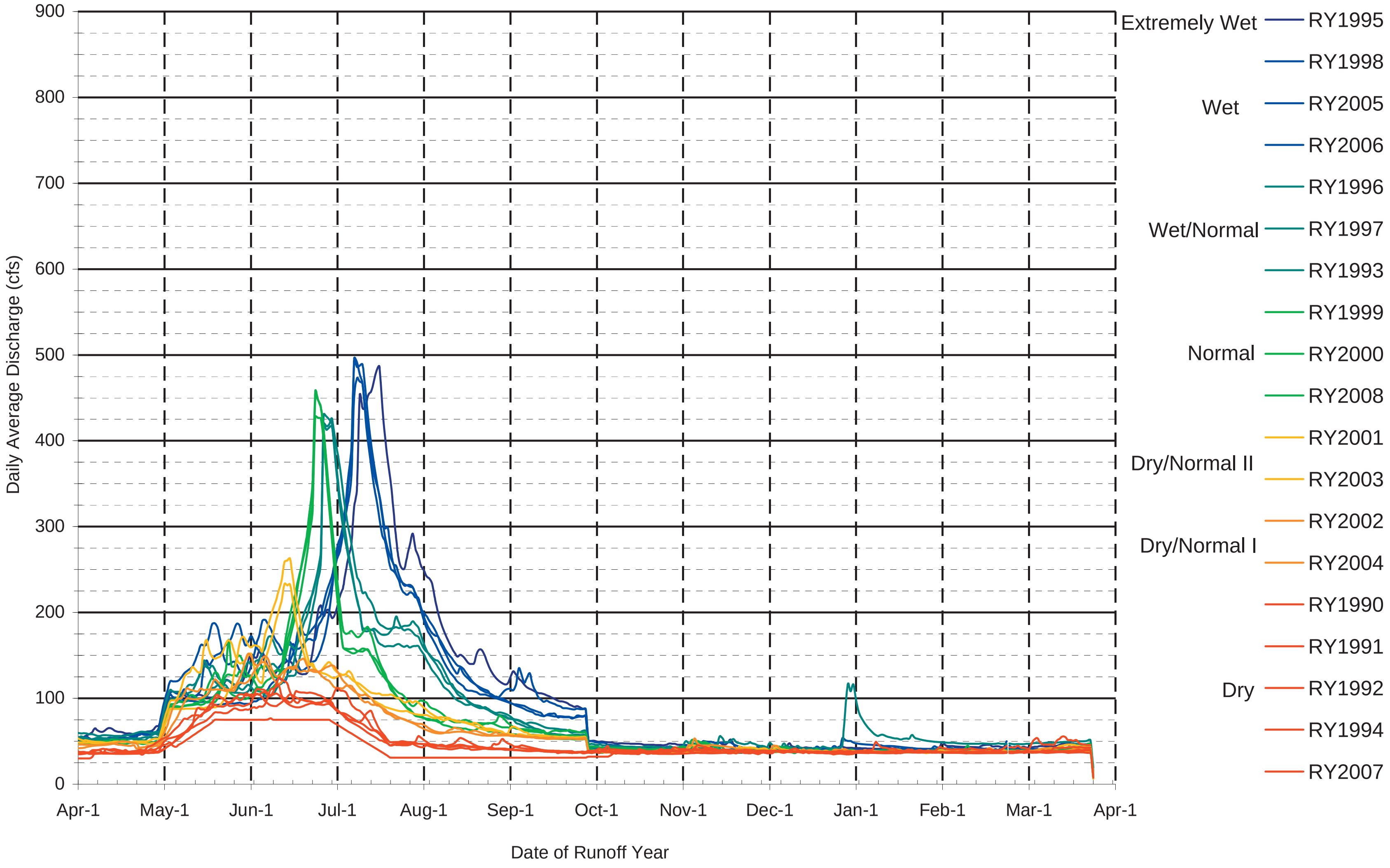
Appendix A-2. Figure 7. Lee Vining Creek above Intake composite hydrographs for Runoff Years 1990-2008.



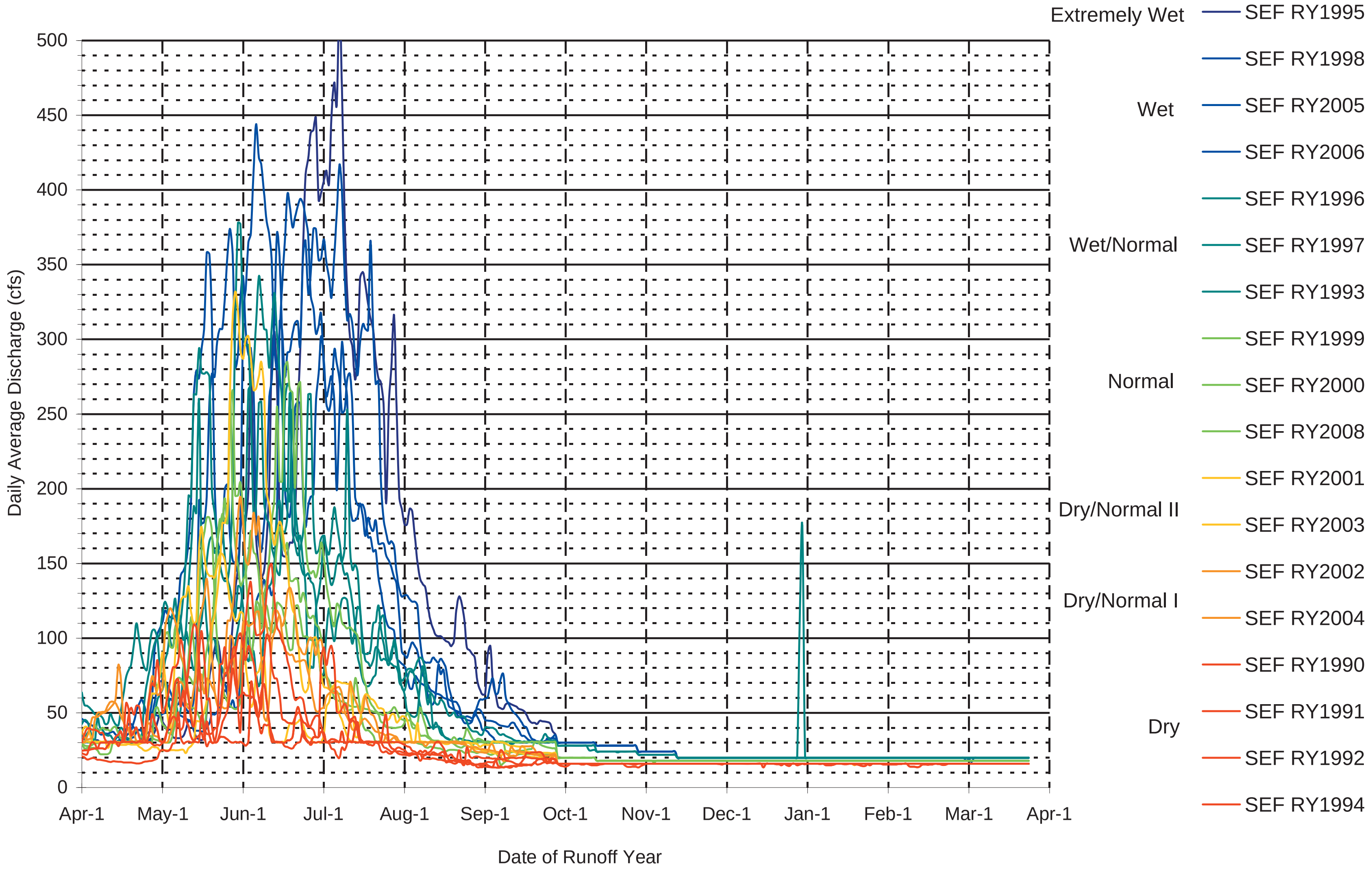
Appendix A-2. Figure 8. Lee Vining Creek below Intake composite hydrographs for Runoff Years 1990-2008.



Appendix A-2. Figure 9a. Rush Creek below Narrows SEF composite hydrographs for Runoff Years 1990-2008 with recommended SCE releases.



Appendix A-2. Figure 9b. Rush Creek below Narrows SEF composite hydrographs for Runoff Years 1990-2008 without recommended SCE releases.



Appendix A-2. Figure 10. Lee Vining Creek below Intake SEF composite hydrographs for Runoff Years 1990-2008.

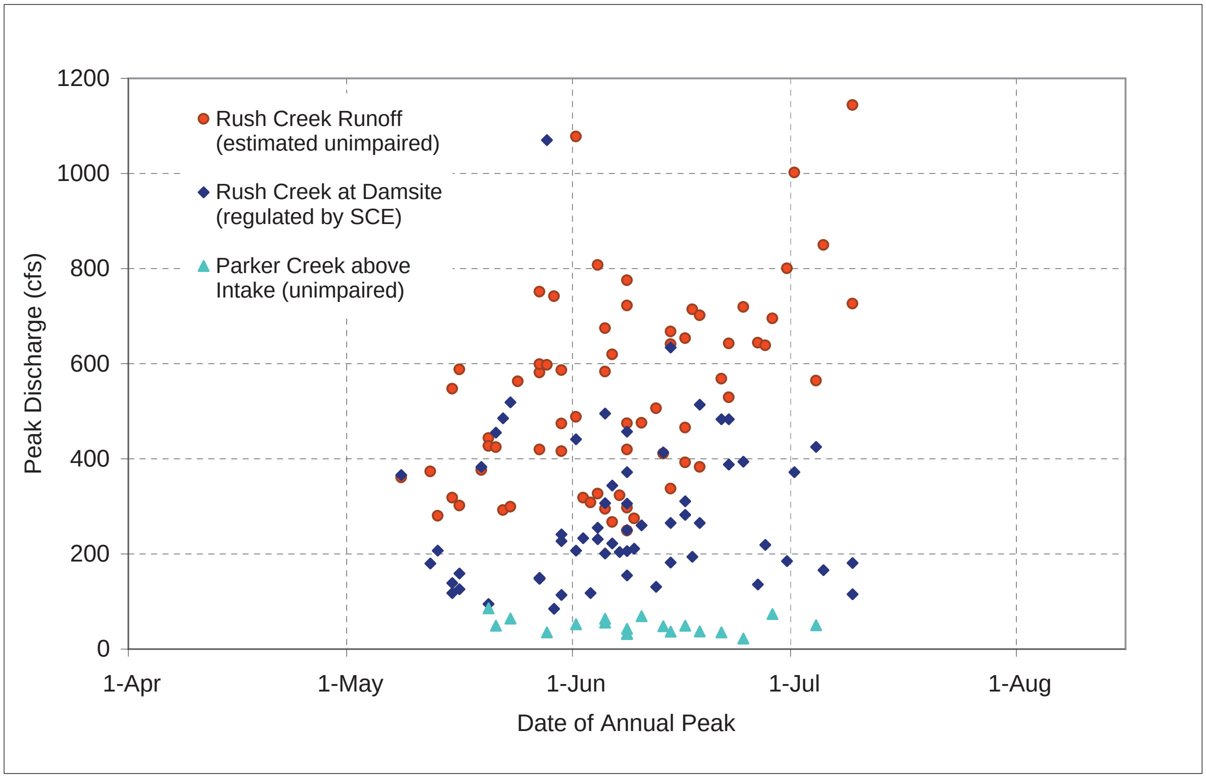
APPENDIX A-3. HYDROGRAPH COMPONENT ANALYSIS

Appendix A-3. Table 1. Rush Creek Runoff hydrograph components analysis.

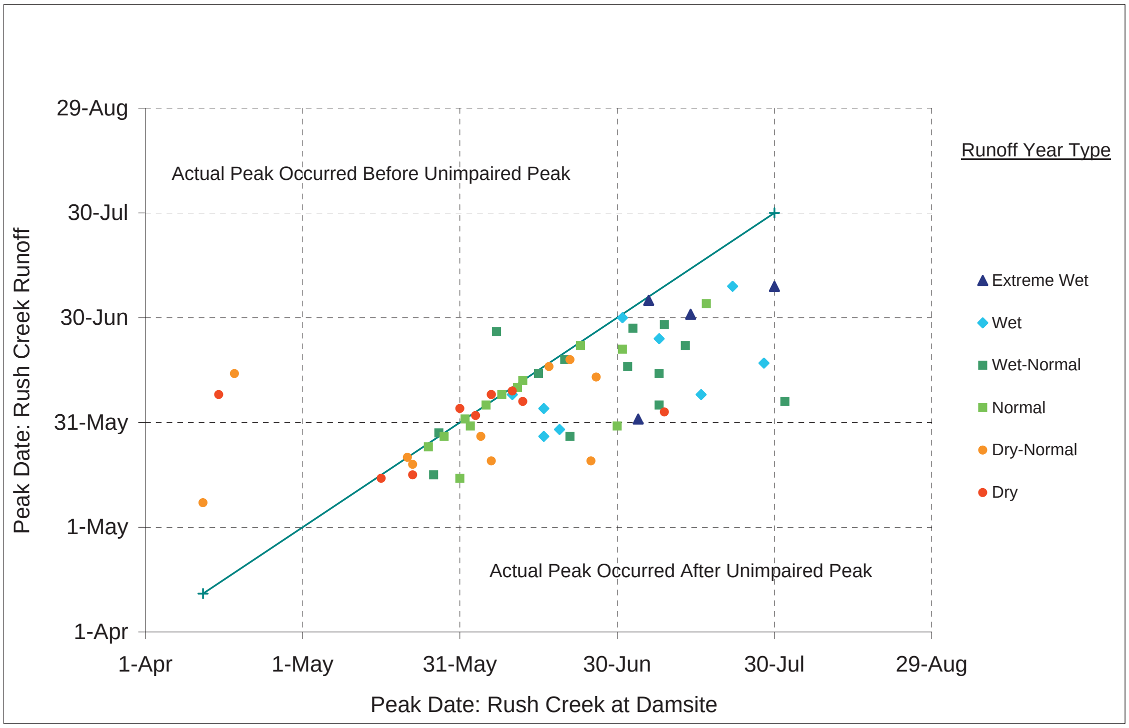
Hydrograph Component	*RUNOFF YEAR TYPE*					
	Extreme Wet	*Wet*	*Wet-Normal*	*Normal*	*Dry-Normal*	*Dry*
Number of Runoff Years for Modeled Unimpaired	1	4	9	8	6	5
Daily Average Annual Discharge (cfs)	269	117	94	76	61	60
Average Annual Yield (af)	100,411	84,666	68,160	54,902	44,340	31,549
Maximum Annual Yield (af)	100,411	91,617	76,709	58,487	47,173	39,016
Minimum Annual Yield (af)	100,411	80,151	63,078	49,000	41,855	24,397
Fall Baseflow (Oct 1 - Dec 20)						
Median	39	42	32	25	18	18
Minimum	39	32	23	18	14	14
Maximum	39	50	44	41	28	24
Winter Baseflow (Dec 21 - Mar 21)						
Median	35	30	29	26	23	17
Minimum	35	24	23	20	15	17
Maximum	35	36	56	35	35	21
Winter Floods (Dec 21 - Mar 30)						
Flood Magnitude (maximum)		491	1,048	169		
Flood Magnitude (average)		301	499	169		
Flood Duration (median number of days)		1	3	1		
Flood Frequency (number of winter storms)		2	6	1		
Earliest Flood Date		23-Dec	11-Nov	16-Jan		
Latest Flood Date		23-Mar	5-Feb	16-Jan		
Average Flood Volume (AF)		1,308	1,673	456		
Number of Runoff Years for Computed Unimpaired	*5*	*7*	*13*	*12*	*13*	*11*
Spring Early Snowmelt Peaks (Mar 21- May 31)						
Secondary Peak Magnitude (median)	*507*	*411*	*377*	*262*	*306*	*203*
Secondary Peak Duration (median)	*21*	*22*	*24*	*17*	*14*	*19*
Start of Snowmelt Ascension (median)	*15-May*	*6-May*	*2-May*	*1-May*	*3-May*	*4-May*
Secondary Snowmelt Peak Date (median)	*30-May*	*20-May*	*16-May*	*16-May*	*15-May*	*7-May*
End of Snowmelt Ascension (median)	*8-Jun*	*29-May*	*29-May*	*22-May*	*22-May*	*25-May*
Snowmelt Ascension Runoff Volume	*16,908*	*8,544*	*9,477*	*5,580*	*5,106*	*4,356*
Daily Ramping Rates (maximum)	33%	40%	33%	35%	33%	39%
Daily Ramping Rates (average)	12%	13%	12%	12%	13%	13%
Spring Snowmelt Flood (May 1 - July 15)						
Magnitude used to Compute Duration	*686*	*591*	*498*	*400*	*356*	*254*
Snowmelt Flood Magnitude (median)	*807*	*695*	*586*	*470*	*419*	*299*
Snowmelt Ascension Duration (median)	*22*	*13*	*13*	*16*	*11*	*8*
Snowmelt Flood Duration (median)	*3*	*4*	*9*	*6*	*10*	*4*
Start of Snowmelt Flood (median)	*8-Jun*	*29-May*	*29-May*	*22-May*	*22-May*	*25-May*
End of Snowmelt Flood (median)	*17-Jul*	*30-Jul*	*17-Jul*	*1-Jul*	*26-Jun*	*12-Jun*
Date of Flood Peak (median)	*1-Jul*	*14-Jun*	*21-Jun*	*7-Jun*	*8-Jun*	*5-Jun*
Snowmelt Runoff Volume (median)	*49,941*	*51,675*	*32,021*	*27,248*	*19,319*	*9,042*
Snowmelt Recession (July 15 - Sep 30)						
Start of Snowmelt Recession (median date)	*17-Jul*	*30-Jul*	*17-Jul*	*1-Jul*	*26-Jun*	*12-Jun*
End of Snowmelt Recession (median date)	*31-Aug*	*28-Aug*	*20-Aug*	*27-Jul*	*15-Jul*	*10-Jul*
Duration of Recession (median number of days)	*45*	*31*	*31*	*31*	*25*	*25*
Daily Ramping Rates (maximum)	10%	18%	12%	9%	10%	17%
Daily Ramping Rates (average)	5%	5%	5%	4%	5%	6%
Snowmelt Recession Runoff Volume (median)	18,924	7,503	7,192	4,606	3,238	2,614
Summer Baseflow						
Minimum (median)	77	72	35	28	23	14
Maximum (median)	77	103	49	50	31	25

Appendix A-3. Table 2. Lee Vining Creek Runoff hydrograph components analysis.

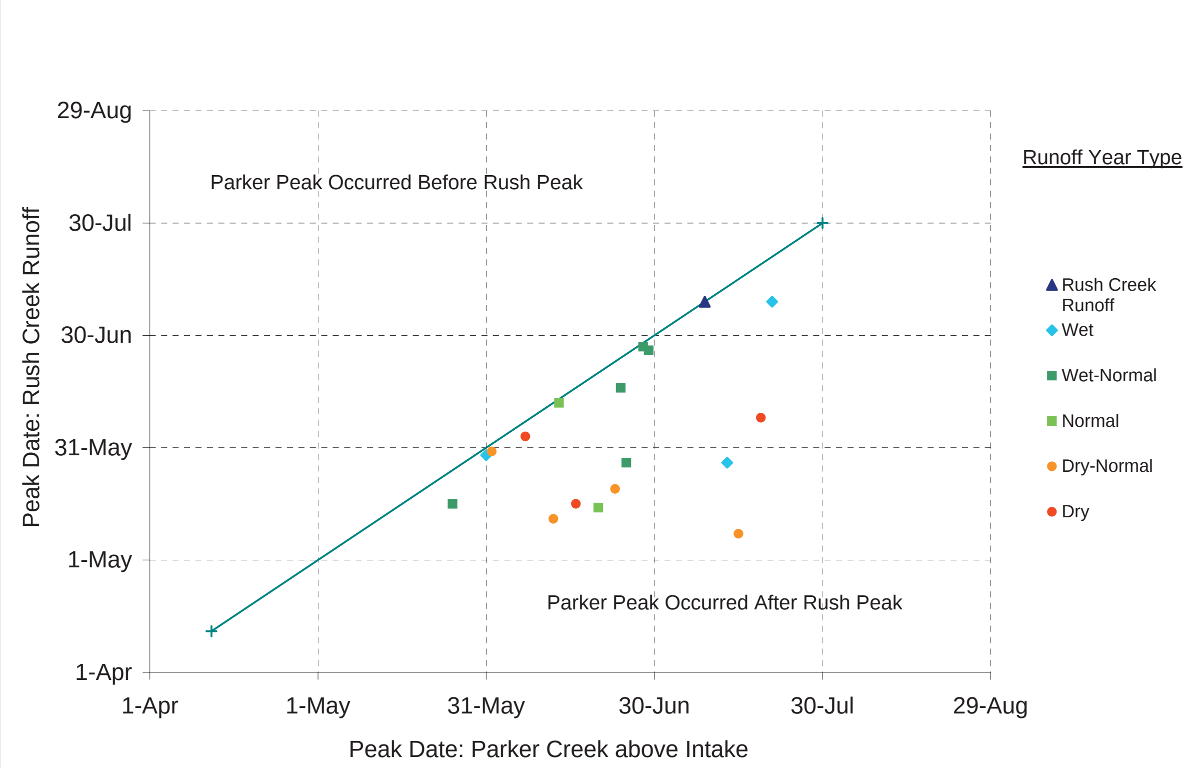
Hydrograph Component	***RUNOFF YEAR TYPE***					
	Extreme Wet	***Wet***	***Wet-Normal***	***Normal***	***Dry-Normal***	***Dry***
Number of Runoff Years for Computations	1 (+2 partial Rys)	6	6	6	6	9
Daily Average Annual Discharge (cfs)	171	123	105	73	58	40
Average Annual Yield (af)	77,899	67,779	58,900	40,488	36,824	24,701
Maximum Annual Yield (af)	77,899	72,057	65,280	45,910	41,884	27,367
Minimum Annual Yield (af)	77,899	65,111	50,785	35,557	32,757	20,259
Fall Baseflow (Oct 1 - Dec 20)						
Median	23	25	21	16	15	12
Minimum	23	24	19	15	13	10
Maximum	23	25	23	23	18	14
Winter Baseflow (Dec 21 - Mar 21)						
Median	29	20	21	17	18	14
Minimum	29	16	16	14	16	10
Maximum	29	26	35	22	20	18
Winter Floods (Dec 21 - Mar 30)						
Flood Magnitude (maximum)	79	92	677	54	69	73
Flood Magnitude (average)	79	73	266	46	51	52
Flood Duration (median # days >40 cfs)	15	4	11	1	9	2
Flood Frequency (number of winter storms)	1	3	3	3	4	5
Earliest Flood Date	19-Feb	4-Jan	2-Jan	27-Dec	29-Dec	4-Jan
Latest Flood Date	19-Feb	13-Mar	25-Mar	31-Mar	26-Mar	10-Mar
Average Flood Volume (AF)	0	2,725	1,368	311	0	0
Spring Early Snowmelt Peaks (Mar 21- May 31)						
Secondary Peak Magnitude (median)	385	281	284	172	179	91
Secondary Peak Duration (median)	37	39	20	27	30	13
Start of Snowmelt Ascension (median)	1-May	29-Apr	1-May	26-Apr	25-Apr	28-Apr
Secondary Snowmelt Peak Date (median)	30-May	20-May	14-May	15-May	3-May	29-Apr
End of Snowmelt Ascension (median)	7-Jun	27-May	23-May	19-May	22-May	10-May
Snowmelt Ascension Runoff Volume	12,782	7,580	7,326	3,435	6,083	2,144
Daily Ramping Rates (maximum)	54%	91%	72%	52%	53%	138%
Daily Ramping Rates (average)	14%	19%	18%	17%	18%	21%
Spring Snowmelt Flood (May 1 - July 15)						
Magnitude used to Compute Duration	498	437	359	307	260	167
Snowmelt Flood Magnitude (median)	585	514	423	361	306	196
Snowmelt Ascension Duration (median)	21	13	10	9	12	10
Snowmelt Flood Duration (median)	11	11	9	9	8	7
Start of Snowmelt Flood (median)	7-Jun	27-May	23-May	19-May	22-May	9-May
End of Snowmelt Flood (median)	12-Aug	2-Aug	13-Jul	3-Jul	27-Jun	17-Jun
Date of Flood Peak (median)	5-Jul	8-Jun	3-Jun	28-May	2-Jun	19-May
Snowmelt Runoff Volume (median)	40,601	39,030	26,529	17,436	10,188	5,910
Snowmelt Recession (July 15 - Sep 30)						
Start of Snowmelt Recession (median date)	12-Aug	2-Aug	13-Jul	3-Jul	27-Jun	16-Jun
End of Snowmelt Recession (median date)	21-Sep	26-Aug	21-Aug	3-Aug	28-Jul	5-Jul
Duration of Recession (median number of days)	29	21	37	38	29	19
Daily Ramping Rates (maximum)	72%	40%	31%	23%	29%	57%
Daily Ramping Rates (average)	42%	12%	9%	9%	10%	14%
Snowmelt Recession Runoff Volume (median)	5,947	4,188	7,290	5,665	4,351	2,676
Summer Baseflow (August 1 - Sep 30)						
Median	NA	36	33	20	21	19
Minimum (median)	NA	31	15	9	14	12
Maximum (median)	NA	63	38	32	27	26



Appendix A-3. Figure 1. Timing and magnitude of peak flows for Rush Creek Runoff (estimated unimpaired), Rush Creek at Damsite (regulated by SCE), and Parker Creek above Intake (unimpaired).



Appendix A-3. Figure 2. Comparison of snowmelt peak date for Rush Creek Runoff (estimated unimpaired) and Rush Creek at Damsite (actual) for Runoff Years 1990-2008.



Appendix A-3. Figure 3. Comparison of snowmelt peak date for Rush Creek Runoff (estimated unimpaired) and Parker Creek above Intake (unimpaired) for Runoff Years 1990-2008.

APPENDIX A-4. FLOOD FREQUENCY ANALYSIS

Appendix A-4. Table 1. Rush Creek flood peaks for Runoff Years 1973-2008.

Runoff Year	*Rush Creek Unimpaired*	*Rush Creek At Damsite (5013)*	*Rush Creek Below MGORD (5007)*	*Rush Creek Below Narrows Unimpaired*	*Rush Creek Below Narrows Actual*
1973	586	282			
1974	620	383			
1975	668	255			
1976	280	86			
1977	275	86			
1978	722	514			
1979	581	241			
1980	801	322			
1981	419	120			
1982	714	304			
1983	850	418			
1984	563	163			
1985	323	138			
1986	1078	307			
1987	318	83			
1988	295	66			
1989	338	94			
1990	249	116	113	256	120
1991	506	150	101	513	140
1992	361	118	154	367	173
1993	639	388	166	645	205
1994	374	122	99	380	133
1995	1144	634	548	1151	647
1996	874	306	333	881	391
1997	547	211	175	554	233
1998	726	495	538	733	635
1999	654	222	201	660	247
2000	599	372	204	605	256
2001	588	231	161	595	202
2002	416	131	168	423	225
2003	742	311	203	748	283
2004	308	118	343	315	372
2005	751	441	403	758	467
2006	644	483	477	651	584
2007	302	148	45	308	64
2008	427	139	388	434	423

Appendix A-4. Table 2. Lee Vining Creek flood peaks for Runoff Years 1973-2009.

Runoff Year	Unimpaired	Above Intake	Below Intake
1973	382		
1974	423		
1975	404		
1976	190		
1977	303		
1978	412		
1979	389		
1980	637		
1981	301		
1982	498		
1983	585		
1984	422		
1985	266		
1986	631		
1987	196		
1988	180		
1989	234		
1990	125	95	59.5
1991	280	186	164
1992	209	134	114
1993	373	264	231
1994	216	139	125
1995	691	522	436
1996	677	524	422
1997	476	378	354
1998	514	417	391
1999	367	285	274
2000	355	264	258
2001	312	215	201
2002	311	238	233
2003	484	332	317
2004	203	152	141
2005	455	374	372
2006	515	444	457
2007	157	127	45
2008	305	222	167
2009	NA	230	232

Appendix A-4. Table 3. Rush and Lee Vining creeks flood frequency analysis.

(all data in cfs)	1.5-YR		2.0-YR		2.33-YR		5-YR		10-YR		25-YR		50-YR	
	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit
Rush Creek Runoff Unimpaired (1)	420	428	547	505	583	540	716	694	802	820	1,018	981	1,109	1,101
Rush Creek at Damsite (2)	176	173	224	221	250	244	387	363	485	476	643	641	858	780
Rush Creek below Narrows Unimpaired (6)	495	506	638	584	708	619	792	774	855	898	1,108	1,054	1,191	1,170
Lee Vining Creek Runoff (9)	311	305	382	366	408	394	512	515	643	611	683	729	na	814
Lee Vining Creek above Intake (10)	217	200	264	249	281	273	421	382	522	476	na	603	na	702

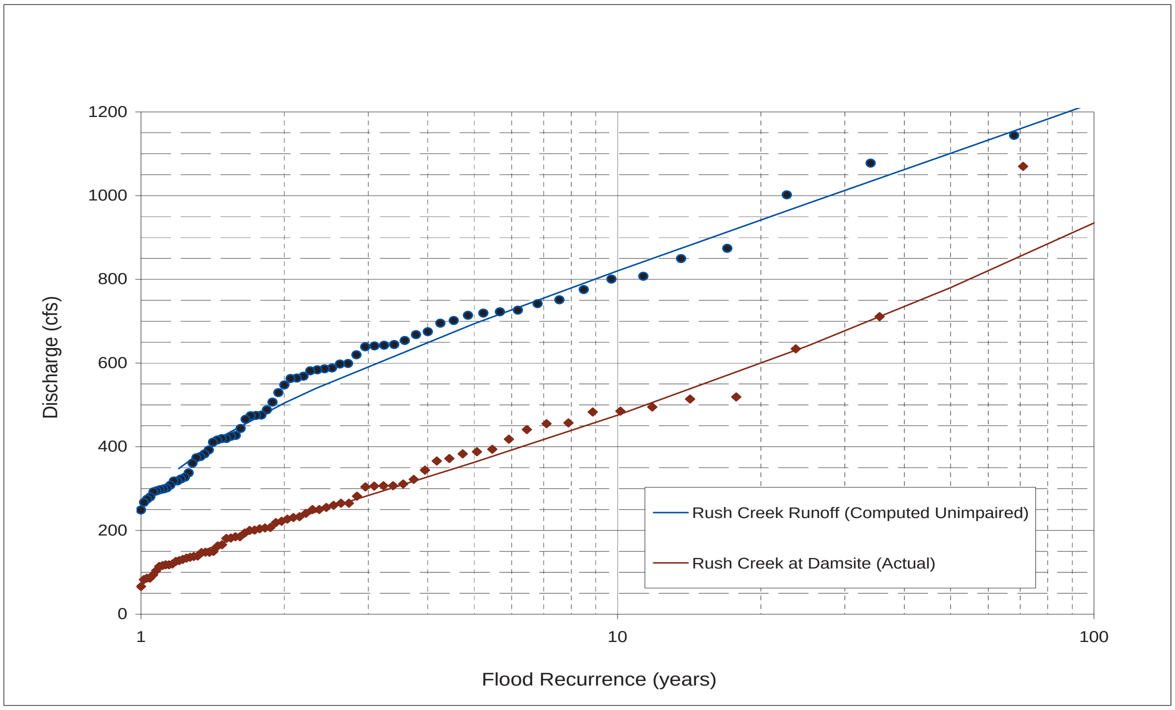
(1) Data Source: LADWP Rush Creek Computed Unimpaired or 'Rush Creek Runoff' (Rush Creek at Damsite + SCE Storage Change)

(2) Data Source: Data for 1937-1979 from USGS 'Rush Creek abv Grant Lake nr June Lake, CA (USGS 10287400)'; Data for 1980-2008 from DWP 'Rush Creek at Damsite'

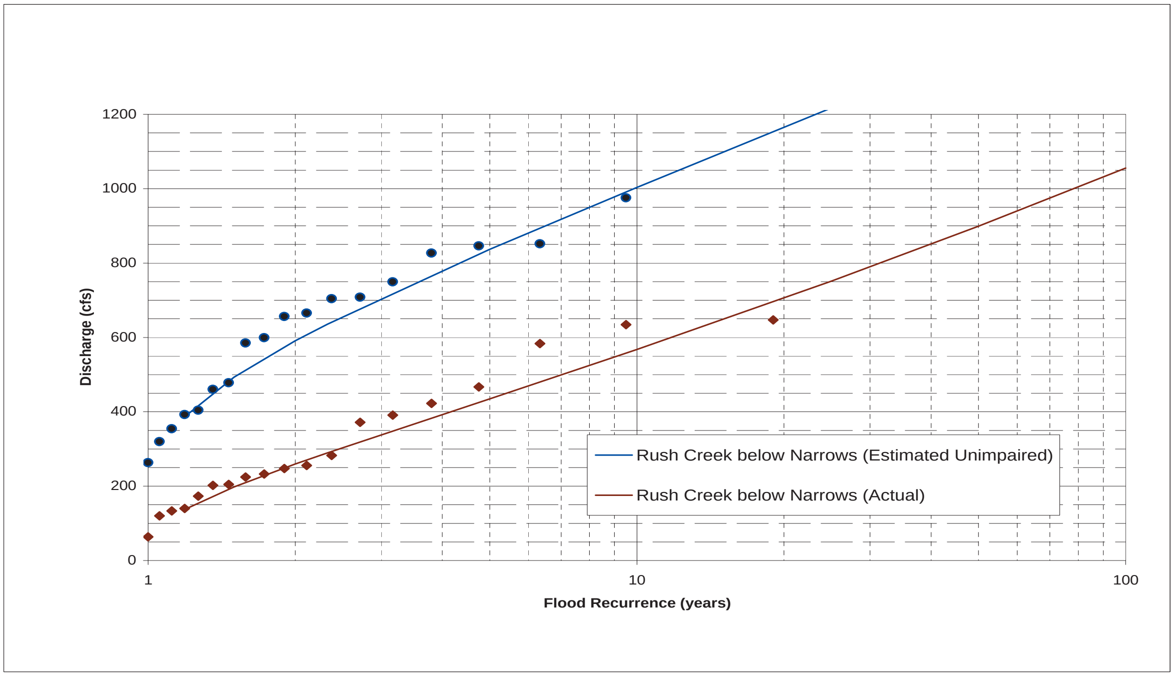
(6) Data Source: Uses 'Rush Creek Computed Unimpaired' for 1941-2008 and adds Parker and Walker Creek average peak flow for each water year class

(9) Data Source: LADWP Lee Vining Creek Computed Unimpaired or 'Lee Vining Creek Runoff' (Lee Vining above Intake + SCE Storage Change)

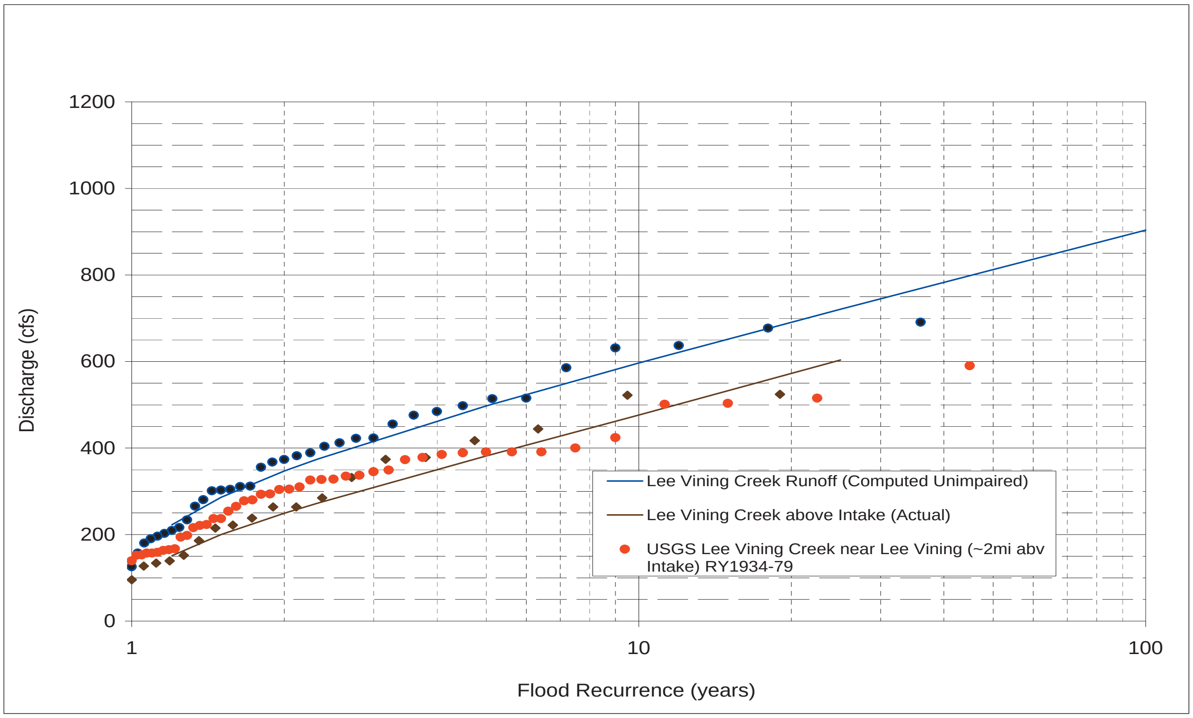
(10) Data Source: Data for 1990 - 2008 from LADWP 'Lee Vining Creek Above Intake'



Appendix A-4. Figure 1. Rush Creek at Damsite (actual) and Rush Creek Runoff (computed unimpaired) flood frequency analysis for Runoff Years 1941-2008.



Appendix A-4. Figure 2. Rush Creek below Narrows (actual) and Rush Creek below Narrows (computed unimpaired) flood frequency analysis.

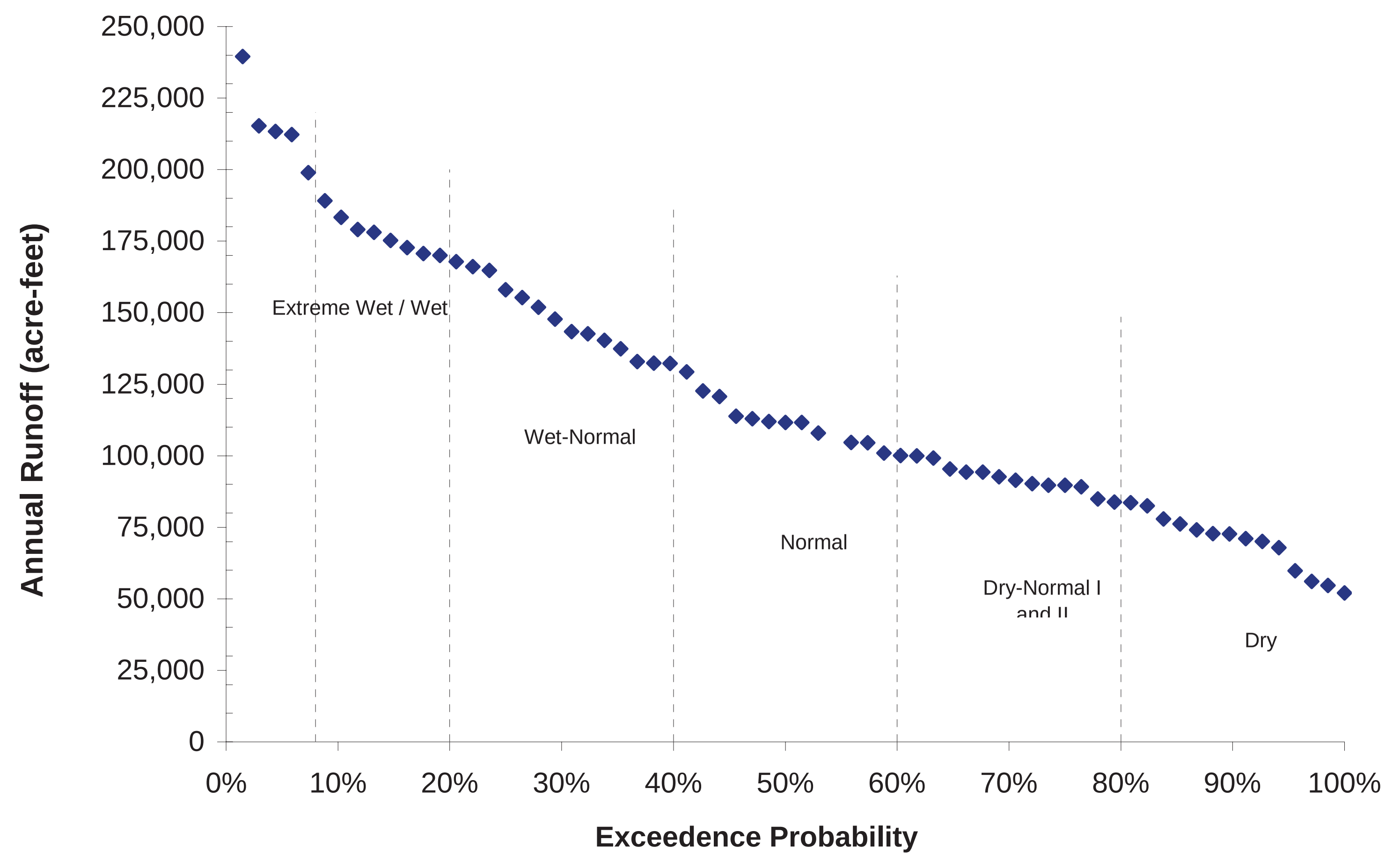


Appendix A-4. Figure 3. Lee Vining Creek above Intake (actual) and Lee Vining Creek Runoff (computed unimpaired) flood frequency analysis for Runoff Years 1973-2008.

APPENDIX A-5. SUMMARY INFORMATION

Appendix A-5. Table 1. Mono Basin annual yield for Runoff Years 1941-2008.

Runoff Year	Runoff for Mono Basin Tributaries (Rush, Parker, Walker, Lee Vining)	Percent of Average Runoff	Runoff Year Type	Rank	Exceedence Probability	Rush Creek at Damsite (af)	Lee Vining Creek above Intake (af)	Parker Creek above Intake (af)	Walker Creek above Intake (af)
1941	183,298	150.1%	WET	7	10%	84,976	65,414		
1942	166,120	136.0%	WET/NORMAL	15	22%	72,982	77,594		
1943	151,895	124.4%	WET/NORMAL	19	28%	63,174	74,834		
1944	100,903	82.6%	NORMAL	39	57%	50,358	34,270		
1945	155,308	127.2%	WET/NORMAL	18	26%	73,248	57,444		
1946	129,306	105.9%	NORMAL	28	41%	66,895	49,077		
1947	83,586	68.4%	DRY	55	81%	35,234	30,824		
1948	94,295	77.2%	DRY/NORMAL II	44	65%	49,968	40,039		
1949	89,708	73.5%	DRY/NORMAL I	50	74%	50,680	28,274		
1950	111,973	91.7%	NORMAL	33	49%	51,565	45,496		
1951	111,651	91.4%	NORMAL	34	50%	48,688	50,444		
1952	175,249	143.5%	WET	10	15%	90,020	66,631		
1953	95,382	78.1%	DRY/NORMAL II	43	63%	43,668	38,782		
1954	83,776	68.6%	DRY/NORMAL I	54	79%	40,167	31,751		
1955	99,234	81.3%	DRY/NORMAL II	42	62%	53,299	36,055		
1956	167,862	137.5%	WET	14	21%	80,586	66,226		
1957	104,570	85.6%	NORMAL	38	56%	46,296	40,319		
1958	158,038	129.4%	WET/NORMAL	17	25%	77,655	57,444		
1959	74,091	60.7%	DRY	59	87%	33,277	29,761		
1960	71,000	58.1%	DRY	62	91%	36,061	29,861		
1961	72,644	59.5%	DRY	61	90%	33,035	31,174		
1962	132,382	108.4%	WET/NORMAL	26	38%	66,315	48,919		
1963	137,370	112.5%	WET/NORMAL	24	35%	64,066	50,398		
1964	84,864	69.5%	DRY/NORMAL I	53	78%	42,443	36,025		
1965	142,599	116.8%	WET/NORMAL	22	32%	69,642	53,979		
1966	94,271	77.2%	DRY/NORMAL II	45	66%	49,567	34,270		
1967	198,927	162.9%	EXTREME WET	5	7%	104,315	65,592		
1968	82,467	67.5%	DRY	56	82%	39,388	32,426		
1969	213,384	174.7%	EXTREME WET	3	4%	108,458	77,117		
1970	104,683	85.7%	NORMAL	37	54%	47,764	42,750		
1971	113,861	93.2%	NORMAL	31	46%	51,229	42,890		
1972	91,468	74.9%	DRY/NORMAL I	47	69%	46,330	33,478		
1973	132,914	108.8%	WET/NORMAL	25	37%	67,628	46,979		
1974	132,217	108.3%	WET/NORMAL	27	40%	63,578	50,248		
1975	120,726	98.9%	NORMAL	30	44%	58,892	44,121		
1976	54,719	44.8%	DRY	67	99%	25,575	21,311		
1977	52,093	42.7%	DRY	68	100%	25,291	18,227		
1978	179,090	146.6%	WET	8	12%	97,880	58,030		
1979	122,670	100.4%	NORMAL	29	43%	59,811	44,062		
1980	170,001	139.2%	WET	13	19%	83,240	63,046	10,855	7,990
1981	100,062	81.9%	DRY/NORMAL II	40	59%	48,657	36,625	6,967	4,518
1982	212,296	173.8%	EXTREME WET	4	6%	105,591	83,134	11,508	9,482
1983	239,529	196.1%	EXTREME WET	1	1%	118,178	90,865	15,350	12,132
1984	147,719	121.0%	WET/NORMAL	20	29%	65,279	62,222	8,834	6,810
1985	107,892	88.3%	NORMAL	36	53%	50,563	42,597	6,516	4,687
1986	170,669	139.8%	WET	12	18%	80,627	67,517	10,867	7,793
1987	67,911	55.6%	DRY	64	94%	34,441	24,485	4,662	3,129
1988	70,036	57.3%	DRY	63	93%	31,677	26,625	4,576	3,232
1989	89,725	73.5%	DRY/NORMAL I	49	72%	42,136	37,126	4,599	3,692
1990	59,782	49.0%	DRY	65	96%	32,246	20,144	4,412	2,433
1991	77,935	63.8%	DRY	57	84%	38,137	26,644	5,890	3,191
1992	72,766	59.6%	DRY	60	88%	39,033	25,173	5,793	3,135
1993	140,291	114.9%	WET/NORMAL	23	34%	73,320	50,313	7,346	5,225
1994	76,218	62.4%	DRY	58	85%	36,619	28,308	5,448	3,509
1995	215,252	176.3%	EXTREME WET	2	3%	110,105	76,813	14,555	9,303
1996	164,817	135.0%	WET/NORMAL	16	24%	78,862	65,295	10,776	7,491
1997	143,433	117.4%	WET/NORMAL	21	31%	63,618	60,554	8,537	6,522
1998	172,744	141.4%	WET	11	16%	86,259	64,044	11,546	8,320
1999	112,946	92.5%	NORMAL	32	47%	51,755	46,773	7,332	5,061
2000	111,621	91.4%	NORMAL	35	51%	57,064	41,236	7,760	4,524
2001	92,630	75.8%	DRY/NORMAL II	46	68%	48,732	32,613	7,809	3,927
2002	90,227	73.9%	DRY/NORMAL I	48	71%	41,264	37,463	6,343	3,779
2003	100,000	81.9%	DRY/NORMAL II	41	60%	50,257	41,342	7,492	3,861
2004	89,101	73.0%	DRY/NORMAL I	51	75%	44,533	34,779	6,118	3,671
2005	178,105	145.8%	WET	9	13%	91,786	65,677	12,616	8,026
2006	189,157	154.9%	WET	6	9%	93,909	74,558	12,463	8,227
2007	56,069	45.9%	DRY	66	97%	22,122	24,097	5,020	2,330
2008	85,709	70.2%	DRY/NORMAL I	52	76%	40,380	32,302	6,031	3,329
2009		88% (Predicted)	NORMAL						
1941-2008 Average F	**121,695**					**59,270**	**46,543**	**8,208**	**5,494**
1941-1990 Average F	**122,124**					**122,124**	**122,124**	**122,124**	**122,124**



Appendix A-5. Figure 1. Mono Basin annual yield for Runoff Years 1941-2008.

Appendix A-5. Table 2. Comparison of forecasted runoff year type and actual runoff for Runoff Years 1970-2009.

Year	April 1 Runoff Forecast	Year Type	Actual Runoff (April-March)	Year Type	Forecast Error
1970	92%	Normal	86%	Normal	-6.5%
1971	88%	Normal	93%	Normal	5.0%
1972	72%	Dry-Normal	75%	Dry-Normal	2.9%
1973	111%	Wet-Normal	109%	Wet-Normal	-2.2%
1974	113%	Wet-Normal	108%	Wet-Normal	-4.8%
1975	97%	Normal	99%	Normal	1.6%
1976	45%	Dry	45%	Dry	0.3%
1977	36%	Dry	43%	Dry	6.8%
1978	142%	Wet	147%	Wet	5.0%
1979	109%	Wet-Normal	100%	Normal	-8.6%
1980	146%	Wet	139%	Wet	-6.9%
1981	83%	Normal	82%	Normal	-0.6%
1982	145%	Wet	174%	Extreme-Wet	28.9%
1983	185%	Extreme-Wet	196%	Extreme-Wet	11.6%
1984	119%	Wet-Normal	121%	Wet-Normal	2.5%
1985	89%	Normal	88%	Normal	-0.5%
1986	155%	Wet	140%	Wet	-15.3%
1987	57%	Dry	56%	Dry	-1.4%
1988	57%	Dry	57%	Dry	0.0%
1989	81%	Dry-Normal	74%	Dry-Normal	-7.0%
1990	55%	Dry	49%	Dry	-6.3%
1991	64%	Dry	64%	Dry	0.0%
1992	68%	Dry	60%	Dry	-8.0%
1993	134%	Wet-Normal	115%	Wet-Normal	-19.0%
1994	51%	Dry	62%	Dry	11.0%
1995	165%	Extreme-Wet	176%	Extreme-Wet	11.0%
1996	115%	Wet-Normal	135%	Wet-Normal	20.0%
1997	125%	Wet-Normal	117%	Wet-Normal	-8.0%
1998	134%	Wet	141%	Wet	7.0%
1999	99%	Normal	95%	Normal	-4.0%
2000	94%	Normal	94%	Normal	0.0%
2001	74%	Dry-Normal	76%	Dry-Normal	2.0%
2002	76%	Dry-Normal	74%	Dry-Normal	-2.0%
2003	72%	Dry-Normal	86%	Normal	14.0%
2004	79%	Dry-Normal	73%	Dry-Normal	-6.0%
2005	132%	Wet-Normal	147%	Wet	15.0%
2006	147%	Wet	152%	Wet	5.0%
2007	52%	Dry	46%	Dry	-6.0%
2008	86%	Normal	70%	Dry-Normal	-16.0%
2009	88%	Normal			

Appendix A-5. Table 3. Rush Creek streamflow gains and losses.

		M&T and MLC DATA RY 2008												M&T and MLC DATA RY 2009				CDFG (1987) Data from PHABSIM STUDY			
Measurement Location	Stream Mile	20-Mar	12-Jun	17-Jul	12-Aug	14-Aug	16-Aug	19-Aug	20-Aug	21-Aug	31-Aug	15-Sep	29-Sep	3-May	4-Jun	10-Jul	28-Jul	21-Aug	5-Sep	22-Oct	28-Nov
MGORD	1.4	26.2	323.4*	46.6*	47.7	61.3	90.9	33.6	31.3	18.8	34.4	50.4	48.5	23.0	47.8	48.5	48.9	18.2	61.0	12.8	20.4
Rush Creek abv Parker Creek	4.9	24.2		32.5											41.8	49.7	39.3	13.4	54.2	10.9	17.6
Parker Creek at Hwy 395		3.0	23.0	21.7+										6.4	27.6	16.8	18.4				
Walker Creek at confluence		6.2	16.1	6.1										6.6	17.4	7.6	4.8				
Rush below Narrows (MGORD+Parker+Walker	5.6	34.6 t	362.5 t	73.6 t	57.4	69.1	98.0	39.7	40.3	24.2	41.4	56.8	53.7	36.0	92.8	73.0	72.1	12.6	54.7	10.9	17.6
Rush below Narrows (Sum of Measured Flows)	5.6	33.4		60.3											86.8	74.2	62.5				
Lower Rush Creek Mainstem blw 10 Falls	7.6	27.3	358.0	59.1	45.7	57.6	77.3	27.1	28.8	14.1	30.0	46.7	44.5	25.1	92.2	69.8	63.8	12.2	49.5	8.9	
Rush Creek at County Road	9.1	27.3														71.5	56.7	9.0	49.4	8.1	13.5
Net Loss MGORD to Parker		1.9		14.1											6.0	-1.2	9.6	4.8	6.8	1.9	2.8
Rate of Flow Loss (cfs/mi)		0.6		4.0											1.7	-0.3	2.7	1.4	1.9	0.6	0.8
Net Loss Narrows to Lower Rush		6.1		1.2											-5.3	4.4	-1.3	0.4	5.2	2.0	17.6
Rate of Flow Loss (cfs/mi)		3.0		0.6											-2.7	2.2	-0.6	0.2	2.6	1.0	8.8
Net Loss MGORD to Lower Rush		7.3	4.5	14.5	11.8	11.5	20.7	12.6	11.5	10.1	11.4	10.1	9.2	10.9	0.6	3.2	8.3	0.4	5.2	2.0	17.6
Rate of Flow Loss (cfs/mi)		1.2	0.7	2.3	1.9	1.9	3.3	2.0	1.8	1.6	1.8	1.6	1.5	1.8	0.1	0.5	1.3	0.1	0.8	0.3	2.8

*=Daily Average Discharge from MGORD Rating Curve (i.e., not directly measured)
t=Daily Average Discharge from MGORD+Parker+Walker releases
+=Measurement confounded by an instantaneous pulse flow release from Parker Conduit by LADWP

Appendix A-5. Table 4. Parker and Walker Creek streamflow gains and losses.

YEAR	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**Average by Month**
YEAR-TYPE	Dry	Dry	Dry	W/N	Dry	ExW	W/N	W/N	Wet	Nor	Nor	D/N2	D/N1	D/N2	D/N1	Wet	Wet	Dry	Nor	
Oct	3.3	6.0	5.6	7.3	7.2	15.6	9.1	12.1	12.9	9.8	7.5	5.6	5.0	5.9	5.7	9.1	9.6	5.4	5.0	**7.8**
Nov	7.3	7.8	5.1	7.1	8.3	12.2	15.4	7.9	13.6	10.6	10.5	9.2	10.6	5.4	7.5	7.5	7.9	4.4	7.1	**8.7**
Dec	5.6	5.9	5.5	7.9	6.1	10.0	11.2	7.4	9.2	8.1	6.1	7.5	6.4	5.6	7.1	9.0	7.4	5.2	5.7	**7.2**
Jan	4.5	5.4	5.4	5.2	8.1	9.5	33.3*	7.3	8.4	6.5	5.9	6.2	5.4	5.6	6.4	12.8	6.9	5.2	5.4	**8.1**
Feb	4.3	5.5	5.1	5.3	8.7	11.8	15.7	7.8	8.9	7.5	5.8	5.9	6.0	6.1	6.8	9.4	6.9	4.9	6.1	**7.3**
Mar	4.9	6.5	8.1	6.4	15.5	12.8	16.5	9.2	8.2	8.0	8.4	6.2	6.8	9.4	8.8	9.7	7.2	6.2	6.9	**8.7**
Average by Water-year Type	**5.0**	**6.2**	**5.8**	**6.5**	**9.0**	**12.0**	**16.9**	**8.6**	**10.2**	**8.4**	**7.4**	**6.8**	**6.7**	**6.3**	**7.1**	**9.6**	**7.7**	**5.2**	**6.0**	**8.0**

Dry (5 years) = 6.2 cfs average
Dry-Normal (4 years) = 6.7 cfs average
Normal (3 years) = 7.3 cfs average
Wet-Normal (2 years) = 7.6 cfs…………………excluded the 1996 average because of the Jan 1st flood*.
Wet/Extreme Wet (4 years) = 9.9 cfs average

APPENDIX A-6. RAMPING RATE ANALYSIS AND MEMORANDUM PRESENTED IN RY2002

McBain & Trush
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April 16, 2002

TO: Steve McBain
Los Angeles Department of Water and Power
111 N. Hope Street, RM1469
Los Angeles, Ca. 90012

RE: Comparison of snowmelt ascending limb ramping rates from unregulated hydrographs with regulated Grant Lake releases to Rush Creek

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The State Water Board Decision 1631 specified maximum rates of change in flow for the Mono Basin tributaries. These rates are determined based on a percentage of change in flow from the average flow over the preceding 24 hours. Currently the maximum ramping rates are (LADWP 2000):

- Lee Vining Creek: not to exceed 20% change during ascending streamflows and 15% during descending streamflows per 24 hours.
- Walker Creek: not to exceed 10% change during ascending or descending streamflows per 24 hours.
- Parker Creek: not to exceed 10% change during ascending or descending streamflows per 24 hours.
- Rush Creek: not to exceed 10% change during ascending or descending streamflows per 24 hours.

The April 1 Runoff Forecast for the Mono Basin was 71% of normal, projecting to approximately 93,000 acre-feet of runoff. This runoff forecast falls within the Mono Basin Operations-Planning Guideline C (forecasted runoff volume 92,207< - <100,750 acre-feet), which will require Rush Creek baseflows of 44 and 47 cfs, and a peak snowmelt release of 250 cfs for 5 consecutive days. During the ascending snowmelt hydrograph, to double the flow from a 47 cfs baseflow to 100 cfs, the current 10% maximum rate of change rule requires increasing flows from 4.7 to 9 cfs per day for 7 days; to achieve the targeted 250 cfs peak for RY 2002 would require 19 days (assuming 47 cfs baseflow).

The goal of this technical memorandum is to evaluate the natural range of variability in ascending limb ramping rates from unregulated streams draining the Eastern Sierra, then use this natural range as a basis for comparing existing or proposed regulated ramping rates for Rush Creek. LADWP is exploring alternative ramping rates for Rush Creek during the ascending limb of peak flow releases for the 2002 runoff season for several reasons. First, synchronizing peak flow releases with the peak in cottonwood seed dispersal may help promote cottonwood regeneration within the Rush Creek corridor. Presently, LADWP personnel rely on field observations to determine cottonwood seed development and seed dispersal timing. A long-duration ascending hydrograph limb makes it difficult to time the snowmelt peak to the ideal cottonwood seed dispersal period. Second, a shorter overall ramping period (ascending limb only) could allow Rush Creek peaks to be released concurrent with Parker and/or Walker Creek peaks, thus achieving a higher overall peak discharge, and more natural daily variation in discharge in Lower Rush Creek reaches (below the Narrows). Finally, the outlet works at the Mono Gate Control House does not provide real-time discharge for the portion of flows released to the Rush Creek Return Ditch when LADWP is diverting water. Maintaining maximum ramping rates within the existing 10% maximum daily change is difficult. Reducing the duration of the ascending limb would minimize operational difficulties.

We evaluated ascending limb ramping rates for several gaged streams draining the Eastern Sierra, including Convict Creek (Owens Basin), Lee Vining, Parker, and Walker Creeks in the Mono Basin, and Buckeye and Virginia Creeks (Walker Basin). Our approach was based on analysis of the ascending limb of each creeks' snowmelt hydrograph to determine a natural range of variability in the rate of change in daily average flows. For each of the creeks, we looked at the maximum daily change in discharge, the maximum 2-day average change in discharge, and the maximum 3-day average change in discharge during the snowmelt ascending limb. Maximum changes in discharge would be expected to be higher within a single day, and decrease when averaged over the course of several days (i.e., maximum rates of increase are generally not sustained for long periods). We converted these rates to unit runoff (cfs/day/mi^2) using drainage area to facilitate comparisons. We then examined how ramping rates would translate to changes in water surface elevation at Rush Creek study site cross sections. We did not assess other geomorphic or any biological implications of these ramping rates.

Lee Vining Creek had the highest natural ramping rates, occasionally exceeding 80 cfs/day (Table 1). These rates may also be due to SCE operations upstream. Walker Creek had the lowest overall ramping rates of the creeks evaluated, potentially due to flow dampening by Walker Lake. Convict Creek was nearest the median of the creeks evaluated, and because it is unregulated, was used as a model for additional analyses.

Table 1. Ramping rates measured during the ascending snowmelt hydrograph for selected streams in the Eastern Sierra vicinity of Rush Creek.

	Drainage Area (mi^2)	1-day avg ramp-up (cfs/sq mi)	2-day avg ramp-up (cfs/sq mi)	3-day avg ramp-up (cfs/sq mi)	1-day avg ramp-up (cfs)	2-day avg ramp-up (cfs)	3-day avg ramp-up (cfs)
Lee Vining Creek above Intake	35.2	2.34	1.78	1.36	82.4	62.7	47.9
Parker Creek	12.2	1.19	0.80	0.63	14.5	9.8	7.7
Walker Creek	7.8	0.46	0.34	0.27	3.6	2.7	2.1
Convict Creek at Mammoth	18.7	0.98	**0.75**	0.66	18.3	14.0	12.3
Buckeye Creek near Bridgeport	44.1	1.37	0.83	0.6	60.4	36.6	26.5
Virginia Creek near Bridgeport	63.6	0.93	0.66	0.46	59.1	42.0	29.3
Rush Creek at Damsite (modeling from Convict Creek)	51.2	0.98	0.75	0.66	50.2	38.4	33.8

We selected the 2-day average change in discharge (cfs) for Convict Creek as a median value within the range of natural variability for the streams we evaluated. This ramping rate was converted based on drainage area, then applied to the anticipated Rush Creek Operations Guideline C, which requires peak releases of 250 cfs for 5 days. The Convict Creek rate of 0.75 cfs/sq mi/day would allow ramping rates of approximately 38 cfs/day for Rush Creek releases. We plotted this "2-day average rate" as an annual hydrograph of daily average flows, along with the extended ramping rate required by the SWRCB "10%

maximum" rule (Figure 1). Compared to the existing 19 day ramping period with the 10% rule, the 2-day average rate (38 cfs/day) would require 7 days to attain the maximum discharge of 250 cfs on Rush Creek. We also compared this rate (38 cfs/day) to the Lee Vining Creek maximum allowed ramping rate of 20% during the ascending limb. These two rates (2-day average and 20% rule) produced very similar hydrograph limbs (Figure 1). With a 20% maximum ramping rule, Rush Creek would require 10 days to attain the targeted peak discharge of 250 cfs. The primary difference, however, is that the 20% rule softens the initial jump in discharge, then increases exponentially for 9 days instead of increasing linearly for 7 days (Figure 1).

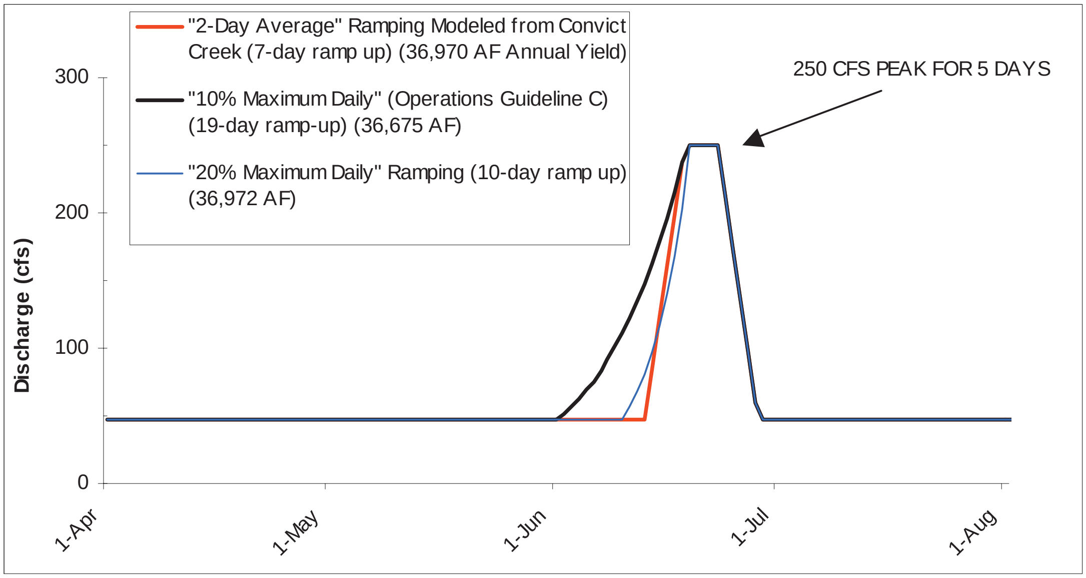


Figure 1. Three alternative Rush Creek snowmelt ascending limbs for RY 2002. Hydrographs would only change in the ascending limb; all other components to the hydrograph follow the SWRCB Operational Guideline C.

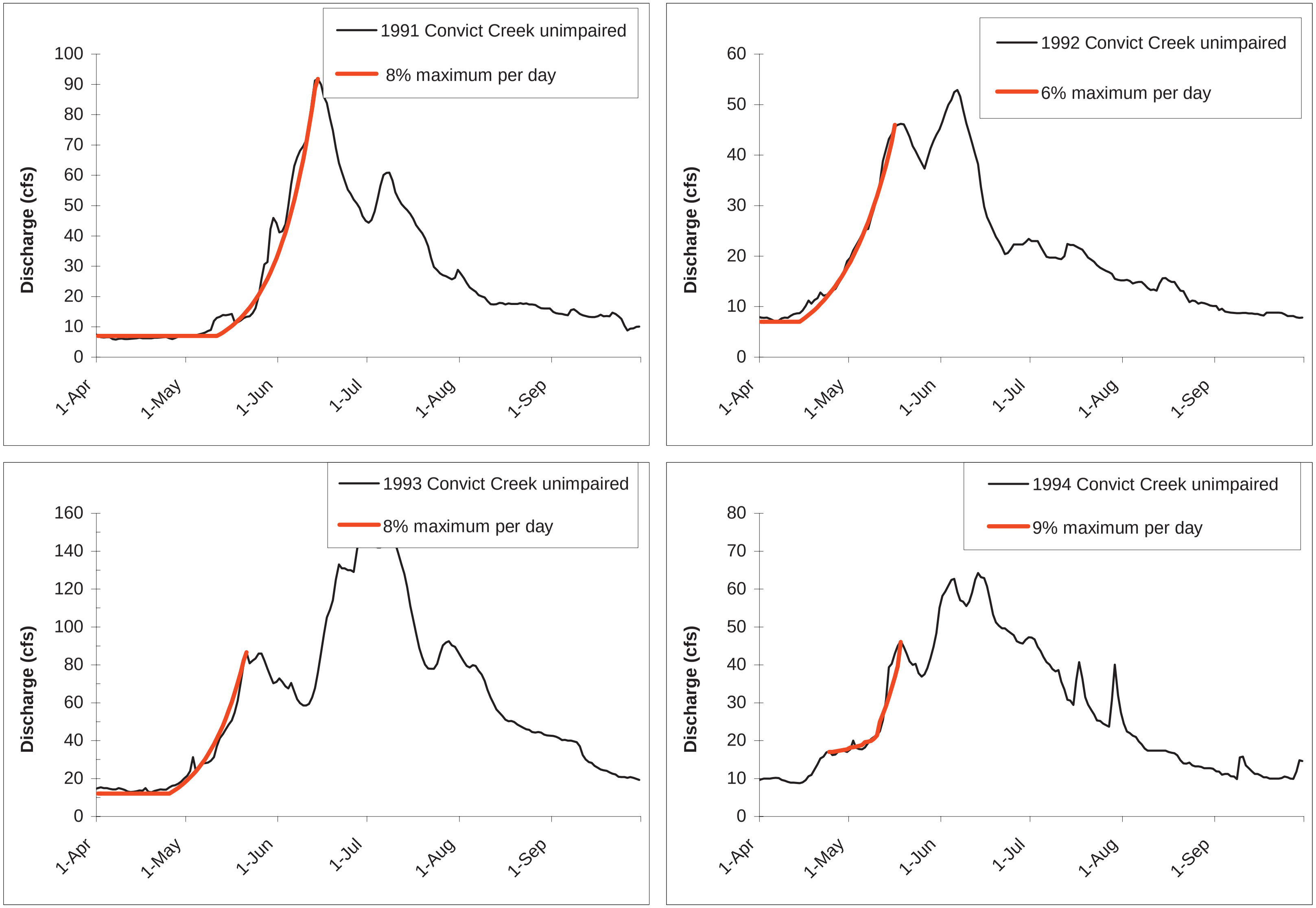
Using the modeled Rush Creek daily discharge changes for the 2-day average rule and the 20% maximum rule and stage-discharge rating curves developed for our study site cross sections, we evaluated potential changes in water surface elevation. We tested the different hydrographs at three cross sections in Lower Rush Creek and one cross section in Upper Rush Creek. For the 2-day average rule (modeled from Convict Creek), the maximum increase in water surface elevation of 0.36 ft (4 inches) would occur during the first day of ramping, and water surface elevation would increase by a maximum of 0.24 ft thereafter. Using the 20% rule, the maximum increase in elevation at our cross sections was only 0.16 ft (less than 2 inches), occurring on the last day of ramping (Table 2). Using the existing 10% maximum ramping rate for Rush Creek, water surface elevation changes ranged between 0.6 and 0.7 ft per day. Stage increases were quite consistent among the different cross sections (Table 2).

Next, we fit a curve to each of the Convict Creek ascending limbs, using a percentage daily increase to obtain a range of values for natural hydrographs (Figure 2). This task was somewhat challenging given the irregularities in natural hydrographs, and thus required some subjective curve fitting. We noted at least two patterns in the natural hydrographs. First, dryer water year types generally peak earlier in the season, and may have less steep ascending hydrographs, whereas wetter years generally appear steeper. Second, many Convict Creek hydrographs had slower ascending limbs leading to preliminary peaks, followed by descending discharge, then rapid ascent to the annual maximum. This two-stage ascending limb is more difficult to mimic with regulated hydrographs. Finally, we plotted each fitted curve on a single chart, along with curves using a 5%, 10%, and 20% maximum change per day rule (Figure 3). Using Convict Creek as a representative natural runoff pattern, most hydrographs were contained between the 5% and 10% maximum ramping rates. The 20% maximum ramping rate is considerably outside the natural rates from Convict Creek.

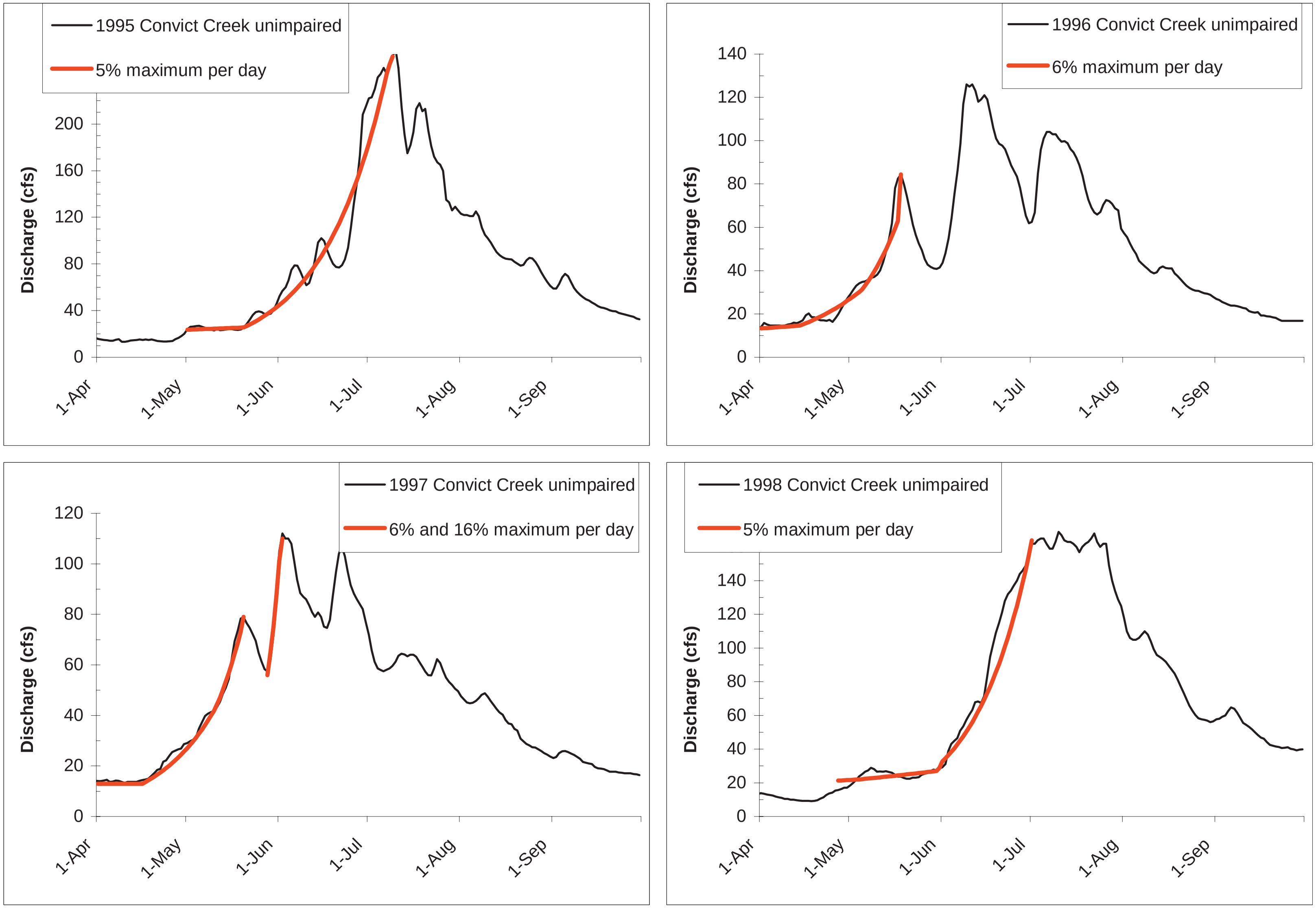
Table 2. Water surface elevation changes predicted at Rush Creek cross sections for the ascending hydrograph limb using the 20% and 10% maximum daily change rule, based on stage-discharge rating curves developed at each cross section.

	WATER SURFACE STAGE CHANGE (ft)			
ASCENDING HYDROGRAPH (CFS) USING 20% RULE	**Lower Rush Creek XS 10+10**	**Lower Rush Creek XS 7+25**	**Upper Rush Creek XS 1+05**	**Lower Rush Creek XS -9+82**
47				
56	0.09	0.10	0.09	0.11
68	0.09	0.10	0.09	0.11
81	0.09	0.11	0.09	0.11
97	0.09	0.11	0.10	0.12
117	0.10	0.11	0.10	0.12
140	0.10	0.12	0.10	0.12
168	0.10	0.12	0.10	0.13
202	0.10	0.12	0.11	0.13
250	0.12	0.15	0.13	0.16

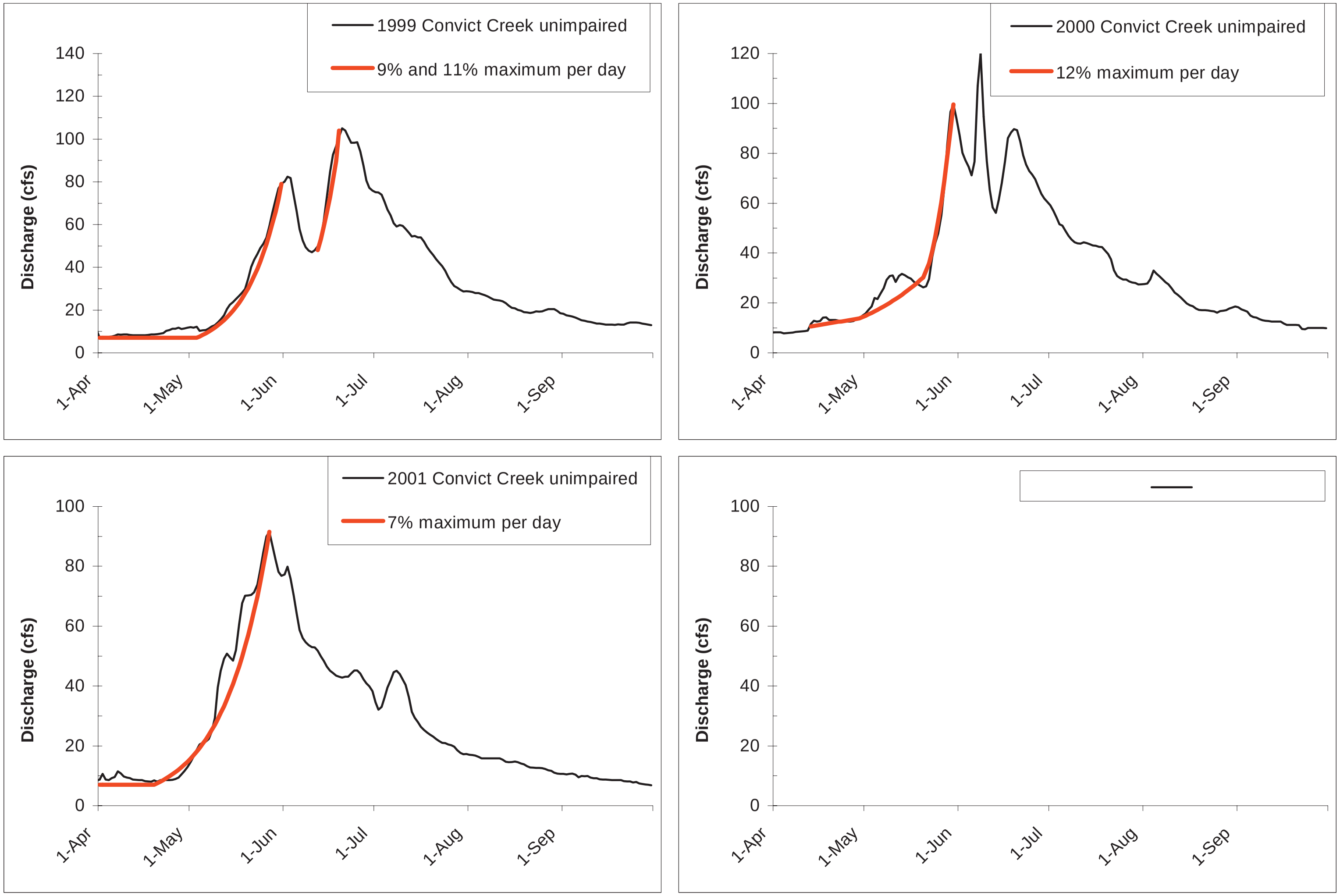
	WATER SURFACE STAGE CHANGE (ft)			
ASCENDING HYDROGRAPH (CFS) USING 10% MAX	**Lower Rush Creek XS 10+10**	**Lower Rush Creek XS 7+25**	**Upper Rush Creek XS 1+05**	**Lower Rush Creek XS -9+82**
47				
52	0.04	0.05	0.05	0.06
57	0.05	0.05	0.05	0.06
63	0.05	0.05	0.05	0.06
69	0.05	0.06	0.05	0.06
76	0.05	0.06	0.05	0.06
83	0.05	0.06	0.05	0.06
92	0.05	0.06	0.05	0.06
101	0.05	0.06	0.05	0.06
111	0.05	0.06	0.05	0.06
122	0.05	0.06	0.05	0.06
134	0.05	0.06	0.05	0.06
148	0.05	0.06	0.05	0.07
162	0.05	0.06	0.05	0.07
178	0.05	0.06	0.06	0.07
196	0.05	0.07	0.06	0.07
216	0.05	0.07	0.06	0.07
238	0.06	0.07	0.06	0.07
250	0.03	0.04	0.03	0.04



Convict Creek abv Hwy 395 (Station # 4014)



Convict Creek abv Hwy 395 (Station # 4014)



Convict Creek abv Hwy 395 (Station # 4014)

Figure 2. Convict Creek near Mammoth annual hydrographs during snowmelt runoff, with fitted curve superimposed to show the maximum rate of increase.

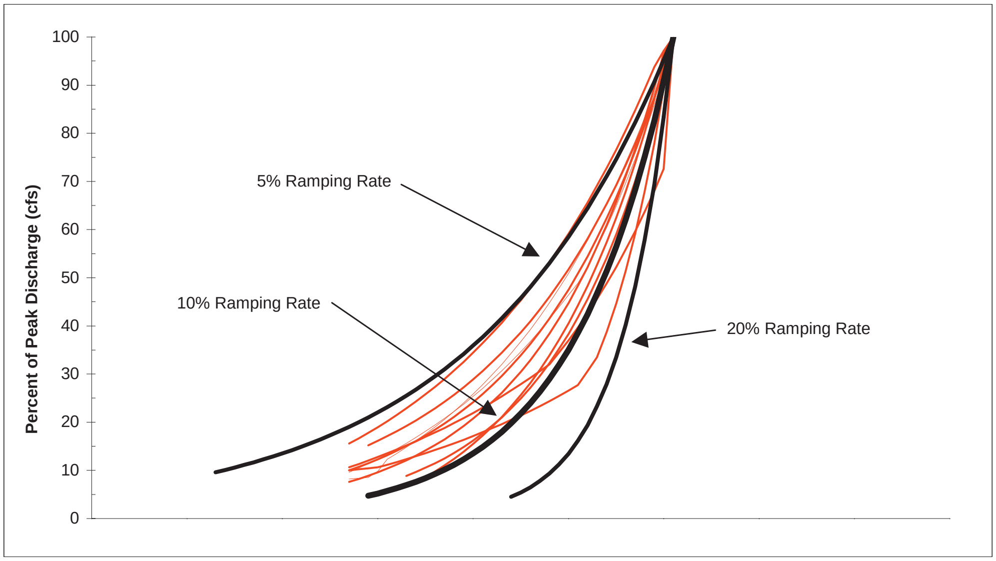


Figure 3. Ascending limb hydrographs from Convict Creek "standardized" based on the percentage of the annual peak magnitude, to compare the natural range in ramping rates to alternative regulated conditions.

APPENDIX B. GEOMORPHOLOGY

Geomorphic evaluations conducted during the past 12 runoff years in Rush and Lee Vining creeks for this synthesis report have included several data collection efforts quantifying the geomorphic responses to peak flood magnitude and duration, including:

- Cross section and longitudinal profile surveys
- Channelbed mobility and bed scour experiments
- Sediment transport measurements
- Floodplain inundation mapping
- Floodplain deposition measurements
- Large wood transport measurements

This Appendix describes data that have been collected and reported in previous annual reports, references specific sections of annual reports where specific data results and summaries are presented, and in some cases, re-presents entire sections of previous Annual Reports that presented detailed analyses that form the basis for conclusions and SEF flow recommendations contained in this Synthesis Report.

In this Appendix, we reference the following data and analyses:

B-1: Cross Section Surveys

There are 53 cross sections installed on Rush, Parker, Walker, and Lee Vining creeks monumented with rebar and referenced with X–Y–Z coordinates. These cross sections have been monitored to track changes in channelbed and water surface elevations through time and in relation to discharge and SRF flow releases. During initial years of monitoring, cross sections were typically resurveyed annually. All Rush Creek and Lee Vining Creek cross sections were resurveyed in 2004, and selected cross sections were re-surveyed in RY 2005 and 2006. In Rush Creek, cross sections were most recently resurveyed in October 2008 following the Rush Creek habitat mapping. In Lee Vining, cross sections were resurveyed in July 2009 following the Lee Vining Creek habitat mapping. The habitat mapping test flow releases provided opportunity to collect stage-discharge data for each cross section over the range of baseflows evaluated (15 to 90 cfs on Rush Creek; 12 to 54 cfs on Lee Vining Creek). Cross section survey and water surface elevation data were presented for Rush Creek in RY 2008 Annual Report (M&T 2009), and will be presented for Lee Vining Creek in the upcoming RY 2010 Annual Report.

B-2: Channelbed Mobility and Scour Experiments

Bed mobility and scour experiments were conducted on Rush and Lee Vining creeks for eight consecutive years, from RY 1997 through 2005 (excluding RY 2003). The bed mobility experiments were designed to test the effect of flood magnitude on surface particle mobility thresholds and scour depths. The RY 2001 Annual Report presented field methods and a description of targeted mobility thresholds. Mobility data span a wide range of snowmelt floods, and most tracer rock sets within the bankfull channel achieved near total mobility. Summary tables for bed mobility and scour from RY 2005 are re-presented in this Appendix for Rush Creek (Tables B1 and B2) and Lee Vining

Creek (Tables B-3 and B-4. Bed mobility charts are also presented for Rush Creek (Figure B1) and Lee Vining Creek (Figure B-2).

Three geomorphic features were targeted for estimating surface mobility thresholds: pool-tails, riffles, and point bars. In RY 2001 Annual Report (M&T 2002) we defined "total" mobility of those geomorphic features occurring at approximately 80% mobility of the tracer rock cross section. Mobility rating curves at Upper Rush Creek XS 12+95 and another at Lower Rush Creek XS 10+10 (both sites are pool tails) showed a consistent trend in increasing mobility with discharge. The mobility threshold for each site was different, however. In Upper Rush Creek, bed mobility occurred between approximately 450 and 550 cfs. In Lower Rush Creek, mobility occurred between approximately 200 and 250 cfs.

On Rush Creek, mobility thresholds were exceeded for 50-80% of D31 and D50 tracer rocks placed on pool tails at approximately 200 to 250 cfs. In many cases 100% of the tracers moved. Tracer rocks on riffles were generally mobilized (80% mobility) at flows of approximately 325-375 in Lower Rush Creek (3 sites), 440 cfs in the 10-Channel (one site), and at 400-625 cfs in Upper Rush Creek. Point bar and floodplain features were either mobilized by the highest flow observed during our study period, or not at all (2 sites). Lower Rush Creek XS -5+07 above the 10 Channel Falls is a good example of a lateral bar feature, that had more than 90% of D_{84}, D_{50}, and D_{31} particles mobilized by the RY 1998 flow of 635 cfs below the Narrows. The surface of the right bank bar feature at Rush Creek County Road reach XS 6+85 did not mobilize during the eight years of mobility studies.

On Lee Vining Creek, tracer rock sets were monitored for six years beginning 1999. Mobility data were more difficult to interpret than on Rush Creek: data were collected over a smaller range of flows capable of mobilizing the bed (the highest flows were 354 cfs in 1997; 391 cfs in 1998; 372 cfs in 2005), peak flows were distributed among several distributary channels and multiple channel reaches, and channel adjustments in many locations (e.g., headcuts) confounded interpretation of the bed mobility and scour data. Most bed mobility monitoring sites did not have 100% mobility across the range of flows observed. Several sites have had only limited mobility, and higher surface sites such as point bars and floodplains have had no mobility. Thresholds were identified for mobilizing pool tails at 275 cfs (A4 XS 5+15) to 390 cfs (mainstem XS 3+45). Riffles appeared to become mobilized at flows ranging between 25-325 cfs (e.g., sites at XS A4 6+80, mainstem XS 9+31, B1 XS6+08 and XS 1+80). Only one point bar, B1 XS 0+87 was observed, with mobility occurring at approximately 275-300 cfs.

B-3: Sediment Transport Measurements

Sediment transport rates were measured in Rush Creek during two runoff years: RY 2004 by Rick Poore of XX Hydrologics, and in RY 2005 by M&T. Only the RY 2005 data collected and analyzed by M&T were used in the Synthesis Report. These data were analyzed and reported in the RY 2005 Annual Report, Section 3.3 (M&T 2006). Given the detailed descriptions and relevance of the sediment transport monitoring to our final SEF flow recommendations, the entire Section 3.3 from RY 2005 Annual Report is re-presented in this Appendix.

B-4: Floodplain Inundation Mapping

During and after the RY 2004 and RY 2005 Rush Creek SRF releases, floodplains surrounding the 8, 4, and 3D channels were mapped to show (1) areas *inundated* by overbank and side channel flow that displayed standing water, and (2) areas *wetted* by groundwater or the capillary fringe intersecting the ground surface that displayed moisture but not standing water on the ground surface. We used the term *saturated* in the RY 2004 Annual Report to describe *inundated* or *wetted* areas, because mapping in 2004 did not distinguish between wetted and inundated. The objective for floodplain mapping was to estimate the area of wetted and inundated floodplains and determine the duration that floodplain soils retained moisture. Laminated aerial photographs were used for field mapping. The 8 and 4 floodplains were mapped on June 28 and August 9, 2005. The 3D Floodplain was mapped on June 29 and August 9, 2005. Those maps are presented in this Appendix. Additional description of the extent and duration of floodplain inundation is provided in the RY 2005 Annual Report, Section 2.4.

In RY 2008, the extent of surface flow was mapped from the 8 Channel downstream to the 11-Channel (Figure 12). The inundation map is presented in this Appendix.

B-5: Floodplain Deposition Experiments

Similar to sediment transport measurements, floodplain deposition was also measured during two snowmelt floods, first in RY 2004, then again in RY 2005. Both runoff year Annual Reports present results of those field experiments (M&T 2005 and 2006). However, the bigger monitoring effort in RY 2005 summarized data and results from both years. Given the detailed descriptions and relevance of floodplain deposition to our final SEF flow recommendations, the entire Section 3.4 from RY 2005 Annual Report is re-presented in this Appendix.

B-6: Large Wood Transport Experiments

Experiments tracking mobilization and transport distances of large wood pieces were conducted during two consecutive runoff years in Rush Creek, RY 2004 and 2005, and during RY 2005 in Lee Vining Creek. The final maps from Appendix E of the RY 2005 Annual Report (M&T 2006) are reprinted in this Appendix.

APPENDIX B-1. CROSS SECTION SURVEYS

- Rush Creek cross section surveys and water surface elevations can be found in the RY 2008 Annual Report (McBain & Trush 2009)
- Lee Vining Creek cross section surveys and water surface elevations will be presented in the RY 2010 Annual Report

APPENDIX B-2. CHANNELBED MOBILITY AND SCOUR EXPERIMENTS

Appendix B-2. Table 1. Rush Creek tracer rock mobility at given discharges.

Creek	Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
Lower Rush Creek	10+10	Pool Tail	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	10%	10%
			7/3/1998	224 cfs	90%	80%	80%
			9/10/1998	387 cfs	100%	100%	100%
			7/20/1999	151 cfs	20%	30%	50%
			8/12/2000	153 cfs	23%	62%	77%
			8/5/2001	102 cfs	0%	38%	63%
			6/8/2002	142 cfs	60%	100%	100%
			6/11/2004	224 cfs	80%	90%	90%
			8/19/2005	286 cfs	90%	100%	100%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	07+70	Riffle	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	0%
			7/3/1998	224 cfs	88%	100%	100%
			9/10/1998	387 cfs	100%	100%	100%
			7/20/1999	151 cfs	43%	71%	86%
			8/12/2000	153 cfs	50%	70%	100%
			8/5/2001	102 cfs	0%	20%	50%
			6/8/2002	142 cfs	40%	10%	60%
			6/11/2004	224 cfs	90%	90%	90%
			8/19/2005	286 cfs	80%	80%	90%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	07+70	Floodplain	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	0%
			7/3/1998	224 cfs	0%	0%	0%
			9/10/1998	387 cfs	0%	14%	29%
			7/20/1999	151 cfs	0%	0%	0%
			8/12/2000	153 cfs	0%	0%	0%
			8/5/2001	102 cfs	0%	0%	0%
			6/8/2002	142 cfs	0%	0%	0%
			6/11/2004	224 cfs	0%	0%	0%
			8/19/2005	286 cfs	0%	0%	0%
				maximum mobility =	0%	14%	29%
Lower Rush Creek	07+25	Riffle	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	14%
			9/10/1998	387 cfs	0%	14%	29%
			7/21/1999	151 cfs	13%	75%	75%
			8/12/2000	153 cfs	0%	13%	13%
			8/5/2001	102 cfs	20%	50%	60%
			6/8/2002	142 cfs	40%	70%	40%
			6/11/2004	224 cfs	60%	60%	100%
			8/19/2005	286 cfs	90%	100%	100%
				maximum mobility =	90%	100%	100%
Lower Rush Creek	07+25	Floodplain	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	0%
			7/3/1998	224 cfs	0%	0%	0%
			9/10/1998	387 cfs	0%	0%	0%
			7/21/1999	151 cfs	0%	0%	0%
			8/12/2000	153 cfs	0%	0%	0%
			8/5/2001	102 cfs	0%	0%	0%
			6/8/2002	142 cfs	0%	0%	0%
			6/11/2004	224 cfs	0%	0%	0%
			8/19/2005	286 cfs	0%	0%	0%
				maximum mobility =	0%	0%	0%
Lower Rush Creek	04+08	Pool Tail	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	14%
			7/3/1998	224 cfs	100%	100%	100%
			9/10/1998	387 cfs	100%	100%	100%
			7/20/1999	151 cfs	29%	43%	57%
			8/12/2000	153 cfs	20%	20%	60%
			8/5/2001	102 cfs	0%	0%	10%
			6/8/2002	142 cfs	20%	40%	40%
			6/11/2004	224 cfs	100%	100%	100%
			8/19/2005	286 cfs	90%	90%	100%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	-05+07	Point Bar	6/4/1998	56 cfs	0%	0%	0%
			7/3/1998	224 cfs	36%	57%	71%
			9/10/1998	387 cfs	93%	93%	93%
			7/20/1999	151 cfs	14%	36%	29%
			8/12/2000	255 cfs	0%	20%	30%
			8/5/2001	102 cfs	0%	0%	20%
			6/8/2002	142 cfs	10%	20%	40%
			6/11/2004	224 cfs	30%	30%	40%
			8/19/2005	286 cfs	30%	70%	90%
				maximum mobility =	93%	93%	93%

Appendix B-2. Table 2. Rush Creek scour and re-deposition at given discharges.

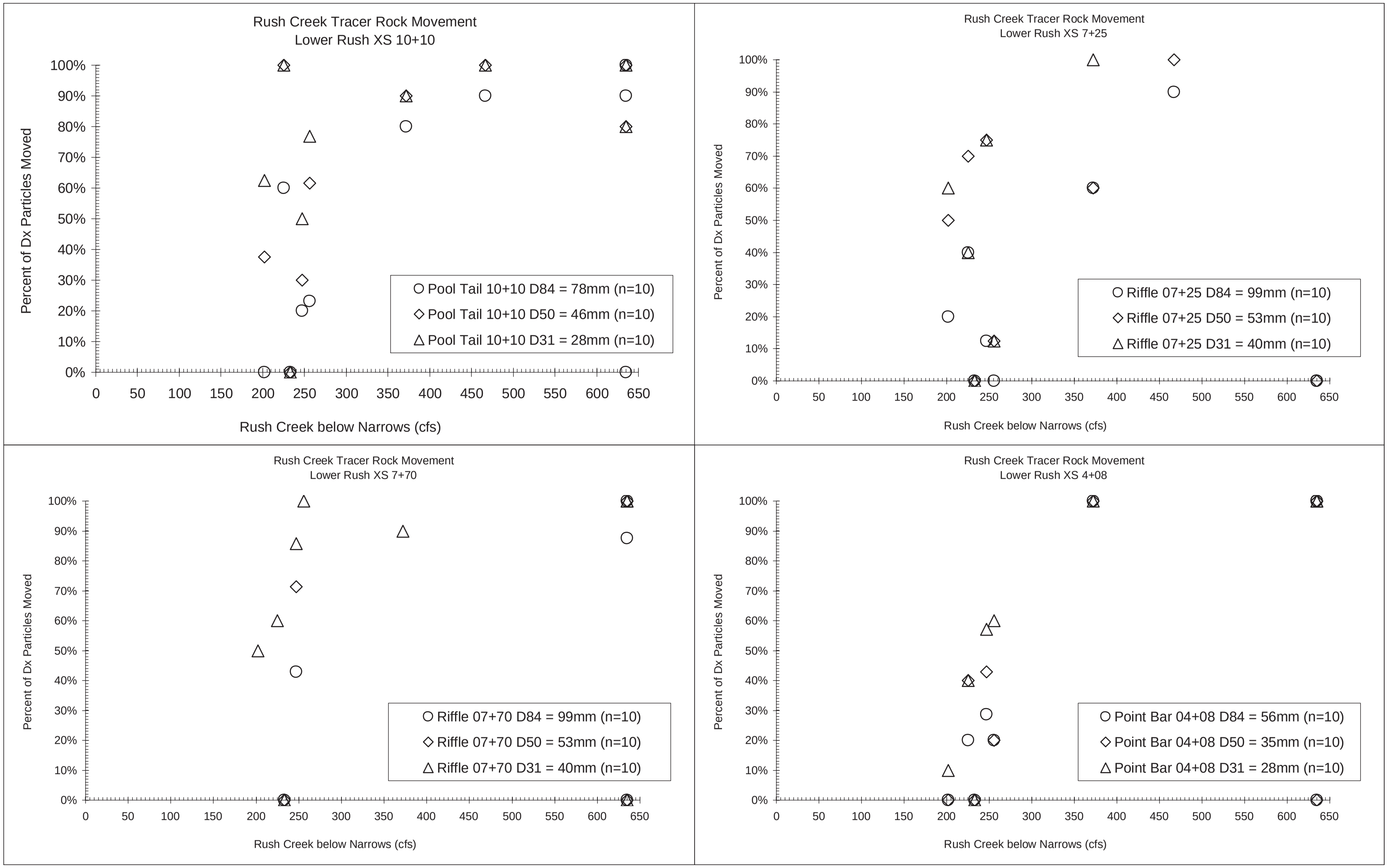
Reach	*Cross Section*	*Year*	*Discharge at Cross Section (cfs)*	*Core #*	*Scour depth (ft)*	*Redeposition depth (ft)*	*Geomorphic feature*
Lower Rush Creek	00+86	1998	396	1	0.00	0.00	Upper point bar / floodplain
				2	0.03	0.00	Middle of point bar
				3	0.21	1.14	Point bar within low water channel
				4	0.30	0.77	Point bar within low water channel
		1999	155	1	0.01	0.00	Upper point bar / floodplain
				2	0.03	0.00	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				4	-	-	Point bar within low water channel
		2000	161	1	0.01	0.00	Upper point bar / floodplain
				2	0.01	0.00	Middle of point bar
				3	0.05	0.00	Point bar within low water channel
				4	-	-	Point bar within low water channel
				5	0.00	0.00	Pool tail
		2001	128	1	0.00	0.00	Upper point bar / floodplain
				2	0.00	0.00	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				4	-	-	Point bar within low water channel
				5	0.00	0.00	Pool Tail
		2002	144	1	0.00	0.00	Upper point bar / floodplain
				2	0.00	0.00	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				5	0.00	0.00	Pool Tail
		2004	241 (281)	5	0.47	0.00	Upper point bar / floodplain
				4	0.10	0.21	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				2	0.00	0.00	Point bar within low water channel
				1	0.00	0.00	Pool Tail
		2005	286	5	N/A	NO DATA	Upper point bar / floodplain
				4	0.05	0.11	Middle of point bar
				3	0.03	0.00	Point bar within low water channel
				2	0.02	0.07	Point bar within low water channel
				1	0.01	0.00	Pool Tail
Lower Rush Creek	03+30	1998	396	1	0.47	0.31	Pool tail at low flow, transverse bar at high flow
				2	>0.55	>0.55	Pool tail at low flow, transverse bar at high flow
				3	>0.75	>0.50	Pool tail at low flow, transverse bar at high flow
		1999	155	1	0.05	0.14	Pool tail at low flow, transverse bar at high flow
				2	0.14	0.14	Pool tail at low flow, transverse bar at high flow
				3	-	-	Not surveyed; assume completely scoured.
		2000	161	1	0.00	0.03	Pool tail at low flow, transverse bar at high flow
				2	0.00	0.00	Pool tail at low flow, transverse bar at high flow
				3	-	-	Not surveyed in 1999; assume completely scoured.
		2001	128	1	0.18	0.00	Pool tail at low flow, transverse bar at high flow
				2	0.00	0.02	Pool tail at low flow, transverse bar at high flow
				3	-	-	Not surveyed in 1999; assume completely scoured.
		2002	144	1	0.18	0.00	Pool tail at low flow, transverse bar at high flow
				2	0.16	0.13	Pool tail at low flow, transverse bar at high flow
		2004	241 (281)	1	0.07	0.75	Pool tail at low flow, transverse bar at high flow
				2	0.06	0.00	Pool tail at low flow, transverse bar at high flow
		2005	286	1	0.10	0.12	Pool tail at low flow, transverse bar at high flow
				2	0.05	0.06	Pool tail at low flow, transverse bar at high flow
Lower Rush Creek	04+08	1998	396	1	>0.46	>0.46	Low-gradient riffle
				2	>0.67	>0.67	Low-gradient riffle
		1999	155	1	0.17	0.20	Low-gradient riffle
				2	0.13	0.00	Low-gradient riffle
		2000	161	1	0.00	0.00	Low-gradient riffle
				2	0.00	0.00	Low-gradient riffle
		2001	128	1	0.02	0.12	Low-gradient riffle
				2	0.00	0.00	Low-gradient riffle
		2002	144	1	0.09	0.00	Low-gradient riffle
				2	0.00	0.00	Low-gradient riffle
		2004	241 (281)	1	0.01	0.00	Low-gradient riffle
				2	0.16	0.25	Low-gradient riffle
		2005	286	1	0.30	0.25	Low-gradient riffle
				2	0.09	0.16	Low-gradient riffle
Lower Rush Creek	05+49	1998	396	1	0	0.00	Riffle (transverse bar), within low water channel
				2	0	0.00	Riffle (transverse bar), within low water channel
				3	0	0.00	Riffle (transverse bar), within low water channel
				4	0	0.00	Riffle (transverse bar), within low water channel
		1999	155	1	0.00	0.00	Riffle (transverse bar), within low water channel
				2	0.00	0.00	Riffle (transverse bar), within low water channel
				3	0.00	0.00	Riffle (transverse bar), within low water channel
				4	0.00	0.00	Riffle (transverse bar), within low water channel
		2000	161	1	0	0.00	Riffle (transverse bar), within low water channel
				2	0	0.00	Riffle (transverse bar), within low water channel
				3	0.00	0.00	Riffle (transverse bar), within low water channel
				4	0	0.00	Riffle (transverse bar), within low water channel
		2001	128	1	0.00	0.00	Riffle (transverse bar), within low water channel
				2	0.00	0.00	Riffle (transverse bar), within low water channel
				3	0.00	0.00	Riffle (transverse bar), within low water channel
				4	0.00	0.00	Riffle (transverse bar), within low water channel
		2002	144	1	-0.03	0.15	Riffle (transverse bar), within low water channel
				2	0.05	0.15	Riffle (transverse bar), within low water channel
				3	-0.02	0.14	Riffle (transverse bar), within low water channel
				4	-0.04	0	Riffle (transverse bar), within low water channel
		2004	241 (281)	1	0.02	0.00	Riffle (transverse bar), within low water channel
				2	0.23	0.22	Riffle (transverse bar), within low water channel
				3	0.02	0.48	Riffle (transverse bar), within low water channel
				4	0.21	0.20	Riffle (transverse bar), within low water channel
		2005	286	1	0.43	0.34	Riffle (transverse bar), within low water channel
				2	0.33	0.52	Riffle (transverse bar), within low water channel
				3	0.57	0.60	Riffle (transverse bar), within low water channel
				4	0.31	0.60	Riffle (transverse bar), within low water channel
Lower Rush Creek	07+25	1998	396	1	0.00	0.00	Upper point bar / floodplain
		1999	155	1	0.01	0.00	Upper point bar / floodplain
		2000	161	1	0.00	0.00	Upper point bar / floodplain

Appendix B-2. Table 3. Lee Vining Creek tracer rock mobility at given discharges.

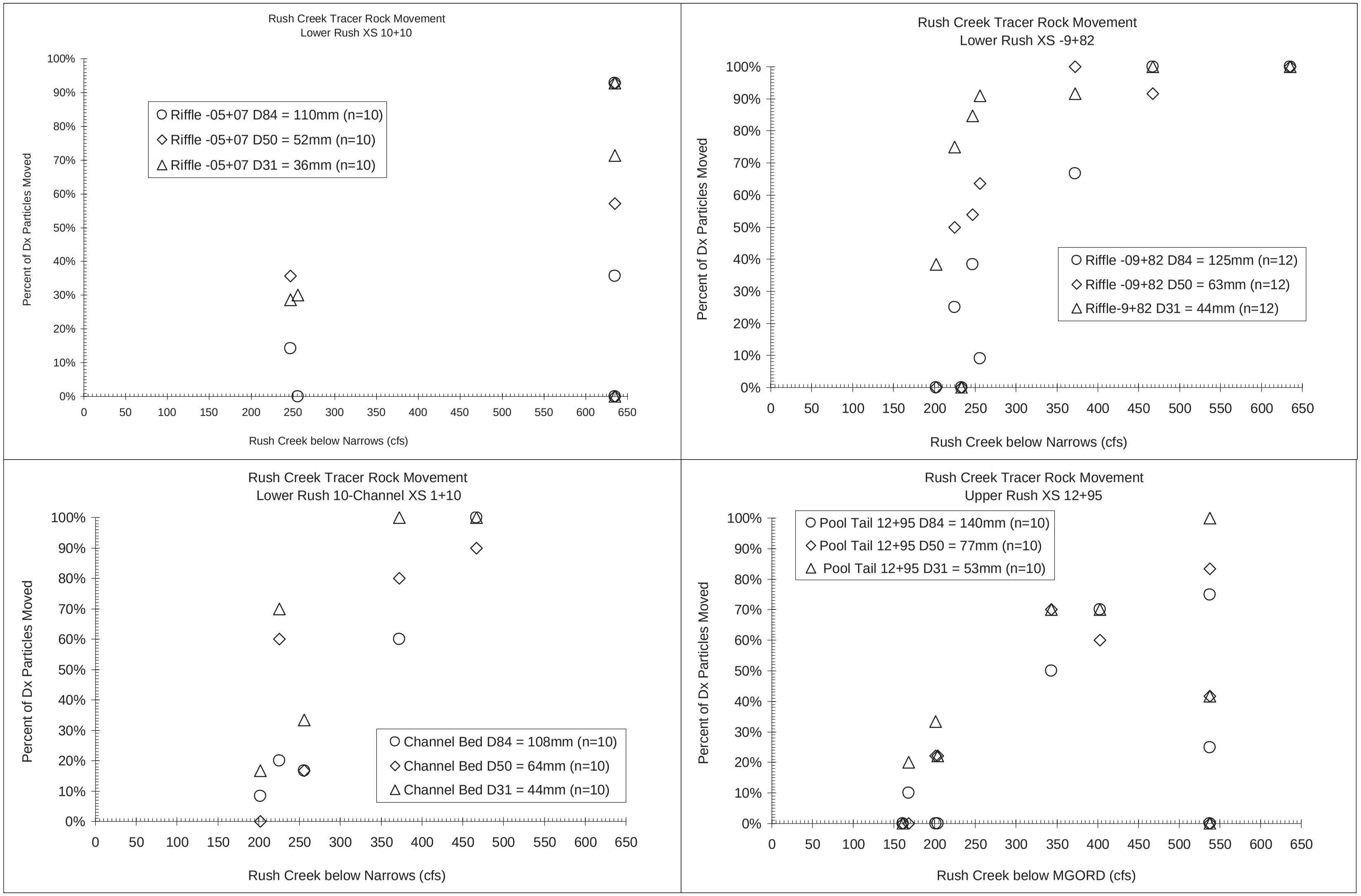
Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
13+92	Riffle	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		6/18/1998	193 cfs	0%	0%	8%
		9/10/1998	242 cfs	0%	25%	42%
		6/5/1999	162 cfs	0%	0%	17%
		7/24/1999	170 cfs	0%	8%	25%
		6/4/2000	204 cfs	0%	0%	0%
		8/3/2001	66 cfs	0%	9%	18%
		4/24/2002	164 cfs	0%	18%	9%
		6/27/2004	45 cfs	0%	9%	9%
		8/18/2005	289 cfs	36%	36%	64%
			maximum mobility =	36%	36%	64%
03+45	Pool Tail	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		7/2/1998	193 cfs	8%	17%	80%
		9/10/1998	242 cfs	47%	60%	80%
		6/5/1999	162 cfs	7%	27%	40%
		7/24/1999	170 cfs	7%	33%	60%
		6/4/2000	204 cfs	21%	14%	7%
		8/3/2001	152 cfs	7%	13%	20%
		4/24/2002	164 cfs	13%	7%	13%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	80%	80%	87%
			maximum mobility =	80%	80%	87%
06+61	Point Bar	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		7/2/1998	193 cfs	0%	0%	8%
		9/10/1998	242 cfs	0%	0%	17%
		6/5/1999	162 cfs	0%	0%	0%
		7/24/1999	170 cfs	0%	0%	0%
		6/4/2000		0%	0%	0%
		8/3/2001	152 cfs	0%	0%	0%
		4/24/2002	164 cfs	0%	0%	0%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	0%	0%	0%
			maximum mobility =	0%	0%	17%
09+31	Riffle	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		9/10/1998	242 cfs	45%	82%	91%
		6/5/1999	162 cfs	27%	36%	36%
		7/24/1999	170 cfs	45%	64%	55%
		6/4/2000	204 cfs	0%	18%	18%
		8/3/2001	152 cfs	0%	0%	18%
		4/24/2002	164	27%	82%	82%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	100%	100%	100%
			maximum mobility =	100%	100%	100%
09+31	Floodplain	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		7/2/1998	193 cfs	0%	0%	0%
		9/10/1998	242 cfs	0%	0%	0%
		6/5/1999	162 cfs	0%	0%	0%
		7/24/1999	170 cfs	0%	0%	25%
		6/4/2000	204 cfs	0%	45%	55%
		8/3/2001	152 cfs	18%	27%	55%
		4/24/2002	164 cfs	0%	0%	0%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	no recovery data	0%	0%
			maximum mobility =	18%	45%	55%
06+80	Riffle	10/3/1997	12 cfs	0%	0%	0%
		6/2/1998	37 cfs	0%	0%	0%
		7/2/1998	118 cfs	17%	83%	100%
		9/10/1998	149 cfs	17%	100%	100%
		6/5/1999	100 cfs	33%	33%	83%
		7/24/1999	104 cfs	20%	60%	80%
		6/4/2000	109 cfs	0%	0%	38%
		8/3/2001	66 cfs	0%	0%	0%
		4/24/2002	82 cfs	13%	0%	13%
		6/27/2004	45 cfs	0%	0%	0%
		8/18/2005	83 cfs	25%	75%	63%
			maximum mobility =	33%	100%	100%

Appendix B-2. Table 4. Lee Vining Creek scour and re-deposition at given discharges.

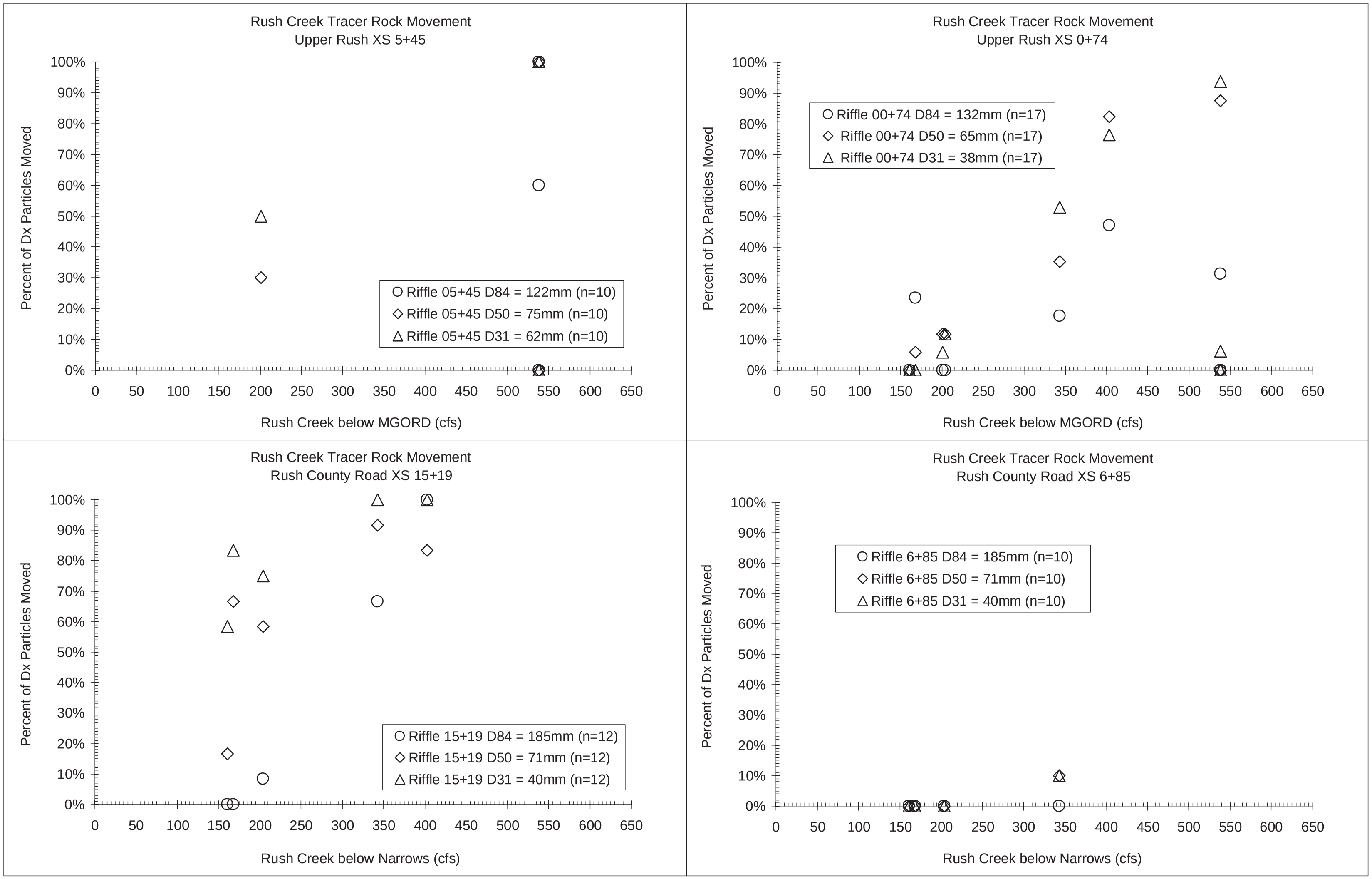
Reach	Cross Section	Year	Discharge at Cross Section (cfs)	Core #	Scour depth (ft)	Redeposition depth (ft)	Geomorphic feature
Lower Lee Vining Creek B-1 Channel	00+87	1999	122	1	0.10	0.04	Point bar, pea gravels
		2000	115	1	0.05	0.04	Point bar, pea gravels
		2001	89	1	0.00	0.04	Point bar, pea gravels
		2002	105	1	0.04	0.04	Point bar, pea gravels
		2004	62	1	0.00	0.00	Point bar, pea gravels
				2	0.16	0.11	
		2005	100	1	0.10	0.00	Point bar, pea gravels
				2	not installed		
Upper Lee Vining Creek	13+92	1998	270	1	0.00	0.11	Eddy deposit, coarse sand
				2	0.20	0.19	Eddy deposit, medium gravels
		1999	190	1	0.08	0.13	Eddy deposit, coarse sand
				2	0.05	0.21	Eddy deposit, medium gravels
		2000	179	1	0.04	0.11	Eddy deposit, coarse sand
				2	0.00	0.07	Eddy deposit, medium gravels
		2001	140	1	0.03	0.12	Eddy deposit, coarse sand
				2	0.01	0.12	Eddy deposit, medium gravels
		2002	164	1	NO DATA		Eddy deposit, coarse sand
				2			Eddy deposit, medium gravels
		2004	103	1	0.02	0.01	Eddy deposit, coarse sand
				2	0.03	0.02	Eddy deposit, medium gravels
		2005	289	1	0.03	0.19	Eddy deposit, coarse sand
				2	0.14	0.14	Eddy deposit, medium gravels
Upper Lee Vining Creek	10+44	1999	190	1	23.11	0.06	Eddy deposit, coarse sand
				2	23.02	0.00	Eddy deposit, medium gravels
		2000	179	1	0.05	0.32	Eddy deposit - spawning gravels
				2	0.21	0.00	Eddy deposit - exposed bar
		2001	140	1	0.04	0.46	Eddy deposit - spawning gravels
				2	0.03	0.42	Eddy deposit - exposed bar
		2002	164	1	0.01	0.16	Eddy deposit - spawning gravels
				2	0.02	0.04	Eddy deposit - exposed bar
		2004	103	1	0.01	0.12	Eddy deposit - exposed bar
				2	0.10	0.08	Eddy deposit - exposed bar
		2005	289	1	0.42	0.64	Eddy deposit - exposed bar
				2	0.37	1.11	Eddy deposit - exposed bar
Upper Lee Vining Creek	03+73	1998	270	1	0.00	0.04	Point bar - pea gravels
				2	0.57	0.05	Point bar - pea gravels
		1999	190	1	0.30	0.00	Point bar - pea gravels
				2	0.30	0.17	Point bar - pea gravels
		2000	179	1	0.00	0.00	Point bar - pea gravels
				2	0.00	0.15	Point bar - pea gravels
		2001	140	1	0	0.00	Point bar - pea gravels
				2	0	0.18	Point bar - pea gravels
		2002	164	1	0.11	0.24	Point bar - pea gravels
				2	0.16	0.16	Point bar - pea gravels
		2004	103	1	0.09	0.30	Point bar - pea gravels
				2	0.14	0.24	Point bar - pea gravels
		2005	289	1	0.03	0.06	Point bar - pea gravels
				2	0.32	0.19	Point bar - pea gravels



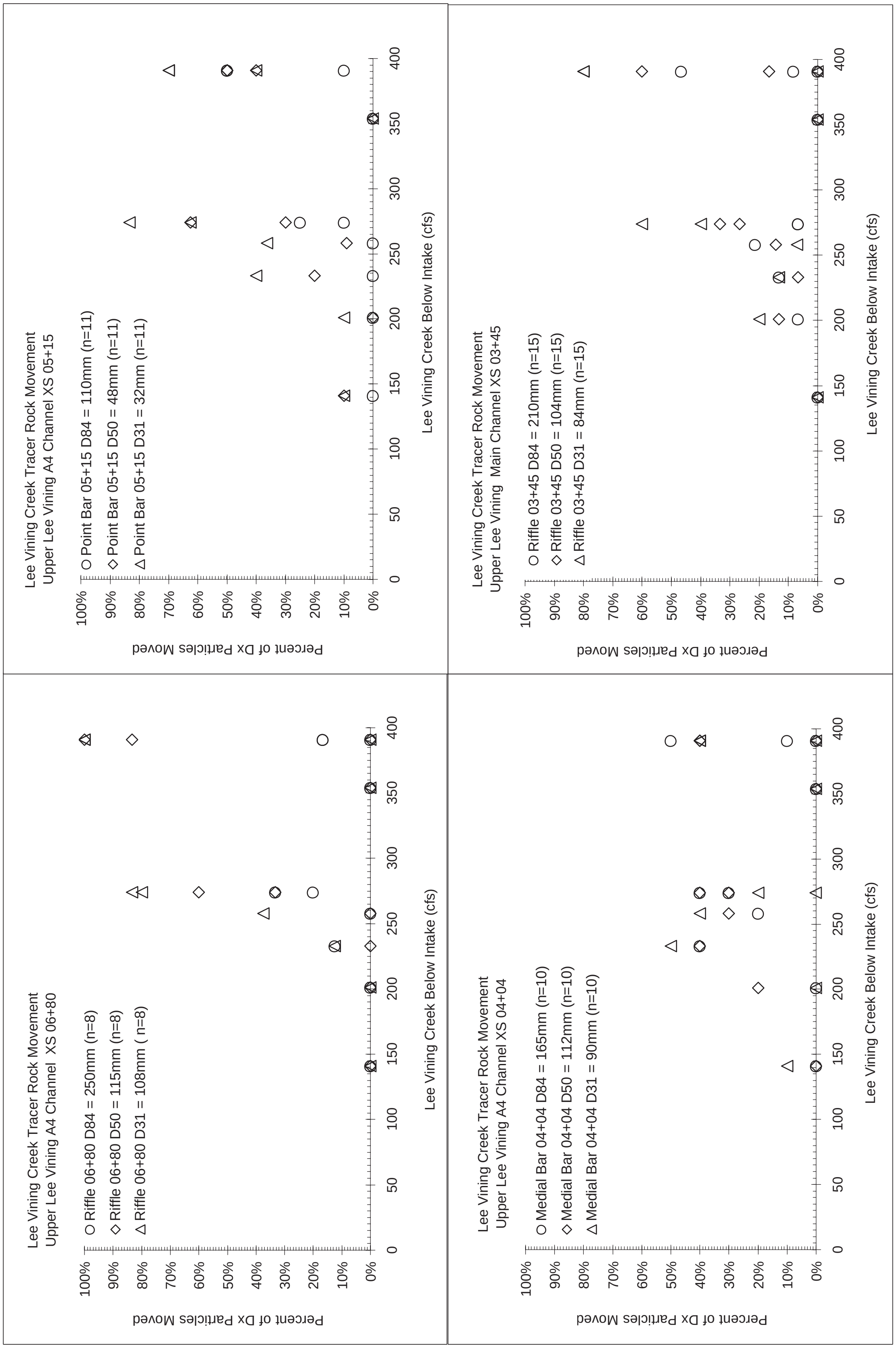
Appendix B-2. Figure 1a. Rush Creek tracer rock experiments.



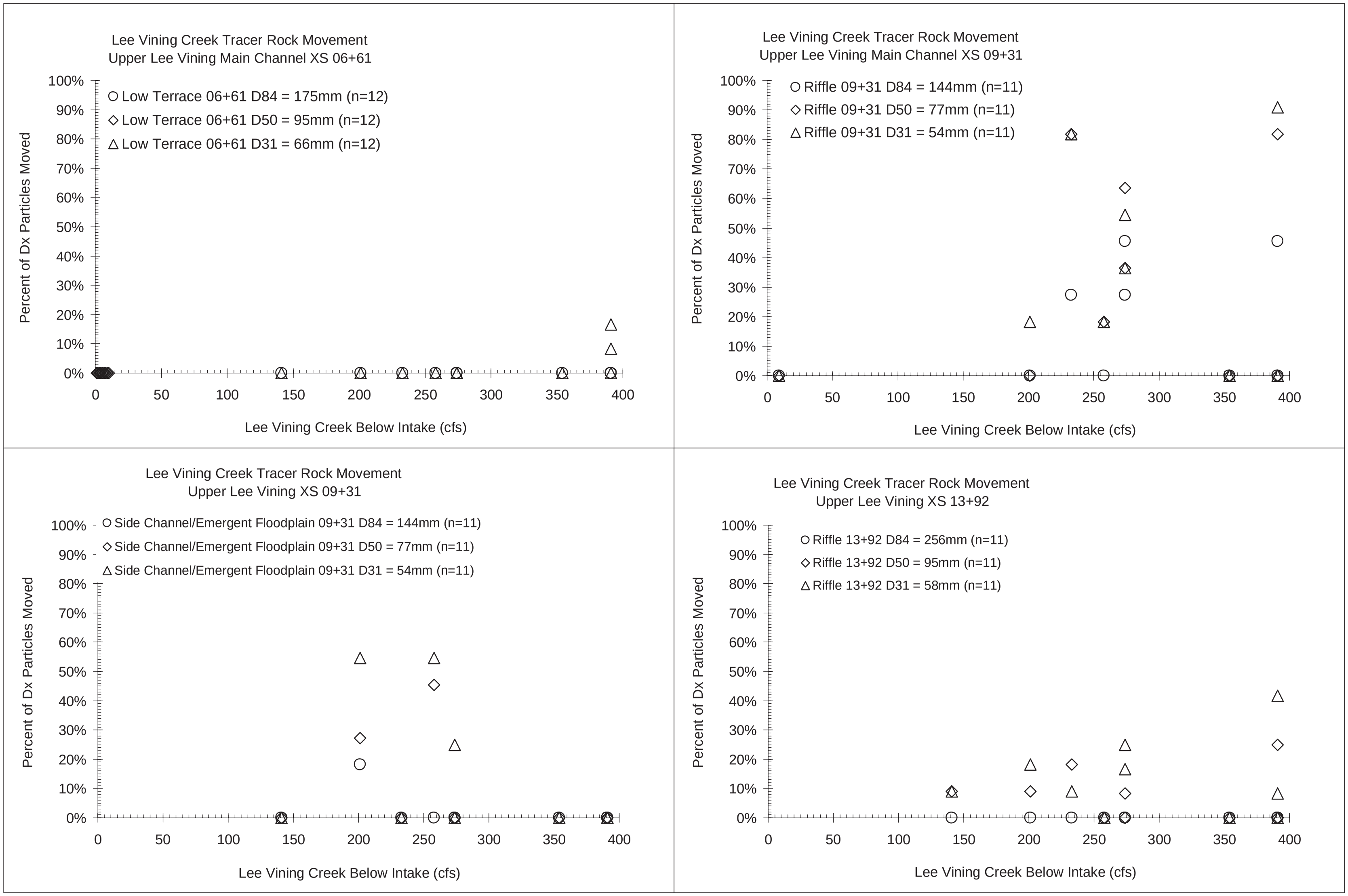
Appendix B-2. Figure 1b. Rush Creek tracer rock experiments.



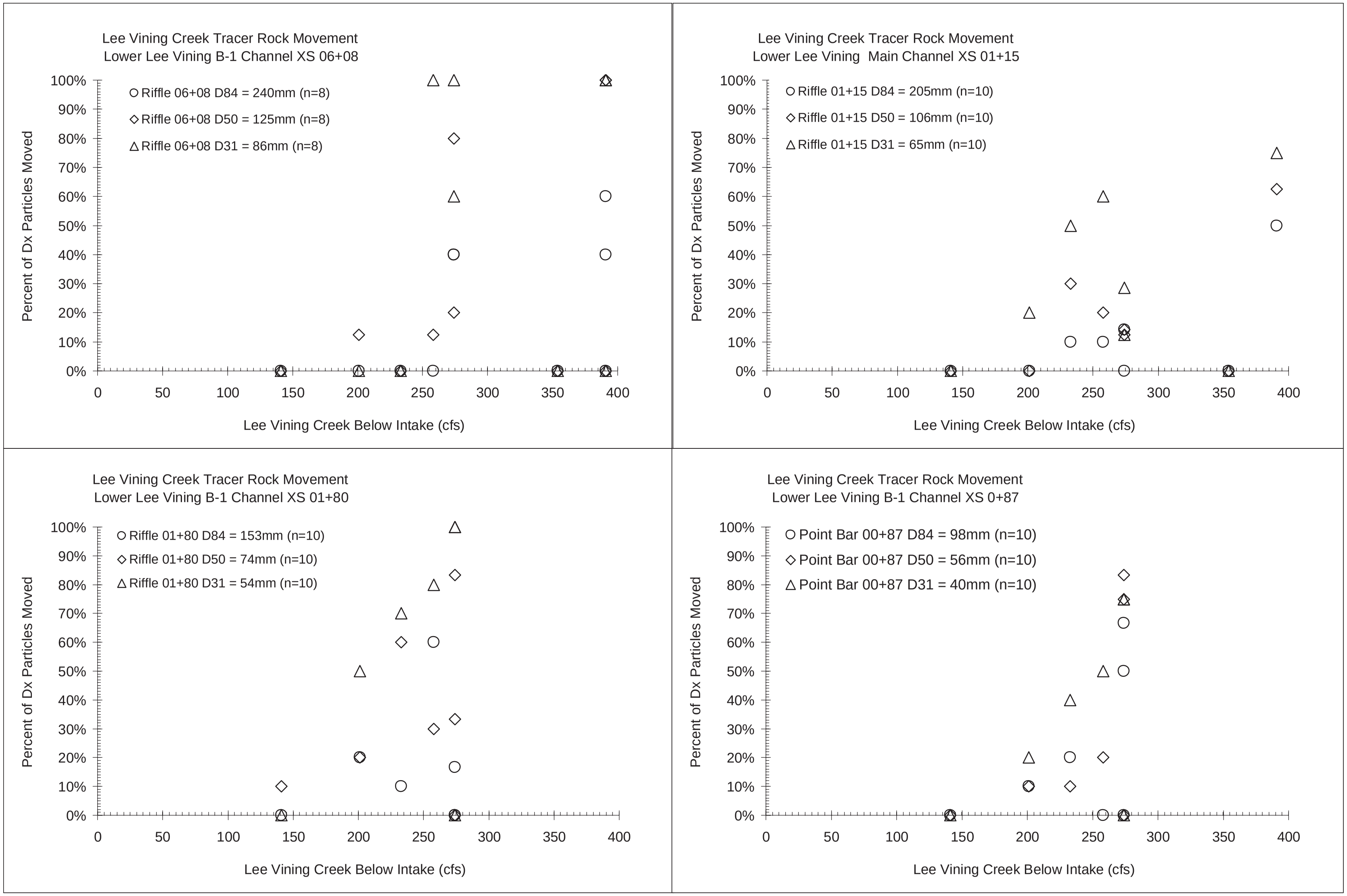
Appendix B-2. Figure 1c. Rush Creek tracer rock experiments.



Appendix B-2. Figure 2a. Lee Vining Creek tracer rock experiments.



Appendix B-2. Figure 2b. Lee Vining Creek tracer rock experiments.



Appendix B-2. Figure 2c. Lee Vining Creek tracer rock experiments.

APPENDIX B-3. SEDIMENT TRANSPORT MEASUREMENTS

3.3 Sediment Transport Measurements

3.3.1 Background and Objectives

Between June 20 and 30, 2005, sediment transport was measured on the ascending limb and during the peak of the SRF releases on Rush Creek. Sediment transport measurements were focused on bedload (the portion of total sediment load moving on or near the streambed). However, some suspended load (the portion of the total load transported in the water column) was measured.

Previous sediment sampling on Rush Creek included bedload transport measurements by StreamWise (2004), as well as fine sediment bedload sampling for floodplain aggradation studies (McBain and Trush 2004 and Section 3.3 of this report). The StreamWise study was conducted during the 2004 SRF flow releases and measured bedload transport but not suspended sediment. Bedload sampling was performed at floodplain study sites as part of ongoing field experimentation to expand our understanding of floodplain aggradation rates and pathways.

Given that Grant Lake historically (glacial moraine lake) and contemporarily (man-made reservoir) has trapped most sediment supplied from the watershed, and flood magnitudes have been reduced, we hypothesized that:

H-1: Fine and coarse sediment supply to Rush Creek is near zero below Grant Lake;

H-2: Fine and coarse sediment transport increases downstream from Grant Lake due to increasing sediment supply, and;

H-3: Sediment transport rates decrease with duration of a high flow release (of constant magnitude) as sediment supply becomes limited.

The 2005 SRF had a planned release of 400 cfs for eight days. Previous bed mobility monitoring had shown that mobility thresholds of active alluvial features were exceeded by 300 to 400 cfs at both study sites. We estimated eight days would exceed the duration required to observe a decline in transport rates. These estimates assumed total bed mobility when 80 percent of the D_{84} size class was mobilized (McBain and Trush 2002). Based on our hypotheses and the scheduled 2005 SRF releases, our objectives for sediment sampling were:

(1) Measure sediment transport rates on the ascending limb and during the sustained peak of the 2005 SRF releases (assesses hypotheses #2 and #3);

(2) Compare sediment transport rates at upper and lower sampling sites (assess Hypothesis #1);

To address Hypothesis 1, sediment transport was measured in upper and lower Rush Creek mainstem reaches. Two of the three sites sampled by StreamWise in 2004 were reoccupied: Upper Rush Creek, approximately 60 ft upstream of cross section 01+05, and Lower Rush Creek at cross section -9+82 (Figure 22). Sampling sites experienced most of the SRF releases (i.e., no major side channels bypassed the sampling sites, and only minor floodplain inundation occurred). We measured flow in the two small side channels at the upper site, which had 4.7 cfs and 8.8 cfs on 6-24-05, which represented a small percentage of the total release of 402 cfs).

3.3.2 Sampling Methods

The Rush Creek SRF releases provided a ramp-up and steady flows of 400 cfs (Figure 23). McBain and Trush partnered with Graham Matthews and Associates (GMA) for field work and laboratory analyses. Sampling was performed from catarafts designed specifically for sediment sampling. Two catarafts were used, each dedicated to a site. A two-member crew traveled between sites to collect sediment samples; one crew member was certified by the U.S. Geological Survey (USGS) for sediment sampling. Sampling cross sections remained fixed during the entire sampling period (Figure 24).

Bedload samples were collected on eight sample days (June 20 to 25, 27, and 30) over the eleven day sampling period. Samples were collected using the ‘single equal-width-increment’ (SEWI) method (Edwards and Glysson 1999), and used a Toutle River-2 (TR-2) bedload sampler with a 6 inch by 12-inch nozzle and a 0.5 mm mesh collection bag. The TR-2 was sufficient at the Upper Rush Creek site to sample the entire width of the moving bed, but the Lower Rush Creek site required a 3-inch hand-held Helley-Smith sampler to sample the left edge of the moving bed. Using the SEWI method, bedload samples were collected at equal-width intervals (verticals) across the cross section, with the TR-2 sampler resting on the bed surface for three minutes at each vertical. The USGS generally recommends a one minute sampling duration, but we increased sample times to three minutes

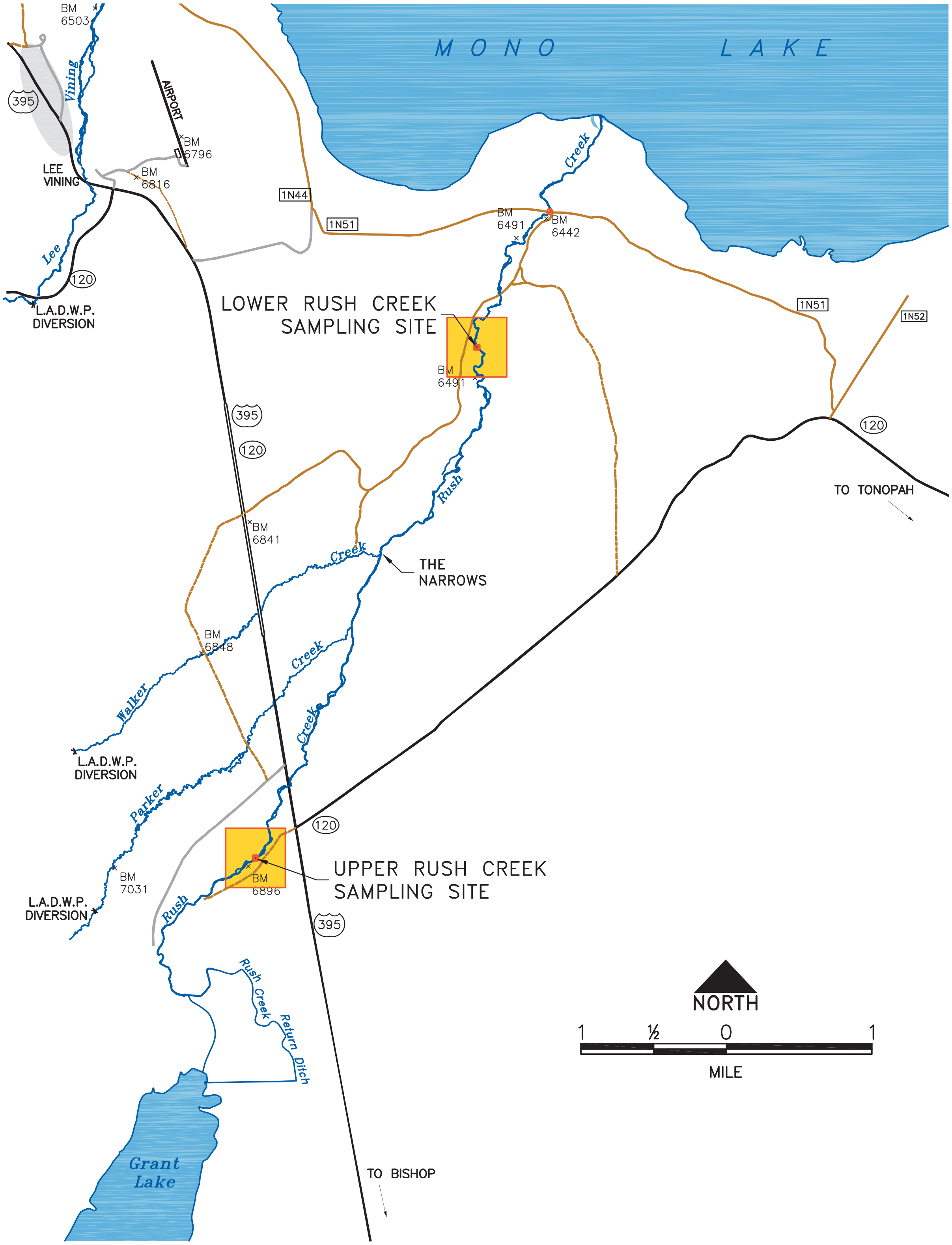


Figure 22. Upper and lower bedload sampling sites on Rush Creek.

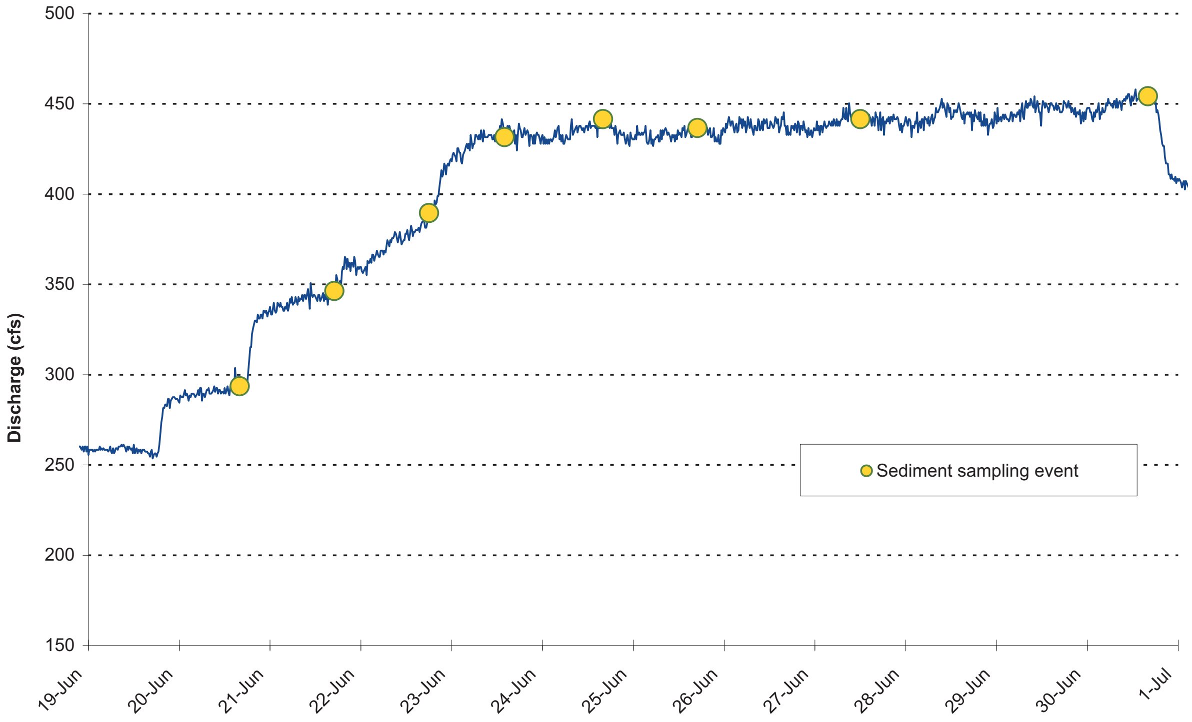


Figure 23. Preliminary 15-minute hydrograph at lower Rush Creek XS -9+82 with sediment sampling events plotted from June 20 – June 30, 2005.

duration to reduce variability in our bedload samples. Verticals were spaced every two feet (with a 1 ft wide nozzle), allowing 50 percent of the moving bed width to be sampled. This spacing provided high sampling precision. Three passes across the channel were made for each flow release. Starting at one bank and proceeding to the opposite bank (1 pass), individual samples were collected at each vertical, and then combined into a single sediment transport volume. The three passes were then averaged into one sample to compute the bedload transport rate for each discharge.

Suspended sediment samples were collected using a cable-deployed D-74 sampler; a hand-held DH-48 sampler was used at the Lower Rush Creek site to sample the channel margins. Sampling transit rates and sampler nozzle sizes were determined from measurements of maximum mean water velocity for each flow release. Depth-integrated (isokinetic) suspended sediment samples were collected for a single pass at each site, as there was less variability in suspended sediment transport.

To summarize, sediment sampling at each study site consisted of one bedload sample (three passes) and one suspended sediment sample (one pass). Each site was sampled once on each designated sampling day. Bedload transport rates were computed using the average of the three passes. Suspended sediment concentration was represented by a single pass.

Streamflows were obtained from either direct measurement by field crews or from LADWP gages (Figure 23). Water surface elevations in the reaches upstream of bedload sampling cross sections were measured for each sampled flow release using rebar stakes and staff plates. These reference marks were surveyed so water surface slopes could be computed for each sampling day.

After field sampling was completed, sediment samples were transported to a laboratory, then dried, weighed, and sieved for particle-size analyses. Samples were sieved in half-phi increments to -1

Figure 24a. Sediment sampling from the cataraft at the Upper Rush Creek site on June 25, 2005. The cataraft is attached to a cable that spans the channel, and is maneuvered between banks to collect sediment samples at discrete locations along the streambed and in the water column. One crew member operates a reel which raises and lowers the sampler, while the other crew member controls the sampler as it is lowered and raised through the water column. View is from the right bank, flow is from left to right and is approximately 400 cfs.

phi (2 mm) and then at whole-phi increments to 4 phi (0.063 mm). Suspended sediment samples were filtered, dried, and weighed to determine sediment concentration (mg/L). Concentrations were determined for 1 phi (0.5 mm), 4 phi (0.063 mm), and material passing 4 phi (finer than 0.063 mm).

3.3.3 Analysis and Results

Total sediment load is the mass of all sediment passing through a given cross section per unit time, including the coarsest material moving as bedload down to the finest particles traveling in suspension. An estimate of total sediment load was made from the data collected, because the estimate is not entirely additive (bedload + suspended sediment ≠ total sediment load) and requires several assumptions.

3.3.3.1 Bedload and suspended sediment transport computations

Bedload transport rates were calculated following Edwards and Glysson (1999) for each sampling date based on (1) the average mass collected during each sampling event, and (2) the total time the sampler was on the bed. Transport rates were calculated for total bedload transport, bedload transport finer than 8.0 mm, and bedload transport finer than 2.0 mm (Tables 12a and 12b;Figures 25a and 25b). Suspended sediment concentrations were determined for total suspended sediment, and for

Figure 24b. Cataraft set-up at the Lower Rush Creek site, June 25, 2005. Bank configuration on the left channel margin and vegetation along the right channel margin prevented the reel-operated samplers (TR-2 and D-74) to be used along the edges, so sampling along both channel edges was performed with hand-held samplers (3-inch Helley-Smith and DH-48). View is from the left bank, flow is from lower right and is approximately 465 cfs.

concentrations greater than 0.5 mm, greater than 0.063 mm, and finer than 0.063 mm. Suspended sediment concentrations measured for each flow release (Tables 13a and 13b;Figures 26a and 26b).

3.3.3.2 Measured sediment transport

The 400 cfs peak SRF releases began on June 23 and was held constant through June 30, 2005. Suspended sediment concentrations at both sites peaked on June 23 (Figures 26a and 26b), while bedload transport at both sites peaked on June 24 (Figures 25a and 25b). These data suggested suspended sediment responded more rapidly than bedload to changes in flow magnitude on the ascending hydrograph limb.

Following peak transport rates, both suspended sediment concentration and bedload transport showed similar trends in declining transport. Suspended sediment transport tapered off at both upper and lower sites, but the average rate of decline through June 25 (two day total) was much greater at Upper Rush Creek than at Lower Rush Creek: 3.57 mg/L/d at Upper Rush Creek compared to 0.6 mg/L/d at the Lower Rush Creek site. Suspended sediment supply became limited at Upper Rush Creek faster than at Lower Rush Creek, supporting our hypothesis that fine sediment supply increased with distance downstream.

Table 12a. Computed bedload transport rates (Qb, tons/day) for the Upper Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Qb total (tons/day)	Qb < 8mm (tons/day)	Qb < 2mm (tons/day)	D84 (mm)	D50 (mm)
6/21/2005	314	4.26	3.6	2.16	7.5	2
6/22/2005	362	7.24	5	2.93	30.3	2.8
6/23/2005	402	12.05	8.1	4.23	25.4	3.6
6/24/2005	402	13.51	8	3.49	46.5	5.1
6/25/2005	401	5.95	4.5	2.57	17	2.5
6/27/2005	402	4.93	3.9	2.08	13.3	2.5
6/30/2005	389	7.87	3.8	1.71	67.3 [2]	8.8 [2]

[1] Daily average streamflow for Rush Creek below Mono Ditch.

[2] Results skewed due to anomalously large volume sampled during first sampling pass (Pass #1 of 3). Also see discussion in text.

Table 12b. Computed bedload transport rates (Qb, tons/day) for the Lower Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Qb total (tons/day)	Qb < 8mm (tons/day)	Qb < 2mm (tons/day)	D84 (mm)	D50 (mm)
6/20/2005	298	2.1	2.0	1.64	2.7	0.9
6/21/2005	367	3.8	2.9	2.15	20.0	1.6
6/22/2005	418	7.6	5.1	3.18	65.5	3.3
6/23/2005	461	13.0	6.1	4.28	73.7	9.5
6/24/2005	465	18.2	9.1	5.57	103.5	8.4
6/25/2005	465	12.0	8.2	5.74	41.6	2.3
6/27/2005	462	8.0	5.7	3.73	23.2	2.5
6/30/2005	461	6.9	5.0	3.48	34.1	2.0

[1] Daily average streamflow for Rush Creek below Narrows.

The interpretation of limiting sediment supply in the upper river was also supported by the bedload data. Although the measured bedload transport peaked on June 24, a pronounced change in transport rate occurred on the ascending limb at Upper Rush Creek on June 23; Lower Rush Creek transport rates continued to rise at the same rate of approximately 5 tons/day, but daily Upper Rush Creek transport rates slowed from a rate of approximately 4 tons/day to 1.4 tons/day. This rate decrease implied that bedload supply became limited at Upper Rush Creek faster than Lower Rush Creek.

3.3.3.3 Transport trend deviations

Although both sites showed an overall decline in sediment transport rate following their peaks, two deviations were observed on June 30: bedload transport increased at the Upper Rush Creek site and suspended sediment concentration increased slightly at the Lower Rush Creek site. We noted that the first pass collected on June 30 was four times heavier and captured more large rocks than the subsequent two passes, skewing the three-pass average. Although previous sampling at both sites collected consistent sample masses, we attributed the large sample to an episodic pulse in bedload transport.

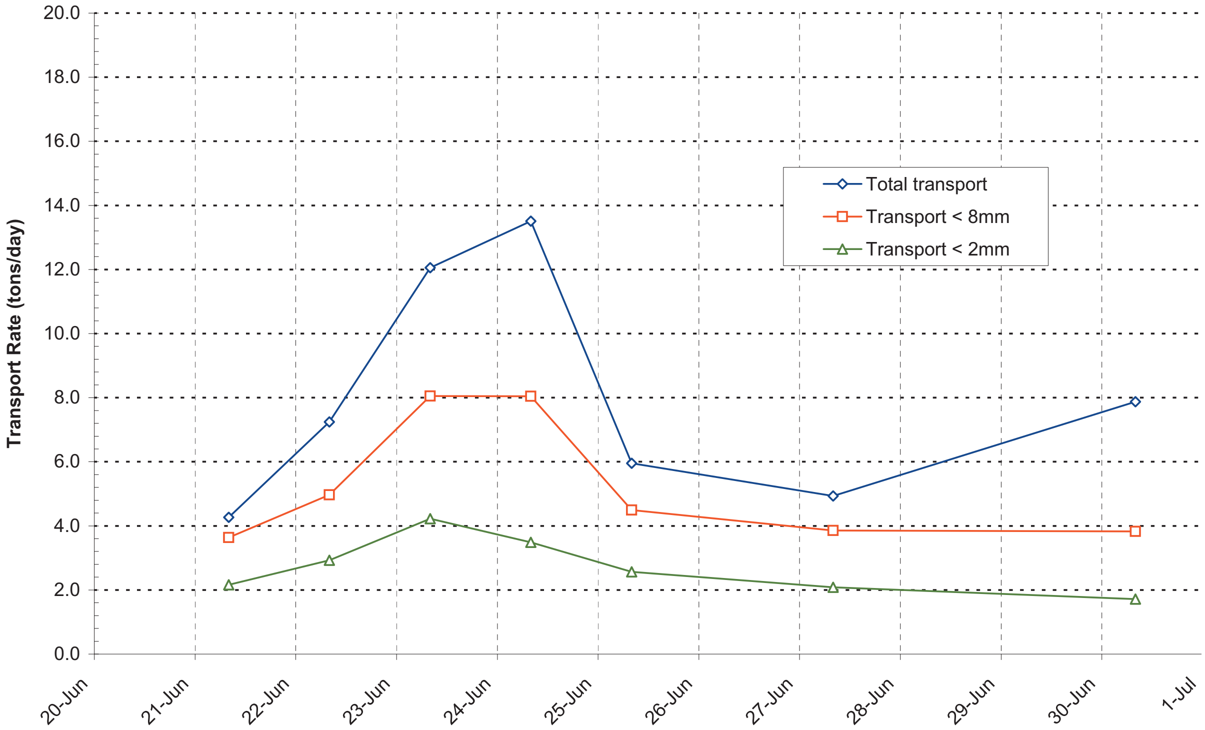


Figure 25a. Upper Rush Creek bedload transport (tons/day), June 20 to July 1, 2005.

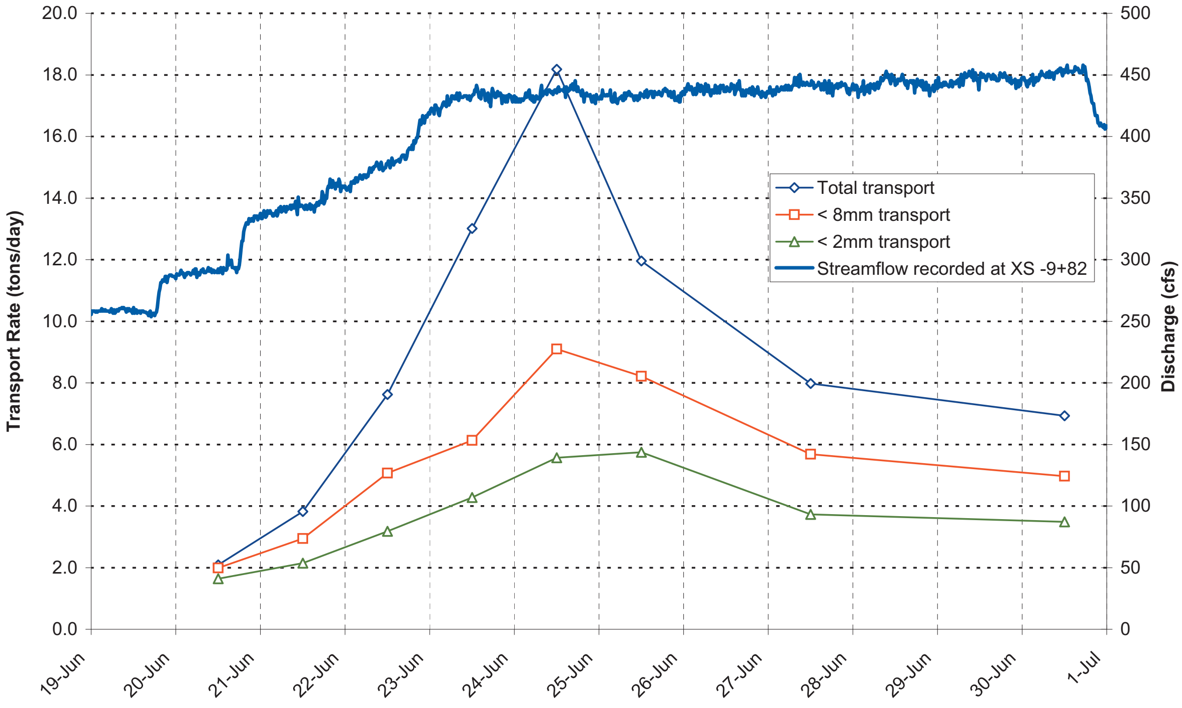


Figure 25b. Lower Rush Creek bedload transport (tons/day) and preliminary 15-minute hydrograph, June 19 to July 1, 2005.

Table 13a. Suspended sediment concentrations (SSC, mg/L) measured at the Upper Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Total SSC (mg/L)	SSC > 0.5 mm (mg/L)	SSC > 0.063 mm (mg/L)	SSC < 0.063 mm (mg/L)
6/21/2005	314	10.7	0.98	4.88	4.83
6/22/2005	362	10.6	1.82	4.51	4.31
6/23/2005	402	15.7	5.24	5.66	4.74
6/24/2005	402	11.4	4.18	3.74	3.49
6/25/2005	401	8.56	2.4	3.07	3.09
6/27/2005	402	5.37	1.05	1.75	2.57
6/30/2005	389	3.96	<0.5	1.61	1.93

[1] Daily average streamflow for Rush Creek below Mono Ditch

Table 13b. Suspended sediment concentrations (SSC mg/L) measured at the Lower Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Total SSC (mg/L)	SSC > 0.5 mm (mg/L)	SSC > 0.063 mm (mg/L)	SSC < 0.063 mm (mg/L)
6/21/2005	367	26	1.2	14.7	10.2
6/22/2005	418	29.1	3.64	16.8	8.7
6/23/2005	461	32.7	4.37	16.9	11.4
6/24/2005	465	31.6	5.58	16.4	9.64
6/25/2005	465	31.5	4.91	19.2	7.34
6/27/2005	462	18.7	2.18	10.4	6.16
6/30/2005	461	21.7	3.74	10.5	7.5

[1] Daily average streamflow for Rush Creek below Narrows.

A similar condition existed for the Lower Rush Creek suspended sediment sample collected on June 30, where suspended sediment concentration increased slightly from 18.7 mg/L on June 27 to 21.7 mg/L. Nothing in the data analysis or in the field notes suggested an anomalous condition, and we interpreted this increase as a perturbation in an overall decreasing trend. This perturbation was not observed at the Upper Rush Creek site.

3.3.4 Discussion

Trends in sediment transport occurred as expected (i.e., sediment transport rates increased on the ascending limb of the SRF release hydrograph and then tapered off after the flow was sustained at 400 cfs). However, sample volumes at the Upper Rush Creek site were much larger than expected. The following sections focus on results as they related to our hypotheses.

3.3.4.1 Sediment transport gradient (Hypotheses #1 and #2)

We hypothesized that sediment supply immediately below Grant Lake should be near zero (Hypothesis #1), but as drainage area increased below the dam, sediment supply would increase (Hypothesis #2). We expected to measure relatively little sediment at the Upper Rush Creek site compared to the lower site. Although lower transport rates were measured at the upper site, transport rates were much higher than expected, indicating a large volume of sediment was being transported

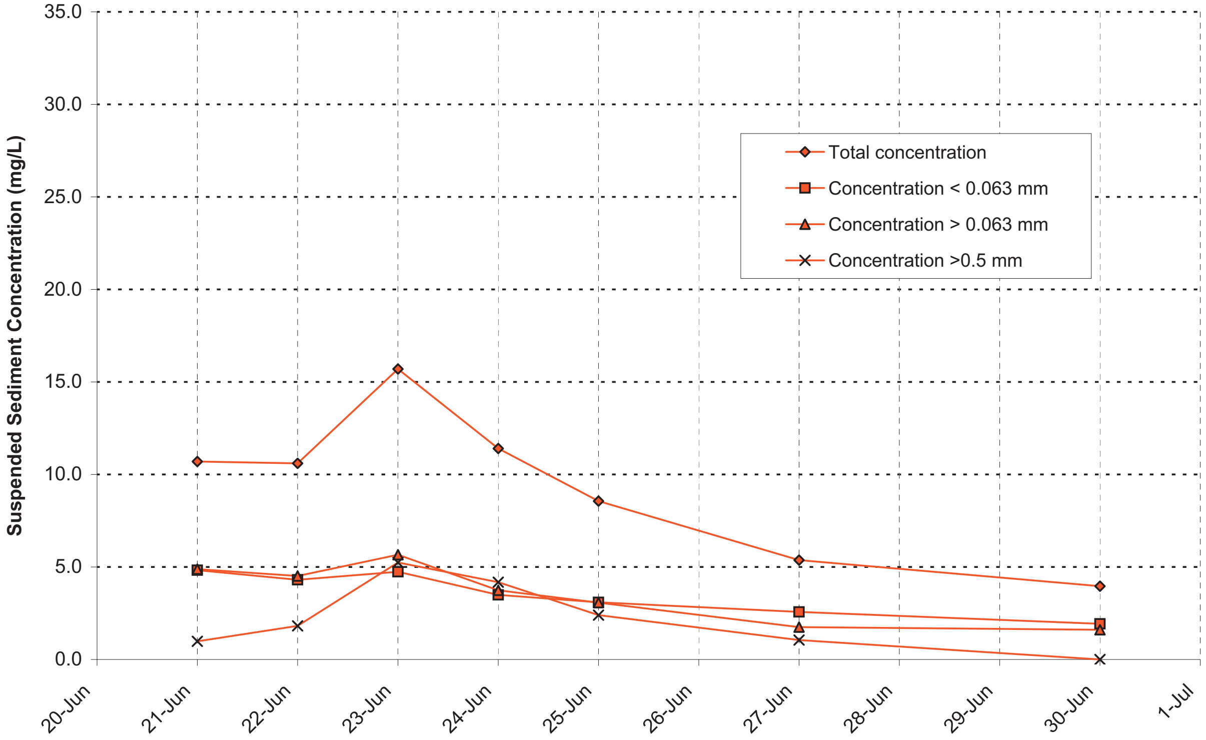


Figure 26a. Upper Rush Creek suspended sediment concentrations (mg/L), June 20 to July 1, 2005.

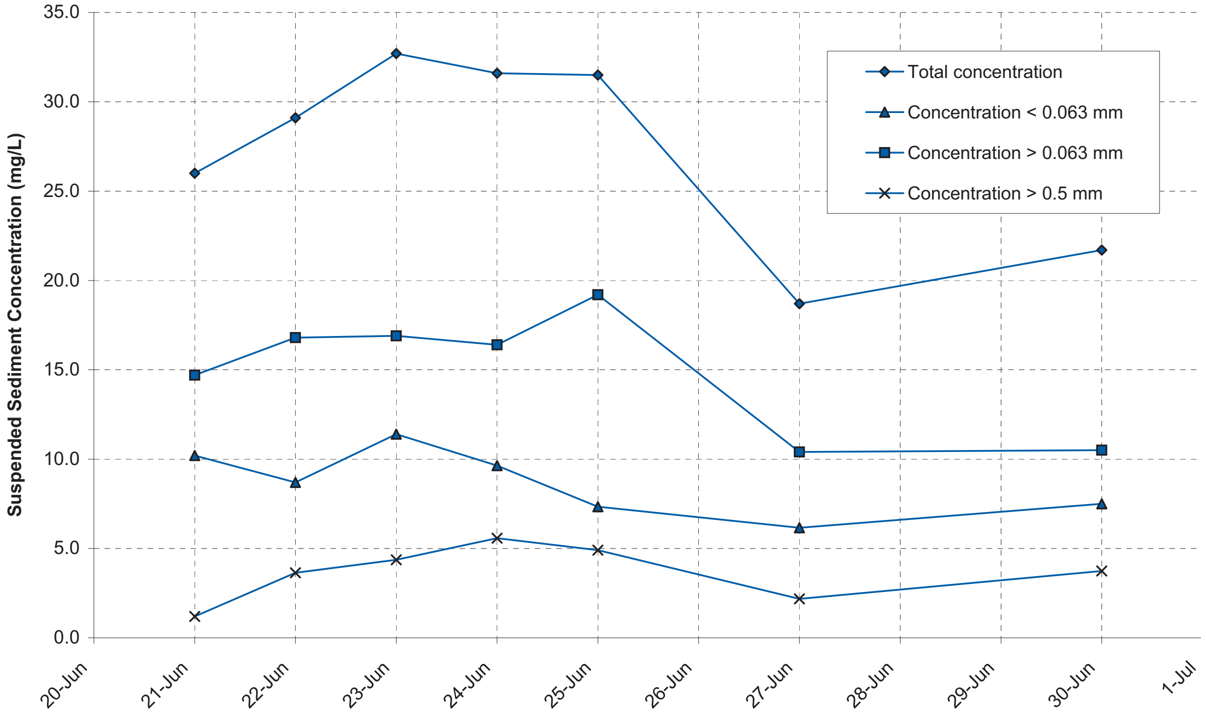


Figure 26b. Lower Rush Creek suspended sediment concentrations (mg/L), June 20 to July 1, 2005.

from the reach above the upper site, which includes approximately 8,130 ft of historic channel and approximately 7,850 ft of the Return Ditch. We were not able to determine the source of sediment delivered to the upper sampling site (i.e., is sediment being supplied by the Return Ditch, by the channel below the Return Ditch, or both?). One possibility is that recent Return Ditch construction may have increased sediment supply, which would likely be temporary.

3.3.4.2 Effectiveness of Flow Magnitude and Duration on Sediment Transport Rates (Hypothesis #3)

Do sediment transport rates decrease with flow duration? To evaluate the effect of flow duration at the Lower Rush Creek site, we plotted cumulative bedload transport during the 400 cfs release period (Figure 27a). We expected transport rates to approach an asymptote as an equilibrium was reached between sediment supply and sediment transport. This trend was observed at Lower Rush Creek, where over 75 percent of the total bedload transported over the 8-day bench was transported the first three days (Figure 27a). The remaining 25 percent was transported the last five days. For a 400 cfs release, two to three days may therefore be a sufficient duration to transport the majority of available bedload. A similar trend was observed in the Upper Rush Creek bedload data (Figure 28a), with 71 percent of the total bedload transported within the first three days.

Suspended sediment concentration curves at the Upper and Lower Rush Creek sites also had inflections at the third sampling day, corroborating the cumulative bedload transport curves (Figures 27b and 28b). At both upper and lower sites, 70 and 79 percent of the total suspended sediment transported over the 8-day bench were transported within the first three days. Therefore a 400 cfs

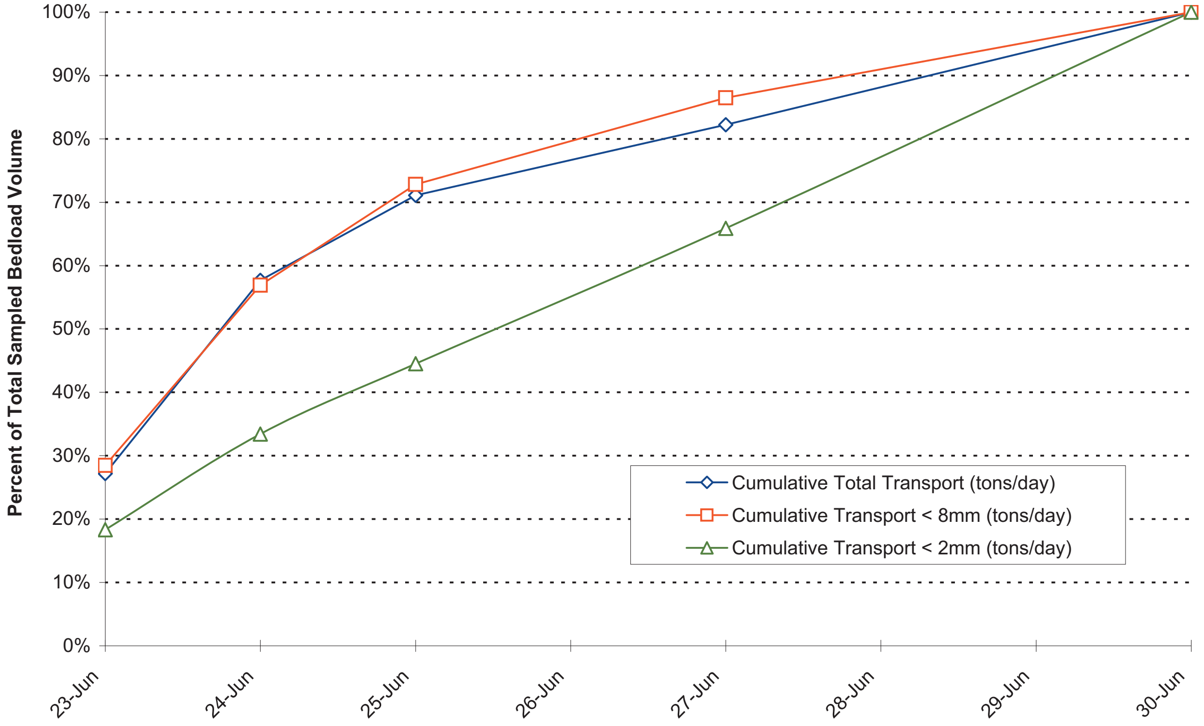


Figure 27a. Lower Rush Creek cumulative bedload transport volume for the scheduled 400 cfs SRF release period. An inflection in the percent of total bedload sampled occurred on June 25, 2005, with approximately 75 percent of the total bedload transported within the first three days.

release of two to three days may be sufficient to transport most available suspended sediment.

One notable difference was in the cumulative bedload transport between the upper and lower sites for the < 2.0 mm particle size range. Only 45 percent of the < 2.0 mm bedload fraction for Upper Rush Creek was transported within the first three days, and cumulative transport continued to increase in a linear trend through the final day of sampling. This cumulative transport rate did not asymptote similar to the < 8.0 mm curve or the total cumulative transport curves, suggesting that an equilibrium was not reached between sediment supply and sediment transport (i.e., the coarse sand supply did not approach a limiting condition). In addition, the Upper Rush Creek suspended sediment cumulative concentration curve showed a limiting trend, bracketing the non-limited particle size range between 0.5 mm and 2.0 mm (coarse sand). A large volume of coarse sand supply must have existed upstream of the upper sampling site.

3.3.4.3 Sediment Rating Curves

Sediment rating curves are used to estimate transport rates as a function of streamflow. Transport rates predicted from 2005 sampling would be specific to the 2005 SRF releases; for example, a similar-shaped hydrograph may not yield the same transport rates. Sediment transport estimates based on a rating curve from the 2005 SRF releases must therefore consider effects of flow duration, because our data demonstrated that bedload transport rates increased with flow magnitude, then decreased with duration. (Figure 29). Different portions of the hydrograph (e.g., rising limb or falling limb) had demonstrably different sediment transport rates, confounding the development of rating curves.

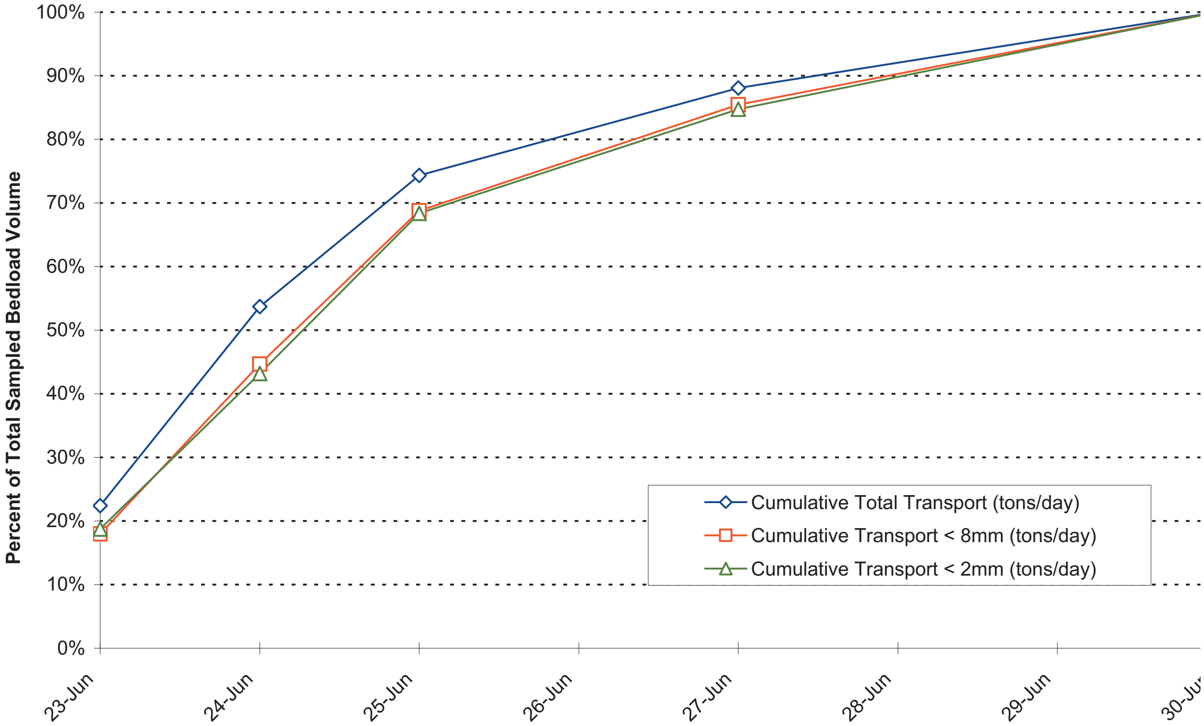


Figure 27b. Upper Rush Creek cumulative bedload transport volume for the scheduled 400 cfs SRF release period. An inflection in the percent of total bedload sampled occurred on June 25, 2005, with approximately 71 percent of the total bedload transported within the first three days.

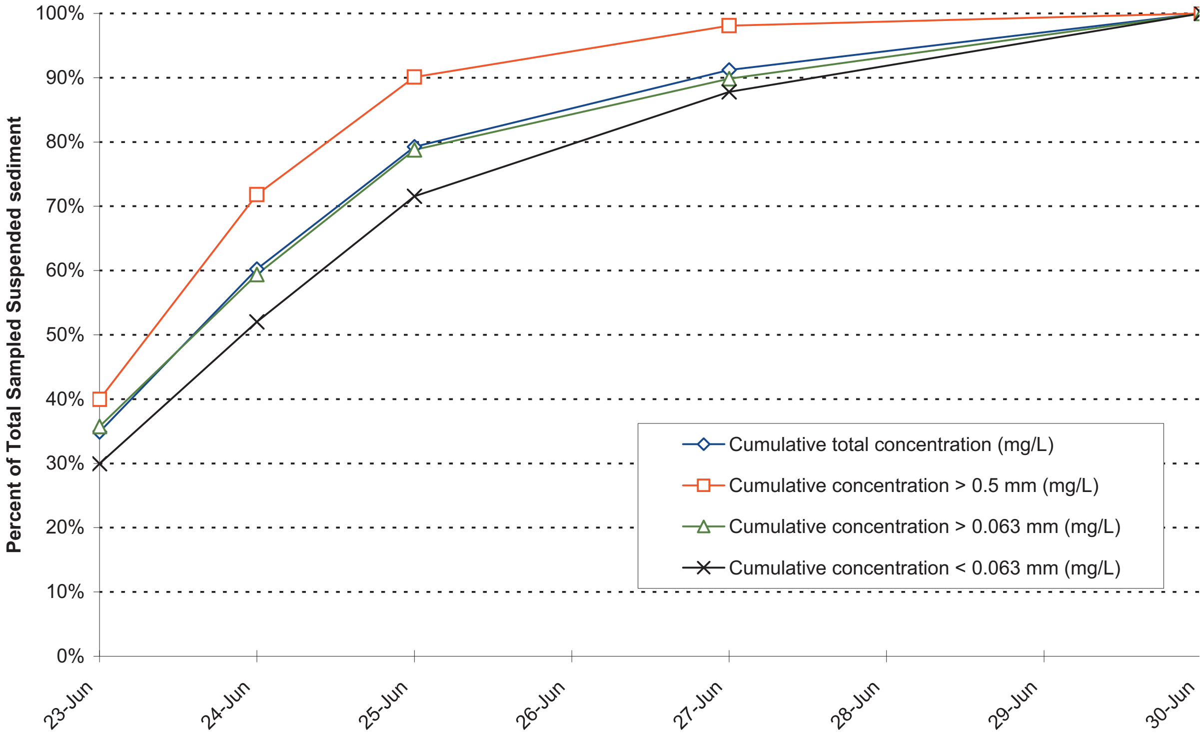


Figure 28a. Upper Rush Creek cumulative suspended sediment concentration for the scheduled 400 cfs SRF release period. An inflection in the percent of suspended sediment sampled occurred on June 25, 2003, with approximately 79 percent of the total suspended sediment (and up to approximately 90 percent of suspended sediment > 0.5mm) was transported within the first three days.

Hysteresis loops, a common effect in sediment transport versus discharge plots (e.g., Dunne and Leopold 1978; GMA 2005), graphically portray the variation of bedload transport with streamflow during a single storm or flood hydrograph. The hysteresis loop (Figure 29) demonstrated bedload transport was greatest on the rising limb of the hydrograph and then tapered off during the 400 cfs bench. The decrease in transport rates following the first day of the 400 cfs peak may be attributed to depletion of sediment supply following the rising limb of the SRF releases hydrograph (i.e., supply available for transport becomes limited). For the Rush Creek bedload transport data (Figure 29), a hysteresis loop would be better defined if additional sampling followed the 400 cfs bench. We added a hypothetical data point to demonstrate the expected hysteresis loop.

3.3.4.4 Summary

Our field equipment and methods yielded high quality bedload transport data and good quality suspended sediment data. Sediment transport was higher in Lower Rush Creek, but the difference was less than expected and does not necessarily support all our hypotheses. These results provided evidence to support Hypotheses #1 and #2, but more information would be needed to determine the cause for the greater-than-expected sediment transport at the upper sampling site. The sediment supply from the Return Ditch may be temporarily high due to reconstruction in 2003.

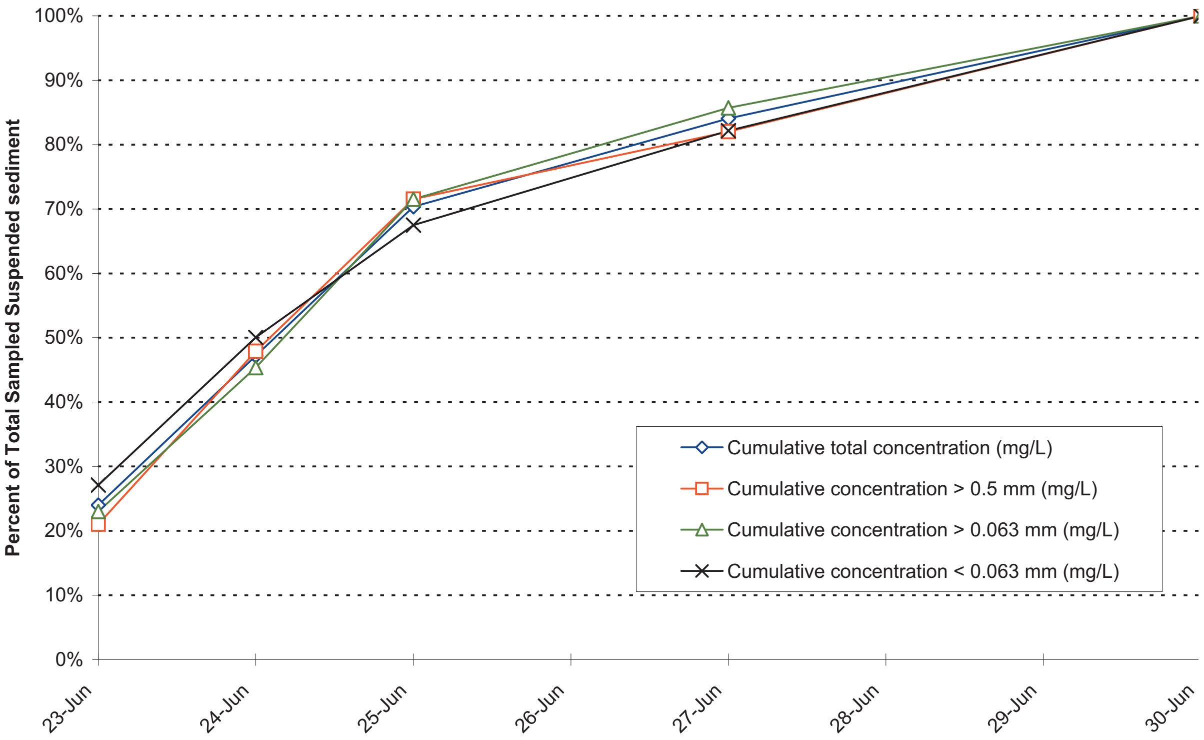
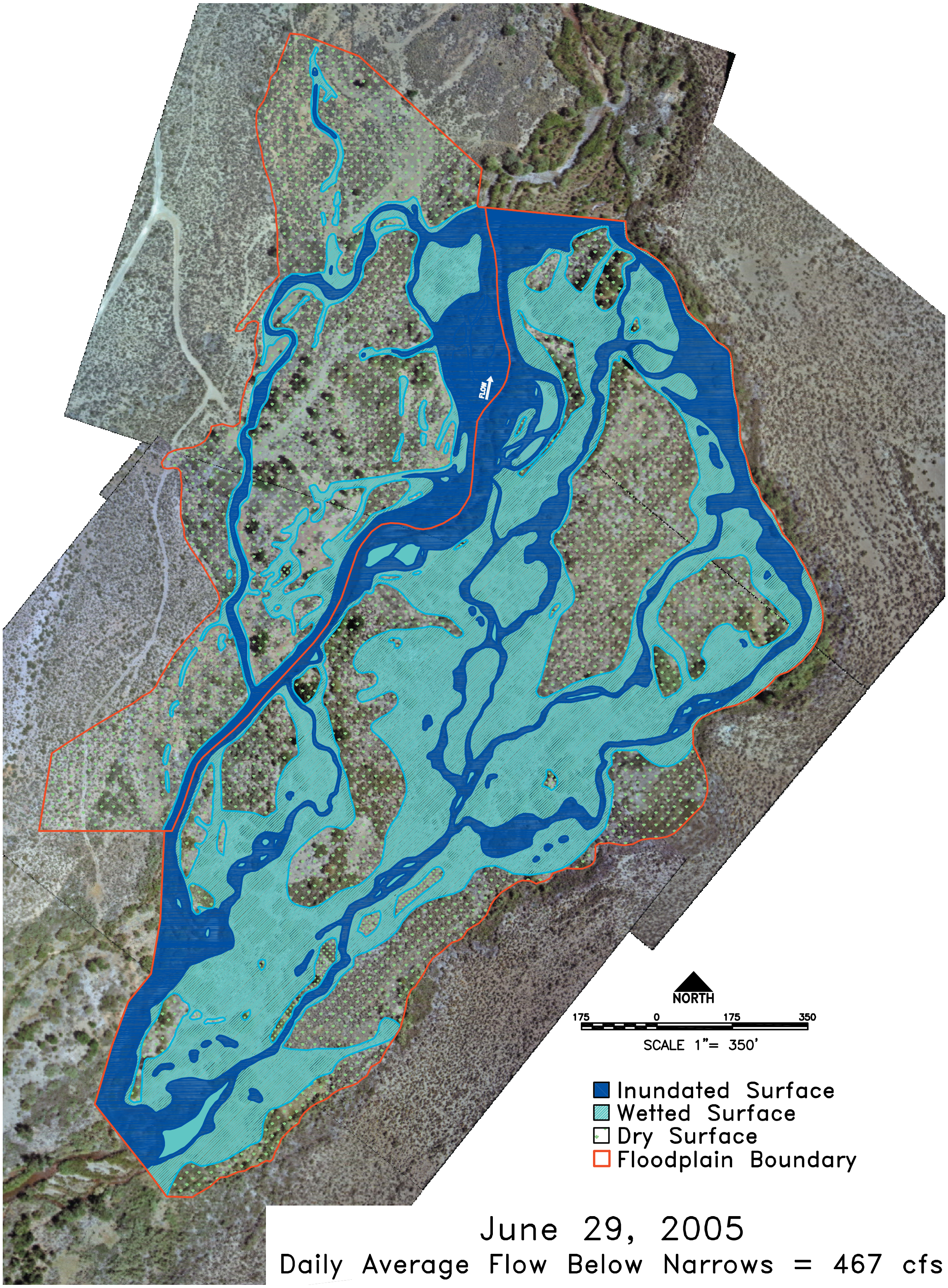


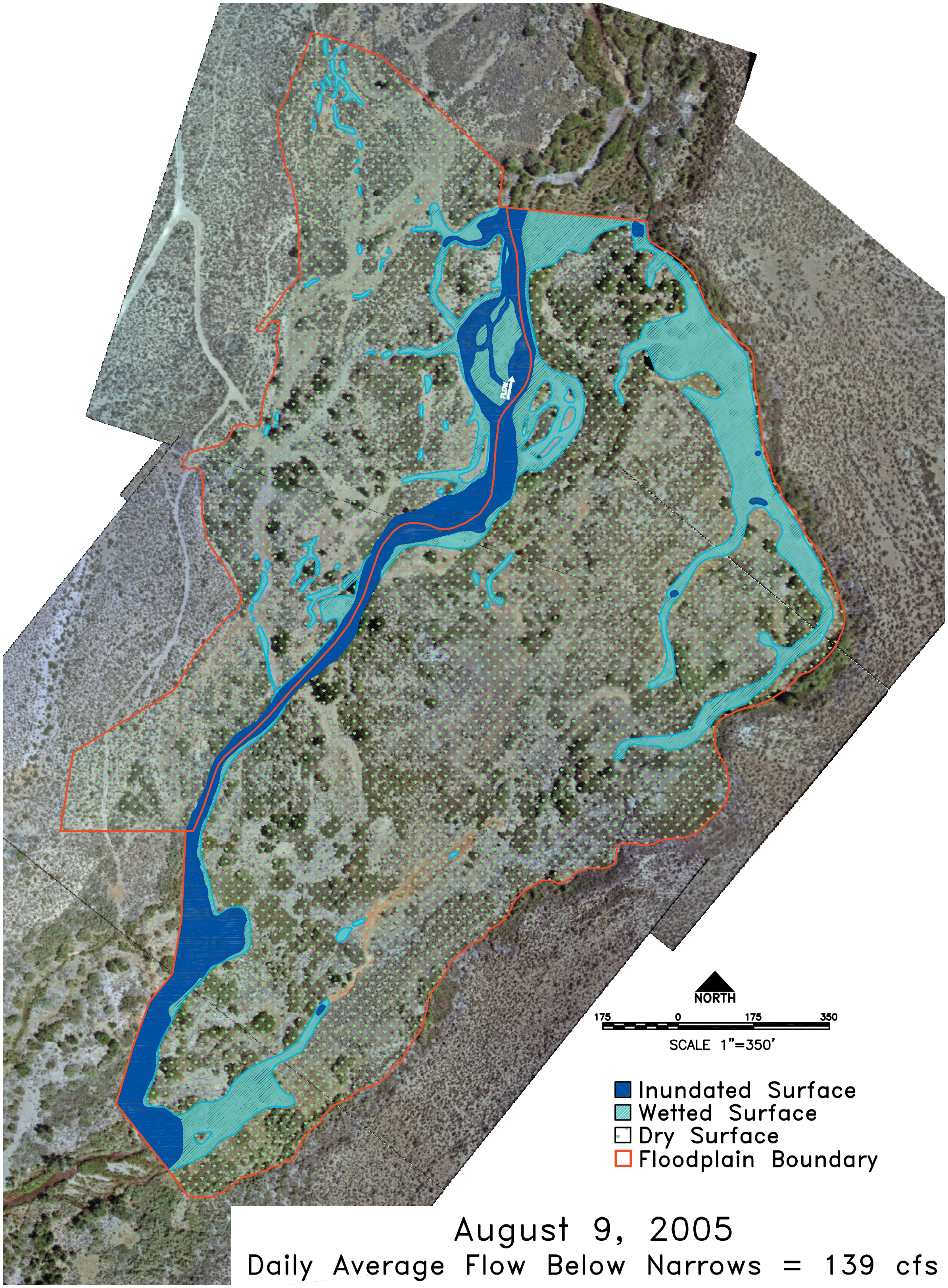
Figure 28b. Lower Rush Creek cumulative suspended sediment concentration for the scheduled 400 cfs SRF release period. An inflection in the percent of suspended sediment sampled occurred on June 25, 2003, indicating approximately 70 percent of the total suspended sediment was transported within the first three days.

Sediment transport decreased with increasing duration of constant flow magnitude, supporting Hypothesis #3. The first two to three days of the 400 cfs release transported a substantial portion of the total bedload and suspended sediment transported by the 2005 release. Shorter duration, higher magnitude high flow releases may be more water-efficient in accomplishing geomorphic work (using sediment transport flux as an index of "geomorphic work") than longer duration moderate flow releases. Other measures of geomorphic work, such as bed mobility, bed scour, channel migration, and sediment recruitment need to be considered in the magnitude and duration of future high flow releases. There are several possible high flow management implications from these findings, which will be explored in subsequent reports.

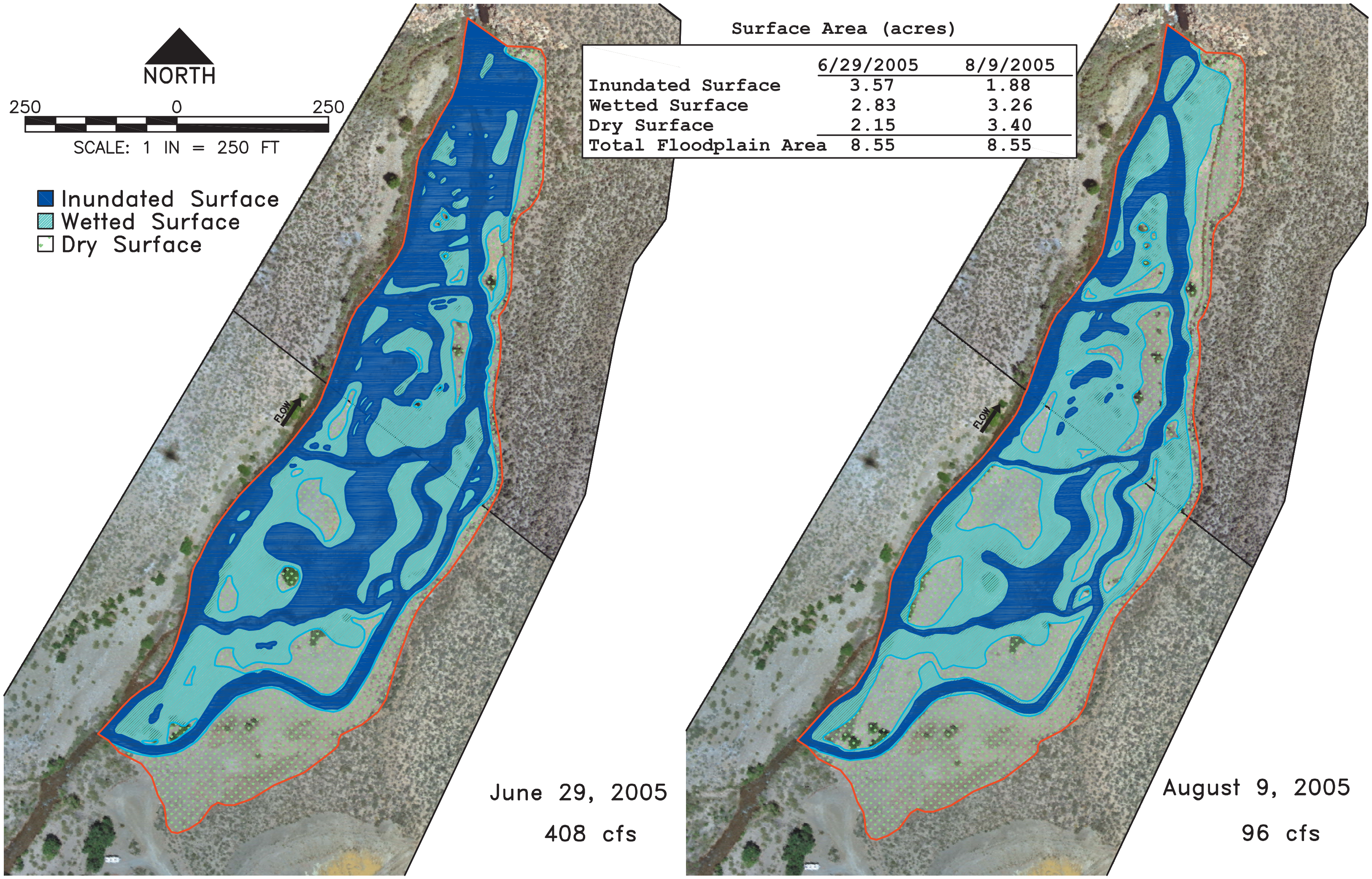
APPENDIX B-4. FLOODPLAIN INUNDATION MAPPING



Appendix B-4. Figure 1. The 8 and 4bii floodplain with the extent of wetted and inundated areas on June 28, 2005, resulting from flow entering the 8 Channel and 4bii Channel.



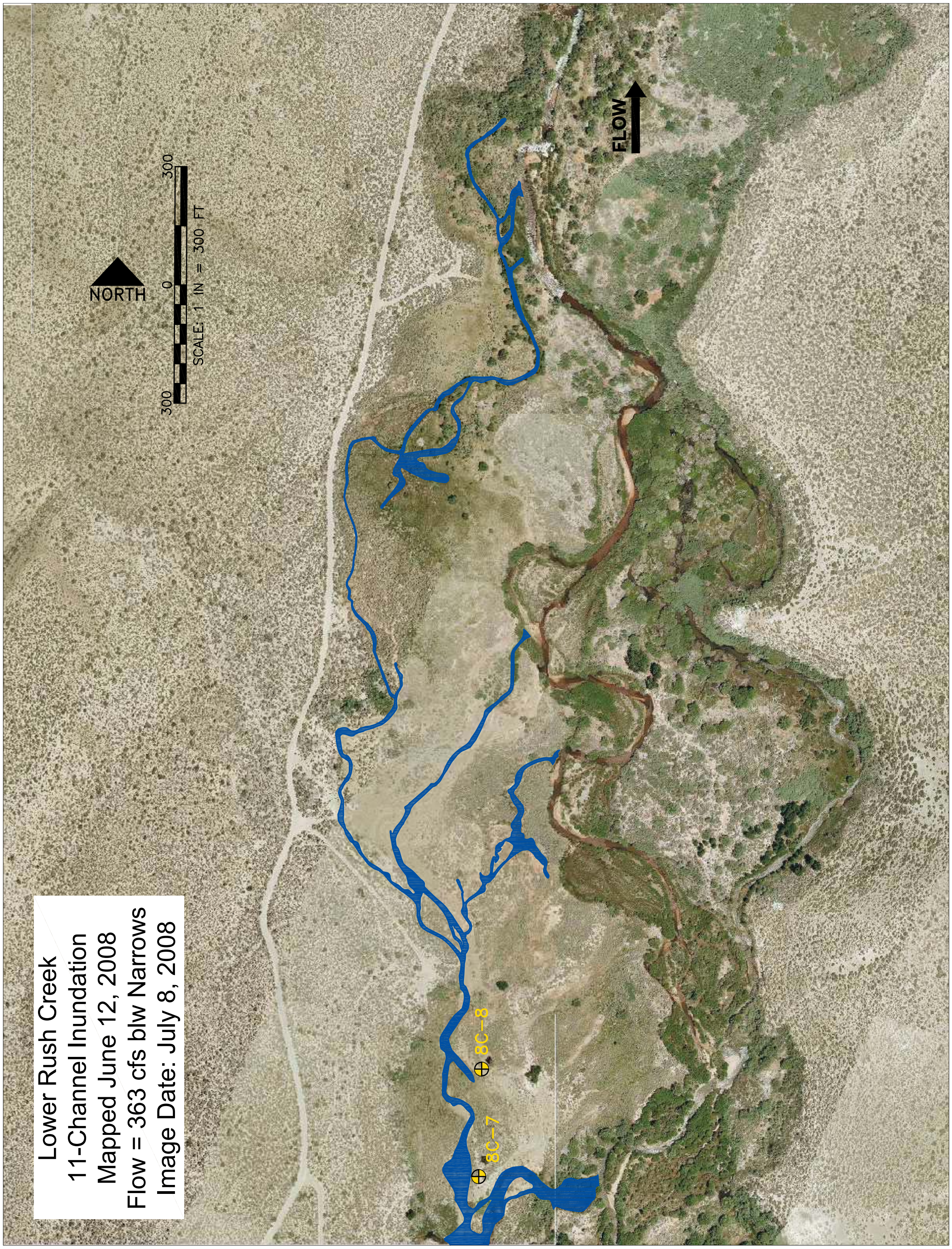
Appendix B-4. Figure 2. The 8 and 4bii floodplain with the extent of wetted and inundated areas on August 9, 2005, resulting from flow entering the 8 Channel and 4bii Channel.



Surface Area (acres)

	6/29/2005	8/9/2005
Inundated Surface	3.57	1.88
Wetted Surface	2.83	3.26
Dry Surface	2.15	3.40
Total Floodplain Area	8.55	8.55

Appendix B-4. Figure 3. Reconstructed 3D floodplain with the extent of wetted and inundated areas on June 29, 2005, and August 9, 2005.



Appendix B-4. Figure 4. Pathway of 8 Channel surface flow during the peak Rush Creek SRF releases, mapped on July 12, 2008.

APPENDIX B-5. FLOODPLAIN DEPOSITION EXPERIMENTS

3.4 Floodplain Deposition Experiments

In RY 2004, we began field experiments to evaluate the role of streamflow magnitude and duration on reconfinement of the lower Rush Creek channel via natural floodplain construction processes (coarse and fine sediment deposition during high flows). In RY 2004, the SRF releases fluctuated between 240 cfs and 384 cfs over a three-day period. The duration of the 384 cfs peak was less than one day (the daily average peak was 354 cfs) (McBain & Trush, 2005). This peak flow release deposited small volumes of fine sediment at our floodplain study sites. The short peak duration combined with flow fluctuations ruled out any evaluation of duration in deposition rates and volumes.

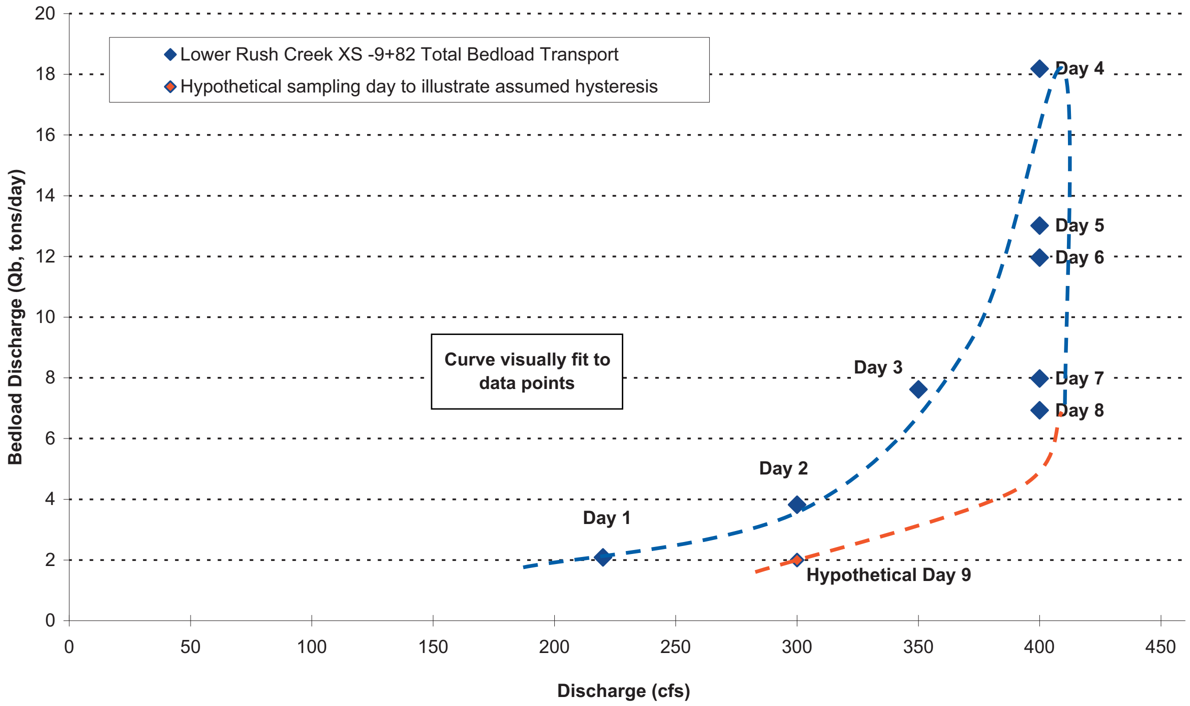


Figure 29. Lower Rush Creek total bedload discharge as a function of streamflow, with increasing transport rate on ascending limb of hydrograph, and then decreasing transport rate following the first day of the 400 cfs bench.

Wet-Normal runoff conditions in RY 2005, (see Section 2.1) provided an opportunity to evaluate the role of peak flow magnitude and duration on floodplain deposition and channel reconfinement processes. The Rush Creek SRF releases were modified, in part, to accommodate floodplain deposition experimental objectives. The higher magnitude snowmelt runoff anticipated on Lee Vining Creek also allowed us to plan and implement floodplain sediment deposition studies on Lee Vining Creek. Experimental sites were installed on the B-1 channel and main channel of Lee Vining Creek.

Previous annual reports describe historical floodplain conditions and the importance of channel confinement to stream recovery, as well as provide conceptual models describing floodplain processes that lead to confinement (McBain and Trush 2000, 2005). Objectives for RY 2005 monitoring were to address two primary questions:

(1) Do floodplain deposition rates decrease with increasing peak flow duration? Or rephrased, what additional deposition “work” is accomplished with each additional day of peak flow duration? Does fine sediment supply to the floodplains decrease with duration?

(2) How much floodplain deposition results from successive days of a 400 cfs peak flow release?

These questions address the sufficiency of the magnitude and duration of SRF peak flows to re-confine the bankfull channel, rebuild geomorphically active floodplain elevations, and re-create healthy aquatic habitat.

3.4.1 Sampling methods

Five cross sections were selected on lower Rush Creek for RY 2005 experiments (Figure 30): XS -25+00, XS 319+62, XS 321+02, XS 239+00, and XS 1+10. Several cross sections used in RY 2004 were abandoned in RY 2005 in favor of sites we anticipated to be more dynamic and responsive to the

2005 peak flow magnitude. Cross section 1+10 was located at the upstream end of the 10 Channel, while the remaining four cross sections were located on the main channel. Cross sections 319+62 and 321+02 were new locations not sampled in RY 2004, and were selected in part because they were located on a large developing floodplain where all the flow was in a single channel (compared to several RY 2004 cross sections adjacent to channels that only conveyed a portion of the total flow in the stream). Cross section 239+00 was selected because it traverses a recently constructed floodplain at the 3D site that is at a very low elevation relative to the channel (and therefore susceptible to deposition).

Four cross sections were selected on lower Lee Vining Creek for RY 2005 experiments (Figure 31): XS 0+87, XS 1+28, XS 4+31, and XS 3+45. Cross section 3+45 i on the main channel, and the remaining three are on the lower B-1 channel. All experiments were located on existing cross sections and were not sampled in RY2004.

In 2004, one-foot wide strips of indoor-outdoor carpet were installed on several cross sections to clearly detect deposition directly attributable to the 2004 SRF releases. This method proved successful, and carpet strips were installed at the four cross sections on Lee Vining Creek and the five cross sections on Rush Creek (Table 14). The carpets were installed upside down with a rough fabric surface facing upwards, and nailed onto the floodplain with 12" long spikes flush to the existing floodplain surface. Following the peak flow release, local deposition depths were measured at frequent intervals on the carpets with a metal ruler, and samples of deposited sediment were collected and transported to a laboratory to be dried, sieved, and weighed.

Bedload transport rates were measured at consistent stations on Rush Creek cross sections 319+62 and -25+00 during Day 1, 2, 3, 4, 6, and 8 of the 400 cfs peak SRF release (June 23, 24, 25, 26, 28, and 30). A 3-inch square Helley-Smith bedload sampler was used. Most samples were collected with the sampler held on the bed surface for 10 minutes. Bedload samples were also transported home for particle size analysis. Bedload sampling was initiated at cross section 1+10 and 321+02, but because transport rates were small, we stopped sampling after the first day of the peak flow release. Bedload sampling was not conducted on Lee Vining Creek due to uncertainty whether there would be adequate inundation and transport.

To address Question #1 (does deposition rate decrease with peak flow duration?), we attempted to use colored sand as a tracer. Colored sand was sprinkled immediately upstream of the carpet in places where there was noticeable deposition, with the expectation that it would settle in discrete horizontal layers on the carpet. With multiple layers of colored sand interspersed with naturally deposited sand, the distance between colored sand lenses could be measured, and that depth divided by the duration of flow (in days) that caused that deposition depth would yield a deposition rate. Colored sand was distributed as follows:

- Day 0-add yellow sand to signify initial conditions when Q=400 cfs;
- Day 1-add red sand to signify sand deposition after 1 day of 400 cfs;
- Day 2-add blue sand to signify sand deposition after 2 days of 400 cfs;
- Day 8-measure top of natural sand deposition to signify sand deposition after 8 days of 400 cfs.

The bedload and suspended sediment sampling on the mainstem of Rush Creek was closely coordinated with the floodplain deposition studies to correlate floodplain deposition rates and volumes with the mainstem sediment transport rates in Rush Creek as a function of longitudinal location (upstream versus downstream) and duration. This integrated monitoring addressed whether fine sediment supply was near zero at the outlet of Grant Lake, and significantly increased downstream of the Highway 395 Bridge where glacial outwash terraces may provide a higher sediment supply to Rush Creek.

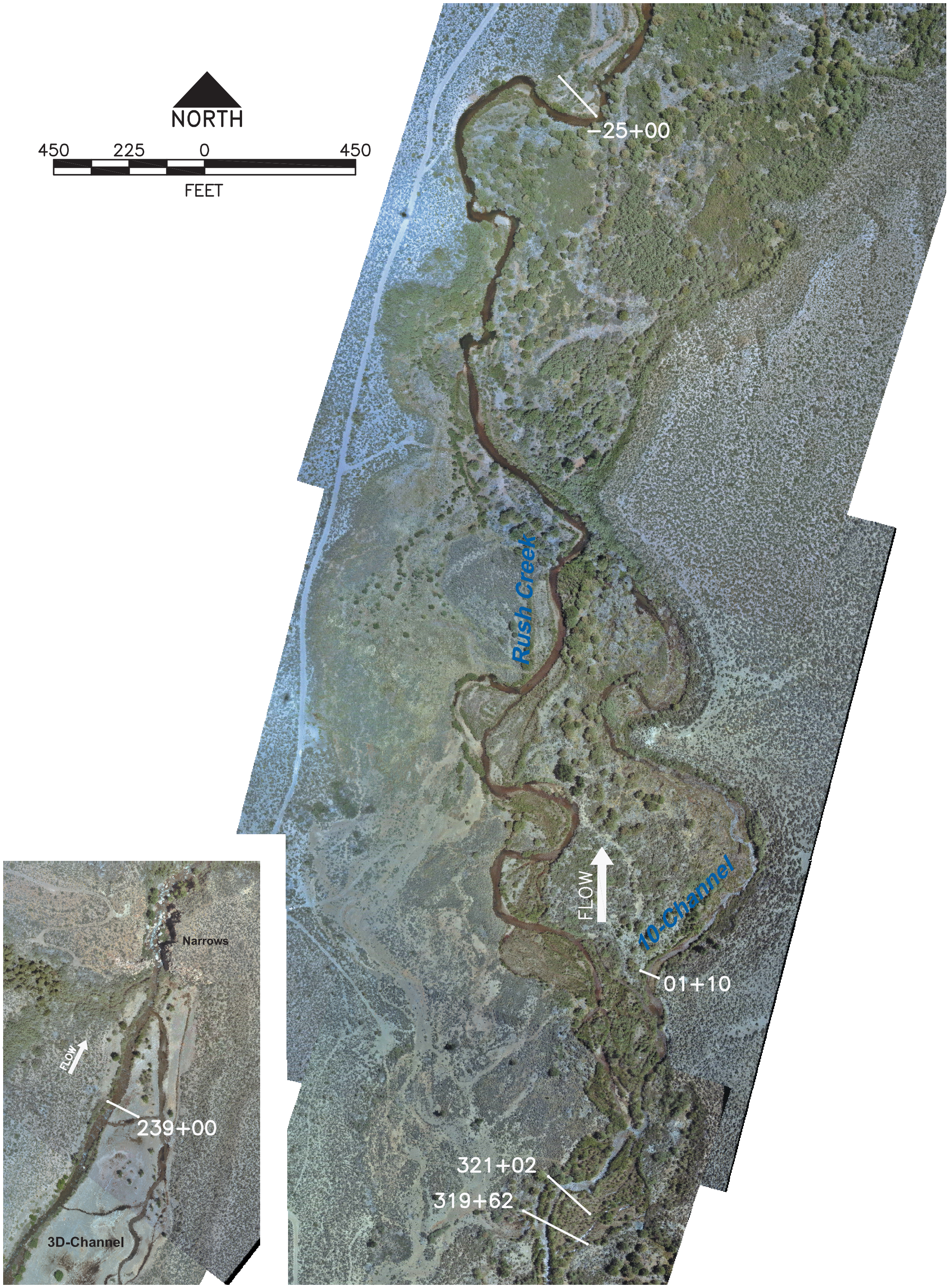


Figure 30. Location of Rush Creek floodplain deposition monitoring cross sections.

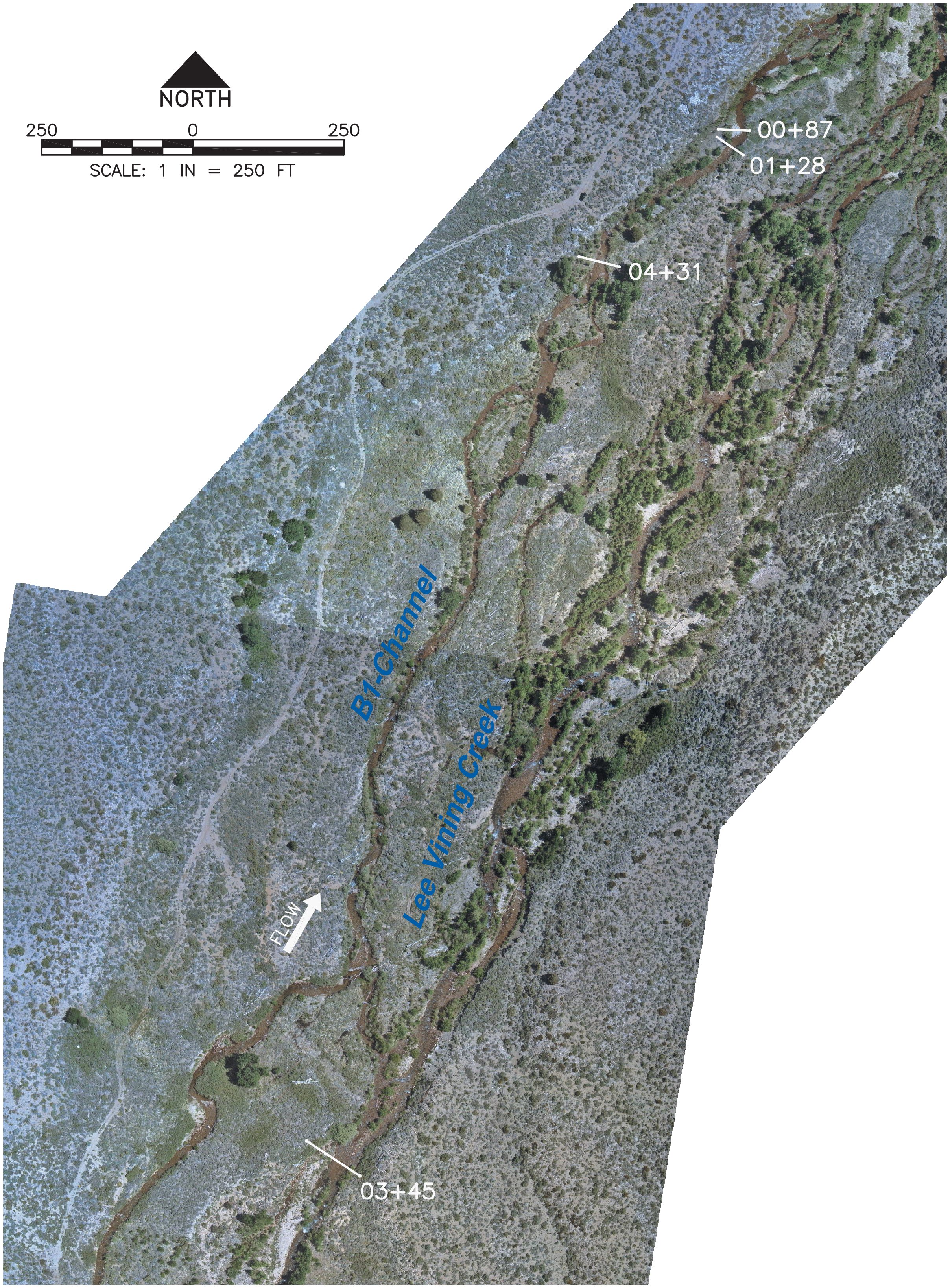


Figure 31. Location of Lee Vining Creek floodplain deposition monitoring cross sections.

Table 14. Summary of experiments at Lee Vining and Rush Creek cross sections conducted during the peak flow release for RY 2005.

Creek	Cross Section	Before/After Deposition Measured?	Colored Sand Experiment?	Bedload Sampling?	Figure # (Appendix G)
Rush Creek	239+00 (main channel)	N[1]	Y	N	G-1
	319+62 (main channel)	Y	Y	Y	G-2
	321+02 (main channel)	Y	Y	N[2]	G-3
	1+10 (10 Channel)	Y	Y	N[2]	G-4
	-25+00 (main channel)	Y	Y	Y	G-5
Lee Vining Creek	3+45 (main channel)	Y	N	N	G-6
	4+31 (B-1 Channel)	Y	N	N	G-7
	1+28 (B-1 Channel)	Y	N	N	G-8
	0+87 (B-1 Channel)	Y	N	N	G-9

[1] Gravel bar formed during high flow, no fine sediment deposition

[2] Bedload sampling initiated, but transport rates too low and not continued

3.4.2 Analysis and Results

As with RY 2004 results, sediment transport and floodplain deposition data collected during the 2005 SRF releases should be considered site-specific, and extrapolated only with caution for the following reasons: (1) there are site differences in sediment supply, transport rates, and physical conditions influencing the extent and duration of inundation, (2) low-elevation floodplain sites were selected to increase the probability of inundation during the June 2004 SRF releases and not selected to represent the range of floodplain surfaces found along Rush and Lee Vining creeks, and (3) the data are from only one peak flood event and may differ from other high flow releases of similar magnitude and duration, which have access to different sources and supplies of stored sediment.

Despite the site-specificity of our results, the 2005 SRF releases and corresponding floodplain deposition monitoring improved our understanding of floodplain recovery processes, particularly with regard to the magnitude and duration of SRF releases. Floodplain deposition depths and final elevations are illustrated in cross section plots in Appendix G-1 to G-12. Bedload transport rates measured at floodplain deposition sites are provided in Appendix G-13 to G-17, and floodplain depositional rates are illustrated in Figure 32. The D_{84} and D_{50} grain size of floodplain deposits are summarized in Table 15. In contrast to the floodplain deposition samples, the grain size of the bedload samples was too small to compute the D_{84} based on the sieve set used, so results are presented as:

(1) the range of sieves where the largest particle was trapped, and (2) the percent of total sample captured on that largest sieve opening (Table 16).

3.4.3 Discussion

The 2005 peak SRF release magnitude of 400 cfs (resulting in a 467 cfs peak in Lower Rush Creek) was larger than the RY 2004 releases (384 cfs), but more significantly, had a longer duration (1 day in 2004 versus 8 days in 2005). Consequently, floodplain deposition was more pronounced than in RY 2004. Deposition depths were still modest, however, with most deposition at our study sites less than 40 mm (1.5 inches) (Appendix G-4, G-5, G-7, G-9, G-10). Deposition depths were slightly larger along channel margins, with depths up to 100 mm (4 inches) (Appendix G-3, G-6, G-7, G-8).

Fine sediment deposition was greatest on the floodplain edge immediately adjacent to the channel margin. In addition, bedload transport rates and floodplain depositional rates were also greatest along the channel margins (Figure 32). Visual observations and particle size sampling on cross section -25+00 indicated the grain size and depth of the depositional material was greatest along the channel margins on the inside of point bars where coarser bedload was deposited (Table 15, Appendix G-14 and G-17). On the large floodplain traversed by cross section 319+62 (Figure 33), significant deposition occurred behind clumps of vegetation adjacent to lanes of substantial bedload transport across the floodplain (Appendix G-3 and G-12), but this deposition was still smaller than along the channel margins where bedload from the main channel was deposited among the first vegetation. This pattern of deposition explains the asymmetrical floodplain morphology frequently observed in Rush Creek, in which the floodplain elevation is highest along the channel margins and slopes downward away from the channel.

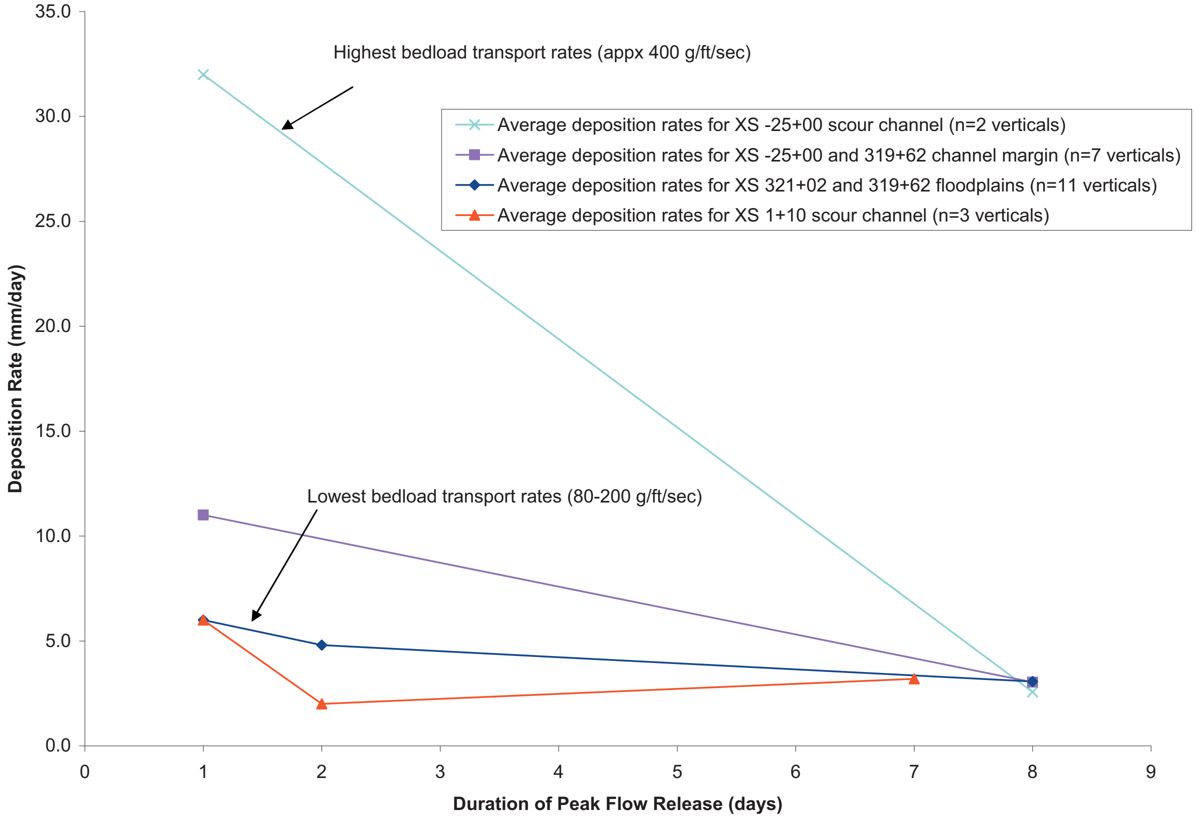


Figure 32. Average deposition rates as a function of peak flow release duration for geomorphic features on selected verticals on Rush Creek cross sections 321+02, 319+62, 1+10, and -25+00.

Floodplain bedload transport rates, while more variable than the mainstem bedload transport results presented in Section 3-3, followed the same trend of decreasing transport rates with duration (Appendix G-15 through G-17, Figure 32). With the exception of cross section -25+00 Station 126.0, the bedload transport rates decreased dramatically (by 50% or more) after a 3-day duration. A similar decrease in bedload transport rates was observed on the mainstem, but occurred after a 2-day duration, suggesting that there may have been a 1-day lag time between mainstem and floodplain transport rates. There was no detectable change in maximum grain size in bedload samples with increasing duration (Table 16), although the range of sieves did not allow a precise analysis of changing grain sizes with duration.

The colored sand experiments were not as useful as hoped due to several factors. The experiment would work well for sites where the primary depositional process was settling of suspended sediment (e.g., cross section 319+62 near station 172, Figure 34); however, most depositional features were formed by bedload deposition and many had a high exchange with bedload transport, preventing the desired "lenses" of colored sand from being retained. For those stations where the bedload exchange was minimal and the experiment performed well, the rates of deposition as a function of duration were computed and averaged for scour channel locations, channel margins, and floodplains (Figure

Table 15. Summary of D_{84} and D_{50} grain sizes of floodplain depositional features on Rush Creek and Lee Vining Creek cross sections.

Stream	Cross Section	Station (ft)	D_{84} (mm)	D_{50} (mm)
Rush Creek	319+62	101.2	0.31	0.17
		103.4	0.34	0.18
		107.3	0.34	0.17
		113.3	0.44	0.23
		119.6	0.65	0.37
		133.0	0.39	0.18
		150.3	0.40	0.18
		154.6	0.29	0.15
		155.6	0.48	0.34
		174.5	0.31	0.17
Rush Creek	321+02	143.6	0.83	0.44
		152.0	0.46	0.22
		157.7	0.46	0.25
		159.1	0.46	0.20
Rush Creek	1+10	45.0	0.38	0.20
		46.5	0.59	0.32
		50.4	0.38	0.20
Rush Creek	-25+00	123.6	0.42	0.20
		124.8	0.45	0.21
		159.5	1.25	0.44
		161.0	0.80	0.40
		162.5	0.88	0.42
		164.0	0.80	0.36
		165.5	1.63	0.64
		167.0	0.94	0.41
		168.7	0.61	0.34
Lee Vining Creek	3+45	38.0	0.43	0.27
Lee Vining Creek	4+31	20.2 - 21.2	1.03	0.56
Lee Vining Creek	1+28	26.3 - 27.3	0.41	0.20

Table 16. Summary of maximum grain sizes of floodplain bedload samples on Rush Creek as a function of duration.

Cross Section	Station	Date	Flow Release Duration (days)	Largest particle size class in bedload sample (mm)	Percent of total sample weight contained in the largest particle size class sieve
319+62	183.2	23-Jun-05	1	2 mm - 4 mm	2.2%
		24-Jun-05	2	4 mm - 8 mm	0.2%
		25-Jun-05	3	4 mm - 8 mm	0.4%
		26-Jun-05	4	4 mm - 8 mm	0.2%
		28-Jun-05	6	4 mm - 8 mm	0.2%
		30-Jun-05	8	4 mm - 8 mm	2.1%
319+62	152.6	23-Jun-05	1	8 mm - 16 mm	0.5%
		24-Jun-05	2	4 mm - 8 mm	0.9%
		25-Jun-05	3	8 mm - 16 mm	0.3%
		26-Jun-05	4	4 mm - 8 mm	1.0%
		28-Jun-05	6	4 mm - 8 mm	0.2%
		30-Jun-05	8	4 mm - 8 mm	0.5%
319+62	106.7	23-Jun-05	1	2 mm - 4 mm	0.8%
		24-Jun-05	2	4 mm - 8 mm	0.4%
		25-Jun-05	3	4 mm - 8 mm	0.1%
		26-Jun-05	4	4 mm - 8 mm	1.1%
		28-Jun-05	6	4 mm - 8 mm	0.2%
		30-Jun-05	8	2 mm - 4 mm	8.7%
-25+00	153.3	23-Jun-05	1	8 mm - 16 mm	0.4%
		24-Jun-05	2	8 mm - 16 mm	0.6%
		25-Jun-05	3	8 mm - 16 mm	0.5%
		26-Jun-05	4	4 mm - 8 mm	2.1%
		28-Jun-05	6	4 mm - 8 mm	4.0%
		30-Jun-05	8	4 mm - 8 mm	6.5%
-25+00	126.0	23-Jun-05	1	8 mm - 16 mm	3.4%
		24-Jun-05	2	8 mm - 16 mm	1.0%
		25-Jun-05	3	8 mm - 16 mm	2.3%
		26-Jun-05	4	8 mm - 16 mm	1.0%
		28-Jun-05	6	8 mm - 16 mm	0.7%
		30-Jun-05	8	8 mm - 16 mm	0.6%

32). While there was some variability at individual verticals, the average values indicated a decreasing rate of deposition with duration, and were most pronounced in zones where bedload transport was highest. This helped corroborate our qualitative field observations that most net deposition for a given high flow occurred rapidly, reaching equilibrium conditions in a day or two. The higher the sediment supply (inferred from bedload transport rates), the faster the initial deposition to near equilibrium conditions occurred. On floodplains with lower bedload transport rates and/or dominated by suspended sediment deposition, the rate of deposition did not appear to change significantly, although the small sample size tempered our confidence in this observation as a verified "conclusion". If the experiment were conducted again, a better approach would be to insert a thin metal ruler into the fresh deposit each day at consistent stations to track deposition depth. Hydraulic disturbance to the deposit would be minimal with this method, and disturbance to the micro-topography of the deposit would be reversed within a minute or two from fresh bedload exchange.

As observed in RY 2004, the primary depositional process during incipient floodplain development in 2005 was bedload deposition rather than suspended sediment deposition. Suspended sediment

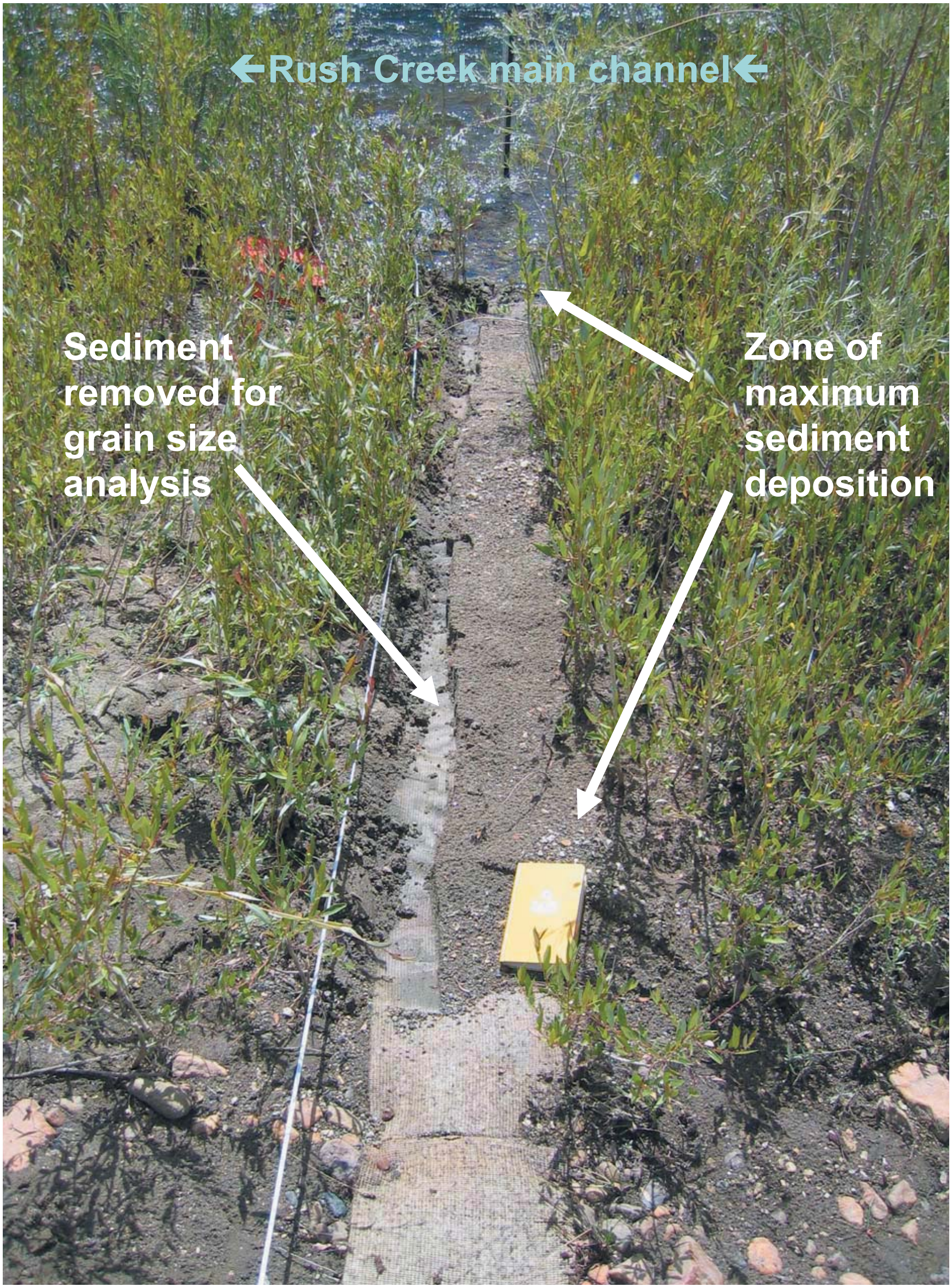


Figure 33. Floodplain deposition carpets installed across XS 319+62 on Lower Rush Creek, showing sediment deposited along the mainstem channel margin after the RY 2005 SRF recession.

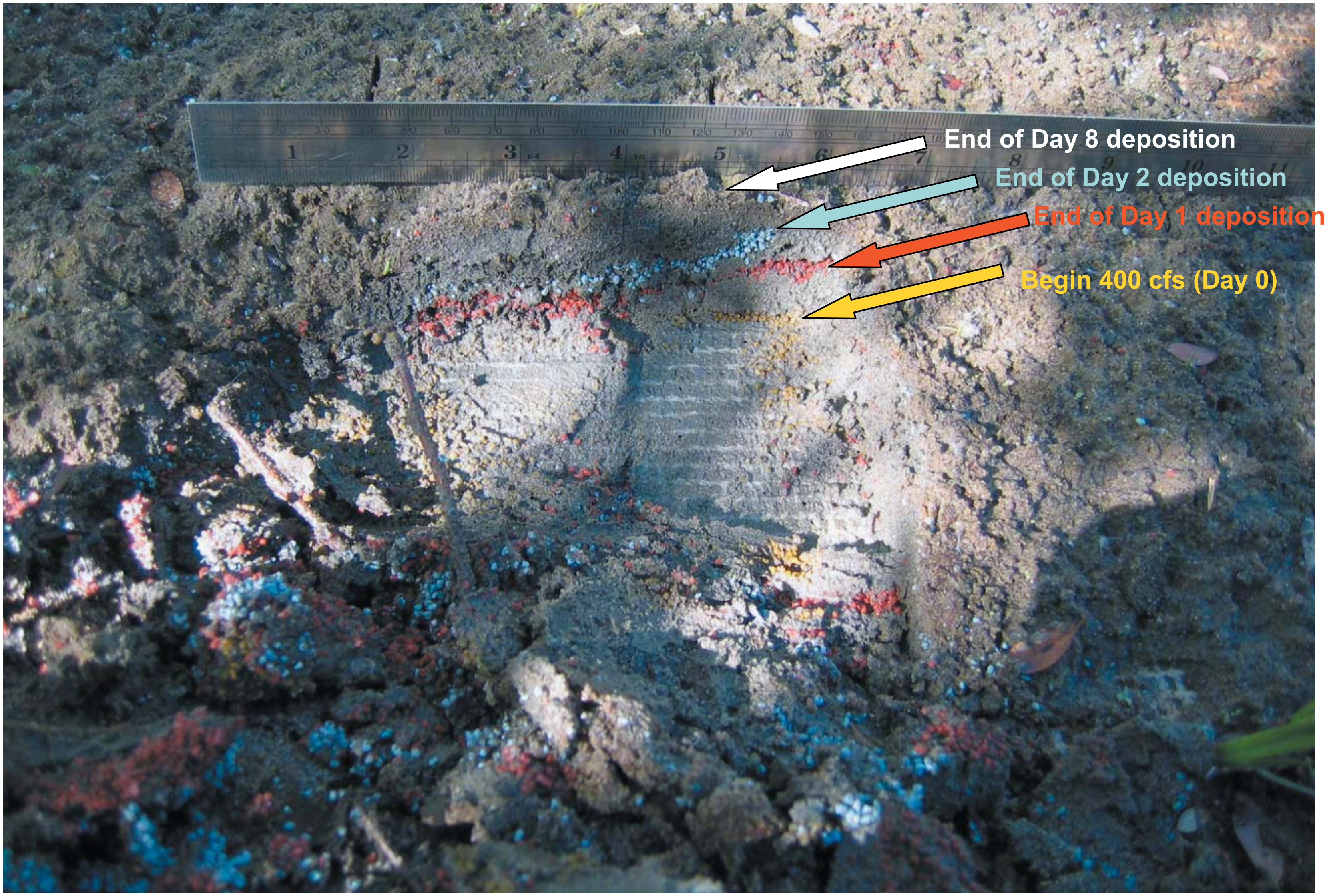


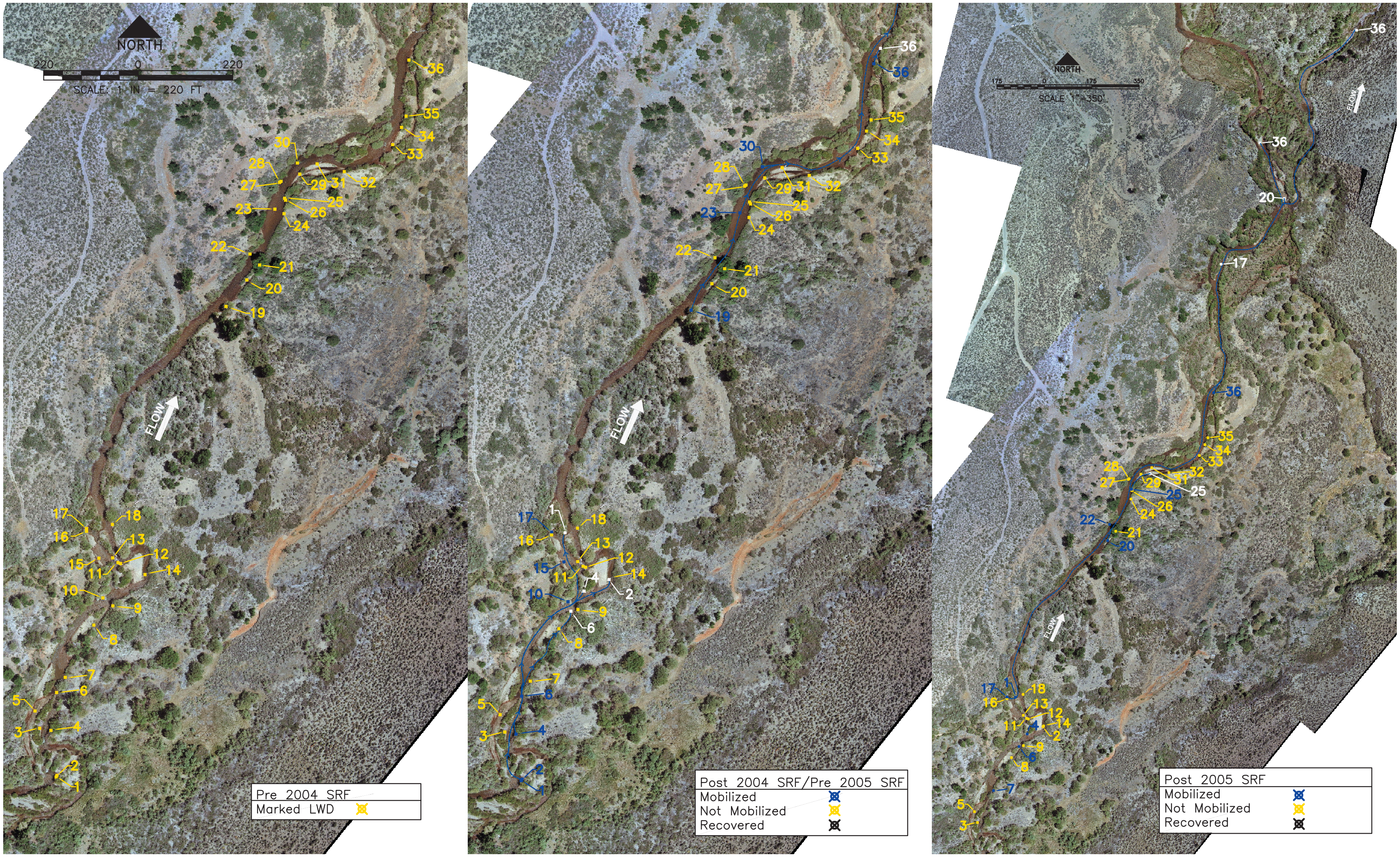
Figure 34. Close-up of floodplain deposition on Lower Rush Creek, showing successive depositional layers indicated by colored sand sprinkled across the surface during the SRF release.

concentrations were again low during this release (see Section 3-3), minimizing the contribution of suspended sediment deposition in floodplain development. Suspended sediment deposition was observed independent of bedload deposition on certain portions of cross sections (e.g., XS 319+62 at station 172), but the deposition depths were less than 20 mm (3/4 inch) (Appendix G-7). Accretion from fine sediment deposition likely plays only a minor role in floodplain building at the sites monitored.

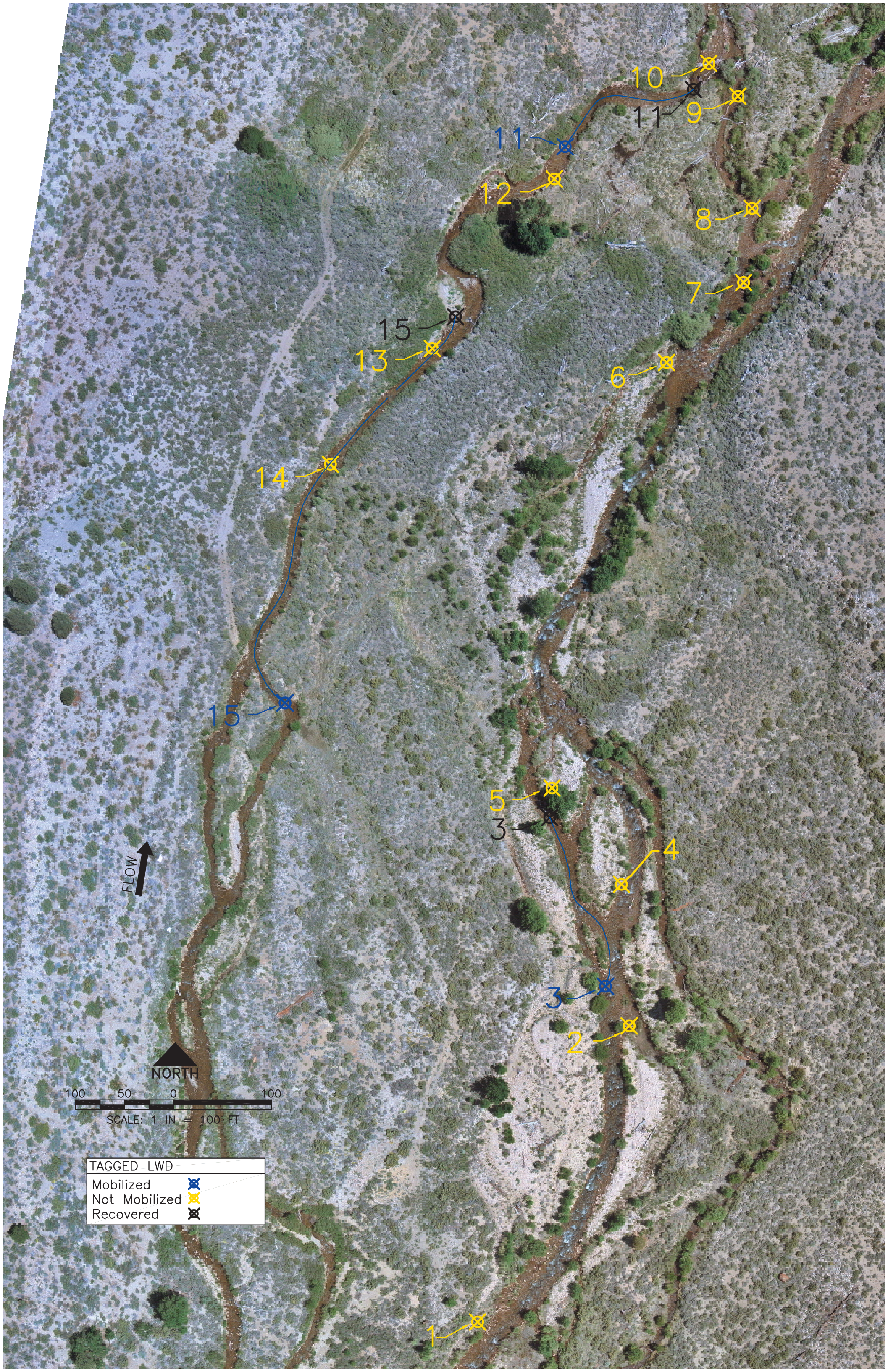
Fine sediment deposition on what were considered floodplains on the Lee Vining Creek B-1 channel was minimal during the 2005 peak flow (372 cfs, approximately a 5.6-yr flood) because flow did not substantially inundate those surfaces. Channel incision within the multiple channels in Lee Vining Creek may have largely abandoned these former floodplains, preventing their inundation by frequent flood events (i.e., 1.5 to 2-year floods). The maximum deposition depth at the Lower Lee Vining B-1 cross sections was less than 20 mm at cross section 1+28 (Appendix G-8). More substantial fine sediment deposition occurred on the main channel cross section 3+45 (up to 100 mm) in the backwater channel (Appendix G-6). This backwater may eventually fill with fine sediment over the long term, unless the entrance opens up and the channel avulses.

As observed in RY 2004 and RY 2005, SRF release magnitudes of approximately 400 cfs met several important ecological objectives expected for a Normal and Wet-Normal runoff year type (see Figure 18 of RY 2003 Annual Report [McBain and Trush 2004]). As expected, this release magnitude appeared to be a minimum threshold for measurable fine sediment deposition on incipient floodplains. Flow magnitudes larger than 400 cfs scheduled for Wet and Extremely-Wet runoff year types will be required to re-build (aggrade) floodplains and re-confine channels close to pre-1941 levels. As a rough approximation of the discharge needed to initiate deposition, the stage height of a given high flow can be assumed commensurate with fine sediment deposition elevation. The RY 1999 Report (McBain and Trush 2000) recommended a minimum inundation depth of 0.5 ft for initiating floodplain deposition. In lieu of attempting complex fine sediment deposition models as a way to determine how to maximize floodplain deposition rates, we recommend targeting a minimum inundation depth. This approach would address the variability of floodplain elevations, and would require increasingly larger floods to achieve the same inundation depth as floodplains build over time. However, this need for larger floods is counterbalanced by increases in stage height for a given flow magnitude that results from increased channel and floodplain roughness. The RY 1999 Report (McBain and Trush 2000) provides additional description of this process.

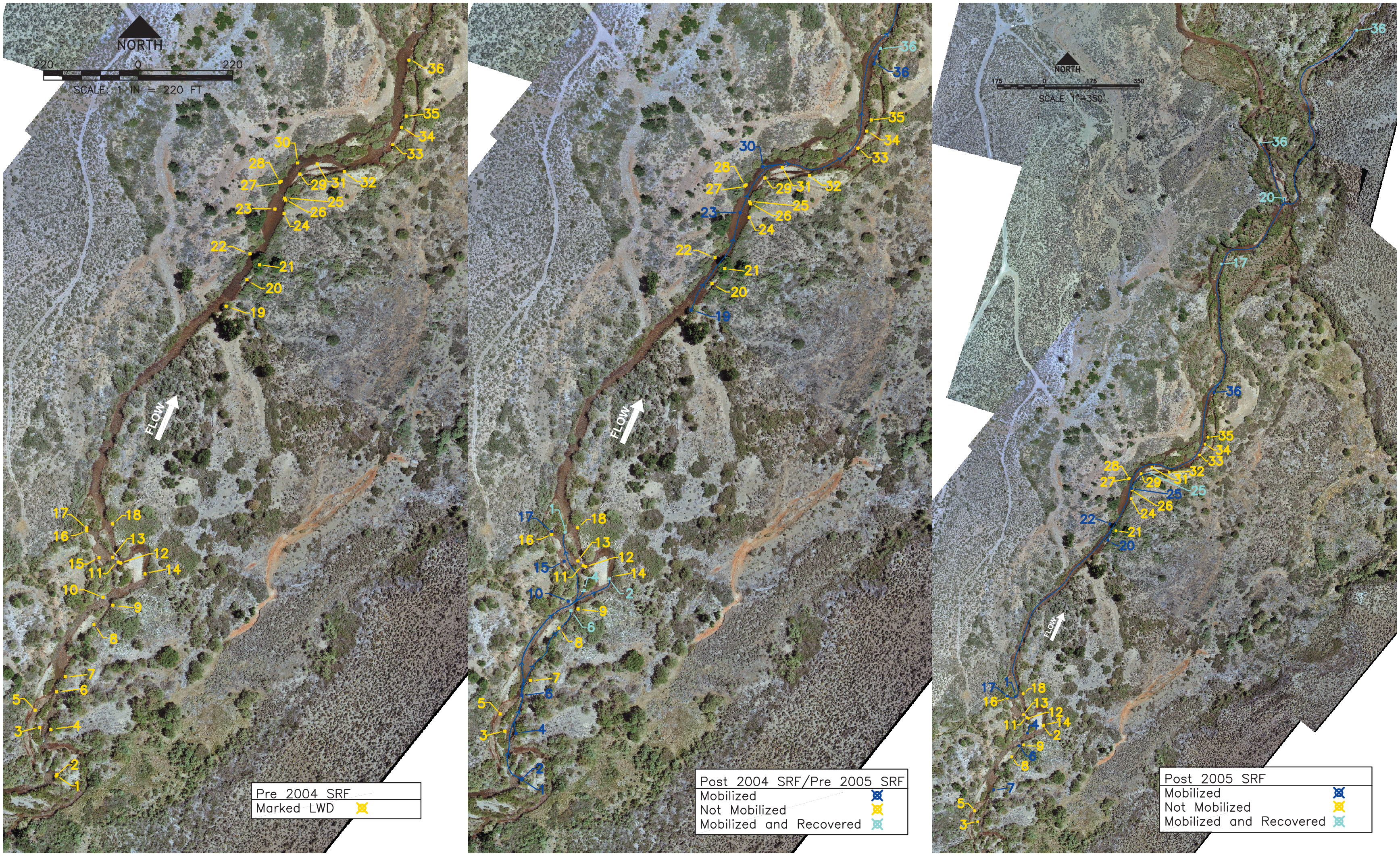
APPENDIX B-6. LARGE WOOD TRANSPORT



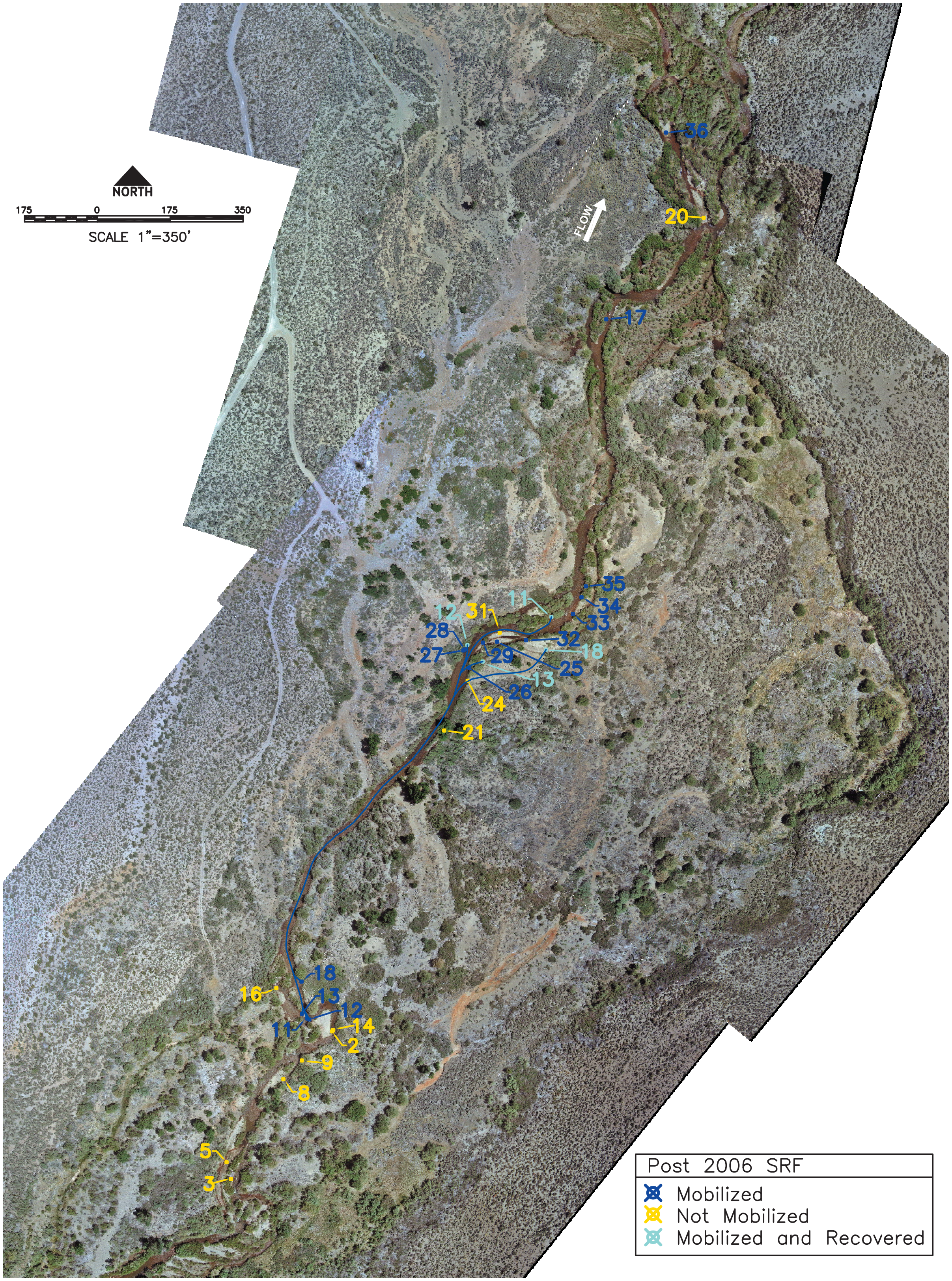
Appendix B-6. Figure 1. Large woody debris marked and relocated on Lower Rush Creek before and after the RY 2004 and 2005 SRF releases.



Appendix B-6. Figure 2. Large woody debris marked and relocated on Lee Vining Creek before and after the RY 2005 snowmelt peak.



Appendix B-6. Figure 3. Runoff Year 2005 large wood transport tracking in Lower Rush Creek.



Appendix B-6. Figure 4. Runoff Year 2006 large wood transport recovery in Lower Rush Creek.

APPENDIX C. RIPARIAN VEGETATION AND SHALLOW GROUNDWATER ANALYSES

Riparian vegetation and groundwater monitoring, primary topics of several Annual Reports (M&T 2000, 2004, 2005, 2006, and 2007), was designed to evaluate SRFs and baseflows that sustain groundwater conditions that in turn promote the desired ecological outcomes identified for riparian vegetation recovery. Recovery (i.e., the ‘desired ecological outcomes’ for riparian vegetation) entails: (1) expanding riparian vegetation acreage to occupy geomorphic surfaces capable of sustaining riparian vegetation, (2) maintaining a naturally fluctuating riparian corridor through sequences of dry runoff years (i.e., preventing major, but not all, die-back of vegetation during drought), (3) periodically regenerating dominant woody riparian tree species (primarily willows and cottonwoods) in wetter years through seed germination and eventual recruitment, and (4) developing structural complexity within riparian corridors defined by species diversity, a mature canopy and understory, and a varied age-class structure.

Riparian vegetation recovery along Rush and Lee Vining creeks depends on two primary functions the annual hydrograph provides: overbank/side-channel streamflows during spring snowmelt and shallow groundwater maintenance in the floodplains throughout the growing season (May 1 to September 30), Seasonal re-watering of side-channels plays an important role in both functions. To predict the extent and timing of moist floodplain surfaces during snowmelt streamflows, interactions among shallow groundwater, mainstem streamflows, and side-channel streamflows had to be understood rudimentarily. Seed dispersal periods for dominant woody riparian tree species were measured. Regeneration will not occur unless moist floodplain surfaces coincide with seed availability. Another important objective was estimating the elevation of the shallow groundwater (relative to the floodplain surface elevation) needed by established woody riparian plants to uptake shallow groundwater through the growing season.

With a basic understanding of these processes, woody riparian vegetation recovery was evaluated to determine if each distinct floodplain surface within the Rush and Lee Vining creek corridors could/would recover under the recommended SEF streamflows. Several streamflow thresholds critical for eventual recovery were established to formulate and evaluate how well the SEF annual hydrograph recommendations would perform relative to unregulated, SCE-regulated, and SRF annual hydrographs. This was accomplished by computing NGDs and NGYs for the key recovery processes described.

C-1: Riparian Vegetation Life History Characteristics in Relation to the Annual Snowmelt Hydrograph

Riparian corridors are, by definition, located adjacent to a stream channel where groundwater is higher than if sustained only by precipitation (Warner and Hendrix 1984; McBain and Trush

2004). Riparian corridors for Rush and Lee Vining creeks generally are the areas between the valley toe-slopes or, in the delta reaches, at a topographic break between 1929 low and high terraces (McBain and Trush 2004). Riparian vegetation has been distinguished throughout the monitoring as either woody riparian vegetation, grasslands, or wet meadows, with mapped "plant stands" defined by the dominant or co-dominant species. Most riparian monitoring and analyses focused on the dominant woody riparian species – willows and cottonwood.

Three riparian plant life history stages were identified (Figure C-1). Initiation is the earliest life stage, beginning when a seed finds a suitable nursery site (defined by substrate, moisture availability, sunlight, etc.) and germinates. Initiation continues as germinated seedlings find perennial water and set roots and extends through a plant's first growing season until leaf abscission. Establishment begins at the end of the first growing season with a plant's first leaf abscission. The establishment stage can extend over several growing seasons. Recruitment (maturity) begins when vegetation matures and begins to expend energy to reproduce through flowering and seed propagation.

Successful willow and cottonwood initiation relies on the coincidence of late-spring snowmelt floods, the timing and rate of the snowmelt recession, available nursery sites, and the timing of seed dispersal (Bradley and Smith 1986, Scott et al. 1993, Segelquist 1993, Mahoney and Rood 1998, Stuart and Rood 2000). Typically riparian woody plant seed dispersal overlaps with the annual snowmelt flood and snowmelt recession and ends during summer baseflows (Figure C-2). Historically, the receding limb of the unimpaired snowmelt hydrograph often extended into late-August and occasionally to the end of the growing season in late-September (Figure C-3). The variability in the annual streamflow recession rate allowed woody riparian plants to successfully colonize a broad range of floodplain surface elevations.

Within the Mono Basin, seed dispersal periods vary between species: yellow willow starts early in the growing season, black cottonwood occurs shortly after the annual snowmelt flood, and narrowleaf willow disperses seeds until August (Table C-1). Seeds from one species or another are thus available throughout most of the growing season regardless of the runoff year type, which means that every year some woody riparian plant initiation can occur.

During the establishment stage (after the first growing season), seedlings are subject to numerous mortality agents bracketed by two extremes: flood-induced scour, and desiccation (Figure C-1). The upper elevation limit of seedling establishment is a function of desiccation; the lower limit of establishment is primarily a function of scour. Large floods are important in creating seedbeds and facilitating seedling germination higher and farther away from the stream channel and groundwater table. However, large floods occur less frequently. Seedlings that germinate higher on the bank risk desiccation. Seedlings more often establish along channel margins where water is more readily available during seed release and germination periods, and where groundwater recession is less pronounced. But plants that germinate on lower surfaces are more vulnerable to scour induced mortality.

Individual woody riparian plants typically live less than 150 years, but under certain conditions can survive past 400 years. In the Mono Basin, most woody riparian plant species can persist for several decades without a flood event causing initiation of new cohorts from seeds. However, a plant's ability to clone or successfully grow another generation of individuals through root sprouting allows some woody plant species to persist for centuries and survive long periods of drought.

C-2: Sources of Groundwater for Sustaining Riparian Vegetation

Streamflow-groundwater recharge processes are described in M&T 2004. Riparian corridor width is a function of the extent of shallow groundwater tables supplied by streamflow, either through lateral recharge from the stream channel or floodplain inundation from overbank flows. Our conceptual model also assumes the presence of a deeper groundwater table recharged through precipitation. During snowmelt runoff, the deep groundwater rises and often merges with the stream-fed shallow groundwater. In many instances, riparian vegetation recovery is limited by the inability to affect the deeper groundwater table by surface streamflow to broaden the shallower "riparian" groundwater table. Managed streamflows to recover and sustain riparian vegetation are intended primarily to affect the shallow groundwater table.

The riparian corridors in Rush and Lee Vining creeks are a mosaic of geomorphic surfaces of varying area and shapes, proximity to surface flow, and elevation above the shallow groundwater table. The breadth, volume, and duration of surface flow distribution across the stream corridor, the volume and duration of main-channel flow, and the volume and duration of overbank flow all affect the extent of shallow groundwater available to support riparian vegetation. In general, geomorphic surfaces that are higher and more distant from the stream channel have a deeper groundwater and a shorter-duration surface saturation period in which to allow seed germination and initiation. Reaches with a single perennial channel typically have narrow riparian corridors; locations with seasonal or perennial side channels have wider riparian corridors. Only in wetter years will riparian plants successfully initiate on elevated surfaces or farther from the stream. Desiccation, resulting from seasonal groundwater decline and multi-year drought periods, defines the physical boundaries of the riparian corridor.

Riparian vegetation only initiates and successfully establishes where environmental conditions meet each plant species' life history requirements. The distance roots must grow to reach a perennial water source and the duration a plant can survive drought are common environmental conditions each plant species must cope with. Historically riparian plant vigor and riparian corridor width along Rush and Lee Vining creeks varied with different patterns of wet and dry years. In both creeks, under unimpaired conditions, riparian vegetation likely flourished in wetter years. In drier years, riparian vegetation vigor was not maintained in some locations, and resulted in vegetation die-back. Consecutive dry or wet years (Figure C-4) created periods of drought when the riparian corridor would contract and periods of abundant water and plant regeneration when the riparian corridor would expand. The contrast between vigorous growth and dieback created during wet and dry years historically resulted in structural complexity and a patchy distribution of riparian vegetation.

C-3: Groundwater and Soil Moisture Responses to Streamflow

Successful plant establishment begins with seed germination and root formation where sufficient soil moisture is available when and where seeds are present. Seedlings die unless their roots can utilize available soil moisture and grow until they reach perennial groundwater. The soil moisture needed to satisfy annual growth differs between plant species. When soil moisture diminishes beyond the point at which a root can extract enough water to survive, the plant wilts permanently. The 'permanent wilting point' is different for each plant species. Desert species have permanent wilting points at very low soil moisture content; the permanent wilting points of riparian plants are much higher.

The relationship between groundwater and soil moisture is complex. Above the distinct groundwater table elevation are two less distinct zones of varying moisture content – the capillary fringe and the zone of diminishing soil moisture (Figure C-5). The soil is saturated up to the groundwater table and within the capillary fringe, but then gradually diminishes above the capillary fringe boundary. Changes in stream stage affect groundwater elevation adjacent to the stream, which in turn affect saturation within the soil profile. The capillary fringe provides a buffer from diurnal and seasonal streamflow fluctuations. This buffer is considered in streamflow and groundwater management recommendations. Soil moisture above the capillary fringe can promote plant germination, initiation, and establishment. The ability to develop quantitative soil moisture targets (above the capillary fringe) to maintain riparian vegetation is limited by an understanding of the soil moisture needs of all riparian plant species, the variation in soil moisture created by different soil textures in the field, and the rate of soil moisture change as a function of groundwater depth, season, and climatic conditions. Thus while streamflow management to maintain shallow groundwater is an important mechanism to manage riparian plant establishment and growth, the streamflow recommendations are intended to maintain groundwater and a defined capillary fringe, but not soil moisture, and are thus conservative.

Based on field observations from several monitoring seasons, soil within the capillary fringe remains saturated up to approximately 1.6 ft above the groundwater table. The capillary fringe is variable based on soil texture; finer soils can draw groundwater up farther into the soil column than coarser soils. The capillary fringe associated with fine sand is 1.6 ft (a prevalent soil texture in Rush and Lee Vining Creek riparian corridors) and 0.5 ft for coarse sand (M&T 2005). When groundwater rises to the elevation of the ground surface, the soil is by definition saturated throughout the profile (i.e., the process that occurs during overbank flood events). Additionally, groundwater can recede to the limit of the capillary fringe associated with the soil texture and the soil will still be saturated at the ground surface. For example, groundwater sustained by streamflows could theoretically recede instantaneously 1.6 ft below the ground surface; locations with fine sand substrate would still maintain a fully saturated ground surface. A saturated soil profile to a depth of 1.6 ft would exceed the soil moisture needs of all plants and would meet the requirements for seedling germination and root growth.

Sustaining saturated (or near saturated) soil at the ground surface is vital to successful willow and cottonwood seed germination. However, once the capillary fringe begins to recede, the rate at which the soil transitions from saturated to permanent wilting point is a function of evapotranspiration, solar radiation, and distance from ground surface. The surface dries within hours in many instances. A duration of 21 continuous days of surface saturation was used as a threshold for ensuring a seedling's roots have grown sufficiently deep to reduce effects from additional recession in stream stage. Recession rates associated with unimpaired snowmelt floods, and therefore recession in groundwater table elevation, would have been much slower than the rate necessary for seeds to germinate and seedlings' roots to grow.

C-4: Vegetation Patterns Reflect Shallow Groundwater Hydrology

Given limitations of how site-specific data represent conditions found throughout Rush and Lee Vining creek corridors, several key assumptions were made to simplify our analyses: (1) groundwater responses to streamflows quantified in greater detail on Rush Creek were similar in Lee Vining Creek which was studied less intensively, (2) stream channel water surface elevation, projected laterally as a flat plane across the stream corridor defines an upper limit to groundwater elevation (though not soil moisture driven by capillarity, discussed in the next section), and (3) the vegetation patch type was defined by the distance above this projected groundwater surface. The 2009 riparian vegetation patches (individually mapped plant stands) were overlaid onto the 2003 Digital Terrain Model (DTM) derived from aerial photogrammetry of Rush and Lee Vining creeks. Next, height of the 2009 patch types above the projected 91 cfs water surface elevation on Rush Creek (below the Narrows) and above the projected 63 cfs water surface on Lee Vining Creek (below the Intake) on June 23, 2003 (the dates and discharges during the 2003 aerial photography flight) were estimated from the model.

On Rush Creek, more than 70% of cover associated with specific riparian patch types occurred within 5 ft of the 91 cfs projected water surface; on Lee Vining Creek more than 70% occurred within 3 ft of the projected water surface. As a threshold to better preserve and promote self-sustaining riparian vegetation (herbaceous or woody), groundwater sustained by mainstem baseflow should be within 5 ft of the floodplain surface on Rush Creek and within 3 ft of the floodplain surface on Lee Vining Creek. (Figures C-6 and C-7).

C-5: Groundwater and Riparian Vegetation Monitoring Study Sites

Groundwater studies focused on several key locations in the Rush Creek and Lee Vining Creek bottomlands, primarily where side-channels were re-watered. Five side-channels on Rush Creek have been re-watered since RY1995: the 10, 1A, 3D, 4bii, and 8 channels. On Lee Vining Creek, the A-2, A-3, and A-4 side-channels were also mechanically re-watered.

Groundwater monitoring by the Mono Lake Committee began in RY1995 at several piezometer arrays near the Rush Creek 10-Channel and on Lee Vining Creek between the mainstem and A-4 Channels (summarized in RY2003 and RY2004 Annual Reports (McBain and Trush 2004, 2005).

McBain and Trush began monitoring groundwater on Rush Creek at the 8C and the 3D after these channels were re-watered in RY2002 (McBain and Trush 2002). The 8-Channel was initially opened to allow Rush Creek below the Narrows streamflows of approximately 275 cfs or greater to access the side-channel (Table C-2); the 3D side-channel was constructed for perennial flow. In RY2004, piezometers were installed to monitor the effect of side-channel re-watering on the groundwater and riparian vegetation.

Groundwater analyses focused initially on data from the 8-Channel. This site proved ideal for evaluating: (1) temporal responses of groundwater to streamflow with different background runoff year and SRF conditions, (2) variable effects of mainstem, seasonal side-channel, and perennial side-channel streamflows on groundwater elevation, and (3) riparian vegetation responses to different surface flow patterns (i.e., mainstem, seasonal, and perennial) on geomorphic surfaces and with variable elevation and distance relative to surface flow (Figure C-8). Results from these three categories of analysis are in the following Section (Section 1.6). The 4bii side-channel was re-watered in RY2006 then modified in RY2007 to allow perennial flow. There were no piezometers installed near the 4bii Channel; field observations and photographs were used to substantiate groundwater analyses from the 8-Channel.

The 8-Channel entrance was first modified in RY2004 to allow seasonal flow above approximately 275 cfs. In this first season, streamflows barely inundated the 8-channel (for approximately 6 days) and provide baseline data describing groundwater response to streamflow without a side-channel. The channel entrance was subsequently expanded twice: (1) in RY2005, the entrance was enlarged to facilitate higher magnitude and longer (seasonal) flow and (2) in RY2007 the entrance was enlarged again to allow perennial streamflow. Groundwater data from piezometer arrays along the 8-Channel (Figure C-9) were used to monitor varying durations of seasonal and perennial inundation (Table C-2).

Riparian vegetation response monitoring began in fall of RY2004 at the 3D and 8-channels, using nested quadrats (McBain and Trush 2005), qualitative observations, and seedling mapping (McBain and Trush 2005, 2006, and 2007). Riparian vegetation monitoring at the 8-Channel was used to link mainstem and side-channel streamflows, groundwater (and soil moisture) conditions, and riparian vegetation response.

C-6: Groundwater and Riparian Response Monitoring Results

Groundwater response to surface flow

Previous analyses (McBain and Trush 2005, 2006) demonstrated that groundwater elevation responds rapidly to changes in mainstem streamflow. Relationships between streamflow and groundwater were evaluated by converting streamflow to stage using rating curves developed at several main channel locations adjacent to piezometers. 'Stage-o-graphs' were plotted from daily average streamflow and daily average groundwater elevations to assess changes in shallow groundwater with changing streamflow, and the influence of seasonal or perennial side-channels on groundwater.

In addition to rapid response to streamflow change, the 8-Channel piezometer data also demonstrate proportionally larger changes in groundwater stage with smaller incremental changes in streamflow stage(Figure C-10), and different proportional changes at different discharge ranges. For example, during the August 2008 instream flow test releases at Piezometer 8C-5, the change in discharge below the Narrows from 101 cfs to 24 cfs (August 16 to 20) resulted in a 0.25 ft stream stage change and a 0.56 ft groundwater stage change. Later in the fall (at 8C-5), the change in discharge below the Narrows from 51 cfs to 21 cfs resulted in a 0.10 ft stream stage change, and a 2.15 ft groundwater stage change. This relationship appears especially strong in the lower streamflow ranges, in which small changes in streamflow cause groundwater stage to drop precipitously (Figure C-10). Small adjustments in streamflow magnitude thus disproportionately affect shallow groundwater and consequently influence successful establishment and annual growth of riparian vegetation. The primary mechanism for this relationship is streamflow *rate*, in contrast to streamflow *stage* (elevation). Our analysis thus focused on identifying a streamflow threshold in the baseflow range that would sustain higher groundwater elevations and prevent precipitous drops in groundwater elevation during the riparian growing season

Groundwater responses to varying mainstem and side-channel conditions

Groundwater and riparian vegetation responses to streamflows at the 8-Channel (Rush Creek below the Narrows) were used to identify streamflow thresholds with specific riparian functions. Riparian thresholds were then used to guide SRF streamflow evaluation and SEF recommendations via NGD analyses.

Different streamflow magnitudes, soil textures, and the presence or absence of seasonal or perennial side-channels influence the rates at which groundwater tables rise and fall. The flow rate and duration that inundated the 8-Channel entrance varied among years. However, regardless of the side-channel flow duration, groundwater fluctuations in response to changes in stream discharge were similar among all 8-Channel piezometers (Figure C-11). This observation suggests that groundwater throughout the riparian corridor fluctuates (to varying degrees) with changes in streamflows regardless of the presence or absence of a side-channel. Streamflows in a side-channel and in the mainstem increase the proximity of the groundwater table to the ground surface. A side-channel can elevate the groundwater table farther from the mainstem. The increase in area of shallow groundwater available to riparian vegetation (i.e., within 5 ft of the surface for approximately 50% of the growing season) may in turn increase riparian corridor width. Greater distance from the source of flowing water (either the mainstem or side-channel) resulted in a deeper groundwater table. (Figures C-12 and C-13)

The duration of side-channel flow affected the depth to which shallow groundwater falls in the summer, fall, and winter. Groundwater responses observed in RY2005 and RY2006 (Figure C-12, Piezometer 8C-1 in 2006) suggest that if side-channel flow ceases entirely (seasonal channel), groundwater begins to recede, and continues until it reaches a deeper water table supplied by precipitation. In most years when streamflows start to rise at the onset of snowmelt, the deep groundwater table also begins to rise. When snowmelt runoff and streamflows are of sufficient magnitude and duration, the deeper water table rises and merges with the shallow groundwater supplied by mainstem and side channels. In drier years, however, precipitation may not be sufficient to elevate the deeper groundwater table to allow it to merge with the shallow groundwater. In contrast, groundwater supplied via a perennial side-channel, observed since RY2007 (Figure C-12, Piezometer 8C-1 in 2008), appears to maintain a slightly higher groundwater elevation (approximately 1 ft) and thus requires less water to initiate a seasonal increase in groundwater elevation.

Groundwater effects on initiation, establishment, and annual riparian growth (plant vigor)

Riparian plant species did not respond to RY2004 peak streamflows on geomorphic surfaces sampled at the 8-Channel. In RY 2005 and RY2006, yellow willow and narrowleaf willow seedlings initiated along moist mainstem and side-channel margins. However, farther up the banks of emergent floodplains and aggraded floodplains, successful willow initiation was infrequent. Black cottonwood root sprouting was observed in these locations (emergent and aggraded floodplains). Black cottonwood seedlings initiated in interfluve depressions of aggraded floodplains along the 8-Channel and 4bii-Channel in RY2005 and RY2006. No riparian vegetation response monitoring was conducted during RY2007 or RY2008. In July 2009, floodplain surfaces where seedlings had established in RY2005 and RY2006 were revisited. During the RY2007 growing season (May 1 to September 30), many RY2005 and RY2006 seedlings had died back to the ground and in many instances never resprouted (Figure C-14 former D-16). Other seedlings had died back but then resprouted new shoots in RY2008 (Figure C-15 former D-17).

In Lower Rush Creek, vigorous shoot growth was documented in mature trees on aggraded floodplains during RY2006 (McBain and Trush 2007). Mature cottonwood shoot growth was much shorter in RY2007 than in RY2006, but long shoot growth returned in RY2008. The variable growth, vigor, and seedling establishment success was related to differences in the runoff year sequence and to the duration side-channels flowed or were inundated annually (Figure C-16).

Success and failure of seedling establishment in interfluve depressions on aggraded floodplains where seedlings were documented were assessed to determine the groundwater conditions required to establish woody riparian plants. Interfluve depressions occur in aggraded floodplains on surfaces that may be elevated relative to summer streamflows or located far from a flowing channel (either mainstem or side-channel) (Figure C-8). To establish woody plant seedlings in interfluve depressions, shallow groundwater must provide a moist surface for seeds to germinate, then provide adequate soil moisture for seedling roots to grow into perennial groundwater. Seedling establishment is expected only in Wet-Normal and wetter runoff year types.

Streamflow Thresholds for Lower Rush Creek

During the May 1 through September 30 growing season in the Lower Rush Creek floodplain, vigorous woody riparian vegetation growth depends on shallow, streamflow-supported groundwater. Elevations of floodplain surfaces supporting woody riparian patch types are typically within 4 to 5 ft of the mainstem water surface elevation.

Piezometer data from the 8-Channel indicate a threshold of 80 cfs baseflow sustains shallow groundwater across the floodplain within 4 ft to 5 ft of the rolling floodplain surface (Figure C-17). This snowmelt-supported, shallow groundwater table allows established woody riparian vegetation to uptake groundwater and sustain vigorous growth.. When receding snowmelt streamflows drop under 80 cfs, the shallow groundwater table elevation drops sharply in the floodplain, to elevations well below the elevation of the adjacent riffle crest thalweg. The floodplain's shallow groundwater elevation may eventually drop 5 ft and more only 50 ft from the mainstem (Figure C-17). More dramatic groundwater recession was observed at the 3D Channel (M&T 2006). Maintaining this groundwater-floodplain relationship will be particularly important for future riparian recovery as the migrating mainstem channel creates new floodplains above the present delta

More days flowing with an 80 cfs baseflow or greater between May 1 and September 30 will culminate in longer shoot growth and better overall woody riparian vegetation maintenance. Receding snowmelt streamflows in most unregulated runoff years eventually drop under 80 cfs (e.g., see Appendix A, Figure 3a). Growth will slow, and eventually may cease before the general growing season ends. The NGD analysis (Appendix E) showed that Rush Creek estimated unimpaired below the Narrows streamflows during Dry and Dry-Normal I runoff years typically did not provide vigorous growth (i.e., achieve the 80 cfs threshold) throughout the entire growing season above the Rush Creek delta. 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 annual hydrographs for Rush Creek at Damsite provided only 21 and 46 NGDs for these runoff year types. The analysis used 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. SEF recommendations simulated below the Narrows provide 53 and 61 NGDs for Dry and Dry-Normal I runoff years, improving on SCE regulated streamflows (and the SRF streamflows) but did not attain NGDs under unimpaired conditions.

An early release of 80 cfs, before the snowmelt flood begins, also extends the number of vigorous growth days towards the start of the growing season (May 1). But a pre-snowmelt 80 cfs release accomplishes considerably more. A springtime 80 cfs streamflow leaving the Narrows prior to the snowmelt peak replenishes, and essentially primes, the floodplain's groundwater table to respond quickly, i.e., rise higher quicker, once snowmelt flooding begins. If there is no transitional flow (i.e., the 80 cfs) between low winter baseflows and the onset of snowmelt flooding (as observed in RY2006), the floodplain's groundwater table is slower to ascend. This results in less wetted floodplain surfaces, with shorter duration of surface wetting, available for seedling initiation. More water is required to accomplish less without the transitional (spring bench) streamflow.

Three narrow ranges of rising mainstem streamflows produce ecologically significant jumps in shallow groundwater elevation within the Lower Rush Creek floodplain (Figure C-18-21). These narrow streamflow ranges are important thresholds for seedling initiation; seeds need a moist surface to germinate. Streamflows of approximately 275 cfs and 230 cfs raise the shallow groundwater table so that the soil's capillary fringe saturates the surface of aggraded floodplains and their interfluves, respectively, without active side-channels present. Streamflows between 120 cfs and 160 cfs saturate the surfaces (via the capillary fringe intersecting the floodplains' surfaces) of emergent floodplains and of aggraded floodplains with active side-channels present. Future riparian recovery will depend not only on generating these wetted snowmelt-supported floodplain surfaces, but also on providing these wetted surfaces at the right times (coinciding with viable seed release periods) and of sufficient duration for willow and cottonwood seedlings to successfully initiate.

Streamflows promoting groundwater conditions favorable to woody riparian plant initiation along a single mainstem channel were prioritized. Side-channel contributions to shallow groundwater are preserved or increased by prioritizing streamflows that meet the needs of the riparian groundwater where there is a single mainstem channel, but not vice versa. Riparian areas with a single mainstem channel are more common along Rush Creek, and locations where there are single channels require higher streamflows to achieve desired ecological outcomes for riparian vegetation. Locations where perennial side-channels support shallow groundwater require considerably less streamflow to create floodplain surface conditions where seedlings can initiate.

Streamflow Thresholds for Lee Vining Creek

In Lee Vining Creek, groundwater is recharged through multiple channels, similar to the condition observed at the Rush Creek 8-Channel. Groundwater is shallower in locations that sustain riparian vegetation than observed in the Rush Creek bottomlands (Figure C-7), possibly a result of fire, vegetation die-off, and soil loss beginning in the mid-1950's. When riparian vegetation began to re-grow, it occupied locations closer to the shallow groundwater table. Stream restoration in the early-1990's also re-watered and constructed several side-channels that helped raise the shallow groundwater table to increase riparian corridor width. Without benefit of piezometer data from continuously recording dataloggers, our analysis used groundwater data collected by the MLC, plotted as time-series, to identify a threshold of 30 cfs at Lee Vining below Intake that sustained higher groundwater elevations (Figure C-22). At streamflows below 30 cfs, groundwater was observed through many runoff years to drop precipitously.

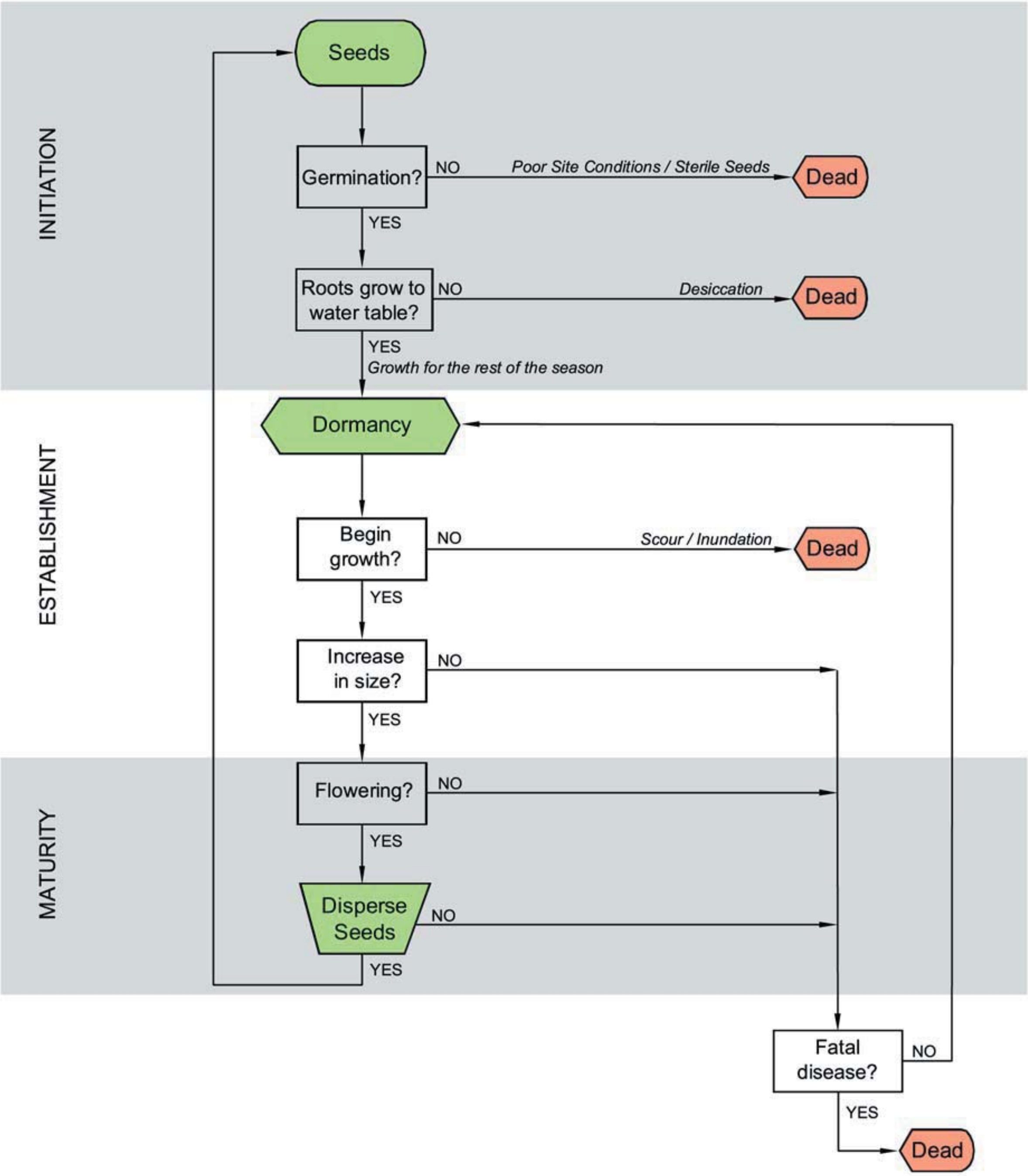


Figure C-1. Generalized riparian plant life history showing life stage, and mortality agents that affect life stages.

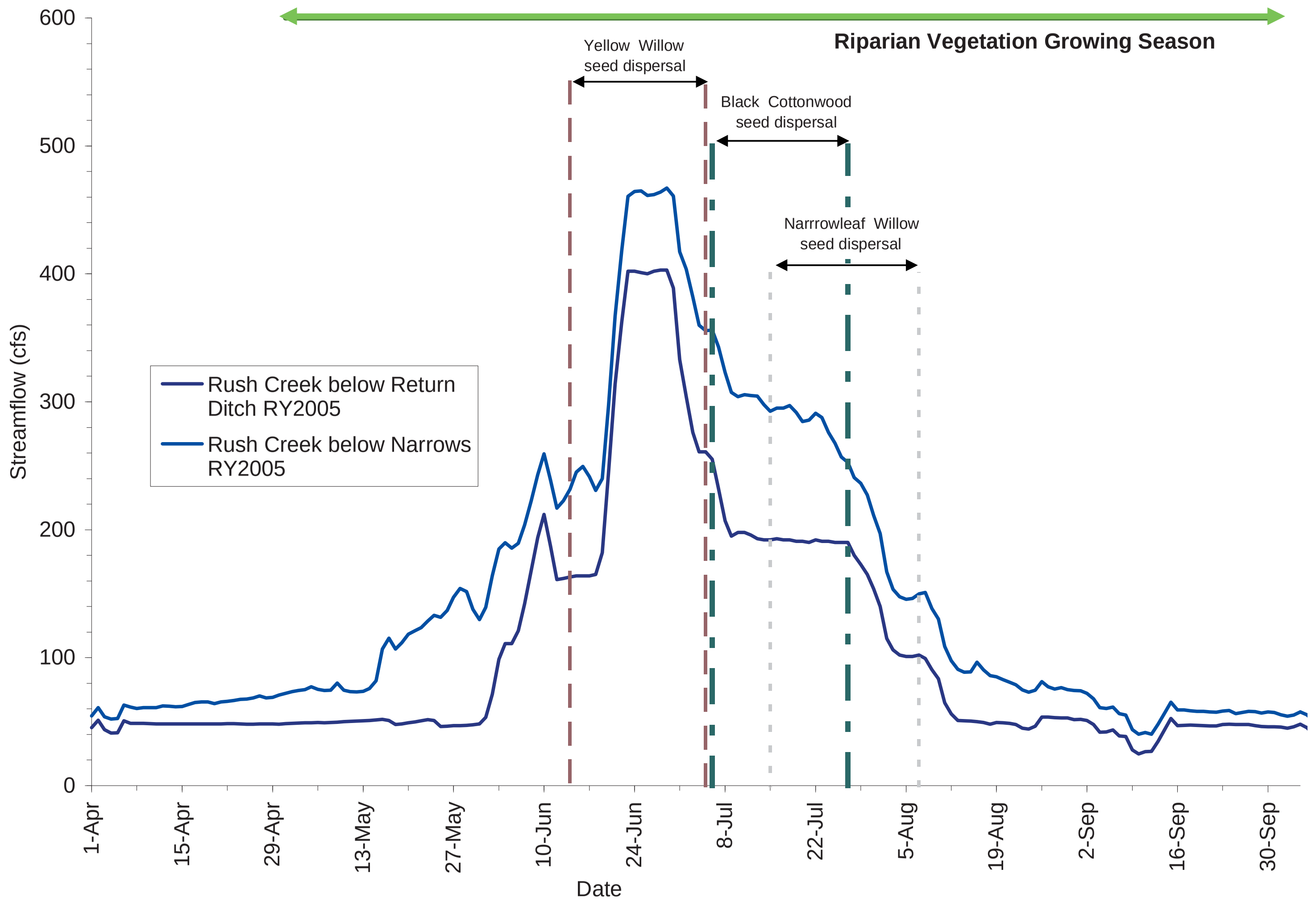


Figure C-2. Rush Creek RY2005 annual daily average hydrograph with the average timing of yellow willow, black cottonwood, and narrowleaf willow peak seed dispersal periods.

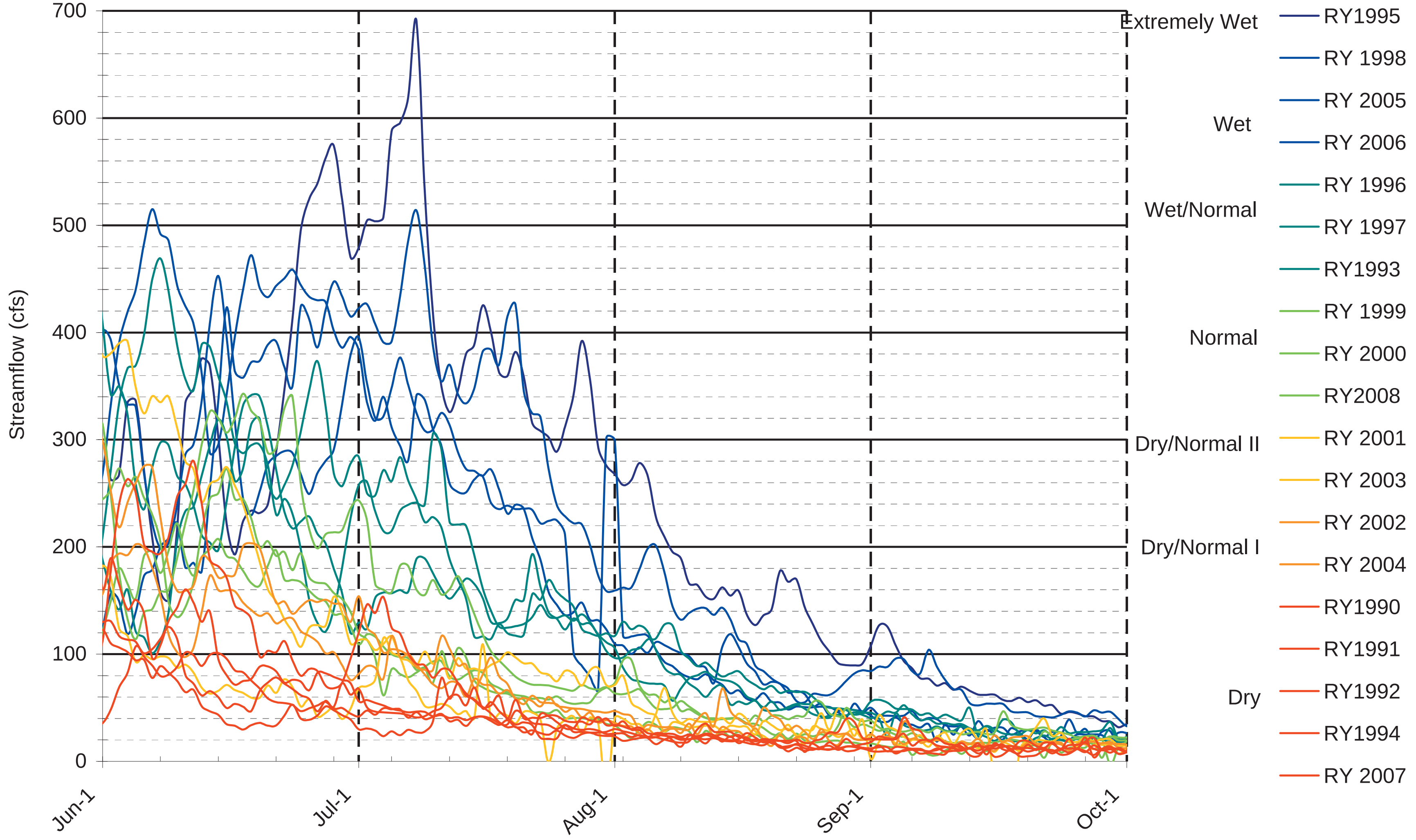


Figure C-3. Unimpaired Lee Vining Creek streamflows during the snowmelt recession between July 1 and Oct 1.

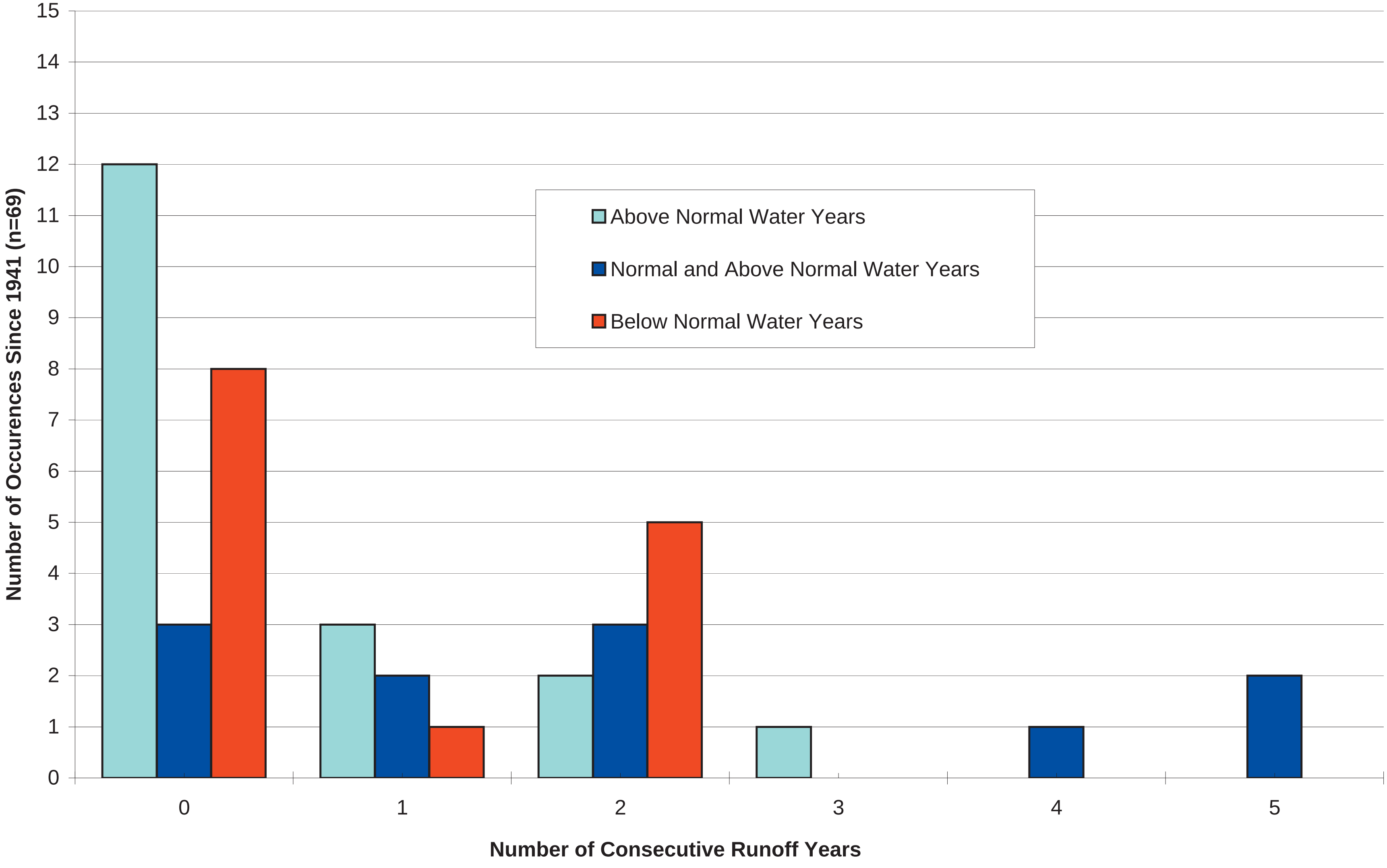


Figure C-4. Number of consecutive above normal, normal and above normal combined, and below normal water years between 1941 and 2008.

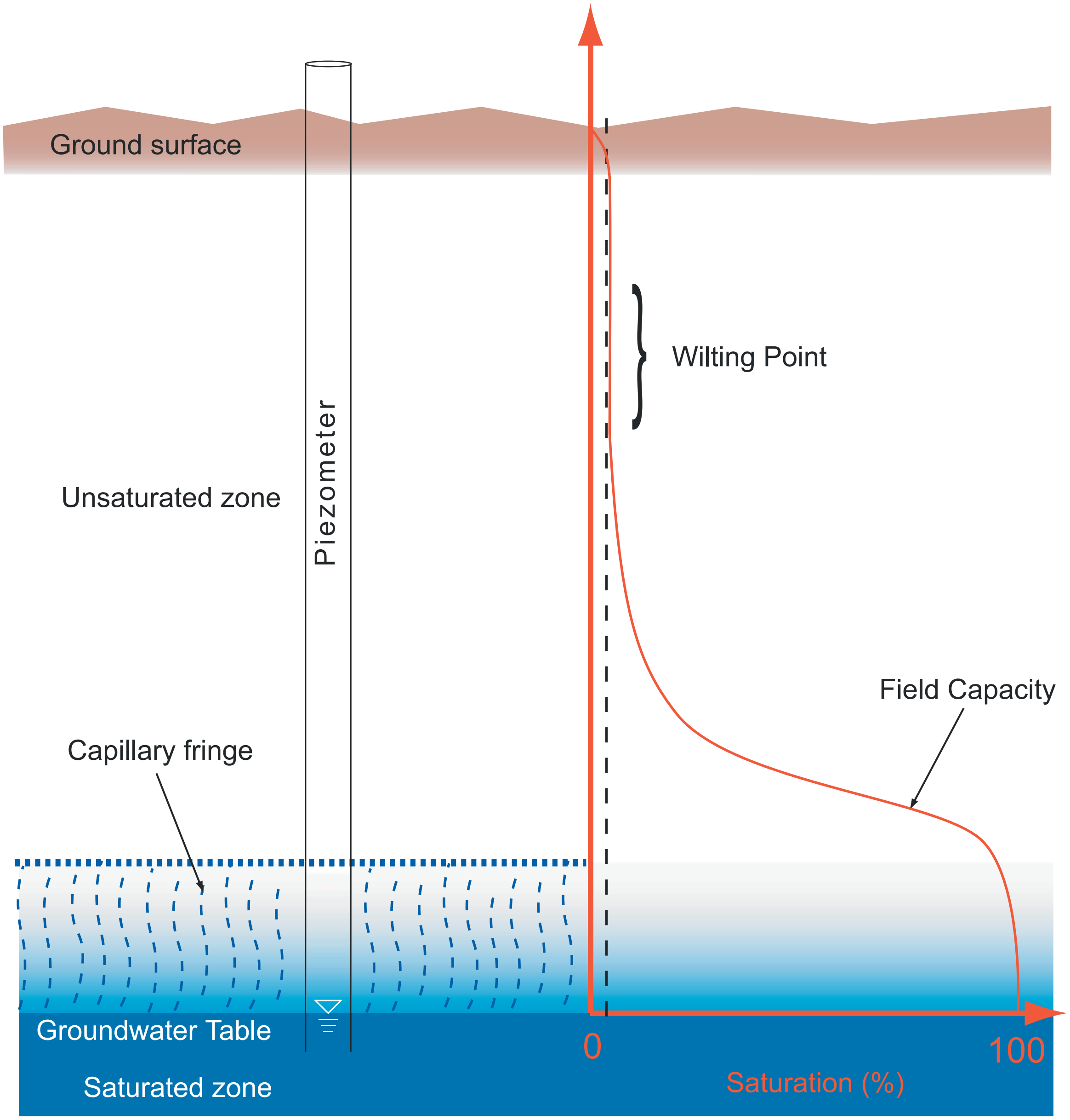


Figure C-5. Conceptual soil moisture profile for Rush and Lee Vining creek riparian corridors.

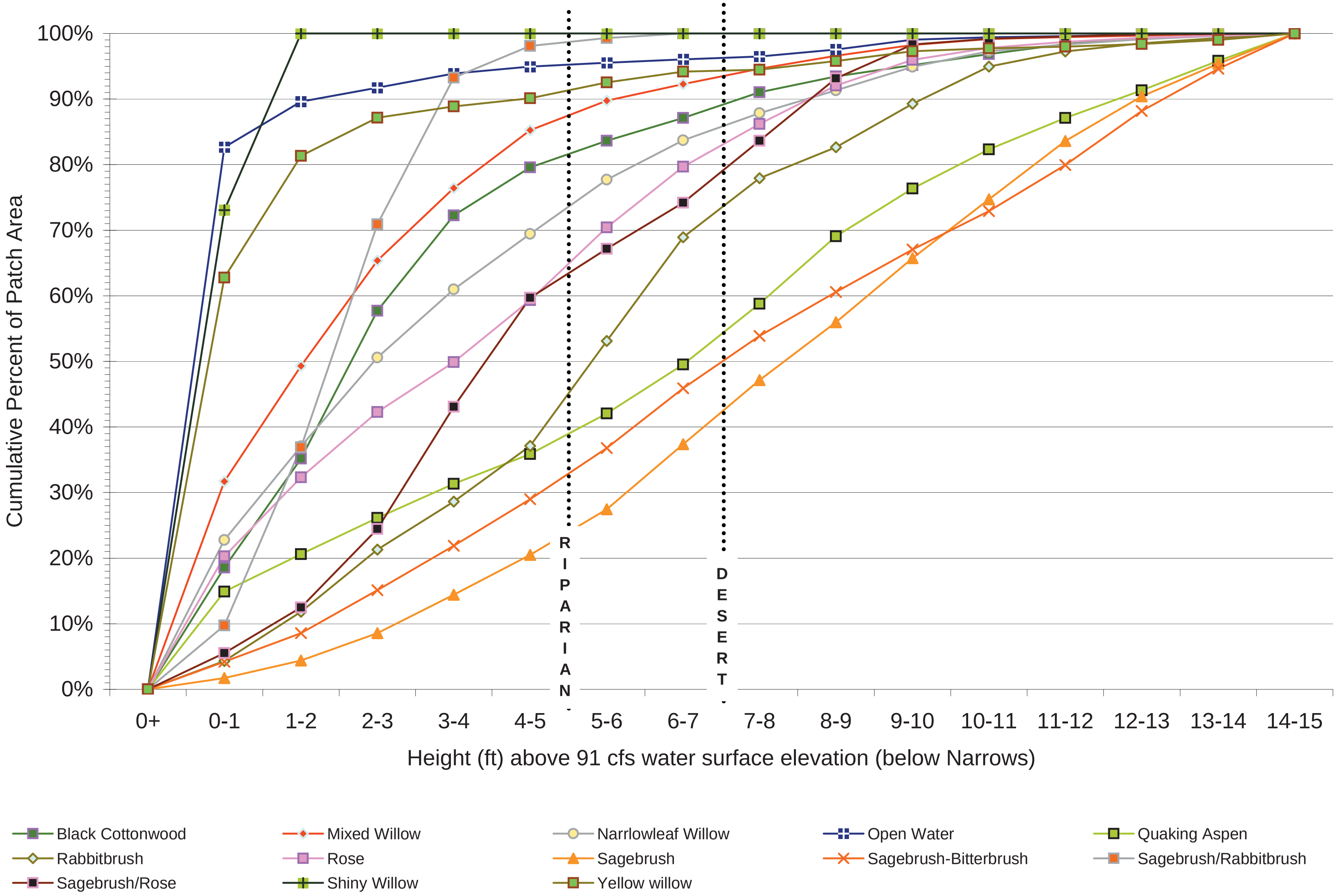


Figure C-6. Cumulative Percent of riparian and desert patch types above the June 23, 2003 streamflow on Rush Creek 91 cfs below the Narrows).

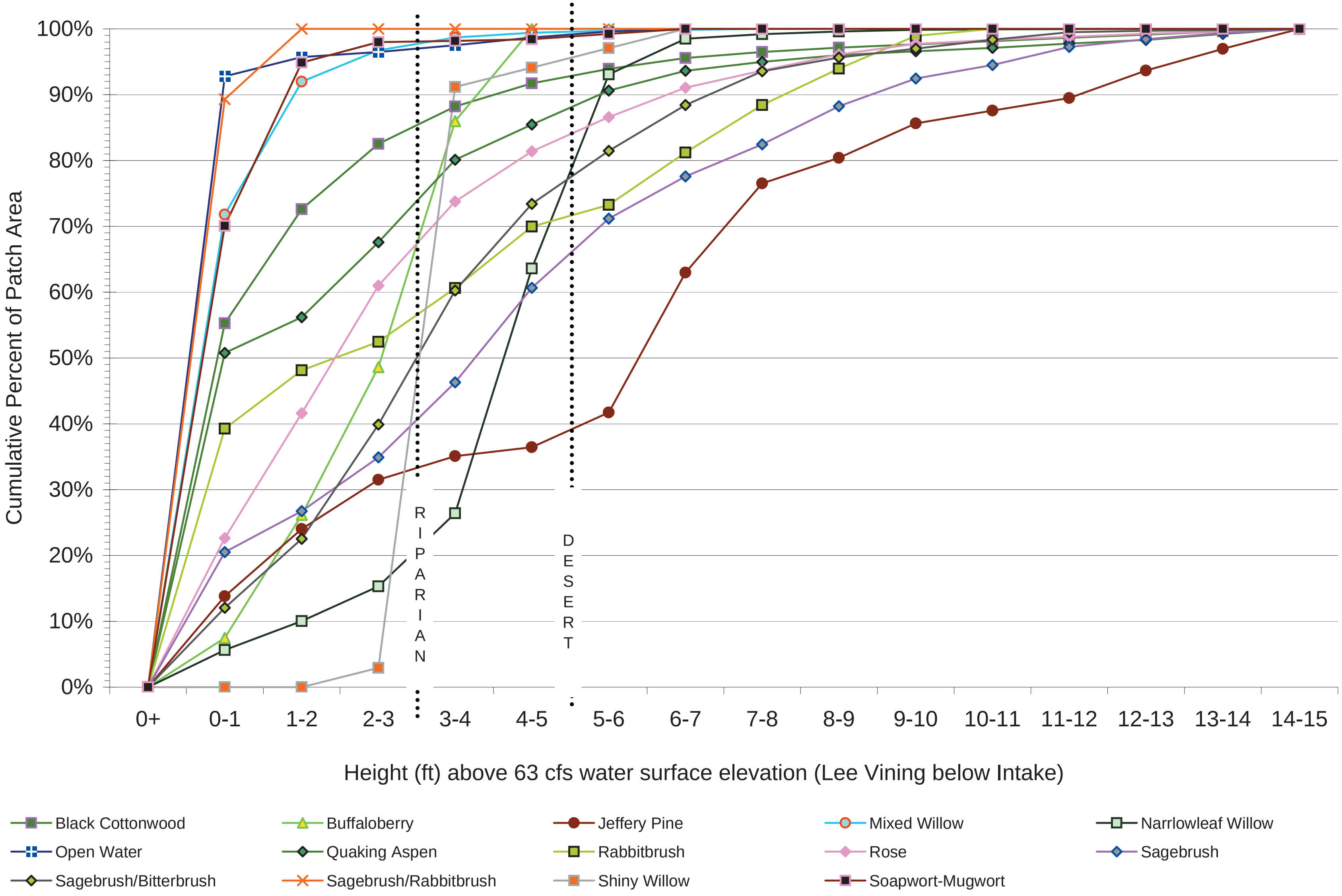


Figure C-7. Cumulative Percent of riparian and desert patch types above the June 23, 2003 streamflow on Lee Vining Creek (63 cfs below the LVC intake).

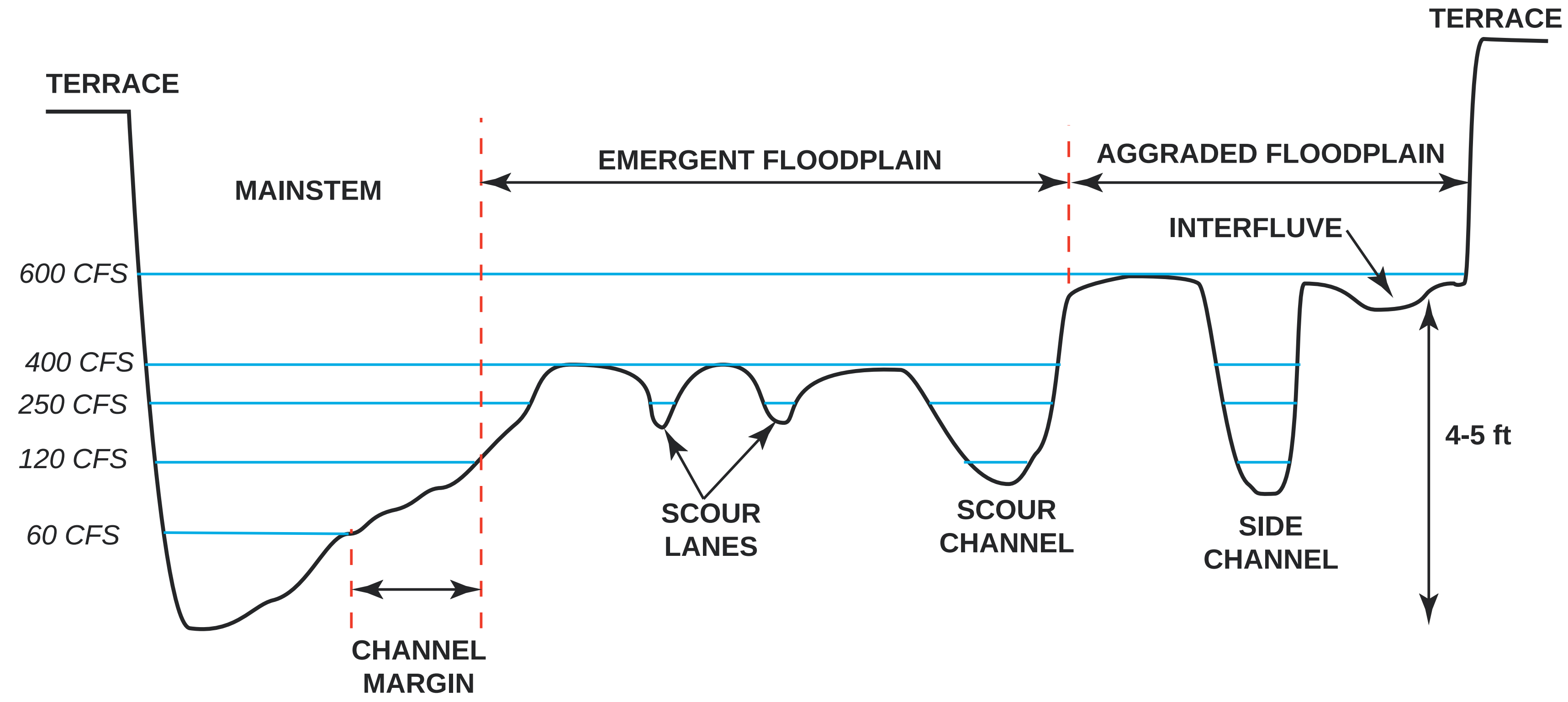


Figure C-8. Conceptual cross section showing different geomorphic surfaces relative to a range of flood stages.

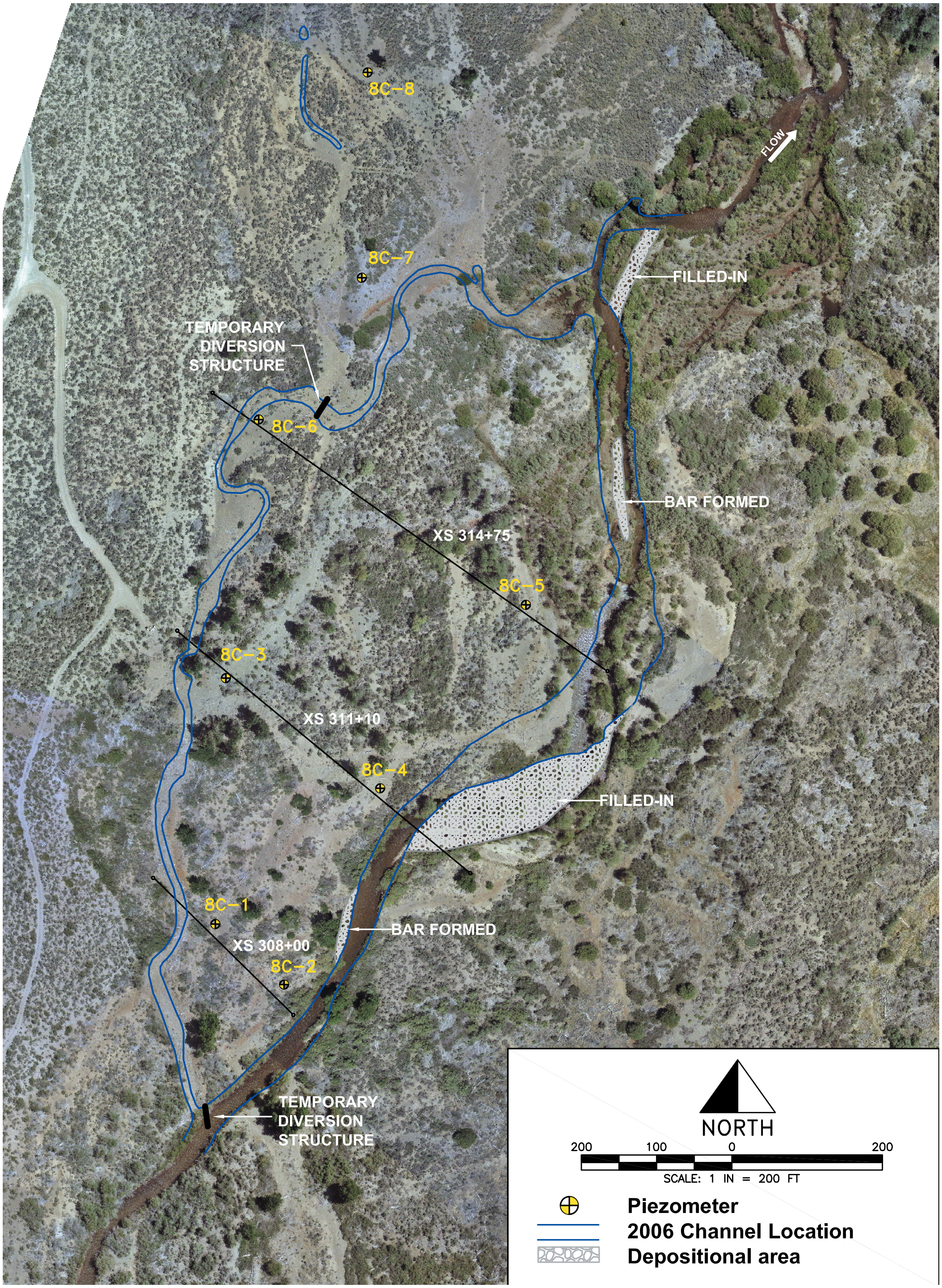


Figure C-9. The 8-Channel groundwater and riparian response study area in the Rush Creek bottomlands

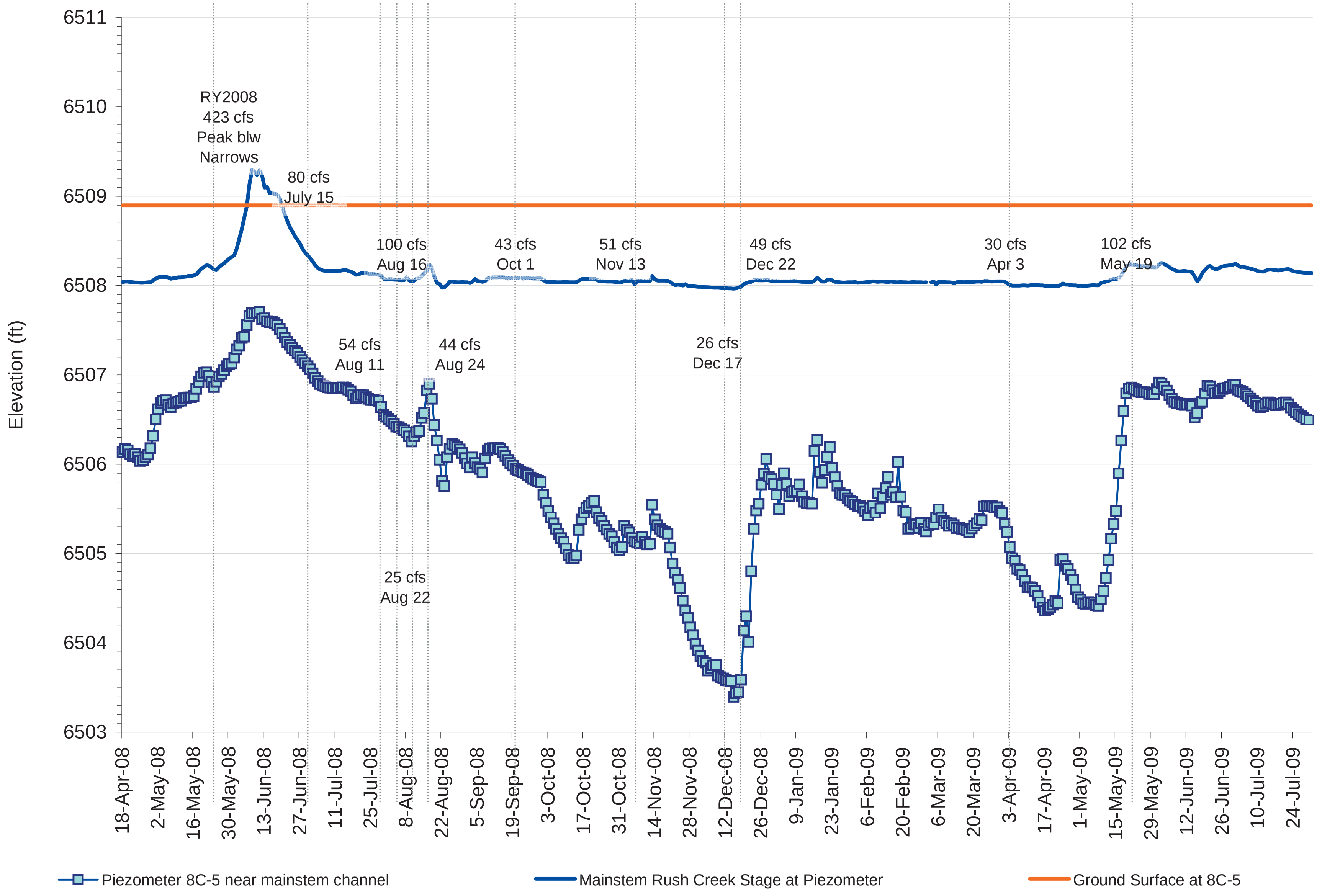


Figure C-10. RY2009-2010 mainstem Rush Creek stream stage and groundwater stage at piezometer 8C-5.

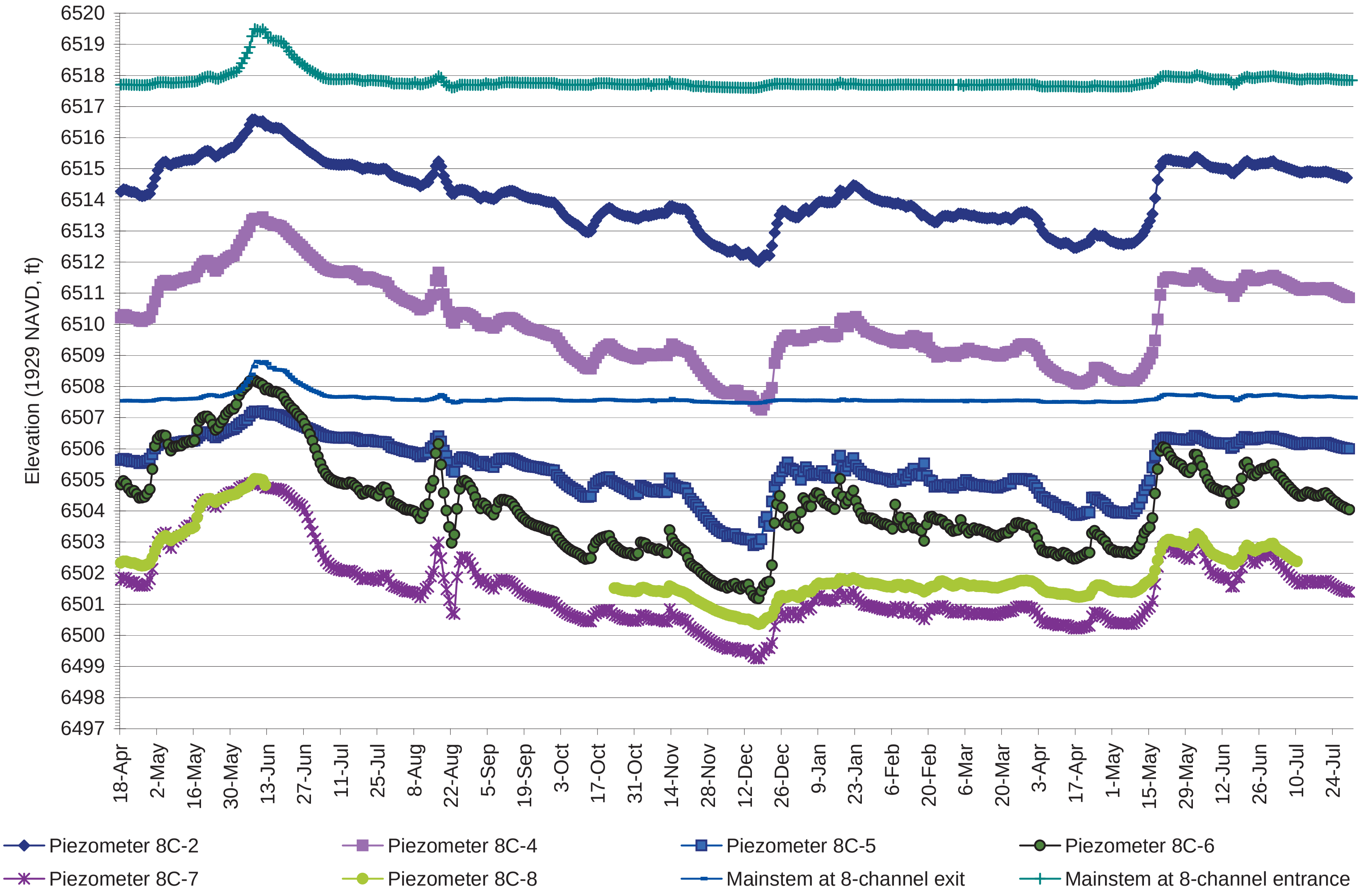


Figure C-11. RY2009-2010 mainstem Rush Creek stream stage and groundwater at six piezometers within the 8-Channel study area.

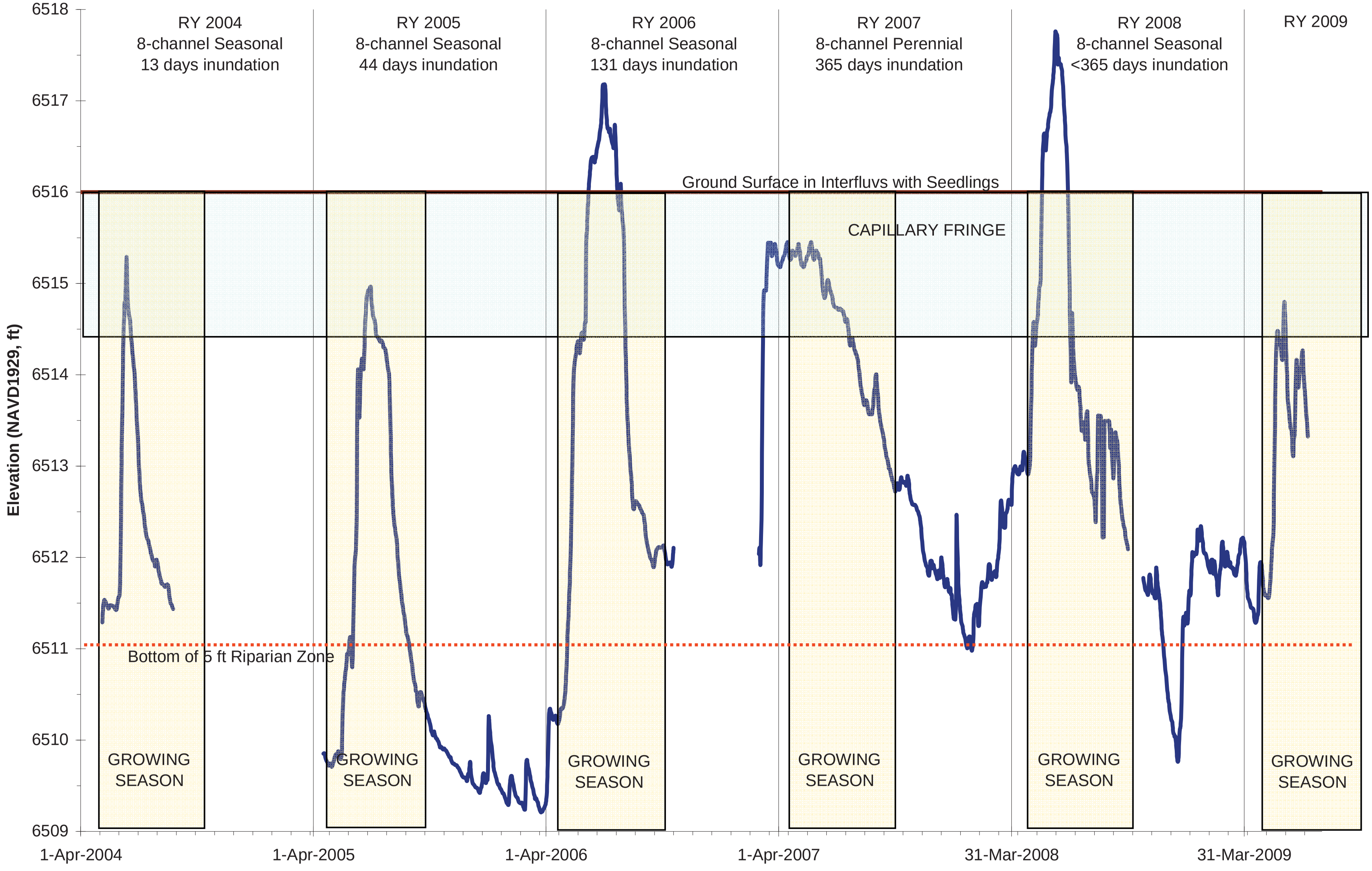


Figure C-12. Groundwater response at piezometer 8C-1 to seasonal and perennial side channel inundation between RY2004 and RY2009.

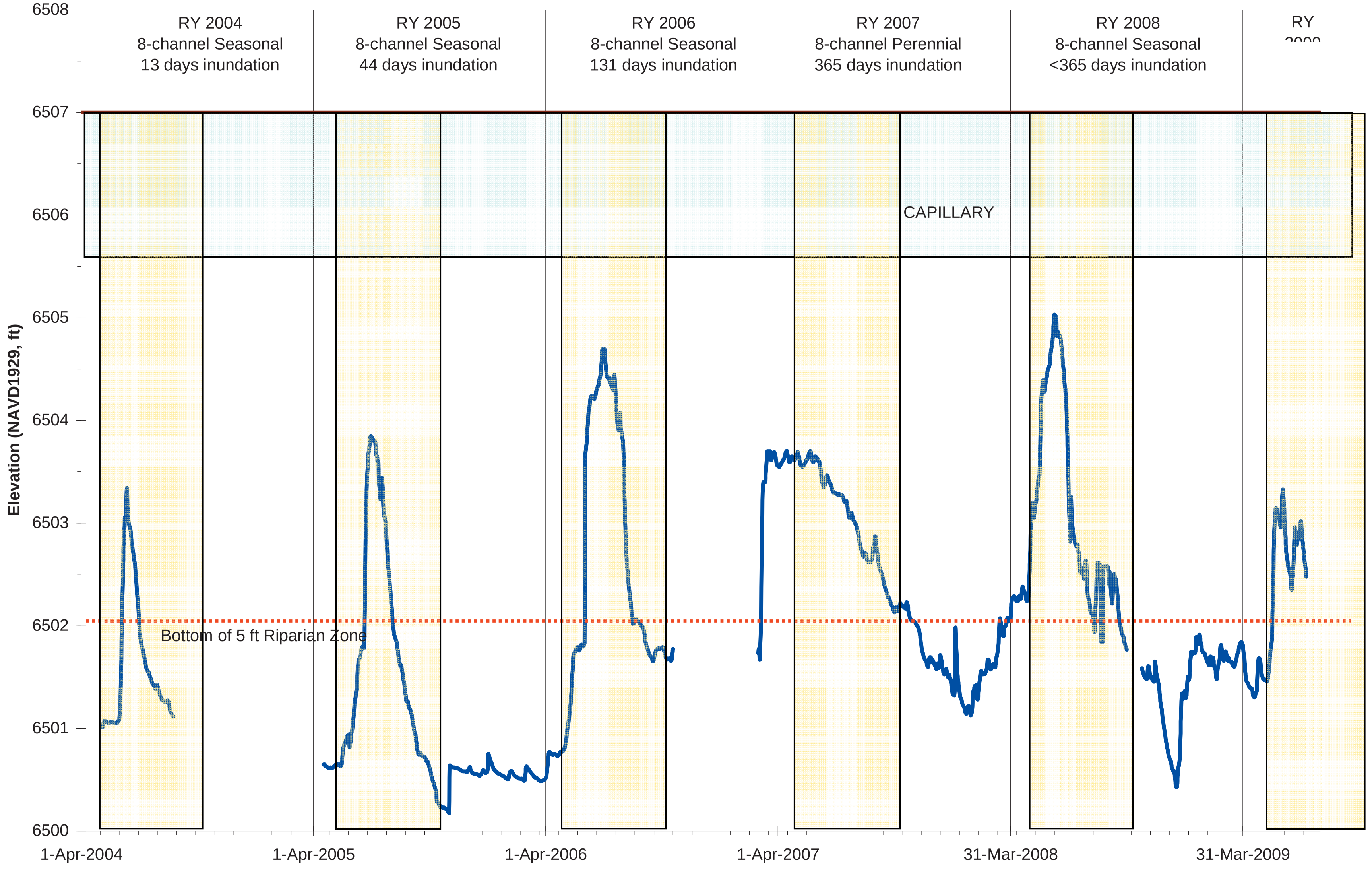


Figure C-13. Groundwater response at piezometer 8C-8 to seasonal and perennial side channel inundation between RY2004 and RY2009.

Figure C-14. Dead seedling on interfluv depressions between the mainstem and the 8-channel.

Figure C-15. Seedling on interfluv depressions between the mainstem and the 8-channel that resprouted in 2008 after dying back to the ground in 2007

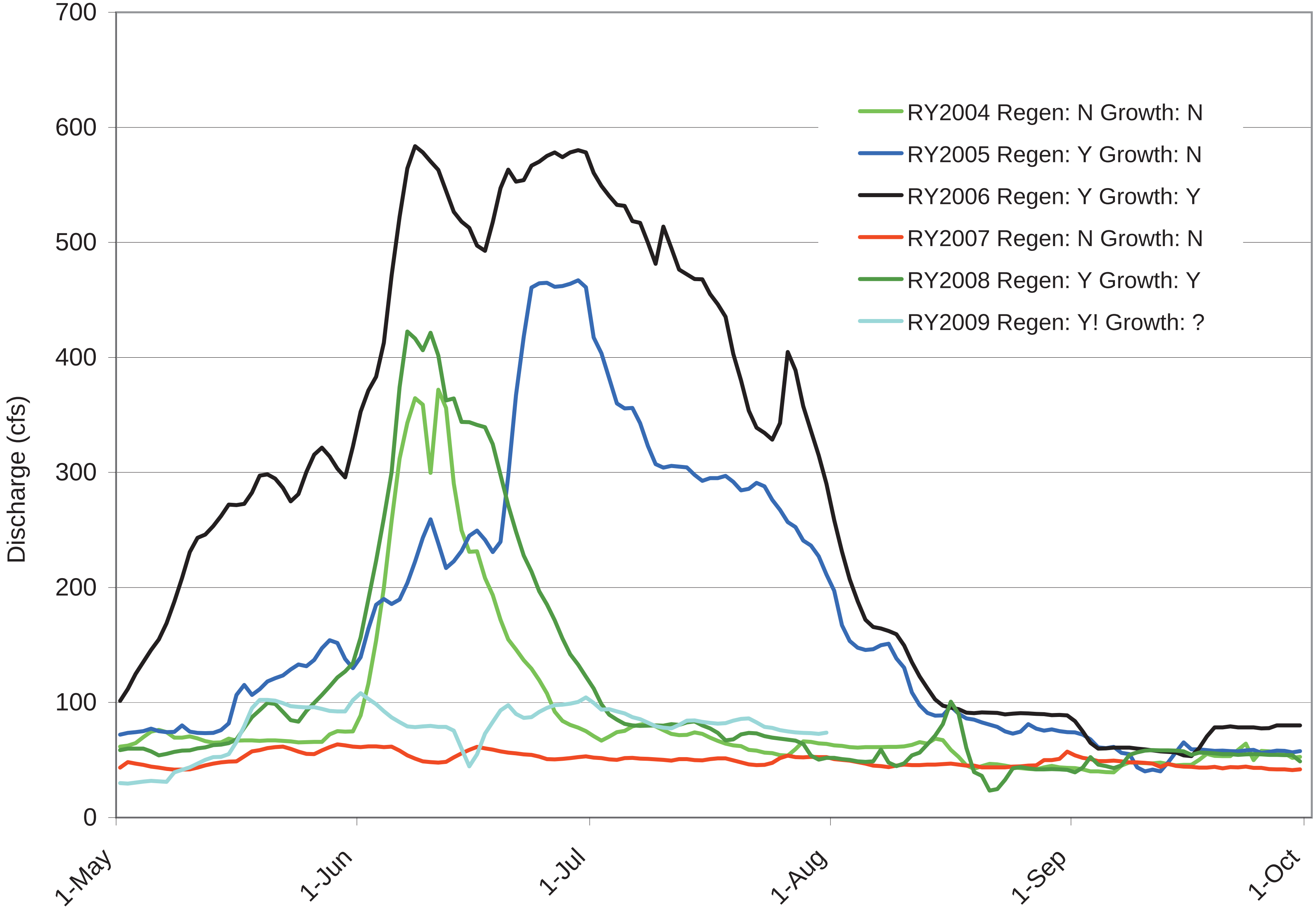


Figure C-16. Rush Creek snowmelt hydrographs for RY2004 to RY2008, indicating riparian vegetation germination and growth outcomes observes at 8-Channel interfluves.

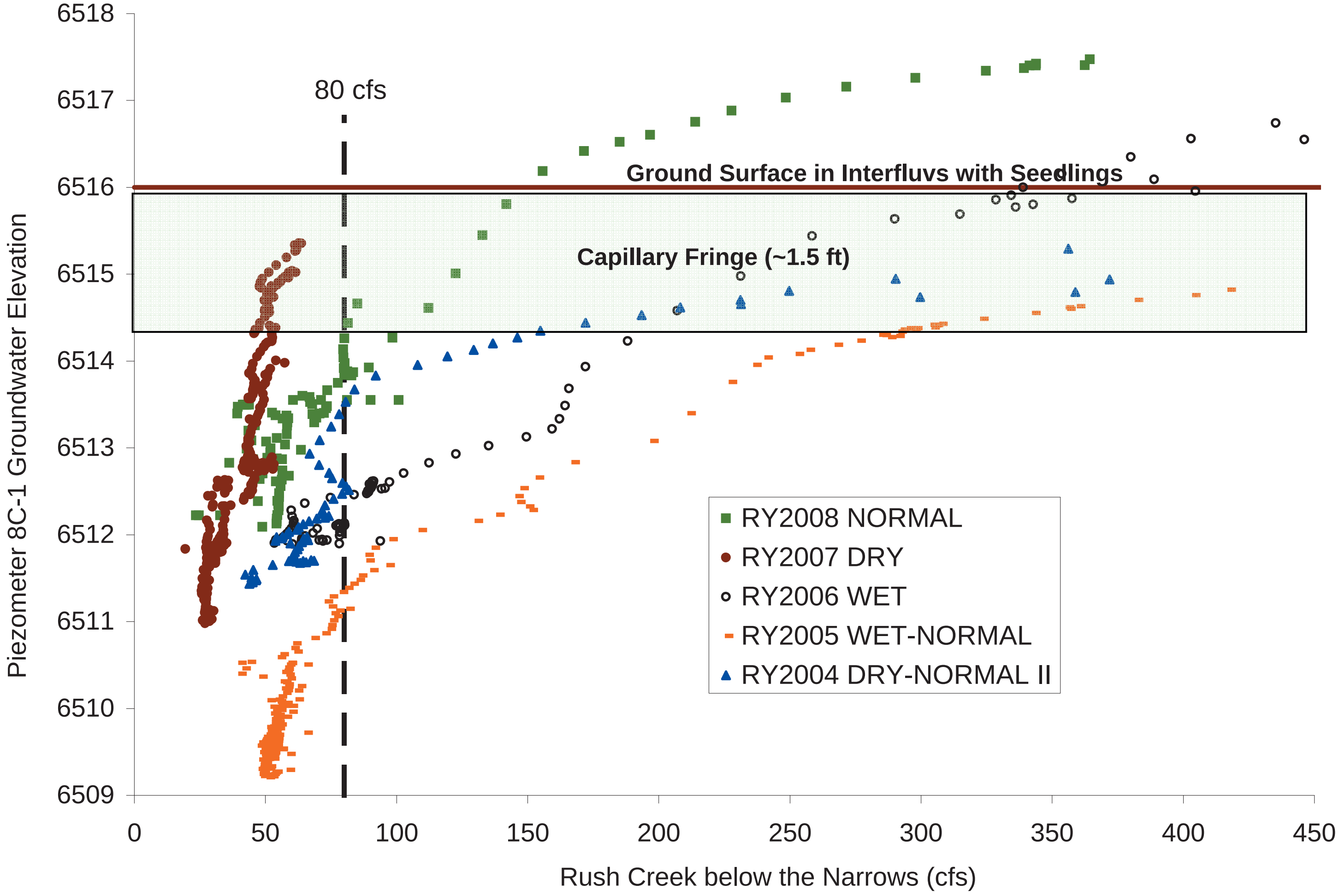


Figure C-17. Piezometer 8C-1 groundwater response to streamflow during the snowmelt recession for RY2004 to RY2008.

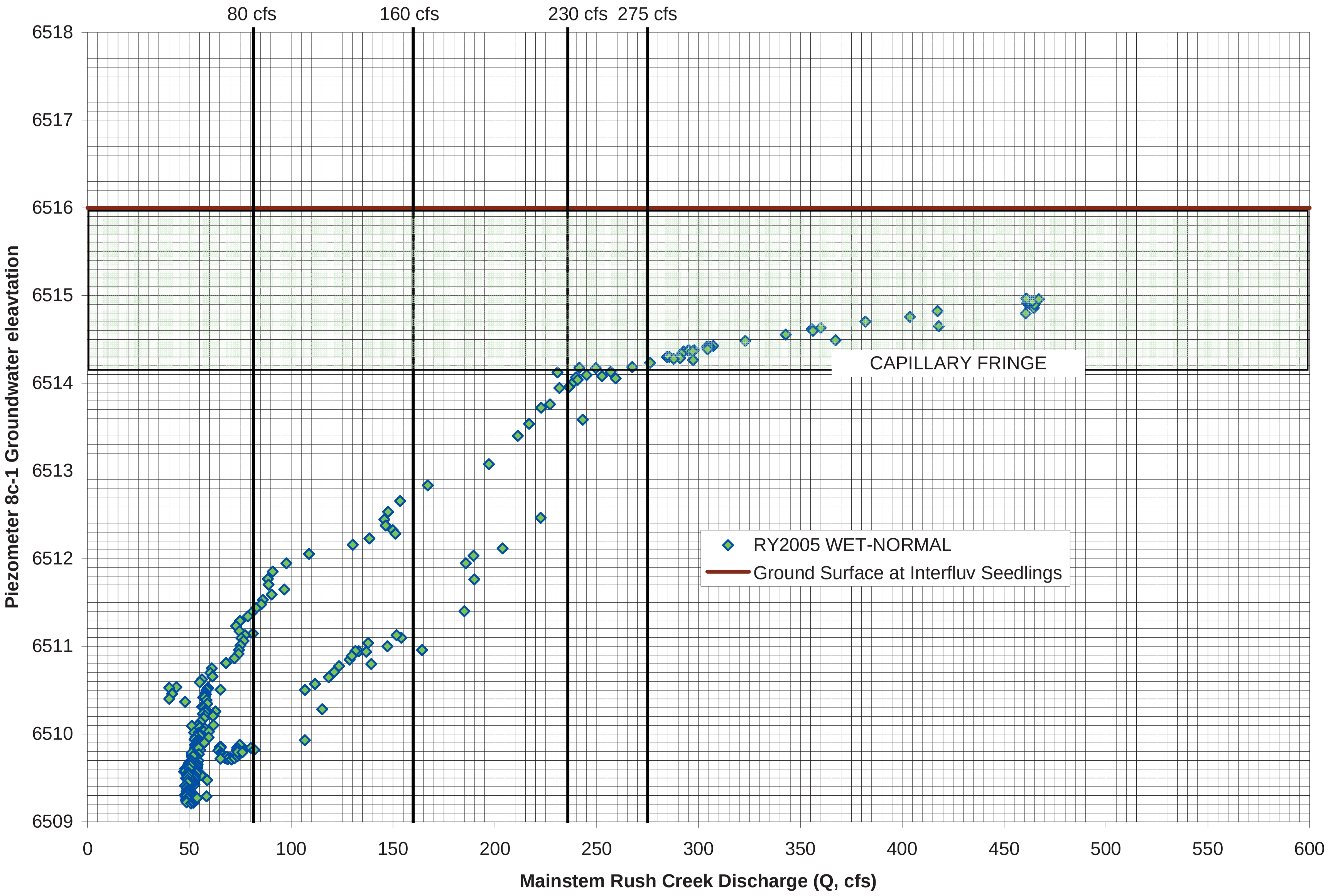


Figure C-18. Piezometer 8C-1 groundwater response to streamflow during Wet-Normal RY2005.

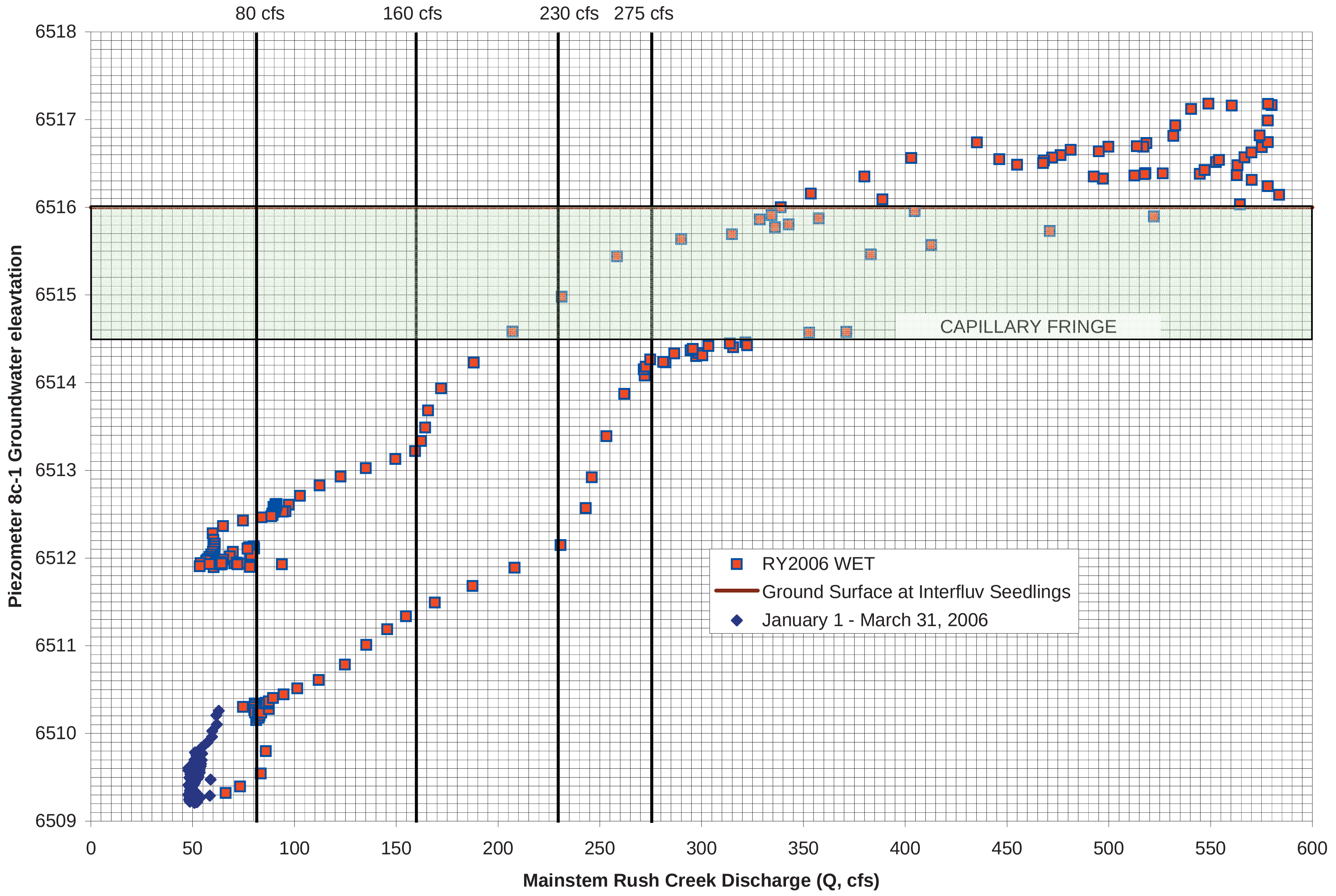


Figure C-19. Piezometer 8C-1 groundwater response to streamflow during Wet RY200.

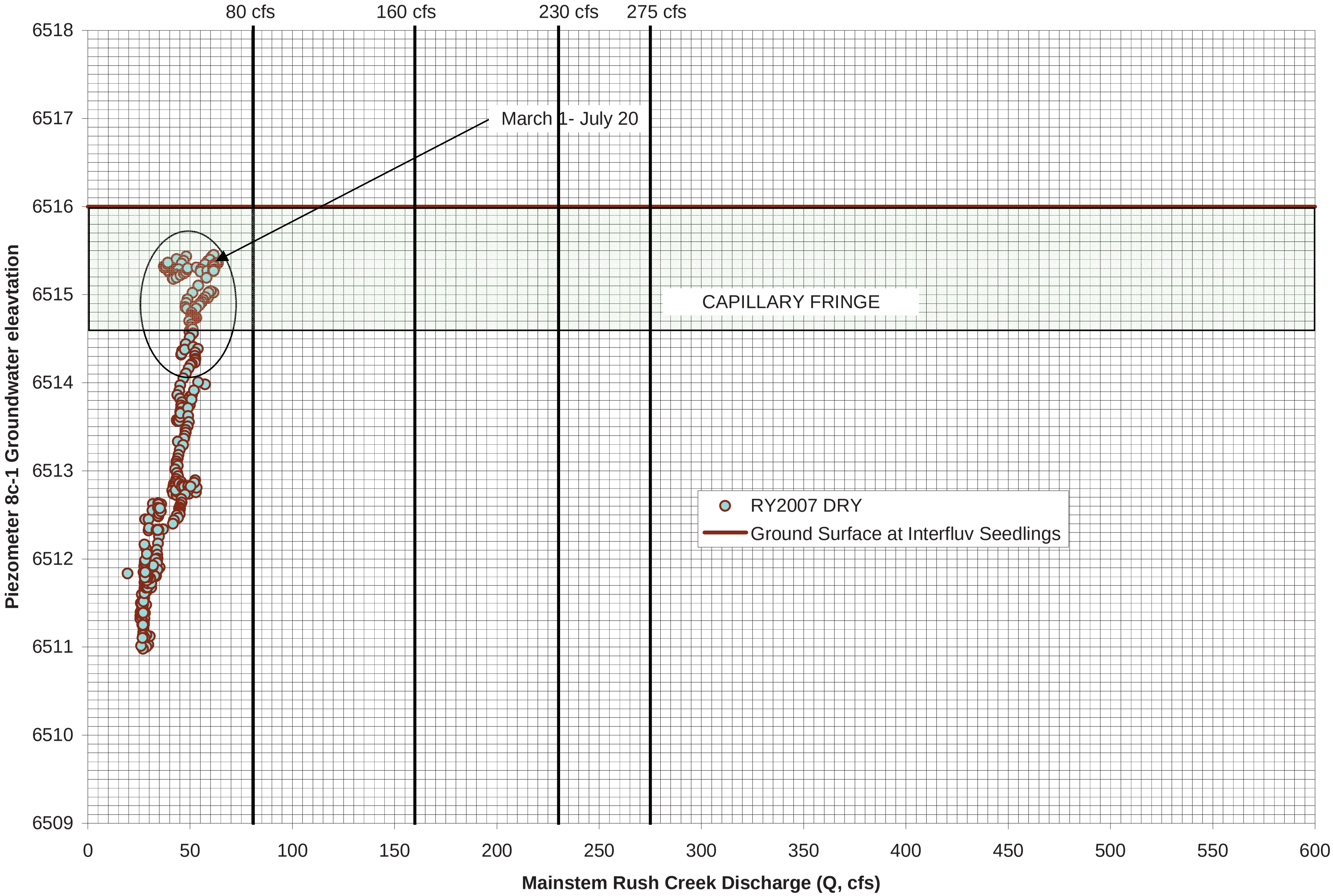


Figure C-20. Piezometer 8C-1 groundwater response to streamflow during Dry RY2007.

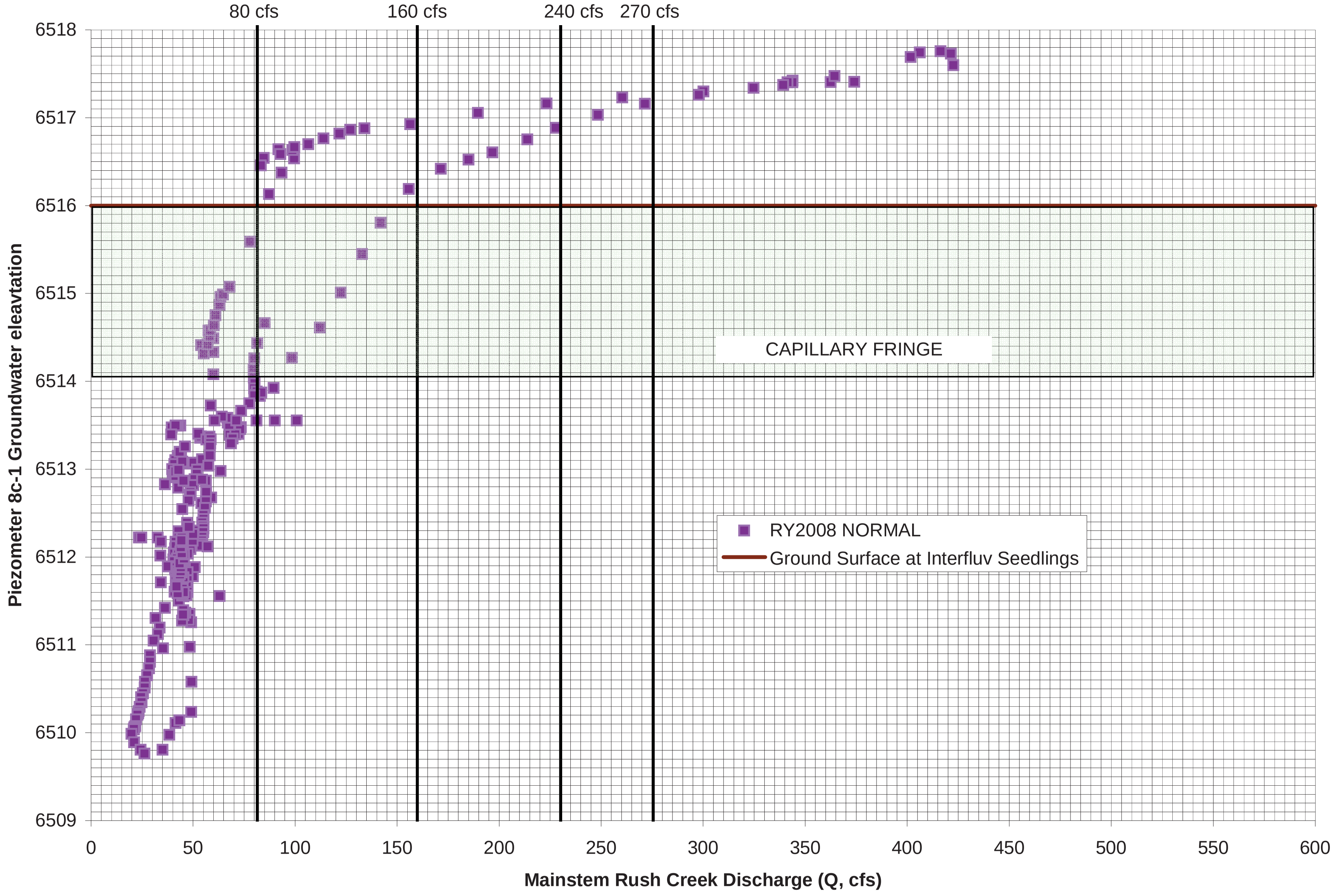


Figure C-21. Piezometer 8C-1 groundwater response to streamflow during Normal RY 2008.

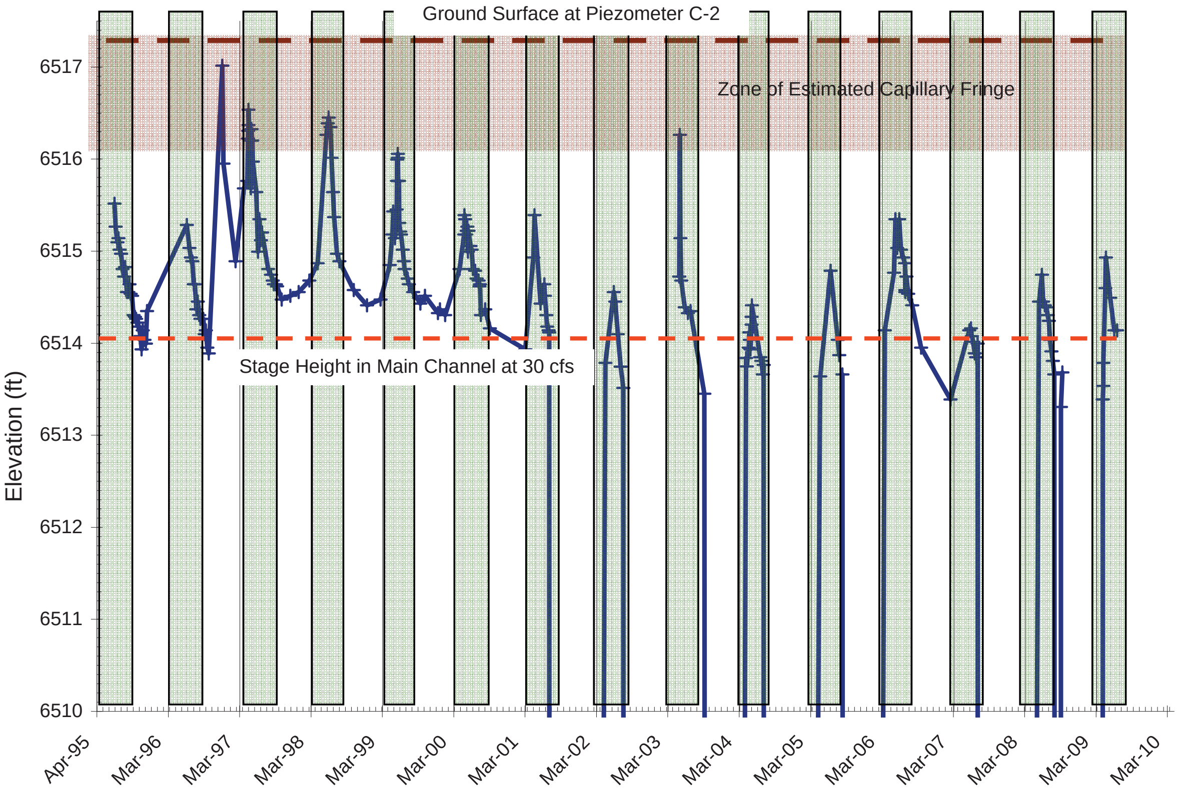


Figure C-22. Groundwater response at the Upper Lee Vining Creek piezometer C-2 streamflows from RY1995 to RY2009.

Table C-1. Average peak seed dispersal periods for three common riparian hardwoods growing along Rush and Lee Vining creeks.

Common Name	**Scientific Name**	**Begin Peak Seed Dispersal (average)**	**End Peak Seed Dispersal (average)**
black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	6-Jul	27-Jul
yellow willow	*Salix lutea*	14-Jun	5-Jul
narrowleaf willow	*Salix exigua*	15-Jul	7-Aug

Table C-2. Water year class and associated discharges that seasonally and perennially inundated the 8-channel entrance and the duration that the 8 channel flowed between RY2004 and RY2008.

Runoff Year	Runoff Year Class	Peak below Narrows (cfs)	Estimated discharge that inundates 8-channel (cfs)	Number of days 8 Channel entrance inundates 0.01ft	Number of days 8 Channel entrance inundates 0.10 ft	Number of days 8 Channel entrance inundates 0.25 ft	Number of days 8 Channel entrance inundates 0.50 ft	Number of days 8 Channel entrance inundates 1.0 ft	Notes about entrance
2002-2003	Dry-Normal I	225	496 +	0	0	0	0	0	Fall 02 8 channel opened to inudate at ~275 cfs
2003-2004	Dry-Normal I	283	496 +	0	0	0	0	0	
2004-2005	Dry-Normal II	372	333 +	6	5	2	0	0	Spring 2004 entrance enlarged #1
2005-2006	Wet-Normal	467	224 ++	44	36	28	16	8	Spring 2005 entrance enlarged #2; Channel went sub-surface between 8c-3 and 8c-6 July 24th 2005
2006-2007	Wet	584	100 ++	131	98	91	85	59	Spring 2006 entrance evolved; 4bii was opened to seasonal flow; G. Reis "channel closed itself"; Oct 18-20 channel was observed drying up
2007-2008	Dry	64	40 +	365	365	59	0	0	March 2007 DWP spent two days opening the 8 channel; the 4bii was opened to periennial flow
2008-2009	Normal	423	40 +	365	364	133	36	21	

+ = Estimates developed from survey and stage discharge relationships at the 8-channel entrance
++ = Estimates based on field observation (McBain and Trush 2005, McBain and Trush 2006, and McBain and Trush 2007)

APPENDIX D. MONO BASIN FISHERIES

The non-native trout fisheries residing within streams of the Mono Lake Basin have been the subject of a multitude of past studies and analyses. This technical Appendix provides additional information and analyses from previously conducted studies and prepared reports; as well as information from analyses conducted specifically for the Synthesis Report.

In this Appendix, we present the following additional data and analyses relevant to the revised Stream Ecosystem Flows recommended in the Synthesis Report:

Appendix D-1: Review of California Department of Fish and Game's Instream Flow Studies

Appendix D-2: Development of Brown Trout Holding Habitat Criteria

Appendix D-3: Predicting Brown Trout Emergence Times for Lee Vining and Rush Creeks

Appendix D-4: Modeling Rush Creek Summer Water Temperatures and Predictions of Brown Trout Growth

APPENDIX D-1: REVIEW OF CALIFORNIA DEPARTMENT OF FISH AND GAME'S INSTREAM FLOW STUDIES

We evaluated the currently prescribed flows for Rush and Lee Vining creeks as determined by studies conducted by CDFG and other experts in the late 1980s and early 1990s ((Smith and Aceituno 1987; CDFG 1991; CDFG 1993). While these older studies were probably conducted with the best available information and methodologies at the time and have provided the streams adequate flow regimes to start the recovery process; we contend these studies and resulting flow recommendations are dated.

A couple of our concerns were also raised as far back as the 1993 Water Board hearings. First, the stream channels have evolved so much that the original flow recommendations for trout habitat are no longer relevant. At the 1993 hearing, Jim Canaday asked Dr. Thomas Hardy to elaborate on an IFIM premise that the stream channel must be stable, and if a channel had undergone measureable changes how would this affect flow recommendations. After Dr. Hardy agreed that the Rush Creek channel had changed as a result of increased flows between 1987 and 1993, Canaday specifically asked Hardy, "Would that affect the applicability of the recommendations from either one of those studies if the stream is significantly different today than it was when those studies were put on?" Dr. Hardy responded, "It definitely has that potential, sir." Dr. Hardy was also questioned about applying WUA curves derived from a wide, shallow channel to a narrower, deeper channel more indicative of pre-1941 conditions. Dr. Hardy responded that the amount of habitat would be quite different. Habitat typing and pool surveys conducted between 1991 and 2008 (Trihey and Associates 1994; Knudson et al 2009) along with time-series photographs (Figures 7a-f) support our contention that significant riparian and channel evolution has occurred over the past 17 years, and that the present channels are not representative of channel conditions used in developing the currently prescribed instream flows for trout.

The second issue discussed during the 1993 Water Board hearing was development of habitat criteria curves. Dr. Hardy was again asked to comment on the issue. Mr. Birmingham asked, "If you were to develop onsite criteria curves, would you take all your data at a flow lower than the zero percentile flow for that stream?" Dr Hardy responded, "No. I would want to collect observations from a wider range of flows as I could physically collect the data in the stream." Mr. Birmingham then asked, "So would you then have a criticism of the E.A. study based on the fact that they took all of their observations at 19 cfs?" Hardy responded, "From that viewpoint, it would be a criticism." When cross-examined by Bruce Dodge, Dr. Hardy was asked why he would want a broader range of flows. Dr. Hardy responded, "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." This response echoes the concluding sentence of a journal article that critiqued WUA estimates derived from PHABSIM studies (Williams 1995).

> *"It seems wiser to put effort into learning the basic biology of the species of concern, which alone can provide a firm foundation for valid applied methods and sound water management decisions"*

We concur with Dr. Hardy's responses and have delved further into the issue of habitat criteria curves by examining the habitat preference criteria study used in developing the CDFG flow recommendations. Smith and Aceituno (1987) readily admitted that all of their brown trout observations were made during the daytime and also during the spring, summer, and fall. They cautioned against using these data for making either night time or winter flow recommendations; yet CDFG used these data for generating instream flow recommendations for all seasons, including winter months. Smith and Aceituno (1987) also made very few direct observations of brown trout utilizing habitat deeper than 2 ft, probably because few pools were present with depths greater than 2 ft, yet CDFG still used these preference criteria to prescribe instream flows to address juvenile and adult brown trout pool habitat.

Smith and Aceituno (1987) alluded to measuring focal point velocities of observed brown trout. However; all of the 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, rather than being based on focal velocities taken near the stream bottom in locations actually occupied by the observed brown trout (CDFG 1991; 1993). During our 12 years of studying the basic biology of brown trout in Rush and Lee Vining creeks, including extensive day and night snorkeling and three years of relocating radio-tagged fish, we came to the conclusion that mean water column velocities are a very poor descriptor of brown trout habitat. This is because more than 80% of the brown trout observations made during our field surveys were either directly on, or within 0.5 ft, of the stream bottom (Appendix D-2). We therefore contend that focal velocities taken at 0.5 ft (or even closer to the stream bottom) more accurately describe the velocity preferences of brown trout in their holding positions compared to velocities taken higher in the water column in a location that brown trout are rarely, if ever, observed utilizing as holding habitat. Our findings are consistent with those reported by Raleigh et al (1986); Clapp et al (1992); Meyers et al (1992); and Heggenes (2002).

Unlike many other instream flow studies, our 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. We used site-specific habitat measurements, taken at each relocation site, to develop holding habitat criteria for brown trout on Rush Creek. We did not need to extrapolate non-winter observations to winter conditions, like most other IFS recommendations, including CDFG's studies on Rush and Lee Vining creeks (CDFG 1991; 1993).

APPENDIX D-2: DEVELOPMENT OF BROWN TROUT HOLDING HABITAT CRITERIA

Prior to the development of brown trout holding habitat criteria for the IFS, we focused on studying the relevant biology and habitat of brown trout in Rush and Lee Vining creeks, which we felt would provide the most valid foundation for the methods needed to support sound water management decisions for this species in the Mono Lake Basin. Annual fish population estimate surveys conducted from 1999-2009 evaluated changes that occurred to the numbers, biomass, age-class structure and condition of the populations during different water-year types (Hunter et al. 2000 – 2009). The analysis of Rush Creek water temperature data in concert with fish population data identified statistical relationships between Grant Lake Reservoir storage levels, water temperatures, and brown trout abundance and condition factor (Shepard et al. 2009a-b). The extent of potential adult brown trout holding habitat was documented by measuring the frequency and distribution of high-quality pools (Platts et al. 1987) throughout the length of Rush Creek during 2002 and 2003 (Knudson et al. 2009). The evolution of the Rush Creek channel towards more high-quality pools as a result of large SRF flow releases in 2005 and 2006 was evaluated by repeating the pool survey in 2008 (Knudson et al. 2009).

The Platts et al. (1987) methodology rated pools based on their depth, surface area and amount of hiding cover, but did not factor water velocities into the ratings. While conducting day and night snorkel surveys in 2000 and 2002, we noticed that there were often relatively low numbers of brown trout in some of the high-quality pools identified during the pool survey. It appeared that brown trout largely avoided pools with relatively high water column velocities near the stream bottom, even when good to excellent hiding cover was present. This apparent preference by brown trout for low velocity holding areas was confirmed during our three-year study of the movement and habitat preferences of radio-tagged juvenile and adult fish in Rush Creek (Taylor et al. 2009). During this study, measured habitat parameters included the amounts and types of hiding cover, total water depths, and water column velocity measurements at 6/10th and 9/10th of total stream depth for each tagged fish that was relocated during winter (December-March) and non-winter (April-November) months. Habitat measurements were made for 132 relocated radio-tagged brown trout, including 45 juveniles (197-206 mm) that were tagged in Rush Creek; 56 adults (244-304 mm) tagged in Rush Creek; and 31 adults (314-518 mm) tagged in the MGORD that were subsequently relocated in Rush Creek downstream of the MGORD.

During winter months, all (100%) of the MGORD adults that were relocated downstream in Rush Creek proper, were holding in locations where water column velocities near the stream bottom ranged from 0.1 to 0.7 ft per second (fps), as were 91% of the brown trout adults tagged in Rush Creek, and even 85% of the Rush Creek juveniles (Figure D-2.1). This demonstrated that all sizes of brown trout, not just the large MGORD adults, preferred low-velocity holding habitats and would benefit from increases in areas where stream bottom velocities are 0.0 to 0.7 fps.

During the non-winter months, a somewhat higher proportion of all sizes of brown trout were relocated at sites where focal velocities were >0.7 fps, but 82% of all the adult fish and 81% of the juveniles were still found at locations with focal velocities ranging from 0.0 to 0.7 fps (Figure D-2.2).

There does, however, seem to be a slight preference for lower focal velocities during the winter months, since mean stream bottom velocity for all brown trout relocated during winter (0.36 fps) was lower than the non-winter mean (0.53 fps) (Table D-2.1). For the large MGORD fish this difference was even greater: 0.33 fps during winter vs. 0.59 fps during non-winter (Table D-2.1).

The winter graph (Figure D-2.1) justifies why we used stream bottom velocities of 0.0 to 0.7 fps, measured 0.5 ft off the stream bottom, as the velocity criteria for delineating adult brown trout winter holding habitat during the IFS. Comparing mean column water velocities measured at 6/10th total depth to velocities measured at 9/10th total depth supports our contention that mean water column velocities are a poor descriptor of brown trout habitat (Table D-2.2). For 123 instances where a relocated fish occupied a location with a focal point velocity less than 0.7 fps, 33% of the time the mean column water velocities exceeded 0.7 fps (Table D-2.2).

Our water column depth criteria of >1.0 ft was based on the fact that 87% of the adult brown trout relocated during winter months were found where water column depths exceeded 1.0 ft (Figure D-2.3). Brown trout relocated in non-winter months also showed a strong preference for locations with water column depths greater than 1.0 ft (Figure D-2.4). Direct cover was the third criterion used to delineate winter holding habitat during the IFS and was also derived directly from Movement Study results. Our cover criterion was very straight-forward; there had to be enough direct hiding cover to provide at least 12 ft^2 of protection from surface detection.

The developed focal velocity, depth and cover criteria were utilized to measure the surface areas of adult brown trout holding habitat polygons during the IFS on Rush and Lee Vining creeks (Taylor et al. 2009). During the IFS mapping, water depths were measured to the nearest 0.1 ft. and focal velocities to the nearest 0.1 fps. The study reaches for this mapping effort were based, in part, on habitat typing surveys conducted on these streams just prior to the IFS, where we measured the lengths and locations of all the pool, riffle and glide/run habitats (Knudson et al. 2009). In Rush Creek, a bulk of the IFS direct habitat mapping effort was directed to the reach downstream of the Narrows because of the clusters of high-quality pools present and also because of this reach’s documented geomorphic response to high runoff flows (Knudson et al. 2009). The Fisheries Scientists suggest that this reach best represents the likely future condition of the stream channel in lower Rush Creek and chose to concentrate the IFS’s direct habitat mapping in this reach to better analyze flow affects for this likely future channel condition. As previously mentioned, our habitat measurements were collected during all seasons, so we did not need to extrapolate non-winter observations to winter conditions like was done during many other IFS recommendations, such as CDFG (1991; 1993) did with the habitat preference criteria developed by Smith and Aceituno (1987).

During our IFS mapping, we applied several QA/QC procedures. Depth and velocity measurements were double-checked by measuring these parameters until a polygon boundary was located, and by re-measuring at several points along the boundary. During and after each polygon was delineated, the data recorder and the person who was measuring depths and velocities always conferred to ensure that the dimensions and location of each polygon were correctly displayed. For each polygon boundary point, the distance from the previous point was recorded and triangulation with at least one other boundary point or other known reference point was done by measuring the two distances. The locations of the polygon boundary points were therefore very quantifiable and easily measured with a stadia rod, current meter and measuring tape. The boundaries between suitable and unsuitable focal velocities were usually quite obvious (i.e., clear velocity “break-points” occurred when the flow meter was moved a matter of inches, not feet); and measurements of depths (being either deeper or shallower than one-foot) were also very straight-forward, as was the presence or absence of direct overhead hiding cover.

We believe that our stream and species-specific approach for determining holding habitat criteria for adult brown trout provided a sound foundation for our IFS recommendations. The extensive data set generated from the Movement Study clearly demonstrated that holding habitat as defined by our IFS mapping criteria was utilized by several size classes of juvenile and adult brown trout during both winter and non-winter months. Management decisions that expand the area of winter habitat defined by these criteria should enhance the survival and condition of adult brown trout in Rush and Lee Vining creeks.

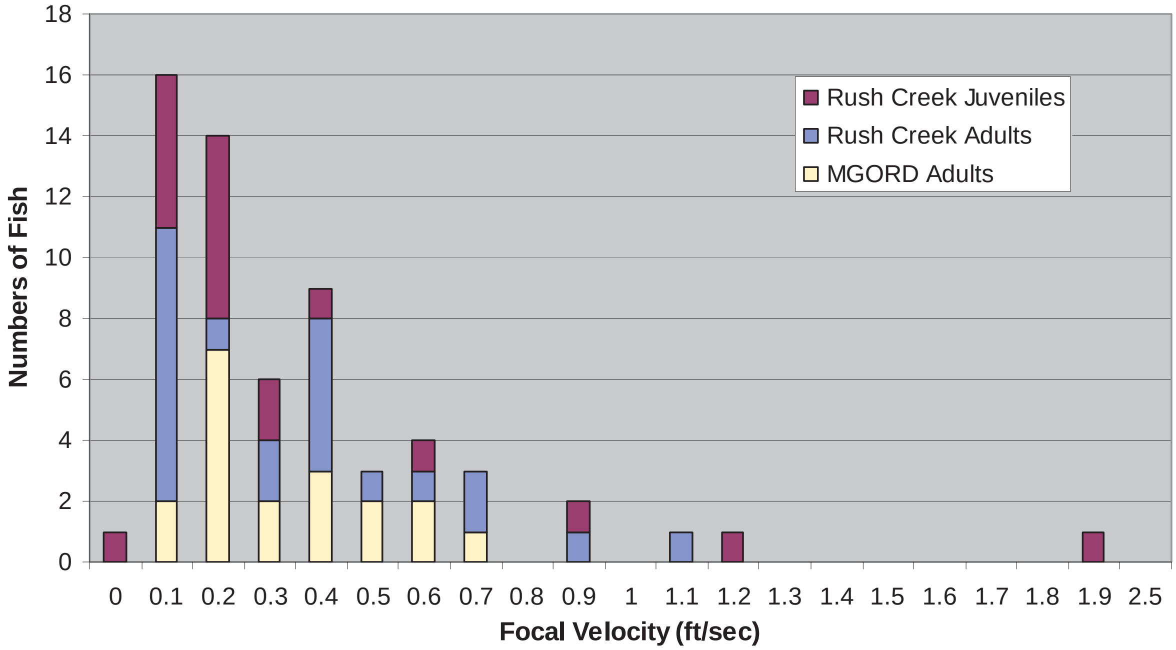


Figure D-2.1. Distribution of focal velocities for brown trout relocated during winter months (December-March) in Rush Creek.

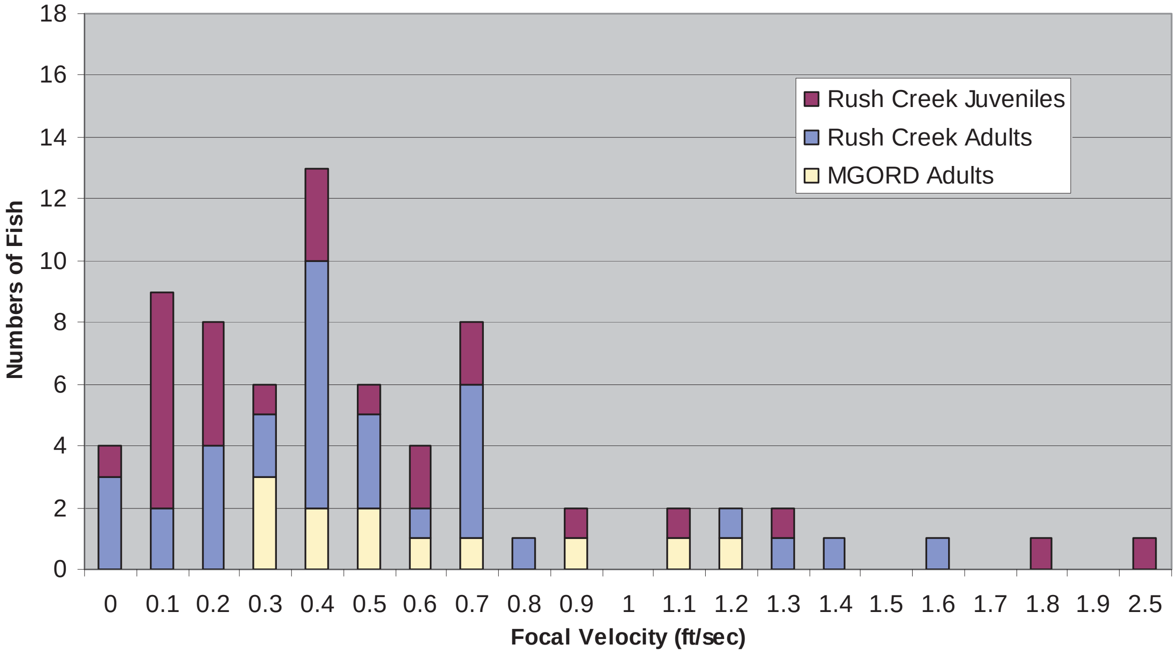


Figure D-2.2. Distribution of focal velocities for brown trout relocated during non-winter months (April-November) in Rush Creek.

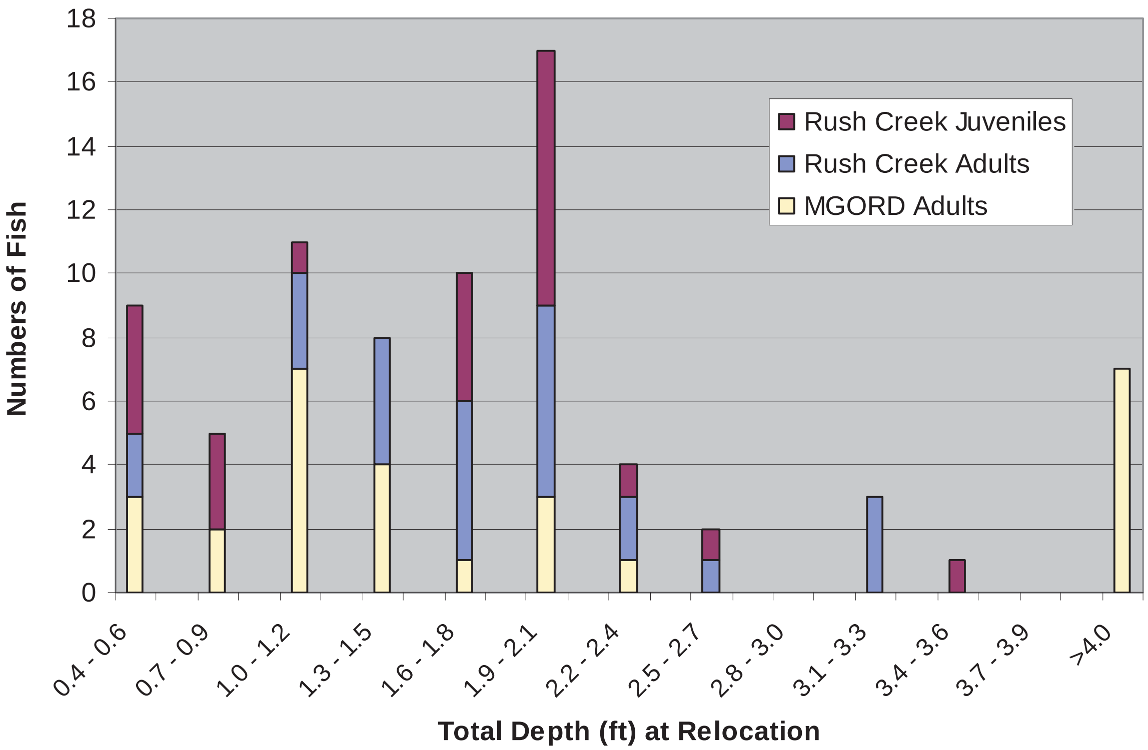


Figure D-2.3. Total depths measured at locations of brown trout relocated during winter months (December-March) in Rush Creek.

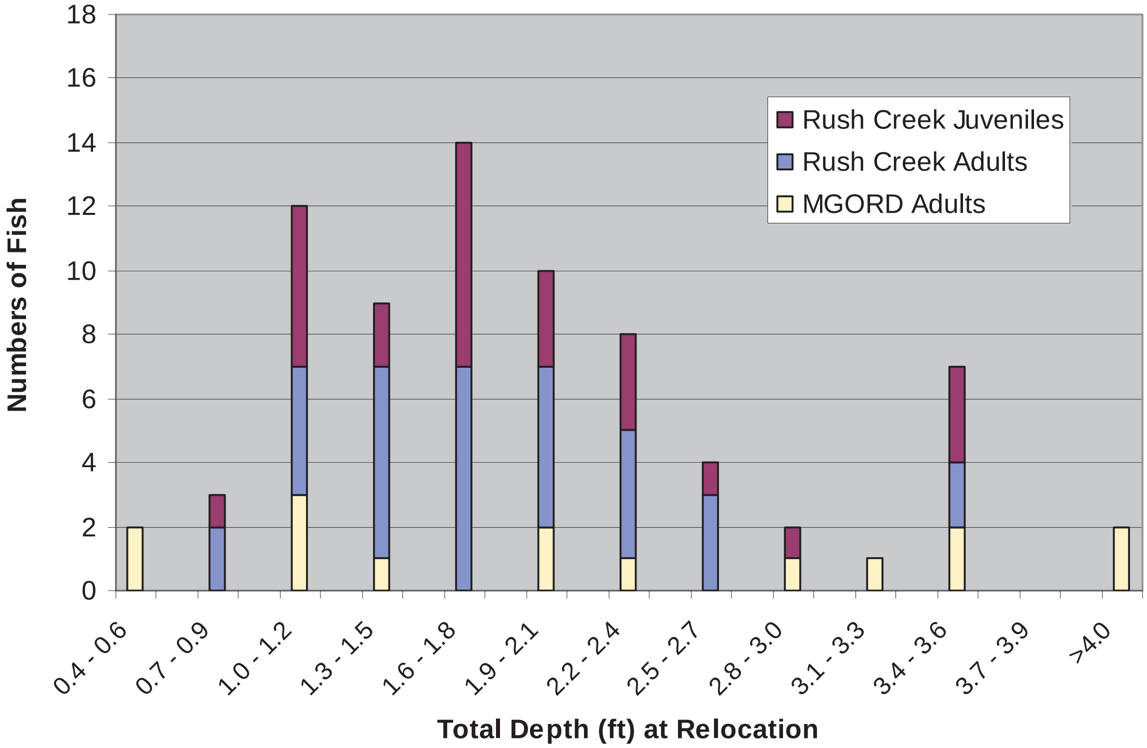


Figure D-2.4. Total depths measured at locations of brown trout relocated during non-winter months (April-November) in Rush Creek.

Table D-2.1. Total depths and water column velocities measured at 6/10th and 9/10th of total stream depth associated with relocated brown trout on Rush Creek.

Winter Period (November – March)					Non-winter Period (April – October)				
Focal Velocity (fps)	*Number of Rush Ck Juveniles*	*Number of Rush Ck Adults*	*Number of MGORD Adults*	*Total No. Relocated Fish*	*Focal Velocity (fps)*	*Number of Rush Ck Juveniles*	*Number of Rush Ck Adults*	*Number of MGORD Adults*	*Total No. Relocated Fish*
0	1	0	0	1	0	1	3	0	4
0.1	5	9	2	16	0.1	7	2	0	9
0.2	6	1	7	14	0.2	4	4	0	8
0.3	2	2	2	6	0.3	1	2	3	6
0.4	1	5	3	9	0.4	3	8	2	13
0.5	0	1	2	3	0.5	1	3	2	6
0.6	1	1	2	4	0.6	2	1	1	4
0.7	0	2	1	3	0.7	2	5	1	8
0.8	0	0	0	0	0.8	0	1	0	1
0.9	1	1	0	2	0.9	1	0	1	2
1.0	0	0	0	0	1.0	0	0	0	0
1.1	0	1	0	1	1.1	1	0	1	2
1.2	1	0	0	1	1.2	0	1	1	2
1.3	0	0	0	0	1.3	1	1	0	2
1.4	0	0	0	0	1.4	0	1	0	1
1.5	0	0	0	0	1.5	0	0	0	0
1.6	0	0	0	0	1.6	0	1	0	1
1.7	0	0	0	0	1.7	0	0	0	0
1.8	0	0	0	0	1.8	1	0	0	1
1.9	1	0	0	1	1.9	0	0	0	0
2.5	0	0	0	0	2.5	1	0	0	1
TOTALS	**19**	**23**	**19**	**61**	TOTALS	**26**	**33**	**12**	**71**
Average Velocities (fps)	**0.38**	**0.36**	**0.33**	**0.36**	Average Velocities (fps)	**0.53**	**0.51**	**0.59**	**0.53**

Table D-2.2. Measured focal velocities for three size groups of brown trout on Rush Creek during winter and non-winter periods, using the higher of the 6/10th versus 9/10th water column depths' velocity measurements for 43 observations with total depths ranging from 0.4-1.3 ft; and the 9/10th water column depths' velocity measurements for the remaining 89 observations (total depths 1.4-4.1 ft).

Rush Creek Section	*Date*	*Fish Code Number*	*Fish Length (mm)*	*Fish Weight (g)*	*Velocity at 0.6 total depth (fps)*	*Velocity at 0.9 total depth (fps)*	*Total Depth at Relocation (ft)*
Upper Rush Creek Sampling Section	10/18/2005	31	194	78	0.8	0.6	2.2
	10/18/2005	32	197	77	2.5	0.2	1.0
	10/18/2005	33	201	88	0.6	0.4	1.8
	10/18/2005	35	204	83	0.9	0.1	1.7
	10/18/2005	36	199	76	0.2	0.1	1.7
	10/18/2005	37	197	82	0.7	0.7	1.2
	10/18/2005	51	304	297	1.3	1.4	1.6
	10/18/2005	53	291	250	1.3	1.2	1.7
	10/18/2005	54	266	205	0.9	0.3	2.7
	10/18/2005	55	291	262	0.7	0.6	0.9
	10/18/2005	57	294	298	1.1	0.7	2.3
Lower Rush Creek Sampling Section	10/19/2005	29	475	1220	0.0	0.3	3.4
	10/19/2005	42	196	75	0.0	0.2	1.9
	10/19/2005	48	201	95	1.9	0.7	1.8
	10/19/2005	50	200	82	0.8	0.5	2.5
	10/19/2005	58	276	221	0.2	0.0	1.4
	10/19/2005	59	244	165	0.3	0.2	2.6
	10/19/2005	65	250	151	0.8	0.5	2.2
	10/19/2005	67	291	223	1.9	0.7	1.8
	10/19/2005	68	274	208	0.8	0.5	2.2
	10/19/2005	69	266	186	0.4	0.3	1.2
Rush Creek Co. Road Sampling Section	10/20/2005	40	194	75	0.1	0.9	2.0
	10/20/2005	43	202	80	1.8	1.3	0.8
	10/20/2005	45	195	72	0.8	0.1	1.6
	10/20/2005	46	206	88	0.4	0.4	1.1
	10/20/2005	61	257	170	0.1	0.2	0.9
	10/20/2005	62	265	185	0.9	0.0	2.0
	10/20/2005	66	272	209	0.2	0.0	1.1
	10/20/2005	70	257	179	1.8	0.7	1.4
Upper Rush Creek Sampling Section	11/16/2005	21	518	1311	1.1	0.5	1.1
	11/16/2005	23	338	392	1.2	0.5	3.5
	11/16/2005	33	201	88	0.4	1.1	2.2
	11/16/2005	35	204	83	0.4	0.1	1
	11/16/2005	37	197	82	0.5	0.2	1.5
	11/16/2005	54	266	205	1.2	0.5	3.5
	11/16/2005	55	291	262	0.9	0.8	1.7
	11/16/2005	57	294	298	1.2	0.2	1.5

Table D-2.2. Continued. Measured focal velocities for three size groups of brown trout on Rush Creek during winter and non-winter periods, using the higher of the 6/10th versus 9/10th water column depths' velocity measurements for 43 observations with total depths ranging from 0.4-1.3 ft; and the 9/10th water column depths' velocity measurements for the remaining 89 observations (total depths 1.4-4.1 ft).

Rush Creek Section	*Date*	*Fish Code Number*	*Fish Length (mm)*	*Fish Weight (g)*	*Velocity at 0.6 total depth (fps)*	*Velocity at 0.9 total depth (fps)*	*Total Depth at Relocation (ft)*
Narrows down through Upper Rush Creek Sampling Section	11/17/2005	28	513	1110	0.6	0.5	1.1
	11/17/2005	29	475	1220	1.2	0.5	0.6
	11/17/2005	42	196	75	0.4	0.1	3.5
	11/17/2005	44	201	79	0.4	0.1	3.5
	11/17/2005	49	197	80	1.3	0.8	1.2
	11/17/2005	50	200	82	0.7	0.6	2.3
	11/17/2005	58	276	221	0.2	0.2	1.4
	11/17/2005	59	244	165	0.1	0.1	2.2
	11/17/2005	64	254	151	0.4	0.1	3.5
	11/17/2005	65	250	151	0.6	0.4	2.0
	11/17/2005	67	291	223	0.7	0.3	1.4
	11/17/2005	68	274	208	0.6	0.4	2.0
	11/17/2005	69	266	186	0.3	0.7	1.6
Ford down to County Road Culvert	11/15/2005	43	202	80	0.4	0.3	3.6
	11/15/2005	45	195	72	0	0.2	1.7
	11/15/2005	46	206	88	0.1	0.0	1.9
	11/15/2005	47	200	84	0.3	0.1	1.8
	11/15/2005	61	257	170	0.9	0.4	1.7
	11/15/2005	62	265	185	0.7	0.4	2.0
	11/15/2005	63	254	160	0.6	0.4	1.2
	11/15/2005	66	272	209	1.3	0.4	1.1
	11/15/2005	70	257	179	0.1	0.0	1.9
Gorge down to Highway 395	12/16/2005	25	362	510	0.3	0.1	0.7
	12/16/2005	35	204	83	1.8	0.6	1.8
	12/16/2005	37	197	82	0.2	0.1	0.7
	12/16/2005	53	291	250	0.1	0.1	1.0
	12/16/2005	54	266	205	1.1	0.5	1.1
	12/16/2005	55	291	262	0.9	0.6	1.1
	12/16/2005	57	294	298	0.2	0.1	2.2
Highway 395 down through Lower Sampling Section	12/17/2005	14	465	925	0.3	0.2	1.4
	12/17/2005	42	196	75	1.1	1.2	2.2
	12/17/2005	44	201	79	0.6	0.1	1.6
	12/17/2005	48	201	95	0.4	0	2.1
	12/17/2005	49	197	80	0.2	0.2	0.4
	12/17/2005	58	276	221	0.6	0.1	1.6
	12/17/2005	59	244	165	1.3	0.5	3.3
	12/17/2005	65	250	151	0.7	0.4	2.2
	12/17/2005	67	291	223	0.2	0.4	2.1
	12/17/2005	68	274	208	0.9	0.7	2
	12/17/2005	69	266	186	0.2	0.1	1.4

Table D-2.2. Continued. Measured focal velocities for three size groups of brown trout on Rush Creek during winter and non-winter periods, using the higher of the 6/10th versus 9/10th water column depths' velocity measurements for 43 observations with total depths ranging from 0.4-1.3 ft; and the 9/10th water column depths' velocity measurements for the remaining 89 observations (total depths 1.4-4.1 ft).

Rush Creek Section	*Date*	*Fish Code Number*	*Fish Length (mm)*	*Fish Weight (g)*	*Velocity at 0.6 total depth (fps)*	*Velocity at 0.9 total depth (fps)*	*Total Depth at Relocation (ft)*
MGORD to Highway 395	1/28/2006	25	362	510	0.4	0.3	1.0
	1/28/2006	37	197	82	0.2	0.1	0.7
	1/28/2006	53	291	250	0.2	0.1	1.5
	1/28/2006	57	294	298	0.1	0.3	0.4
Lower Rush Creek Sampling Section	1/27/2006	44	201	79	0.6	0.1	1.6
	1/27/2006	48	201	95	0.1	0.1	1.8
	1/27/2006	49	197	80	0.2	0.2	0.4
	1/27/2006	58	276	221	0.6	0.1	1.6
	1/27/2006	59	244	165	0.1	0.1	2.7
	1/27/2006	67	291	223	0.1	0.1	1.8
	1/27/2006	68	274	208	0.9	0.7	2.0
Co. Road Section	1/26/2006	40	194	75	0.3	0.1	0.9
	1/26/2006	47	200	84	0.1	0.1	2.1
MGORD to Hwy 395	3/15/2006	25	362	510	0.4	0.3	1.1
	3/15/2006	37	197	82	0.2	0.1	0.6
	3/15/2006	57	294	298	0.1	0.3	0.4
Hwy 395 to Narrows	3/13/2006	14	465	925	0.9	0.2	1.9
	3/13/2006	54	266	205	0.8	0.6	1.6
	3/13/2006	65	250	151	0.4	0.1	1.3
Lower Rush Creek Sampling Section	3/12/2006	39	187	80	1.9	0.2	1.2
	3/12/2006	42	196	75	0.1	0.3	2.1
	3/12/2006	44	201	79	0.5	0.4	1.9
	3/12/2006	48	201	95	0.1	0.1	1.9
	3/12/2006	58	276	221	0.5	0.4	1.9
	3/12/2006	59	244	165	0.8	0.2	3.2
	3/12/2006	67	291	223	0.2	0.1	3.2
	3/12/2006	68	274	208	0.7	0.4	2.0
Co. Road Section	3/13/2006	43	202	80	0.9	0.9	2.6
	3/13/2006	45	195	72	0.2	0.1	0.5
MGORD to Hwy 395	5/13/2006	35	204	83	1.6	0.4	3
	5/13/2006	53	291	250	1.1	0.4	1.8
	5/14/2006	54	266	205	1.6	0.7	1.3
Hwy 395 Narrows	5/16/2006	14	465	925	0.1	0.6	1.2
Lower Rush	5/14/2006	58	276	221	3.1	0.4	2.7
Co. Road Section	5/15/2006	45	192	72	0.1	0.1	1.3

Table D-2.2. Continued. Measured focal velocities for three size groups of brown trout on Rush Creek during winter and non-winter periods, using the higher of the 6/10th versus 9/10th water column depths' velocity measurements for 43 observations with total depths ranging from 0.4-1.3 ft; and the 9/10th water column depths' velocity measurements for the remaining 89 observations (total depths 1.4-4.1 ft).

Rush Creek Section	*Date*	*Fish Code Number*	*Fish Length (mm)*	*Fish Weight (g)*	*Velocity at 0.6 total depth (fps)*	*Velocity at 0.9 total depth (fps)*	*Total Depth at Relocation (ft)*
MGORD to Hwy 395	12/5/2006	12	508	1118	1.2	0.3	1.4
	12/5/2006	26	357	461	0.2	0.6	1.5
	12/5/2006	73	382	607	0.5	0.2	1.2
	12/5/2006	74	378	593	0.6	0.4	0.6
	12/5/2006	75	387	662	0.1	0.2	1.4
	12/5/2006	100	314	317	0.2	0.2	0.6
	12/5/2006	107	331	395	0.3	0.2	1.7
Hwy 395 to Ford	12/6/2006	28	513	1110	1.5	0.2	4.1
	12/6/2006	80	457	1056	0.5	0.1	2.0
MGORD to Hwy 395	2/17/2007	72	410	695	0.2	0.1	1.2
	2/17/2007	74	378	593	0.7	0.1	1
	2/17/2007	101	342	414	0.3	0.4	2.1
	2/17/2007	103	338	427	0.5	0.2	0.9
MGORD Hwy 395	5/1/2007	26	357	461	1.2	0.4	3.3
	5/1/2007	105	341	462	0.7	0.3	2.1
Hwy395 to Ford	5/2/2007	104	340	450	0.4	0.1	0.5
	5/2/2007	80	457	1056	0.9	0.5	2.9
MGORD to Hwy 395	9/14/2007	12	508	1118	0.7	0.3	2.3
	9/15/2007	103	338	427	0.9	0.4	1.3
	3/19/2008	89	518	1728	0.1	0.1	2.4

APPENDIX D-3: PREDICTING BROWN TROUT EMERGENCE TIMES FOR LEE VINING AND RUSH CREEKS

The peak emergence timing of brown trout was estimated for both Lee Vining and Rush creeks. The purpose of this analysis was to better evaluate how emergence timing coincided with the timing of higher streamflows during the snowmelt period in late-spring and early summer. The development of salmonid eggs and alevins is dictated by water temperature, with slower (thus longer) development occurring in cooler water temperatures. Because brown trout are fall-spawners, their progeny typically emerge in the spring close to the onset of snowmelt-driven peak flows. Recent research in northern Utah examined the effects of environmental factors on early survival and invasion success of brown trout. Wood and Budy (2009) found embryo survival was lower in high-elevation stream reaches and that model predictions based on winter water temperature data indicated that brown trout fry in higher elevation watersheds probably failed to emerge prior to the onset of high spring flows.

Daily average water temperatures were calculated from the hourly data sets collected and compiled by McBain and Trush for several locations within Lee Vining and Rush creeks. The daily average temperatures were then used with two models for brown trout development to estimate the proportion of total development that would have occurred at that average temperature on a specific day. 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. This equation is:

$$\log D = b \log(\mathrm{T} - \acute{\alpha}) + \log a \qquad (1)$$

where T is water temperature (^{o}C), $\acute{\alpha}$ is a temperature correction (^{o}C), and a and b are constants given in Table 2 of Crisp (1981).

Then a model from Crisp (1988) was used to convert time to 50% hatch into time 50% emergence. This model was based on the comparison between time needed to reach 50% hatch and time needed to reach 50% emergence, and was developed by laboratory experiments in which brown trout embryos and fry were incubated over a range of constant water temperatures. The following equation was used:

$$D_3 = 1.66\, D_2 + 5.4 \qquad (2)$$

where D2 is the number of days from fertilization to 50% hatch, calculated using equation (1).

Using the results from the above equations, the percent of total development (from fertilization to emergence) likely achieved during each day (1/x where x = the number of days required for emergence, based on the average temperature for each daily time-step) was estimated. The percent development for each day was then added to the accumulated total percent development from each of the previous days. An Excel spreadsheet designed to calculate emergence times was graciously provided by Dr. Phaedra Budy from Utah State University.

Ideally, information from frequent, annual spawning surveys is utilized to accurately determine the timing of peak spawning (Wood and Budy 2009). We made some limited observations of brown trout spawning in Rush Creek during the radio-telemetry movement in the autumns of 2005 and 2006, in which most activity occurred between mid-November and mid-December. We have no brown trout spawning observations from Lee Vining Creek and the only reference to spawning surveys was in November 1991 when consultants field-checked areas between the DWP diversion and the USFS storage year where "spawning beds" had been created by introduction of gravels (Dalton and Mesick 1991). None of these 1991 surveys were conducted downstream of Highway 395 within our long-term monitoring reaches (Dalton and Mesick 1991). Because we lacked detailed information to select a single date of when peak spawning occurred during specific years where water temperature data were available, we conducted the spreadsheet analyses to predict peak emergence timing for three dates on each creek to cover when the bulk of spawning probably occurred. We assumed that brown trout spawn a bit earlier on Lee Vining Creek than Rush Creek due to the cooler water temperatures. For Lee Vining Creek, the three dates selected for "peak spawning" were November 1st, November 15th and November 21st (Table D-3.1). For Rush Creek, the three dates selected for "peak spawning" were November 15th, November 30th and December 7th (Tables D-3.2-

The daily average water temperature data were available for nine spawning-to-emergence periods between 1999 and 2008; however complete data sets were not available for any specific reach for the entire period of record. Thus in Lee Vining Creek, peak emergence timing was predicted for five periods (Table D-3.1). The three earliest predictions (1999-2000, 2000-2001, 2003-2004) were made with temperature data collected at the Upper LV monitoring site, and the later two predictions (2006-2007 and 2007-2008) were made with temperature data collected at the LV Ford crossing (Table D-3.1). Unfortunately, for Lee Vining Creek incomplete temperature data sets prevented us from predicting timing of peak emergence in wet year-types with large discharges, primarily 2004-2005 and 2005-2006. In Rush Creek, peak timing to emergence was estimated for seven periods within the MGORD, five periods at the Narrows and for six periods at the County Road (Tables D-3.2-4).

Compared to Rush Creek, colder winter water temperatures in Lee Vining Creek resulted in longer periods of time between the presumed date of peak spawning and the predicted peak emergence (Tables D-3.1-4). For the 1999-2000 period; the length of time from peak spawning to peak emergence (start date of November 15th in both creeks) was 196 days in Lee Vining Creek, 162 days at the MGORD and 166 days at both the Narrows and County Road (Tables D-3.1-4). The longest time between the presumed date of peak spawning (November 15th) and the predicted peak emergence in Lee Vining Creek occurred during the 2007-2008 period and was 202 days (Table D-3.1). For this same period, the time between the presumed date of peak spawning (November 15th) and the predicted peak emergence in Rush Creek was 178 to 183 days (Tables D-3.2-4).

The timing and magnitude of peak discharges were also included in Tables 1-4 to determine if predicted peak emergence occurred before, during, or after peak run-off flows. In Tables D-3.1-4, the Peak flow data for Lee Vining Creek downstream of the DWP diversion were from "LVC at Intake" (#5009). In Lee Vining Creek, the predicted peak emergence typically occurred during, or soon after, the peak snowmelt period (Table D-3.1). In Rush Creek, the predicted peak emergence generally occurred prior to peak flows in most years, except wetter years such as 2005 and 2006 (Tables D-3.2-4). In most years, the predicted peak emergence on Rush Creek occurred two to five weeks prior to the peak discharge, depending on the presumed date of peak spawning. In annual fisheries monitoring reports, we have previously cited several papers that investigated the effects of peak flows on recruitment of age-0 brown trout. Cattaneo (2002) concluded that hydrology only constrained trout dynamics during the critical emergence period, after which intra-cohort interactions regulated age-0+ densities in 30 French stream reaches. Nuhfer et al. (1994) monitored brown trout populations in the South Branch of the Au Sable River in Michigan for 16 years and used linear regression to test empirical relationships between age-0 recruitment and stream flow and winter severity. Results indicated that variations in stream flow (higher discharges) during the 30-day period corresponding to brown trout emergence and initial foraging behavior was when flow significantly influenced recruitment. No other time period (including spawning and incubation period) showed statistical relationships between flow and age-0 recruitment. No relationship was found between age-0 recruitment and measures of winter severity.

Nuhfer et al. (1994) may best explain the severe drops in age-0 brown trout densities often recorded in Lee Vining Creek and occasionally documented in Rush Creek (Hunter et al. 2006). According to our peak emergence predictions, peak snowmelt run-offs in Lee Vining Creek typically occur during, or soon after, brown trout fry have emerged and are attempting to forage and establish territories along channel margin areas. During these peak flows the channel bed is most likely mobile, velocities are high, and visibility may be reduced by turbid conditions making it difficult to successfully forage and/or maintain positions along channel margins. The SRF hydrographs as defined by WR 98-05 require that LADWP passes the primary peak on Lee Vining Creek and then may resume diversions. We have suspected that in some years the resumption of diversions on top the already rapidly dropping falling limb may have exacerbated stranding of newly emerged brown trout fry in side channels.

Because water temperature has been considered a possible indicator of conditions affecting the survival brown trout of embryos (Wood and Budy 2009), winter water temperature data from Lee Vining Creek for the two coldest months were also summarized (Table D-3.5). The three seasons with the coldest two-month periods occurred in 2000-2001, 2006-2007, and 2007-08; however each of these three years produced estimates of age-0 brown trout, including two of the three highest density estimates in the Lee Vining Creek main channel (Figure D-3.1). Interestingly, there was no peak discharge in the spring of 2007 and a relatively small peak of 131 cfs in the spring of 2008, the two years with high density estimates of age-0 brown trout (Table D-3.1 and Figure D-3.1).

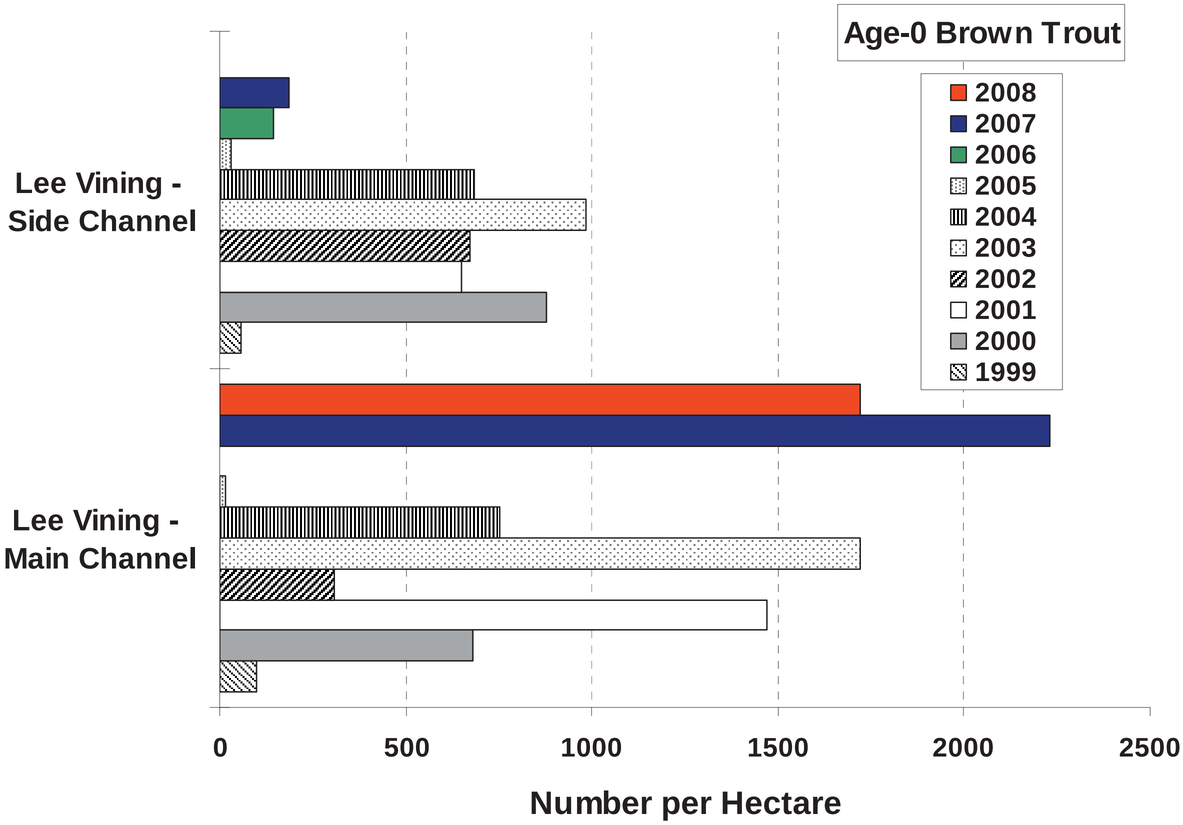


Figure D-3.1. Estimated number of age-0 brown trout per hectare in sections of Lee Vining Creek from 1999 to 2008.

Table D-3.1. Predicted peak emergence timing of brown trout 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

Table D-3.2. Predicted peak emergence timing of brown trout in Rush Creek at the MGORD.

Spawning Season	Presumed Date Peak Spawning	Predicted Peak Emergence (PPE)	Q at PPE (cfs)	Timing and Magnitude of Peak Discharge
1999-2000	Nov 15th	April 24th	49	June 25th – 30th 59 to 204 cfs <100 cfs on July 17th
	Nov 30th	May 5th	47	
	Dec 7th	May 9th	46	
2000-2001	Nov 15th	May 10th	49	May 31st – June 14th 56 to 161 cfs <100 cfs on June 23rd
	Nov 30th	May 19th	53	
	Dec 7th	May 22nd	50	
2001-2002	Nov 15th	April 24th	51	June 4th – 8th 57 to 168 cfs <100 cfs on June 14th
	Nov 30th	May 3rd	51	
	Dec 7th	May 5th	52	
2003-2004	Nov 15th	May 1st	48	June 1st – 11th 59 to 343 cfs <100 cfs on June 22nd
	Nov 30th	May 6th	48	
	Dec 7th	May 8th	49	
2005-2006	Nov 15th	May 12th	189	May 2nd – June 10th 75 to 477 cfs <100 cfs on August 12th
	Nov 30th	May 25th	241	
	Dec 7th	May 28th	255	
2006-2007	Nov 15th	April 23rd	32	No peak discharge
	Nov 30th	May 4th	31	
	Dec 7th	May 7th	31	
2007-2008	Nov 15th	May 13th	48	May 25th – June 7th 64 to 388 cfs <100 cfs on June 28th
	Nov 30th	May 19th	49	
	Dec 7th	May 20th	50	

Table D-3.3. Predicted peak emergence timing of brown trout in Rush Creek at the Narrows. Discharge data includes accretions from Parker and Walker creeks.

Spawning Season	Presumed Date of Peak Spawning	Predicted Peak Emergence (PPE)	Q at PPE (cfs)	Timing and Magnitude of Peak Discharge
1999-2000	Nov 15th	April 28th	57	May 21st – June 30th 70 to 256 cfs <100 cfs on July 20th
	Nov 30th	May 6th	60	
	Dec 7th	May 8th	61	
2000-2001	Nov 15th	May 10th	97	May 21st – June 11th 73 to 202 cfs <100 cfs on 6/26
	Nov 30th	May 15th	101	
	Dec 7th	May 17th	141	
2002-2003	Nov 15th	May 7th	41	May 23rd – June 3rd 67 to 283 cfs <100 cfs on June 21st
	Nov 30th	May 14th	45	
	Dec 7th	May 17th	54	
2005-2006*	Nov 21st	May 16th	272	April 21st – June 8th 73 to 584 cfs <100 cfs on August 15th
	Nov 30th	May 21st	295	
	Dec 7th	May 24th	281	
2007-2008**	Nov 15th	May 16th	68	May 11th – June 7th 60 to 423 cfs <100 cfs on July 2nd
	Nov 30th	May 20th	100	
	Dec 7th	May 22nd	92	

*Note later start date due to no data available earlier than the 15th

**Temp data was collected at Old Highway 395 bridge

Table D-3.4. Predicted peak emergence timing of brown trout in Rush Creek at County Road. Discharge data includes accretions from Parker and Walker creeks.

Spawning Season	*Presumed Date of Peak Spawning*	*Predicted Peak Emergence (PPE)*	*Q at PPE (cfs)*	*Timing and Magnitude of Peak Discharge*
1999-2000	Nov 15th	April 28th	57	May 21st – June 30th 70 to 256 cfs <100 cfs on July 20th
	Nov 30th	May 4th	61	
	Dec 7th	May 7th	62	
2000-2001	Nov 15th	May 9th	93	May 21st – June 11th 73 to 202 cfs <100 cfs on 6/26
	Nov 30th	May 14th	99	
	Dec 7th	May 16th	130	
2003-2004	Nov 15th	May 1st	62	May 28th – June 11th 72 to 372 cfs <100 cfs on June 26th
	Nov 30th	May 6th	76	
	Dec 7th	May 8th	69	
2004-2005	Nov 15th	May 10th	75	May 4th – June 29th 75 to 467 cfs <100 cfs on August 12th
	Nov 30th	May 15th	82	
	Dec 7th	May 16th	107	
2006-2007	Nov 15th	April 28th	38	No peak discharge
	Nov 30th	May 4th	46	
	Dec 7th	May 7th	42	
2007-2008	Nov 15th	May 11th	60	May 11th – June 7th 60 to 423 cfs <100 cfs on July 2nd
	Nov 30th	May 16th	68	
	Dec 7th	May 17th	78	

Table D-3.5. Mean water temperatures for the two coldest winter months in Lee Vining Creek.

Spawning/Incubation Season	*Mean Water Temperature for Two Coldest Months*	*Two Coldest months of Incubation Period*
1999 – 2000	34.32°F (1.29°C)	December-January
2000 – 2001	33.11°F (0.62°C)	January-February
2003 – 2004	36.69°F (2.61°C)	January-February
2005 – 2006	33.94°F (1.08°C)	January-February
2006 - 2007	33.49°F (0.83°C)	December-January
2007 - 2008	32.93°F (0.52°C)	December-January

APPENDIX D-4: MODELING RUSH CREEK SUMMER WATER TEMPERATURES AND PREDICTING BROWN TROUT GROWTH

D-4.1: Introduction

Beak Consultants Inc (1991) conducted an instream flow requirement study for brown trout in Rush Creek as part of a cooperative study with California Department of Fish and Game and Los Angeles Department of Water and Power. As part of that study water temperatures in Rush Creek were modeled and predictions of water temperatures were made for various flow scenarios based on calibration of a model (the QUAL2E model developed by the U.S. Environmental Protection Agency) using water temperature measurements recorded from July 1, 1987 through August 4, 1988. This study found that modeled water temperatures were generally within + 2˚F, weather conditions strongly influenced water temperatures, maximum predicted water temperatures and ranges of daily fluctuations decreased with higher flows, and that at the lowest flow tested (19 cfs) predicted water travel times were sufficiently slow that temperatures lower in the stream were more influenced by weather than at higher flows with shorter travel times when water temperatures lower in the stream were more effected by Grant Lake Reservoir (GLR) outflow temperatures. This study had limited use in predicting thermal effects on trout populations because it only evaluated effects of maximum temperatures. While the study found that maximum water temperatures approached and could exceed 80˚F for relatively short time periods at the lowest flow tested (19 cfs), the authors concluded that it was unclear whether moderately short-term durations of these exposures would influence trout populations.

Shepard et al. (2009a; 2009b) found that body condition and densities of brown trout in Rush Creek were associated with flow levels and water temperatures. In general, they found that lower peak flows, moderate summer flows, and the number of days that water temperatures were ideal for growth (52 to 67˚F based on work by Raleigh et al. 1986; Elliott 1975a; Elliott 1975b; Elliott et al. 1995; Elliott and Hurley 1999; Elliott and Hurley 2000; Ojanguren et al. 2001; Figure D-4.1) resulted in higher abundances and better body conditions of brown trout in Rush Creek. Ideal growth temperatures were determined primarily using work by Elliott and Hurley (1999), who found that growth (positive weight gain) only occurred in brown trout when water temperatures ranged from 3 to 19˚C (37 to 67˚F), with the highest growth rate occurring at 14˚C (57˚F). At water temperatures above 67˚F and below 37˚F no growth occurred, even when the test fish were provided with full rations. Raleigh et al. (1986) recommended an "optimum temperature range" for growth and survival of brown trout of 54 to 66˚F.

A stream network temperature model SNTEMP (Theurer et al. 1984; Bartholow 1989; Bartholow 1991; Bartholow 2000) was suggested by both the Stream Scientists and California Department of Fish and Game and agreed upon by all Mono Basin collaborators during the scoping process to be the most useful model for predicting stream temperatures in Rush Creek. The SNTEMP model was originally developed by U.S. Fish and Wildlife Service (now USGS) scientists in Fort Collins, Colorado. This model uses a stream network approach to track thermal fluxes throughout a stream network. One major advantage to this model is its ability to evaluate different flow and temperature scenarios and predict changes in temperatures throughout a networked system. We used a Windows®

operating system version of the DOS® operating system SNTEMP model called “StreamTemp” (version 1.0.4, Thomas R. Payne and Associates 2005) that is easier to use in a PC Windows environment. This model was calibrated for Rush Creek using data from 2000 through 2008 (Shepard et al. 2009c).

Shepard et al. (2009c) hypothesized that:

(1) Higher summer stream flows would result in more optimal water temperatures for trout growth, but higher flows would also increase water velocities and provide fewer slow-water habitats preferred by brown trout (Taylor et al. 2009).

(2) Providing optimal temperatures for trout growth will result in increased annual growth rates for juvenile and adult brown trout, potentially increasing their survival and overall size of trout in the Mono Basin streams.

(3) Intermediate flow levels may provide optimal conditions for brown trout by balancing water temperature mediation with availability of slow-water habitats.

The purpose of this report is to summarize predictions of average summer water temperatures in several reaches of Rush Creek for numerous different flow, GLR elevation, and augmentation of flows into upper Rush Creek from Lee Vining Creek via the 5-Siphon Bypass, water availability, and climate scenarios to evaluate probable effects of these different scenarios on potential growth of brown trout. We are making the assumption that increasing growth potential for brown trout by providing them with water temperatures that are better for growth will increase the potential for producing more larger brown trout by increasing their annual survival and growth. Increasing survival of brown trout should also maximize the standing crop of brown trout supported in Rush Creek.

D-4.2: Model Runs

Since the StreamTemp water temperature prediction model does a much better job of predicting average daily water temperatures than either minimum or maximum water temperatures (Bartholow 1989), we elected to use average daily water temperature criterion for evaluating model outputs for different flow scenarios. We evaluated four different types of scenarios to evaluate likely response in water temperatures of Rush Creek to varying flow and temperature regimes:

(1) Varying flows (from 30 to 120 cfs) released into the MGORD from GLR using the climate and water temperature data available for 2008.

(2) Varying both flows (from 30 to 120 cfs) and initial water temperatures (from 50 to 70˚F in 5˚F increments) released into the MGORD from GLR using the climate and water temperature data available for 2008.

(3) Varying flows (from 30 to 120 cfs) released into the MGORD from GLR and adding flows to Rush Creek immediately below the MGORD (5-Siphon Bypass from Lee Vining Creek – additions of 5 and 10 cfs) using the climate and water temperature data available for 2008.

(4) Recommended timing and volume of flow releases from GLR based on seven classes of water availability (based on snowpack water availability projections), applying measured GLR outflow temperatures (measured at the MGORD footbridge) and modifying these outflow temperatures by 3.7˚F depending upon whether GLR was “full” or “empty” (Cullen and Railsback 1993), and adding or not adding water to upper Rush Creek from Lee Vining Creek via the 5-Siphon Bypass. Timing and volume of water moved from Lee Vining Creek to Rush Creek were also based on the seven classes of water availability.

Scenario types one through three above represented exploratory analyses to evaluate how changes in flows and starting water temperatures influenced the predicted average daily water temperatures throughout Rush Creek. We evaluated these scenarios by examining daily predictions of average water temperatures at various sites along Rush Creek under the different GLR outflow volumes and water temperatures. Scenario-type four represented potential flow management scenarios that would likely be implemented in Rush Creek. To evaluate these scenarios we predicted summer growth of brown trout using a growth-prediction model developed for brown trout (Elliott et al. 1995) that uses water temperature to predict growth. We also investigated the longitudinal predictions of daily average water temperatures for several of these scenarios.

D-4.3: Criteria Used to Evaluate Predictions of Water Temperatures

We used a model that predicts growth of brown trout based on water temperature developed by Elliott et al. (1995) and field-tested by Elliott (2009) to predict growth (grams) of juvenile brown trout over the summer (June 1 to September 30) period.

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

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

W_0 = 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),

$$T_{LIM} = T_L \text{ if } T \leq T_M \text{ or } T_{LIM} = T_U \text{ if } T > T_M$$

Where, T_L and T_U are the lower and upper temperature limits when growth equals zero and T_M is the temperature at which optimum growth occurs.

T_L = 3.56˚C (Elliott et al. 1995),

T_U = 19.48˚C (Elliott et al. 1995),

T_M = 13.11˚C (Elliott et al. 1995).

This equation results in a triangular relationship whereby predicted growth increases as temperature rises from T_L to T_M and then decreases as temperature increases further from T_M to T_U. We applied this model and computed 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 third summer) and grew the fish each day based on the predicted average daily water temperature. Total weight (W_t) at the end of the summer (September 30) was converted to weight gain (grams) by subtracting the initial weight (June 1).

We evaluated the growth-prediction model of Elliott et al. (1995) using data we collected on weight gains of marked age-0 fish in Rush Creek. Our preliminary field-evaluation of this model indicated this model provided reasonable results for age-0 brown trout in Rush Creek from September 1 to August 31. Our preliminary analyses indicated that this growth model provided the best way to evaluate the different flow scenarios, so we relied primarily on this growth model for displaying predicted differences for the various flow scenarios. We caution that this growth model was initially developed for brown trout fed unlimited rations of food, so actually growth in the field could be lower if brown trout do not receive a full ration of food. We also found that predicted growth during the June 1 to September 30 summer period may represent only about 60 to 70% of total annual growth predictions based on model tests we ran for the Rush Creek temperature data. In spite of these limitations, we believe this model provides the best index of temperature-mediated effects on brown trout.

We also evaluated past water temperature data collected in Rush Creek to determine a reasonable average daily water temperature criterion. There were 2,794 daily water temperature measurements recorded for sites in Rush Creek during the June 1 through September 30 time period. We first observed average daily water temperatures that were recorded on days when minimum and maximum water temperatures fell within the range of 52 to 67˚F. Of the 2,794 total records, there were a total of 1,338 daily records when temperatures fell within the 52 to 67˚F range. The overall mean for the average daily temperatures for these days (52 to 67˚F range) was 58.46˚F (S.D. = 2.2). The 95% confidence interval fell between 54.1 and 62.8˚F. Using this range as a starting point, we evaluated three different average daily temperature ranges as potential criteria: 54.0 to 62.5˚F, 55.5 to 60.5˚F, and 56.0 to 60.0˚F.

There were 1,256 days (94%) when an average range of 54.0 to 62.5˚F fell within the 1,338 days with minimums >52˚F and maximums <67˚F, dropping to 983 days (73%) for an average range of 55.5 to 60.5˚F, and 846 days (63%) for an average range of 56 to 60˚F. We also assessed how many days each of these average ranges would fall outside the 52 to 67˚F range. There were 667 days (23% of total days) that an average range of 54.0 to 62.5˚F fell outside the preferred range, dropping to 314 days (11%) for an average range of 55.5 to 60.5˚F, and 211 days (8%) for an average range of 56.0 to 60.0˚F. We explored the distributions of minimum and maximum water temperatures actually recorded for those days when these three ranges of daily average water temperatures fell outside the 52 to 67˚F daily ranges (Figure D-4.2). It appeared that for most days when these daily average ranges fell outside the 52 to 67˚F daily temperatures the differences in either daily minimums or daily maximums were usually within one to three degrees of either 52 or 67˚F and the broader average temperature range of 54.0 t 62.5˚F had many more days when maximum water temperatures fell more than 1.0 F outside this upper range of 67˚F. Based on these analyses we decided to set the range of predicted daily mean temperatures at 55.5 to 60.5˚F as the criterion for assessing how many days different flow scenarios provide good growth temperatures for brown trout.

We were also interested in determining the potential number of days that were potentially harmful to brown trout due to water temperatures exceeding their preferred thermal range. Since we had to rely on average water temperatures, we selected an upper limit on the average water temperature of 65˚F as an index that daily water temperatures were exceeding 70˚F. We used the number of days that the daily average water temperature exceeded 65˚F as the index for the number of bad thermal days experienced by brown trout.

D-4.4: Modeling Fixed-Effects

Climate - 2008 – Hot Climate Year

The summer of 2008 was one of the hotter summers on record with an average air temperature of 66.1˚F and an average monthly maximum air temperature of 81.9˚F (Figure D-4.3). For the 57-year period of record only five years had higher summer average air temperatures and only four years had higher average monthly maximum air temperatures. We used 2008 as the initial flow scenario year because GLR was very low and this resulted in outflow temperatures from GLR to the MGORD being warmer than all other years during the critical time of year (July 15 to September 1; Figures D-4.4 and D-4.5). These hot release temperatures resulted in very few days when measured daily average water temperatures at the MGORD or County Road sites were best for brown trout growth (Figure D-4.6).

Incremental Flow Scenario with No 5-Siphon Bypass

We first ran a scenario where we tested temperature effects due to different flows (in 30 cfs increments from 30 to 120 cfs) released from GLR into the MGORD with no releases from the 5-Siphon Bypass using the water temperatures measured at the MGORD footbridge during 2008 as the base condition. Interestingly, it appeared that at lower flows (especially 30 and 60 cfs) the water was actually cooled as it traveled down the Rush Creek Channel (Figure D-4.7). We speculate that this cooling is due to 1) air temperatures being similar to or cooler than released water temperatures during many days (Figure D-4.6), and 2) relatively small inputs of cool water (1 cfs groundwater into Rush at the head of the Gorge and flows input from Parker and Walker creeks).

Incremental Flow and Incremental Temperature Scenario - No 5-Siphon Bypass

Next, we ran scenarios where we altered both the upper temperatures at the MGORD footbridge from 50 to 70˚F in 5˚F increments and flows at the MGORD footbridge from 30 to 120 cfs in 30 cfs increments for the climate data for 2008. These model runs indicated that when relatively warm water temperatures were exiting the MGORD, cooling of the water occurred as it moved down the Rush Creek system and more cooling occurred at lower flows, probably due to the two speculative reasons given above (Figure D-4.8). However, warming occurred down the length of Rush Creek when cooler water temperatures were exiting the MGORD, especially during the hot time period between July 15 and September 1 (Figure D-4.9). Again, more warming occurred at the lower flows.

Incremental Flow Scenario with 5-Siphon Bypass Releases

Next, we ran scenarios for various flows from 30 to 120 cfs released from GLR into the MGORD using measured water temperatures at the MGORD footbridge for 2008 along with 5 and 10 cfs inputs from the 5-Siphon Bypass. We assumed that 5-Siphon Bypass water temperatures were equal to the water temperatures measured in upper Lee Vining Creek plus one degree F to account for potential warming as the water flowed through the LADWP conduit. When flows in upper Rush Creek were augmented by 10 cfs through the 5-Siphon Bypass water temperatures down Rush Creek were lower and temperatures in Rush Creek were coolest when the lowest flow of 30 cfs was released from GLR (Figure D-4.10). For releases of 5 cfs from the 5-Siphon Bypass an effect was also seen, but water was not cooled as much as when 10 cfs was released.

Conclusions Based on Fixed-Effects Modeling

It appears that water temperatures in Rush Creek are regulated by a moderately complex interaction of water temperatures and flow volumes released from GLR and climatic conditions (particularly air temperatures). 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 types of relationships exist when water is added to the Rush Creek channel from either the 5-Siphon Bypass or by flows from Parker and Walker creeks. If water temperatures in Rush Creek are warmer than water temperatures of input waters than cooling of Rush Creek occurs and more cooling occurs as flow volumes of Rush Creek decline.

D-4.5: Water Availability Scenarios

We next evaluated different scenarios based on water availability predictions for seven classes of snowpack runoff forecasts (Dry, Dry Normal I, Dry Normal II, Normal, Wet Normal, Wet, and Extreme Wet). This strategy was used because LADWP flow releases down Rush Creek are modified based on the predicted water availability during any given year. The Stream Scientists and their associates collaborated in recommending flows that would be released from GLR and diverted from Lee Vining Creek for these seven different water availability scenarios (Tables D-4.1 and D-4.2; Appendix B).

Flows

Final recommended Rush Creek summer flows were developed by taking initial fish flow recommendations and re-shaping the flow curves to better mimic the estimated unimpaired hydrographs (Appendix B). Differences between initial fish flow recommendations and final flow recommendations primarily resulted in final recommended flows being lower than fish flows during the receding limb of the hydrograph under conditions of normal to wet water availability and being higher than fish flows under extreme wet water availability. Differences in Lee Vining Creek diversion rates also existed between the final recommended flows and fish flows with less flow at final flow recommendations for lower water conditions and final flows being higher for the Lee Vining diversion at the highest water conditions. Flows recommended to be delivered from Lee Vining Creek via the 5-Siphon Bypass to upper Rush Creek or GLR were based on two-week averages of actual flows observed from 1999 through 2008 by water availability (Table D-4.2).

GLR Outflow and Lee Vining Creek Diversion Temperatures

Outflow temperatures from GLR as recorded at the MGORD footbridge were set for three different temperature regimes based on the above seven water availability scenarios as follows: (1) temperatures recorded during 2008 were used for Dry and Dry Normal I, (2) temperatures recorded during 2000 were used for Dry Normal II, Normal, and Wet Normal, and (3) temperatures recorded during 2006 were used for Wet and Extreme Wet (Table D-4.3). GLR release temperatures were modified based on whether we tested for effects of GLR being full or empty. For the Wet and Extreme Wet tests, GLR was assumed to be full and we did not test a scenario where GLR was empty. Since GLR was near empty in during the summer of 2008 (Figure D-4.5), the Dry and Dry Normal I baseline MGORD water temperature represented GLR being empty and we subtracted 3.6 F from the MGORD water temperatures recorded during 2008 to simulate the effect of GLR being full (Cullen and Railsback 1993). Since GLR was near full during the summer of 2000 (Figure D-4.5), the Dry Normal II, Normal, and Wet Normal water availability types, baseline MGORD water temperature represented GLR being full and we added 3.6 F to the MGORD water temperatures recorded during 2000 to simulate GLR being empty.

We used water temperatures recorded in upper Lee Vining Creek during 2008 for all modeled scenarios. We added one degree Fahrenheit to these measured temperatures to account for some warming of this water as it flowed through the LADWP water conduit. Initial starting water temperatures for the various scenarios illustrated that when GLR was full, water temperatures were generally lower and temperatures provided by the 5-Siphon Bypass from Lee Vining Creek were lower than all starting MGORD temperatures except for wet years when GLR was full (Figure D-4.11).

D-4.6: Climate Scenarios

We used three different climate scenarios including a current hot air temperature summer (2008), an average summer (2004), and a future hotter summer based on the assumption that global warming will increase daily average air temperatures by 2˚F. For the global warming climate scenario we opted to use a moderate increase in daily air temperatures that would possibly occur within the next 10-25 years. Predicted increases in North America and California air temperatures range from 2.2 to over 10˚F (Houghton et al. 2001; Moser et al. 2009). These increases are predicted to occur over the next 50 to 100 years.

We applied three different climate scenarios because water availability and summer climate are not necessarily correlated with each other. For example, it is possible to have a wet water year based on high snowpack and then have a hot summer when that snowpack melts and runs off as stream flow. In contrast, it is also possible to have a low snowpack year with summer temperatures that are cool.

As mentioned earlier, the summer of 2008 was one of the hotter summers on record (Figure D-4.3). We used air temperatures during the summer of 2008 to represent the current hot climate conditions. We added 2˚F to the average daily air temperatures recorded during 2008 to model the global warming scenario. Air temperatures during 2004 were considered average because the overall summer average air temperatures for the period of record was 63.6˚F and the summer maximum air temperature averaged 79.8˚F, while the summer average air temperature during 2004 was 64.1˚F and the summer maximum air temperature was 80.1˚F (Figure D-4.3).

For the average climate summer of 2004 there were no water temperature data for the MGORD footbridge site, so we used water temperature data for this site during the year 2000 as the starting temperatures for all average air temperature scenarios. Of the years for which MGORD water temperature data were available, air temperatures during 2000 were most similar to air temperatures during 2004. For the global warming climate scenario, we used the same MGORD footbridge water temperatures as were used for the “hot” summer (2008) scenarios.

Water Availability Model Runs

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 D-4.12 through D-4.15). 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 poorer under drier water availability scenarios than for wetter scenarios. For wetter water availability scenarios (Wet and Extreme Wet) growth of trout was predicted to be better under hotter climate scenarios than for the average climate scenario. This better growth for wetter water availability scenarios under the hotter climate scenarios reflected the fact that 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 climate air temperatures did not warm this water. The average climate scenario illustrated that the cool water was not warmed and consequently was below temperatures that are ideal for growth and thus limited growth.

Predicted water temperatures based on the Stream Scientists’ 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 (2008). Based on snowpack water availability forecasts, 2008 was a “Normal” water year, so we used the “Normal” water year Stream Scientists’ recommended flows. This comparison illustrates how Stream Scientists’ 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 being very similar to what was actually released during 2008 (Figure D-4.16). When the Stream Scientists' 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 395 and 16 g at County Road based on the differences between water temperatures actually measured during 2008 and predicted water temperatures for these recommendations (Figure D-4.17).

For the hot climate year of 2008 predicted average daily water temperatures for the various flow scenarios indicated that the number of days that were good for brown trout growth were highest for the scenario when GLR was full and flows in upper Rush Creek were augmented with flows from the 5-Siphon Bypass (Figure D-4.18). Wetter flow years had more days of good water temperatures. In contrast, more bad temperature days were observed for scenarios when GLR was empty and no 5-Siphon Bypass flows were added to Rush Creek, and these bad days increased during lower water availability (Figure 18).

For the average climate year of 2004 predicted average daily water temperatures followed a similar pattern as for the hot climate year of 2008 with the scenario that had GLR full and flows added to Rush Creek from the 5-Siphon Bypass having the most days that were good for brown trout growth and the least number of days were average daily temperatures were higher than 65˚F (Figure D-4.19). There were fewer bad temperature days under an average summer's air temperatures than for a hot summer (Figure D-4.19 versus Figure D-4.18). There were also a few days under wet water availability that were below good temperatures.

Longitudinal Temperatures

Average daily water temperature predictions were compared longitudinally down the length of Rush Creek across several different dates during the summer and among several different scenarios. Longitudinal distances were originally recorded in miles with the terminus of Rush Creek at Mono Lake set at mile zero; however, the StreamTemp model only outputs distances in kilometers for graphs it produces (Figures D-4.20 and D-4.21). Predicted daily average water temperatures are usually cooled by the additions of Parker and Walker creeks (at kilometers 8.24 and 7.33, respectively); however, from the MGORD to Parker Creek and from Walker Creek to Mono Lake water temperatures may be cooled or warmed depending upon starting water temperatures and date (Figures D-4.20 and D-4.21).

D-4.7: MGORD Modeling

As detailed in Shepard et al. (2009) we could not model the effects of the MGORD on water temperatures under different flow regimes because water temperature data were not collected at the top of the MGORD during temperature model development. Instead, we used the SSTEMP (stream segment temperature model) to assess the potential influences of the MGORD reach (top of the MGORD down to the footbridge) on water temperatures.

An analysis of the MGORD from its outflow (mile 0.001) to the footbridge (mile 1.44) was completed with SSTEMP model. This analysis was done for mid-August with an average air temperature of 70˚F, 70% sunshine, a relative humidity of 40%, and a wind speed of 4 mph (all conditions that were typical for 2008 during relatively hot days). The outflow water temperature was assumed to be 65˚F. Temperature modeling of the MGORD for this single warm day at different flows from 20 to 60 cfs predicted that water temperatures would warm less than 1˚F for all flows except flows of 20 cfs, for which water would warm 1.3˚F (Figure D-4.22). When air temperatures were increased to 80˚F, predicted water temperatures increased less than 2˚F for all flows tested. Flows above 60 cfs were also tested and predict water temperature increases were less at these higher flows.

We also compared different starting water temperatures (at the top of the MGORD) and different average air temperatures from 45 to 80˚F for flows of 30 cfs. These analyses indicated that water temperatures at the top of the MGORD usually were within two degrees Fahrenheit of those temperatures measured at the MGORD footbridge. The only exception was at extremely low starting water temperatures (45˚F) and high air temperatures (80˚F) when temperatures warmed up to three degrees. For the StreamTemp modeling analyses, we suggest that when conditions were such that GLR outflow temperatures were lower than average air temperatures, outflow temperatures were probably one to two degrees lower than temperatures measured at the MGORD footbridge. Conversely, when water temperatures released from GLR were much warmer than average air temperatures, outflow temperatures were probably one to two degrees higher than temperatures measured at the MGORD footbridge.

Increases in Shading

We evaluated flow-related temperature mediation measures such as varying stream flow, filling of GLR, and augmenting flows in upper Rush Creek by releasing water originating from Lee Vining Creek via the 5-Siphon Bypass in the above sections of this report. Increasing shade along the channel to reduce solar heating is another way to mediate water temperatures and could potentially reduce high temperatures during the summer. We evaluated potential influences of increased shading along the MGORD and along Rush Creek to determine the potential effects of increasing shade. Shade components could be increased either due to the natural establishment and succession of the riparian community or by anthropogenic enhancement. We suspect that natural shading will occur along the stream channel, but that anthropogenic efforts may be required along the MGORD, should shading of this artificial channel be desired.

Shading of the MGORD channel is currently estimated at about 3%. If shading were increased water temperatures could be reduced in direct proportion to the amount of shading provided (Figure D-4.23). If enough shade was created along the MGORD to provide 50% shading there would be no increase in water temperature at a starting water temperature of 65˚F and an average daily water temperature of 70˚F.

Current shading along the main Rush Creek channel below the MGORD ranged from about 10 to 40% and the weighted average was slightly over 19%. If shading were increased to a consistent 50% level from current levels along main Rush Creek, predicted water temperatures would be reduced by slightly under 0.5˚F at the Old Highway 395 site and by 1.0˚F at the County Road site (Figure D-4.24).

D-4.8: Discussion

Shepard et al. (2009c) hypothesized that higher summer stream flows would result in more optimal water temperatures for trout growth, based primarily on Beak Consultants Inc (1991) temperature modeling predictions for Rush Creek. However, current modeling results indicate that water temperatures in Rush Creek are regulated by a moderately complex interaction of water temperatures and flow volumes released from GLR and climatic conditions (particularly air temperatures). When water temperatures released from GLR into the MGORD are cooler than average daily air temperatures, this water is warmed as it moves down Rush Creek and this warming becomes more pronounced when Rush Creek flow volumes are lower. 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.

Potential reasons for differences between Beak Consultants Inc's (1991) findings and recommendations related to flow and water temperature and our findings and recommendations are: 1) changes in Rush Creek channel that have occurred during the last 15 to 20 years have resulted in different travel times for water moving down the channel; 2) the fact that the Beak Consultants Inc study relied on a single year of water temperatures to validate the model they used to predict water temperatures while we used several years for calibration and a few other years for validation of the model we used; 3) the use of slightly different water temperature prediction models; and 4) complex interactions between air temperature, flow, and water temperatures for which the earlier model did not fully account. An important finding was that average water temperatures delivered from GLR are often as high as, or higher, than average air temperatures during the summer. When this occurs, lower flows actually promote cooling of the water. Preliminary information from 2009 suggests that water temperatures entering GLR may already be elevated due to warming in lakes and reservoirs in the upper basin, as well as the low-gradient meandering meadow reaches of Rush Creek above GLR.

Cullen and Railsback (1993) estimated that water temperatures delivered from a full GLR would decrease by about 2˚C (3.6˚F) compared to temperatures delivered from a near-empty GRL. These Cullen and Railsback (1993) estimates of the mediating effect of GLR elevation on water temperatures delivered from GLR were used to modify MGORD footbridge water temperatures for modeling purposes. Also, the Stream Scientists are recommending that much cooler Lee Vining Creek water be delivered to GLR and Rush Creek at volumes proportional to water availability. While delivery of relatively high volumes of cool water to GLR from Lee Vining Creek via the 5-Siphon Bypass will undoubtedly result in cooler water temperatures in GLR, the exact outflow temperature decline cannot be predicted with any degree of confidence at this time (see Cullen and Railsback 1993 for a discussion of the problems in predicting water temperatures released from GLR).

We relied primarily on predicted weight gains of brown trout to evaluate the effects of different flow management scenarios on trout in Rush Creek. We caution that while we believe that these predicted weight gain estimates provide useful indices for evaluating different flow regimes, actual weight gained by brown trout is dependent upon many other factors besides water temperature and flow. We used predicted weight gains because weight gain is related to both annual survival (particularly overwinter survival) and condition factor for trout (Sloman et al. 2000; Goodwin et al. 2008).

High daily fluctuations in water temperatures can negatively impact brown trout (e.g. Wehrly et al. 2007). Measured water temperatures in Rush Creek during 2008 at the Old Highway 395 and County Road sites fluctuated up to 19˚F and had a mode of about 10˚F (Figure D-4.25). Unfortunately, the StreamTemp (SNTEMP) model does a relatively poor job of predicting maximum and minimum water temperatures, compared to its ability to predict average water temperatures, due to its reliance on daily averages for input parameters. Consequently, predicted daily temperature fluctuations during 2008 only ranged from one to five degrees Fahrenheit (Figure D-4.25).

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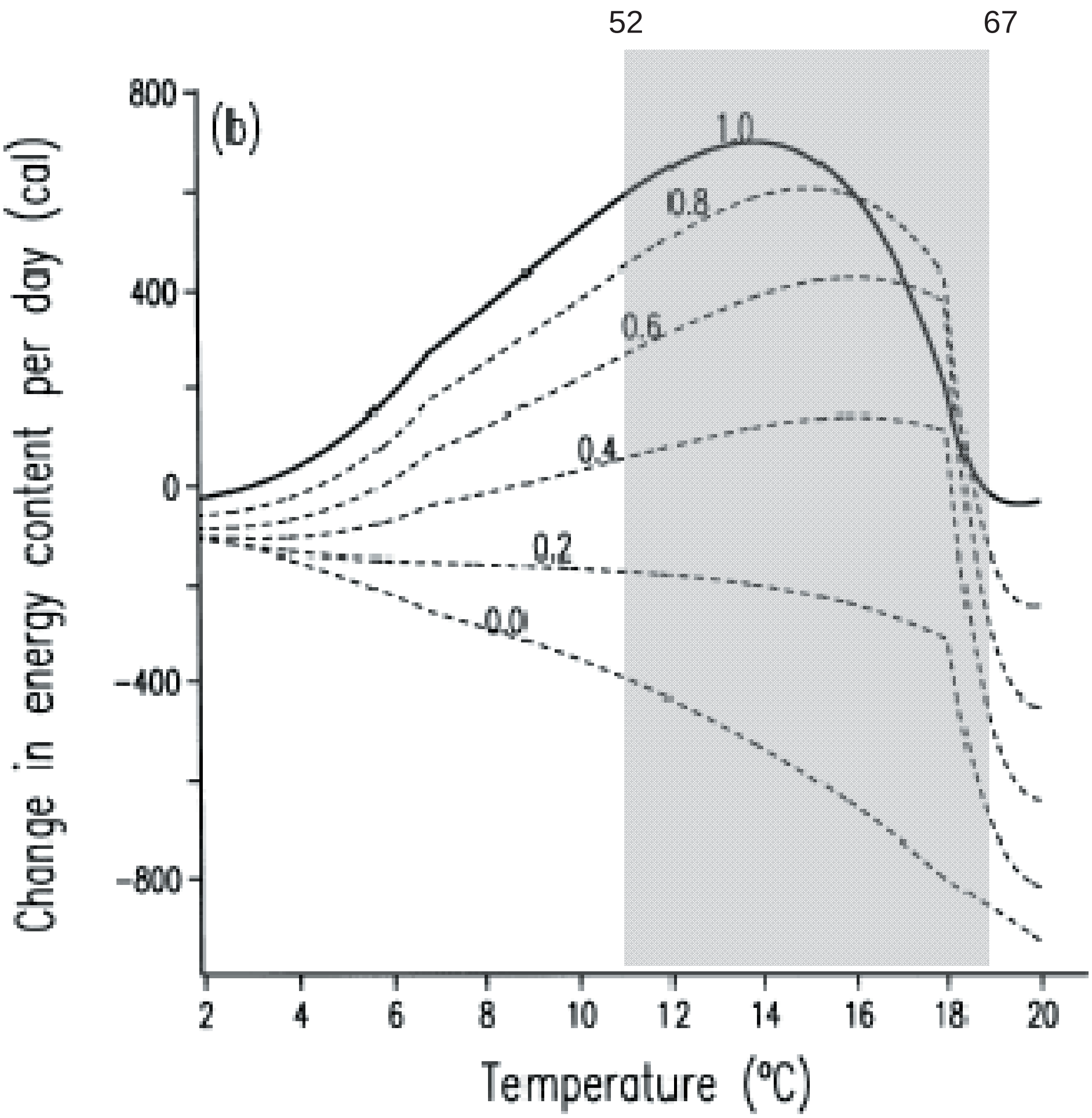
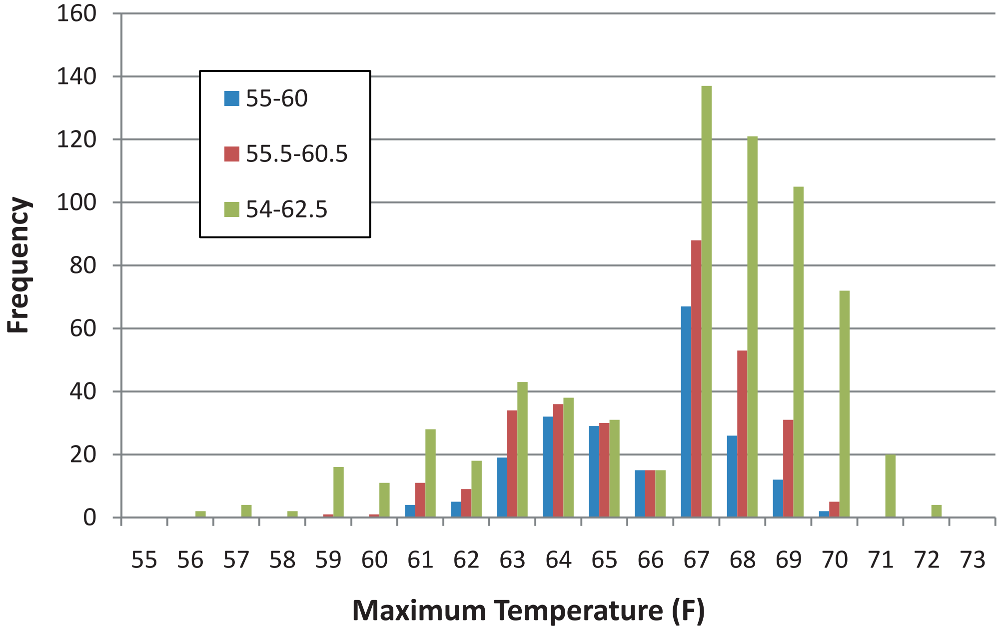


Figure D-4.1.Relationship between water temperature (C) and growth (expressed in change in energy content per day in calories) with numbers showing proportion of full ration provided to fish (graph from Elliott and Hurley 1999). The shaded portion of the graph is the temperature range used as "ideal temperature" for growth based on several studies (Raleigh et al. 1986; Elliott 1975a; Elliott 1975b; Elliott et al. 1995; Elliott and Hurley 1999; Elliott and Hurley 2000; Ojanguren et al. 2001).



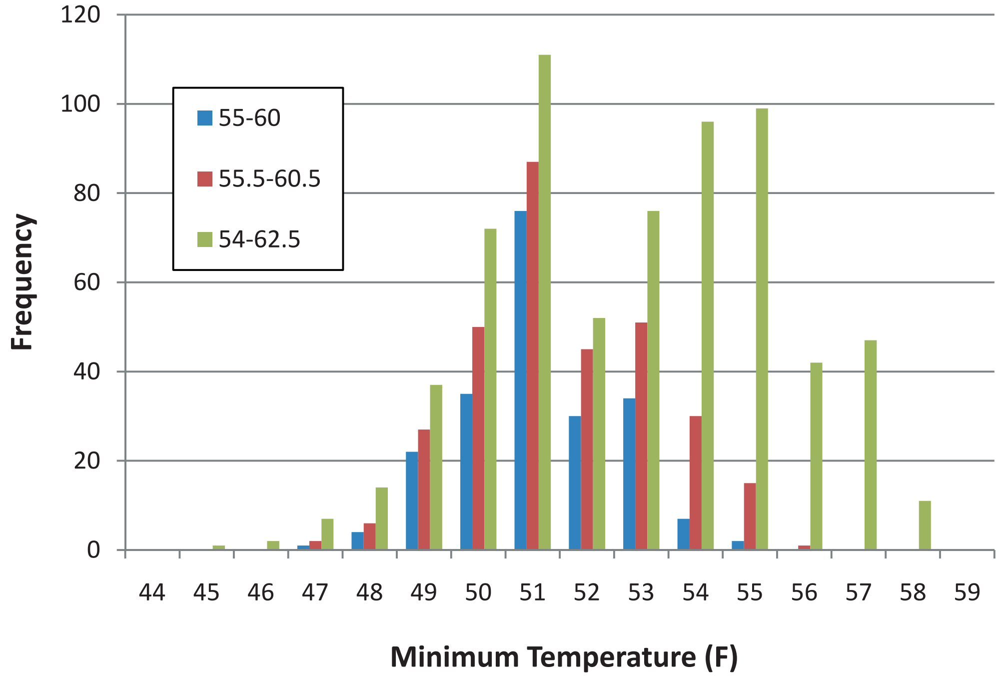


Figure D-4.2. Distributions of maximum daily (top) and minimum daily (bottom water temperatures for three average daily temperature ranges that occurred on days when daily water temperature ranges were outside the 52 to 67 F range.

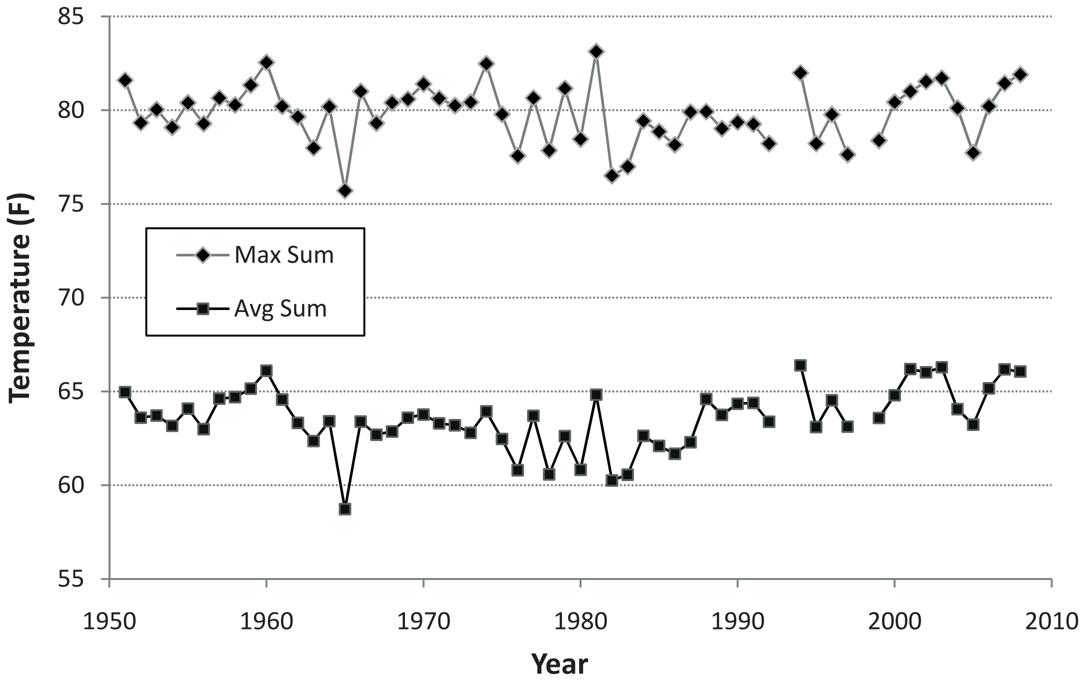


Figure D-4.3. Average monthly maximum (Max Sum) and montly average (Avg Sum) air temperatures for the summer months (June through September) measured at the Mono Lake and Lee Vining climate stations from 1951 through 2008.

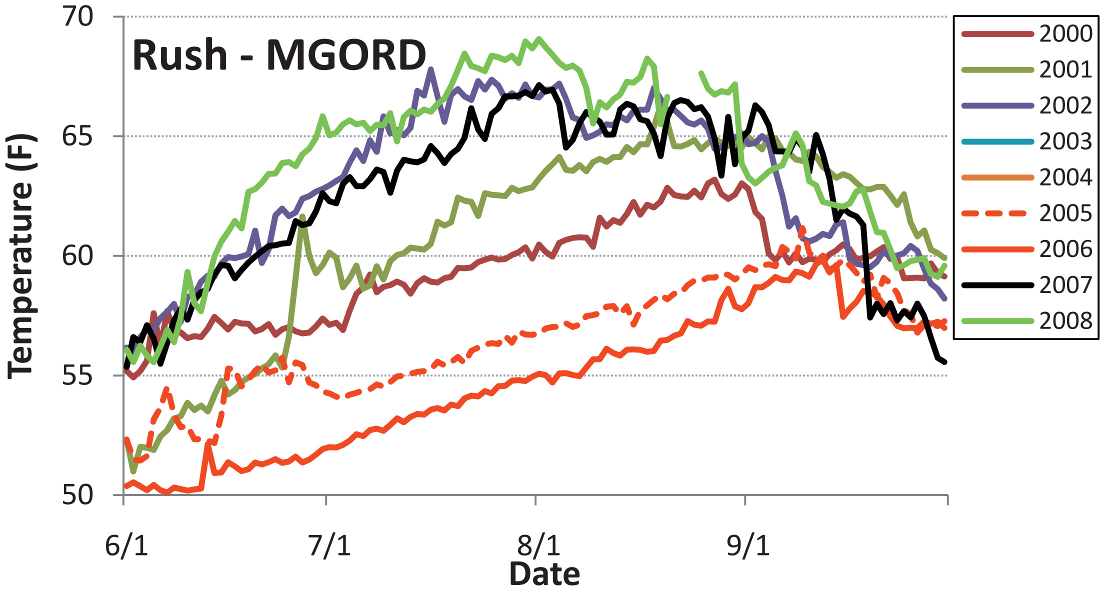


Figure D-4.4. Average daily water temperatures at the MGORD footbridge for June through September from 2000 through 2008. Note that 2008 was a warm water year.

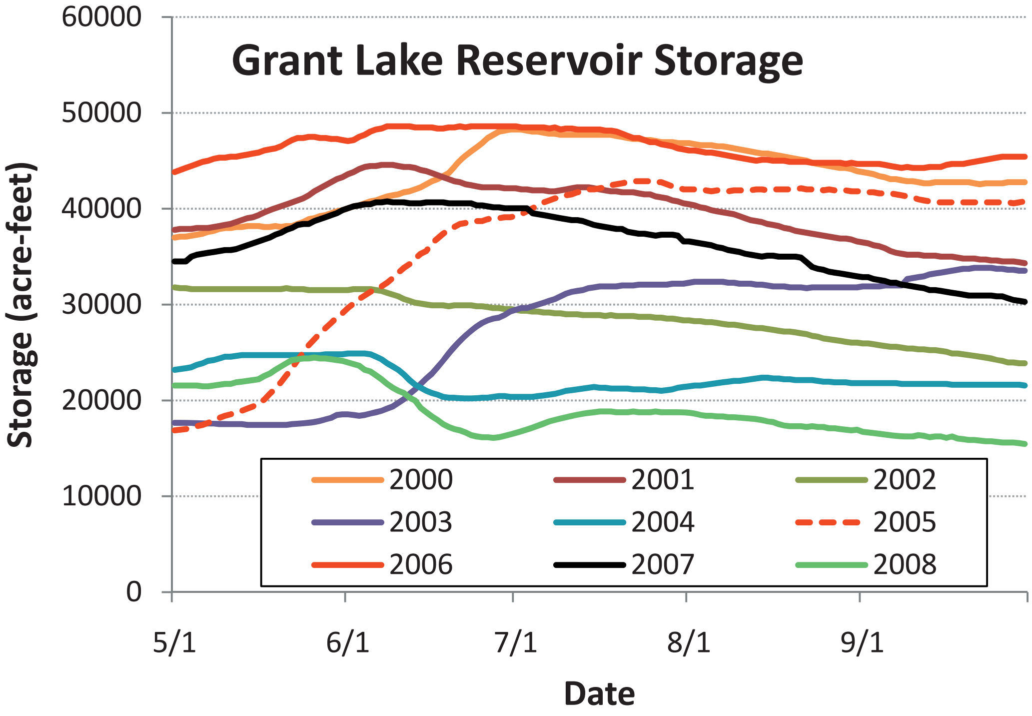


Figure D-4.5. Water elevations in Grant Lake Reservoir from 2000 through 2008 showing that during the year 2008 was a low level (near base conditions).

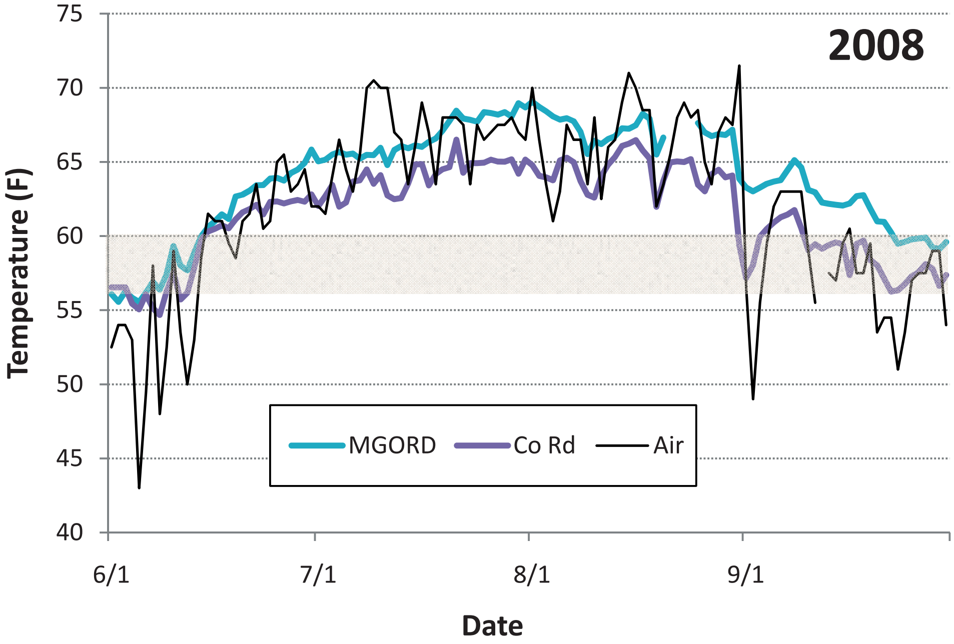


Figure D-4.6. Average daily water temperatures recorded at the MGORD footbridge and County Road culvert water temperature monitoring sites and average daily air temperatures recorded at Cain Ranch during 2008 (base condition). The shaded area represents water temperatures from 56 to 60˚F.

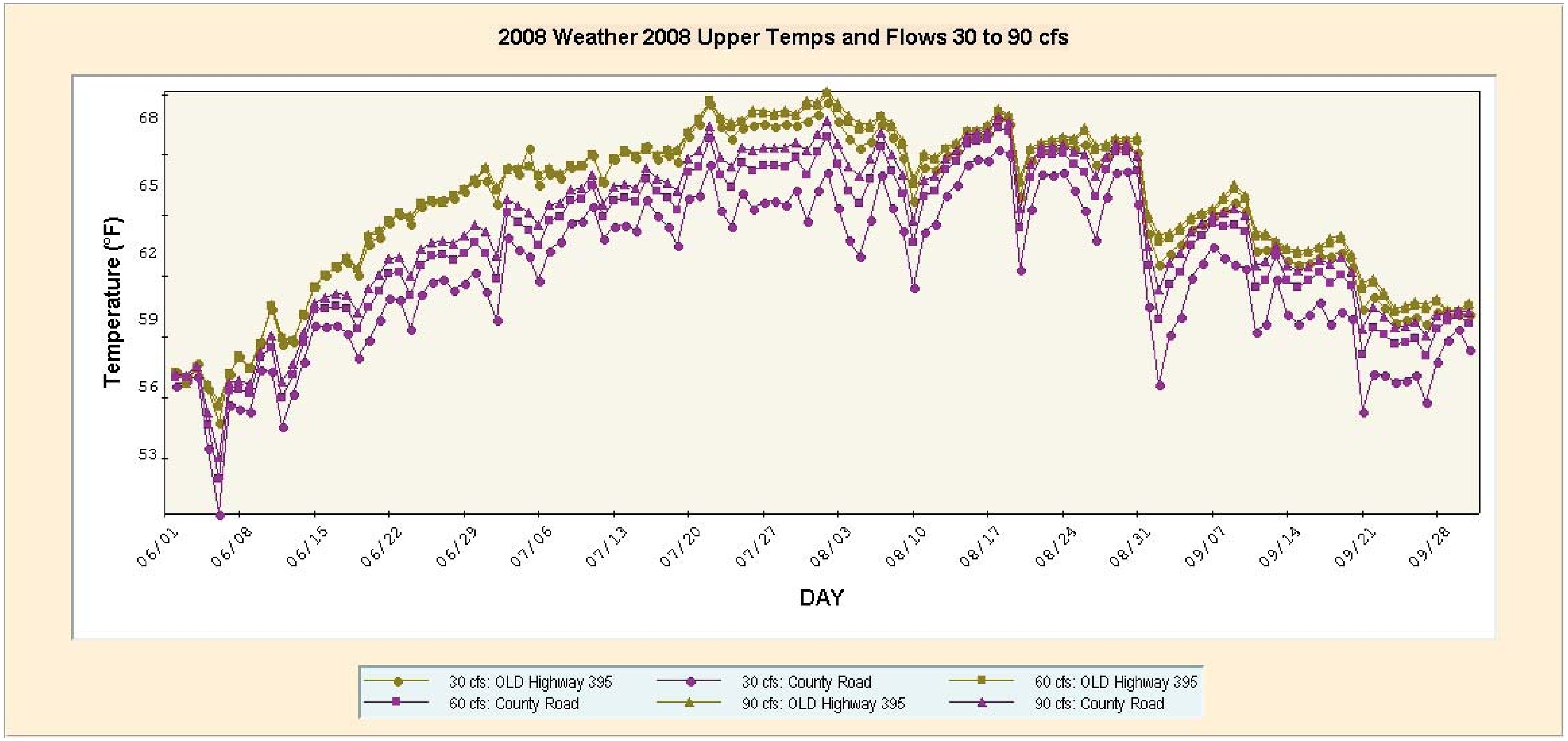


Figure D-4.7. Predicted daily average water temperatures in Rush Creek at Old Highway 395 (gold) and at the County Road culvert (purple) at different flows from 30 to 90 cfs. Note that water cooled from 395 to the County Road culvert and that this cooling was more pronounced for flows of 30 cfs (solid dots) than flows of 90 cfs (solid triangles).

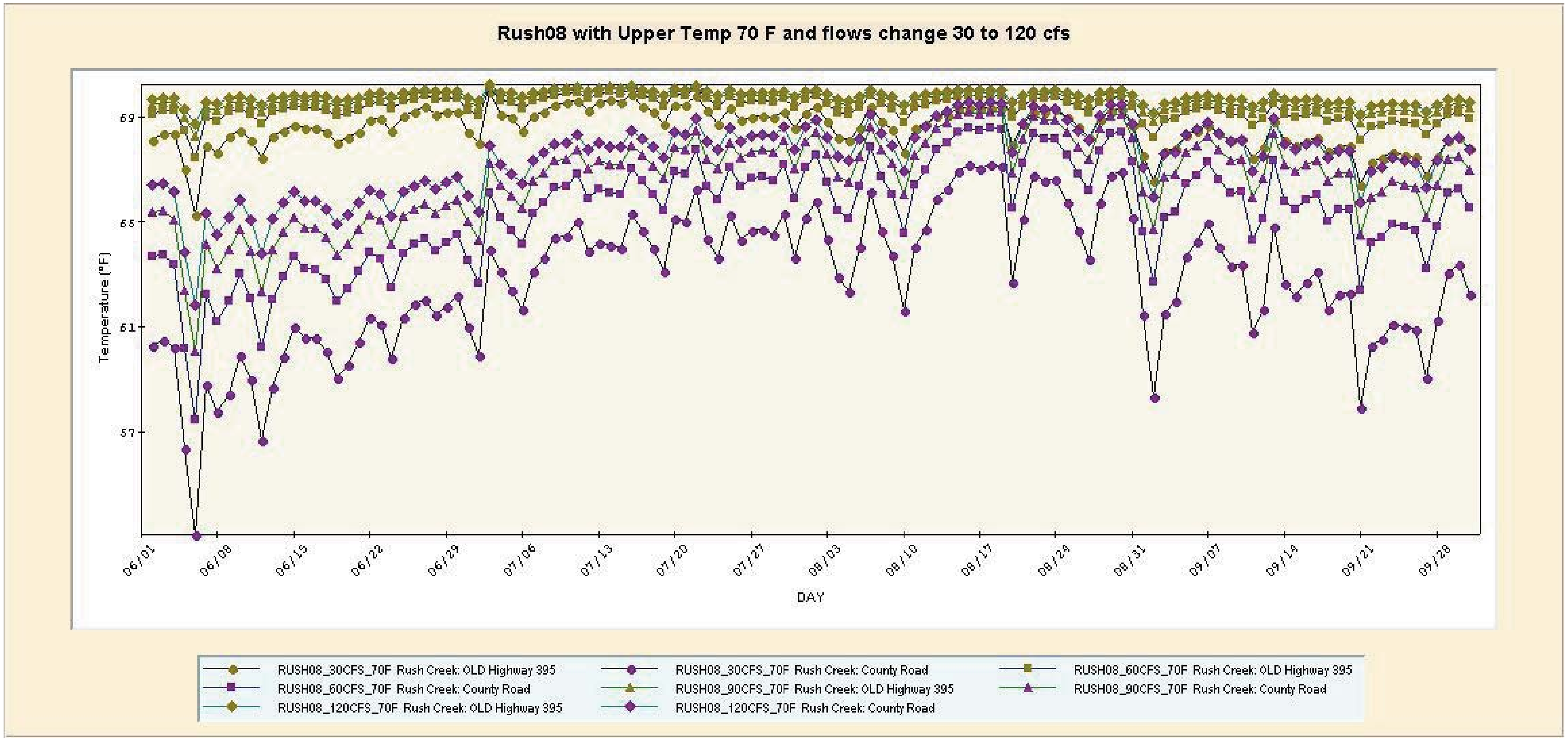


Figure D-4.8. Predicted daily average water temperatures in Rush Creek at Old Highway 395 (gold) and at the County Road culvert (purple) at different flows from 30 to 90 cfs and at a fixed outflow temperature of 70˚F. Note that water cooled from 395 to the County Road culvert and that this cooling was more pronounced for flows of 30 cfs (solid dots) than flows of 90 cfs (solid triangles). NOTE: was in landscape for page set-up.

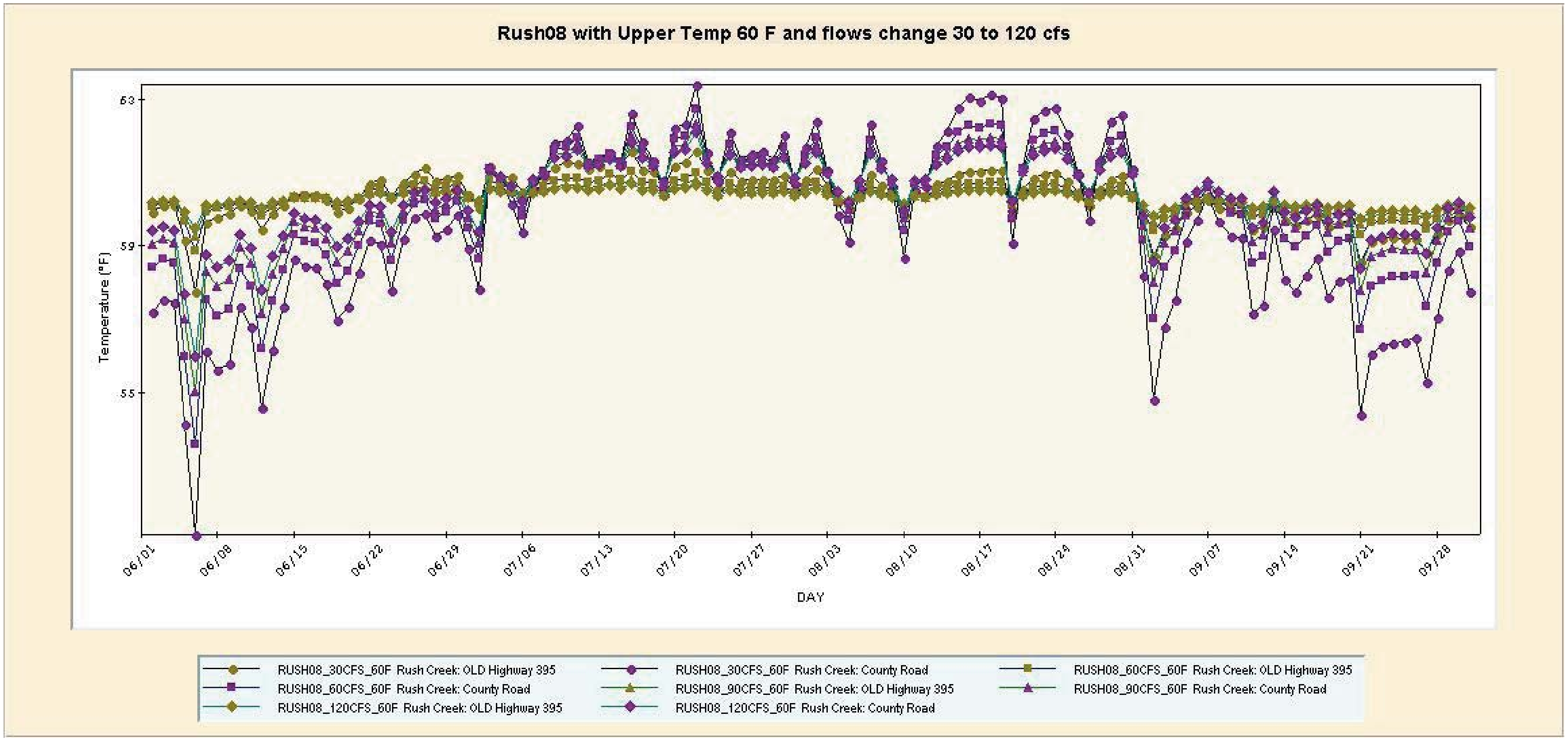


Figure D-4.9. Predicted daily average water temperatures in Rush Creek at Old Highway 395 (gold) and at the County Road culvert (purple) at different flows from 30 to 90 cfs and at a fixed outflow temperature of 60˚F. Note that water primarily warmed from 395 to the County Road culvert from July 10 through August 31 and that this warming was more pronounced for flows of 30 cfs (solid dots) than flows of 90 cfs (solid triangles). NOTE: was in landscape for page set-up.

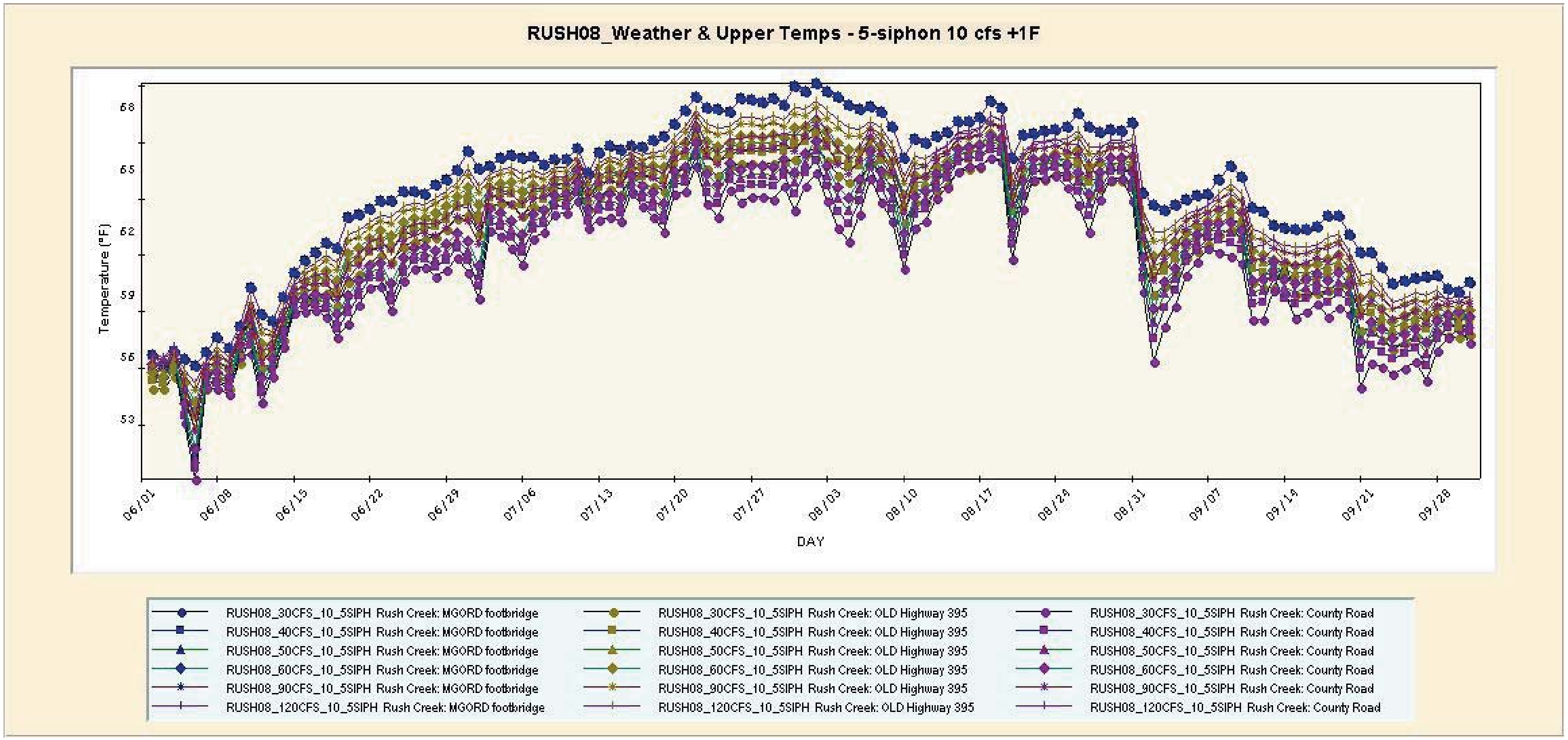


Figure D-4.10. Predicted daily average water temperatures in Rush Creek at Old Highway 395 (gold) and at the County Road culvert (purple) at different flows from 30 to 90 cfs and at outflow temperatures measured during 2008 (MGORD footbridge). Note that water cooled from the MGORD down to the County Road culvert from July 10 through August 31 and that cooling was related to flow volumes with more cooling at lower flows. NOTE: was in landscape for page set-up.

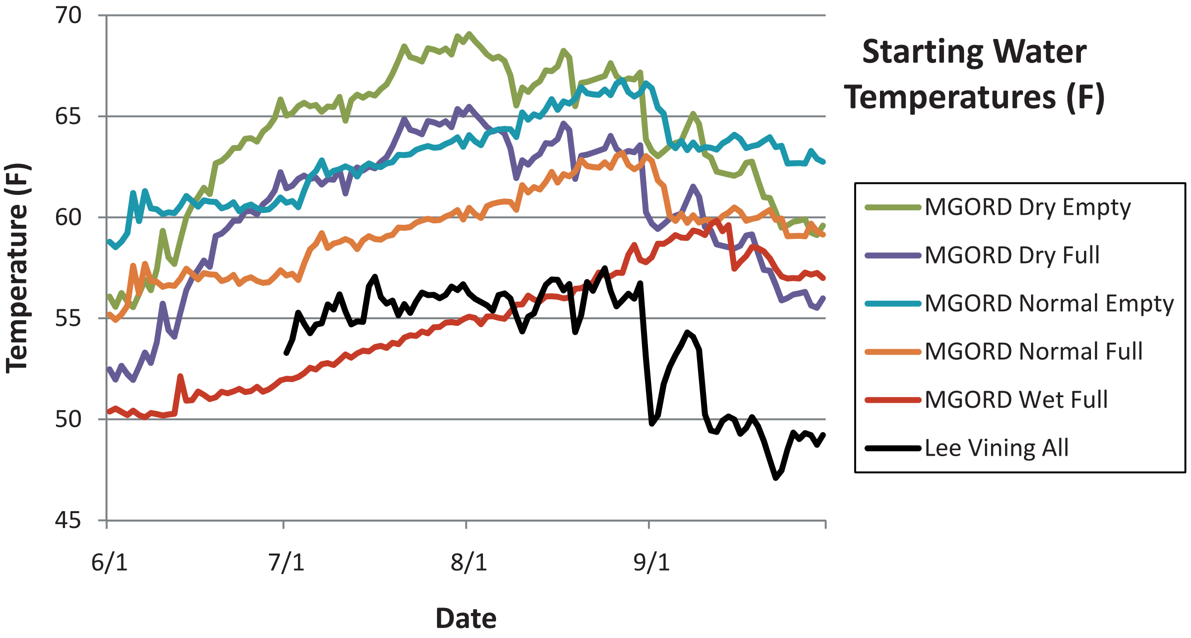


Figure D-4.11. Initial water temperatures at the MGORD footbridge site and delivered to upper Rush Creek through the 5-Siphon Bypass (Lee Vining All) for the various flow scenarios during the "hot" summer of 2008.

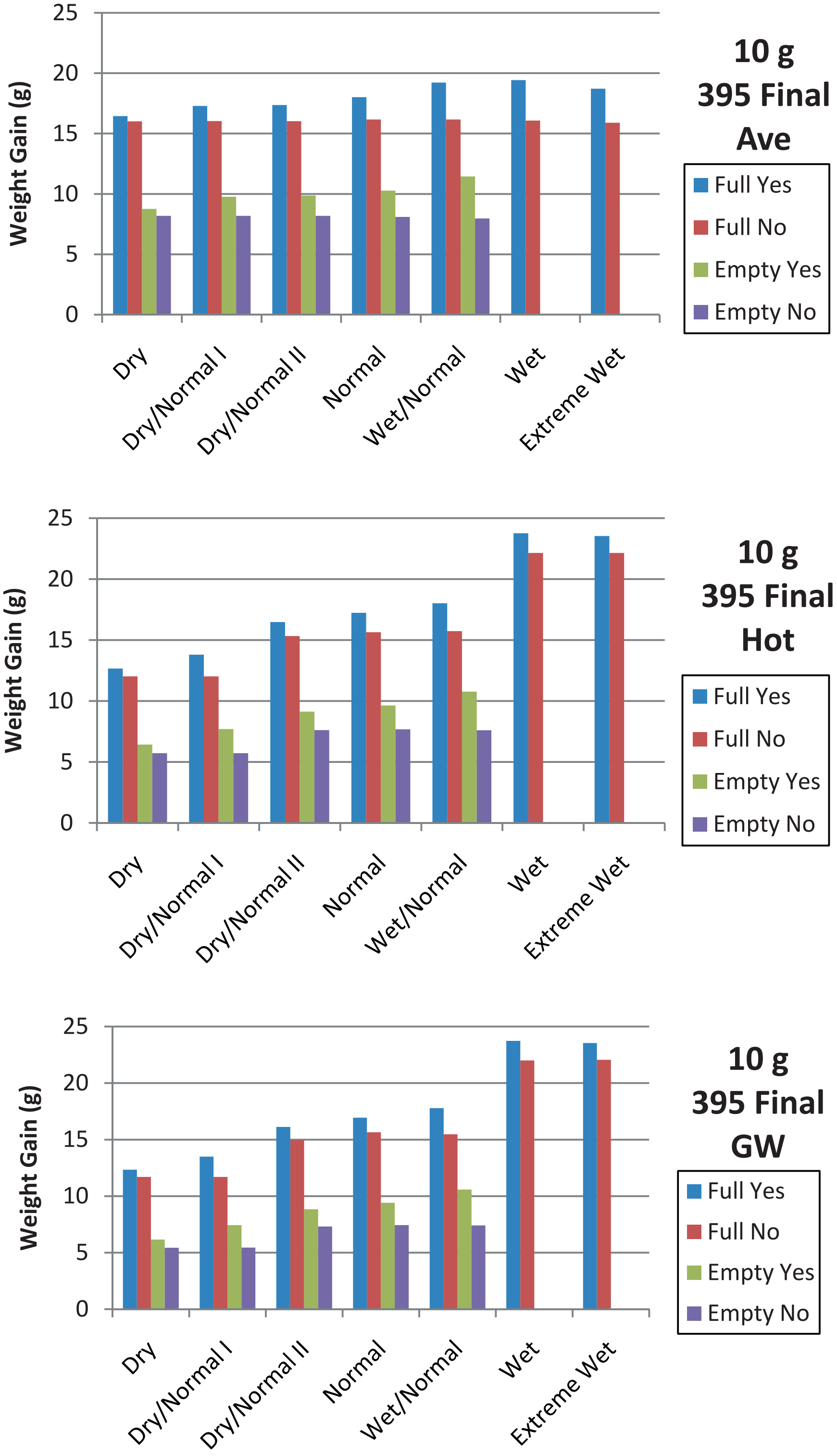


Figure D-4.12. Predicted summer growth (g) of 10 g brown trout at Old 395 bridge site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), GLR full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

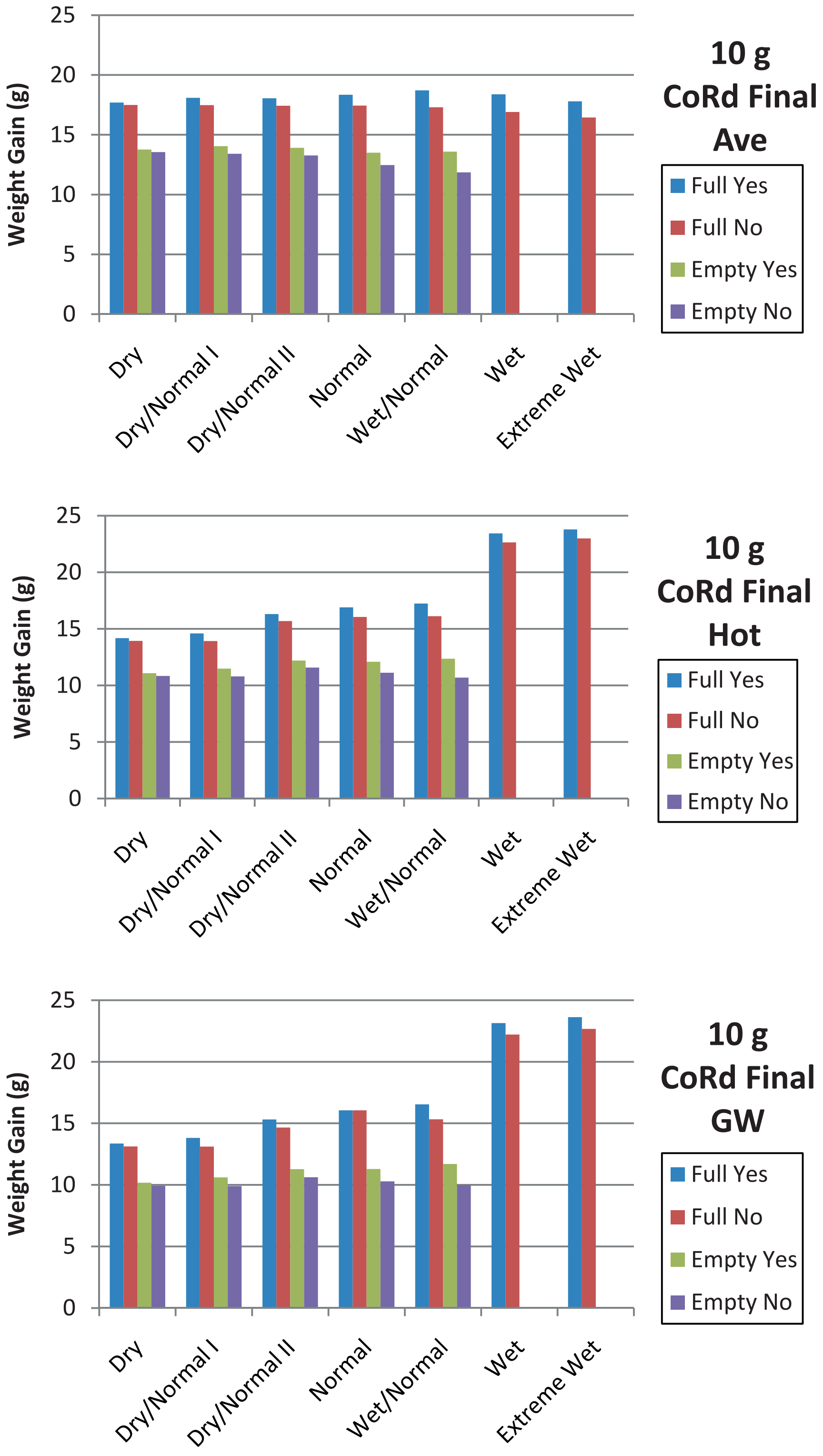


Figure D-4.13. Predicted summer growth (g) of 10 g brown trout at the County Road site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), GLR full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

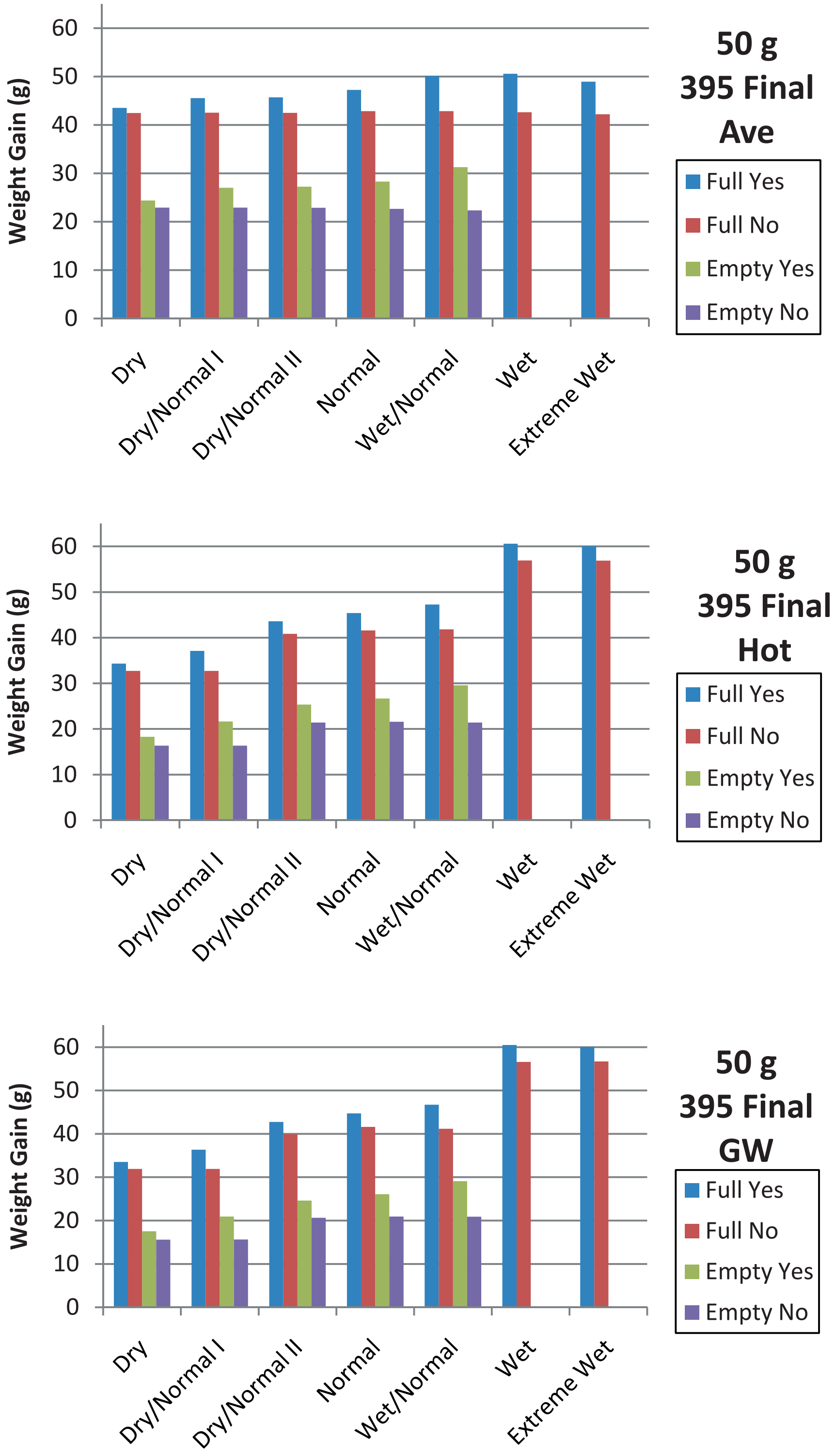


Figure D-4.14. Predicted summer growth (g) of 50 g brown trout at Old 395 bridge site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), GLR full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

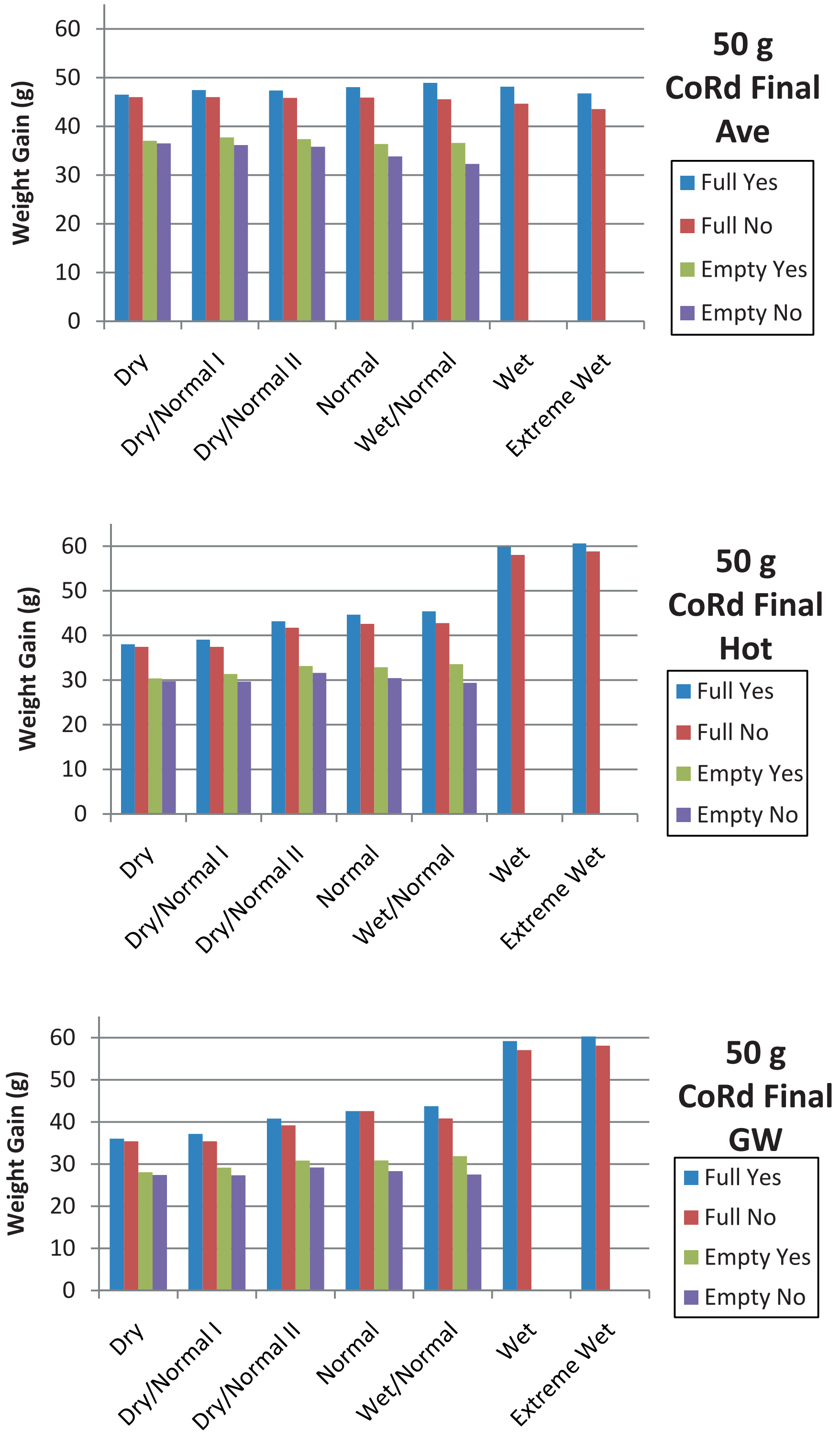


Figure D-4.15. Predicted summer growth (g) of 50 g brown trout at County Road site in Rush Creek by water year availability (x-axis), climate (Ave, Hot, or global warming: GW), GLR full or empty (Full or Empty), and 5-Siphon Bypass flows added or not added to Rush Creek (Yes or No).

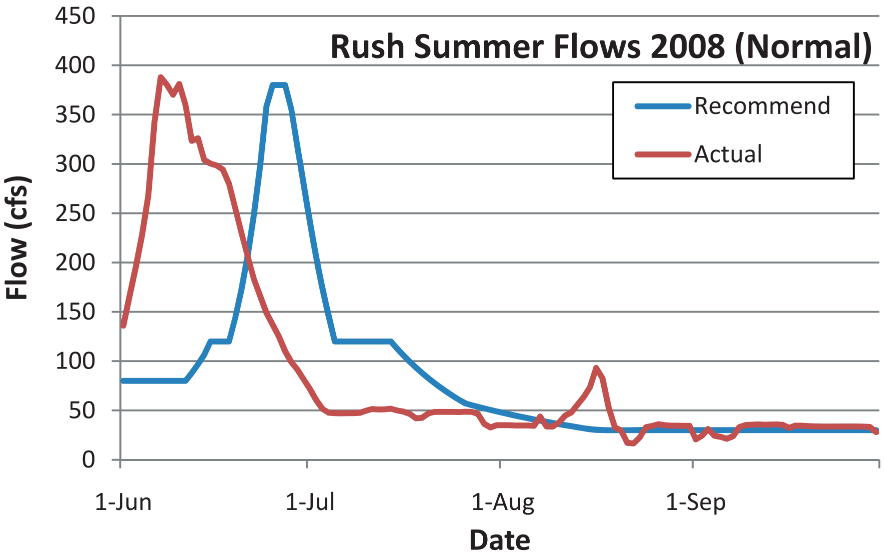


Figure D-4.16. Comparison of recommended flows (Recommend) and actual flows released down upper Rush Creek (Actual) during 2008. The short-duration increase and decline in "Actual" flows during mid-August represents test-flow releases for the instream flow study and usually SRF flows are held near 44 cfs throughout this period.

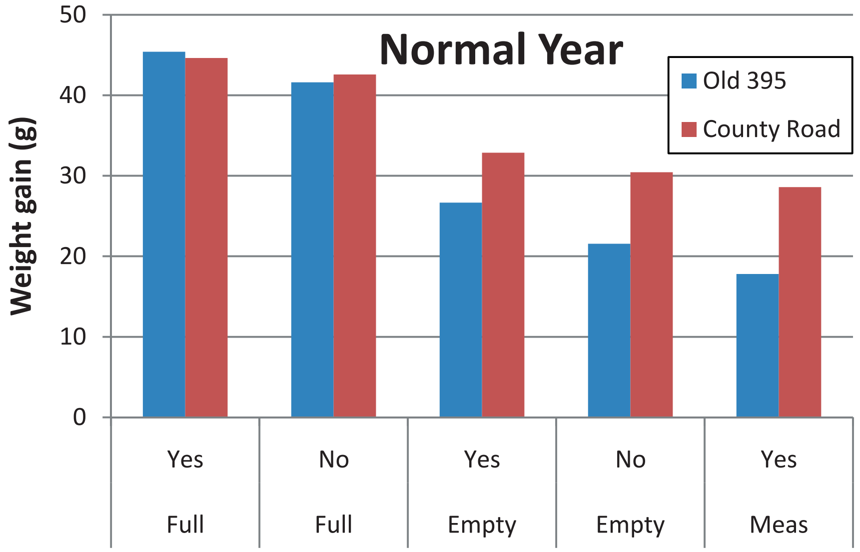


Figure D-4.17. Comparison of predicted growth of a 50 g brown trout during the summer of 2008 (a year of Normal water availability and hot summer temperatures) at the Old Highway 395 and County Road sites in Rush Creek to predicted growth for recommended flows and GLR (Full or Empty) and 5-Siphon Bypass (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 .

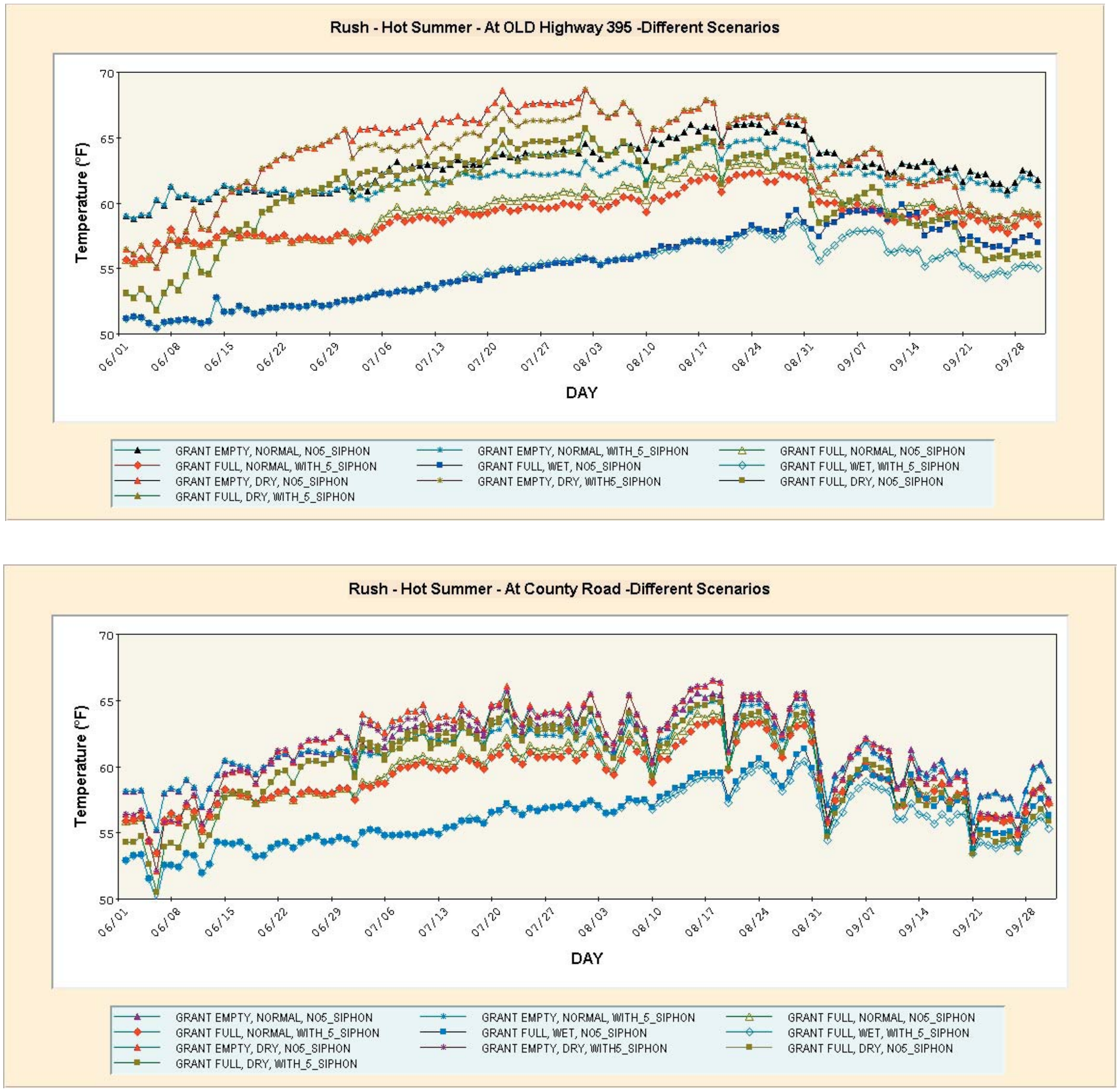
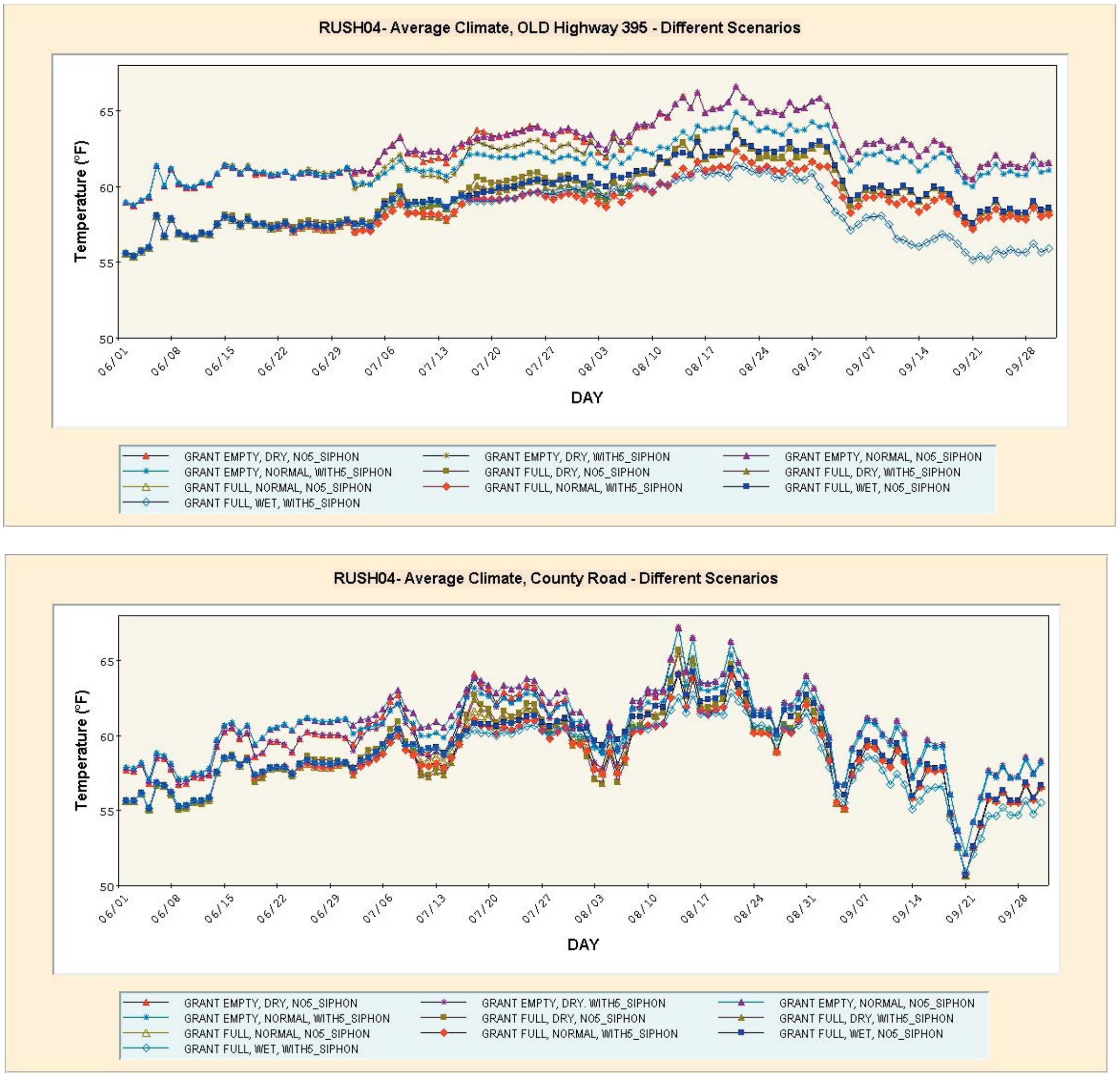


Figure D-4.18. Predicted daily average water temperatures at Old Highway 395 (top) and County Road (bottom) sites in Rush Creek during a hot summer (2008) and various scenarios (different lines). The horizontal dotted line is the 65˚F threshold above which temperatures were rated as bad for brown trout and the shaded box represents average temperatures that were rated as good for brown trout.


RUSH04- Average Climate, OLD Highway 395 - Different Scenarios

RUSH04- Average Climate, County Road - Different Scenarios

Figure D-4.19. Predicted daily average water temperatures at Old Highway 395 (top) and County Road (bottom) sites in Rush Creek during an average summer (2004) and various scenarios (different lines). The horizontal dotted line is the 65F threshold above which temperatures were rated as bad for brown trout and the shaded box represents average temperatures that were rated as good for brown trout.

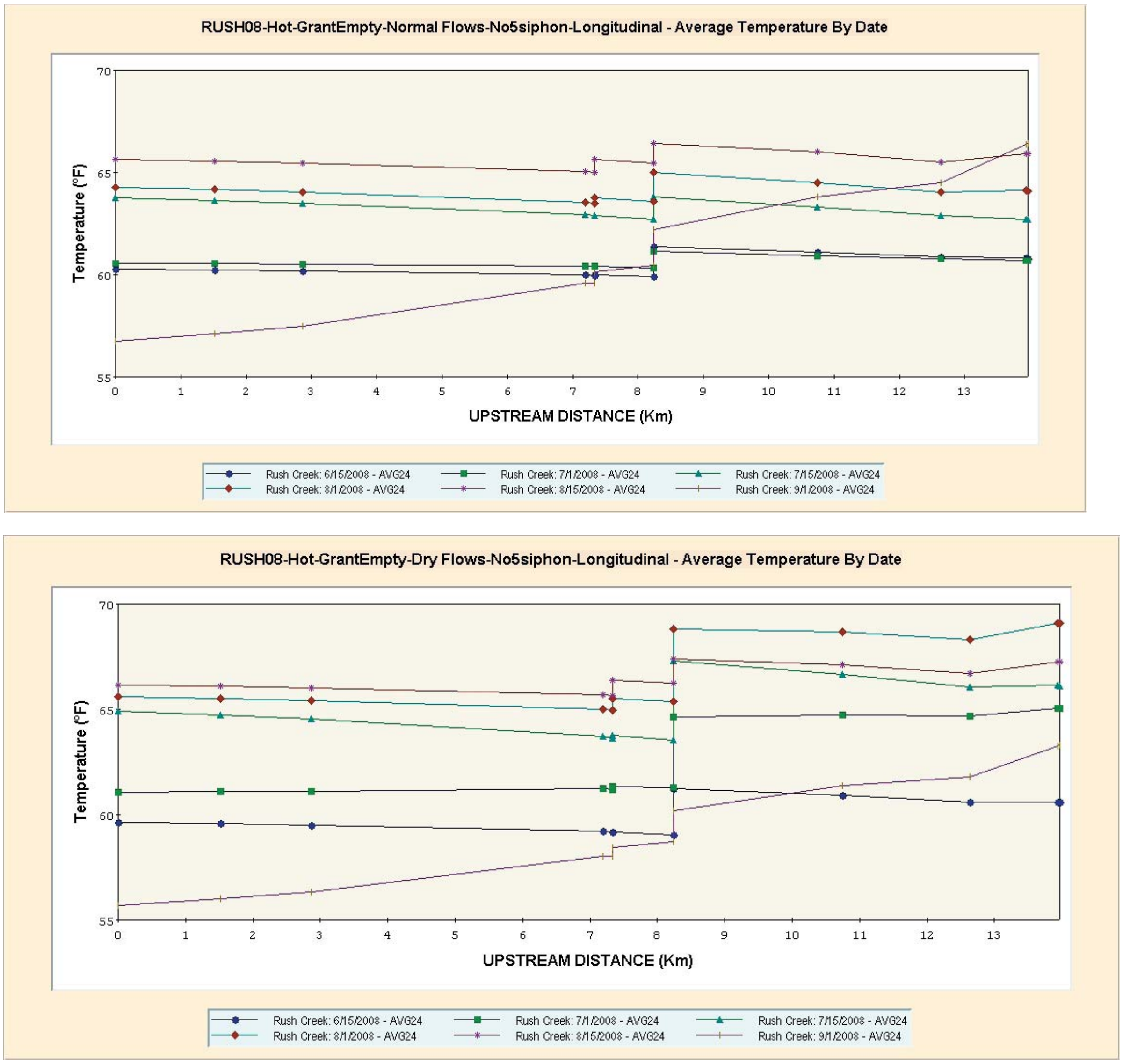


Figure D-4.20. Longitudinal temperature predictions for scenarios of a hot climate (2008), GLR empty, no input from the 5-Siphon Bypass, and normal (top) and dry (bottom) water availability.

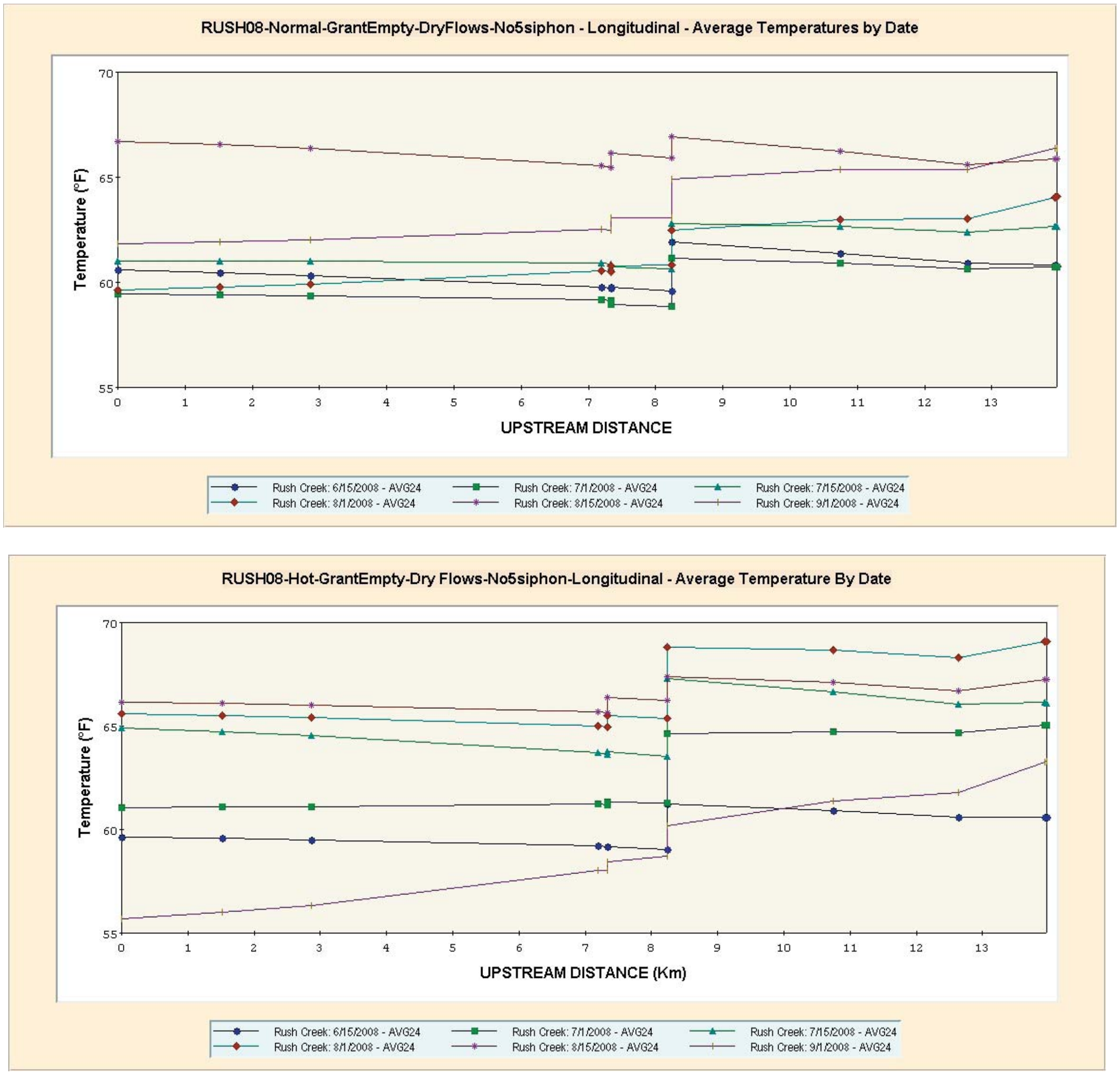


Figure D-4.21. Longitudinal temperature predictions for scenarios of an average climate (2004; top) and hot climate year (2008; bottom) and a scenario where GLR is empty, no input from the 5-Siphon Bypass, and dry water availability.

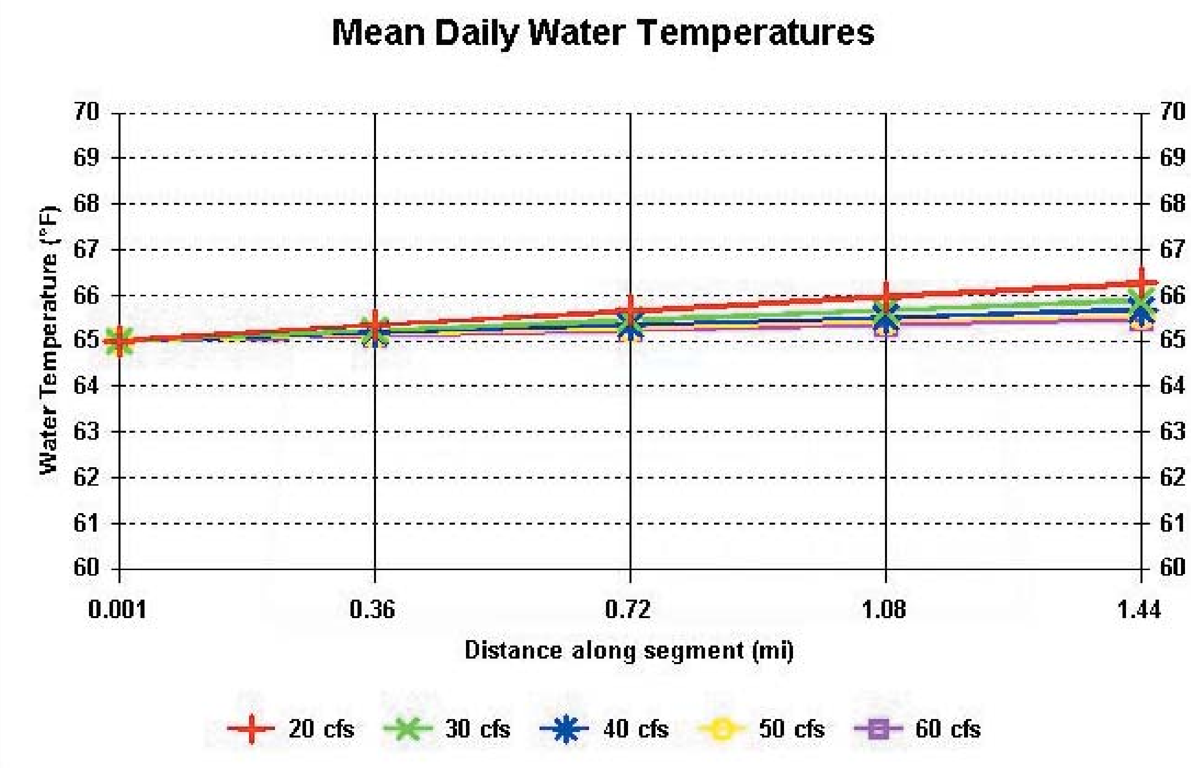


Figure D-4.22. Water temperatures predicted from the top of the MGORD (mile 0.001) to the footbridge (mile 1.44) based on a starting water temperature of 65˚F and climate conditions shown on the lower left corner of the figure illustrating the amount of warming that occurs down the length of the MGORD at different flows from 20 to 60 cfs.

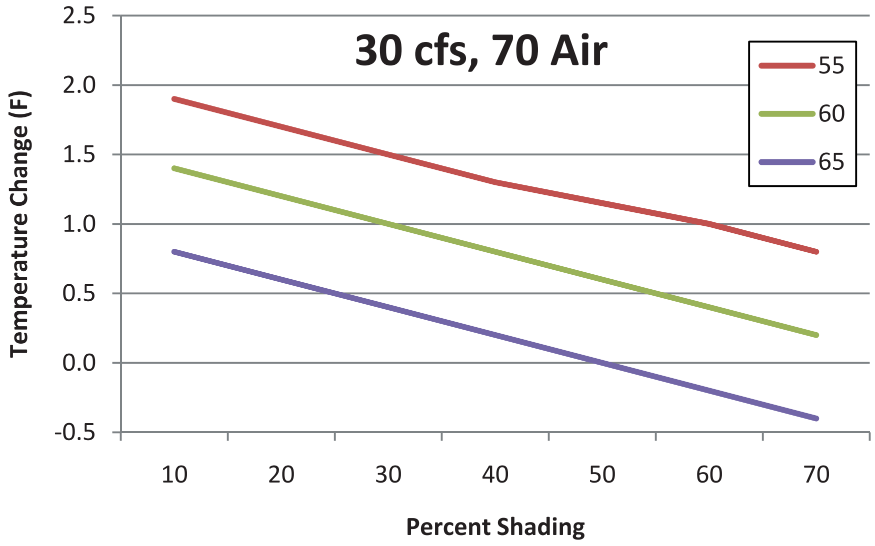


Figure D-4.23. Temperature changes at the bottom of the MGORD due to theoretical increases in shade along the MGORD for flows of 30 cfs and a daily air temperature of 70˚F at three different starting water temperatures (different lines).

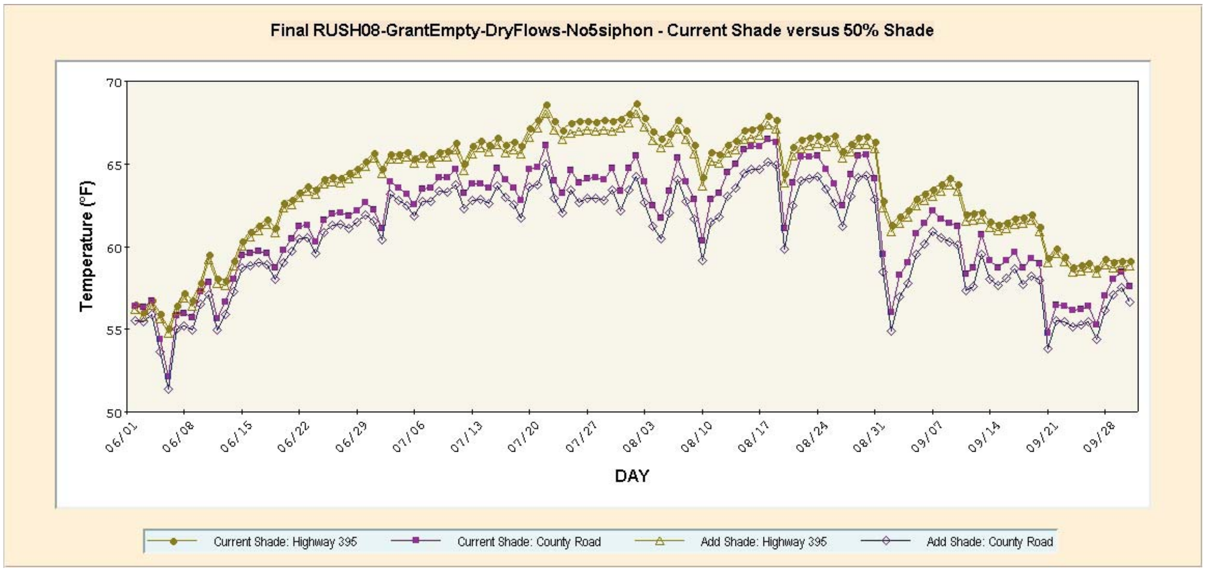


Figure D-4.24. Predicted water temperatures at the Old Highway 395 and County Road sites of Rush Creek at current levels and a consistent 50% level of channel shading for the scenario of a hot climate, dry water availability, GLR empty, and no 5-Siphon Bypass addition to upper Rush Creek.

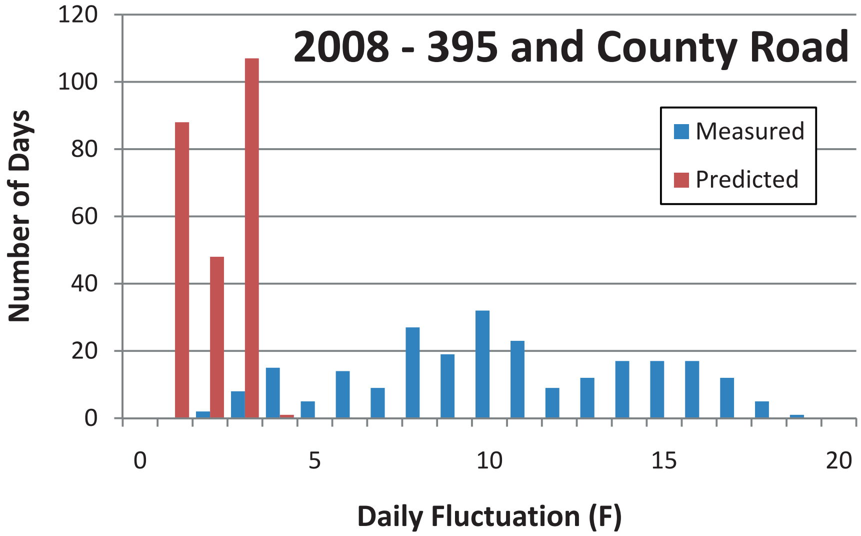


Figure D-4.25. Measured and predicted daily fluctuations in water temperatures at the Old Highway 395 and County Road sites in Rush Creek during 2008.

Table D-4.1. Daily flows (cfs) released from GLR from June 1 through September 30 based on predicted water availability by type for FINAL flows.

DATE	Dry	Dry/Normal I	Dry/Normal II	Normal	Wet/Normal	Wet	Extreme Wet
1-Jun	70	80	80	80	80	80	80
2-Jun	70	80	80	80	80	80	80
3-Jun	70	80	80	80	80	80	80
4-Jun	70	80	80	80	80	80	80
5-Jun	70	80	80	80	80	80	80
6-Jun	70	80	80	80	80	80	80
7-Jun	70	80	80	80	80	80	80
8-Jun	70	80	96	80	80	80	80
9-Jun	70	80	115	80	80	80	80
10-Jun	70	80	138	80	80	80	80
11-Jun	70	80	166	80	80	80	80
12-Jun	70	80	200	88	88	88	88
13-Jun	70	80	200	97	97	97	97
14-Jun	70	80	200	106	106	106	106
15-Jun	70	80	180	120	117	117	117
16-Jun	70	80	162	120	129	129	129
17-Jun	70	80	146	120	142	142	142
18-Jun	70	80	131	120	145	156	156
19-Jun	70	80	118	144	145	170	171
20-Jun	70	80	106	173	145	170	189
21-Jun	70	80	96	207	145	170	207
22-Jun	70	80	86	249	145	170	220
23-Jun	70	80	80	299	145	170	220
24-Jun	70	80	80	358	145	170	220
25-Jun	70	80	80	380	145	170	220
26-Jun	70	80	80	380	174	170	220
27-Jun	70	80	80	380	209	170	220
28-Jun	70	80	80	355	251	170	220
29-Jun	70	80	80	317	301	170	220
30-Jun	70	80	80	279	361	170	220
1-Jul	70	75	75	241	380	170	220
2-Jul	70	71	71	206	380	170	220
3-Jul	70	66	66	174	380	170	220
4-Jul	70	62	62	146	380	170	220
5-Jul	70	59	59	120	342	204	220
6-Jul	66	55	55	120	308	245	220
7-Jul	62	52	52	120	277	294	220
8-Jul	58	49	49	120	249	380	220
9-Jul	55	47	47	120	224	380	264
10-Jul	51	46	46	120	202	380	317
11-Jul	48	45	45	120	182	380	380
12-Jul	45	43	43	120	164	380	380
13-Jul	44	42	42	120	147	342	380
14-Jul	43	41	41	120	145	308	380
15-Jul	41	39	39	113	145	277	380
16-Jul	40	38	38	106	145	249	380

Table D-4.1. Continued. Daily flows (cfs) released from GLR from June 1 through September 30 based on predicted water availability by type for FINAL flows.

DATE	Dry	Dry/Normal I	Dry/Normal II	Normal	Wet/Normal	Wet	Extreme Wet
17-Jul	39	37	37	100	145	224	380
18-Jul	38	36	36	94	145	202	380
19-Jul	37	35	35	88	145	182	342
20-Jul	36	34	34	83	145	170	308
21-Jul	35	33	33	78	145	170	277
22-Jul	33	32	32	73	145	170	249
23-Jul	32	31	31	69	145	170	220
24-Jul	31	30	30	65	136	170	220
25-Jul	30	30	30	61	128	170	220
26-Jul	30	30	30	57	120	170	220
27-Jul	30	30	30	55	113	170	220
28-Jul	30	30	30	54	106	170	220
29-Jul	30	30	30	52	100	170	220
30-Jul	30	30	30	51	94	170	220
31-Jul	30	30	30	49	88	170	220
1-Aug	30	30	30	48	83	170	220
2-Aug	30	30	30	46	78	160	220
3-Aug	30	30	30	45	73	150	220
4-Aug	30	30	30	43	69	141	220
5-Aug	30	30	30	42	67	133	220
6-Aug	30	30	30	41	65	125	220
7-Aug	30	30	30	40	63	117	220
8-Aug	30	30	30	38	61	110	220
9-Aug	30	30	30	37	59	104	220
10-Aug	30	30	30	36	57	97	220
11-Aug	30	30	30	35	56	92	207
12-Aug	30	30	30	34	54	86	194
13-Aug	30	30	30	33	52	81	183
14-Aug	30	30	30	32	51	76	172
15-Aug	30	30	30	31	49	71	161
16-Aug	30	30	30	30	48	69	152
17-Aug	30	30	30	30	46	67	143
18-Aug	30	30	30	30	45	65	134
19-Aug	30	30	30	30	44	63	126
20-Aug	30	30	30	30	42	61	118
21-Aug	30	30	30	30	41	60	111
22-Aug	30	30	30	30	40	58	105
23-Aug	30	30	30	30	39	56	98
24-Aug	30	30	30	30	38	54	93
25-Aug	30	30	30	30	36	53	90
26-Aug	30	30	30	30	35	51	87
27-Aug	30	30	30	30	34	50	84
28-Aug	30	30	30	30	33	48	82
29-Aug	30	30	30	30	32	47	79

Table D-4.1. Continued. Daily flows (cfs) released from GLR from June 1 through September 30 based on predicted water availability by type for FINAL flows.

DATE	Dry	Dry/Normal I	Dry/Normal II	Normal	Wet/Normal	Wet	Extreme Wet
30-Aug	30	30	30	30	31	45	77
31-Aug	30	30	30	30	30	44	75
1-Sep	30	30	30	30	30	43	73
2-Sep	30	30	30	30	30	41	70
3-Sep	30	30	30	30	30	40	68
4-Sep	30	30	30	30	30	39	66
5-Sep	30	30	30	30	30	38	64
6-Sep	30	30	30	30	30	37	62
7-Sep	30	30	30	30	30	35	60
8-Sep	30	30	30	30	30	34	59
9-Sep	30	30	30	30	30	33	57
10-Sep	30	30	30	30	30	32	55
11-Sep	30	30	30	30	30	31	53
12-Sep	30	30	30	30	30	30	52
13-Sep	30	30	30	30	30	30	50
14-Sep	30	30	30	30	30	30	49
15-Sep	30	30	30	30	30	30	47
16-Sep	30	30	30	30	30	30	46
17-Sep	30	30	30	30	30	30	45
18-Sep	30	30	30	30	30	30	43
19-Sep	30	30	30	30	30	30	42
20-Sep	30	30	30	30	30	30	41
21-Sep	30	30	30	30	30	30	39
22-Sep	30	30	30	30	30	30	38
23-Sep	30	30	30	30	30	30	37
24-Sep	30	30	30	30	30	30	36
25-Sep	30	30	30	30	30	30	35
26-Sep	30	30	30	30	30	30	34
27-Sep	30	30	30	30	30	30	33
28-Sep	30	30	30	30	30	30	32
29-Sep	30	30	30	30	30	30	31
30-Sep	30	30	30	30	30	30	30

Table D-4.2. Daily flows (cfs) diverted from Lee Vining Creek into the LADWP conduit for release into upper Rush Creek via the 5-Siphon Bypass from July 1 through September 30 based on predicted water availability by type for FINAL flows.

Date	Dry	Dry Normal I and II	Normal	Wet Norm	Wet	Ext Wet
1-Jul	10.8	19.8	25.2	33.6	4.7	0.0
2-Jul	10.8	19.8	25.2	33.6	4.7	0.0
3-Jul	10.8	19.8	25.2	33.6	4.7	0.0
4-Jul	10.8	19.8	25.2	33.6	4.7	0.0
5-Jul	10.8	19.8	25.2	33.6	4.7	0.0
6-Jul	10.8	19.8	25.2	33.6	4.7	0.0
7-Jul	10.8	19.8	25.2	33.6	4.7	0.0
8-Jul	10.8	19.8	25.2	33.6	4.7	0.0
9-Jul	10.8	19.8	25.2	33.6	4.7	0.0
10-Jul	10.8	19.8	25.2	33.6	4.7	0.0
11-Jul	10.8	19.8	25.2	33.6	4.7	0.0
12-Jul	10.8	19.8	25.2	33.6	4.7	0.0
13-Jul	10.8	19.8	25.2	33.6	4.7	0.0
14-Jul	10.8	19.8	25.2	33.6	4.7	0.0
15-Jul	10.8	19.8	25.2	33.6	4.7	0.0
16-Jul	5.0	13.9	17.3	26.9	30.7	2.7
17-Jul	5.0	13.9	17.3	26.9	30.7	2.7
18-Jul	5.0	13.9	17.3	26.9	30.7	2.7
19-Jul	5.0	13.9	17.3	26.9	30.7	2.7
20-Jul	5.0	13.9	17.3	26.9	30.7	2.7
21-Jul	5.0	13.9	17.3	26.9	30.7	2.7
22-Jul	5.0	13.9	17.3	26.9	30.7	2.7
23-Jul	5.0	13.9	17.3	26.9	30.7	2.7
24-Jul	5.0	13.9	17.3	26.9	30.7	2.7
25-Jul	5.0	13.9	17.3	26.9	30.7	2.7
26-Jul	5.0	13.9	17.3	26.9	30.7	2.7
27-Jul	5.0	13.9	17.3	26.9	30.7	2.7
28-Jul	5.0	13.9	17.3	26.9	30.7	2.7
29-Jul	5.0	13.9	17.3	26.9	30.7	2.7
30-Jul	5.0	13.9	17.3	26.9	30.7	2.7
31-Jul	5.0	13.9	17.3	26.9	30.7	2.7
1-Aug	0.0	6.5	10.9	21.2	25.8	36.9
2-Aug	0.0	6.5	10.9	21.2	25.8	36.9
3-Aug	0.0	6.5	10.9	21.2	25.8	36.9
4-Aug	0.0	6.5	10.9	21.2	25.8	36.9
5-Aug	0.0	6.5	10.9	21.2	25.8	36.9
6-Aug	0.0	6.5	10.9	21.2	25.8	36.9
7-Aug	0.0	6.5	10.9	21.2	25.8	36.9
8-Aug	0.0	6.5	10.9	21.2	25.8	36.9
9-Aug	0.0	6.5	10.9	21.2	25.8	36.9
10-Aug	0.0	6.5	10.9	21.2	25.8	36.9
11-Aug	0.0	6.5	10.9	21.2	25.8	36.9
12-Aug	0.0	6.5	10.9	21.2	25.8	36.9
13-Aug	0.0	6.5	10.9	21.2	25.8	36.9

Table D-4.2. Continued. Daily flows (cfs) diverted from Lee Vining Creek into the LADWP conduit for release into upper Rush Creek via the 5-Siphon Bypass from July 1 through September 30 based on predicted water availability by type for FINAL flows.

Date	Dry	Dry Normal I and II	Normal	Wet Norm	Wet	Ext Wet
14-Aug	0.0	6.5	10.9	21.2	25.8	36.9
15-Aug	0.0	6.5	10.9	21.2	25.8	36.9
16-Aug	0.1	1.4	6.1	14.2	19.5	28.4
17-Aug	0.1	1.4	6.1	14.2	19.5	28.4
18-Aug	0.1	1.4	6.1	14.2	19.5	28.4
19-Aug	0.1	1.4	6.1	14.2	19.5	28.4
20-Aug	0.1	1.4	6.1	14.2	19.5	28.4
21-Aug	0.1	1.4	6.1	14.2	19.5	28.4
22-Aug	0.1	1.4	6.1	14.2	19.5	28.4
23-Aug	0.1	1.4	6.1	14.2	19.5	28.4
24-Aug	0.1	1.4	6.1	14.2	19.5	28.4
25-Aug	0.1	1.4	6.1	14.2	19.5	28.4
26-Aug	0.1	1.4	6.1	14.2	19.5	28.4
27-Aug	0.1	1.4	6.1	14.2	19.5	28.4
28-Aug	0.1	1.4	6.1	14.2	19.5	28.4
29-Aug	0.1	1.4	6.1	14.2	19.5	28.4
30-Aug	0.1	1.4	6.1	14.2	19.5	28.4
31-Aug	0.1	1.4	6.1	14.2	19.5	28.4
1-Sep	0.0	0.0	3.2	9.8	16.8	21.0
2-Sep	0.0	0.0	3.2	9.8	16.8	21.0
3-Sep	0.0	0.0	3.2	9.8	16.8	21.0
4-Sep	0.0	0.0	3.2	9.8	16.8	21.0
5-Sep	0.0	0.0	3.2	9.8	16.8	21.0
6-Sep	0.0	0.0	3.2	9.8	16.8	21.0
7-Sep	0.0	0.0	3.2	9.8	16.8	21.0
8-Sep	0.0	0.0	3.2	9.8	16.8	21.0
9-Sep	0.0	0.0	3.2	9.8	16.8	21.0
10-Sep	0.0	0.0	3.2	9.8	16.8	21.0
11-Sep	0.0	0.0	3.2	9.8	16.8	21.0
12-Sep	0.0	0.0	3.2	9.8	16.8	21.0
13-Sep	0.0	0.0	3.2	9.8	16.8	21.0
14-Sep	0.0	0.0	3.2	9.8	16.8	21.0
15-Sep	0.0	0.0	3.2	9.8	16.8	21.0
16-Sep	0.0	0.0	1.6	7.0	12.8	16.9
17-Sep	0.0	0.0	1.6	7.0	12.8	16.9
18-Sep	0.0	0.0	1.6	7.0	12.8	16.9
19-Sep	0.0	0.0	1.6	7.0	12.8	16.9
20-Sep	0.0	0.0	1.6	7.0	12.8	16.9
21-Sep	0.0	0.0	1.6	7.0	12.8	16.9
22-Sep	0.0	0.0	1.6	7.0	12.8	16.9
23-Sep	0.0	0.0	1.6	7.0	12.8	16.9
24-Sep	0.0	0.0	1.6	7.0	12.8	16.9

Table D-4.2. Continued. Daily flows (cfs) diverted from Lee Vining Creek into the LADWP conduit for release into upper Rush Creek via the 5-Siphon Bypass from July 1 through September 30 based on predicted water availability by type for FINAL flows.

Date	Dry	Dry Normal I and II	Normal	Wet Norm	Wet	Ext Wet
25-Sep	0.0	0.0	1.6	7.0	12.8	16.9
26-Sep	0.0	0.0	1.6	7.0	12.8	16.9
27-Sep	0.0	0.0	1.6	7.0	12.8	16.9
28-Sep	0.0	0.0	1.6	7.0	12.8	16.9
29-Sep	0.0	0.0	1.6	7.0	12.8	16.9
30-Sep	0.0	0.0	1.6	7.0	12.8	16.9

Table D-4.3. Various flow scenarios for which average daily water temperatures in Rush Creek were predicted, including the year and temperature adjustments for which average water temperature data were used for the MGORD site and Lee Vining Creek water delivered via the 5-Siphon Bypass, based on water availability.

Air Temperature	Water Availability	Grant	5-Siphon Bypass flow	MGORD water temperature	5-Siphon (LV) water temperature
Hot - 2008	Dry	Full	No	2008 - 3.6F	2008 + 1F
	Dry/Normal I	Full	No	2008 - 3.6F	2008 + 1F
	Dry/Normal II	Full	No	2000	2008 + 1F
	Normal	Full	No	2000	2008 + 1F
	Wet/Normal	Full	No	2000	2008 + 1F
	Wet	Full	No	2006	2008 + 1F
	Extreme Wet	Full	No	2006	2008 + 1F
Hot - 2008	Dry	Full	Yes	2008 - 3.6F	2008 + 1F
	Dry/Normal I	Full	Yes	2008 - 3.6F	2008 + 1F
	Dry/Normal II	Full	Yes	2000	2008 + 1F
	Normal	Full	Yes	2000	2008 + 1F
	Wet/Normal	Full	Yes	2000	2008 + 1F
	Wet	Full	Yes	2006	2008 + 1F
	Extreme Wet	Full	Yes	2006	2008 + 1F
Hot - 2008	Dry	Empty	No	2008	2008 + 1F
	Dry/Normal I	Empty	No	2008	2008 + 1F
	Dry/Normal II	Empty	No	2000 + 3.6F	2008 + 1F
	Normal	Empty	No	2000 + 3.6F	2008 + 1F
	Wet/Normal	Empty	No	2000 + 3.6F	2008 + 1F
Hot - 2008	Dry	Empty	Yes	2008	2008 + 1F
	Dry/Normal I	Empty	Yes	2008	2008 + 1F
	Dry/Normal II	Empty	Yes	2000 + 3.6F	2008 + 1F
	Normal	Empty	Yes	2000 + 3.6F	2008 + 1F
	Wet/Normal	Empty	Yes	2000 + 3.6F	2008 + 1F
Average - 2004	Dry	Full	No	2008 - 3.6F	2008 + 1F
	Dry/Normal I	Full	No	2008 - 3.6F	2008 + 1F
	Dry/Normal II	Full	No	2000	2008 + 1F
	Normal	Full	No	2000	2008 + 1F
	Wet/Normal	Full	No	2000	2008 + 1F
	Wet	Full	No	2006	2008 + 1F
	Extreme Wet	Full	No	2006	
Average - 2004	Dry	Full	Yes	2008 - 3.6F	2008 + 1F
	Dry/Normal I	Full	Yes	2008 - 3.6F	2008 + 1F
	Dry/Normal II	Full	Yes	2000	2008 + 1F
	Normal	Full	Yes	2000	2008 + 1F
	Wet/Normal	Full	Yes	2000	2008 + 1F
	Wet	Full	Yes	2006	2008 + 1F
	Extreme Wet	Full	Yes	2006	2008 + 1F

Table D-4.3. Continued. Various flow scenarios for which average daily water temperatures in Rush Creek were predicted, including the year and temperature adjustments for which average water temperature data were used for the MGORD site and Lee Vining Creek water delivered via the 5-Siphon Bypass, based on water availability.

Air Temperature	Water Availability	Grant	5-Siphon Bypass flow	MGORD water temperature	5-Siphon (LV) water temperature
Average - 2004	Dry	Empty	No	2008	2008 + 1F
	Dry/Normal I	Empty	No	2008	2008 + 1F
	Dry/Normal II	Empty	No	2000 + 3.6F	2008 + 1F
	Normal	Empty	No	2000 + 3.6F	2008 + 1F
	Wet/Normal	Empty	No	2000 + 3.6F	2008 + 1F
Average - 2004	Dry	Empty	Yes	2008	2008 + 1F
	Dry/Normal I	Empty	Yes	2008	2008 + 1F
	Dry/Normal II	Empty	Yes	2000 + 3.6F	2008 + 1F
	Normal	Empty	Yes	2000 + 3.6F	2008 + 1F
	Wet/Normal	Empty	Yes	2000 + 3.6F	2008 + 1F
Global Warming 2008 + 2F	Dry	Full	No	2008 - 3.6F	2008 + 1F
	Dry/Normal I	Full	No	2008 - 3.6F	2008 + 1F
	Dry/Normal II	Full	No	2000	2008 + 1F
	Normal	Full	No	2000	2008 + 1F
	Wet/Normal	Full	No	2000	2008 + 1F
	Wet	Full	No	2006	2008 + 1F
	Extreme Wet	Full	No	2006	2008 + 1F
Global Warming 2008 + 2F	Dry	Full	Yes	2008 - 3.6F	2008 + 1F
	Dry/Normal I	Full	Yes	2008 - 3.6F	2008 + 1F
	Dry/Normal II	Full	Yes	2000	2008 + 1F
	Normal	Full	Yes	2000	2008 + 1F
	Wet/Normal	Full	Yes	2000	2008 + 1F
	Wet	Full	Yes	2006	2008 + 1F
	Extreme Wet	Full	Yes	2006	2008 + 1F
Global Warming 2008 + 2F	Dry	Empty	No	2008	2008 + 1F
	Dry/Normal I	Empty	No	2008	2008 + 1F
	Dry/Normal II	Empty	No	2000 + 3.6F	2008 + 1F
	Normal	Empty	No	2000 + 3.6F	2008 + 1F
	Wet/Normal	Empty	No	2000 + 3.6F	2008 + 1F
Global Warming 2008 + 2F	Dry	Empty	Yes	2008	2008 + 1F
	Dry/Normal I	Empty	Yes	2008	2008 + 1F
	Dry/Normal II	Empty	Yes	2000 + 3.6F	2008 + 1F
	Normal	Empty	Yes	2000 + 3.6F	2008 + 1F
	Wet/Normal	Empty	Yes	2000 + 3.6F	2008 + 1F

APPENDIX E. NUMBER OF GOOD DAYS AND REFERENCE CONDITION CURVES

The Number of Good Days analysis used **threshold** magnitudes and durations identified for each ‘desired ecological outcome’ (Synthesis Report Table 3-1) to compute the number of days each ecological outcome was met for each runoff year. As with other analyses in this Report, RYs 1990 to 2008 were examined. The NGD analysis was slightly different for Lee Vining Creek and Rush Creek. For Lee Vining Creek, the analysis was applied to a range of diversion rates (computed for allowable stage change of 0.0 to 0.5 ft with representative XS 6+61 rating curve) to identify a balance between increasing diversion rate with minimizing impacts to ecological outcomes. The analysis used the Lee Vining Creek Runoff unimpaired and Lee Vining Creek above Intake (SCE regulated) annual hydrographs as reference conditions. Reference condition curves were plotted for all runoff years combined (Figure E-1) and for each of five runoff year types (Dry, Dry-Normal, Normal, Wet-Normal, Wet). By contrasting NGDs among different reference (baseline) conditions, the ecological performance (measured in NGD) was evaluated These reference curves were used (in concert with other information) to develop Lee Vining Creek diversion rate recommendations. The NGD (and NGY) results were considered guidelines, not absolute decision-makers for recommending the SEFs.

For Lee Vining Creek, Tables 1-4 (in this Appendix) present the results of NGD analyses for each of four sets of annual hydrographs for RYs 1990 to 2008: (1) Lee Vining Creek Unimpaired, (2) Lee Vining Creek above Intake (SCE Regulated), (3) Lee Vining Creek below Intake (SRF streamflows), and (4) Lee Vining Creek simulated SEF streamflows. The simulated SEF streamflows use the recommended diversion rates and bypass flows presented in the Synthesis Report Chapter 2. Tables 1-4 present NGDs for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

Table 3-1 of the Synthesis Report, showing the threshold criteria for each ‘desired ecological outcome’ therefore, is the centerpiece of the NGD analysis. All computations are derived from the magnitude, duration, timing, and frequency thresholds provided, and these were distilled from 12 years of monitoring, analyses, and field experience. The NGD results tables allow readers to do performance analyses without doing the computations. To compare how well the SEFs perform ecologically relative to the SRFs, NGDs for SEFs and SRFs can be contrasted. SCE’s effects on Lower Rush Creek, without LADWP downstream, can be evaluated by comparing NGDs computed from the unimpaired annual hydrographs.

In Rush Creek, the NGD analytical procedure to assess alternative diversion rates was not required. The NGD analysis used threshold criteria for each ‘desired ecological outcome’ presented in the Synthesis Report Table 3-1, and computed NGDs for the following sets of annual hydrographs for RYs 1990 to 2008:

- Rush Creek unimpaired (at Damsite)
- Rush Creek unimpaired (below the Narrows)
- Rush Creek at Damsite (5013) (SRF streamflows)
- Rush Creek at Damsite plus Parker and Walker creeks below the Conduit (5013+5003+5002) (simulating Rush Creek below the Narrows with a constant full GLR and no SRF flow releases)
- Rush Creek below Narrows actual (SRF below Narrows streamflows)
- Rush Creek recommended SEF streamflows (at Damsite)
- Rush Creek recommended SEF streamflows (below the Narrows)

Tables 5-11 present NGDs for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

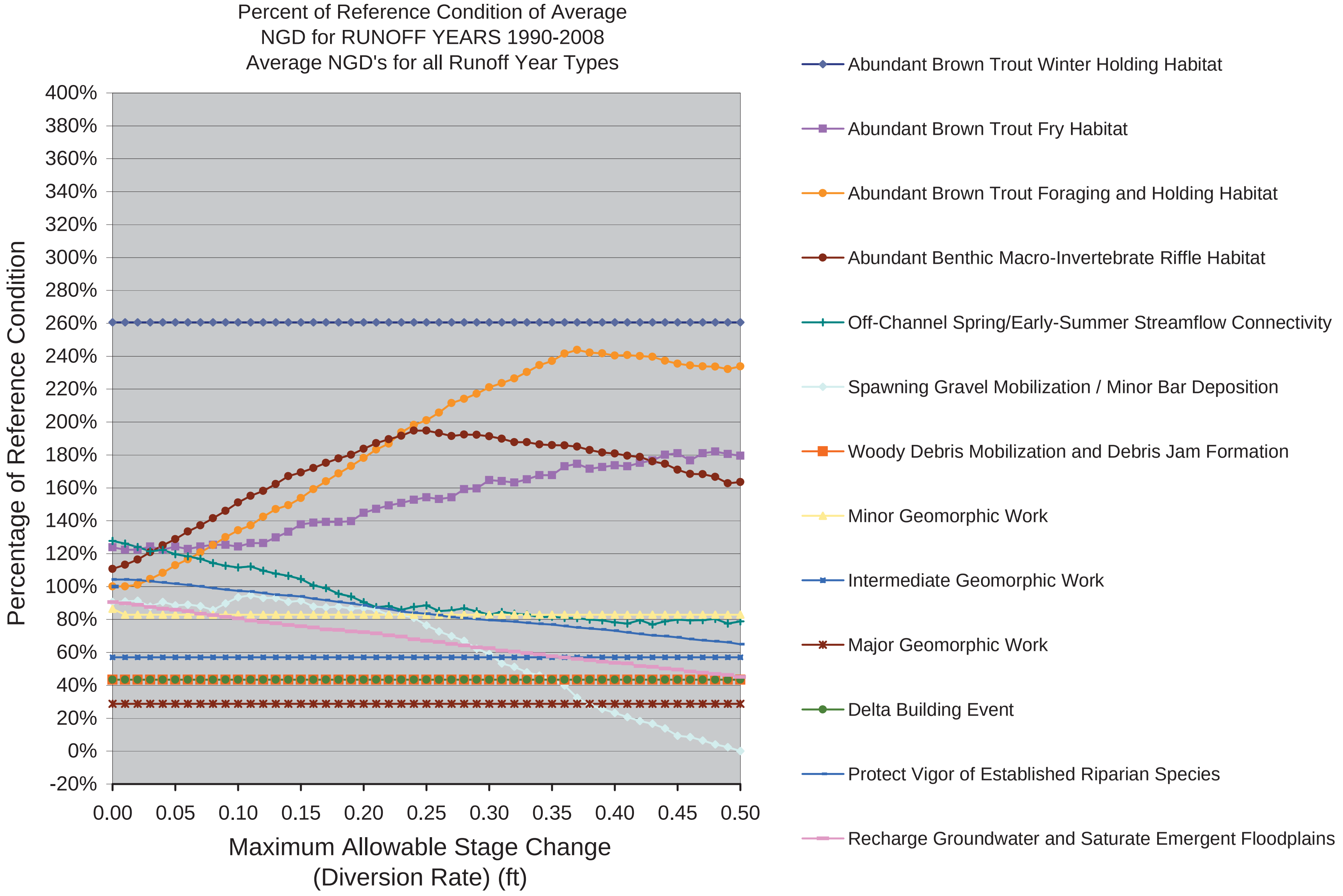


Figure E-1. NGD analysis with Lee Vining Creek unimpaired as reference condition, allowable diversion rates ranging from 0.0 (no diversion) to 0.5 ft stage change (at Lee Vining Creek reference XS 6+61). Average NGDs for ALL runoff years (1990-2008) combined.

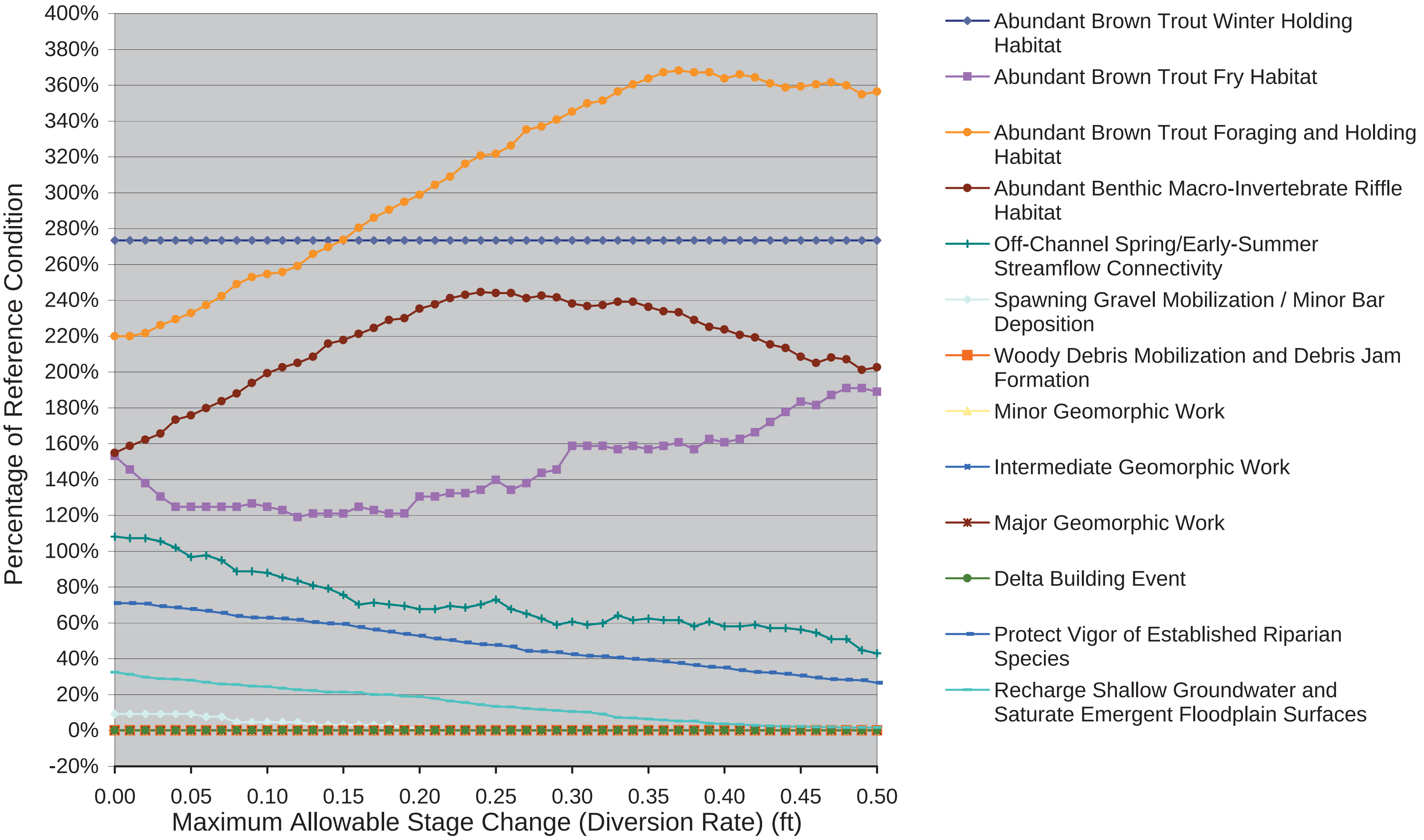


Figure E-2. NGD analysis with Lee Vining Creek unimpaired as reference condition, allowable diversion rates ranging from 0.0 (no diversion) to 0.5 ft stage change (at Lee Vining Creek reference XS 6+61). Average NGDs for DRY runoff years (1990-2008) combined.

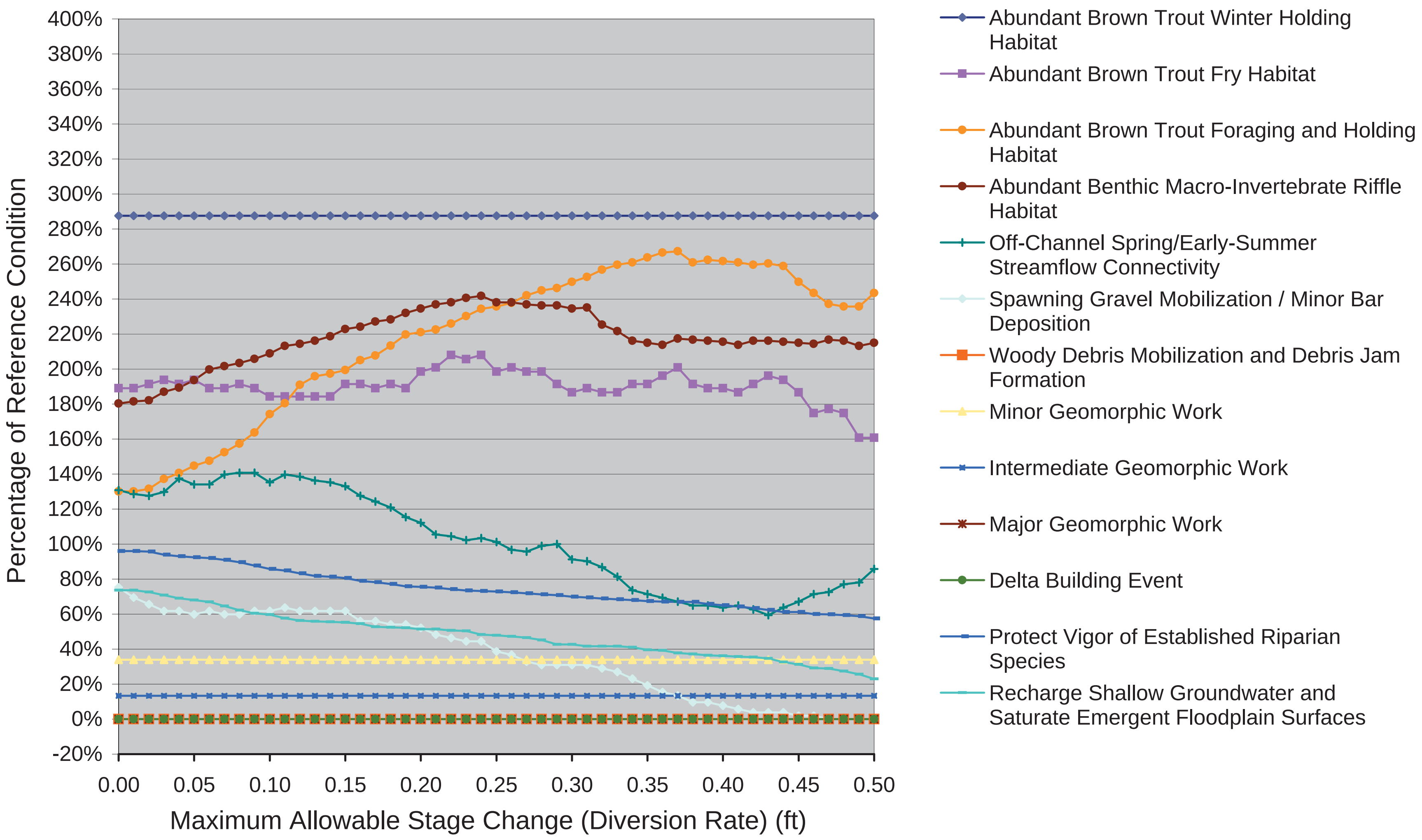


Figure E-3. NGD analysis with Lee Vining Creek unimpaired as reference condition, allowable diversion rates ranging from 0.0 (no diversion) to 0.5 ft stage change (at Lee Vining Creek reference XS 6+61). Average NGDs for DRY-NORMAL runoff years (1990-2008) combined.

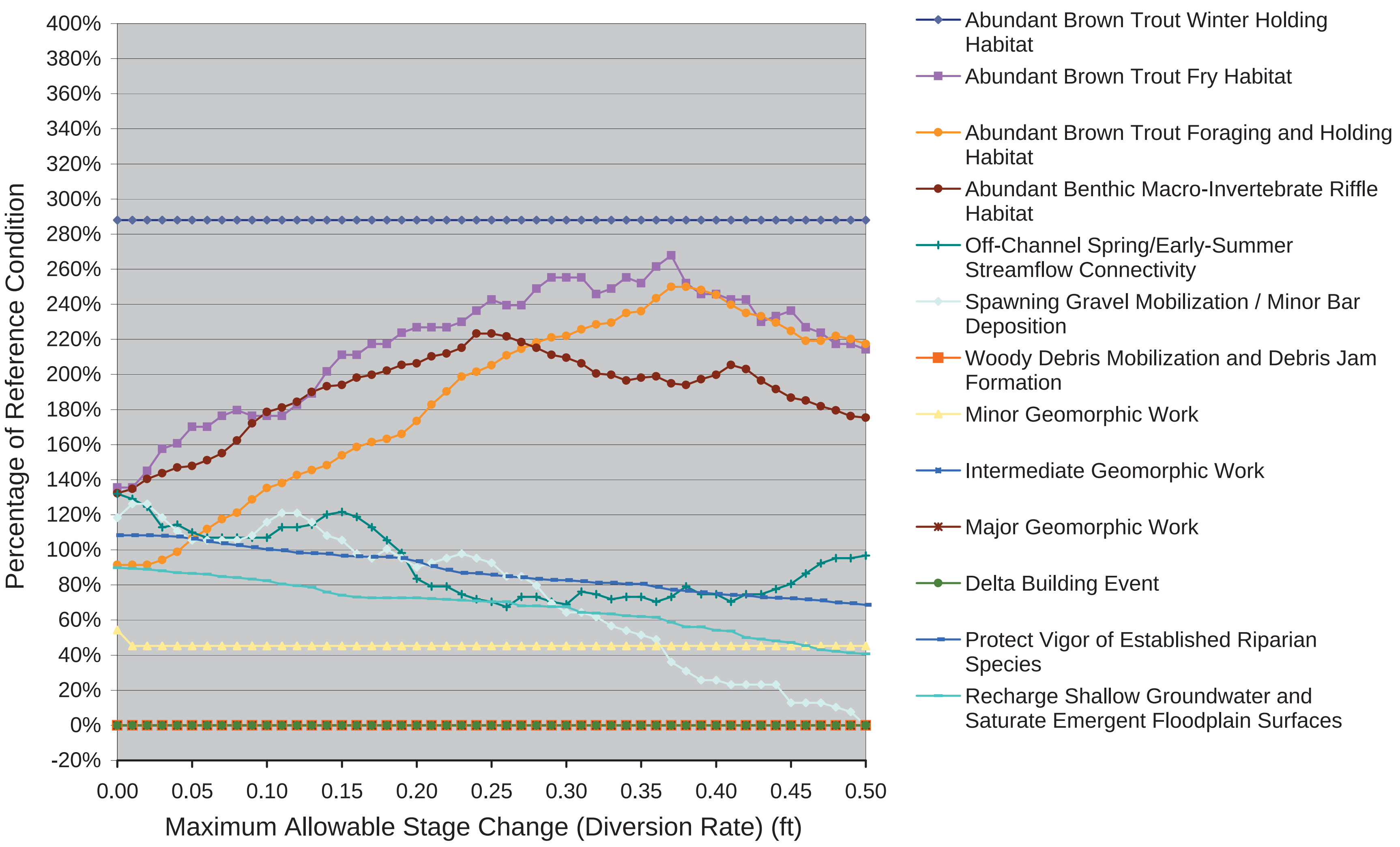


Figure E-4. NGD analysis with Lee Vining Creek unimpaired as reference condition, allowable diversion rates ranging from 0.0 (no diversion) to 0.5 ft stage change (at Lee Vining Creek reference XS 6+61). Average NGDs for NORMAL runoff years (1990-2008) combined.

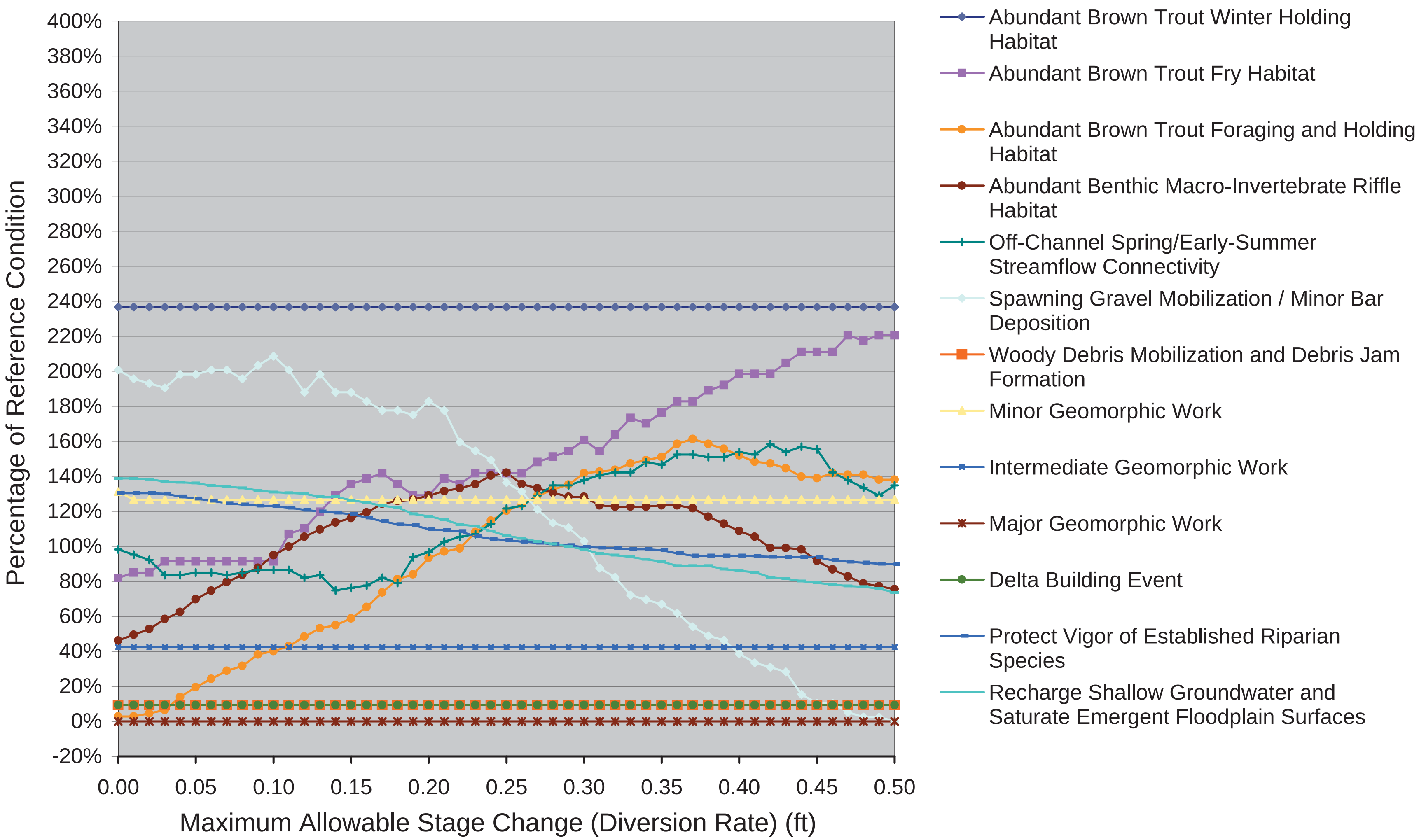


Figure E-5. NGD analysis with Lee Vining Creek unimpaired as reference condition, allowable diversion rates ranging from 0.0 (no diversion) to 0.5 ft stage change (at Lee Vining Creek reference XS 6+61). Average NGDs for WET-NORMAL runoff years (1990-2008) combined.

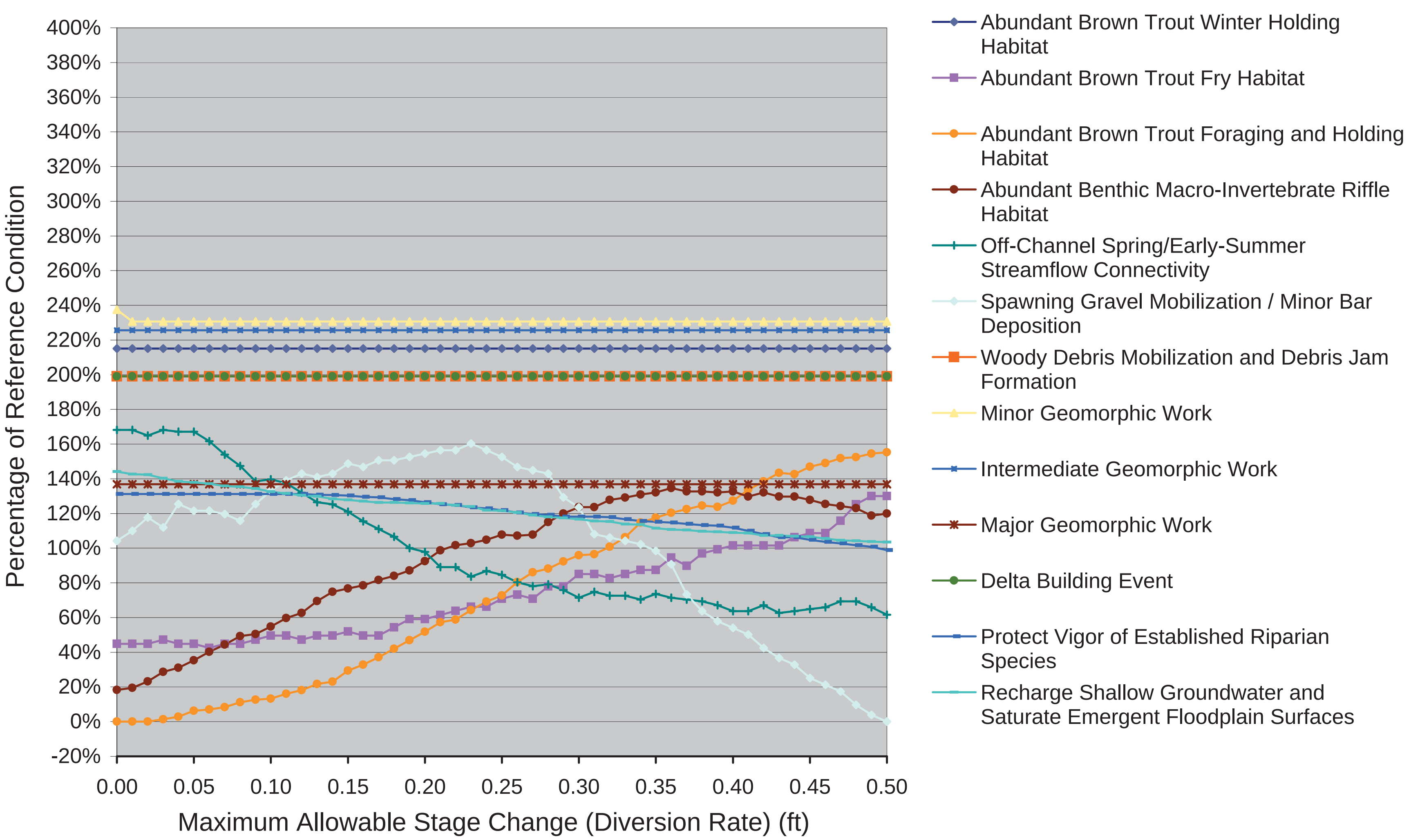


Figure E-6. NGD analysis with Lee Vining Creek unimpaired as reference condition, allowable diversion rates ranging from 0.0 (no diversion) to 0.5 ft stage change (at Lee Vining Creek reference XS 6+61). Average NGDs for WET runoff years (1990-2008) combined.

TABLES 5-11 PRESENT NGDS FOR EACH RUNOFF YEAR, AVERAGES FOR EACH RUNOFF YEAR TYPE, AND AVERAGES FOR ALL RUNOFF YEARS COMBINED.

Table E-1. NGDs for Lee Vining Creek unimpaired RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

Desired Ecological Condition	Date	Flow Range (cfs)	Average NDGs Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
Stream Productivity and Brown Trout Habitat								
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	16-22	44	73	80	75	57	63
Abundant Brown Trout Fry Habitat in Mainstem and along Channel Margin	May 20 to June 30	12-28; 80-150	18	15	6	7	4	11
Abundant Brown Trout Foraging and Holding Habitat	April 1 to September 30	15-30	49	43	43	21	18	36
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	20-38	49	48	47	29	29	41
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	55-80	25	22	25	17	24	23
Geomorphic Thresholds								
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	150-200	6	13	20	22	10	13
General LWD Transport and Debris Jam Formation	April 1 to September 30	>350	0	2	1	5	28	7
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	250-300	1	4	6	15	14	7
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	300-400	0	4	8	13	25	9
Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	400-500	0	1	0	2	12	3
Delta Building Event	April 1 to September 30	>350 for 5+ consec days	0	2	1	5	28	7
Mainstem Channel Avulsion	April 1 to September 30	500+	0	0	0	0	4	1
Riparian Growth and Maintenance								
Mainstem and Side-Channel Margins as well as on the Floodplain	May 1 to September 30	>30	88	109	116	137	146	117
Groundwater and Saturating Emergent Floodplain Surfaces	June 15 to August 26	>80	36	66	70	102	103	72

Table E-1. Continued.

Lee Vining Creek Unimpaired																		
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
15	55	47	99	69	44	41	84	79	90	67	75	64	71	82	51	52	34	82
8	16	17	6	19	9	14	0	7	4	3	10	12	9	28	0	0	28	11
41	67	52	27	35	4	23	12	17	38	39	33	39	58	41	25	26	50	52
43	43	58	39	40	15	30	17	20	51	43	47	33	76	36	40	39	62	48
47	15	17	11	26	27	20	19	34	21	33	20	26	8	34	19	16	19	20
0	12	2	16	12	16	19	30	16	20	13	10	21	5	15	3	4	5	27
0	0	0	1	0	31	11	4	32	1	1	0	0	8	0	18	29	0	0
0	4	0	22	0	14	11	13	2	7	9	3	6	8	0	21	17	0	3
0	0	0	8	0	24	14	16	24	17	6	1	2	13	0	29	24	0	1
0	0	0	0	0	7	3	3	15	0	0	0	0	4	0	7	20	0	0
0	0	0	1	0	31	11	4	32	1	1	0	0	8	0	18	29	0	0
0	0	0	0	0	13	0	0	1	0	0	0	0	0	0	0	1	0	0
86	94	74	138	90	153	131	141	153	131	118	114	106	107	109	137	139	96	98
15	48	35	100	42	112	97	108	100	75	69	47	73	74	69	99	100	39	66

Table E-2. NGDs for Lee Vining Creek above Intake (SCE Regulated) RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Average NDGs					
Desired Ecological Condition	Date	Flow Range (cfs)	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
Stream Productivity and Brown Trout Habitat								
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	16-22	71	21	28	0	4	28
Abundant Brown Trout Fry Habitat in Mainstem and along Channel Margin	May 20 to June 30	12-28; 80-150	16	20	14	9	5	13
Abundant Brown Trout Foraging and Holding Habitat	April 1 to September 30	15-30	79	47	33	1	0	36
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	20-38	64	74	54	19	8	45
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	55-80	25	30	30	22	38	29
Geomorphic Thresholds								
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	150-200	1	10	15	26	14	12
General LWD Transport and Debris Jam Formation	April 1 to September 30	>350	0	0	0	1	14	3
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	250-300	0	3	4	10	18	6
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	300-400	0	1	0	4	21	5
Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	400-500	0	0	0	0	4	1
Delta Building Event	April 1 to September 30	>350 for 5+ consec days	0	0	0	1	14	3
Mainstem Channel Avulsion	April 1 to September 30	500+	0	0	0	0	0	0
Riparian Growth and Maintenance								
Mainstem and Side-Channel Margins as well as on the Floodplain	May 1 to September 30	>30	83	112	126	152	153	122
Groundwater and Saturating Emergent Floodplain Surfaces	June 15 to August 26	>80	23	53	65	100	104	65

Table E-2. Continued.

Lee Vining Creek above Intake																		
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
128	60	40	0	20	0	0	0	1	0	3	19	32	3	28	4	11	106	82
4	23	15	9	22	10	17	0	9	6	11	12	23	12	33	0	0	17	26
73	98	87	0	64	0	3	0	0	7	26	52	42	54	38	0	0	71	65
54	46	102	32	60	15	25	0	0	44	40	92	50	99	55	10	5	56	79
20	18	23	16	39	29	17	34	56	21	51	21	35	23	40	36	32	23	18
0	6	0	26	0	16	26	26	18	17	19	16	16	6	1	6	14	0	10
0	0	0	0	0	17	0	2	13	0	0	0	0	0	0	5	22	0	0
0	0	0	3	0	15	9	17	10	11	1	0	0	10	0	30	15	0	0
0	0	0	0	0	14	8	4	29	0	0	0	0	5	0	13	29	0	0
0	0	0	0	0	12	0	0	1	0	0	0	0	0	0	0	4	0	0
0	0	0	0	0	17	0	2	13	0	0	0	0	0	0	5	22	0	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
85	85	73	153	81	153	150	153	153	153	127	112	111	110	115	153	153	90	99
7	34	23	95	27	111	99	106	98	75	59	40	59	57	56	96	110	26	60

Table E-3. NGDs for Lee Vining Creek below Intake (SRF streamflows) RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Average NDGs					
Desired Ecological Condition	Date	Flow Range (cfs)	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
Stream Productivity and Brown Trout Habitat								
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	16-22	70	27	40	0	9	32
Abundant Brown Trout Fry Habitat in Mainstem and along Channel Margin	May 20 to June 30	12-28; 80-150	9	16	13	13	6	11
Abundant Brown Trout Foraging and Holding Habitat	April 1 to September 30	15-30	70	49	36	4	0	35
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	20-38	62	74	57	21	10	46
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	55-80	17	45	35	21	39	31
Geomorphic Thresholds								
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	150-200	1	8	16	25	16	12
General LWD Transport and Debris Jam Formation	April 1 to September 30	>350	0	0	0	1	14	3
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	250-300	0	1	3	7	17	5
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	300-400	0	0	0	2	19	4
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	400-500	0	0	0	0	4	1
Delta Building Event	April 1 to September 30	>350 for 5+ consec days	0	0	0	1	14	3
Mainstem Channel Avulsion	April 1 to September 30	500+	0	0	0	0	0	0
Riparian Growth and Maintenance								
Mainstem and Side-Channel Margins as well as on the Floodplain	May 1 to September 30	>30	75	109	126	151	153	119
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces	June 15 to August 26	>80	11	36	52	97	99	55

Table E-3. Continued.

Lee Vining Creek SRF																		
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
119	65	37	0	18	0	0	0	1	1	14	26	39	4	37	4	29	111	104
1	16	7	17	20	10	21	1	9	7	11	10	24	9	22	6	0	0	20
81	59	84	7	58	0	6	0	0	20	22	52	42	61	42	0	0	68	66
62	49	94	33	47	15	31	0	0	50	41	87	50	99	58	14	9	58	81
5	17	24	21	37	30	13	29	56	21	38	23	34	55	66	41	30	0	47
0	3	0	31	0	16	23	21	18	18	22	15	16	2	0	14	17	0	7
0	0	0	0	0	15	0	2	13	0	0	0	0	0	0	4	22	0	0
0	0	0	0	0	17	8	14	11	8	1	0	0	3	0	23	16	0	0
0	0	0	0	0	17	5	2	26	0	0	0	0	1	0	9	24	0	0
0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	11	0	0
0	0	0	0	0	15	0	2	13	0	0	0	0	0	0	4	22	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	84	55	153	81	153	147	153	153	149	131	112	111	103	111	153	153	92	99
0	24	5	90	26	108	97	104	92	73	55	37	58	21	28	84	110	0	27

Table E-4. NGDs for Lee Vining Creek recommended SEF streamflows for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Average NDGs					
Desired Ecological Condition	Date	Flow Range (cfs)	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
Stream Productivity and Brown Trout Habitat								
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	16-22	173	182	182	150	136	165
Abundant Brown Trout Fry Habitat in Mainstem and along Channel Margin	May 20 to June 30	12-28; 80-150	10	21	24	14	6	14
Abundant Brown Trout Foraging and Holding Habitat	April 1 to September 30	15-30	81	51	35	7	1	39
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	20-38	97	96	85	53	38	75
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	55-80	15	26	19	22	22	21
Geomorphic Thresholds								
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	150-200	0	7	12	24	20	11
General LWD Transport and Debris Jam Formation	April 1 to September 30	>350	0	0	0	1	14	3
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	250-300	0	3	3	9	17	6
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	300-400	0	1	0	4	21	5
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	400-500	0	0	0	0	4	1
Delta Building Event	April 1 to September 30	>350 for 5+ consec days	0	0	0	1	14	3
Mainstem Channel Avulsion	April 1 to September 30	500+	0	0	0	0	0	0
Riparian Growth and Maintenance								
Mainstem and Side-Channel Margins as well as on the Floodplain	May 1 to September 30	>30	81	108	125	150	153	120
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces	June 15 to August 26	>80	14	37	52	84	91	52

Table E-4. Continued.

Lee Vining Creek SEF																		
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
158	182	182	151	175	136	149	151	136	182	182	181	182	182	182	136	136	167	182
0	23	5	15	14	11	15	11	13	16	25	14	30	14	25	0	1	7	31
76	99	91	15	68	1	5	0	0	9	28	60	47	55	42	2	0	73	68
119	63	122	71	82	40	60	28	27	87	67	118	84	102	81	47	38	97	100
10	10	22	26	13	16	15	25	33	12	20	17	26	24	35	24	16	22	25
0	1	0	32	0	21	20	19	6	14	16	6	9	12	0	25	28	0	5
0	0	0	0	0	17	0	2	13	0	0	0	0	0	0	5	22	0	0
0	0	0	3	0	15	9	16	9	9	1	0	0	10	0	29	15	0	0
0	0	0	0	0	14	8	4	29	0	0	0	0	5	0	13	29	0	0
0	0	0	0	0	12	0	0	1	0	0	0	0	0	0	0	4	0	0
0	0	0	0	0	17	0	2	13	0	0	0	0	0	0	5	22	0	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
82	84	71	148	80	153	148	153	153	151	126	106	106	110	111	151	153	90	98
0	29	8	73	18	101	88	92	78	64	54	31	45	39	33	82	101	13	39

Table E-5. NGDs for Rush Creek unimpaired at Damsite for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Rush Creek Unimpaired at Damsite				
Desired Ecological Condition	Date	Flow Range (cfs)	1990	1991	1992	1993	1994
Stream Productivity and Trout Habitat							
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	10	15	35	11	64
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	21	59	36	13	34
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	71	40	43	50	45
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	52	27	24	19	23
Geomorphic Thresholds							
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	8	3	15	11	10
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	4	0	21	0
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	4	0	17	0
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	4	0	20	0
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0	1	0
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	2	0	7	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0	0	0
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	>80	65	67	48	102	48
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	9	21	4	24	1
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 5	>275	0	3	0	22	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	9	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	0	0
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 5	>230	0	5	0	22	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0	10	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	1	0
Emergent Floodplains and Aggraded Floodplains with Side-Channels							
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	5	19	0	22	1
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	4	5	4	22	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	3	0	1	24	0

Table E-5. Continued.

1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
58	68	30	50	26	26	24	25	17	39	94	37	24	62
4	19	14	20	35	21	35	43	32	20	15	12	50	37
59	35	49	59	42	44	52	36	58	59	57	58	60	41
31	23	40	39	17	28	16	43	18	35	28	14	28	32
20	27	13	7	12	12	6	10	3	20	5	2	0	12
45	12	8	39	12	10	11	0	17	0	40	39	0	0
13	6	7	1	5	6	6	2	2	0	12	9	0	1
24	10	8	28	12	10	11	0	12	0	32	38	0	0
6	2	0	10	1	0	0	0	3	0	6	1	0	0
35	9	5	32	4	7	4	0	11	0	26	24	0	0
4	0	0	1	0	0	0	0	3	0	2	0	0	0
129	95	95	116	72	80	57	69	60	75	104	100	38	74
19	33	29	17	17	10	5	12	13	10	15	16	2	13
21	9	5	22	12	14	0	0	5	0	21	22	0	3
22	0	0	22	0	0	0	0	0	0	16	11	0	0
24	0	0	15	0	0	0	0	0	0	7	4	0	0
22	18	8	22	14	15	0	0	6	0	22	22	0	5
22	6	0	22	0	0	0	0	0	0	18	19	0	0
24	0	0	16	0	0	0	0	0	0	9	10	0	0
22	22	19	22	22	22	3	13	17	10	22	22	2	16
22	17	16	22	7	1	2	0	1	1	22	22	0	0
24	11	7	24	0	1	0	0	0	0	19	18	0	0

Table E-6. NGDs for Rush Creek unimpaired below the Narrows for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Rush Creek Unimpaired Below Narrows					
Desired Ecological Condition	Date	Flow Range (cfs)	1990	1991	1992	1993	1994	1995
Stream Productivity and Trout Habitat								
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	16	56	55	45	93	102
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	29	62	27	15	37	0
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	61	40	60	57	61	49
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	56	24	18	9	34	37
Geomorphic Thresholds								
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	13	6	14	12	13	7
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	8	0	35	0	61
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	4	0	8	2	3
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	8	0	32	0	27
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0	2	0	13
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	6	0	20	0	52
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0	1	0	6
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	>80	74	74	58	107	61	141
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	17	26	5	24	2	11
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 5	>275	0	5	0	22	0	22
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	10	0	22
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	1	0	24
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 5	>230	0	9	0	22	0	22
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	1	0	15	0	22
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	6	0	24
Emergent Floodplains and Aggraded Floodplains with Side-Channels								
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	9	22	0	22	3	22
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	7	9	5	22	0	22
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	5	0	2	24	0	24

Table E-6. Continued.

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
53	82	54	59	45	63	40	44	40	80	67	36	70
17	14	3	32	18	32	35	6	15	13	3	40	38
50	44	64	64	52	58	44	87	57	51	62	77	39
28	34	47	5	33	23	40	29	42	38	22	38	30
15	16	12	8	8	9	14	6	18	5	4	3	8
18	14	41	18	15	19	3	20	0	53	52	0	1
6	9	3	5	11	4	1	2	0	8	10	0	3
13	14	10	16	13	15	3	11	0	29	30	0	1
5	1	24	1	2	4	0	4	0	16	21	0	0
13	9	39	12	10	12	0	17	0	45	41	0	0
0	0	7	1	0	0	0	4	0	8	1	0	0
109	105	133	77	90	73	70	81	81	116	117	49	78
23	41	19	17	19	10	26	21	18	20	13	4	25
18	9	22	16	18	0	0	6	0	22	22	0	5
9	0	22	0	0	0	0	0	0	20	21	0	0
0	0	17	0	0	0	0	0	0	11	12	0	0
19	14	22	21	18	0	4	9	3	22	22	0	9
10	1	22	0	0	0	0	0	0	21	22	0	0
1	0	24	0	0	0	0	0	0	14	13	0	0
22	22	22	22	22	7	22	21	16	22	22	4	21
22	22	22	11	14	4	5	6	3	22	22	0	8
19	17	24	2	8	0	0	2	0	24	24	0	0

Table E-7. NGDs for Rush Creek at Damsite (5013) for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Rush Creek at Damsite			
Desired Ecological Condition	Date	Flow Range (cfs)	1990	1991	1992	1993
Stream Productivity and Trout Habitat						
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	160	113	91	30
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	3	35	35	0
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	156	134	131	69
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	15	27	24	50
Geomorphic Thresholds						
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	0	0	0	28
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	0	0	0
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	0	0	0
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	0	0	0
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0	0
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	0	0	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0	0
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	>80	2	33	22	149
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	0	0	0	56
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 5	>275	0	0	0	4
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	7
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	0
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 5	>230	0	0	0	11
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0	7
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	0
Emergent Floodplains and Aggraded Floodplains with Side-Channels						
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	0	1	0	22
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	0	0	0	22
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	0	0	0	24

Table E-7. Continued.

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
60	6	15	87	26	64	105	0	4	11	3	8	83	10	62
71	5	0	0	0	36	25	21	45	45	29	6	5	81	72
112	18	103	69	53	61	95	91	129	89	134	79	70	52	98
6	57	103	121	85	68	54	33	6	58	21	47	39	33	28
0	21	13	5	18	6	7	4	0	4	0	5	19	0	0
0	26	0	0	6	0	0	0	0	0	0	0	5	0	0
0	18	0	0	9	0	0	0	0	0	0	9	29	0	0
0	25	0	0	6	0	0	0	0	0	0	0	5	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	153	151	153	148	86	75	51	18	79	34	122	118	35	38
0	18	15	49	45	31	24	2	0	22	0	17	16	0	7
0	22	5	0	0	0	9	0	0	3	0	22	22	0	0
0	22	0	0	20	0	0	0	0	0	0	17	13	0	0
0	24	0	0	16	0	0	0	0	0	0	9	4	0	0
0	22	6	0	20	0	12	0	0	6	0	22	22	0	0
0	22	0	0	22	0	0	0	0	0	0	19	13	0	0
0	24	0	0	16	0	0	0	0	0	0	10	4	0	0
0	22	15	17	22	21	22	0	0	22	0	22	22	0	7
0	22	6	19	22	11	11	2	0	4	0	22	22	0	0
0	24	4	18	24	2	2	0	0	0	0	24	20	0	0

Table E-8. NGDs for Rush Creek at Damsite plus Parker and Walker creek below the Conduit for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Rush Creek at Damsite		
Desired Ecological Condition	Date	Flow Range (cfs)	1990	1991	1992
Stream Productivity and Trout Habitat					
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	181	176	166
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	155	0	0
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	9	140	138
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	0	0	0
Geomorphic Thresholds					
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	0	0	0
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	0	0
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	0	0
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	0	0
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	0	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0
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	>80	0	0	0
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	0	0	0
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 5	>275	0	0	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0
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 5	>230	0	0	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0
Emergent Floodplains and Aggraded Floodplains with Side-Channels					
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	0	0	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	0	0	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	0	0	0

Table E-8. Continued.

+ Parker&Walker below Conduit															
1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
0	128	0	0	0	0	0	0	0	0	0	0	0	0	178	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140	134	92	127	132	108	144	136	138	153	148	157	94	95	153	142
13	0	142	26	33	66	21	29	39	21	16	16	78	68	0	17
6	0	0	7	6	6	7	7	7	8	7	11	4	5	0	6
0	0	0	3	0	18	1	1	0	0	0	0	17	17	0	0
5	0	0	12	5	3	4	4	0	0	0	0	3	4	0	5
0	0	0	3	0	18	1	1	0	0	0	0	18	18	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	9	0	0	0	0	0	0	16	6	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	153	71	80	153	61	66	63	42	50	38	140	142	0	54
19	0	62	22	21	24	14	15	10	18	10	15	20	17	0	15
10	0	0	10	10	13	16	16	5	0	6	0	12	13	0	15
12	0	0	12	12	18	4	3	0	0	0	0	18	18	0	4
3	0	0	3	3	9	0	0	0	0	0	0	9	9	0	0
12	0	0	13	14	15	18	19	9	7	9	7	14	17	0	17
13	0	0	14	14	20	6	5	0	0	0	0	20	20	0	5
4	0	0	5	5	11	0	0	0	0	0	0	11	11	0	0
21	0	18	22	22	22	22	22	16	18	17	16	22	22	0	22
20	0	22	22	22	22	13	13	0	0	0	0	22	22	0	12
11	0	24	13	13	23	4	4	0	0	0	0	19	18	0	3

Table E-9. NGDs for Rush Creek below the Narrows (SRF streamflows) for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Rush Creek below Narrows Actual				
Desired Ecological Condition	Date	Flow Range (cfs)	1990	1991	1992	1993	1994
Stream Productivity and Trout Habitat							
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	165	3	2	0	97
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	0	29	1	0	0
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	102	123	164	51	178
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	153	38	77	80	28
Geomorphic Thresholds							
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	0	0	0	18	0
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	0	0	0	0
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	0	0	0	0
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	0	0	0	0
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0	0	0
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	0	0	0	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0	0	0
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	>80	123	44	92	153	50
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	0	16	5	73	2
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 5	>275	0	0	0	0	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	0	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	0	0
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 5	>230	0	0	0	0	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0	0	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	0	0
Emergent Floodplains and Aggraded Floodplains with Side-Channels							
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	0	16	4	22	2
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	0	0	1	22	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	0	0	1	24	0

Table E-9. Continued.

1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
0	0	0	0	0	0	0	0	0	1	0	27	157	118
0	0	0	0	0	0	0	0	0	0	0	0	2	3
16	31	80	83	148	146	143	172	161	160	98	79	174	144
71	71	60	29	47	47	39	26	18	9	30	30	0	21
50	24	30	11	13	4	2	5	4	5	16	6	0	4
15	0	0	22	0	0	0	0	0	0	8	42	0	0
2	0	0	2	0	0	0	0	0	0	3	5	0	5
13	0	0	20	0	0	0	0	0	0	8	42	0	0
3	0	0	2	0	0	0	0	0	0	0	0	0	0
11	0	0	19	0	0	0	0	0	0	0	31	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
153	153	130	117	84	68	66	48	57	30	101	128	0	59
45	64	63	25	30	27	10	0	0	10	22	12	0	11
5	10	0	20	0	0	0	0	0	0	16	22	0	6
7	0	0	22	0	0	0	0	0	0	19	22	0	0
18	0	0	19	0	0	0	0	0	0	10	17	0	0
12	16	0	21	1	4	0	0	0	3	22	22	0	8
20	0	0	22	7	0	0	0	0	0	22	22	0	0
24	0	0	22	0	0	0	0	0	0	15	19	0	0
22	22	22	22	14	16	11	1	0	10	22	22	0	17
22	22	22	22	16	11	0	0	0	0	22	22	0	0
24	24	24	24	7	3	0	0	0	0	24	24	0	0

Table E-10. NGDs for Rush Creek recommended SEF streamflows for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Rush Creek Recommended SEF				
Desired Ecological Condition	Date	Flow Range (cfs)	1990	1991	1992	1993	1994
Stream Productivity and Trout Habitat							
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	181	181	181	181	181
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	95	95	95	0	95
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	84	84	84	127	84
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	0	0	0	46	0
Geomorphic Thresholds							
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	0	0	0	5	0
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	0	0	0	0
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	0	0	0	0
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	0	0	0	0
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0	0	0
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	0	0	0	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0	0	0
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	>80	0	0	0	74	0
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	0	0	0	40	0
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 5	>275	0	0	0	6	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	2	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	0	0
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 5	>230	0	0	0	8	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0	5	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	0	0
Emergent Floodplains and Aggraded Floodplains with Side-Channels							
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	0	0	0	16	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	0	0	0	22	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	0	0	0	22	0

Table E-10. Continued.

1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
181	181	181	181	181	181	181	181	181	181	181	181	181	181
0	0	0	0	0	0	0	0	0	0	0	0	95	0
130	127	127	138	141	141	170	183	170	183	138	138	84	141
74	46	46	70	40	40	47	42	47	42	70	70	0	40
5	5	5	4	4	4	3	0	3	0	4	4	0	4
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
118	74	74	104	65	65	62	51	62	51	104	104	0	65
28	40	40	33	23	23	6	0	6	0	33	33	0	23
0	6	6	0	8	8	0	0	0	0	0	0	0	8
14	2	2	10	0	0	0	0	0	0	10	10	0	0
7	0	0	1	0	0	0	0	0	0	1	1	0	0
0	8	8	2	12	12	0	0	0	0	2	2	0	12
17	5	5	13	0	0	0	0	0	0	13	13	0	0
8	0	0	4	0	0	0	0	0	0	4	4	0	0
6	16	16	9	22	22	7	0	7	0	9	9	0	22
22	22	22	22	9	9	0	0	0	0	22	22	0	9
24	22	22	24	0	0	0	0	0	0	24	24	0	0

Table E-11. NGDs for Rush Creek recommended SEF streamflows plus Parker and Walker creeks above the Conduit for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

Desired Ecological Condition	Date	Flow Range (cfs)	Rush Creek Recommended SEF +P&W 1990	1991	1992	1993	1994
Stream Productivity and Trout Habitat							
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	181	181	181	180	167
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	77	2	0	0	0
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	84	141	132	113	126
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	0	32	24	46	39
Geomorphic Thresholds							
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	0	0	0	5	0
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	0	0	0	0
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	0	0	4	0
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	0	0	0	0
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0	0	0
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	0	0	0	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0	0	0
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	>80	0	47	55	88	55
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	0	0	0	33	0
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 5	>275	0	0	0	8	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	3	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	0	0
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 5	>230	0	0	0	9	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0	5	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	0	0
Emergent Floodplains and Aggraded Floodplains with Side-Channels							
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	0	0	0	22	0
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	0	0	0	22	0
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	0	0	0	14	0

Table E-11. Continued.

below Conduit													
1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
153	81	178	163	178	174	181	179	181	181	174	181	181	181
0	0	0	0	0	0	0	0	0	0	0	0	1	3
83	109	105	112	130	121	121	121	133	131	89	86	139	87
50	44	52	49	40	53	50	56	24	59	38	33	35	52
9	16	10	14	4	3	5	0	5	0	24	11	0	4
6	1	0	5	1	1	0	0	0	0	6	5	0	0
5	5	5	1	4	4	0	0	0	0	2	1	0	4
6	1	0	5	1	1	0	0	0	0	6	5	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
130	98	97	113	76	82	62	64	46	66	111	113	54	76
24	36	35	45	24	24	9	19	11	12	44	41	0	23
13	8	8	1	11	10	0	0	0	0	2	4	0	10
22	4	3	16	0	0	0	0	0	0	14	13	0	0
24	0	0	7	0	0	0	0	0	0	5	4	0	0
16	9	9	18	14	13	1	0	2	0	11	18	0	12
22	7	5	22	0	0	0	0	0	0	22	22	0	0
24	0	0	17	0	0	0	0	0	0	16	17	0	0
22	22	22	22	22	22	10	20	10	12	22	22	0	22
22	22	22	22	14	13	0	0	0	0	22	22	0	12
24	18	16	24	5	4	0	0	0	0	24	24	0	3

Table E-12. NGDs for Rush Creek recommended SEF streamflows, with simulated spills, plus Parker and Walker creeks above the Conduit for RYs 1990-2008, computed for each runoff year, averages for each runoff year type, and averages for all runoff years combined.

			Rush Creek Recommended			
Desired Ecological Condition	Date	Flow Range (cfs)	1990	1991	1992	1993
Stream Productivity and Trout Habitat						
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	181	181	181	181
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	103	103	103	35
Abundant Productive Benthic Macro-Invertebrate Riffle Habitat	April 1 to September 30	40-110	75	75	75	101
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	0	0	0	31
Geomorphic Thresholds						
Spawning Gravel Mobilization in Pool Tails / Minor Bar Deposition	April 1 to September 30	200-250	0	0	0	4
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	0	0	0	0
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	0	0	0	0
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	0	0	0	0
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	0	0	0
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	0	0	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	0	0	0
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	>80	0	0	0	51
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	0	0	0	32
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 5	>275	0	0	0	7
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	2
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	0
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 5	>230	0	0	0	8
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0	3
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	0
Emergent Floodplains and Aggraded Floodplains with Side-Channels						
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	0	0	0	20
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	0	0	0	21
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	0	0	0	12

Table E-12. Continued.

SEF with Simulated Spills (Pre-Transition)														
1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
181	0	9	126	45	97	104	110	160	113	99	25	96	181	0
103	0	35	14	0	50	50	74	69	29	69	11	11	86	0
75	55	52	75	76	91	80	75	111	118	111	75	68	74	0
0	39	39	46	83	37	36	13	9	22	1	23	20	31	0
0	17	15	4	24	4	5	9	0	10	0	14	21	0	0
0	17	0	0	0	0	0	0	0	0	0	0	1	0	0
0	23	0	0	9	0	1	0	0	0	0	9	31	0	0
0	17	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	140	93	97	153	55	63	35	31	40	0	101	112	34	0
0	16	29	33	43	22	19	4	0	20	0	17	19	0	0
0	22	11	7	0	8	11	0	0	0	0	22	22	0	0
0	22	2	2	21	0	0	0	0	0	0	15	13	0	0
0	24	0	0	17	0	0	0	0	0	0	6	4	0	0
0	22	13	8	5	10	13	0	0	3	0	22	22	0	0
0	22	3	3	22	0	0	0	0	0	0	21	15	0	0
0	24	0	0	18	0	0	0	0	0	0	12	6	0	0
0	22	22	22	22	21	22	5	0	21	0	22	22	0	0
0	22	21	21	22	0	9	0	0	0	0	22	22	0	0
0	24	12	12	24	0	0	0	0	0	0	23	23	0	0

Table E-13. Summary of NGDs for Rush Creek for each of the hydrology data sets, with averages for each runoff year type, and averages for all runoff years combined.

Desired Ecological Condition	Date	Flow Range (cfs)	Rush Creek Unimpaired at Damsite						Rush Creek Unimpaired Below Narrows					
			Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
Stream Productivity and Trout Habitat														
Abundant Brown Trout Winter Holding Habitat	October 1 to March 31	25-45	30	26	38	36	60	38	51	47	58	60	76	0
Abundant Brown Trout Foraging and Holding Habitat Spring through Early-Fall	April 1 to September 30	15-35	40	33	31	15	13	27	39	22	29	15	5	23
Abundant Productive Benthic Macro-Invertebrate Riffle Habita	April 1 to September 30	40-110	52	51	42	45	58	50	60	62	52	50	57	57
Off-Channel Spring/Early-Summer Streamflow Connectivity	April 1 to July 30	90-160	31	28	26	27	28	28	34	34	23	24	36	31
Geomorphic Thresholds														
Spawning Gravel Mobilization in Pool Tails / Minor Bar Depositio	April 1 to September 30	200-250	7	10	12	17	9	10	10	12	8	14	7	10
General LWD Transport and Debris Jam Formation	April 1 to September 30	>450	1	7	7	14	41	14	2	11	11	22	52	19
Emergent Floodplain Deposition / Channel Maintenance / Significant Fine Bed Material Transport / Point Bar Extension / Minor Riffle Mobilization	April 1 to September 30	400-450	1	3	4	10	9	5	1	2	6	8	6	4
Intermediate Floodplain Deposition / Bar Formation / Significant Coarse Bed Material Transport / Deep Pool Scour / Coarse Riffle Mobilization	April 1 to September 30	450-600	1	6	7	13	31	11	2	7	10	20	24	12
Advanced Floodplain Deposition / Prominent Bar Formation / Significant Side Channel Entrance Alteration	April 1 to September 30	600-700	0	1	0	1	6	2	0	2	1	3	19	5
Delta Building Event	April 1 to September 30	>500 for 5+ consec days	0	4	4	7	29	9	1	7	7	14	44	0
Mainstem Channel Avulsion	April 1 to September 30	700-800	0	1	0	0	2	1	0	1	0	0	6	0
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	>80	53	65	75	97	112	79	61	76	82	107	127	89
Minimum Streamflows Recharging Shallow Groundwater and Saturating Emergent Floodplain Surfaces for Willows and Black Cottonwood : 120 cfs to 275 cfs	June 15 to August 26	120-275	7	10	13	29	17	14	11	19	20	29	16	18
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 5	>275	1	1	10	12	22	8	1	2	13	16	22	10
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>275	0	0	0	3	18	4	0	0	0	6	21	5
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>275	0	0	0	0	13	3	0	0	0	0	16	3
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 5	>230	1	2	11	16	22	10	2	4	16	18	22	11
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>230	0	0	0	5	20	5	0	0	0	9	22	6
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>230	0	0	0	0	15	3	0	0	0	2	19	4
Emergent Floodplains and Aggraded Floodplains with Side-Channels														
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 5	>120	5	11	20	21	22	15	8	17	22	22	22	17
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to July 27	>120	3	1	3	18	22	9	4	5	11	22	22	12
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 7	>120	1	0	0	14	21	7	1	1	3	20	24	9
Aggraded Floodplains w/o a Side-Channel (NGY)														
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 26	>275	1	1	10	15	39	12	1	2	13	23	43	15
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to August 17	>275	0	0	0	3	21	5	0	0	0	6	26	7
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 26	>275	0	0	0	0	13	3	0	0	0	0	18	4
Interfluves/Depressions within Aggraded Floodplains w/o a Side-Channel (NGY)														
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 26	>230	1	2	11	21	42	15	2	4	16	27	43	17
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to August 17	>230	0	0	0	5	25	6	0	0	0	9	31	8
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 26	>230	0	0	0	0	16	3	0	0	0	2	23	5
Emergent Floodplains and Aggraded Floodplains with Side-Channels (NGY)														
Number of Days that a yellow willow seed could land a moist surface and germinate	June 14 to July 26	>120	8	12	23	39	43	23	12	21	33	43	43	29
Number of Days that a black cottonwood seed could land on a moist surface and germinate	July 6 to August 17	>120	3	1	3	23	35	12	4	5	11	30	40	17
Number of Days that a narrowleaf willow seed could land on a moist surface and germinate	July 15 to August 26	>120	1	0	0	14	29	8	1	1	3	21	34	11

Table E-13. Continued.

Rush Creek at Damsite						Rush Creek at Damsite + Parker&Walker below Conduit						Rush Creek below Narrows Actual						Rush Creek Recommended SEF						Rush Creek Recommended SEF +P&W below Conduit					
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
87	5	77	44	31	0	51	1	54	14	10	0	86	0	39	0	7	0	181	181	181	181	181	0	178	181	178	146	168	171
45	35	44	0	4	27	28	15	18	0	0	13	6	0	1	0	0	2	95	0	0	0	0	25	16	0	1	0	0	4
117	111	85	80	55	92	121	121	96	49	49	91	148	159	146	54	69	119	84	177	141	127	136	130	124	127	113	109	93	114
21	30	50	91	57	46	37	51	52	87	53	54	59	23	38	70	40	46	0	45	40	46	71	38	26	47	48	47	43	41
0	2	4	15	16	7	0	7	7	25	15	10	0	4	7	24	21	10	0	2	4	5	4	3	0	3	4	10	15	6
0	0	0	0	9	2	0	0	0	0	32	7	0	0	0	0	22	5	0	0	0	0	0	0	0	0	1	0	6	1
0	0	0	0	16	3	0	0	1	3	10	3	0	0	2	0	3	1	0	0	0	0	0	0	0	0	4	5	2	2
0	0	0	0	9	2	0	0	0	0	29	6	0	0	0	0	21	4	0	0	0	0	0	0	0	0	1	0	6	1
0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	2	0	0	0	0	0	21	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	46	66	151	135	78	38	79	90	152	145	95	47	50	70	145	125	87	0	57	65	74	108	56	53	60	78	94	117	75
0	6	21	40	24	0	2	10	31	61	19	0	5	5	23	67	26	0	0	3	23	40	32	0	0	13	24	35	39	20
0	1	3	3	17	5	0	2	6	5	22	7	0	0	2	3	16	4	0	0	8	6	0	2	0	0	10	8	5	4
0	0	0	2	18	4	0	0	0	2	20	4	0	0	0	0	18	4	0	0	0	2	11	3	0	0	0	3	16	4
0	0	0	0	13	3	0	0	0	0	14	3	0	0	0	0	16	3	0	0	0	0	3	1	0	0	0	0	10	2
0	2	4	6	22	6	0	3	10	12	22	9	0	1	4	5	19	6	0	0	12	8	2	3	0	1	13	9	16	7
0	0	0	2	19	4	0	0	0	3	22	5	0	0	2	0	22	5	0	0	0	5	14	4	0	0	0	6	22	6
0	0	0	0	14	3	0	0	0	0	18	4	0	0	0	0	20	4	0	0	0	0	5	1	0	0	0	0	19	4
0	6	17	18	22	11	2	8	20	22	22	13	4	6	16	22	22	13	0	4	22	16	8	8	0	13	22	22	22	14
0	2	7	16	22	9	0	5	15	22	22	12	0	0	9	22	22	10	0	0	9	22	22	10	0	0	13	22	22	10
0	0	1	15	23	7	0	0	8	24	24	10	0	0	3	24	24	9	0	0	0	22	24	9	0	0	4	16	24	8
0	1	3	5	34	9	0	2	6	7	41	11	0	0	2	3	33	8	0	0	8	8	11	5	0	0	10	11	21	8
0	0	0	2	22	5	0	0	0	2	25	6	0	0	0	0	24	5	0	0	0	2	11	3	0	0	0	3	20	5
0	0	0	0	14	3	0	0	0	0	17	4	0	0	0	0	17	4	0	0	0	0	3	1	0	0	0	0	11	2
0	2	4	8	40	11	0	3	10	15	43	13	0	1	7	5	40	10	0	0	12	13	16	7	0	1	13	15	37	12
0	0	0	2	24	5	0	0	0	3	29	7	0	0	2	0	31	7	0	0	0	5	14	4	0	0	0	6	29	7
0	0	0	0	15	3	0	0	0	0	22	5	0	0	0	0	23	5	0	0	0	0	5	1	0	0	0	0	20	4
0	7	24	33	43	20	2	12	35	43	43	25	5	6	25	43	43	22	0	4	31	37	29	18	0	13	35	43	43	24
0	2	7	26	37	13	0	5	17	42	40	19	0	0	9	43	40	17	0	0	9	31	35	14	0	0	13	25	40	14
0	0	1	22	32	10	0	0	8	37	35	15	0	0	3	40	36	14	0	0	0	22	26	9	0	0	4	16	33	10

APPENDIX F. GRANT LAKE RESERVOIR MODELING SCENARIOS

The spreadsheet model developed for the Synthesis Report analyses is described in Report Section 3.4 and Section 6. Each scenario provided an output of daily average Grant Lake Reservoir (GLR) storage (in acre-feet [af]) for the 19 year period of analysis (RYs 1990 to 2008). These output data were used to compute the NGDs for each runoff year in which GLR storage volume was exceeded, for each modeled scenario. The NGDs are compiled in Table E-1.

The output GLR storage chart is presented in this Appendix for each of the following scenarios:

- Scenario 1a: Actual Historical Conditions
- Scenario 1b: Predicted Historical Conditions
- Scenario 2: Historical Rush Creek and Exports; Lee Vining Creek SEF streamflows
- Scenario 3: Historical Exports; Rush and Lee Vining SEF streamflows
- Scenario 4: Rush and Lee Vining SEF streamflows; 16,000 af Export; No Export Curtailment
- Scenario 5: Rush and Lee Vining SEF streamflows; 16,000 af Export; 3 Month curtailment
- Scenario 6: Rush and Lee Vining SEF streamflows; 16,000 af Export; 3 Month curtailment; Change RY2008 to Dry-Normal I [BASELINE SCENARIO]
- Scenario 10: BASELINE SCENARIO + Export Remaining Yield from Each Runoff Year (~30,000 af)
- Scenario 11: BASELINE SCENARIO + Export Remaining Yield from Each Runoff Year (~30,000 af); constrain RY1995 to 10,000 af export.

Table E-1. NGD computations for different Grant Lake Reservoir storage volumes for each modeled scenario.

	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					
	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
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
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
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
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
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
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
Peak Discharge below MGORD	0	0	68	119	255	83							128	233	297	231	485	268	112	192	392	421	489	301

Table E-1. Continued.

Scenario 4B: Rush and Lee Vining SEFs; 16K Export; NO Curtailment						Scenario 4: 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						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	Dry	Dry-Normal	Normal	Wet-Normal	Wet/Extreme-Wet	All Runoff Years
73	0	30	0	0	24	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	335	365	365	341	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
216	365	274	354	365	310	243	365	279	354	365	318	243	365	365	354	365	331	216	365	365	354	365	324	287	365	365	316	350	334	287	365	365	362	365	344
141	365	243	342	365	283	154	365	243	344	365	287	154	365	261	344	365	290	141	365	246	342	365	284	80	65	345	126	284	169	80	365	365	285	350	274
111	365	243	313	365	271	117	365	243	324	365	274	117	365	243	324	365	274	111	365	243	313	365	271	7	0	4	0	86	20	7	99	229	203	300	154
6	35	49	103	187	72	5	42	42	93	169	67	5	42	42	93	169	67	6	35	49	103	187	72	0	0	0	0	4	1	0	0	0	22	69	18
82	170	387	409	472	283	91	191	392	405	492	294	91	191	292	405	492	278	82	170	287	409	472	267	70	140	280	380	392	235	70	140	320	380	428	248

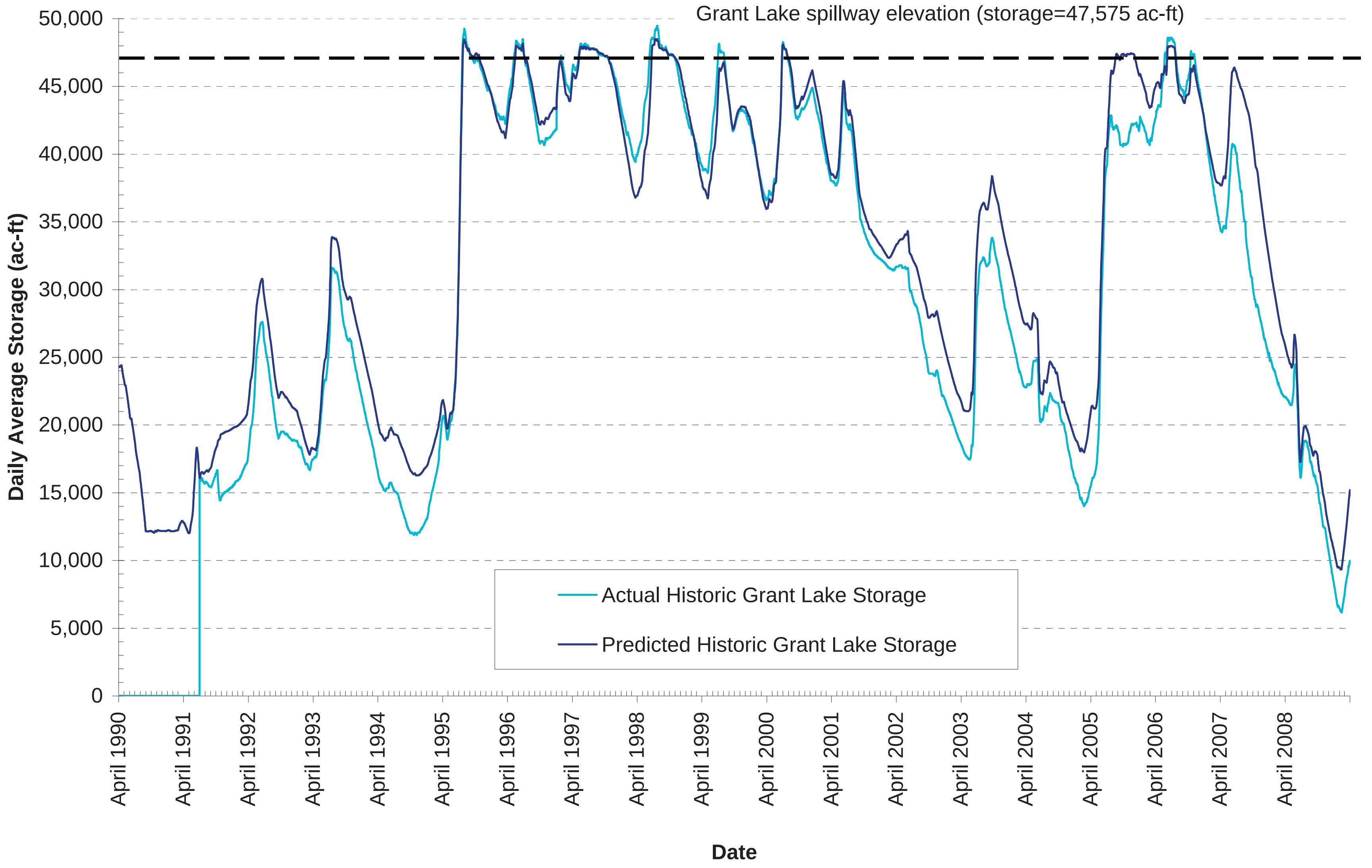


Figure F-1. Scenario 1: Actual and predicted historical conditions.

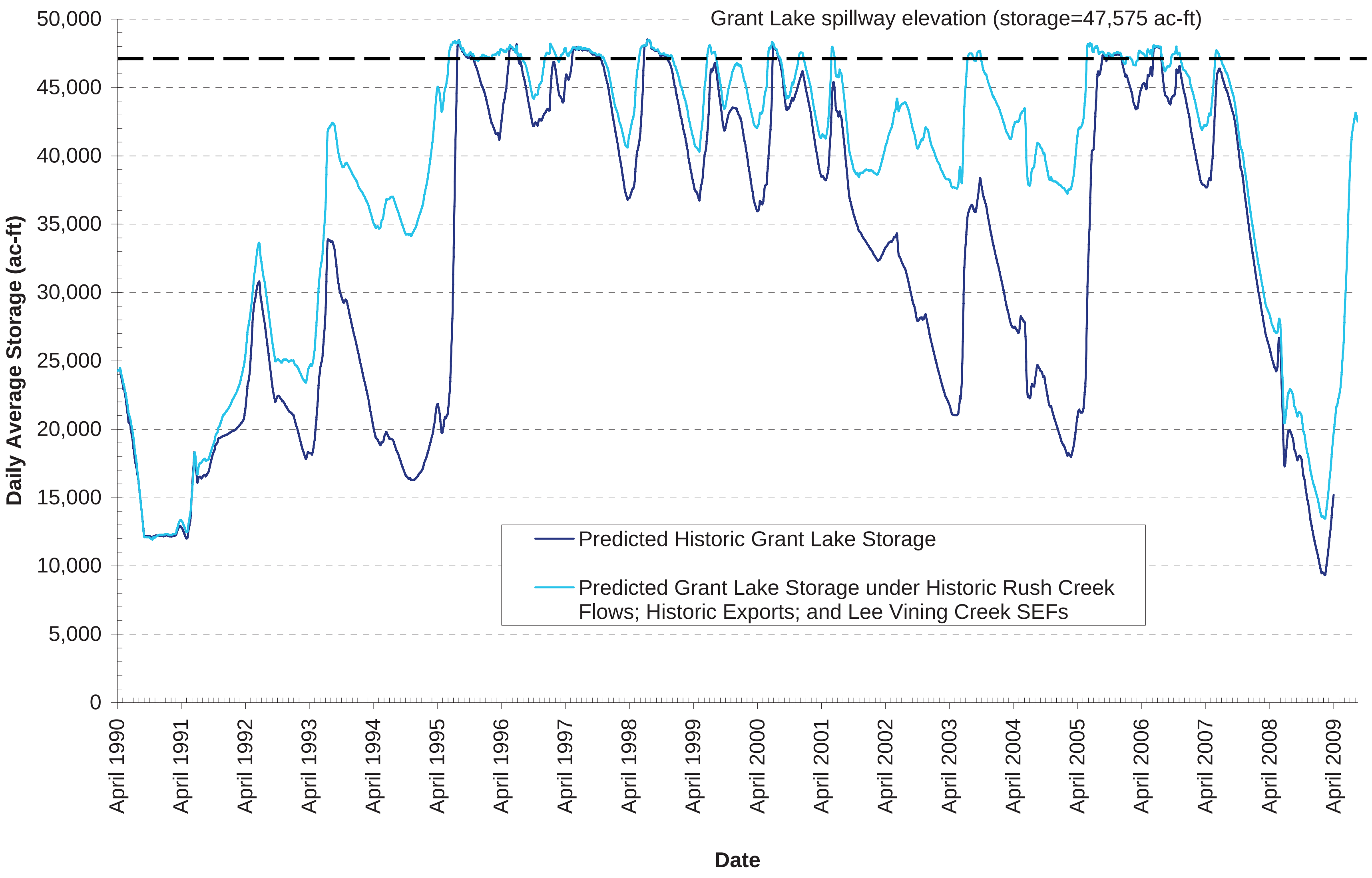


Figure F-2. Scenario 2: Historical Rush Creek and Exports; Lee Vining Creek SEF streamflows.

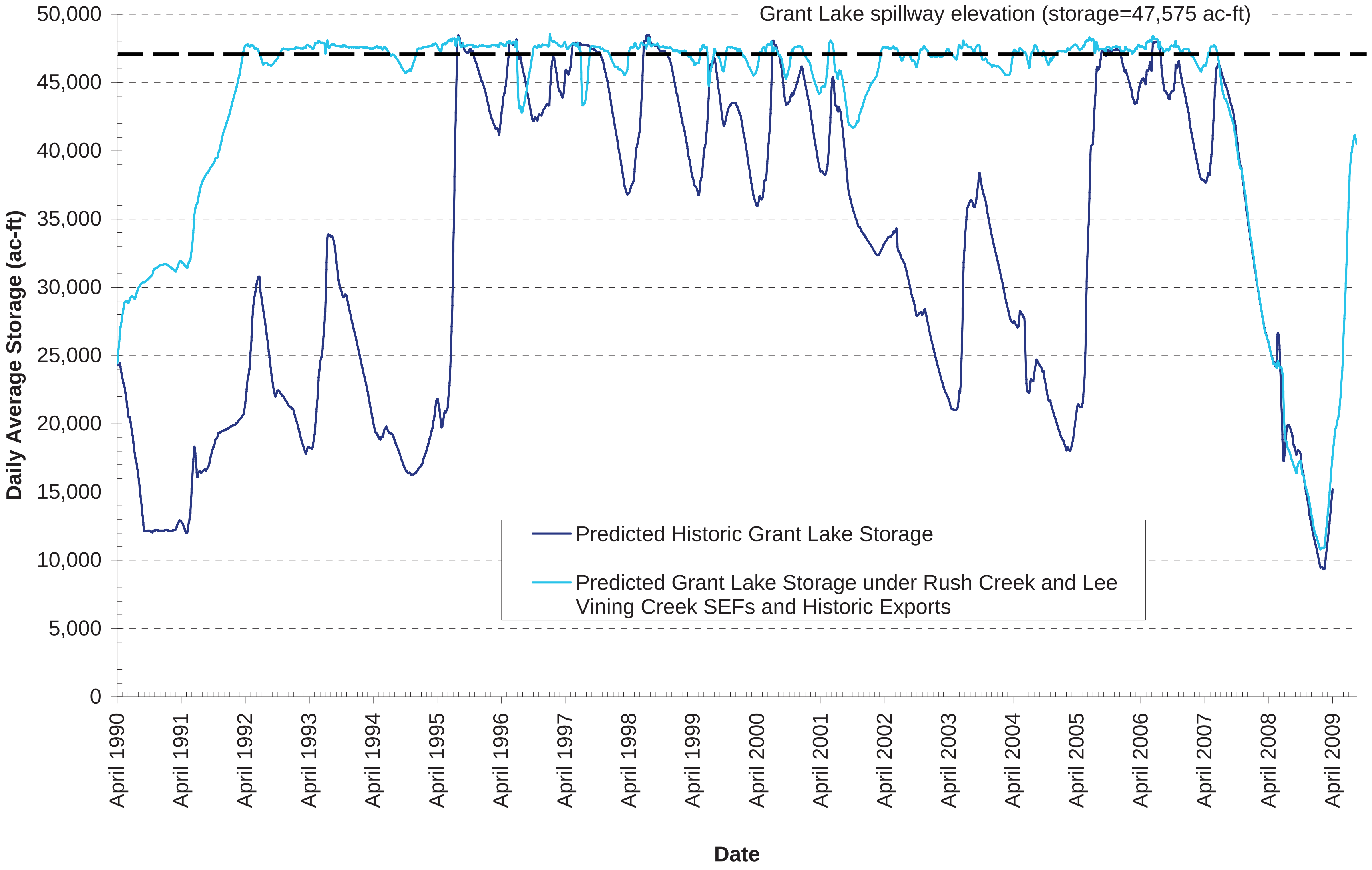


Figure F-3. Scenario 3: Historical Exports; Rush and Lee Vining SEF streamflows.

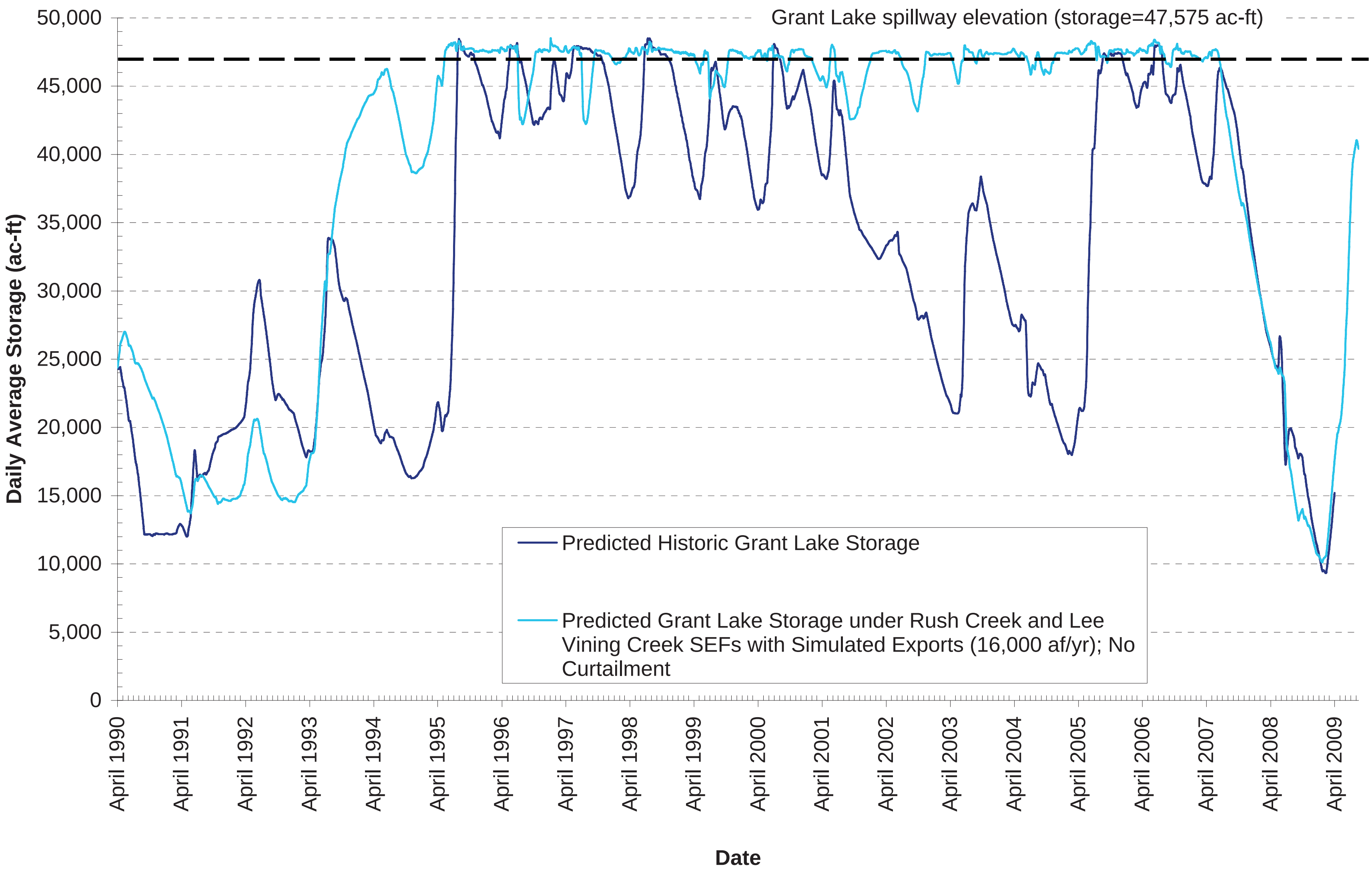


Figure F-4. Scenario 4: Rush and Lee Vining SEF streamflows; 16,000 af Export; No Export Curtailment.

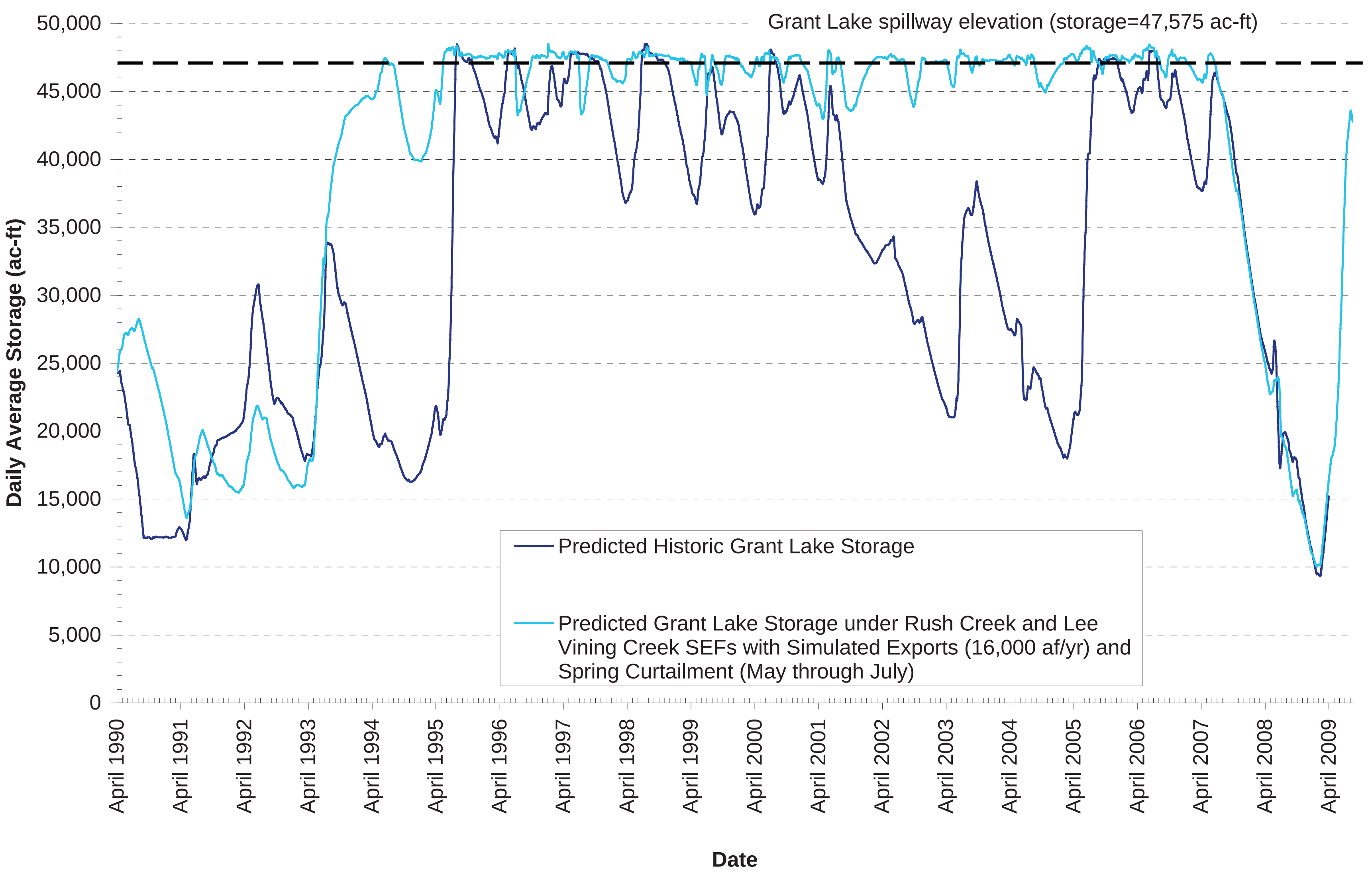


Figure F-5. Scenario 5: Rush and Lee Vining SEF streamflows; 16,000 af Export; 3 Month curtailment.

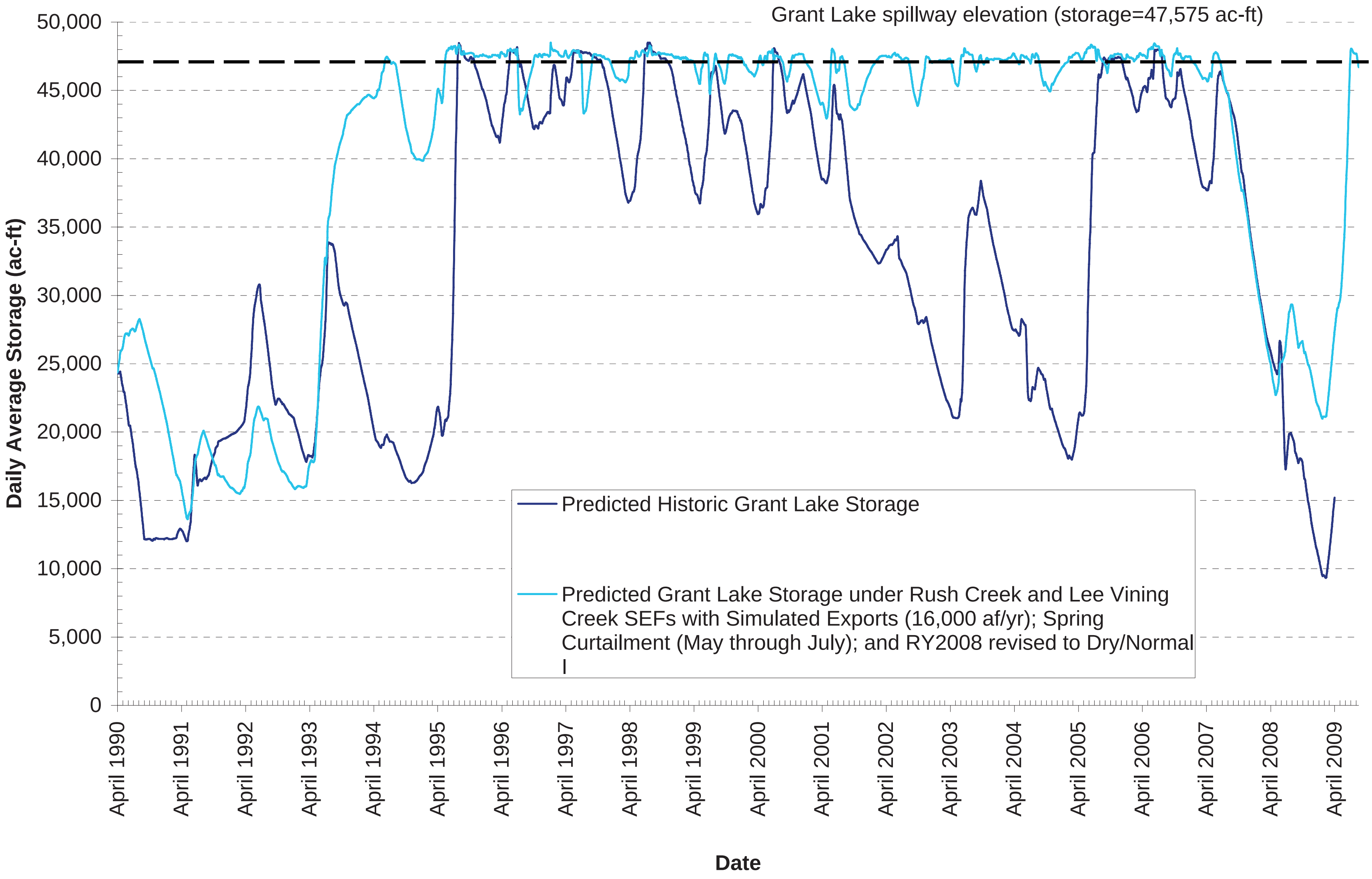


Figure F-6. Scenario 6: Rush and Lee Vining SEF streamflows; 16,000 af Export; 3 Month curtailment; RY2008 revised to Dry-Normal I [BASELINE SCENARIO].

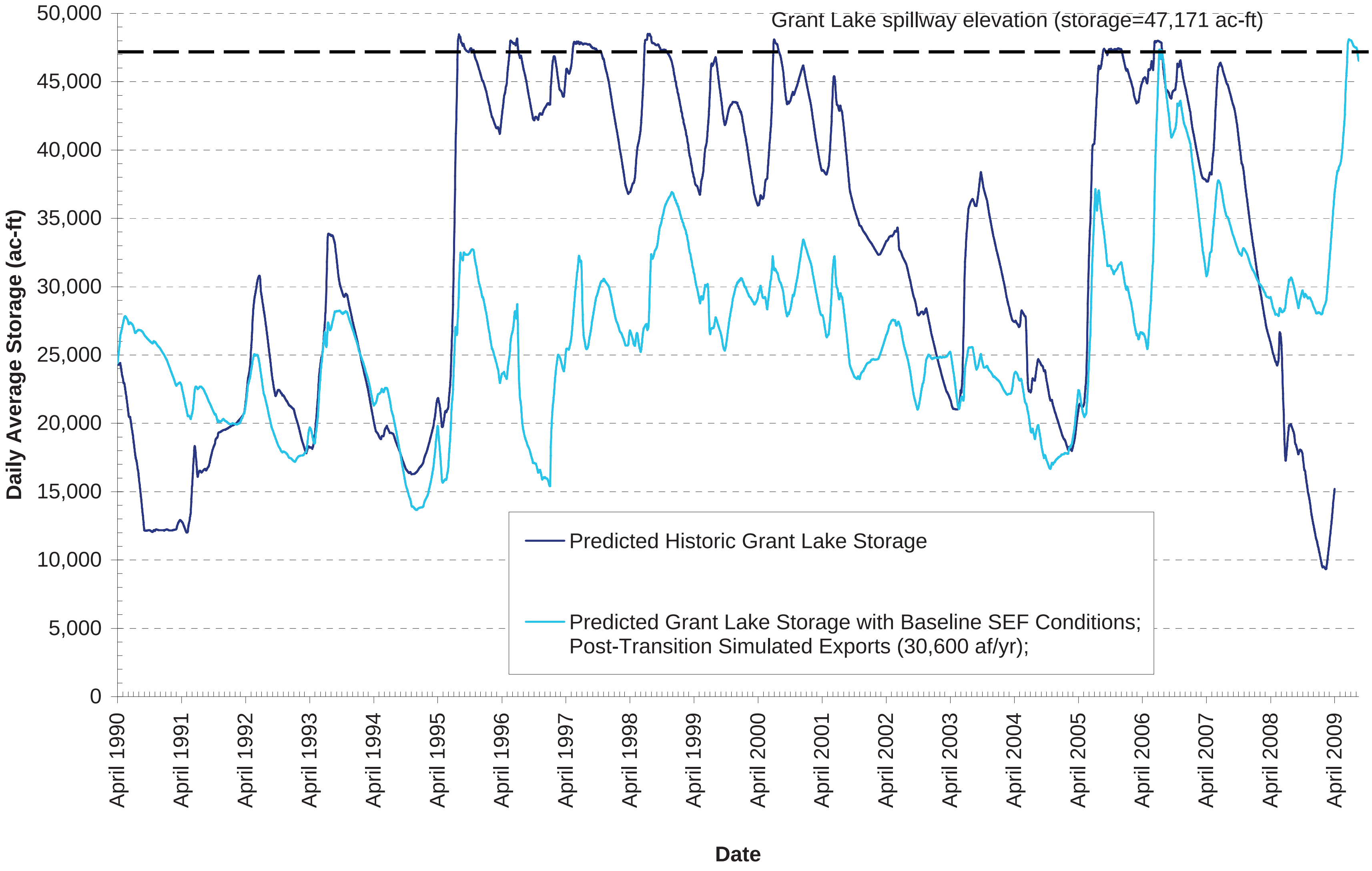


Figure F-7. Scenario 10: BASELINE SCENARIO + Export Remaining Yield from Each Runoff Year (~30,000 af).

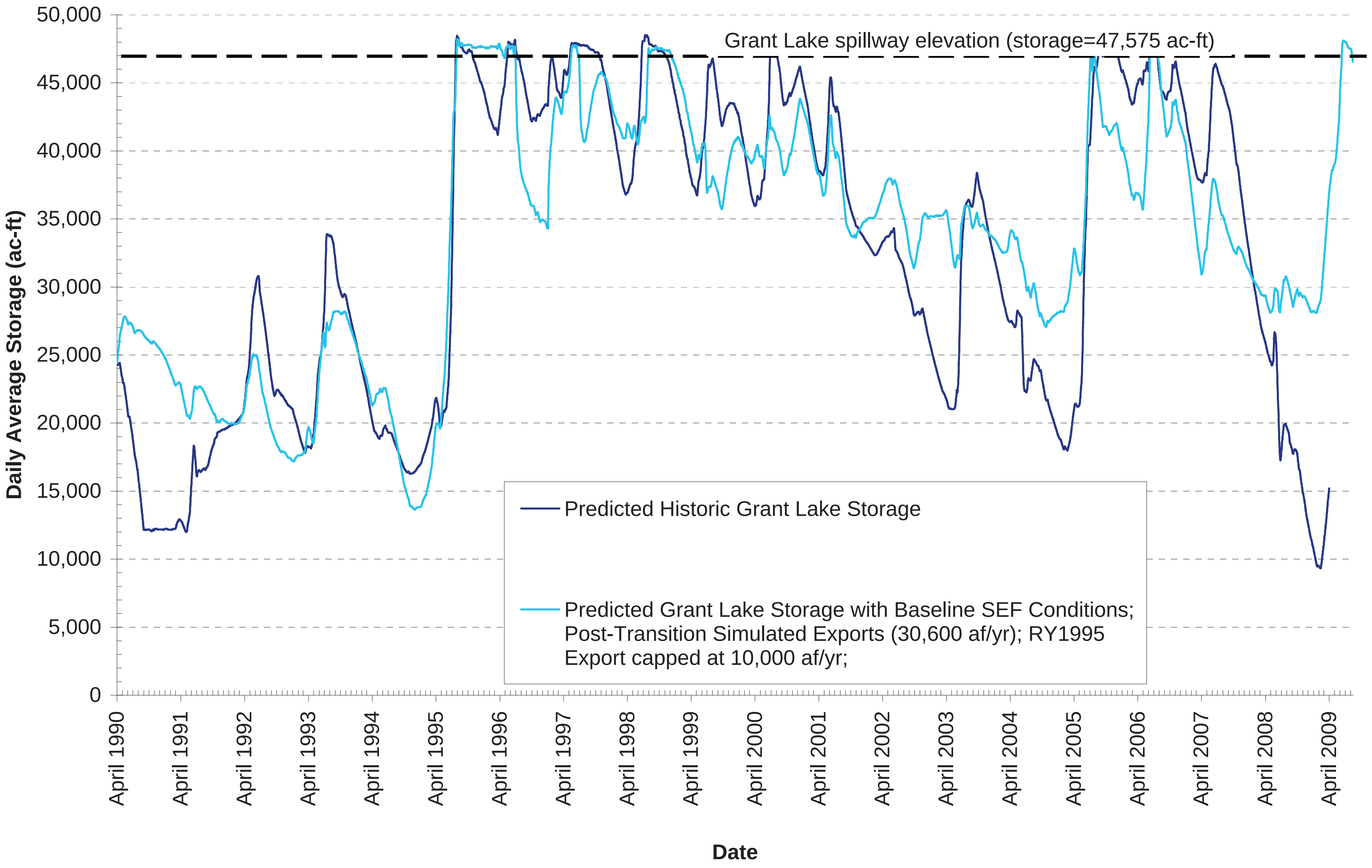


Figure F-8. Scenario 11: BASELINE SCENARIO + Export Remaining Yield from Each Runoff Year (~30,000 af); constrain RY1995 to 10,000 af export.