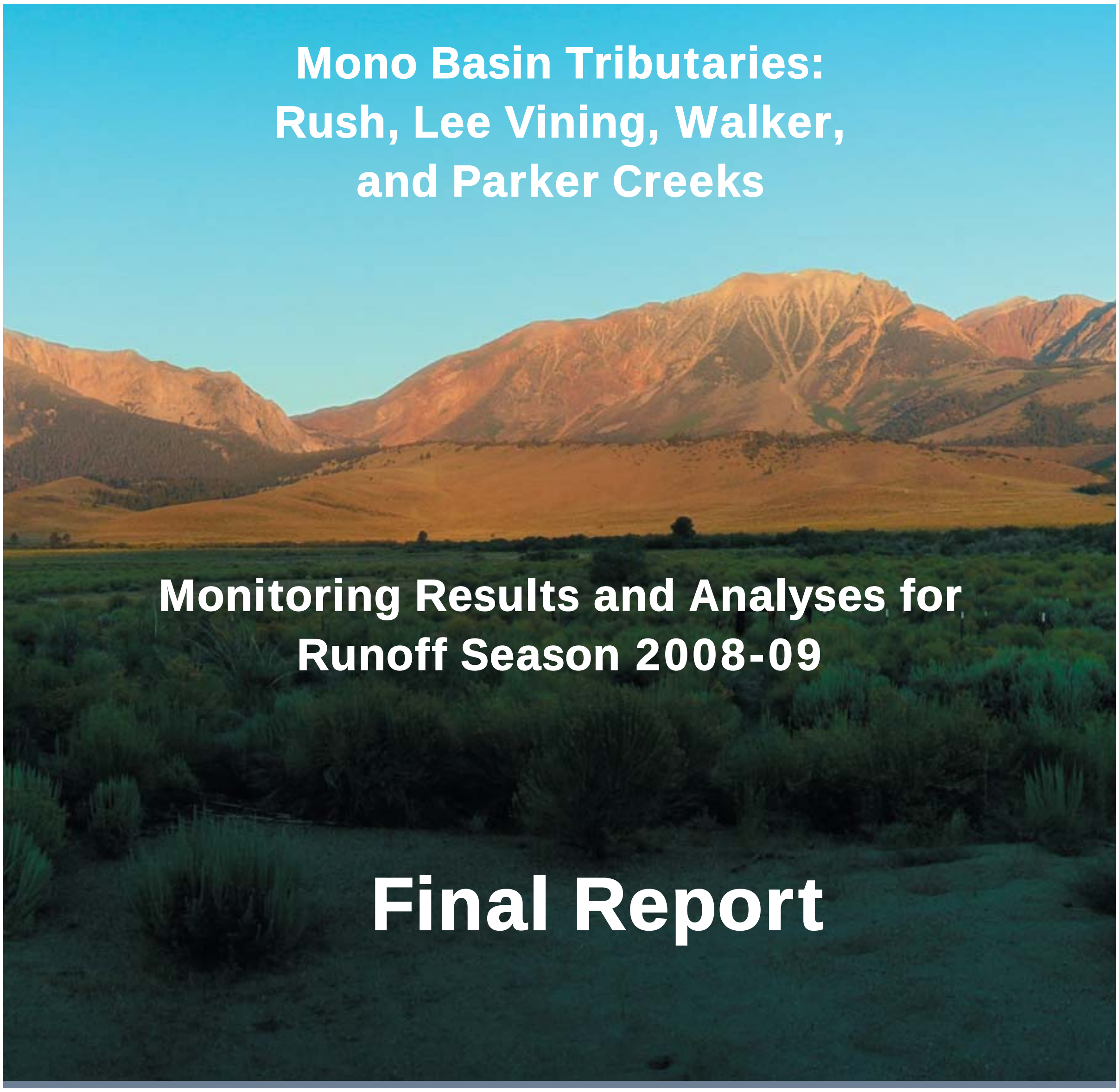
Chapter 4

Mono Basin Tributaries:
Lee Vining, Rush, Walker, and Parker Creeks

Monitoring Results and Analysis
For Runoff Season 2008-09



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Monitoring Results and Analyses for Runoff Season 2008-09

Final Report

Prepared for:
Los Angeles Department of Water and Power

Prepared by:
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April 20, 2009

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1 INTRODUCTION

A decade has passed since the State Water Resources Control Board Orders WR 98-05 and 98-07 were adopted by the Board (on September 2 and November 19, 1998, respectively). Since the Orders were adopted, the appointed Stream Scientists and the Department of Water and Power (DWP) have directed the restoration and monitoring of the four Mono Lake tributaries (Figure 1). Participants in the Mono Basin settlement meet routinely at least twice each year, and communicate extensively about stream and lake restoration issues. Extensive data collection and analysis has taken place in the Mono Basin. In summary, the restoration and monitoring process established by the Orders has functioned well during the preceding ten years.

During the past decade, stream ecosystem recover has been dramatic. The four tributary streams have witnessed a range of runoff conditions producing variable snowmelt flood and baseflow conditions. The 10-year hydrologic time series (Figure 2) has been tailor-made for research and monitoring, with annual snowmelt peaks ascending from 2001 to 2006, then absent (on Rush Creek) during RY 2007's dry conditions. In 1995, 1998, and again in 2006 Rush Creek received large snowmelt floods exceeding 500 cfs below the Mono Gate One Return Ditch (MGORD), and larger below the Narrows. In 2006, Lee Vining Creek had its highest snowmelt flood (457 cfs below Intake) (Figure 3) since the flood of 1967, with a recurrence interval nearing 20 years. Parker and Walker creeks continue to flow largely unimpaired, with only occasional summer streamflow alterations at their upstream impoundments. Finally, the past two years have seen especially dry conditions; the Mono Basin has weathered dry and below average runoff years and is facing a third below average year heading into 2009. The two-year running average annual yield for the Mono Basin for RYs 2007-08 was the driest two year period since the drought of 1990-92. Runoff year 2007 was the third driest since DWP diversions began in 1941.

During RY 2008, the stream monitoring teams conducted several priority studies and data collection activities in the basin. The Rush Creek Habitat Flow Study, contemplated for several years, was implemented in August 2008 as a joint activity among both stream scientists' crews, DWP crews, and with active participation and assistance from the Mono Lake Committee (MLC) and California Trout (CalTrout). The fisheries monitoring team also assembled data and developed a water temperature simulation model for Rush Creek below Grant Reservoir. We collected numerous flow measurements on Rush Creek, spread throughout the spring and summer seasons and intensively during the habitat flow study, and the data were used to evaluate streamflow losses to groundwater below the MGORD. We re-surveyed our established cross sections along Rush Creek and repeated stream substrate measurements (pebble counts) to evaluate surface particle size changes during the past decade. Finally, we continued to track shallow groundwater elevations during low-flow and snowmelt periods, exploring causal mechanisms linking surface flow, groundwater, and riparian vegetation responses.

Looking forward to 2009, the Mono Basin stream restoration program has developed a plan to culminate the preceding intensive phase of hydrologic, geomorphic, riparian, and fisheries data collection in the Mono Basin, and submit a Synthesis Report to the SWRCB. This Synthesis Report will summarize the effectiveness of the flow regime established in the Orders, and may recommend modifications to the Stream Restoration Flows and Baseflows required in Order WR 98-05. This plan is in accordance with SWRCB Division of Water Rights staff, and Order WR 98-05 Section 1.b(2)(a), which states:

> *"The stream monitoring team shall evaluate and make recommendations, based on the results of the monitoring program, regarding the magnitude, duration and frequency of the SRFs necessary for the restoration of Rush Creek; and the need for a Grant Lake bypass to reliably achieve the flows needed for restoration of Rush Creek below its confluence with the*

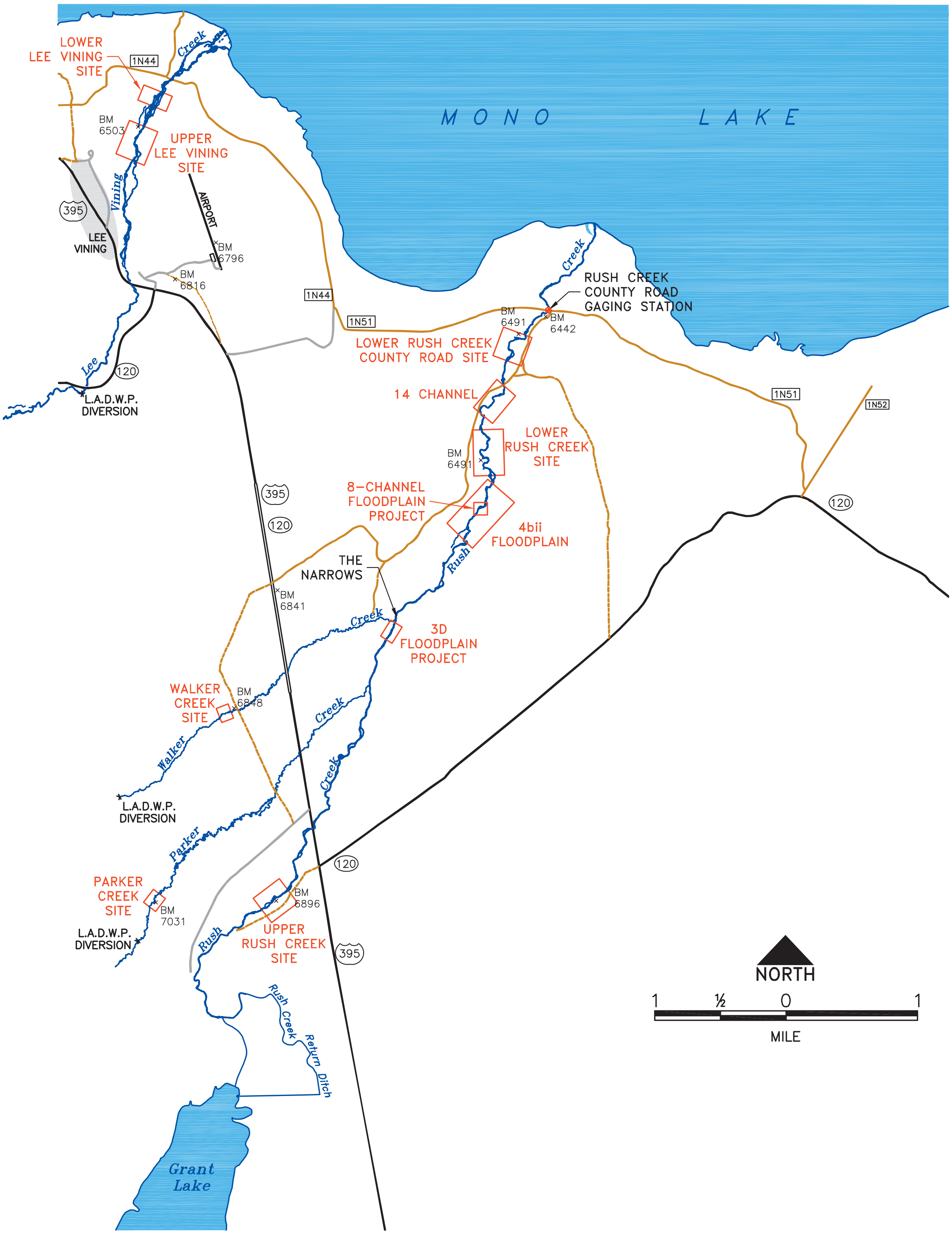

Figure 1. Location of Rush, Parker, Walker, and Lee Vining creek monitoring sites in the Mono Basin, CA.

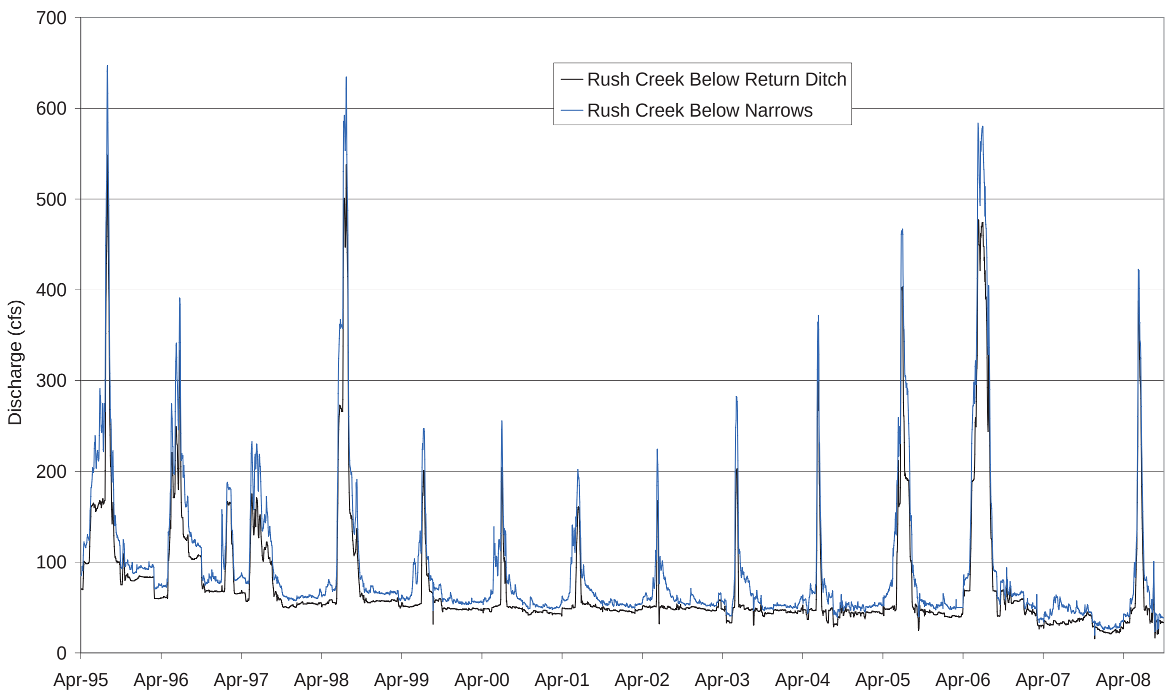

Figure 2. Daily average discharge for Rush Creek below the Return Ditch and below the Narrows since Runoff Year 1995, showing the variation in annual snowmelt peaks since monitoring began under the State Water Board Order 98-05.

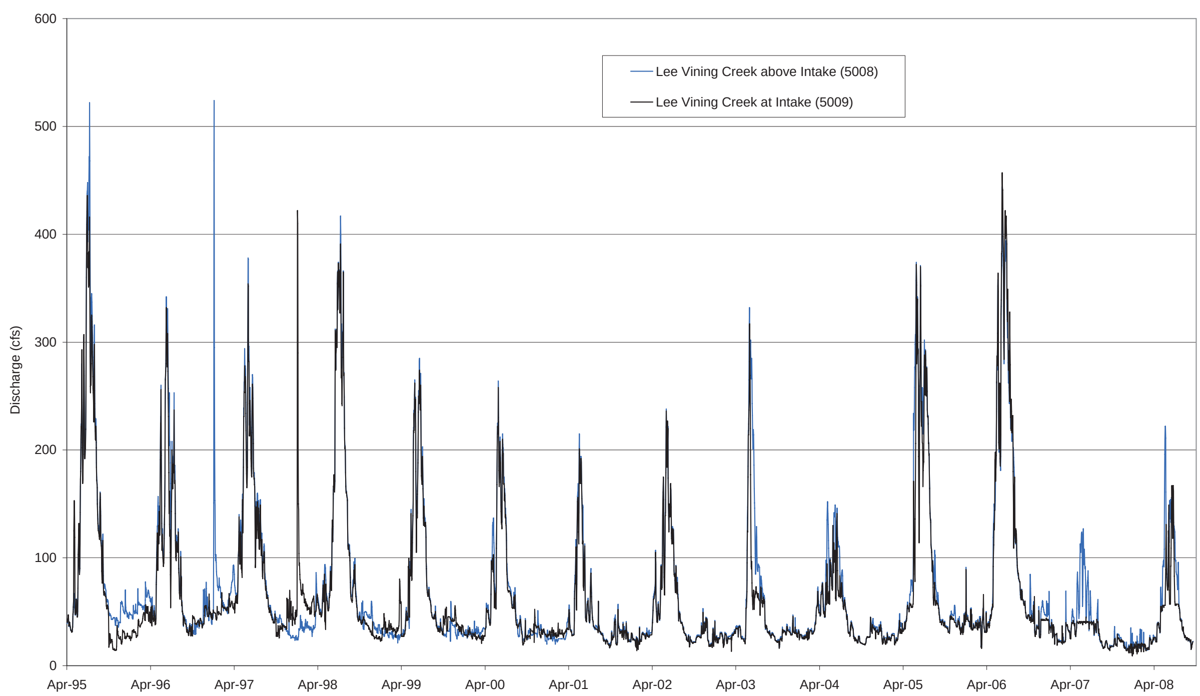

Figure 3. Daily average discharge for Lee Vining Creek above and below the diversion intake since Runoff Year 1995.

Rush Creek Return Ditch. This evaluation shall take place after two data gathering cycles (as defined in the stream monitoring plan), but at no less than 8 years nor more than 10 years after the monitoring program begins."

The Synthesis Report will be accompanied by a long-term Monitoring Plan prepared by the Stream Scientists, and a revised Grant Lake Operation Management Plan prepared by DWP.

2 HYDROLOGY

2.1 Runoff Year 2008-09 Annual Hydrographs

Following the extremely dry Runoff Year 2007, the Eastern Sierra received only a moderate snow pack during the winter 2007-08, again falling below the annual mean. The April 1, 2008 forecast projected the runoff year as "Normal" according to the provisions of Order 98-05, with predicted runoff of 105,200 acre-feet (af), or 86% of the 1951 to 2000 average runoff of 122,557 af. Based on this forecast, Runoff Year (RY) 2008 ranked the 37th wettest year during the period from 1941 to 2005 (68 years), with an exceedence probability of 54%. The Normal runoff conditions following the extremely dry RY 2007 combined to allowed Grant Reservoir to fall from an April 1, 2008 elevation of 7,104 ft and 22,045 af storage to an elevation below 7,081.5 ft and storage volume below 6,600 af as of January 1, 2009. Mono Lake elevation also fell during the 2008 runoff season, from an April 1, 2008 elevation of 6,383.3 ft MSL to 6382.1 ft by November 2008. The end-of-year runoff totals indicate a lower RY 2008 annual yield than the April 1, 2008 forecast predicted.

2.1.1 Rush Creek

The Normal runoff year class requires baseflow releases for Rush Creek of 47 cfs from April to September and 44 cfs from October to March, or to match the inflow to Grant Reservoir, whichever is less; the required Stream Restoration Flow (SRF) releases are 380 cfs for 5 days followed by 300 cfs 7 days. Flow releases to Rush Creek from the MGORD remained below the prescribed 47 cfs during April 2008, instead matching inflow to Grant Lake as specified by Order 98-05. During May, flow releases began ramping, and the SRF releases below the Return Ditch peaked at 388 cfs on June 7, 2008 (Figure 4; Table 1). Flow releases from the MGORD were augmented with Lee Vining flow through the 5-siphon bypass from June 3 to June 17. The annual peak had a recurrence interval of 1.4 yr on the unimpaired flood record, and 5.5 yr recurrence on the regulated (Rush Creek at Damsite) flood record. The SRF releases to Rush Creek exceeded the required 380 cfs for three of the five days, and averaged 376 cfs over the five day peak period. The SRF releases then remained above 300 cfs for seven days before receding gradually over a 20-day period to baseflows of 47 cfs on July 5, 2008. The maximum ramping rate during the SRF recession was 15.5% per day.

Below the Narrows on Rush Creek, peak flows were higher due to contributions from Parker and Walker creeks. The peak flow below the Narrows (calculated from Return Ditch releases + Lee Vining augmentation + Parker Creek + Walker Creek) was 423 cfs on June 7, 2008, augmented by 35 cfs from Parker and Walker creeks. This flow also had a recurrence interval of approximately 1.3 years from the flood frequency analysis of unregulated peak flows.

In RY 2008, operations by Southern California Edison (SCE) significantly impaired the Rush Creek snowmelt flood above Grant Lake. The estimated unimpaired flows on Rush Creek, "Rush Creek Runoff", were calculated by summing the daily average discharge at the Rush Creek at Damsite gage with the mean monthly storage change at the three SCE reservoirs in the Rush Creek Drainage --

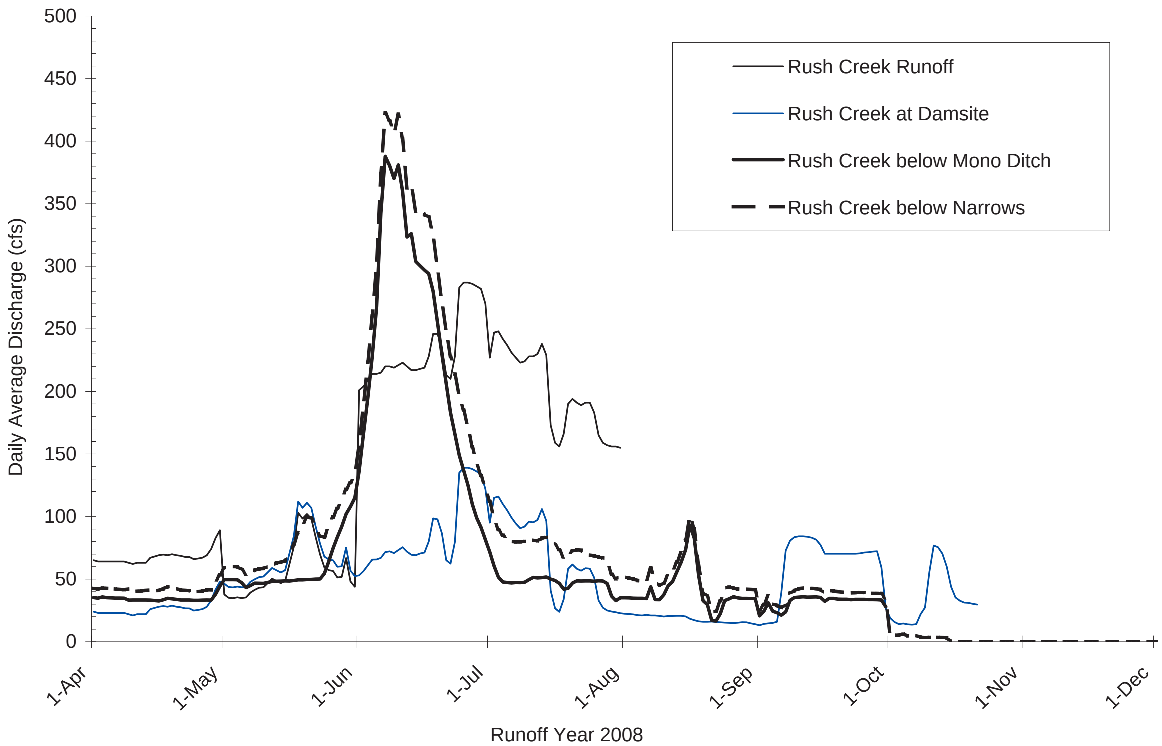

Figure 4. Annual hydrograph of daily average flows for Runoff Year 2008 for Rush Creek Runoff (computed unimpaired), Rush Creek at Damsite, Rush Creek below the Mono Gate One Return Ditch, and Rush Creek below the Narrows.

Waugh, Gem, and Agnew lakes. The Rush Creek Runoff peak was 287 cfs, whereas the Rush Creek at Damsite peak was 139 cfs. The Rush Creek Runoff peak occurred on June 25 and 26, 2008. The estimated unimpaired daily average peak discharge below the Narrows (Rush Creek Runoff + Parker Creek + Walker Creek) was 335 cfs on June 25, 2008, with recurrence interval of 1.12 years on the unimpaired (below Narrows) record.

2.1.2 Lee Vining Creek

The Lee Vining snowmelt runoff extended from May 6 to July 24, 2008. Lee Vining Creek also had modest peak flows during the 2008 runoff season (Figure 5; Table 1) with an early-season peak in May, followed by several smaller peaks in June. The unimpaired 'Lee Vining Creek Runoff' estimate and the 'Lee Vining Creek above Intake' gage had daily average peak flows of 224 cfs and 222 cfs, respectively, both on May 19, 2008. The recurrence interval for both these peaks was 1.5 years using the regulated record.

The Lee Vining Creek diversion operations captured what was to be the largest RY 2008 peak for Lee Vining Creek above Intake (on May 19); the annual peak of 167 cfs for Lee Vining Creek below Intake therefore occurred on June 17 and again on June 22-23, 2008. Flow diversions occurred between and after these peaks, with the post-peak diversions reducing the snowmelt recession relative to the Lee Vining above Intake hydrograph. The below Intake hydrograph receded to 57 cfs on July 1, whereas the above Intake hydrograph reached 54 cfs on July 19, 2008. Riparian phenology data from RY 2005 indicate this early period in July may be a critical seed germination period for riparian hardwood species.

Table 1. Annual peak flows for Rush, Lee Vining, Parker, and Walker creeks for RY 1997-2008.

Station	RY 1997 (cfs)	RY 1998 (cfs)	RY 1999 (cfs)	RY 2000 (cfs)	RY 2001 (cfs)	RY 2002 (cfs)	RY 2003 (cfs)	RY 2004 (cfs)	RY 2005 (cfs)	RY 2006 (cfs)	RY 2007 (cfs)	RY 2008 (cfs)
Runoff Year Type	Wet/Normal	Wet	Normal	Normal	Dry/Normal II	Dry/Normal I	Dry/Normal II	Dry/Normal I	Wet	Wet	Dry	Normal
Runoff Volume (AF)	143,433	172,744	112,946	111,621	92,630	90,227	100,000	89,101	178,105	189,157	56,069	
Percent of Average Runoff	117%	141%	92%	91%	76%	74%	82%	73%	146%	155%	44%	
Rush Creek Runoff [1]	411	601	405	502	491	243	460	228	541	630	161	287
Rush Creek at Damsite (5013)	250	495	222	372	231	102	311	118	441	483	148	139
Rush Creek below Return Ditch	175	538	201	204	162	168	203	343 (384)	403	477	no peak	388
Rush Creek below Narrows (calculated) [2]	467	718	463	582	576	306	518	239	550	640	172	335
Rush Creek below Narrows (actual) [3]	233	635	247	284	202	225	283	354 (413)	467	584	no peak	423
[Lower Rush Creek Main Planmap Reach]	147	396	155	161	128	144	181	241 (281)	174546	374		
[Lower Rush Creek 10-Channel]	89	259	95	99	76	81	102	113 (132)	98182	210		
Rush Creek at County Road Culvert (5186)						151			402			
Lee Vining Creek above Intake (5008)	378 (404)	419	285	264	201	238	332	152	374	444	127	222
Lee Vining Creek at Intake (5009)	354 (399)	391	274	258	201	236	317	141	372	457	45	167
[Upper Lee Vining Creek Mainstem]	245	270	190	179	140	164	231	103	289			
[Upper Lee Vining Creek A-4 Channel]	126	140	96	90	69	82	105	47	83			
[Upper Lee Vining Creek B-1 Channel]	159	176	122	115	89	105	139	62	100			
[Lower Lee Vining Creek Main Channel]	195	215	152	143	112	131	178	79	272			
[Lower Lee Vining Creek B-1 Channel]	159	176	122	115	89	105	139	62	100			
Parker Creek (5003)	48	72	52	49	56	37	49	33	74	64	22	31
Walker Creek (5002)	34	47	30	31	42	26	43	20	51	53	11	21

1 Computed natural flows, assuming no flow regulation
2 Computed by adding Rush Creek runoff + Parker Creek runoff + Walker Creek runoff
3 Computed by adding Rush Creek below Return Ditch + Parker Creek + Walker Creek
4 Only gaged stations provide instantaneous peaks; stations that are calculated provide only the maximum daily average discharge
5 measured flow

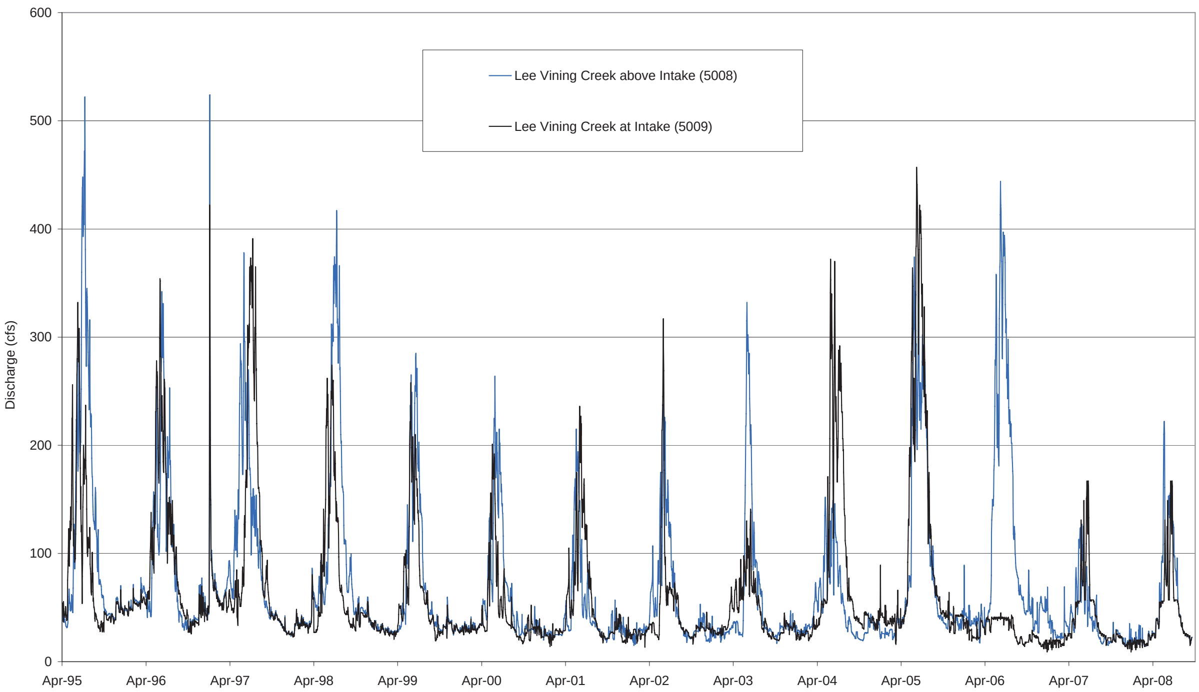

Figure 5. Lee Vining Creek hydrographs for Runoff Year 2008.

The SWRCB Order 98-05 requires baseflows of 54 cfs for April to September, and 40 cfs for October to March, or the flow at the point of diversion, whichever is lowest. By August, baseflows at the point of diversion were well below these otherwise required minimum flows, ranging between 20 and 30 cfs below the Intake.

Flow diversion occurred on Lee Vining during three distinct periods: April 28 to May 22, June 3 to 17, and June 26 to July 18,2008. Flow diversions during the June 3 to 17 period were released to Rush Creek through the 5-siphon diversion, and thus flowed to Mono Lake. Diversions totaled approximately 5,200 af, and occurred during the initial (primary) peak, between the secondary peaks in June, and during the snowmelt recession into July.

2.1.3 Parker and Walker Creeks

With one exception, streamflows from Parker and Walker creeks were not diverted during RY 2008. However, during a one-month period spanning August 8 to September 9, Parker Creek was diverted at the Intake at average and maximum diversion rates of 2.9 and 4.3 cfs, respectively. These diversions were conducted to control discharge in lower Rush Creek during the habitat flow study. The snowmelt hydrograph for these Rush Creek tributaries was similar to the Lee Vining Creek hydrograph: a distinct early-season peak on May 20, 2008, with steep ascending and descending limbs, followed by a longer duration flood with a peak on June 23, 2008, then a gradual snowmelt recession (Figure 6; Table 1). Peak daily average flow for Parker Creek was 31 cfs on June 23, 2008. Peak daily average flow for Walker Creek was 21 cfs on May 20, 2005 (Figure 7; Table 1). Both these peak magnitudes were the second smallest since Order 98-05, larger only than the RY 2007 peak magnitudes.

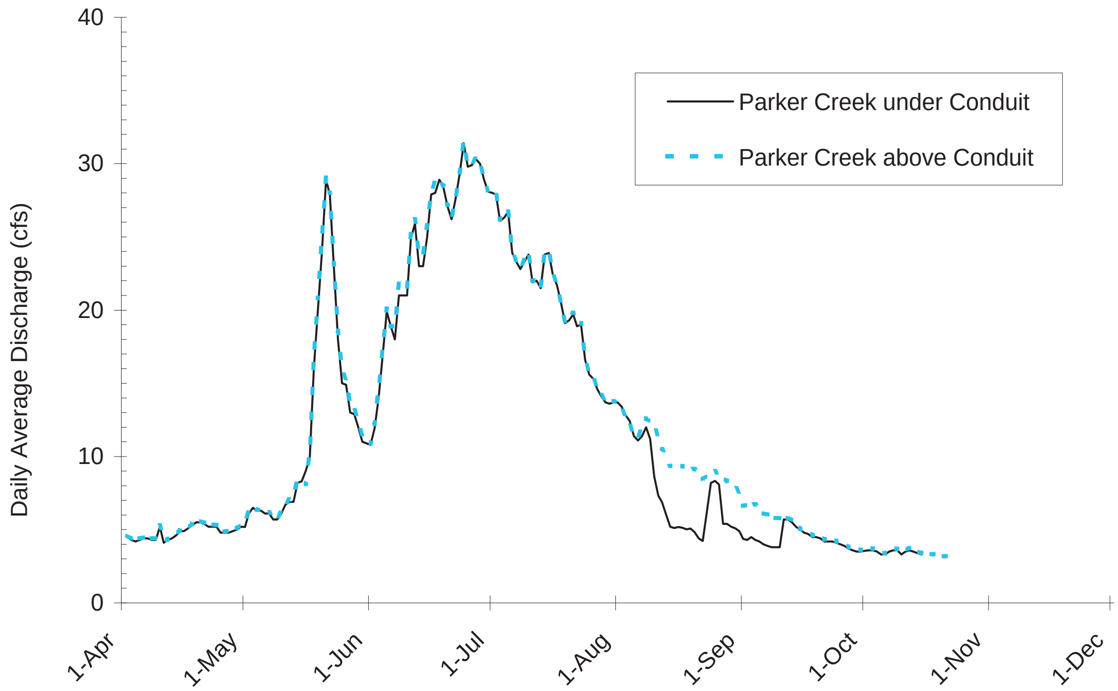

Figure 6. Parker Creek hydrograph for Runoff Year 2008.

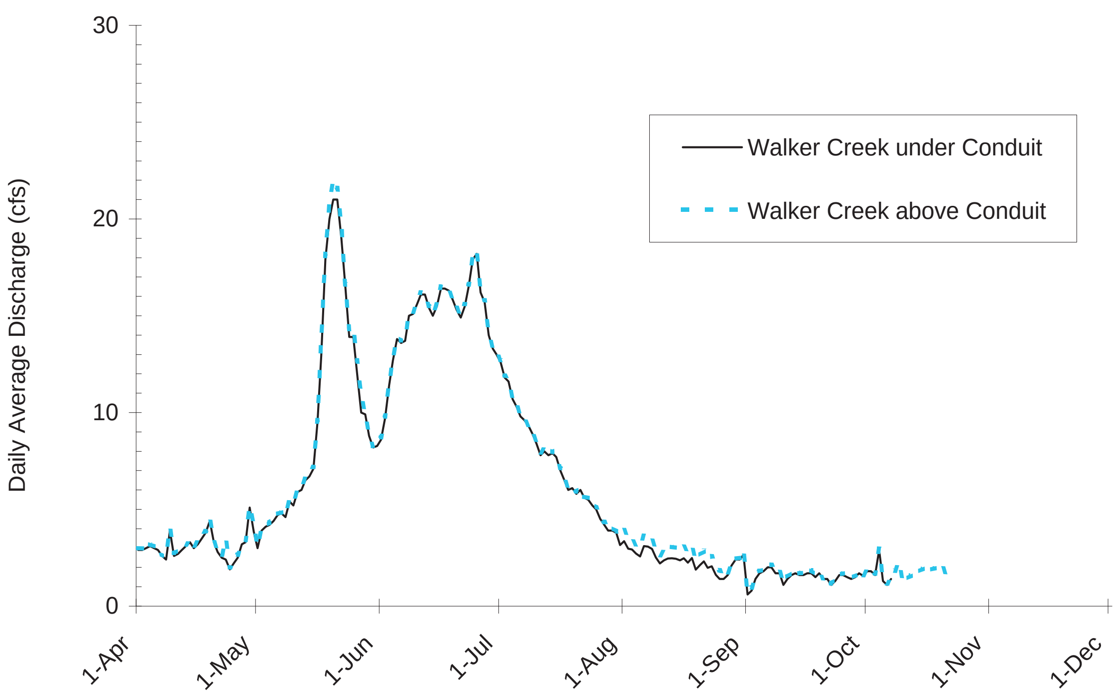

Figure 7. Walker Creek hydrograph for Runoff Year 2008.

2.2 Synoptic Streamflow Gaging

During RY 2008 we accomplished several objectives related to synoptic streamflow gaging on Rush Creek, which were:

- measure discharge at several locations longitudinally along Rush Creek within a single day in March, June, and July, and at multiple locations in August, to quantify streamflow losses to groundwater (and evapotranspiration);
- measure discharge during the five test flow releases on Rush Creek during the August habitat flow study, to provide a precise discharge to associate with habitat area estimates;
- quantify streamflow travel times along the Rush Creek corridor from the MGORD to the lower Rush Creek mainstem gaging station, for calibrating the Rush Creek water temperature model.

2.2.1 Rush Creek Streamflow Losses

During RY 2008 we measured discharge at several locations on Rush Creek for two primary purposes: first, to evaluate streamflow losses to groundwater infiltration along the Rush Creek corridor from the MGORD to lower Rush Creek at different times of year, and second, to associate a measured discharge value to the habitat mapping areas collected during the August 2008 Rush Creek flow study fieldwork.

On March 20, 2008 two field crews (D. Mierau of M&T, and G. Reis of MLC and Casey Shannon of USFS) measured discharge during low baseflow releases at four locations along Rush Creek (MGORD, upstream of Parker confluence, below 10-Falls, and Test Station Rd), and at the mouths of Parker and Walker Creeks. Discharge was measured on June 12, 2008 (M&T crew only) at the gaging cross section (XS -9+82) 300 ft downstream of the 10-Falls, during the peak flow releases, and on July 17, 2008 after the snowmelt recession, at the same locations as the March measurements except the MGORD and Test Station Rd sites were not measured. Data for these three series of measurements are reported in Table 2. All measurement sites were rated as "good" with exception of the Rush Creek above Parker Creek site, which was rated as "fair" due to large boulder substrate and surface turbulence at the measurement cross section. Good measurements are considered accurate to within 5% of the true value; fair measurements are considered accurate to within 8%.

During the March measurement, flow losses were minimal in the upper Rush Creek reach (2 cfs or 0.6 cfs/mi) and much higher in lower Rush Creek (6.1 cfs or 3.0 cfs/mi). Overall corridor-length flow losses in March were 1.2 cfs/mi with approximately 7 cfs of the 26 cfs release presumably lost to groundwater infiltration. In June, measurements were conducted on the first day following the five-day peak releases of 380 cfs. The combined discharge from MGORD releases and 5-Siphon augmentation was 323 cfs. Parker and Walker creeks contributed an additional 39 cfs (from DWP daily average data at Intakes) for a total "below Narrow" discharge of 362 cfs. The June 12 lower Rush Creek measured discharge was 358 cfs. Flow losses following the peak SRF releases were thus minimal (4.5 cfs or 0.7 cfs/mi) and just a fraction of the total flow releases. At the end of the snowmelt recession in July, discharge from the MGORD was 46.6 cfs. Measured discharge at the Parker Creek confluence was 32.5 cfs, equating to a substantial loss of 14.1 cfs or 4 cfs/mi, the highest flow loss measured in 2008. In contrast, only 1.2 cfs (0.6 cfs/mi) was lost in the lower Rush Creek reach, the lowest flow loss measured in 2008.

During the August 2008 habitat flow study, M&T field crews (assisted by DWP field hydrographers) measured discharge in or near each habitat mapping reach to complement habitat area estimates. We used these data to evaluate streamflow losses to groundwater infiltration along the Rush Creek

Table 2. Discharge measurements along Rush Creek from the MGORD to Wet Ford in RY 2008.

Measurement Location	Stream Mile	20-Mar	12-Jun	17-Jul
	(mi)	(cfs)	(cfs)	(cfs)
MGORD	1.4	26.2	323.4*	46.6*
Rush Creek above Parker Creek	4.9	24.2		32.5
Parker Creek at Hwy 395		3.0	23.0	21.7+
Walker Creek at confluence		6.2	16.1	6.1
Rush below Narrows (MGORD+Parker+Walker)	5.6	34.6 t	362.5 t	73.6 t
Rush below Narrows (Sum of Measured Flows)	5.6	33.4		60.3
Lower Rush Creek Mainstem below 10 Falls	7.6	27.3	358.0	59.1
Rush Creek at County Road	9.1	27.3		
Net Loss MGORD to Parker		1.9		14.1
Rate of Flow Loss (cfs/mi)		0.6		4.0
Net Loss Narrows to Lower Rush		6.1		1.2
Rate of Flow Loss (cfs/mi)		3.0		0.6
Net Loss MGORD to Lower Rush		7.3	4.5	14.5
Rate of Flow Loss (cfs/mi)		1.2	0.7	2.3

*=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

corridor from the MGORD to lower Rush Creek during mid-summer of a dry runoff year. To extend this analysis to late August and through September, we paired gaging data obtained at lower Rush Creek below the 10-Falls (described below) with MGORD release data. Data for these measurements are reported in Table 3. The flow magnitude reported for the combined MGORD+Parker+Walker flows is the maximum theoretical magnitude for Rush Creek below the Narrows without losses upstream. However, flow losses likely occurred along the reaches from Parker and Walker intake structures and from MGORD downstream to the Narrows, possibly at a higher rate of loss than in the lower Rush Creek bottomlands.

During the habitat flow study, MGORD flow releases increased from 48 cfs to 60 cfs then to 90 cfs, then decreased to approximately 19 cfs. Flow losses remained relatively constant, between 1.5 and 2.0 cfs/mi, with exception of the August 16th measurement when flows were increased to 90 cfs and the rate of flow loss increased to 3.3 cfs/mi. The higher flow loss observed at the 90 cfs MGORD release agreed with our field observations of a threshold between 60 and 90 cfs, above which flow began to access small distributary side channels and lateral scour channels, and did not return to the main Rush Creek channel.

Table 3. Comparison of rated discharge at the MGORD and measured discharge at lower Rush Creek below the 10-Falls.

Measurement Location	12-Aug	14-Aug	16-Aug	19-Aug	20-Aug	21-Aug	31-Aug	15-Sep	29-Sep
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
MGORD	47.7	61.3	90.9	33.6	31.3	18.8	34.4	50.4	48.5
Rush below Narrows (MGORD+Parker+Walker)	57.4	69.1	98.0	39.7	40.3	24.2	41.4	56.8	53.7
Rush Creek below 10 Falls (xs -09+82)	45.7	57.6	77.3	27.1	28.8	14.1	30.0	46.7	44.5
Net Loss MGORD to Lower Rush	11.8	11.5	20.7	12.6	11.5	10.1	11.4	10.1	9.2
Rate of Flow Loss (cfs/mi)	1.9	1.9	3.3	2.0	1.8	1.6	1.8	1.6	1.5

2.2.2 Rush Creek August 2008 Habitat Flow Study Discharge Measurements

The habitat flow study plan (Hunter et al. 2008) received five streamflow releases from the MGORD, ranging from 15 to 90 cfs. Each flow was to be maintained for two days, with rapid ramping from one flow to the next to maximize time for field crews to map brown trout and benthic invertebrate habitat. Because of known streamflow losses to groundwater along the Rush Creek corridor, we determined that flow measurements would be required at each habitat mapping reach to complement estimated habitat area estimates.

In preparation for the habitat flow study, M&T field crews installed a Global WL-16 pressure transducer and datalogger on the lower Rush Creek mainstem below the 10-Falls (at XS -9+82) to record stream stage height. The datalogger was installed at the same gaging site used during the bedload transport measurements in 2005. The datalogger was installed June 10th and removed October 21, 2008.

During the habitat flow study, M&T and DWP field crews collected at least one discharge measurement within or near each mapping reach during the five flow releases. Discharge was measured in Upper Rush Creek (~2,000 ft upstream of Old Hwy-395), in lower Rush Creek (split channel), in the 10-Channel (split channel), and at the Lower Rush Creek mainstem gaging site below the 10-Falls (full channel). Discharge data collected during the habitat flow study were used to construct a rating curve for the low-flow range of discharge (Figure 8). Only one measurement was collected above 77 cfs, which was 358 cfs measured on June 12; the upper end of the rating curve was truncated at 100 cfs for use in estimating discharge (i.e., during the SRF releases).

The targeted and actual MGORD releases are presented in Table 4, including discharge measurements collected during the habitat flow study. The 15-minute MGORD and Lower Rush Creek discharge data are plotted in Figure 9 with the discharge measurements from the Rush Creek XS -9+82 gage site.

We used the 15-minute flowdata from the DWP MGORD gage and from the Rush Creek XS -9+82 gage (Figure 9) to verify that our instantaneous discharge measurements collected once during each flow release represented the daily discharge at each study site (i.e., that the measured flow persisted during the habitat mapping). In Table 4, the MGORD Actual Release value is the average of the 15-minute discharge between 8AM and 4PM before flow changes were made, which best represent

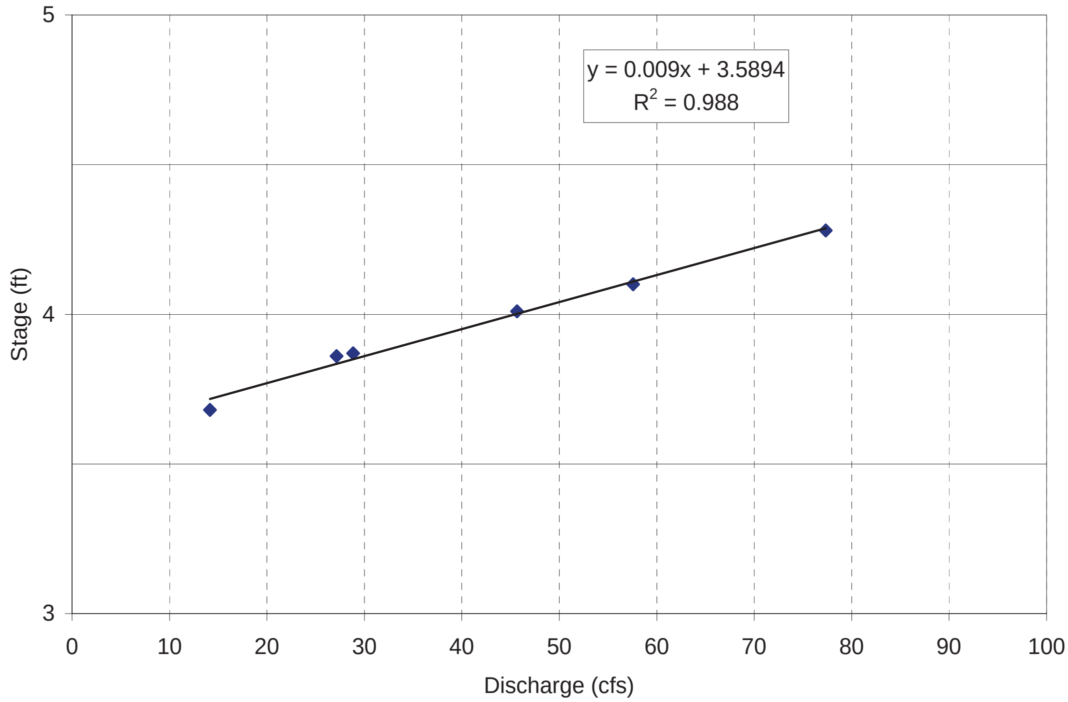

Figure 8. Stage-discharge rating curve developed for the low-flow range for gage installed in Lower Rush Creek at XS -9+82, used to predict continuous discharge during the summer season.

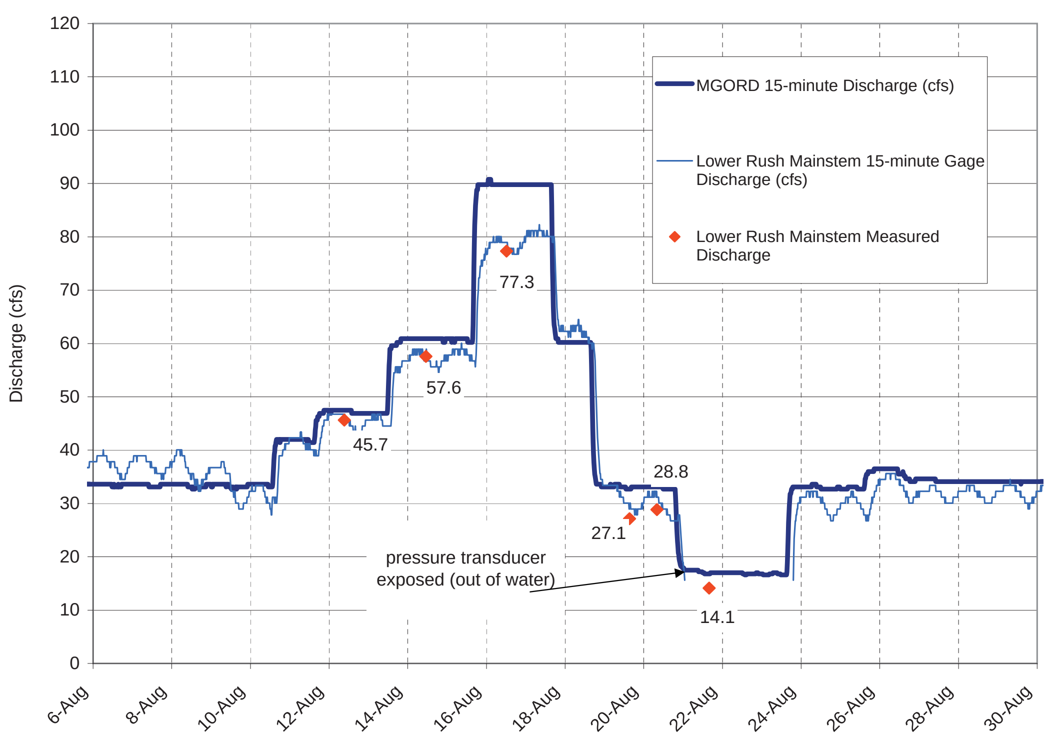

Figure 9. Plot of 15-minute discharge data for the DWP MGORD gage and the M&T Lower Rush Creek gage, with synoptic discharge measured during the August 2008 habitat flow study.

Table 4. Discharge values obtained from DWP gages and from synoptic field measurements during the baseflow habitat study.

					Measured Flow at Sites (cfs)			
Dates	MGORD Targeted Release (cfs)	MGORD Actual Release (cfs) #	Parker+Walker Contributution (cfs) *	Rush Creek Below the Narrows (cfs)	Upper Rush	Lower Rush	10-Channel	Ford - County Road
12-Aug	45	47.3	4.9	52.2				45.7
13-Aug	45	52.8 **	4.9	57.7	43.3	8.6	32.2	
14-Aug	60	60.9	4.9	65.8	64.0			57.6
15-Aug	60	60.6	4.9	65.5		12.1	48.1	
16-Aug	90	89.8	4.9	94.7	94.1	19.2	62.0	77.3
17-Aug	90	89.4	4.9	94.3				
19-Aug	30	33	4.9	37.9	33.5		22.6	27.1
20-Aug	30	32.9	4.9	37.8		6.1		28.8
21-Aug	15	17.1	4.9	22	17.9		12.3	14.1
22-Aug	15	16.9	4.9	21.8		3.0		
# represents the average of 15-minute MGORD data between 8AM and 4PM								
* represents combined flow measured by DWP at tributary confluences on 8/12 and assumed steady through habitat flow study								
** flow release remained 46.9 cfs until mid-day, when flows were ramped up prematurely								

MGORD flow releases present during the habitat mapping. The 15-minute discharge data indicate the MGORD flows were stable during daylight hours when field crews were mapping habitat, and very close to the targeted flows recommended in the study plan (Figure 9). The only exception was the flow change on August 13 at approximately 11:30AM which was detected by mapping crews in Lower Rush Creek at approximately 4PM. The Parker + Walker flow contributions were obtained from flow measurements made by DWP field hydrographers on August 12 and 20, and were assumed to be stable during the 10 day flow study period. The Lower Rush Creek 15-minute gaging data indicate minor diurnal fluctuations on the order of +/- 2 to 3 cfs, which we assume resulted in imperceptible stage, depth, and velocity changes during the habitat mapping.

In summary, considering unavoidable flow losses along Rush Creek, minor diurnal fluctuations in lower Rush Creek, and one slightly premature flow change made at the MGORD, we conclude that the instantaneous discharge measurements collected at each habitat mapping site adequately represent flows present during each day of habitat mapping.

2.2.3 Rush Creek Streamflow Travel Times

We used the 15-minute flowdata from the DWP MGORD gage and from the M&T Lower Rush Creek gage to evaluate travel times at different discharge releases and downstream flow propagation. The data will be useful to calibrate the Rush Creek temperature model, which partly relies on flow travel time. The time of each flow change at the MGORD, the resultant stage change recorded at the Rush Creek XS -9+82 gage, and the estimated travel times are presented in Table 5.

2.3 Side Channel Experiments and Groundwater Dynamics

Several past Annual Reports have addressed processes of shallow groundwater recharge from the annual snowmelt flood (M&T 2004, 2005) and the relationship of groundwater availability to riparian corridor extent (M&T 2005, 2006). On Rush Creek there are six experimental sites where

Table 5. Discharge and travel time estimates during the baseflow habitat study.

Date	Discharge (cfs) (from-to)	MGORD Time of Stage Change (hr)	Lower Rush Time of Stage Change (hr)	Travel Time (hr)
10-Aug	33-42	13:29	16:14	2:45
11-Aug	42-47	14:59	17:29	2:30
13-Aug	47-61	11:29	13:59	2:30
15-Aug	61-90	15:29	17:44	2:15
17-Aug	90-60	15:29	17:29	2:00
18-Aug	60-33	15:29	17:59	2:30
20-Aug	33-17	18:59	21:44	2:45
23-Aug	17-33	14:59	18:44	3:45

side channels have been manipulated and channels constructed to spread the snowmelt floodwaters laterally across the floodplain and increase groundwater infiltration and retention, storage volume, and ultimately, water availability to woody riparian vegetation. We equate this process to annually filling a giant Lower Rush Creek reservoir that temporarily retains water in shallow groundwater storage rather than passing the streamflow immediately to Mono Lake.

The six experimental sites on Rush Creek are:

1. Channel 3B. Located just upstream of Old Hwy-395, this west-side side channel was re-opened to perennial flow in October 1999. This is the only side-channel re-watering project upstream of Hwy 395. Perennial flow has persisted in this side-channel since the initial re-opening.

2. Channel 3C. Located just downstream of the Parker Creek confluence, this west-side side-channel was constructed in 2006 as part of the Marzanno Aggregate Plant reclamation. Perennial flow has persisted in this side-channel since the initial re-opening.

3. Channel 3D. Located between the Parker and Walker creek confluences just upstream of the Narrows, this east-side channel was reconstructed and opened to perennial flow in RY 2002. Since then, the main side-channel and several smaller distributary channels have evolved to seasonally watered channels, primarily due to sediment aggradation at channel entrances.

4. Channel 4Bii. Located in the Rush Creek bottomlands, this east-side channel previously received flow when Rush Creek discharge exceeded approximately 160-200 cfs. In RY 2006 the channel entrance was excavated to allow seasonal flow at lower mainstem discharges. In RY 2007, the channel entrance was excavated to allow perennial flow into the side channel. The perennial flow persisted through RY 2008.

5. Channel 8. Located on the west-side of the Rush Creek bottomlands opposite the 4 Floodplain, the 8 Channel was opened to seasonal flow in RY 2002. In RY 2007, the channel entrance was enlarged to allow perennial flow down the 8 Channel. The perennial flow in the 8 Channel has persisted to the present. The 8 Channel has also seasonally fed streamflow into a series of distributary channels including the old "Indian Ditch", and the 11 Channel. These inundated channels were mapped in RY 2008 and are discussed below. Perennial flow in the 8 Channel persisted through RY 2008.

6. Channel 10. Located on the east-side of the lower Rush Creek bottomlands, the 10 Channel was the first side channel project, opened initially in 1999. Since this opening, the 10 Channel has evolved to progressively capture a larger proportion of the total mainstem flow, and had threatened to dewater the previous "mainstem" Lower Rush Creek channel. Following the RY 2008 SRF releases, the 10 Channel was receiving approximately 70-80% of the total Rush Creek baseflow (see Table 4).

In RY 2008, discharge was monitored in the 4Bii, 8, and 10 Channels, groundwater was monitored at several 8 Channel piezometers, and the fate of perennial flow into the 8 Channel was mapped at the peak SRF releases. The 10 Channel flow data were reported in Section 2 of this report. Monitoring data for the 4Bii and 8 Channels are reported here.

Inundation of the 4 Floodplain resulting from seasonal flow into the 4Bii Channel was mapped in RY 2004 (see McBain and Trush 2005, Figure 18, pg. 22) following the peak discharge of 413 cfs below the Narrows. Mapping was repeated in RY 2005 (see McBain and Trush 2006, Figures 16a and 16b, pg. 28-29) and in RY 2006 (see McBain and Trush 2007, Figure 18 pg. 31). The RY 2008 peak discharge was a comparable 423 cfs (on June 7, 2008), and floodplain inundation was not mapped again at this SRF flow release. Discharge of 19.3 cfs was measured in the 4Bii Channel on June 11, the first day following the peak SRF releases. This was the only discharge measurement in the 4Bii Channel in RY 2008. We observed surface flow and floodplain inundation across the 4 Floodplain, and noted several patches of desert sage converting to riparian vegetation (Figures 10 and 11), a process we've been tracking since 2004. During the August 2008 habitat flow study, Greg Reis from the Mono Lake Committee observed flow into the upper end of the the 4Bii Channel during the 30 cfs test flow on August 19 and at the 15 cfs flow on August 21 and 22 (G. Reis, pers. comm.).

Figure 10. Desert sage patch dying on the 4 Floodplain, likely a result of elevated groundwater from perennial flow into the 4bii Channel.

Figure 11. Seasonally high streamflow in the lower reach of the 4b Channel. The bubbles indicate distributary flow returning to the 4b Channel from the floodplain. Also note the dead sage along the side-channel banks.

We have had more extensive monitoring infrastructure and data collection at the 8 Channel and Floodplain than at other side channel sites since the 8 Channel was reopened in 2002. In RY 2008, given that peak flows were similar to previous years' SRF releases, the entire floodplain was not mapped again during SRF flow release. However, we collected several discharge measurements, collected groundwater elevation data at several piezometers, and mapped the extent of surface flow on June 12, 2008.

A discharge of 37.1 cfs was measured in the 8 Channel on June 11, the first day following the peak SRF releases. This perennial flow in the 8 Channel enabled a portion of the side channel flow to access the old "Indian Ditch" side channel. The side-channel flow then split into three main branches, each meandering across desert sage surfaces, and eventually percolating to groundwater and evaporating. Trickles of flow from two distributary channels returned to the main channel at two locations (Figure 12); the third distributary continued a long, circuitous route, eventually accessing the historic 11 Channel in the lower Rush Creek meadows. Because of the length of this side-channel flow and duration of solar exposure, there was concern that warm water could potentially return to the mainstem Rush Creek. We measured temperature at the terminal end of the 11-Channel at 8:31AM (47.5°F) and again at 5:20PM (70.0 °F) on June 12. However, we observed no flow from this side-channel re-joining the main channel.

The 8C-8 piezometer in lower Rush Creek was monitored through the RY 2008 SRF period with a pressure transducer and datalogger to track hourly groundwater elevations. This logger was deployed seasonally in RY 2005 and 2006, and has run continuously since April 26, 2007 through the past two runoff seasons (Figure 13). On June 13, 2008, following the peak groundwater elevation, the datalogger failed (shut down) due to unknown causes. To have a continuous record at this site for

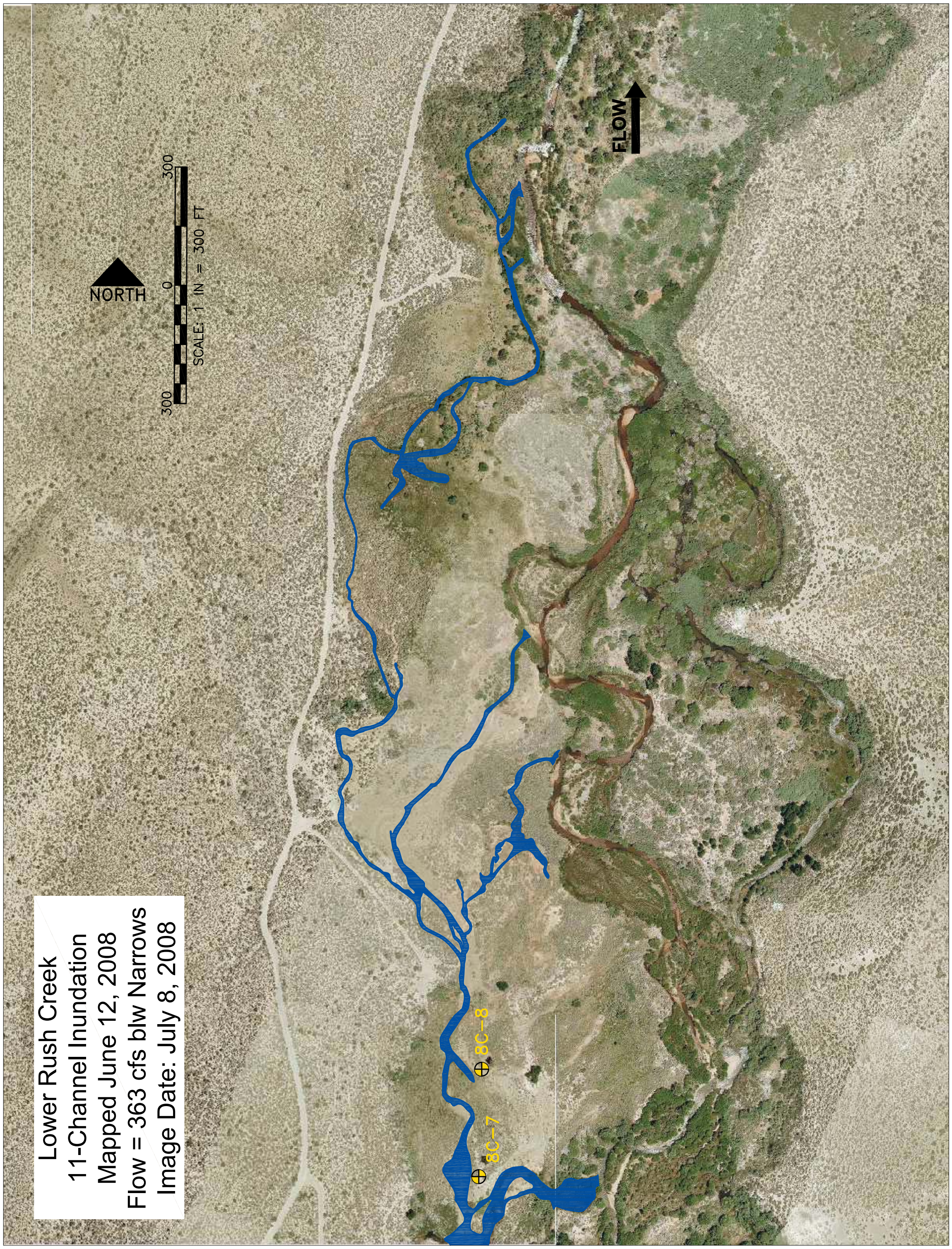

Figure 12. Pathway of 8 Channel surface flow during the peak Rush Creek SRF releases, mapped on July 12, 2008.

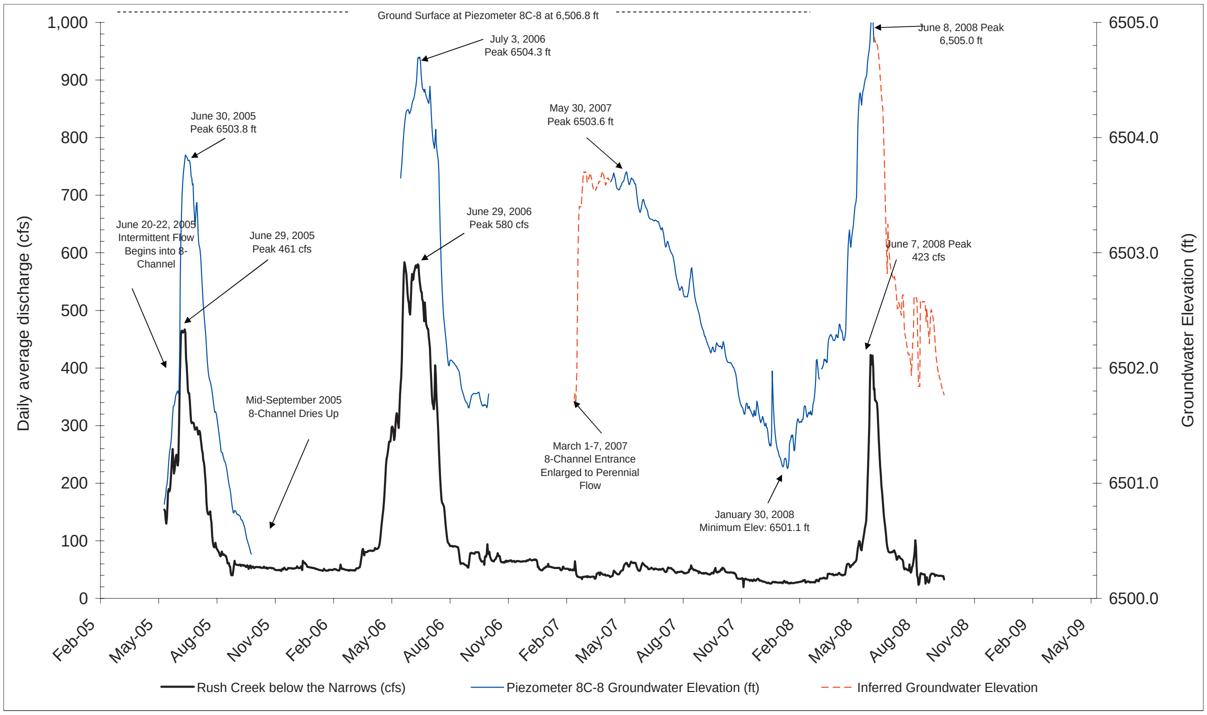

Figure 13. Plot of daily average flow for Rush Creek below the Narrows, and groundwater elevation recorded in the 8-Channel #8 piezometer (located below the 8 Floodplain near the lone Jeffrey Pine) for the past four runoff years.

the past four runoff years, we adjusted data from piezometer 8C-7 to reconstruct an "inferred" groundwater elevation. As we reported in the RY 2007 Annual Report (M&T 2008), RY 2007 was a dry year and Rush Creek had no SRF flow release. During that year, despite the absence of an annual snowmelt flood but with perennial flow in the 8 Channel, groundwater elevation recorded at piezometer 8C-8 rose several feet in elevation, peaked in May of 2007, and had a long, slow recession. In RY 2008, with perennial flow continuing in the 8 Channel, and with a Normal runoff year SRF release, groundwater at piezometer 8C-8 attained its highest elevation since our monitoring began in 2005. We do not know the rate of decline at the 8C-8 piezometer because of the datalogger malfunction, but presume a relatively slow decent to a base groundwater elevation, likely slower than our inferred data because piezometer 8C-7 appears more responsive to 8 Channel surface flow. Despite a smaller streamflow peak in RY 2008 than in RYs 2005 and 2006 (Figure 13), the RY 2008 8C-8 groundwater peak elevation was 0.7 ft higher than the RY 2006 peak and 1.2 ft higher than the RY 2005 peak.

In RY 2008, we obtained low-altitude aerial photographs of Rush Creek from Grant Lake to Mono Lake, and Lee Vining Creek from Hwy-395 to Mono Lake (discussed in detail in Section 3.3 below). Aerial images were collected with a digital camera system that acquired four bands (NIR, Red, Green, and Blue) with a 0.13 ft spatial resolution.

Healthy, chlorophyll-rich vegetation is known to have a high reflectance in the near infrared (NIR) band. To allow this reflected band to be visible in relation to other features in the aerial photographs, we replaced the Green band with the NIR band. Areas with a high vegetation density thus appear bright green in the imagery. This photographic manipulation also allows surface water to remain highly visible as dark blue or black in the imagery. An example showing the Rush Creek bottomlands 4Bii and 8 channels and floodplains is shown in Figure 14. The images were captured just days after the Rush Creek snowmelt recession reached baseflow. Chlorophyll reflectance would presumably be at or near an annual maximum as a result of peak water availability.

2.4 Temperature Monitoring

We continued to collect water temperature data in Rush, Lee Vining, Parker and Walker creeks in RY 2008, at ten sites where data have been collected since RY 2000 (Figure 15). These sites have Onset Pro V2 temperature sensors and dataloggers set to record hourly water temperatures. Dataloggers were downloaded in March and October 2008, and compiled in a database. Of these ten dataloggers, eight collected hourly data for each day of the runoff year. Two loggers, however, malfunctioned: the logger at lower Walker Creek shut down on June 20, 2008 and the logger at Lee Vining at County Road was exposed to air temperatures between June 25 and October 22, 2008. Summary tables for all water temperature data collected at these sites are presented in Appendix A.

Since 2005 we have been reporting water temperatures at the Rush Creek MGORD and at the County Road in relation to the annual hydrograph (Figure 16). During wetter years RY 2005 and 2006, the high Grant Reservoir storage and higher SRF releases resulted in cold water temperature releases into the MGORD. In both those years, daily average water temperatures rose slowly from the low 50's^{o}F in early June to peak daily average temperatures of 61.2^{o}Fand 59.8^{o}F for RY 2005 and RY 2006 respectively, by mid-September. Water temperatures then cooled into the fall. These water temperature conditions provided good summer thermal conditions for brown trout in upper reaches of Rush Creek (B. Shepard, pers. comm.). In both years, daily average water temperatures increased downstream to the County Road; in RY 2006, daily average water temperatures reached 63^{o}F by mid-July, increasing by nearly 9^{o}Ffrom the MGORD. Following RY 2006, two successive dryer years provided different Rush Creek water temperature conditions. Runoff year 2007 had no snowmelt release; RY 2008 had an earlier snowmelt runoff than 2005 or 2006, peaking in early June (Figure 17). Grant Lake elevations and storage volumes were also lower in 2007 and 2008. Water released from the MGORD had higher temperatures, reaching the 60^{o}F threshold by mid-June in both years. Peak daily average water temperatures reached 67.1 and 69.1 for Rush Creek at the MGORD. In contrast to RY 2005 and 2006, water temperatures generally cooled downstream to the County Road, even during periods of peak summer air temperatures in late-July and August. And, in contrast to RY 2005 and 2006, thermal conditions for brown trout were poorer in RY 2007 and 2008 in the lower reaches of Rush Creek (B. Shepard, pers. comm.).

During the August 2008 habitat flow study we deployed a datalogger at the upstream end of the MGORD (MGORD Top) to monitor the temperature of water released from Grant Reservoir. Our long-term monitoring site in the MGORD has been at the downstream end of the Ditch (MGORD Bottom) at the entrance to the 'A' Ditch. The upstream MGORD datalogger was deployed on July 15 and retrieved on October 20. We plotted water temperatures at the MGORD top and bottom during summer months to evaluate warming trends in the MGORD (Figure 18). Given the wide, shallow channel, slow water velocities, and lack of vegetative shading, we expected water temperatures to increase along the 1.4 mile-long Ditch. During the low flow releases (30 and 15 cfs) on August 19-22, the MGORD bottom datalogger was exposed to air temperatures. We plotted the Rush Creek at Hwy 395 data and the MGORD data. As expected, water temperatures were more consistent at the top of the MGORD and daily fluctuations increased down the Ditch. The hourly temperature at MGORD top fluctuated between 65^{o}F and 70^{o}F, whereas daily temperatures at the MGORD bottom (excluding the brief period of ambient exposure) fluctuated as much as 17^{o}F, between low 60's^{o}F and mid to upper 70's^{o}F. However, the average temperature during the monitoring period did not vary from top

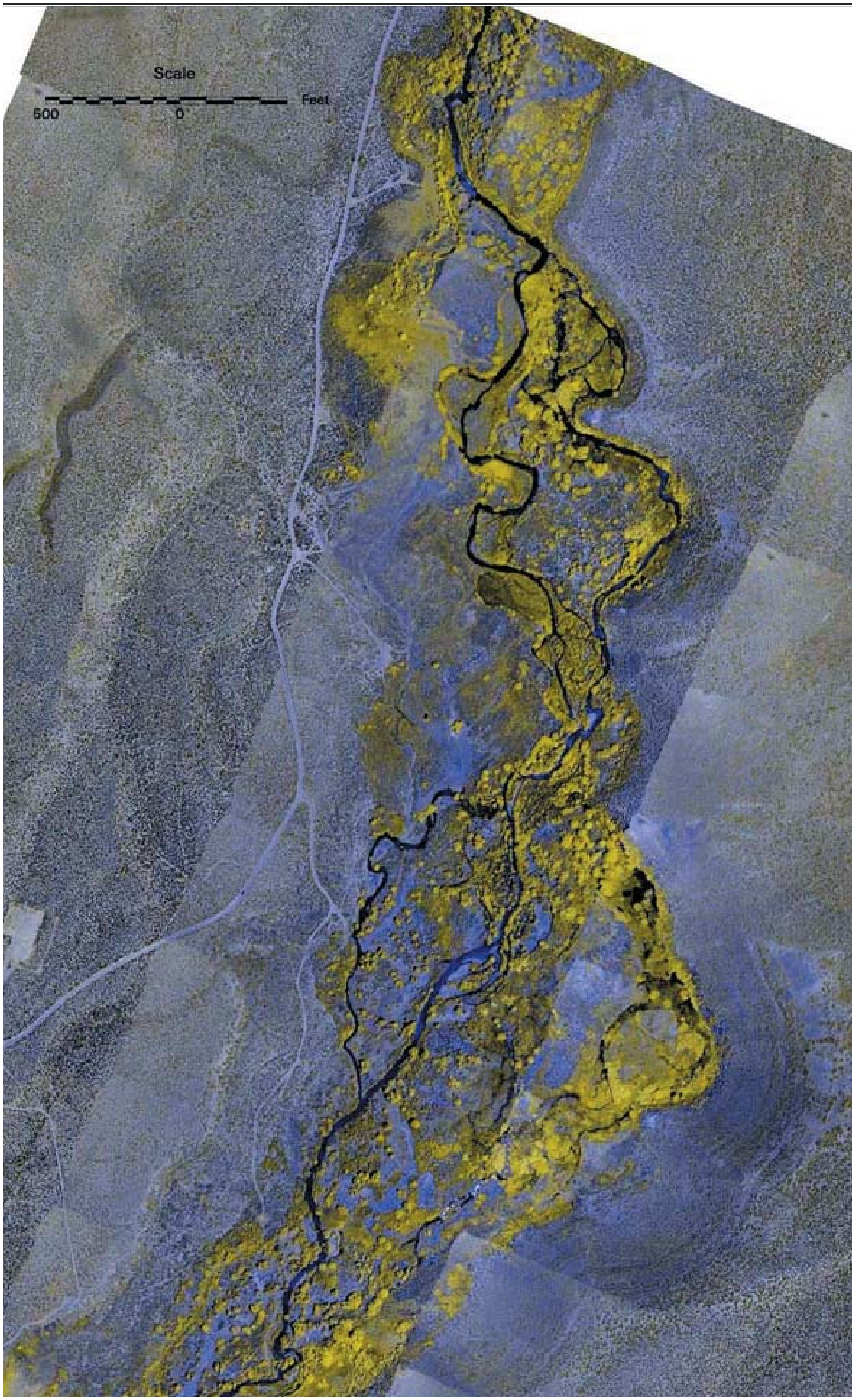

Figure 14. Example of the Near Infra-Red (NIR) band obtained with the July 2008 aerial imagery of Rush Creek and Lee Vining Creek.

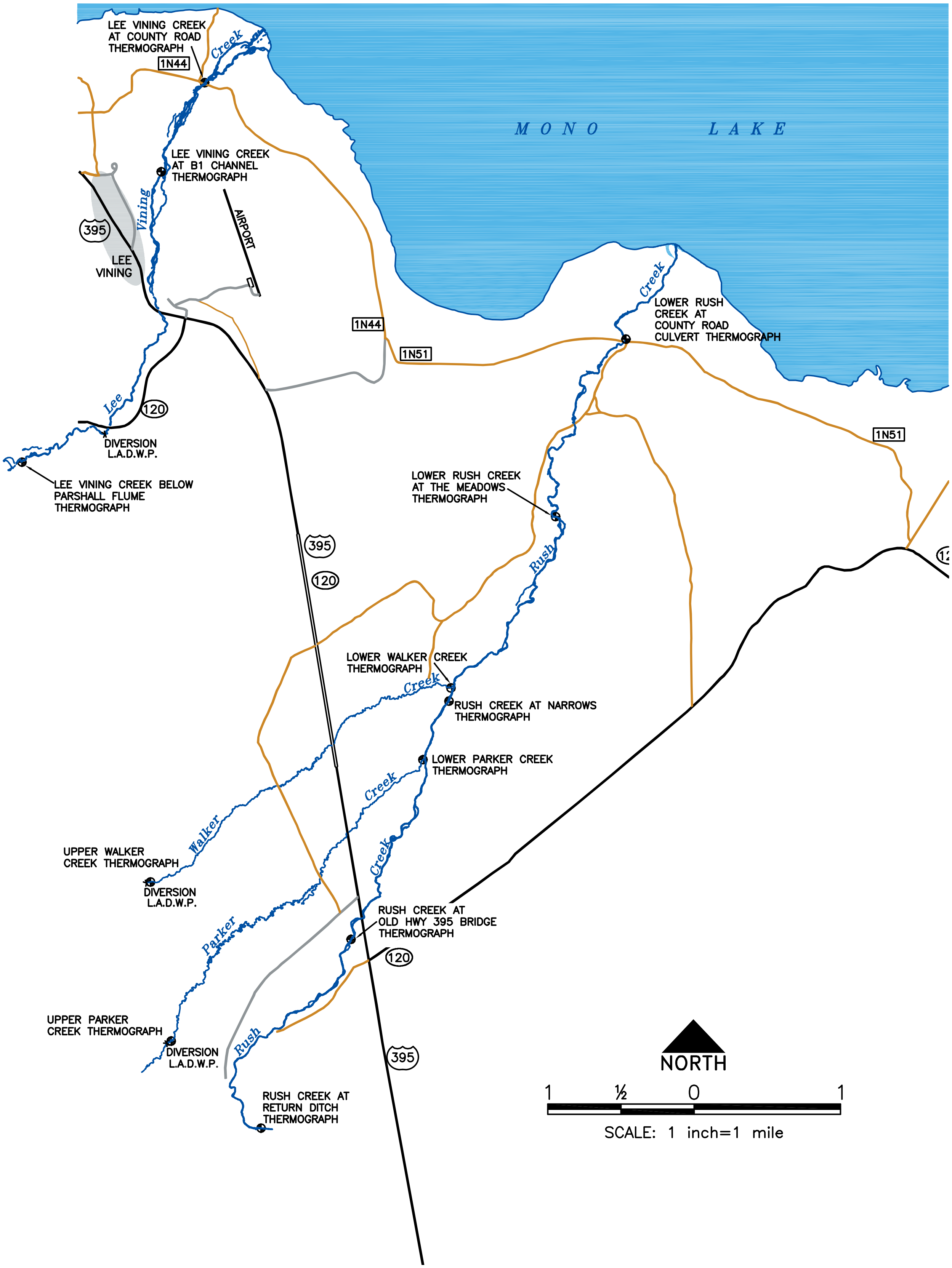

Figure 15. Location of continuously recording water temperature dataloggers deployed on Rush, Parker, Walker, and Lee Vining creeks.

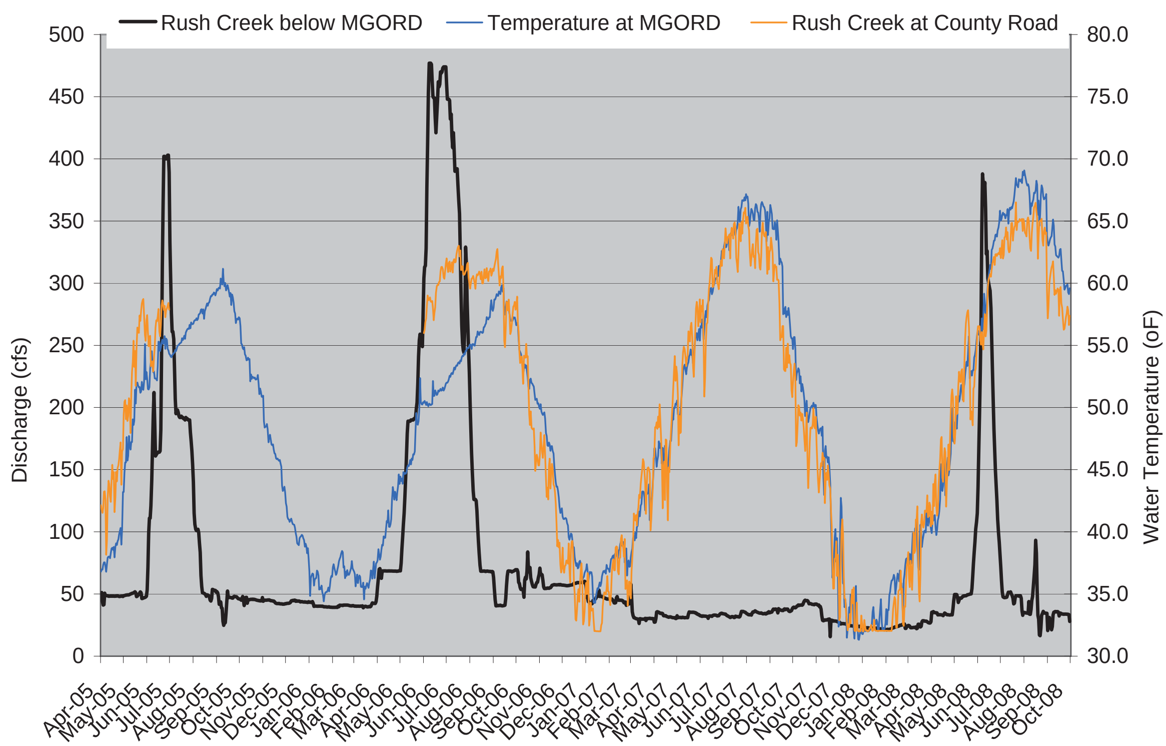

Figure 16. Daily average hydrograph for Rush Creek below the MGORD and water temperatures recorded at two locations on Rush Creek, one at the lower end of the MGORD and another at the Old Hwy 395 bridge.

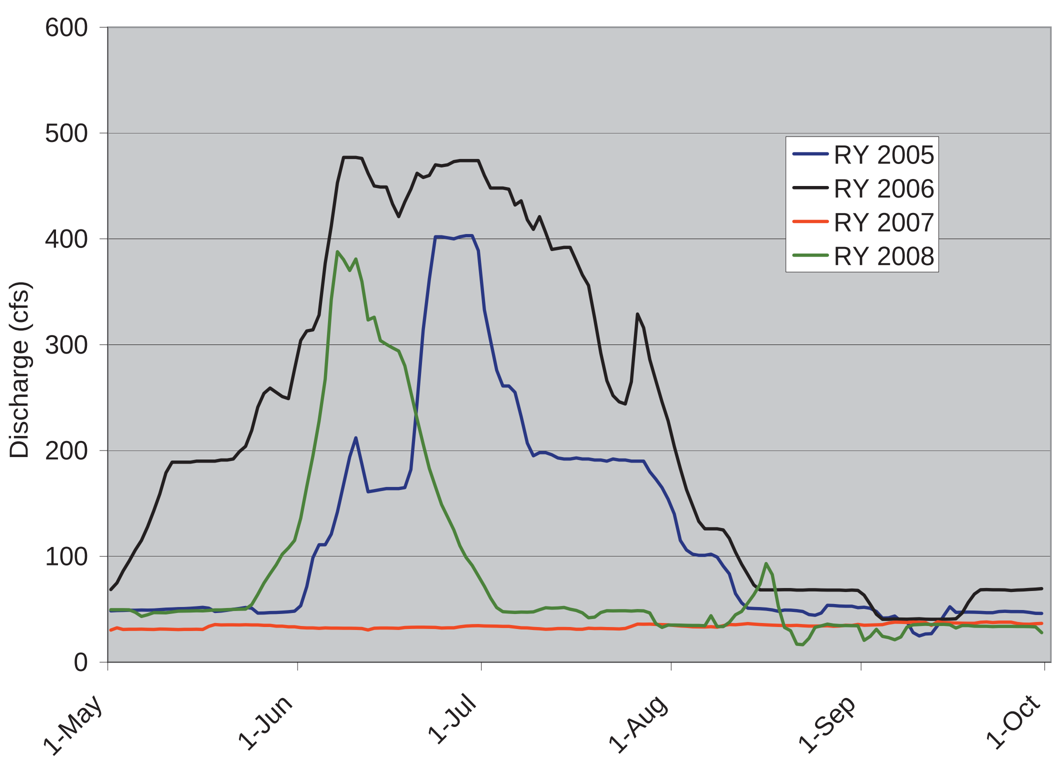

Figure 17. Rush Creek SRF hydrographs released below the MGORD three of the past four years, showing the different timing and magnitudes of snowmelt hydrographs.

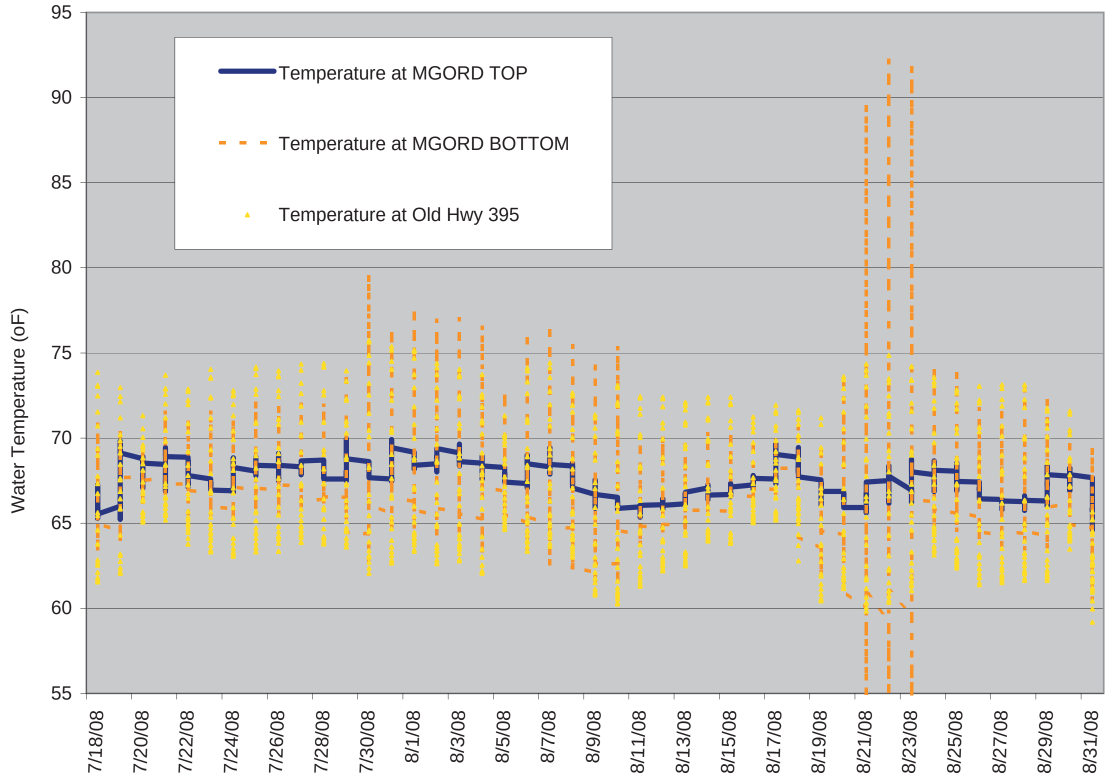

Figure 18. Water temperatures recorded at the top and bottom of the MGORD, and downstream at the Old Hwy 395 bridge from July 18 to August 31, 2008. The three days of MGORD water temperatures exceeding 85°F resulted from datalogger exposure to air temperatures during the 15 cfs release.

to bottom, remaining at 67.3°F. Our RY 2008 data indicate that water temperatures decreased slightly in the reach between the MGORD bottom and Hwy 395, but had approximately the same diurnal temperature fluctuations (Figure 18).

During the August 2008 habitat flow study we deployed two pairs of temperature loggers in pools in the lower Rush Creek bottomlands to observe thermal stratification. Two deeper pools in these reaches were selected, one in the bottomlands reach between the 10-Falls and the Rush Creek Ford, and one in the lower end of the 10-Channel. Temperature loggers were deployed near the water surface and at the bottom of each pool. Loggers were installed on August 13; the pair of loggers in the bottomlands was retrieved on October 21; loggers from the 10-Channel pool were not recovered. From our one data set of paired surface and bottom water temperatures, we observed water temperatures at the bottom of the pool consistently colder than temperatures at the water surface (Figure 19). The maximum daily average temperatures were 64.0°F for bottom temperatures and 65.8°F for surface temperatures for the period monitored. Daily temperature ranges were similar, with daily fluctuations ranging as high as 17°F.

In past annual reports, we have not reported extensively on water temperatures in Parker, Walker, and Lee Vining creeks, primarily because the temperature regimes in these tributaries are generally good. Comparing water temperatures among the four tributaries at the upstream boundary of monitoring reaches, and considering the annual thermograph as a whole, Lee Vining Creek appears to have the coldest and least impaired temperature regime of the four tributaries monitored (Table 6). Parker and Walker creeks have similar annual temperature regimes, with Walker Creek generally slightly warmer.

Rush Creek downstream of Grant Reservoir appears influenced by reservoir storage volume. Water temperatures released from Grant Reservoir into Rush Creek are generally warmer than temperatures in other Mono Lake tributaries.

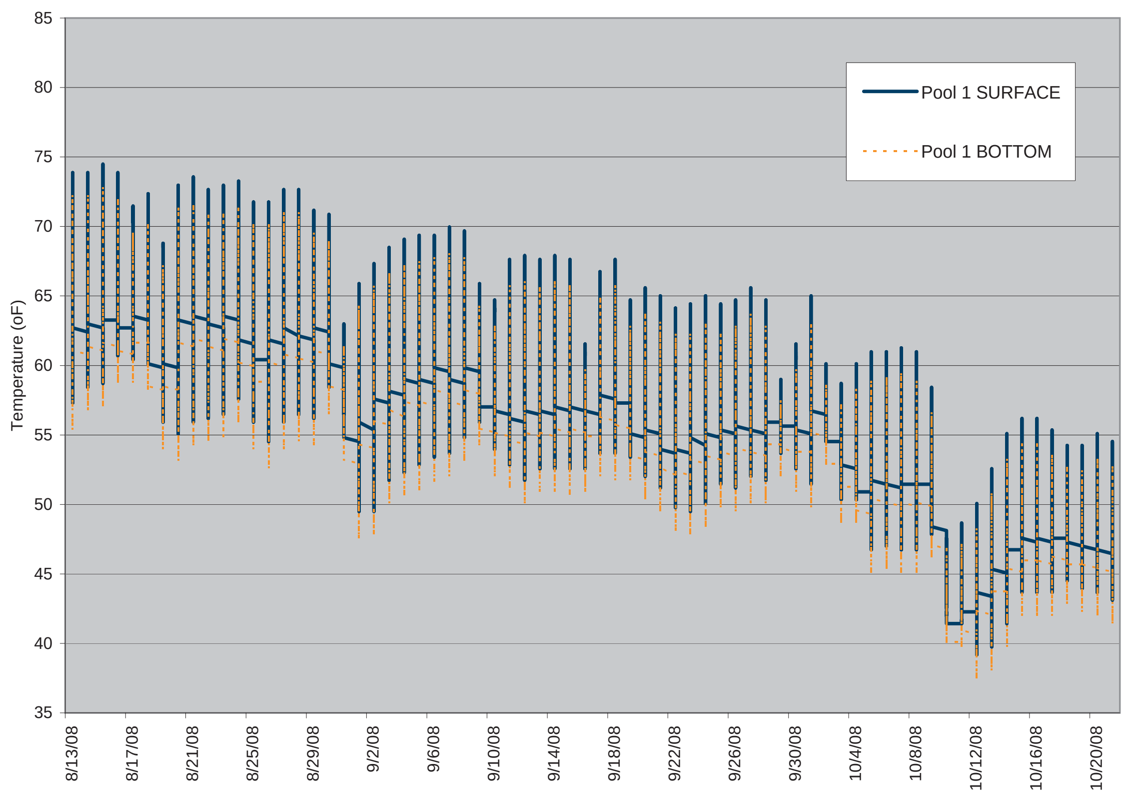

Figure 19. Water temperatures from a lower Rush Creek pool surface and bottom showing thermal stratification, recorded during the Rush Creek habitat flow study in August 2008.

Table 6. Selected water temperature metrics for Lee Vining, Parker, Walker, and Rush creeks for RY 2008.

Station	Annual Maximum (^oF)	Summer Average (^oF)	Maximum Daily Flux (^oF)
Lee Vining at Conduit	63.1	53.2	14.1
Parker at Conduit	62.8	55.2	22.7
Walker at Conduit	66.1	60.1	23.8
Rush at MGORD	79.5	65.6	22.2
Rush at County Road	76.0	63.0	23.0

3 GEOMORPHOLOGY

3.1 Cross Section Surveys

With the opportunity afforded by the Rush Creek habitat flow study conducted in August, 2008, we marked water surface elevations during each streamflow release at our previously established monitoring cross sections. We also marked the water surface elevation at several cross sections on June 12, 2008, at a peak discharge of 323 cfs and 363 cfs above and below the Narrows, respectively. Galvanized nails and color flagging were used to mark the wsel's for later survey with engineer's level. In October 2008, all Rush Creek cross sections were resurveyed, including the marked wsel's and the channelbed profiles. Table 7 summarizes the Rush Creek cross sections that were resurveyed in 2008, and lists the history of those cross sections surveys. Cross sections were plotted in Excel with two charts for each cross section are presented in Appendix B The first chart presents the range of water surface elevations surveyed in 2008 with other peak flow stages recorded in recent years. The second chart shows the bed profile from the first survey when the cross section was installed, plotted with recent surveys, to document channelbed changes at each cross section during the monitoring period. The 8 Floodplain and 3D Floodplain sites were not resurveyed in 2008, with exception of XS 239+00 at the 3D Floodplain.

Without summarizing all cross section and water surface surveys in 2008, we have highlighted major changes and features of particular interest or utility to future monitoring.

3.1.1 Upper Rush Creek

XS 12+95: This cross section traverses a pool-tail, just before the channel drops over a short, steep riffle. The right bank has a small bench barely inundated at low flows when the cross section was installed in 1998. This bench has aggraded approximately 0.4 ft since then, a modest increase in elevation but enough to confine low flows into a narrower channel and allow woody riparian vegetation to establish on the small floodplain surface.

XS 9+15: This "chevron" cross section traverses the upstream entrances of two split channels that have had approximately equal flow at baseflow since monitoring began there in 1998. However, the 2008 survey shows the left side channel aggrading, and the right side-channel deepening slightly, to convey more baseflow. This change may have resulted in part from the loss of the downstream log weir placed by Trihey that scoured away in 2005, and may have allowed a headcut to propagate upstream through the XS 9+40 right channel.

XS 5+45: This cross section has maintained higher confinement than other cross sections in this reach. This confinement resulted in a 1 ft stage change between the August 2008 low flow of 17.9 cfs and the 94.1 cfs. By comparison, the same flows at other cross sections exhibited as little as 0.5 ft stage change.

XS 1+05: This cross section traverses the pool-tail of a constructed pool where spawning gravel and a large root-wad have been placed in the pool. The channelbed profile was static during several years of monitoring, whereas our scour cores indicated substantial scour and deposition in some years. However, the 2006 snowmelt flood transported the root-wad from approximately 50 upstream to approximately 50 ft downstream of the cross section. The root-wad has caused a backwater and allowed an additional one foot of sediment to deposit on the pool-tail.

Table 7. Summary of cross sections and survey history for Rush Creek.

Site	Current Cross Section Label	Upper Left Bank Pin Elev.	Lower Left Bank Pin Elev.	Lower Right Bank Pin Elev.	Upper Right Bank Pin Elev.	Total Cross Section Length	May-95	Sep-95	Oct-97	Jun-98	Sep-98	May-99	Jul-99	Aug-99	Apr-00	May-00	Aug-00	Aug-01	Sep-02	May-04	Jun-04	Jul-04	Oct-04	Jul-05	Oct-05	Oct-08
		(ft)	(ft)	(ft)	(ft)	(ft)																				
Upper	**BM**	**6896.181**																								
Upper	0+00		6885.45	6887.86		76.00					X		X				X	X	X				X			
Upper	0+74		6887.99	6889.02		63.30				X	X		X				X		X		X					X
Upper	1+05		6888.14	6886.43		56.60					X		X				X	X	X		X					X
Upper	5+45		6891.70	6892.13	6896.45	166.70				X	X		X				X		X		X					X
Upper	7+55		6897.36	6896.45	6896.45	155.80					X		X						X		X					X
Upper	9+15		6896.99	6897.17		88.90					X		X				X		X		X					X
Upper	9+40		6896.99	6897.17		51.90						X	X								X					
Upper	11+68		6900.47	6900.37		29.30					X		X													X
Upper	12+95		6903.49	6904.40		47.00				X	X		X				X		X		X					X
Upper	13+36	6907.18	6903.92	6905.26	6905.16	324.80					X		X					X			X			X	X	X
3D Site	**BM**	**6650.30**																								
3D Site	3D-1			6636.98	6638.91																					
3D Site	3D-2			6630.45	6630.22																					
3D Site	3D-3			6625.35	6626.88																					
3D Site	3D-4			6619.19	NONE																					
Historic																										
Historic																										
Historic																										
8C Site	**BM**	**6519.01**																								
8C Site	8C-1	6518.63	6517.44			256																				
8C Site	8C-2	6519.01		6514.99		500.8																				
8C Site	8C-3	6514.64		6508.80		637.4																				
Lower	**BM**	**6491.407**																								
Lower	00+86		6490.07	6486.82		127.50			X		X		X				X		X	X	X					X
Lower	03+30		6488.67	6488.25		52.30			X		X		X				X		X	X	X					X
Lower	04+08	6489.62	6489.22	6492.06		229.40			X		X						X		X	X	X					X
Lower	05+49		6489.45	6489.55		58.50			X		X		X				X		X	X	X					X
Lower	07+25	6492.47	6492.45	6491.26		154.50	X	X	X		X		X				X	X	X	X		X		X		X
Lower	07+70	6494.13	6493.30	6491.27		155.50			X		X		X				X	X	X	X		X				X
Lower	10+10	6497.92	6492.10	6494.89		188.00			X		X		X				X		X	X	X		X			X
Lower	-9+82		6477.75	6476.04		94.70			X		X		X				X			X	X				X	X
Lower	-5+07		6483.70	6481.26		119.50				X	X		X						X	X	X					X
Lower	-1+56		6484.34	6483.21		72.50				X	X															
10-Chan	0+50		6496.01	6496.40		71.60										X	X	X	X		X				X	
10-Chan	1+10		6499.01	6496.09		57.80										X	X		X		X	X			X	X
County Rd	**BM**	**6434.142**																								
County Rd	02+17	6429.19	6428.15	6428.71	6430.67	224.20								X			X		X		X					X
County Rd	06+85	6432.81	6432.62	6432.32		171.00								X	X		X		X		X				X	X
County Rd	08+30	6440.09	6433.76		6437.26	285.90								X				X					X	X		X
County Rd	11+59		6439.11	6436.17		239.50								X			X				X					X
County Rd	15+19	6443.06	6443.41	6441.16	6446.76	318.50								X			X		X		X					X
County Rd	Culvert Gaging Statio	102.67	100.00			94.80																				

3.1.2 Lower Rush Creek

XS 10+10: We have collected abundant data from this cross section, including numerous bed and water surface elevation surveys, measured water velocities on the broad left-bank floodplain, fine sediment deposition on the floodplain, and water surface slope measurements through the cross section. Our resurvey in 2008 indicated that, despite several recent years of inundation at high flows, much of the floodplain surface has not aggraded appreciably. However, a pronounced berm has been forming along the channel margin, with fine bedload deposition extending up to 30 to 40 ft from the channel. In 2008, we observed taller and thicker willows on this berm compared to the lower elevation, wetter floodplain surface. The 2008 survey also revealed channel reconfinement resulting from the reduced flow regime now accessing the lower Rush Creek main channel (more flow is going to the 10 Channel).

XS 7+25: The lower Rush Creek Valley-wide cross section 7+25 was established in 1995 and has since migrated 35 ft. The left bank's desert sage and creeping wild rye grass surface has yielded to high flows and consequent bank erosion. The channel now occupies an entirely new location since 1995. Most of this bank erosion (29 ft) occurred between 1995 and 1997, both of which were wet years with large snowmelt floods. Despite this rapid migration, the low-flow channel width has maintained the same width and confinement: 35 ft wide in 1995 and 31 ft wide in 2008.

XS 0+86: This cross section traverses a pool on the outside of a meander bend. The channel migrated approximately 20 ft between 1997 and 1999, but then only an additional 2 ft since 2004. Past surveys have revealed large sections of left bank calving into the channel.

XS -9+82: This cross section is located downstream of the 10-Chanel "falls" and conveys the full lower Rush Creek discharge. We have collected numerous bed and water surface elevation surveys, stream gaging, bedload transport measurements, and water surface slope measurements through the cross section. Despite subtle bed elevation changes that have confounded development of a long-term stage-discharge relationship for our gaging operations, and after initial thalweg depth adjustments in 1998, the cross section has remained relatively stable in cross section profile. Headcuts prevalent in the last decade in other reaches of Rush Creek, have not been apparent here.

XS 1+10: The 10-Channel cross section is strategically located at the upstream end of the 10-Channel, traversing a low elevation developing floodplain. During several years of surveying, we tracked the gradual sediment deposition on the floodplain, especially highlighting the berm along the low water channel and floodplain slope away from the channel. Floodplain deposition experiments were deployed on this surface in 2004 and 2005. In 2004, we noted higher floodplain elevations <u>during</u> the peak SRF releases than <u>after</u> the snowmelt recession. We have also been observing the evolving 10-Channel entrance in the last several years, as this constructed channel has gradually captured a larger proportion of Rush Creek discharge. During the most recent three surveys (2004, 2005, 2008), the cross section profile has adjusted dimensions with each high flow season, to convey larger flood and base flows. And while the right bank scour channel has also expanded slightly, the floodplain has maintained the approximate same elevation. The important concept to note is the rapid response in cross section profile to changes in flow regime.

3.1.3 Rush Creek County Road Reach

XS 11+59: In this cross section, and others throughout this reach, the thalweg elevation has changed significantly in the last several years, possibly indicating a headcut migrated through this reach. From 1999 to 2004 to 2008 the thalweg elevation lowered from 6,433.0 ft to 6,432.2 ft (Δ=0.8 ft) to 6.431.1 ft (Δ=1.1 ft), for a total thalweg elevation change of 1.9 ft. We have observed no overbank flow at this cross section the past 10 years of monitoring. The channel upstream of this cross section has high confinement.

XS 8+30: From cross section 11+59 (upstream) the channel confinement begins to open up somewhat, and XS 8+30 has had some overbank flow on the left bank floodplain during larger events (e.g., 2005, 2006). The thalweg elevation at XS 8+30 has also downcut, and the low-flow channel expanded, in the four years since our last survey. In the same timeframe, however, little change has been observed on the channel banks and floodplain. Downstream at XS 6+85, the channel has been dynamic (highlighted in several previous annual reports: citations), with several minor headcuts propagating through this cross section, rapid channel migration into the left floodplain and bar building on the right bank in its wake. We assume this reach will continue to show observable changes from each successive years' high flows.

3.1.4 Rush Creek Historic Cross Sections

In 2006, we located an abandoned channel segment in the Rush Creek bottomlands that was suspected to have retained some features of the historic (pre-1941) channel morphology and mature woody riparian trees on its former floodplain. The channel segment is located approximately 2,700 ft downstream of the Narrows, just upstream of the entrance to the so-called "Indian Ditch". We sketch-mapped an accessible segment of this reach, and surveyed three cross sections, traversing what is presumed to have been a riffle unit, a corner pool, and a pool-tail. These cross section plots are presented in Appendix B.

3.1.5 Lee Vining Creek

With the implementation of habitat flow study scheduled for 2009 on Lee Vining Creek, we will follow a similar field plan of marking water surface elevations at the different streamflows mapped, then resurvey the cross sections in fall 2009. Those data would be reported in next year's annual report.

3.2 Pebble Counts

Recent runoff years have had several high flow events capable of scouring and transporting sediment. During these events, fine sediment can be deposited onto floodplains or sorted into more homogenous facies on the channelbed surface. We have conducted 100 rock pebble counts to monitor changes in the particle size distribution of the surface of the channelbed as a way to track trends in bed coarsening or fining. This method includes randomly selecting 100 sediment particles from a homogenously-sorted sediment patch (facies) associated with an established cross section, measuring and recording the 'B' diameter of each particle (in mm), then sorting and plotting the particle size distribution. This information was used in bed mobility experiments reported in previous annual reports. Pebble counts were initially performed when monitoring reaches and cross sections were first installed, repeated in 2000, and again in Rush Creek in 2008. These data will be combined with other information in our forthcoming summary report. Appendix C gives all locations where pebble counts were repeated in 2008.

The three years of data examining particle size distribution at eight sites on Rush Creek show an overall trend in bed coarsening. All 2008 pebble count measurements showed a coarser particle size distribution than measured in previous years. Between the first measurement (1997) and the second measurement (2000), several sites had a shift toward finer particle size distribution.

3.3 Geomorphic Termination Criteria

3.3.1 Aerial Photography

New aerial photography was collected for Rush and Lee Vining Creeks on July 8, 2008 by HJW Geospatial, Inc. In addition, GPS/IMU data were collected and ground control targets were set for orthorectification in ERDAS/LPS software. The final orthorectified imagery has a pixel resolution of 0.13 ft. The imagery was used as the base map in the August 2008 Rush Creek habitat/flow study field mapping.

3.3.2 Changes to Geomorphic Termination Criteria

The 2008 high resolution aerial photographs were used to reevaluate channel reach length termination criteria for Rush and Lee Vining Creeks. We overlaid the 2003 channel centerline onto the 2008 aerial photos and noted where significant changes had occurred since 2003, then recomputed the channel length.

In Rush Creek there were no significant changes in channel location since 2003 in Reaches 2, 3C, 3D, 4A, and 4C. However, Reach 3A was 46 ft longer due to bank erosion and point bar formation. Reach 3B was misreported in 2006 with a reach length of 2,956 ft when it was actually 2,842 ft. Reach 3B length has reduced by 30 ft since 2003 where the main proportion of flow shifted to an adjacent side channel, thus increasing its length deficit to 144 ft. Reach 4B length reduced by 99 ft but has met all three geomorphic termination criteria. Reach 5A, below the ford crossing, reduced in length by 28 ft, despite active channel migration and point bar formation, increasing its deficit to 275 ft.

In Lee Vining Creek, Reach 2B had a reduction in length of 9 ft, Reach 3A increased by 7 ft, Reach 3B had no change, and Reach 3C increased by 3 ft. Overall, there was no real significant change to the existing length deficits.

Updated geomorphic termination criteria are presented in Table 8.

4 RUSH CREEK HABITAT FLOW STUDY

4.1 Study Rationale

In past runoff years our monitoring efforts have focused on fluvial processes, groundwater dynamics, and riparian responses, i.e., processes resulting from the snowmelt hydrograph component on Rush Creek and Lee Vining Creek (Figure 20),. Our approach to evaluating the snowmelt hydrograph component was outlined in our RY 2003 Annual Report (M&T 2004). The Fisheries Scientists have complemented this evaluation of physical process monitoring by conducted extensive research on trout recovery, population dynamics, and migration patterns.

In 2008, the Stream Scientists teamed up to begin an evaluation of the existing Order 98-05 baseflows. These flows include summer/fall low flows when trout are actively feeding and growing, winter low flows when trout are generally dormant, and the transition periods between these and other components. The transition from snowmelt to baseflow in late spring/summer varies with runoff year type, with the snowmelt recession of wetter years typically extending later into summer. Transition from winter low flows to ascending spring snowmelt flows depends strongly on climatic conditions, i.e., when ambient temperatures begin to warm, thus warming water temperatures and increasing discharge. With the unimpaired annual hydrograph as a guide to evaluate existing streamflow requirements, these hydrograph components may have multiple, competing objectives. Integration of fisheries, riparian, and geomorphic functions has always been an overriding objective of the Stream Scientists.

Table 8. Updated geomorphic termination criteria based on RY 2008-09 monitoring data.

RUSH CREEK	MAIN CHANNEL LENGTH (FT)				
Segment	***SWRCB Termination Criteria***	***2004 Lengths***	***2008 Lengths***	***M&T Revised Termination Criteria***	***Length Deficit***
1	4,100				4,100
2	4,820	4,820	4,820	4,820	0
3A	3,800	3,917	3,963	3,800	0
3B	3,100	2,842	2,812	2,956	144
3C	6,940	6,964	6,964	6,940	0
3D	3,370	3,235	3,235	3,032	0
4A	3,070	3,078	3,078	3,070	0
4B	7,810	8,071	7,972	7,810	0
4C	4,360	3,393	3,398	2,830	0
5A	7,320	7,073	7,045	7,320	275
5B	N/A				
Total	48,690	43,391	43,287	42,578	4,519

LEE VINING CREEK	MAIN CHANNEL LENGTH (FT)				
Segment	***SWRCB Termination Criteria***	***2004 Lengths***	***2008 Lengths***	***M&T Revised Termination Criteria***	***Length Deficit***
1	4,500				
2A	7,400				
2B	Combined with 2A	2,112	2,103	2,150	47
3A	3,500	3,139	3,146	3,500	354
3B	4,200	3,795	3,795	4,200	405
3C	1,360	1,210	1,213	1,360	147
3D		1,880	1,887		
Total	20,960	12,137	12,144	11,210	953

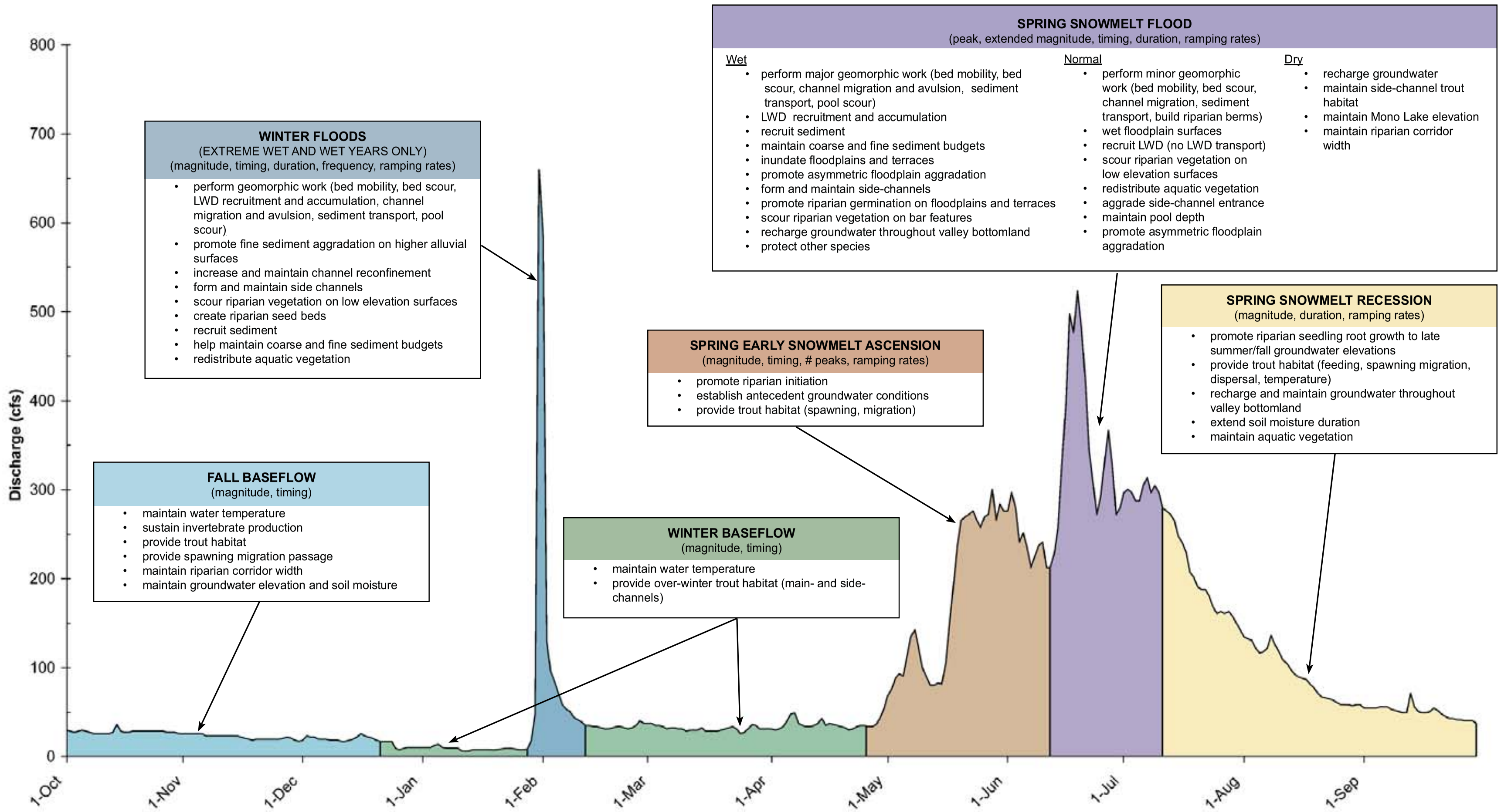

Figure 20. Example of a modeled unimpaired hydrograph for Rush Creek (RY 1963) used to illustrate important hydrograph components identified for Rush Creek, and the important ecological functions associated with each component. This figure was presented in the RY 2003 Annual Report (Figure 18); hydrograph components and their functions will be reconsidered in the upcoming Flow Study Report.

4.2 Rush Creek August 2008 Field Study

Tasks outlined in the Rush Creek study plan were implemented cooperatively in a step-by-step fashion:

The overall study plan was developed cooperatively among the stream scientists in Spring 2008, circulated to the Parties for review on June 30, 2008, then discussed at the Mono Basin Tracking Meeting in Bishop July 16, 2008. The Plan was finalized in a subsequent Study Plan issued August 4, 2008.

Based on the recommended flow release schedule requested by the Stream Scientists for the baseflow habitat study, DWP requested and was granted a variance from the SWRCB for the 12-day flow study period. The Study Plan was implemented August 12 to 22, 2008 with the following general tasks:

- The fisheries crew mapped winter holding and summer foraging habitat on laminated aerial photographs within five reaches on Rush Creek; the M&T crew mapped benthic invertebrate habitat within the same reaches;
- M&T and DWP crews collected discharge measurements along Rush Creek in each habitat mapping reach, and correlated flow measurements with DWP gages; M&T deployed temperature recorders during the field study; M&T crews also collected panoramic photographs at 15 photopoints along the mapping reaches at each measured streamflow;
- M&T and fisheries crew GIS technicians independently digitized trout habitat polygons and computed habitat areas (in ft2); M&T GIS technician digitized the benthic invertebrate polygons;

The fisheries crew will report on the results of the trout habitat mapping in their flow study report. The discharge and temperature data are described in Sections 2.2 and 2.4 of this report. The benthic invertebrate data are presented below.

4.3 Benthic Macroinvertebrate Habitat

4.3.1 Productive Riffle Habitat Mapping Methods

A productive and diverse benthic macroinvertebrate (BMI) community is central to a healthy stream ecosystem. With exception of predation on young-of-year and juvenile trout by larger adult trout, trout in Rush Creek derive most of their prey from drift of benthic macroinvertebrates. Bachman (1984) notes that "the mean amount of drift that passes a particular point in a stream is, over the long run, a linear function of the velocity at that point." Riffles supporting productive BMI habitat, in association with adult trout habitat, will be important for improving trout productivity, growth, and survival through successive life stages (Gore 1989).

A true measure of benthic invertebrate productivity expressed in units of biomass per unit surface area per unit time (e.g., $g/ft^2/day$) is difficult to measure. Even if productivity could be measured, a more daunting task would remain: establishing a quantitative relationship between macroinvertebrate productivity, fish populations, and streamflow. Although easier to measure than productivity, increases in invertebrate biomass, diversity, and drift rate also would be difficult to associate with increases in fish biomass (Gore 1989).

Our primary assumption in investigating benthic invertebrate habitat is that hydraulic conditions in a riffle affect overall invertebrate abundance. "Productive riffle habitat" may therefore be a viable surrogate for quantitatively linking benthic invertebrates to streamflow and brown trout in Rush Creek. The RTC Scientists avoided aquatic macroinvertebrates in the termination criteria and stream monitoring program. However, benthic invertebrates can help in evaluating baseflow recommendations. Statistically significant relationships between benthic invertebrate abundance and habitat suitability have been demonstrated in rivers where suitability functions have been derived (Gore 1989), and benthic invertebrate densities have also been related to more complex hydraulic parameters such as Froude number, Reynolds number, and boundary layer terms (Jowett et al. 1991).

Historically, rising spring flows in the annual hydrograph, on the heels of low winter baseflows, could have multiplied productive riffle area just as the water temperature range became optimal for aquatic macroinvertebrate production in Rush Creek. This portion of the hydrograph, when spring flows were ascending toward the snowmelt peak, may have stimulated benthic invertebrate productivity (a "vernal burst"), and resulted in high(er) invertebrate biomass at the height of the spring and summer trout growing season.

Our study approach was to quantify the area of productive riffle habitat, defined explicitly by depth, velocity, and substrate criteria that vary over a range of baseflows considered suitable for adult trout rearing habitat. Measuring the available productive riffle habitat required the following steps: (1) define 'productive riffle habitat' by designating ranges in physical variables that sustain high macroinvertebrate productivity in riffles, (2) relate productive riffle area to streamflow by habitat mapping a range of baseflows.

Productive riffle habitat for benthic macroinvertebrates was defined using the following physical habitat criteria:

- Depth: the minimum depth inundating the D84 particle size, up to a maximum depth of 1.5 ft for substrates larger than gravel;
- Velocity: >1.5 ft/s;
- Substrate: ranging from the median (D50) to the dominant (D84) particle size, typically gravel approximately 0.2 ft in 'b-axis' diameter (6 cm or 2.5 inches) in Lower Rush Creek, up to large cobble 0.8 ft in 'b-axis' diameter (25 cm or 9.85 in) in Upper Rush Creek;
- Temperature: a 'highly productive temperature range' of 50 oF (10 oC) as the daily minimum to 62 oF (17.2 oC) as the daily maximum (Hynes 1970).

We also mapped two additional channel features: (1) the wetted edge of the stream in the mapping reaches to computate riffle area (as a mesohabitat unit) and riffle wetted width as a function of streamflow, and (2) riffle crest thalweg depths which are the threshold depths that potentially impede trout movement along stream reaches.

4.3.2 Riffle Mapping Results

Productive riffle (BMI) habitat was mapped in the same five representative stream reaches mapped for brown trout habitat during the stream discharge test flows of 15, 30, 45, 60 and 90 cfs. Those reaches included Upper Rush Creek (1,403 ft), the Lower Rush Creek mainstem (1,279 ft) and 10-Channel (823 ft), the Rush Creek Ford reach (between the 10-Falls and the wet ford crossing) (2,157 ft), and the County Road reach (between the wet ford and Test Station Road [County Road]) (1,421 ft) (Figure 21). Habitat polygons were digitized and areas quantified for each mapped discharge.

The BMI habitat area increased in all five reaches between 15 cfs and 45 cfs (Figure 22). In three of the five mapping reaches, BMI habitat area reached an asymptote at 45 cfs, and increased only slightly (10-Channel) or decreased slightly (Upper Rush, Ford reaches) from 45 cfs to 60 cfs, and from 60 cfs to 90 cfs. Only two reaches (lower Rush, County Road) continued to gain BMI habitat area with increased flows from 60 cfs to 90 cfs. These habitat rating curves highlight the differing hydraulic dynamics between the two mainstem reaches: the higher slope and roughness in the upper Rush Creek reach translated into deeper main channel flows compared to the reaches below the Narrows, in which the lower channel gradient, and finer substrate particle size translated into smaller incremental stage changes.

As flow increased during 45 cfs to 60 cfs to 90 cfs releases, we noted a lateral expanse in BMI habitat along the stream margin and gravel bar edges governed by the velocity criterion, and a decrease in mid-channel BMI habitat governed by the depth criterion. An example of our mapping from the Rush Creek Ford reach is provided to illustrate these changes in habitat area with flow (Figure 23). Exceedence of the 1.5 ft depth threshold did not signify that BMI habitat would be bad, only that it was likely not as hydraulically complex and/or as biologically productive. Substrate area that met our particle size criterion was the ultimate limitation to productive riffle area.

Stage changes on representative cross sections were compared to the BMI polygon mapping results to functionally extend the habitat rating curves beyond 90 cfs. At the 90 cfs release, most riffle area remained under 1.5 ft deep. Monitored cross-sections also show this (Appendix B). A 150 cfs streamflow generally exceeds the 1.5 ft depth threshold for a large proportion of the riffle cross-sections.

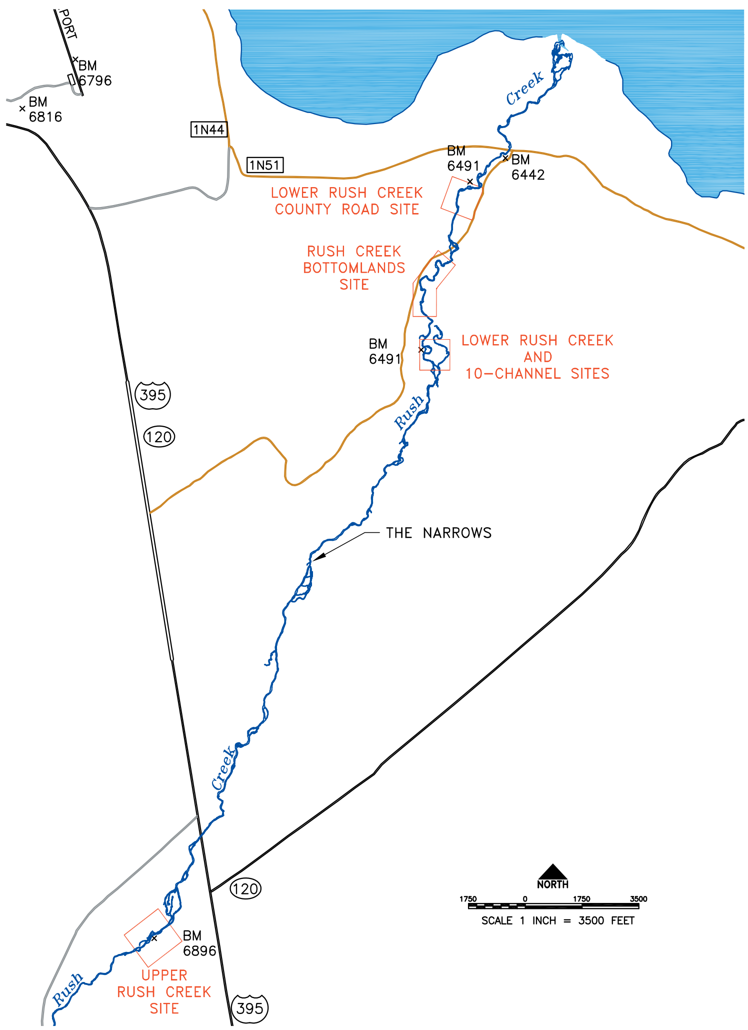

Figure 21. Habitat mapping reaches in Rush Creek where benthic macroinvertebrate habitat was mapped in August 2008.

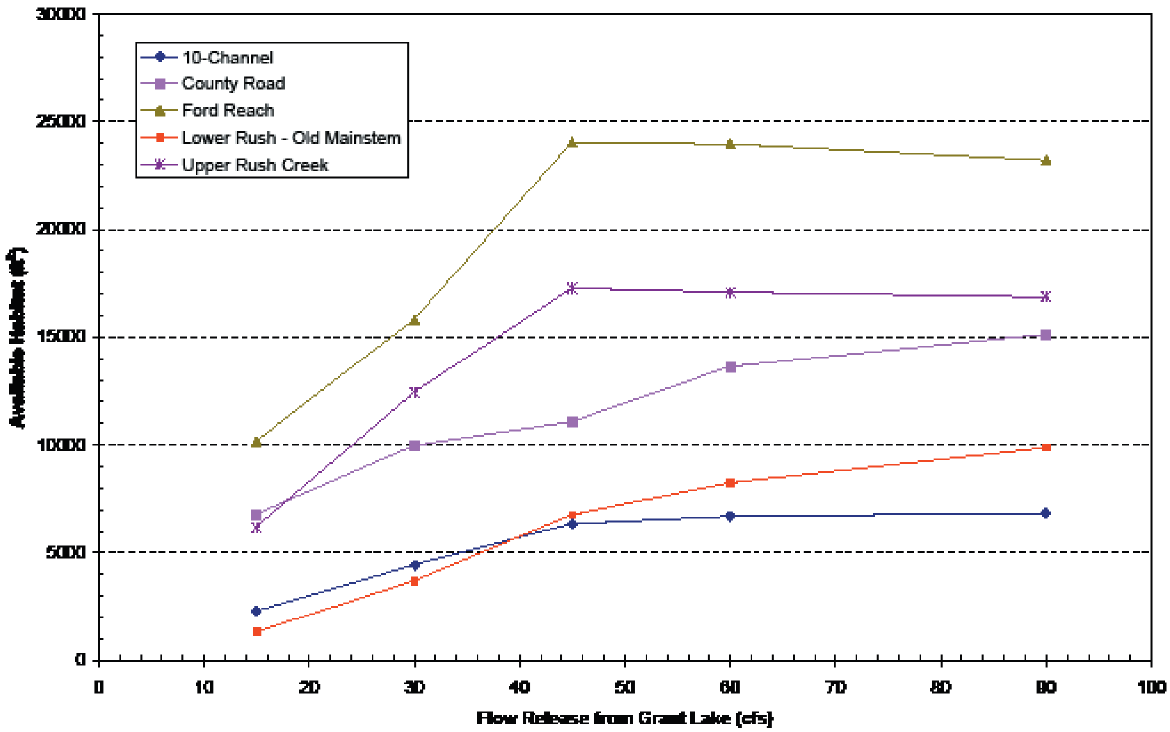

Figure 22. Benthic invertebrate habitat rating curves for five reaches mapped on Rush Creek in August 2008.

During the habitat mapping, we mapped the wetted edge of the channel onto the aerial photographs at each flow to compute riffle wetted area (in ft2) as a function of discharge. We also computed the incremental increase in area of inundated depositional features (e.g., gravel bars), establishing the 15 cfs flow release as a baseline (i.e., assuming no inundation of depositional features at this flow). We plotted these two curves with the BMI curves for the Rush Creek Ford reach (Figure 24). The riffle area curve was relatively flat, with little change in trajectory, indicating the test flows had not reached an asymptote in riffle area. The inundated depositional features curve did appear to surpass a threshold, in which the curve steepened between 45 cfs and 60 cfs, after which the rate of increase in inundated area decreased. Finally, the BMI curve for the Rush Creek Ford reach attained an asymptote at 45 cfs.

We also mapped cut-off channels and side-channels that were flowing during the higher experimental instream flow releases. We noted a general threshold between 60 cfs and 90 cfs in which many (but not all) alcoves, lateral scour channels, and side channels became wet and began flowing. There were only a few of these features in each mapping reach, so this trend may not apply on a reach or river-wide scale. In some cases, the side-channels are often former mainstem channels. The ecological significance of these off-channel features was not quantified. However, several ecological functions are likely, including (1) providing abundant brown trout fry rearing habitat, (2) imputing large organic matter into the mainstem channel, especially willow and alder leaves having fallen the previous autumn, and (3) recharging shallow groundwater close to the mainstem channel. These features are drowned-out by streamflows inundating the entire floodplain (i.e., greater than 300 cfs).

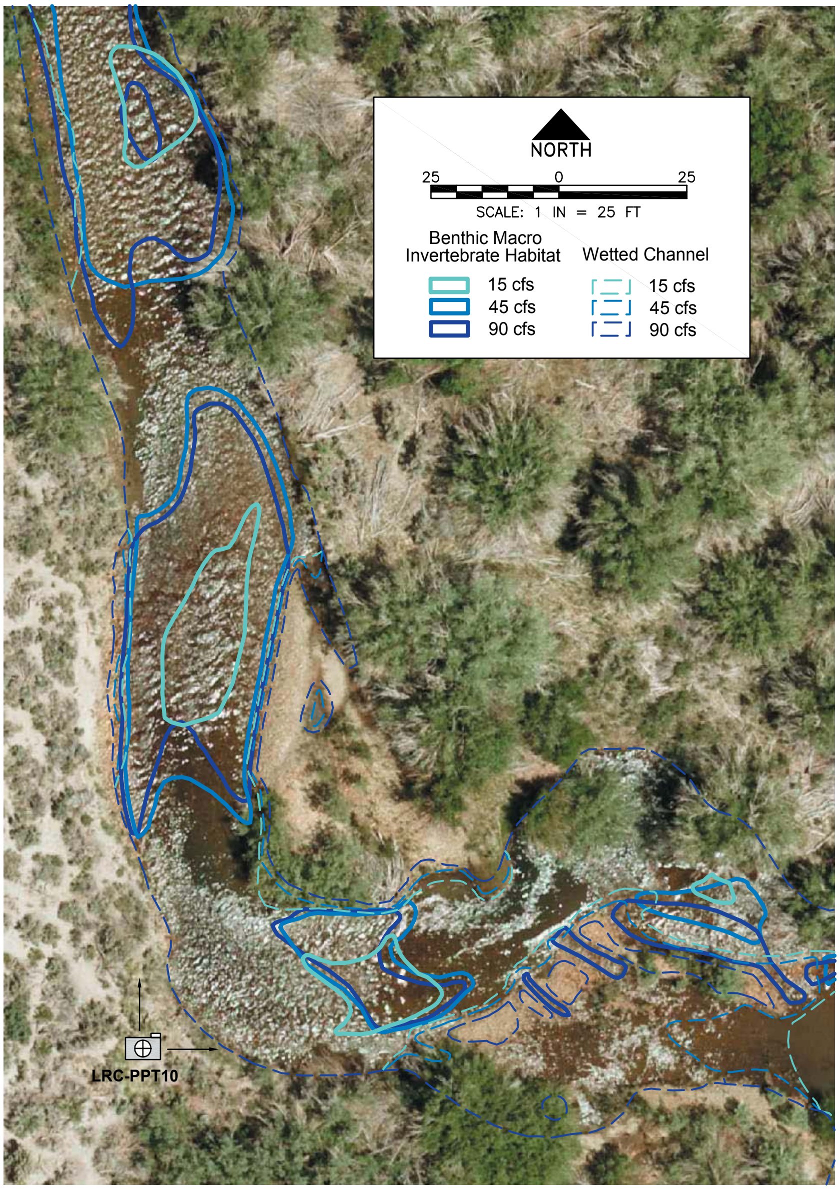

Figure 23. Example habitat map showing three of the five BMI polygons mapped on Rush Creek in the Bottomlands reach. Note the 15 cfs mid-channel polygon at the top of the photo was not mapped as habitat at the 90 cfs flow. In the bottom right of the photo, flow across the gravel bar provided BMI habitat at 90 cfs, but not the lower flows.

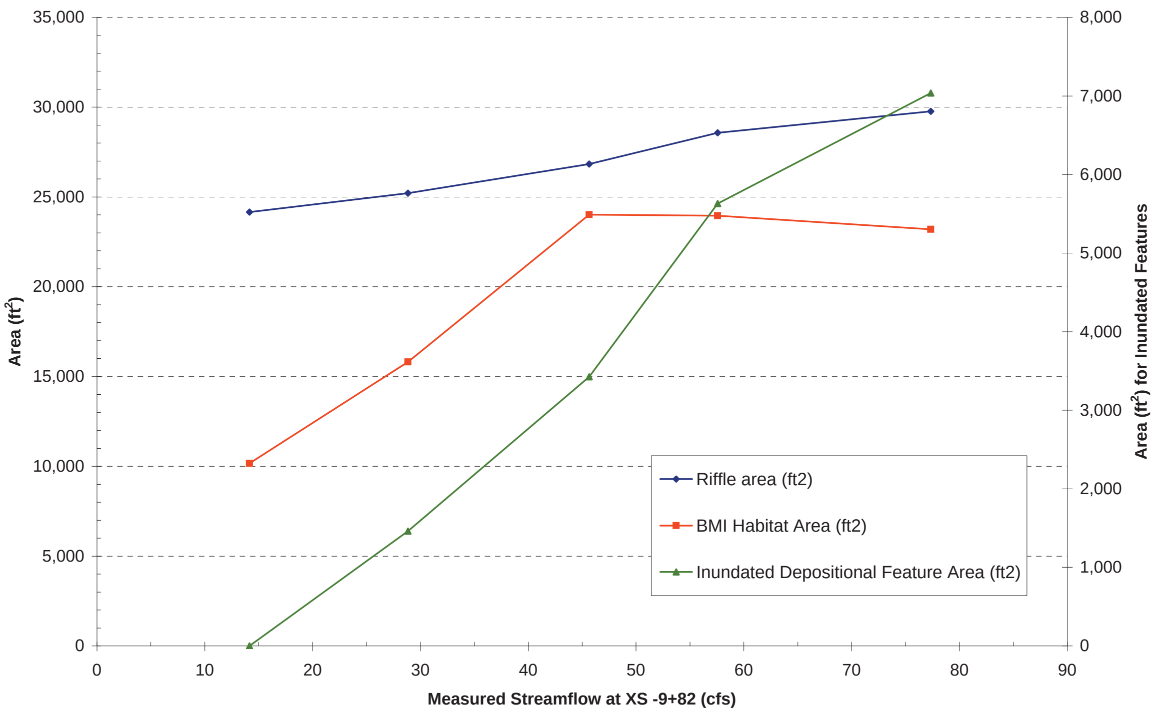

Figure 24. Composite curves showing BMI habitat area, riffle area as measured by increasing inundation of channel margins, and cumulative area of inundated depositional features. The relative shape of the curves and inflection points is the important feature of the chart.

Within our mapping reaches we established fifteen photo monitoring points, at which multiple-photo panoramic photographs were taken during each of the five test flows. These photo images are a useful tool to demonstrate changes in channel and habitat features that were available during the test flows, and as a useful reminder afterward of those conditions. An example photo from Photopoint #4 is shown in Figure 25.

Finally, we measured the thalweg depth at each riffle crest in the mapping reaches, to assess fish passage at each test flow. We plotted the thalweg depths for each reach in reference to their location along Rush Creek (Figure 26), to provide perspective on the distribution of riffle thalweg depths over the range of test flows. We also ranked the thalweg depths measured at each flow for each site, from deepest to shallowest measurement, and plotted those depths as an exceedence frequency (rank divided by the number of measurements). These charts are presented in Appendix D.

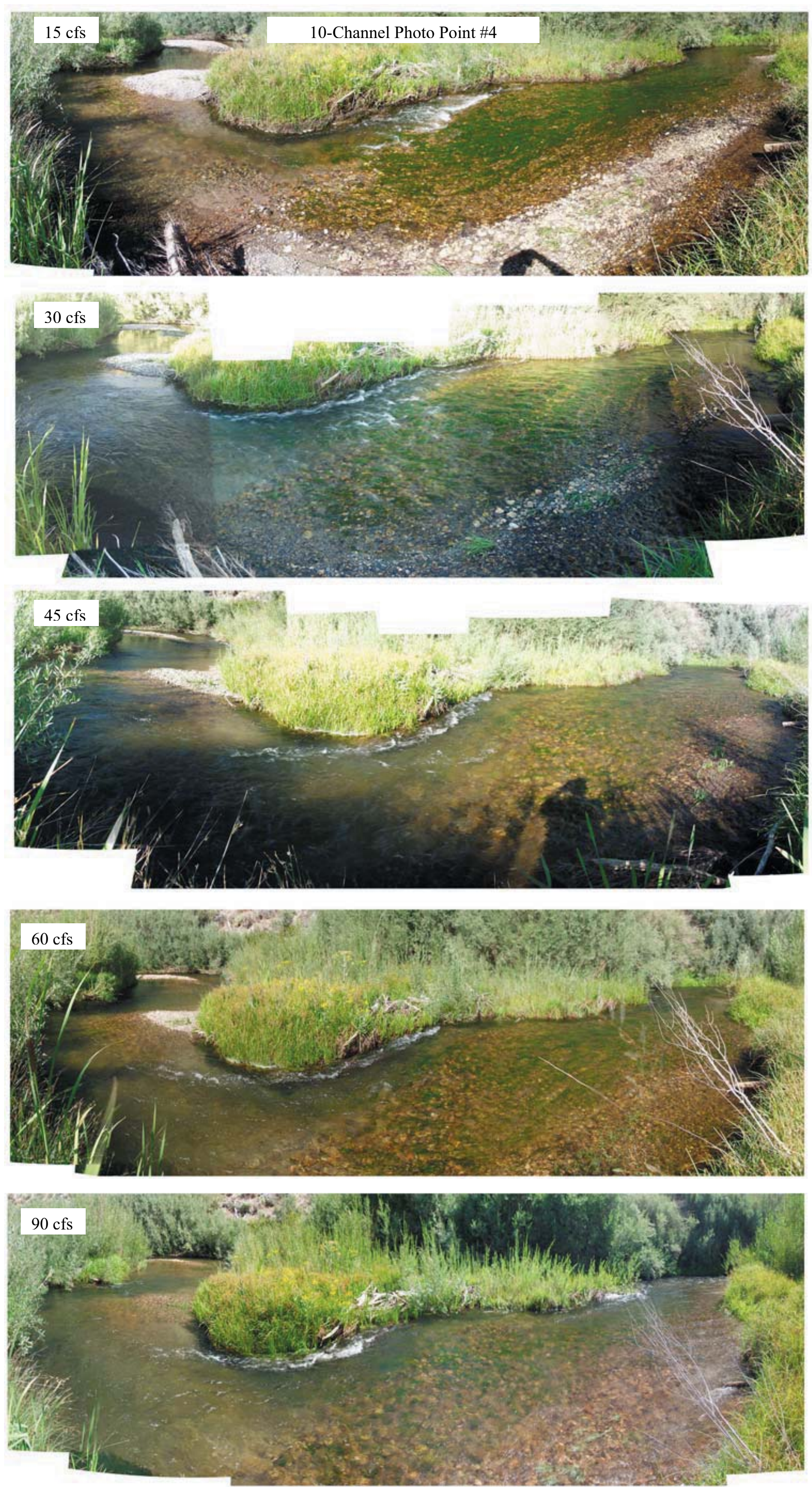

Figure 25. Example of panoramic photographs obtained over the five habitat flows mapped in August 2008.

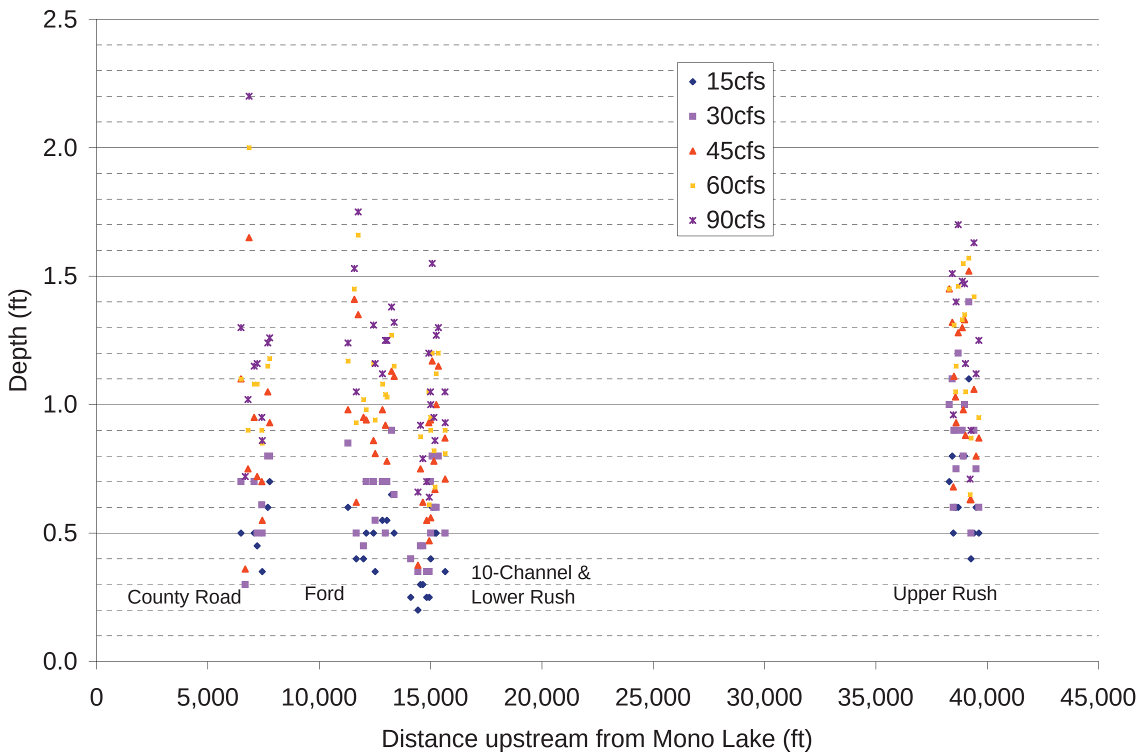

Figure 26. Distribution of riffle thalweg depths measured during the habitat mapping on Rush Creek.

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APPENDIX A

Water Temperature Data for Rush, Lee Vining, Parker, and Walker creeks
for Runoff Years 2000-2008

Rush Creek at Return Ditch									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)	49	49	51	47	43	45	46.3	50.4	49.1
ANNUAL MAX (°F)	67	69	71	69	64	65	64.5	78.1	79.5
ANNUAL MIN (°F)	34	34	32	32	32	32	32	33.2	29.6
MAX DAILY FLUX (°F)	9	10	9	6	9	9	11.1	18.4	22.2
WINTER MAX (°F)	43	42	43	43	44	40	42	51.3	51.3
WINTER MIN (°F)	34	34	32	32	32	32	32	33.2	29.6
WINTER AVERAGE (°F)	37	37	37	37	37	34	37	37.8	34.8
MAX WINTER FLUX (°F)	5	5	5	5	5	5	7	12.3	16.4
SUMMER MAX (°F)	67	69	71	69	.	65	65	78.1	79.5
SUMMER MIN (°F)	55	53	57	60	.	53	50	54.6	54.2
SUMMER AVERAGE (°F)	60	62	64	64	.	57	55	64.1	65.6
MAX SUMMER FLUX (°F)	9	10	8	6	.	9	8	18.4	16.9
MWAT							59.2	66.8	68.6
MWMT							62.8	76.5	76.2
DATE OF ANNUAL MAX	8/27/2000	8/19/2001	7/30/2002	8/20/2003	10/1/2003	9/10/2005	9/12/2006	8/3/2007	7/30/2008
Start Date	10/10/1999	10/1/2000	10/1/2001	10/1/2002	10/1/2003	12/1/2004	10/1/2005	10/1/2006	10/1/2007
End Date	9/30/2000	9/30/2001	9/30/2002	9/30/2003	5/6/2004	9/30/2005	9/30/2006	9/30/2007	9/29/2008
Number of Days Sampled	357	365	365	365	218	303	365	365	365

Rush Creek at Old Highway 395									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)						NA	47.2	49.5	48.3
ANNUAL MAX (°F)						66	66.7	72.2	75.7
ANNUAL MIN (°F)						NA	32	31.5	28.3
MAX DAILY FLUX (°F)						NA	11.3	15.4	19.8
WINTER MAX (°F)						NA	45	51.0	48.0
WINTER MIN (°F)						NA	32	31.5	28.3
WINTER AVERAGE (°F)						NA	34	37.1	33.4
MAX WINTER FLUX (°F)						NA	11	12.6	15.2
SUMMER MAX (°F)						66	67	72.2	75.7
SUMMER MIN (°F)						53	53	52.9	56.1
SUMMER AVERAGE (°F)						57	57	62.7	65.1
MAX SUMMER FLUX (°F)						12	11	15.1	14.5
MWAT							59.2	65.0	67.6
MWMT							64.7	71.0	74.7
DATE OF ANNUAL MAX						NA	9/12/2006	8/8/2007	7/30/2008
Start Date						6/1/2005	10/1/2005	10/1/2006	10/1/2007
End Date						9/30/2005	9/30/2006	9/30/2007	9/29/2008
Number of Days Sampled	0	0	0	0	0	122	365	365	365

Rush Creek at the Narrows/3D Site									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)	48	48	42	45	48	NA	44.3	49.3	48.2
ANNUAL MAX (°F)	71	73	67	67	72	NA	67.2	73.2	74.9
ANNUAL MIN (°F)	32	32	32	32	31	NA	0	32.0	32.0
MAX DAILY FLUX (°F)	20	20	18	21	16	NA	14.5	19.9	20.7
WINTER MAX (°F)	52	50	50	51	49	NA	46	54.3	49.4
WINTER MIN (°F)	32	32	32	32	31	NA	32	32.0	32.0
WINTER AVERAGE (°F)	37	36	36	37	35	NA	33	37.1	34.0
MAX WINTER FLUX (°F)	16	15	15	14	16	NA	13	17.2	16.3
SUMMER MAX (°F)	71	73	67	67	.	NA	67	73.2	74.9
SUMMER MIN (°F)	50	52	53	52	.	NA	48	50.2	52.3
SUMMER AVERAGE (°F)	59	61	58	58	.	NA	57	62.1	63.3
MAX SUMMER FLUX (°F)	17	16	14	14	.	NA	14	17.7	18.0
MWAT							58.5	64.8	66.3
MWMT							64.9	71.2	73.1
DATE OF ANNUAL MAX	8/27/2000	8/19/2001	9/21/2002	5/27/2003	7/23/2004	NA	9/5/2006	7/22/2007	1/0/1900
Start Date	10/10/1999	10/1/2000	10/1/2001	10/1/2002	10/1/2003	10/1/2004	11/22/2005	10/1/2006	10/1/2007
End Date	9/30/2000	9/30/2001	9/30/2002	9/30/2003	9/30/2004	10/19/2004	9/30/2006	9/30/2007	9/29/2008
Number of Days Sampled	357	365	365	365	366	19	313	365	365

Rush Creek at County Road Culvert									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)	48	48	49	45	49	NA	NA	49	48
ANNUAL MAX (°F)	72	71	75	74	75	NA	70	75	76
ANNUAL MIN (°F)	32	32	32	32	32	33	NA	32	32
MAX DAILY FLUX (°F)	22	18	21	18	24	NA	16	22	23
WINTER MAX (°F)	53	47	48	45	56	52	NA	55	50
WINTER MIN (°F)	32	32	32	32	32	34	NA	32	32
WINTER AVERAGE (°F)	37	36	36	37	36	36	NA	37	34
MAX WINTER FLUX (°F)	19	9	12	8	20	17	NA	17	17
SUMMER MAX (°F)	72	71	75	NA	.	NA	70	75	76
SUMMER MIN (°F)	48	52	51	NA	.	NA	48	48	49
SUMMER AVERAGE (°F)	60	61	62	NA	.	NA	61	62	63
MAX SUMMER FLUX (°F)	18	17	16	NA	.	NA	16	20	19
MWAT							62	65	66
MWMT							69	73	74
DATE OF ANNUAL MAX	8/27/2000	7/1/2001	7/25/2002	8/16/2003	7/22/2004	NA	9/6/2006	7/22/2007	8/15/2008
Start Date	10/10/1999	10/1/2000	10/1/2001	/1/2003 to 3/21/200	10/1/2003	10/1/2004	5/31/2006	10/1/2006	10/1/2007
End Date	9/30/2000	9/30/2001	9/30/2002	/11/2003 to 9/30/200	9/30/2004	6/30/2005	9/30/2006	9/30/2007	9/30/2008
Number of Days Sampled	357	365	365	#VALUE!	366	273	122	365	366

Upper Parker Creek									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)	43	43	NA	43	NA	41	42.4	44.2	43.2
ANNUAL MAX (°F)	62	64	NA	69	NA	57	58.2	64.2	62.8
ANNUAL MIN (°F)	26	32	32	32	0	32	32	31.8	31.8
MAX DAILY FLUX (°F)	18	18	14	13	13	12	13.4	12.3	22.7
WINTER MAX (°F)	48	39	43	43	46	40	39	46.2	40.1
WINTER MIN (°F)	39	32	32	32	31	36	32	31.8	31.8
WINTER AVERAGE (°F)	41	33	33	33	33	38	32	34.2	33.0
MAX WINTER FLUX (°F)	18	3	9	8	10	5	5	8.7	6.0
SUMMER MAX (°F)	59	63	NA	69	.	57	58	64.2	62.8
SUMMER MIN (°F)	52	47	NA	45	.	37	40	43.7	44.0
SUMMER AVERAGE (°F)	54	55	NA	55	.	49	51	55.9	55.2
MAX SUMMER FLUX (°F)	18	10	NA	11	.	12	9	10.9	9.8
MWAT							39355.0	56.5	57.7
MWMT							64.2	62.8	62.1
DATE OF ANNUAL MAX	7/30/2000	6/5/2001	NA	8/14/2003	NA	8/12/2005	7/28/2006	7/16/2007	8/24/2008
Start Date	11/7/1999	10/1/2000	10/1/2001	10/1/2002	10/1/2003	10/1/2004	10/1/2005	10/1/2006	10/1/2007
End Date	9/30/2000	9/30/2001	5/2/2002	9/30/2003	5/6/2004	8/16/2005	9/30/2006	9/30/2007	9/30/2008
Number of Days Sampled	329	365	214	365	218	320	365	365	366

Lower Parker Creek									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)					NA		43.1	44.9	43.8
ANNUAL MAX (°F)					72		62.2	68.1	70.8
ANNUAL MIN (°F)					NA		32	21.6	29.7
MAX DAILY FLUX (°F)					16		15.8	23.3	23.7
WINTER MAX (°F)					NA		47	54.8	37.1
WINTER MIN (°F)					NA		32	21.6	31.9
WINTER AVERAGE (°F)					NA		33	33.8	32.2
MAX WINTER FLUX (°F)					NA		14	19.4	3.8
SUMMER MAX (°F)					.		62	68.1	70.8
SUMMER MIN (°F)					.		39	40.6	41.0
SUMMER AVERAGE (°F)					.		53	57.4	56.8
MAX SUMMER FLUX (°F)					.		13	16.6	19.1
MWAT							55.7	60.9	60.2
MWMT							60.2	66.8	69.4
DATE OF ANNUAL MAX					8/11/2004		9/5/2006	8/22/2007	8/15/2008
Start Date					5/6/2004		10/10/2005	10/1/2006	10/1/2007
End Date					9/30/2004		9/30/2006	9/30/2007	9/30/2008
Number of Days Sampled					148		355	365	366

Upper Walker Creek									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)	46	45	NA	45	45	44	44.5	41.5	44.3
ANNUAL MAX (°F)	69	70	NA	77	76	69	68.6	66.3	74.5
ANNUAL MIN (°F)	29	32	32	32	29	31	32	31.8	31.8
MAX DAILY FLUX (°F)	NA	23	16	32	34	16	9.3	9.2	23.5
WINTER MAX (°F)	55	38	45	42	47	37	38	43.8	36.4
WINTER MIN (°F)	41	32	32	32	32	34	32	31.8	31.8
WINTER AVERAGE (°F)	43	33	33	33	33	35	33	33.5	32.4
MAX WINTER FLUX (°F)	24	6	12	9	12	4	4	6.2	3.2
SUMMER MAX (°F)	68	70	NA	71	.	69	69	66.3	68.1
SUMMER MIN (°F)	58	46	NA	43	.	35	41	42.6	44.6
SUMMER AVERAGE (°F)	61	59	NA	59	.	56	58	57.1	59.1
MAX SUMMER FLUX (°F)	32	19	NA	16	.	11	9	7.0	9.3
MWAT							63.7	62.4	63.0
MWMT							66.7	64.7	66.5
DATE OF ANNUAL MAX	7/30/2000	8/16/2001	NA	5/22/2003	9/14/2004	7/19/2005	7/28/2006	7/28/2007	6/12/2008
Start Date	11/7/1999	10/1/2000	10/1/2001	10/1/2002	10/1/2003	10/1/2004	10/1/2005	10/1/2006	10/1/2007
End Date	9/30/2000	9/30/2001	4/4/2002	9/30/2003	9/30/2004	8/16/2005	9/30/2006	9/30/2007	9/29/2008
Number of Days Sampled	329	365	186	365	366	320	365	279	365

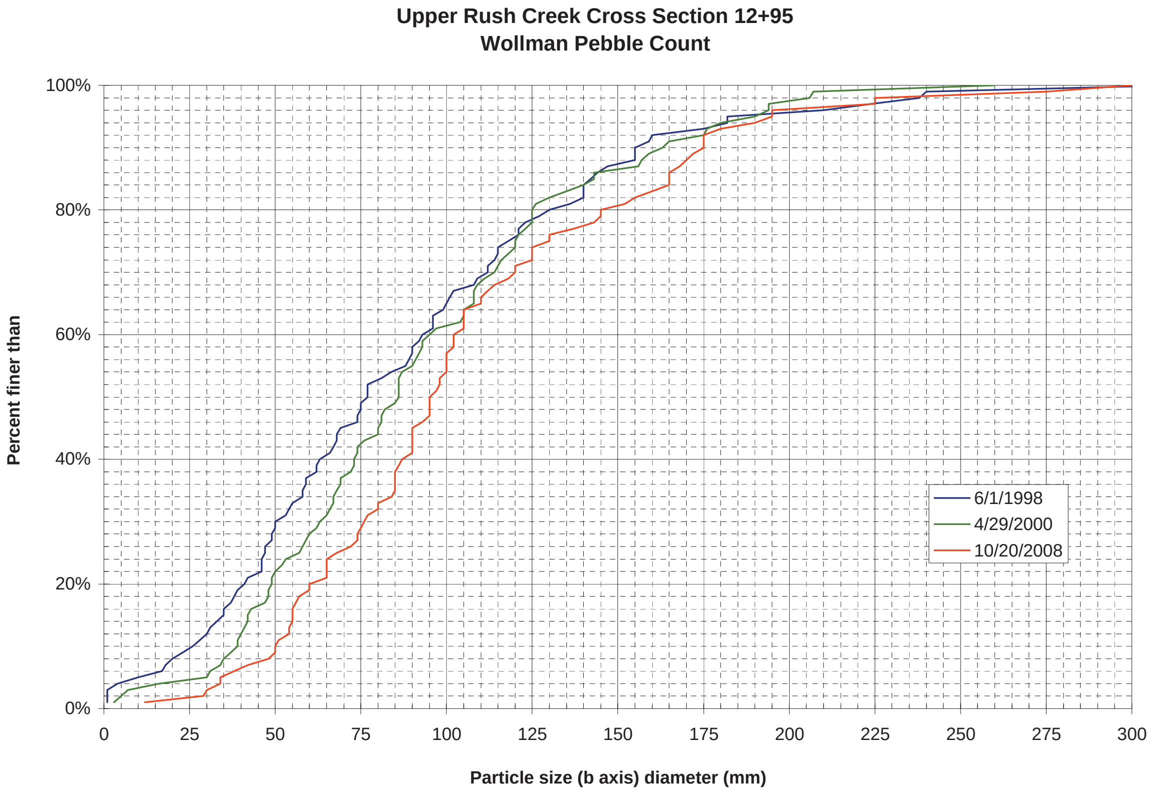
Lower Walker Creek									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)					NA	45	46.1	45.8	39.7
ANNUAL MAX (°F)					76	71	71.9	72.0	66.1
ANNUAL MIN (°F)					NA	27	33	31.8	0.0
MAX DAILY FLUX (°F)					NA	17	30.7	20.6	23.8
WINTER MAX (°F)					NA	46	44	52.9	43.7
WINTER MIN (°F)					NA	34	33	31.8	29.6
WINTER AVERAGE (°F)					NA	36	35	34.8	32.9
MAX WINTER FLUX (°F)					NA	13	11	16.7	11.8
SUMMER MAX (°F)					.	71	72	72.0	66.0
SUMMER MIN (°F)					.	43	37	41.8	0.0
SUMMER AVERAGE (°F)					.	60	58	57.8	60.1
MAX SUMMER FLUX (°F)					.	13	31	20.6	11.2
MWAT							63.9	61.8	44.6
MWMT							69.0	69.0	50.5
DATE OF ANNUAL MAX					9/14/2004	7/17/2005	9/5/2006	7/12/2007	1/0/1900
Start Date					5/6/2004	10/1/2004	10/1/2005	10/1/2006	10/1/2007
End Date					9/30/2004	9/30/2005	9/30/2006	9/30/2007	3/19/2008
Number of Days Sampled					147	365	365	365	170

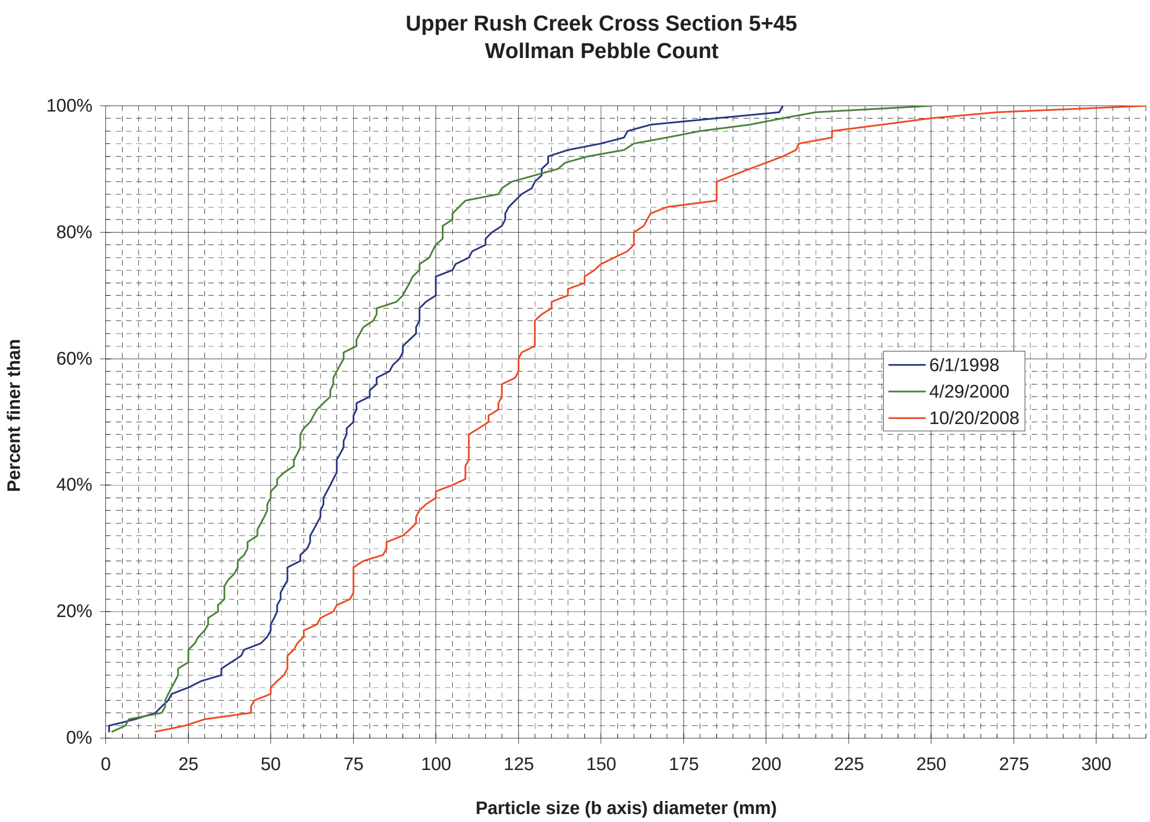
Lee Vining Creek below Intake									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)						not available	not available	not available	42.0
ANNUAL MAX (°F)						53	not available	64.7	63.1
ANNUAL MIN (°F)						not available	31	30.9	31.5
MAX DAILY FLUX (°F)						12	not available	16.4	14.9
WINTER MAX (°F)						not available	41	not available	43.7
WINTER MIN (°F)						not available	31	not available	31.5
WINTER AVERAGE (°F)						not available	34	not available	33.7
MAX WINTER FLUX (°F)						not available	8	not available	9.9
SUMMER MAX (°F)						51	not available	64.7	63.1
SUMMER MIN (°F)						43	not available	40.9	42.4
SUMMER AVERAGE (°F)						47	not available	53.1	53.2
MAX SUMMER FLUX (°F)						4	not available	14.5	13.8
MWAT									55.3
MWMT									62.2
DATE OF ANNUAL MAX						8/14/2005	not available	7/30/2007	8/15/2008
Start Date						4/17/2005	11/21/2005	4/24/2007	10/1/2007
End Date						8/15/2005	4/30/2006	9/30/2007	9/30/2008
Number of Days Sampled						120	160	159	366

Lee Vining at County Road									
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
DAILY AVERAGE (°F)					not available	not available	41.9	44.4	not available
ANNUAL MAX (°F)					66	not available	60.4	67.0	not available
ANNUAL MIN (°F)					not available	32	32	31.9	31.9
MAX DAILY FLUX (°F)					not available	not available	13.8	14.0	not available
WINTER MAX (°F)					not available	47	42	47.0	45.1
WINTER MIN (°F)					not available	32	32	31.9	31.9
WINTER AVERAGE (°F)					not available	35	34	34.8	33.7
MAX WINTER FLUX (°F)					not available	12	10	10.8	10.5
SUMMER MAX (°F)						not available	60	67.0	not available
SUMMER MIN (°F)						not available	41	43.4	not available
SUMMER AVERAGE (°F)						not available	52	56.2	51.4
MAX SUMMER FLUX (°F)						not available	11	13.9	not available
MWAT							55.0	48.5	50.8
MWMT							58.8	56.3	55.5
DATE OF ANNUAL MAX					8/9/2004		7/28/2006	7/30/2007	not available
Start Date					5/5/2004	10/1/2004	10/14/2005	10/1/2006	10/1/2007
End Date					9/30/2004	4/17/2005	9/30/2006	9/30/2007	6/25/2008
Number of Days Sampled					148	198	352	365	269
									logger swept out of

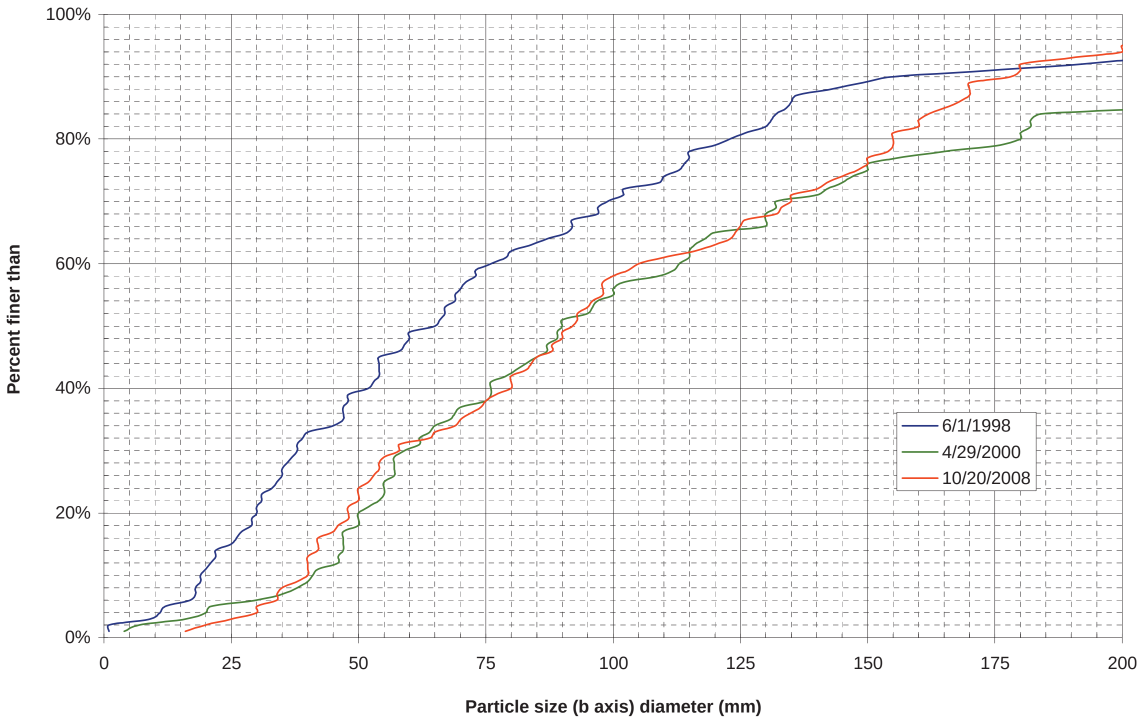
APPENDIX B

Pebble Count Data for Rush Creek
for Runoff Years 1997-2008

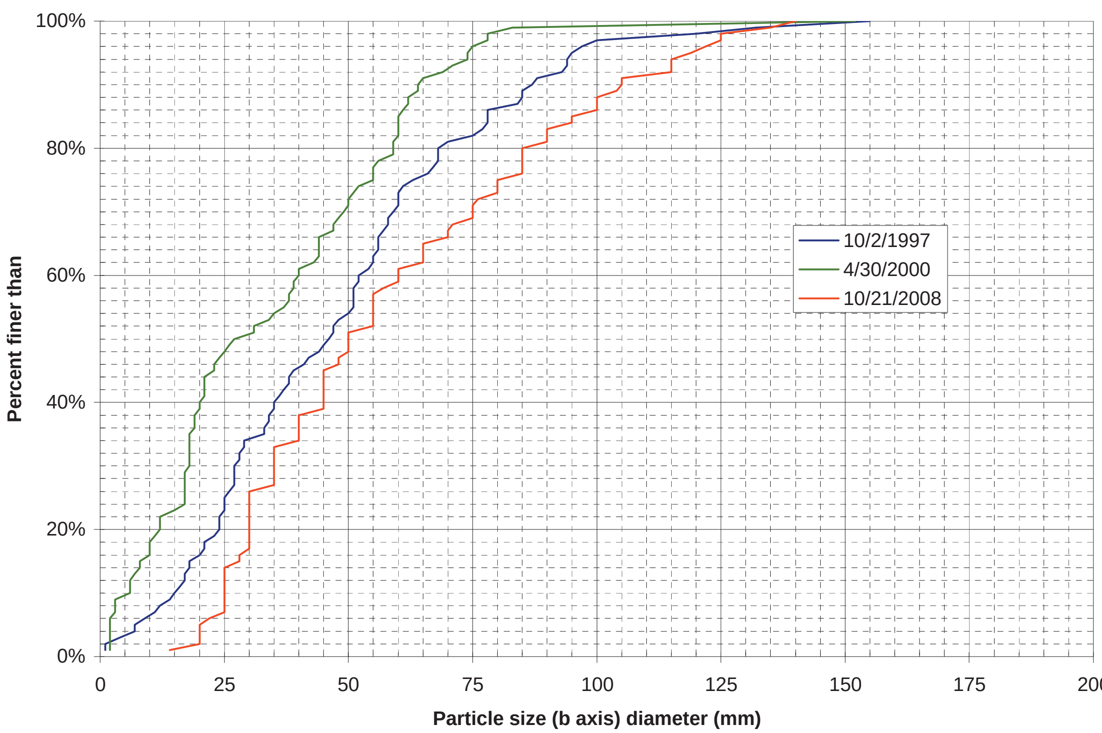

Upper Rush Creek Cross Section 12+95
Wollman Pebble Count
Percent finer than
0%
20%
40%
60%
80%
100%
0
25
50
75
100
125
150
175
200
225
250
275
300
Particle size (b axis) diameter (mm)
6/1/1998
4/29/2000
10/20/2008


Upper Rush Creek Cross Section 5+45
Wollman Pebble Count
Percent finer than
0%
20%
40%
60%
80%
100%
0
25
50
75
100
125
150
175
200
225
250
275
300
Particle size (b axis) diameter (mm)
6/1/1998
4/29/2000
10/20/2008

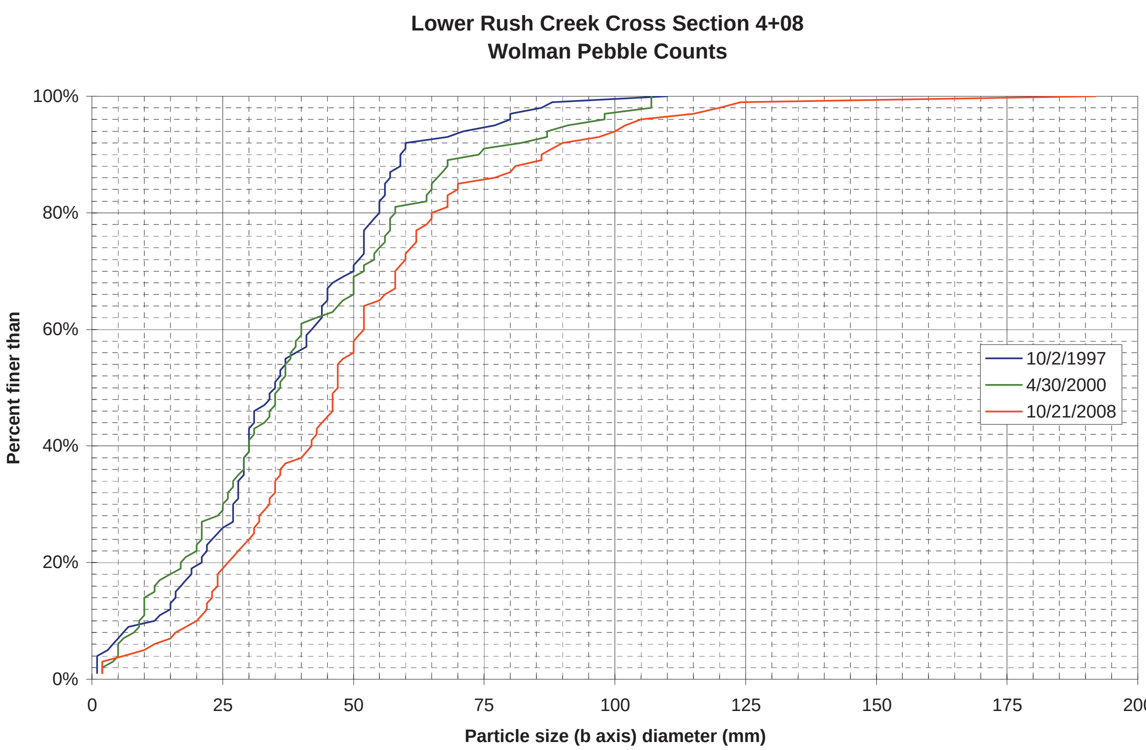
Upper Rush Creek Cross Section 00+74
Wollman Pebble Count

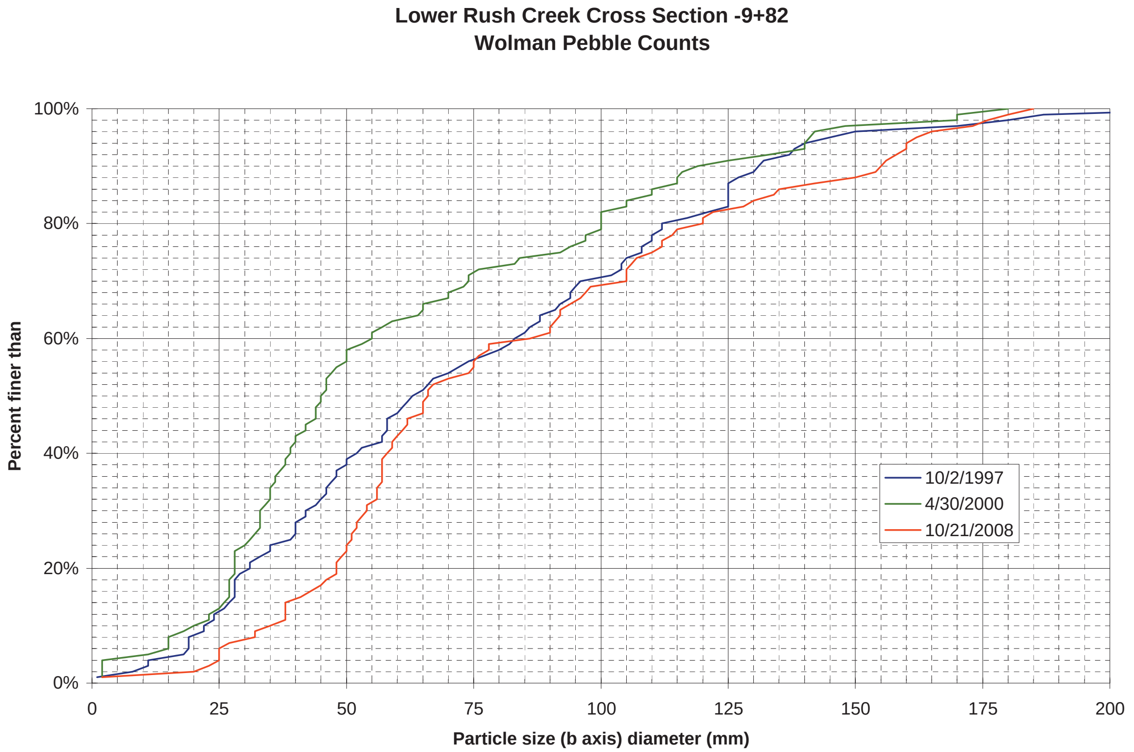


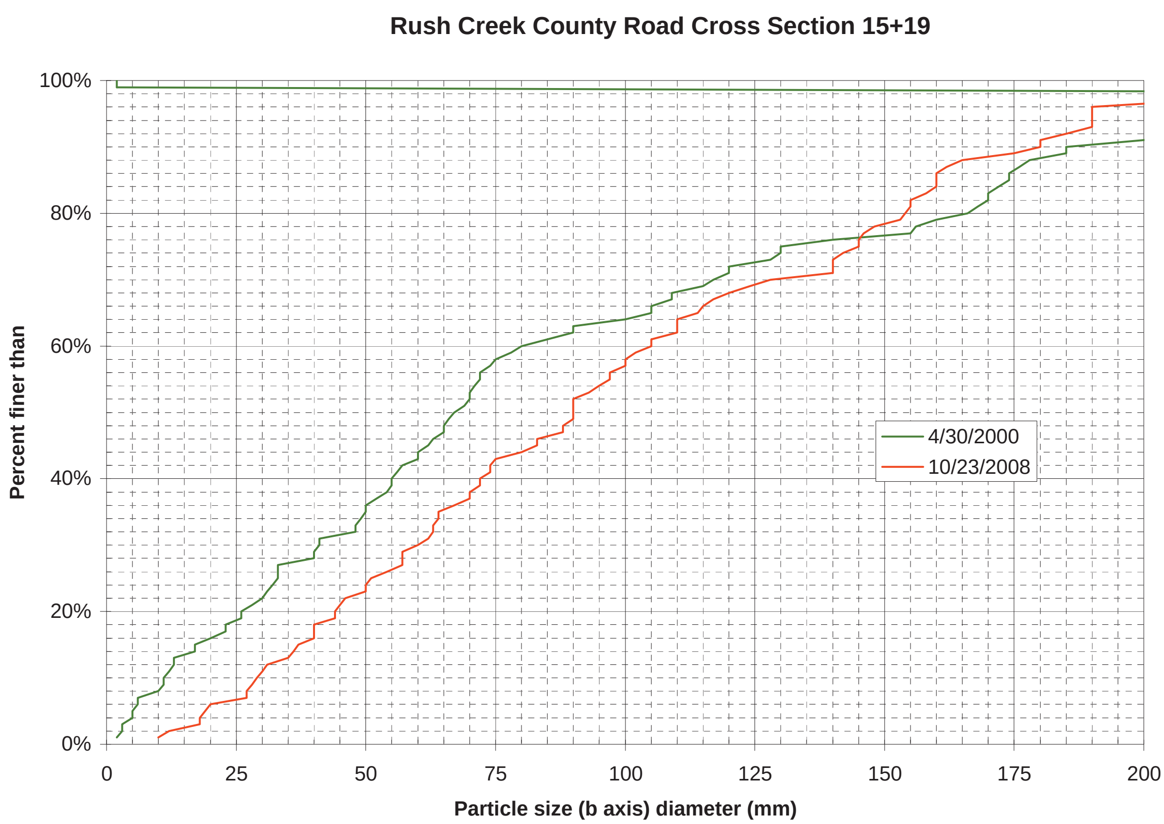
Lower Rush Creek Cross Section 10+10




Lower Rush Creek Cross Section 7+25
Percent finer than
100%
80%
60%
40%
20%
0%
0
25
50
75
100
125
150
175
200
Particle size (b axis) diameter (mm)
4/30/2000
10/21/2008


Lower Rush Creek Cross Section 4+08
Wolman Pebble Counts
Percent finer than
100%
80%
60%
40%
20%
0%
0
25
50
75
100
125
150
175
200
Particle size (b axis) diameter (mm)
10/2/1997
4/30/2000
10/21/2008

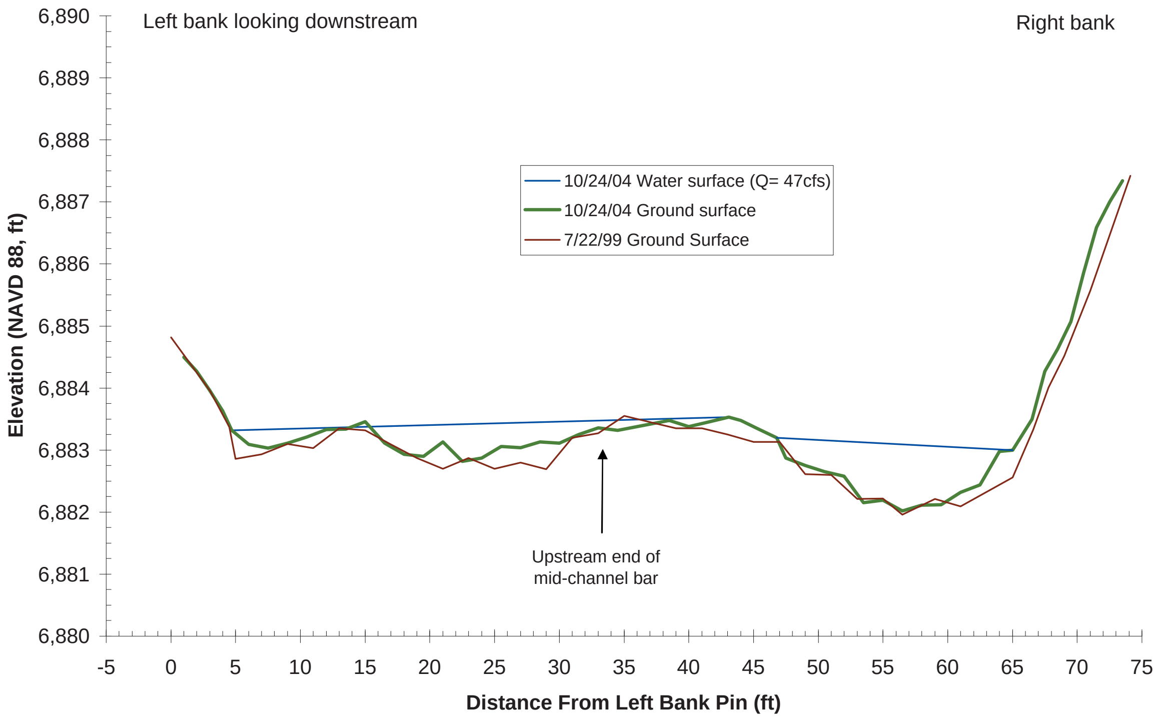

Lower Rush Creek Cross Section -9+82
Wolman Pebble Counts
Percent finer than
100%
80%
60%
40%
20%
0%
0
25
50
75
100
125
150
175
200
Particle size (b axis) diameter (mm)
10/2/1997
4/30/2000
10/21/2008

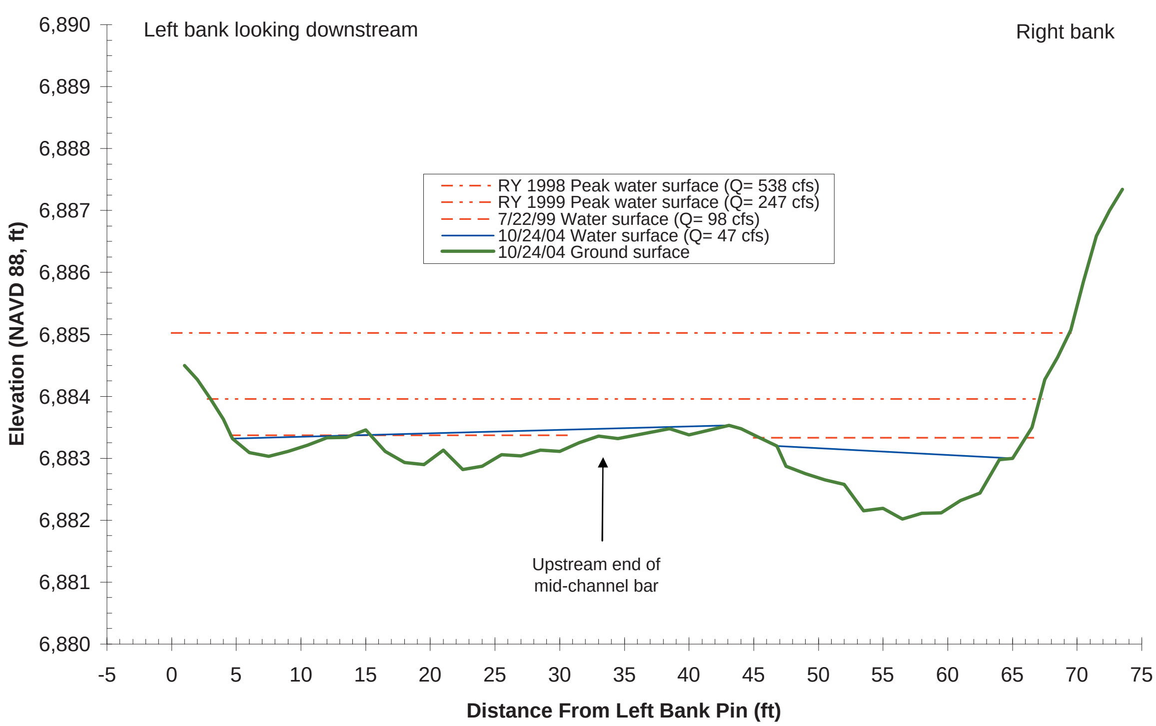

Rush Creek County Road Cross Section 15+19
Percent finer than
100%
80%
60%
40%
20%
0%
0
25
50
75
100
125
150
175
200
Particle size (b axis) diameter (mm)
4/30/2000
10/23/2008

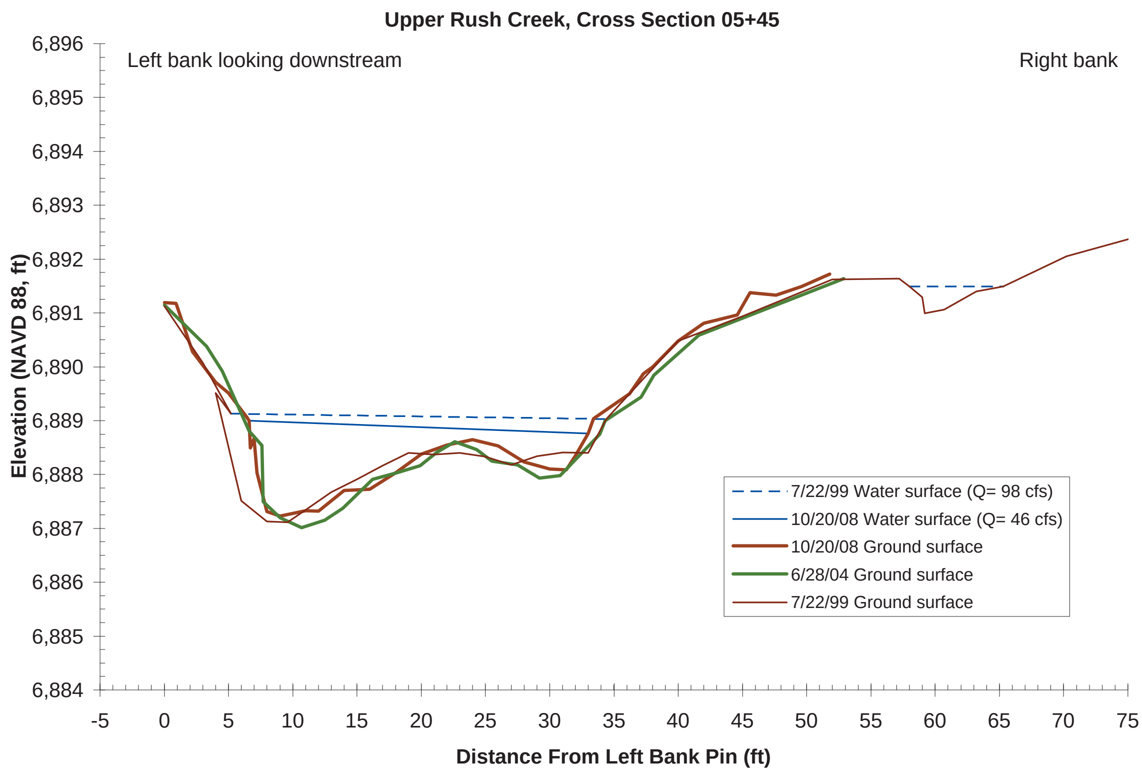
APPENDIX C

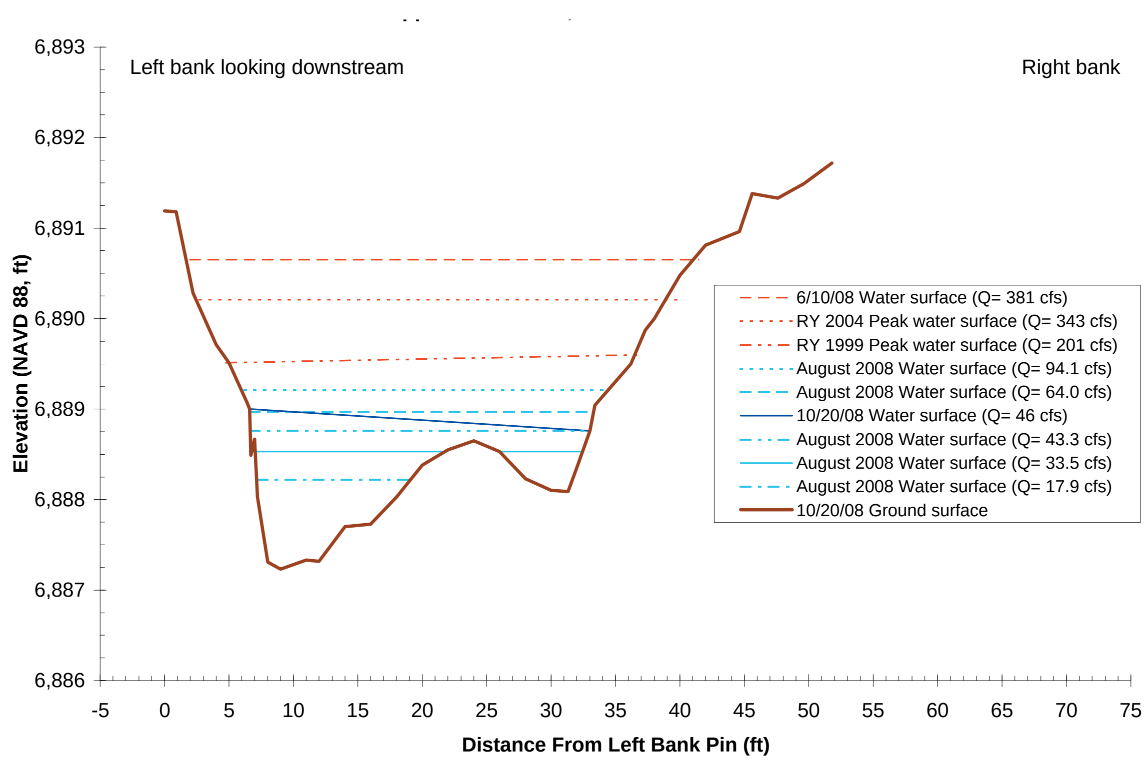
Topographic and Water Surface Surveys for Rush Creek
for Runoff Years 1995-2008

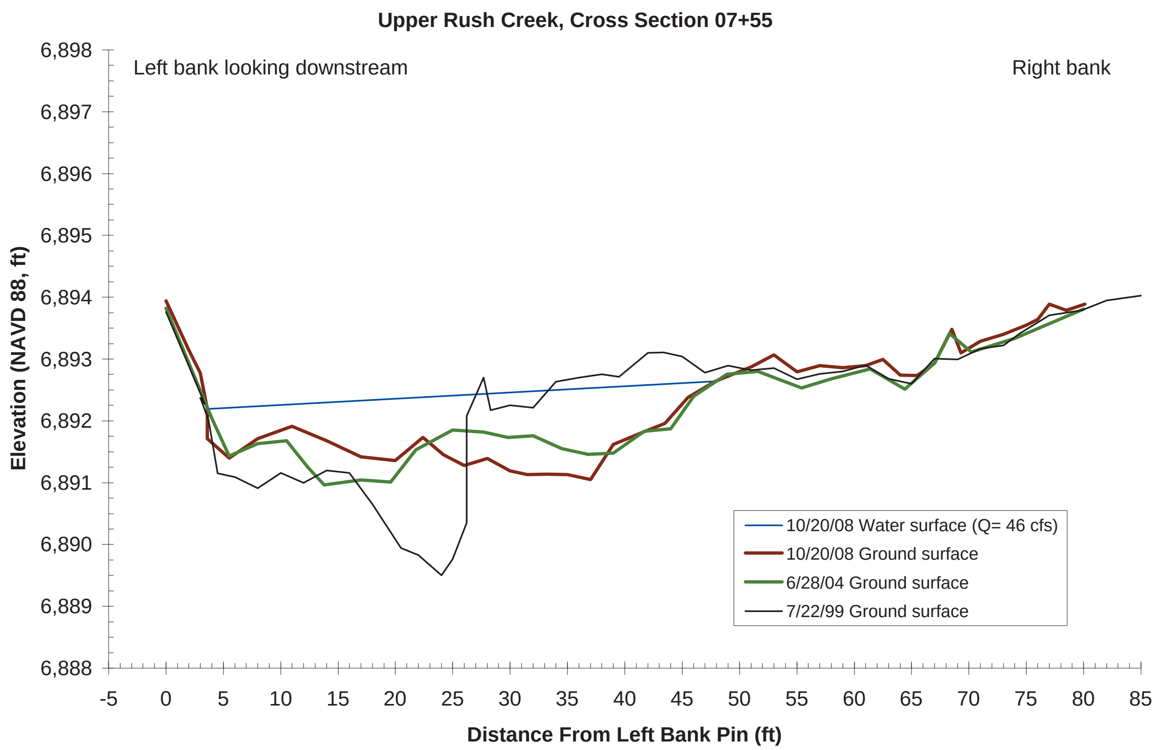
Upper Rush Creek, Cross Section 00+00

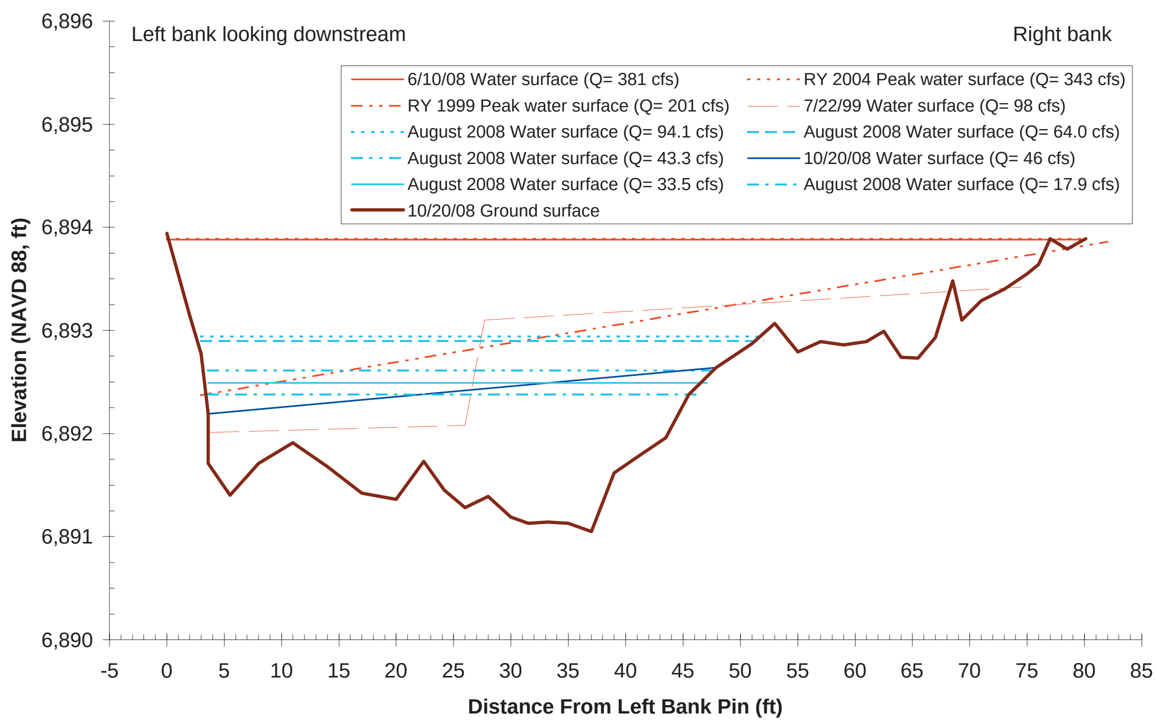




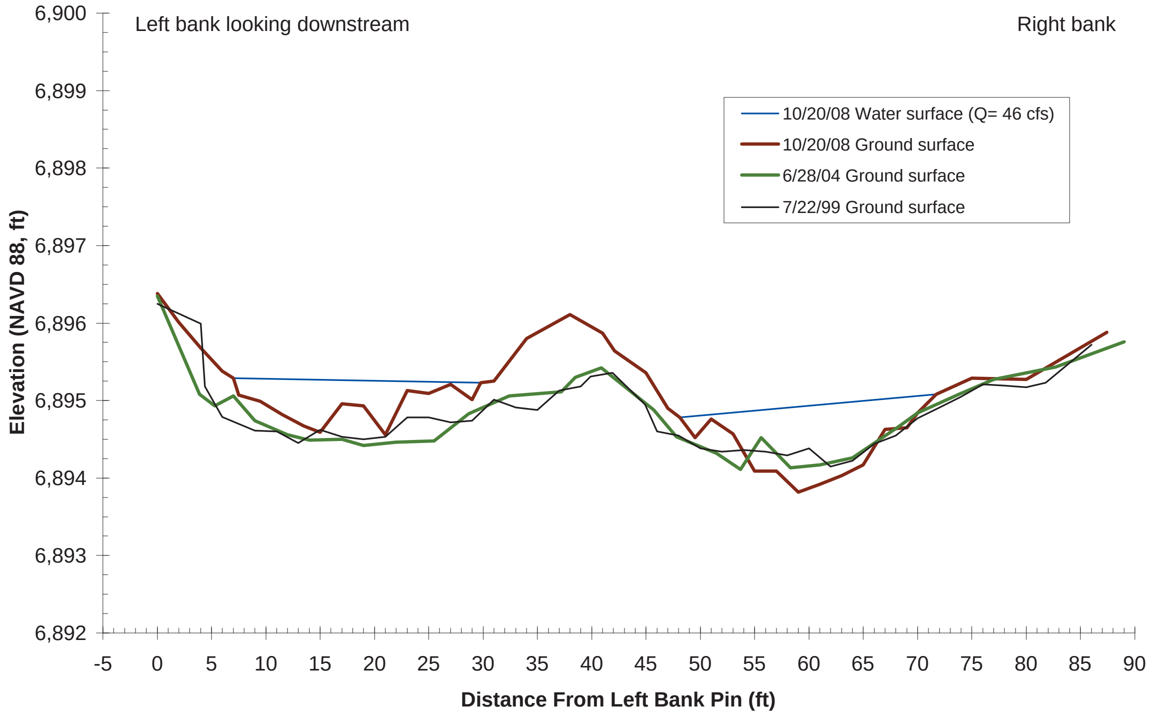

Upper Rush Creek, Cross Section 05+45
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,896
6,895
6,894
6,893
6,892
6,891
6,890
6,889
6,888
6,887
6,886
6,885
6,884
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)
7/22/99 Water surface (Q= 98 cfs)
10/20/08 Water surface (Q= 46 cfs)
10/20/08 Ground surface
6/28/04 Ground surface
7/22/99 Ground surface

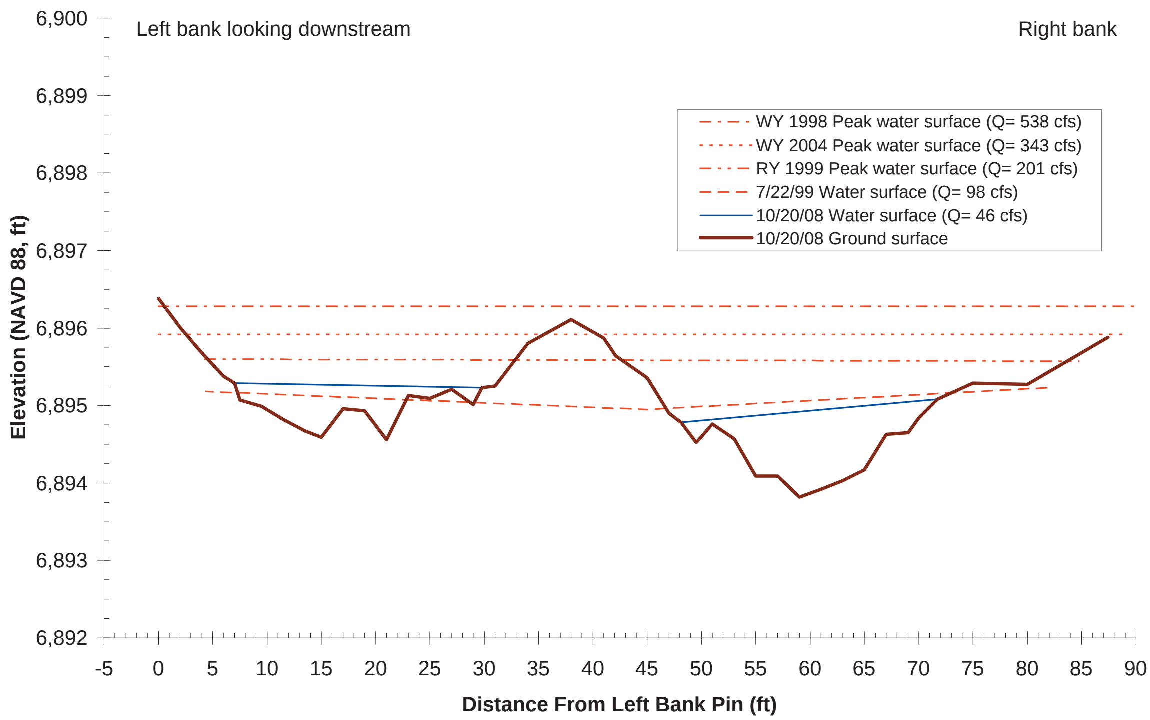

Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,893
6,892
6,891
6,890
6,889
6,888
6,887
6,886
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)
6/10/08 Water surface (Q= 381 cfs)
RY 2004 Peak water surface (Q= 343 cfs)
RY 1999 Peak water surface (Q= 201 cfs)
August 2008 Water surface (Q= 94.1 cfs)
August 2008 Water surface (Q= 64.0 cfs)
10/20/08 Water surface (Q= 46 cfs)
August 2008 Water surface (Q= 43.3 cfs)
August 2008 Water surface (Q= 33.5 cfs)
August 2008 Water surface (Q= 17.9 cfs)
10/20/08 Ground surface

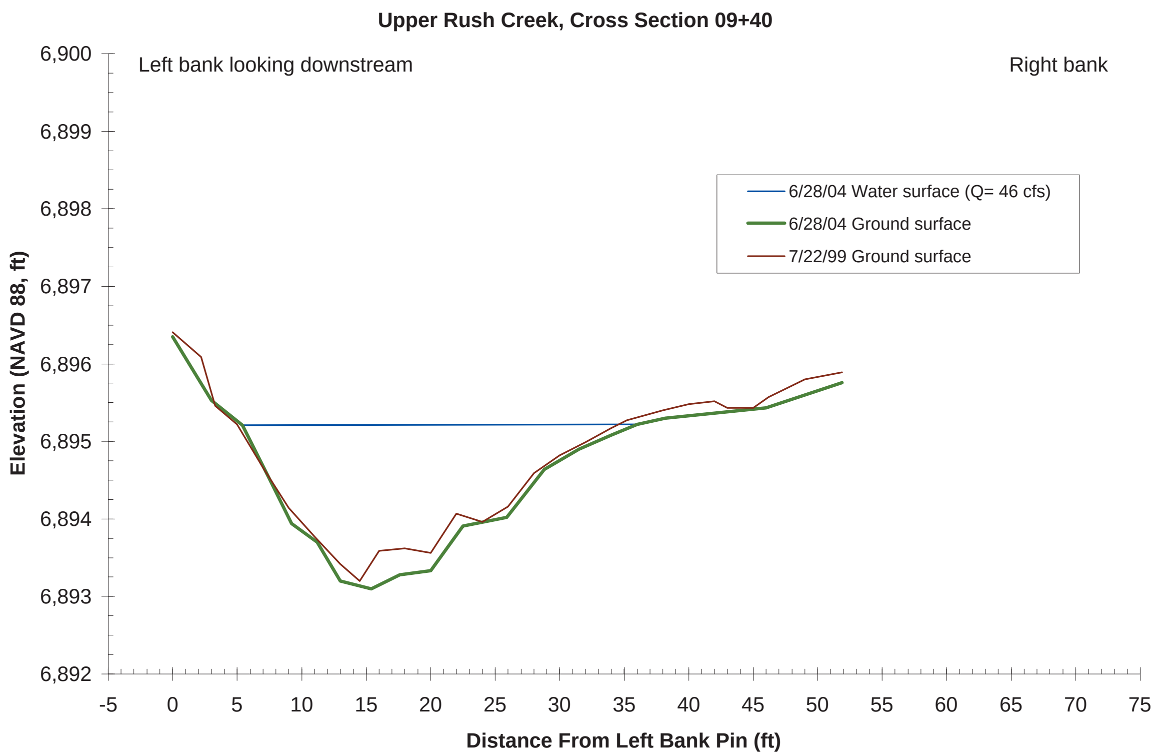

Upper Rush Creek, Cross Section 07+55
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,898
6,897
6,896
6,895
6,894
6,893
6,892
6,891
6,890
6,889
6,888
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
Distance From Left Bank Pin (ft)
10/20/08 Water surface (Q= 46 cfs)
10/20/08 Ground surface
6/28/04 Ground surface
7/22/99 Ground surface

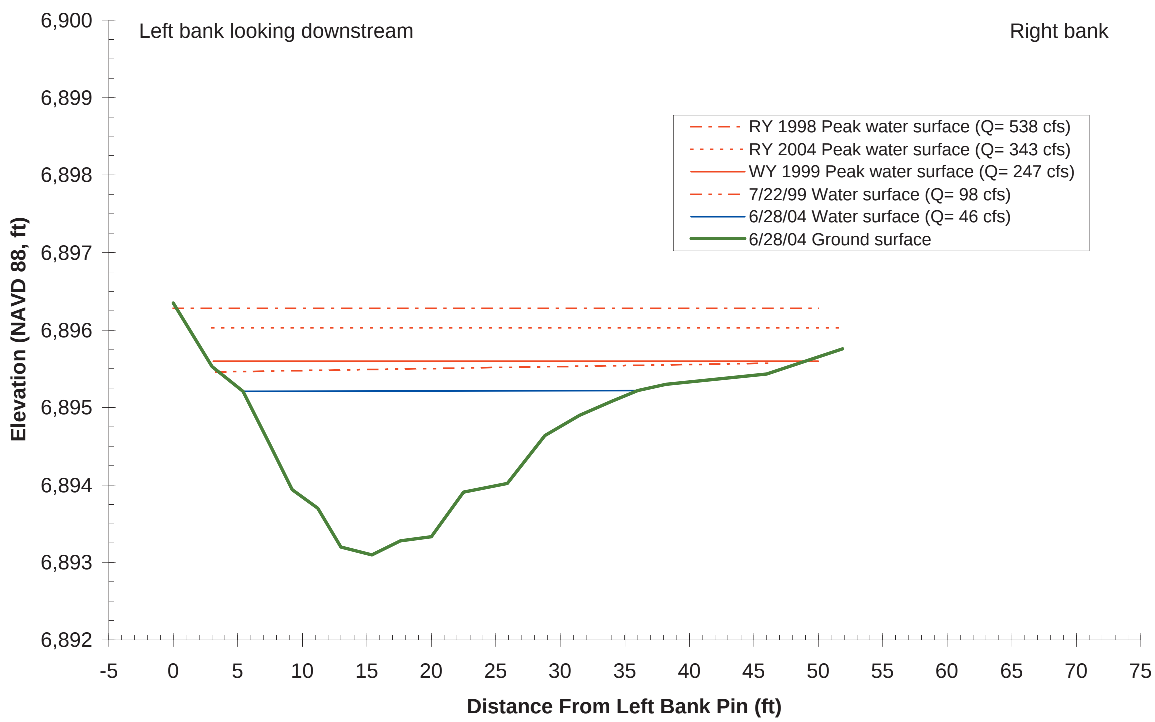

Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,896
6,895
6,894
6,893
6,892
6,891
6,890
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
Distance From Left Bank Pin (ft)
6/10/08 Water surface (Q= 381 cfs)
RY 2004 Peak water surface (Q= 343 cfs)
RY 1999 Peak water surface (Q= 201 cfs)
7/22/99 Water surface (Q= 98 cfs)
August 2008 Water surface (Q= 94.1 cfs)
August 2008 Water surface (Q= 64.0 cfs)
August 2008 Water surface (Q= 43.3 cfs)
10/20/08 Water surface (Q= 46 cfs)
August 2008 Water surface (Q= 33.5 cfs)
August 2008 Water surface (Q= 17.9 cfs)
10/20/08 Ground surface

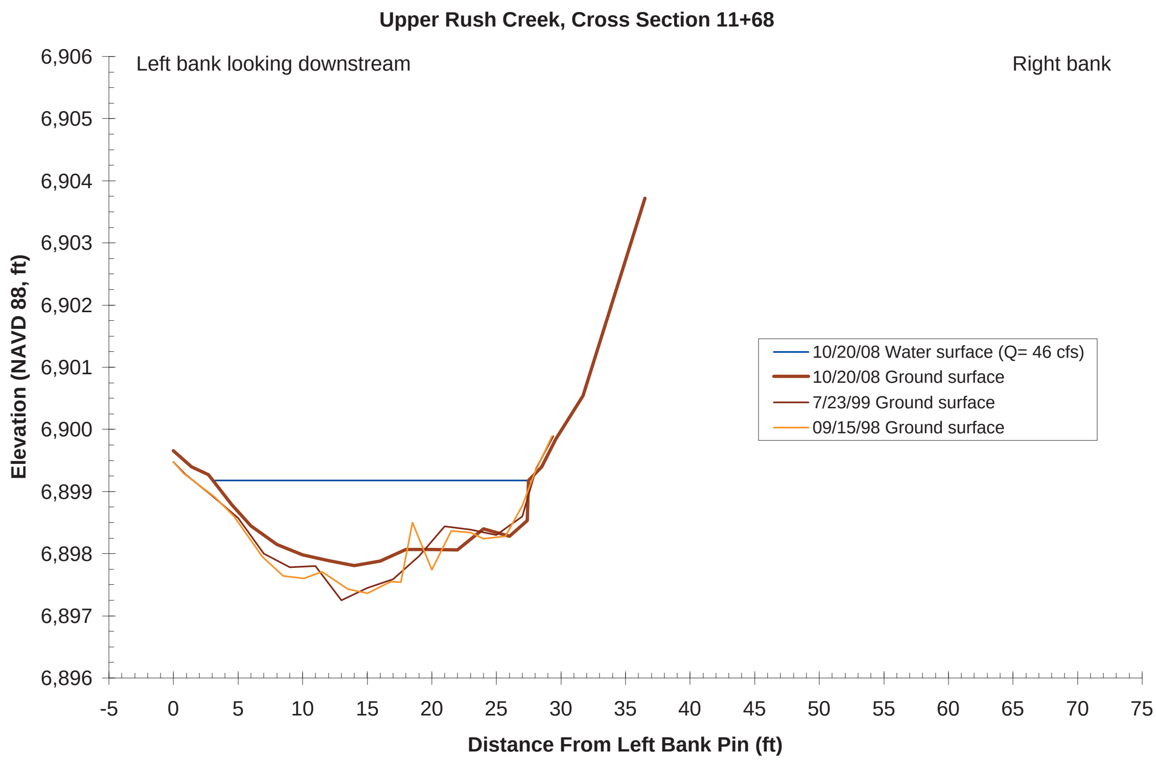
Upper Rush Creek, Cross Section 09+15

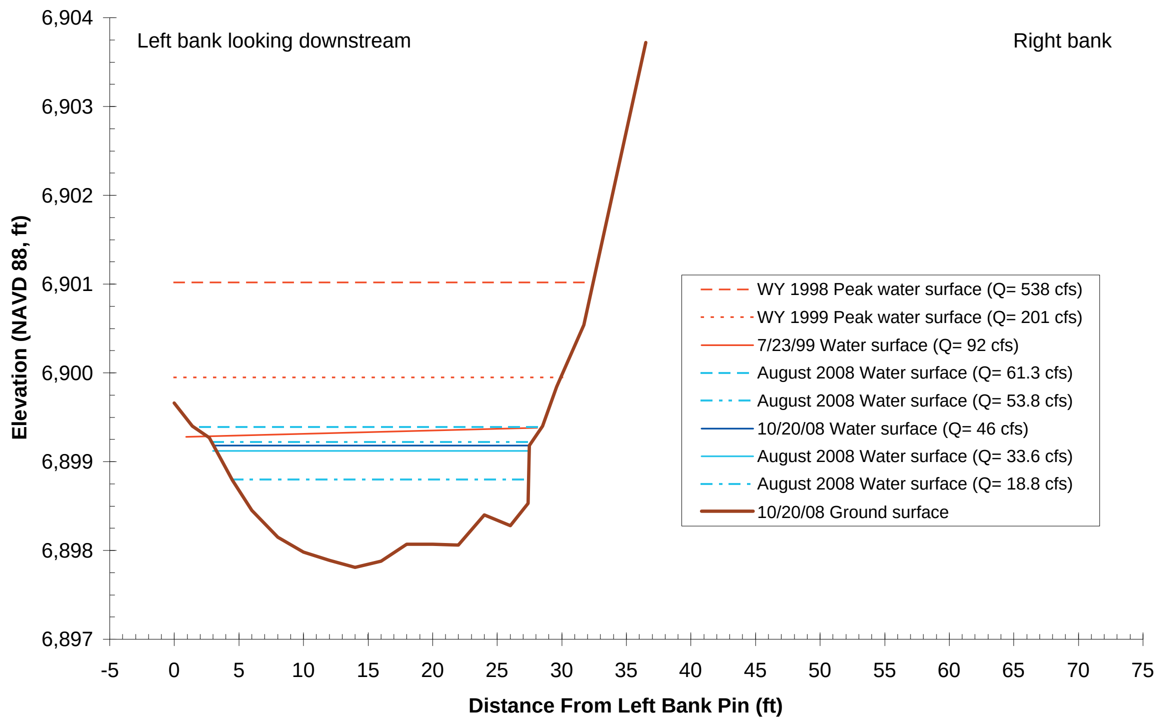


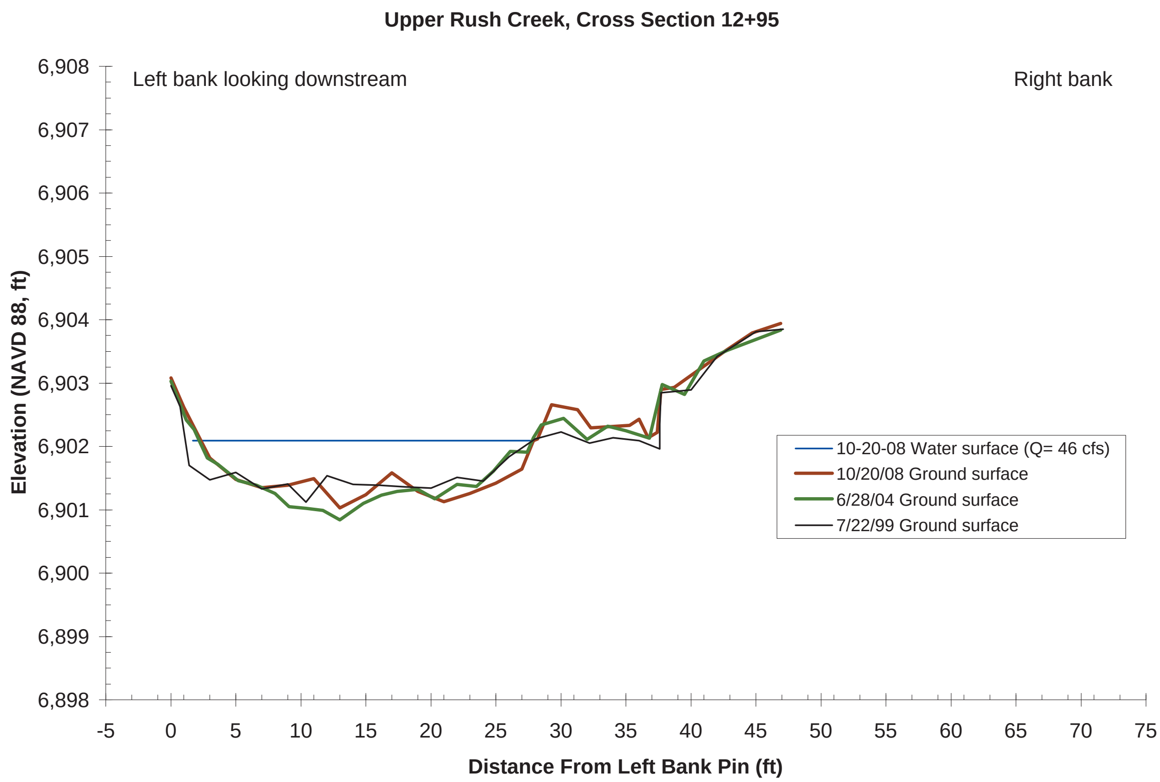


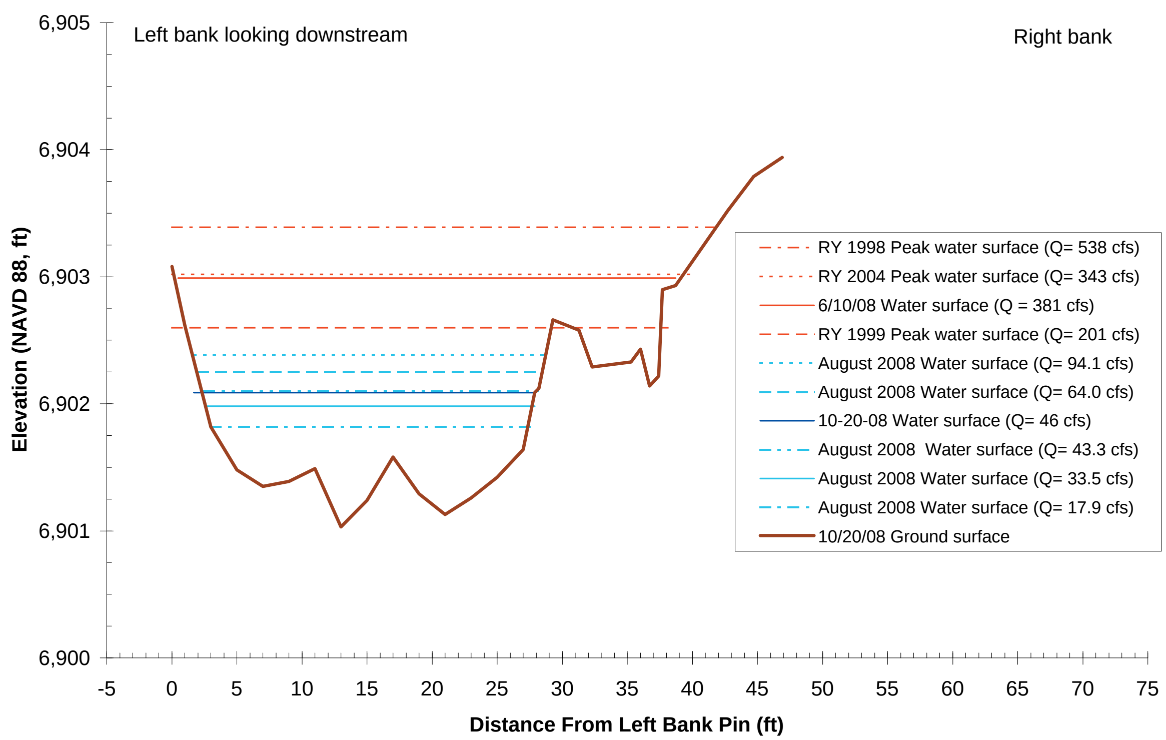

Upper Rush Creek, Cross Section 09+40
Left bank looking downstream
Right bank
6/28/04 Water surface (Q= 46 cfs)
6/28/04 Ground surface
7/22/99 Ground surface
Elevation (NAVD 88, ft)
6,900
6,899
6,898
6,897
6,896
6,895
6,894
6,893
6,892
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Distance From Left Bank Pin (ft)

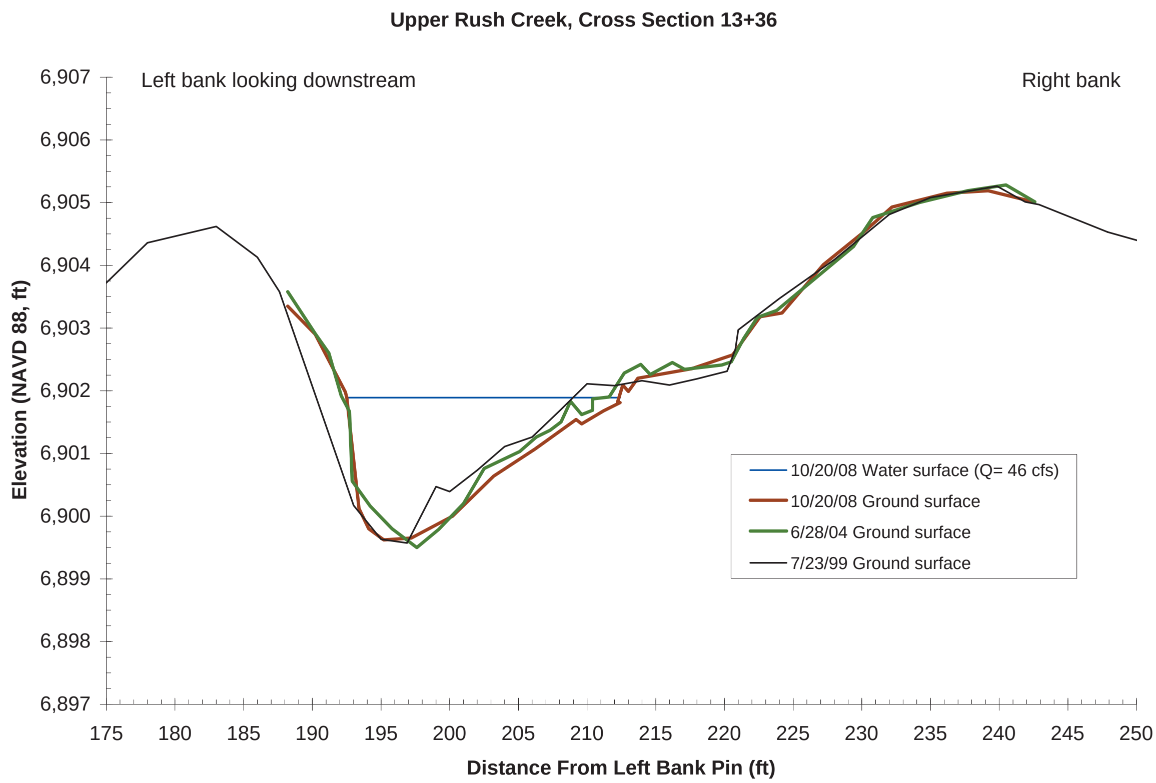

Left bank looking downstream
Right bank
RY 1998 Peak water surface (Q= 538 cfs)
RY 2004 Peak water surface (Q= 343 cfs)
WY 1999 Peak water surface (Q= 247 cfs)
7/22/99 Water surface (Q= 98 cfs)
6/28/04 Water surface (Q= 46 cfs)
6/28/04 Ground surface
Elevation (NAVD 88, ft)
6,900
6,899
6,898
6,897
6,896
6,895
6,894
6,893
6,892
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Distance From Left Bank Pin (ft)

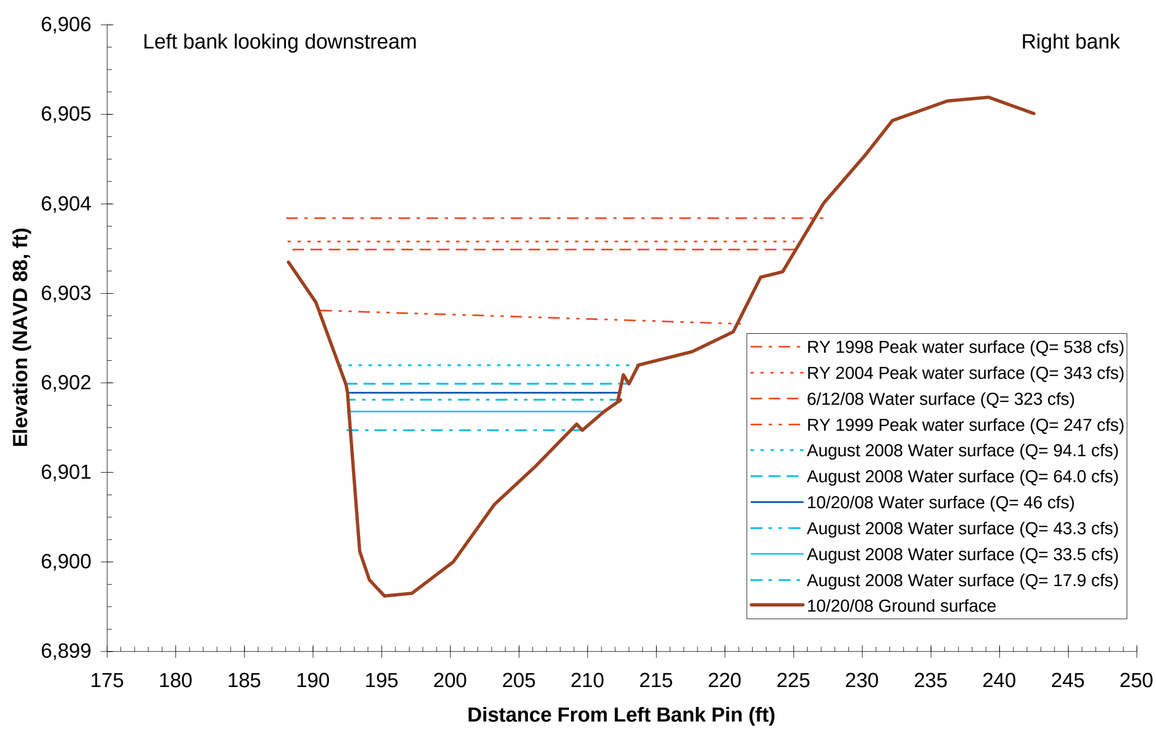

Upper Rush Creek, Cross Section 11+68
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,906
6,905
6,904
6,903
6,902
6,901
6,900
6,899
6,898
6,897
6,896
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)
10/20/08 Water surface (Q= 46 cfs)
10/20/08 Ground surface
7/23/99 Ground surface
09/15/98 Ground surface

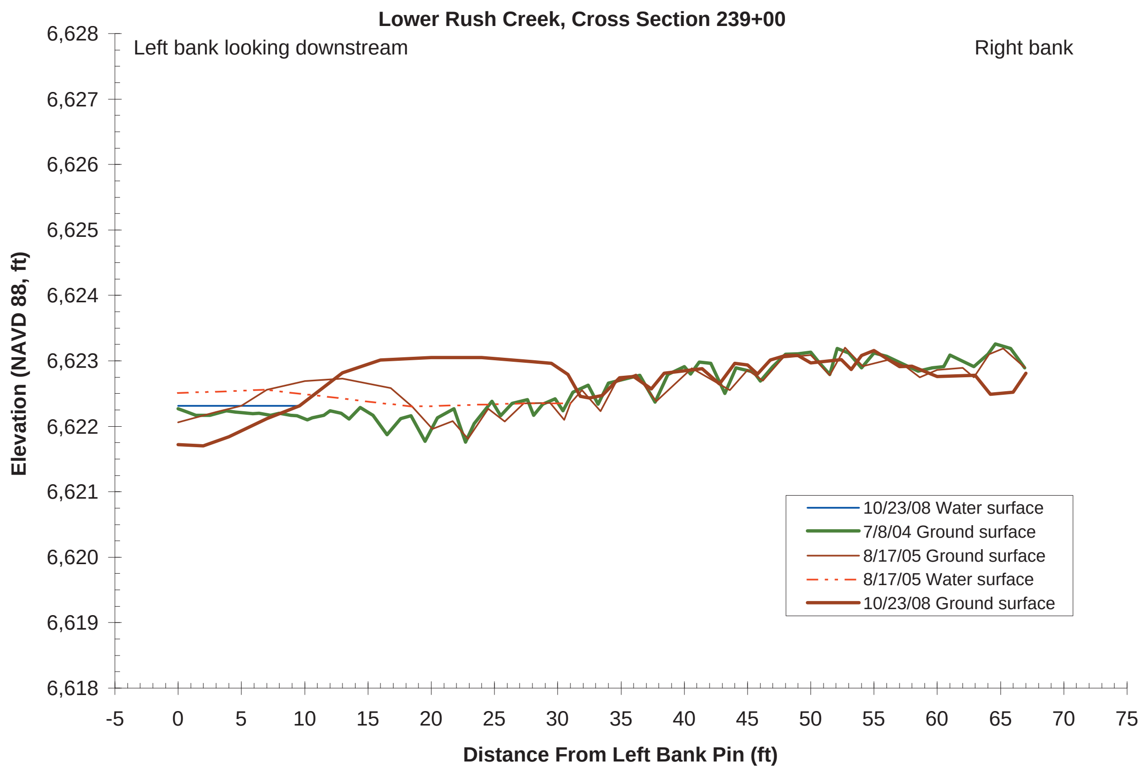

Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,904
6,903
6,902
6,901
6,900
6,899
6,898
6,897
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)
WY 1998 Peak water surface (Q= 538 cfs)
WY 1999 Peak water surface (Q= 201 cfs)
7/23/99 Water surface (Q= 92 cfs)
August 2008 Water surface (Q= 61.3 cfs)
August 2008 Water surface (Q= 53.8 cfs)
10/20/08 Water surface (Q= 46 cfs)
August 2008 Water surface (Q= 33.6 cfs)
August 2008 Water surface (Q= 18.8 cfs)
10/20/08 Ground surface

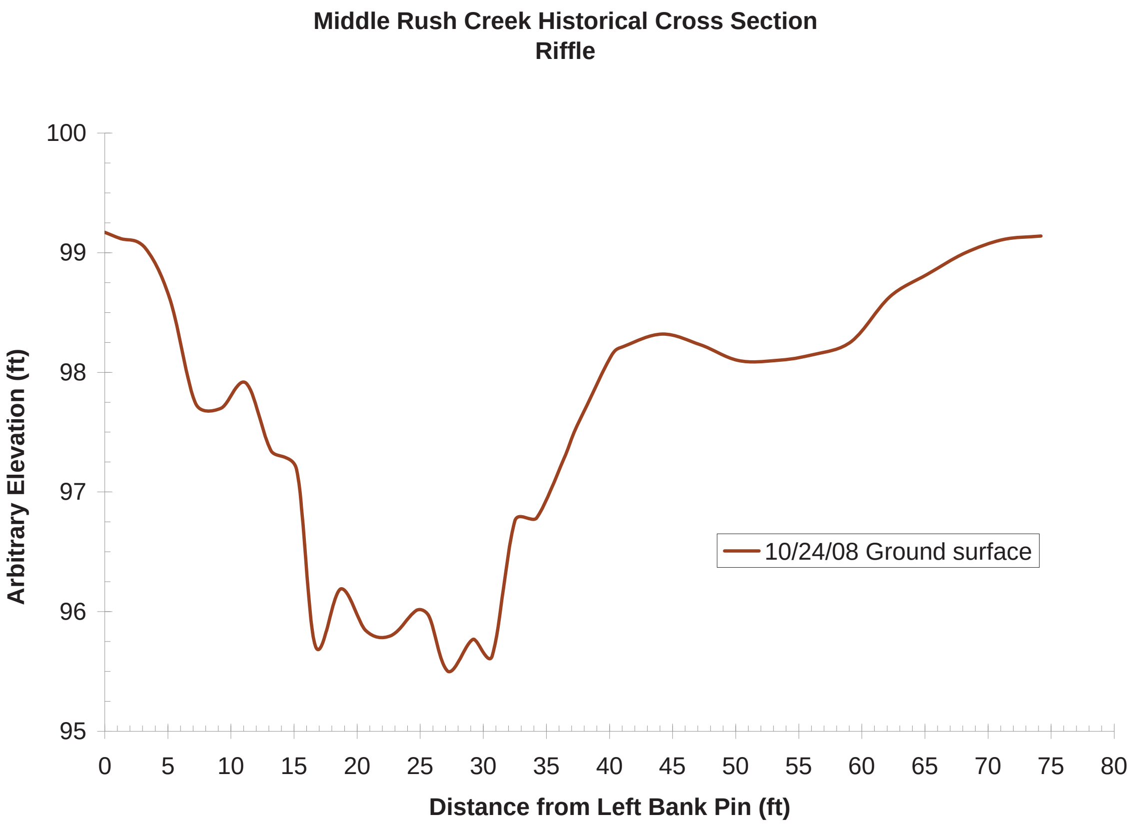

Upper Rush Creek, Cross Section 12+95
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,908
6,907
6,906
6,905
6,904
6,903
6,902
6,901
6,900
6,899
6,898
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)
10-20-08 Water surface (Q= 46 cfs)
10/20/08 Ground surface
6/28/04 Ground surface
7/22/99 Ground surface

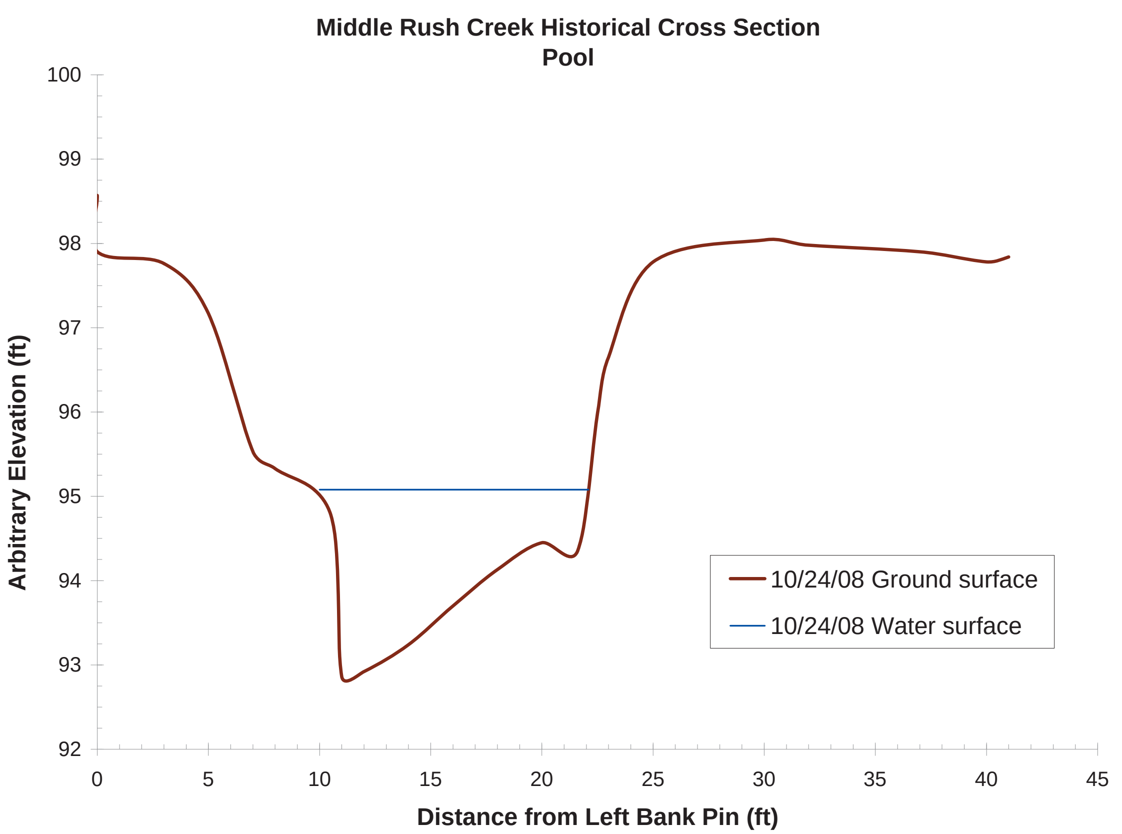

Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,905
6,904
6,903
6,902
6,901
6,900
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)
RY 1998 Peak water surface (Q= 538 cfs)
RY 2004 Peak water surface (Q= 343 cfs)
6/10/08 Water surface (Q = 381 cfs)
RY 1999 Peak water surface (Q= 201 cfs)
August 2008 Water surface (Q= 94.1 cfs)
August 2008 Water surface (Q= 64.0 cfs)
10-20-08 Water surface (Q= 46 cfs)
August 2008 Water surface (Q= 43.3 cfs)
August 2008 Water surface (Q= 33.5 cfs)
August 2008 Water surface (Q= 17.9 cfs)
10/20/08 Ground surface

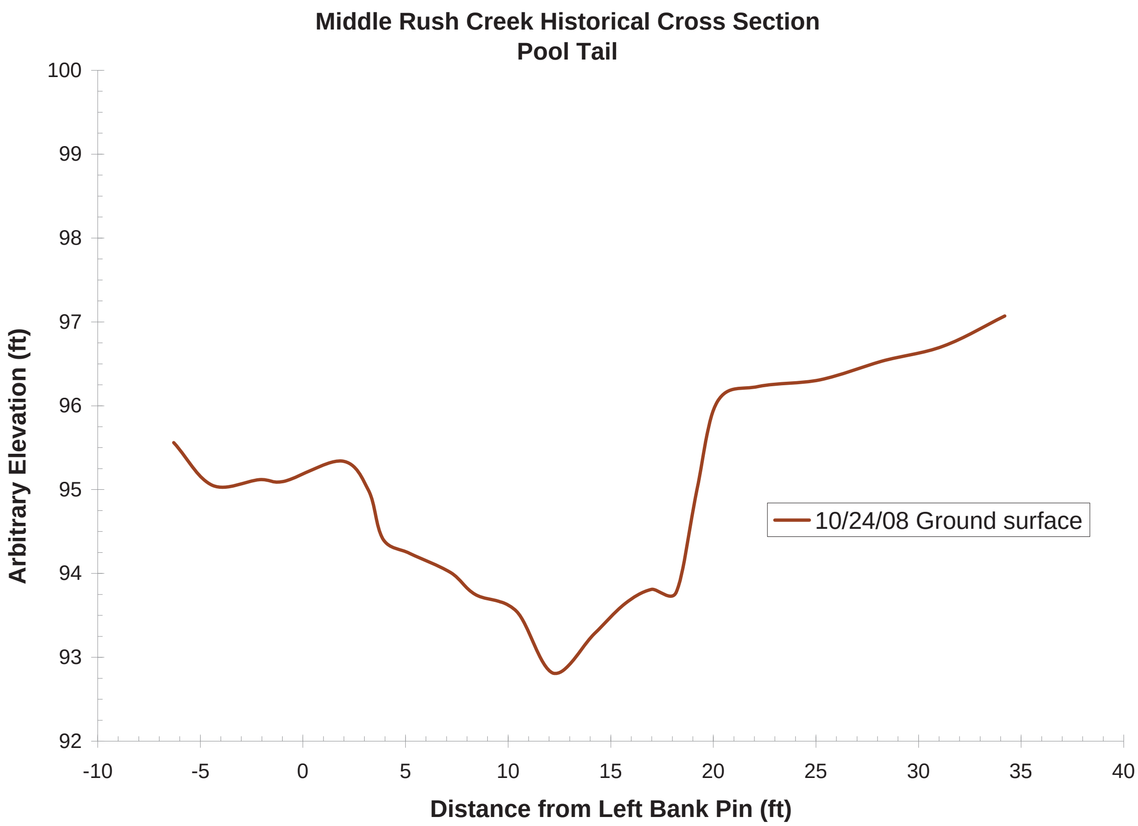

Upper Rush Creek, Cross Section 13+36
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,907
6,906
6,905
6,904
6,903
6,902
6,901
6,900
6,899
6,898
6,897
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
Distance From Left Bank Pin (ft)
10/20/08 Water surface (Q= 46 cfs)
10/20/08 Ground surface
6/28/04 Ground surface
7/23/99 Ground surface

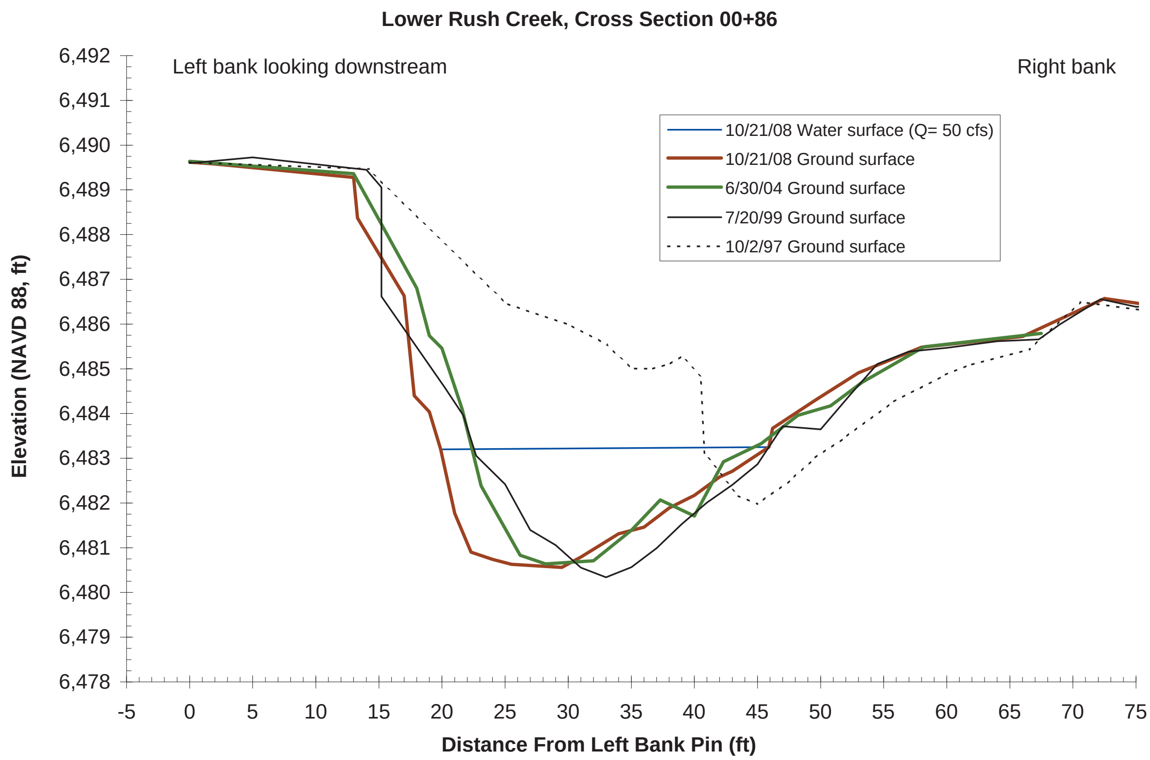

Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,906
6,905
6,904
6,903
6,902
6,901
6,900
6,899
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
Distance From Left Bank Pin (ft)
RY 1998 Peak water surface (Q= 538 cfs)
RY 2004 Peak water surface (Q= 343 cfs)
6/12/08 Water surface (Q= 323 cfs)
RY 1999 Peak water surface (Q= 247 cfs)
August 2008 Water surface (Q= 94.1 cfs)
August 2008 Water surface (Q= 64.0 cfs)
10/20/08 Water surface (Q= 46 cfs)
August 2008 Water surface (Q= 43.3 cfs)
August 2008 Water surface (Q= 33.5 cfs)
August 2008 Water surface (Q= 17.9 cfs)
10/20/08 Ground surface

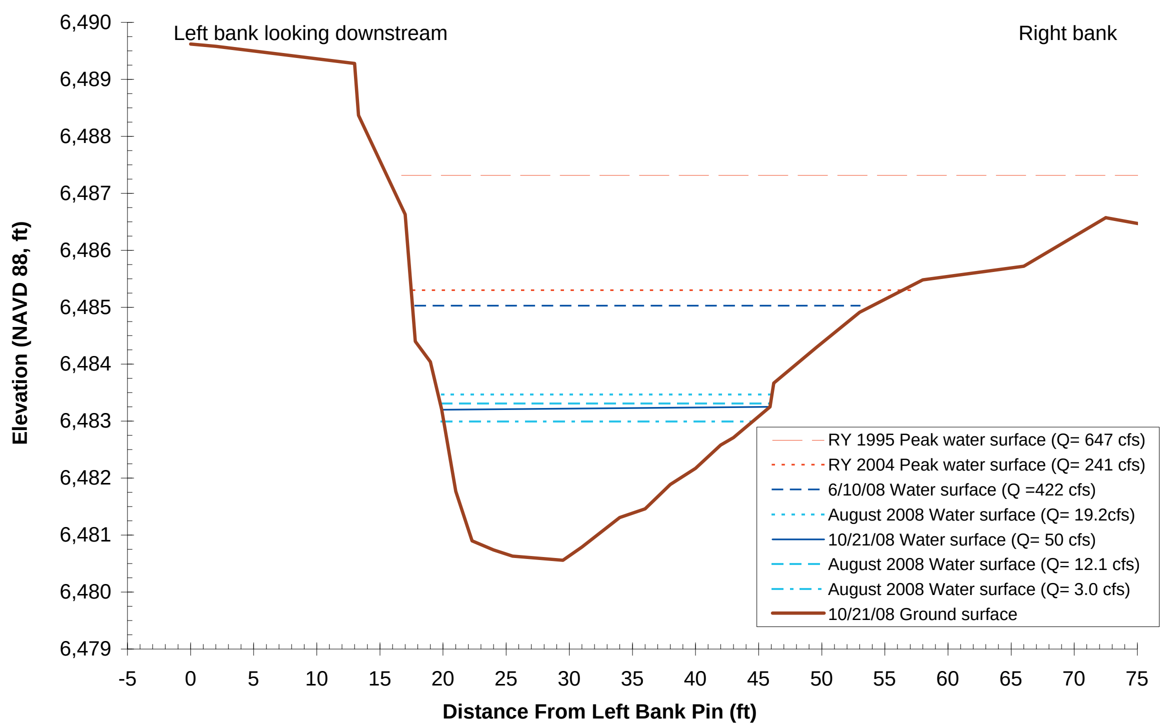

Lower Rush Creek, Cross Section 239+00
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,628
6,627
6,626
6,625
6,624
6,623
6,622
6,621
6,620
6,619
6,618
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)
10/23/08 Water surface
7/8/04 Ground surface
8/17/05 Ground surface
8/17/05 Water surface
10/23/08 Ground surface

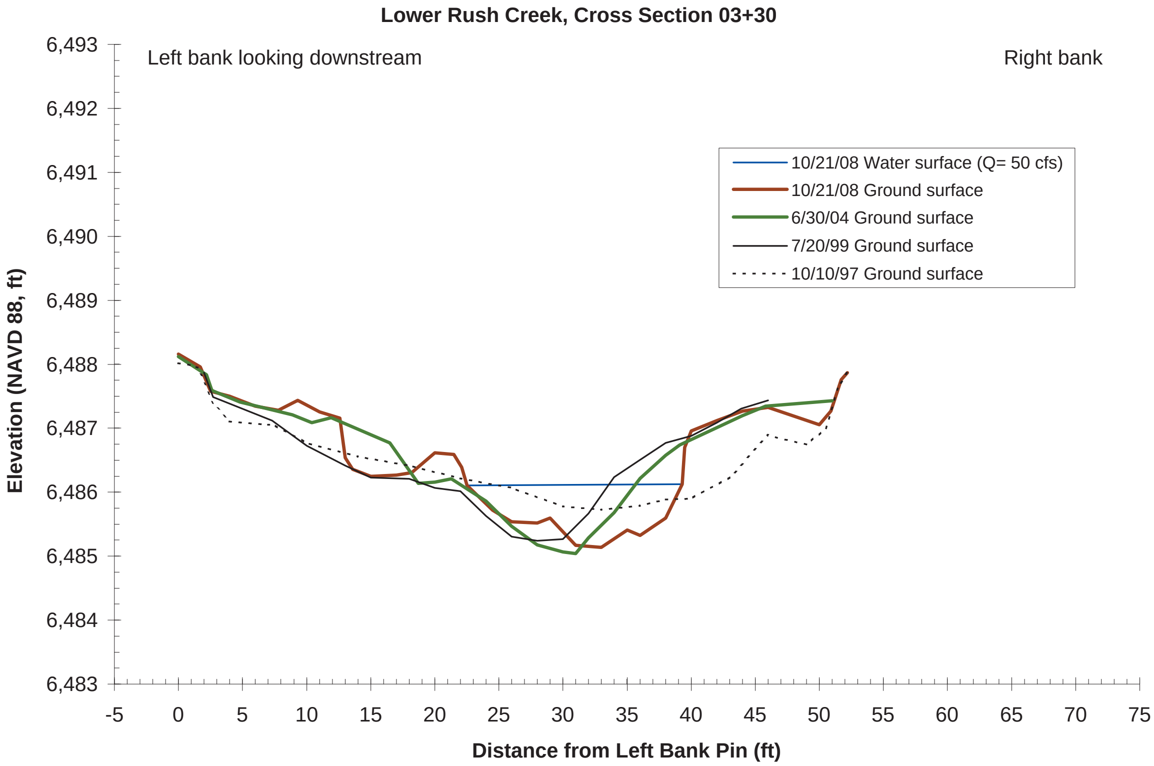

Middle Rush Creek Historical Cross Section
Riffle
Arbitrary Elevation (ft)
100
99
98
97
96
95
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Distance from Left Bank Pin (ft)
10/24/08 Ground surface

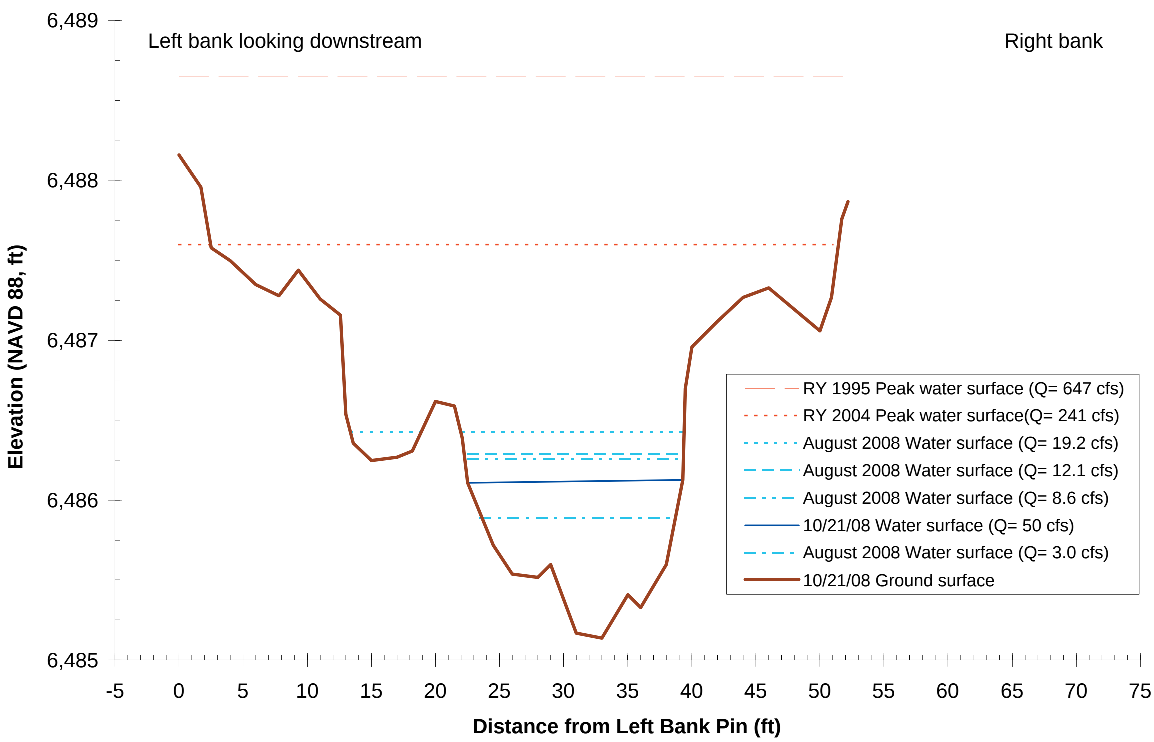

Middle Rush Creek Historical Cross Section
Pool
Arbitrary Elevation (ft)
100
99
98
97
96
95
94
93
92
0
5
10
15
20
25
30
35
40
45
Distance from Left Bank Pin (ft)
10/24/08 Ground surface
10/24/08 Water surface

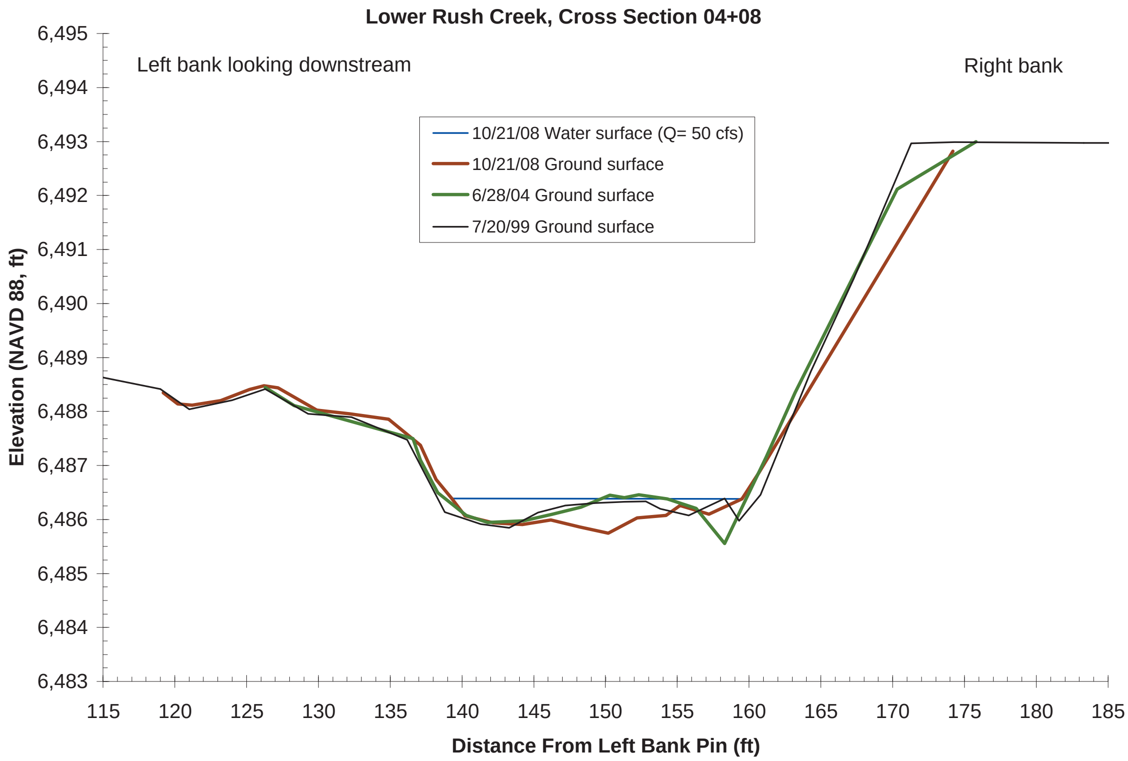

Middle Rush Creek Historical Cross Section
Pool Tail
Arbitrary Elevation (ft)
100
99
98
97
96
95
94
93
92
-10
-5
0
5
10
15
20
25
30
35
40
Distance from Left Bank Pin (ft)
10/24/08 Ground surface

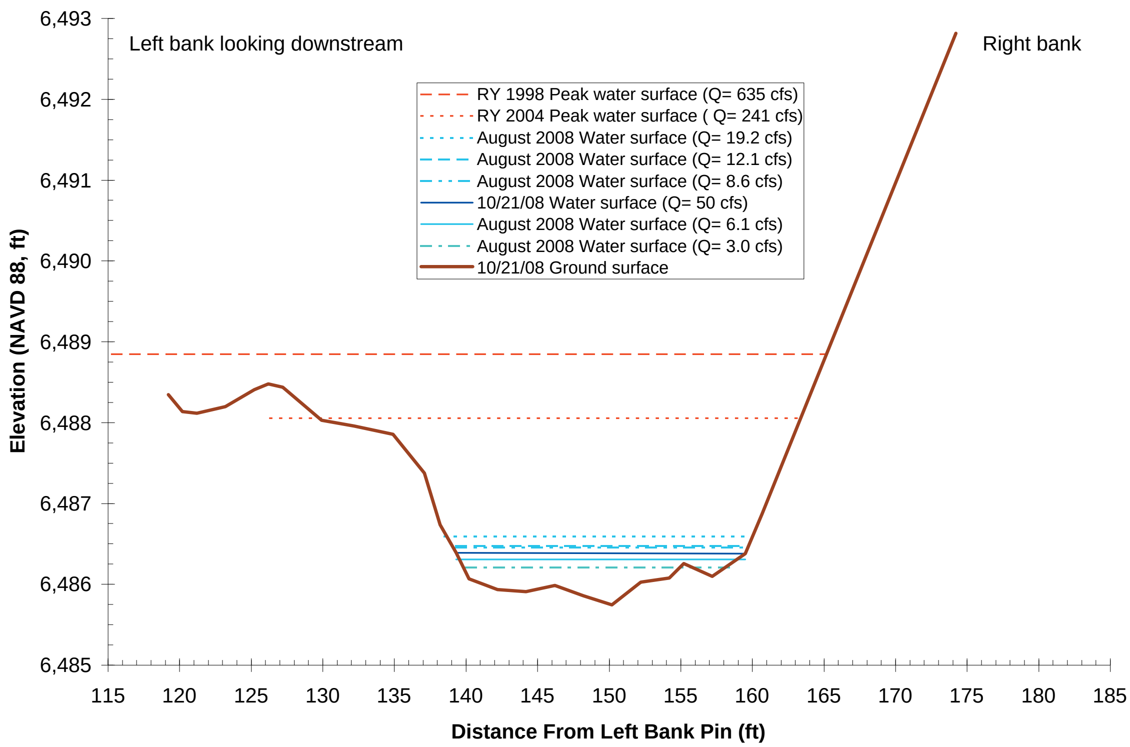

Lower Rush Creek, Cross Section 00+86
Left bank looking downstream
Right bank
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
6/30/04 Ground surface
7/20/99 Ground surface
10/2/97 Ground surface
Elevation (NAVD 88, ft)
6,492
6,491
6,490
6,489
6,488
6,487
6,486
6,485
6,484
6,483
6,482
6,481
6,480
6,479
6,478
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Distance From Left Bank Pin (ft)

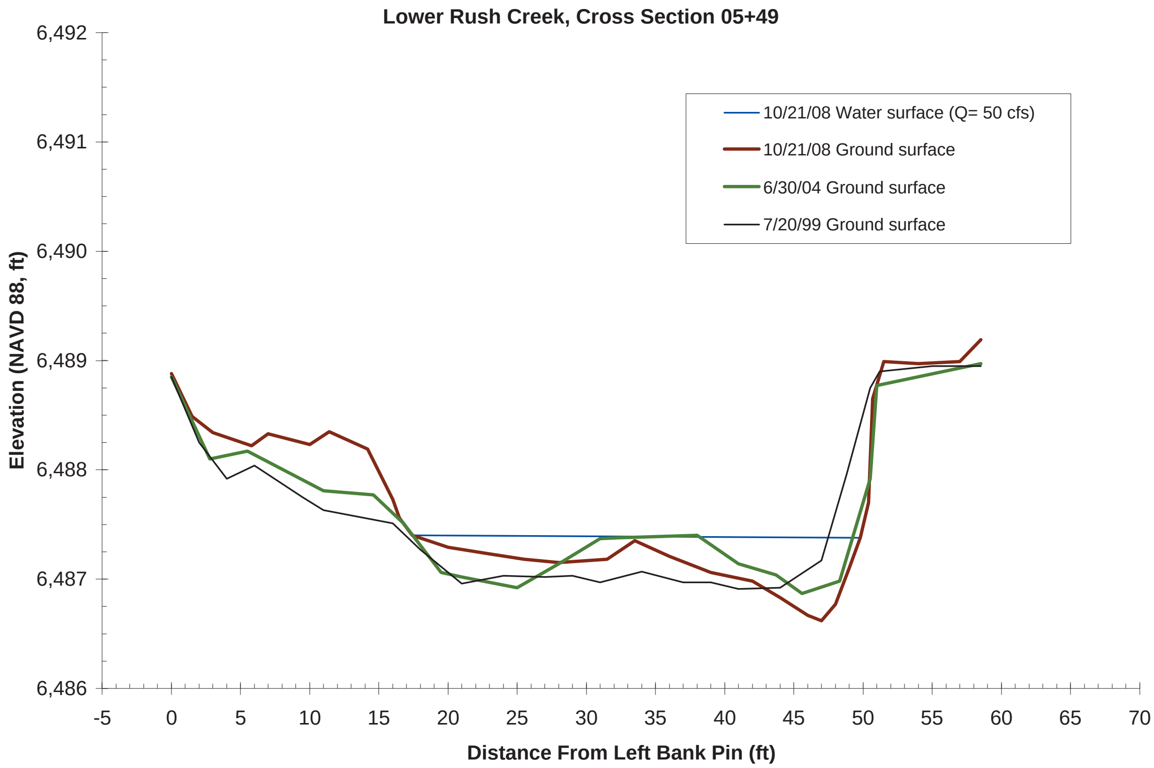

Left bank looking downstream
Right bank
RY 1995 Peak water surface (Q= 647 cfs)
RY 2004 Peak water surface (Q= 241 cfs)
6/10/08 Water surface (Q =422 cfs)
August 2008 Water surface (Q= 19.2cfs)
10/21/08 Water surface (Q= 50 cfs)
August 2008 Water surface (Q= 12.1 cfs)
August 2008 Water surface (Q= 3.0 cfs)
10/21/08 Ground surface
Elevation (NAVD 88, ft)
6,490
6,489
6,488
6,487
6,486
6,485
6,484
6,483
6,482
6,481
6,480
6,479
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Distance From Left Bank Pin (ft)

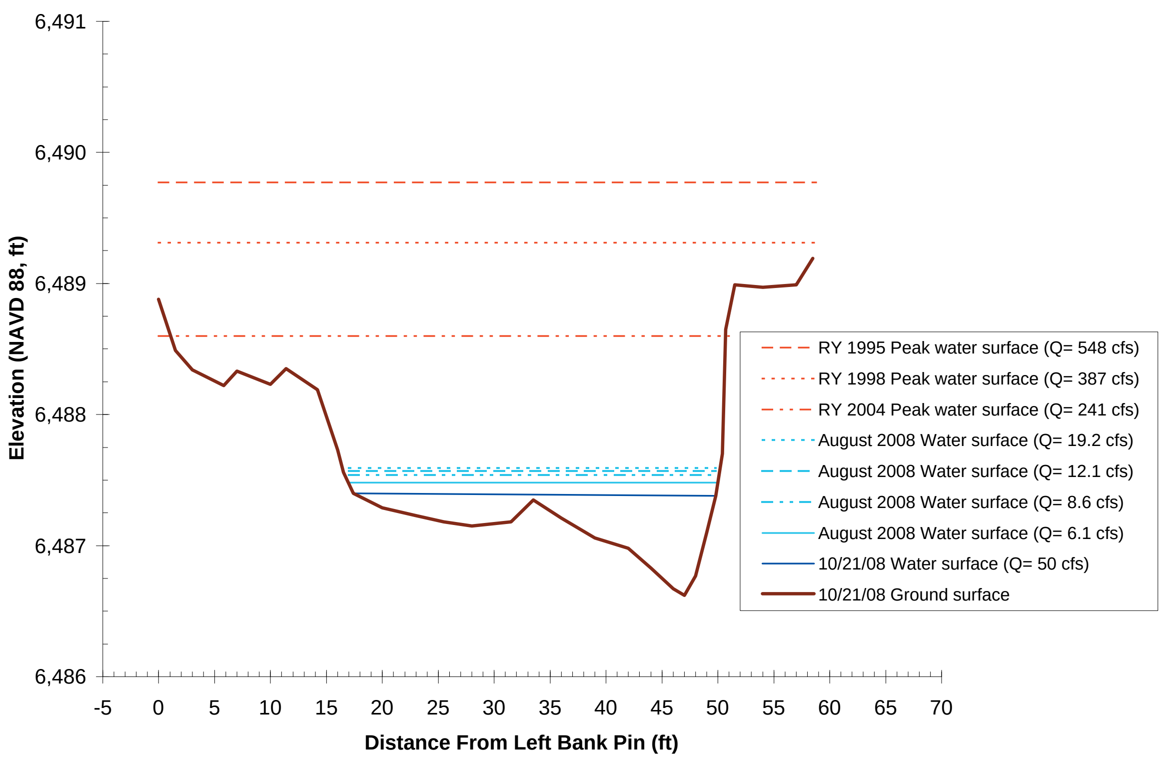

Lower Rush Creek, Cross Section 03+30
Left bank looking downstream
Right bank
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
6/30/04 Ground surface
7/20/99 Ground surface
10/10/97 Ground surface
Elevation (NAVD 88, ft)
6,493
6,492
6,491
6,490
6,489
6,488
6,487
6,486
6,485
6,484
6,483
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance from Left Bank Pin (ft)


Left bank looking downstream
Right bank
RY 1995 Peak water surface (Q= 647 cfs)
RY 2004 Peak water surface(Q= 241 cfs)
August 2008 Water surface (Q= 19.2 cfs)
August 2008 Water surface (Q= 12.1 cfs)
August 2008 Water surface (Q= 8.6 cfs)
10/21/08 Water surface (Q= 50 cfs)
August 2008 Water surface (Q= 3.0 cfs)
10/21/08 Ground surface
Elevation (NAVD 88, ft)
6,489
6,488
6,487
6,486
6,485
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance from Left Bank Pin (ft)

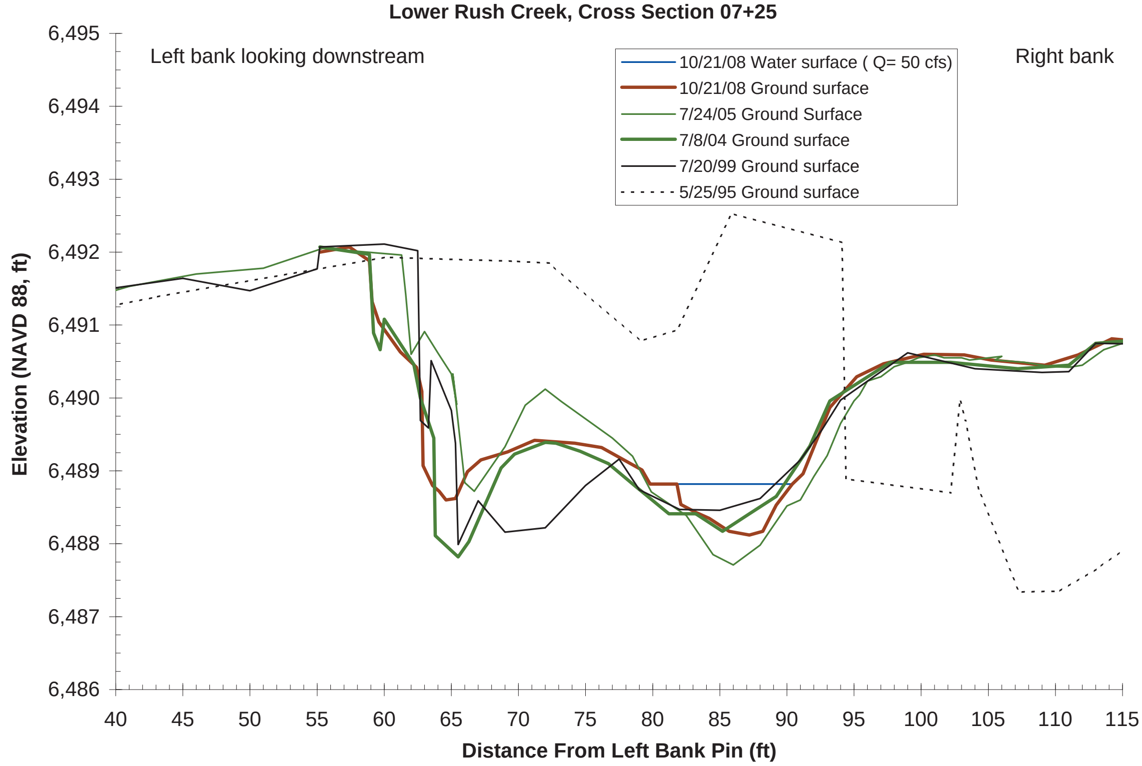

Lower Rush Creek, Cross Section 04+08
Left bank looking downstream
Right bank
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
6/28/04 Ground surface
7/20/99 Ground surface
Elevation (NAVD 88, ft)
6,495
6,494
6,493
6,492
6,491
6,490
6,489
6,488
6,487
6,486
6,485
6,484
6,483
115 120 125 130 135 140 145 150 155 160 165 170 175 180 185
Distance From Left Bank Pin (ft)

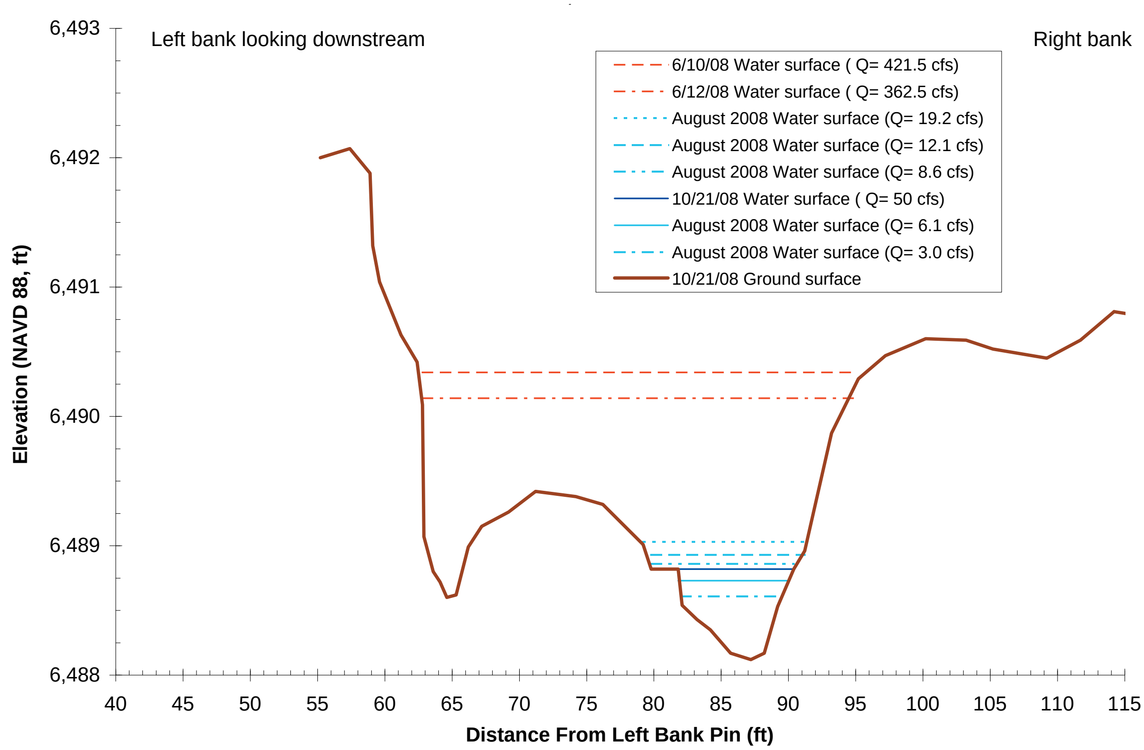

Left bank looking downstream
Right bank
RY 1998 Peak water surface (Q= 635 cfs)
RY 2004 Peak water surface (Q= 241 cfs)
August 2008 Water surface (Q= 19.2 cfs)
August 2008 Water surface (Q= 12.1 cfs)
August 2008 Water surface (Q= 8.6 cfs)
10/21/08 Water surface (Q= 50 cfs)
August 2008 Water surface (Q= 6.1 cfs)
August 2008 Water surface (Q= 3.0 cfs)
10/21/08 Ground surface
Elevation (NAVD 88, ft)
6,493
6,492
6,491
6,490
6,489
6,488
6,487
6,486
6,485
115 120 125 130 135 140 145 150 155 160 165 170 175 180 185
Distance From Left Bank Pin (ft)

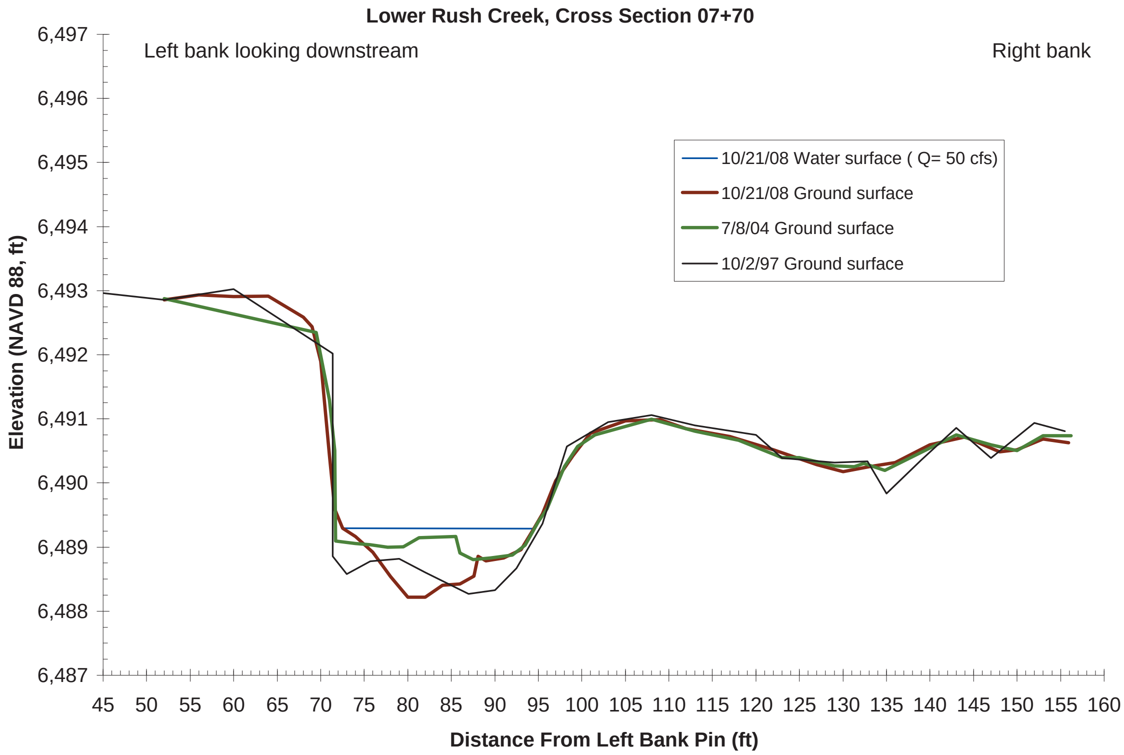

Lower Rush Creek, Cross Section 05+49
6,492
6,491
6,490
6,489
6,488
6,487
6,486
Elevation (NAVD 88, ft)
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Distance From Left Bank Pin (ft)
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
6/30/04 Ground surface
7/20/99 Ground surface

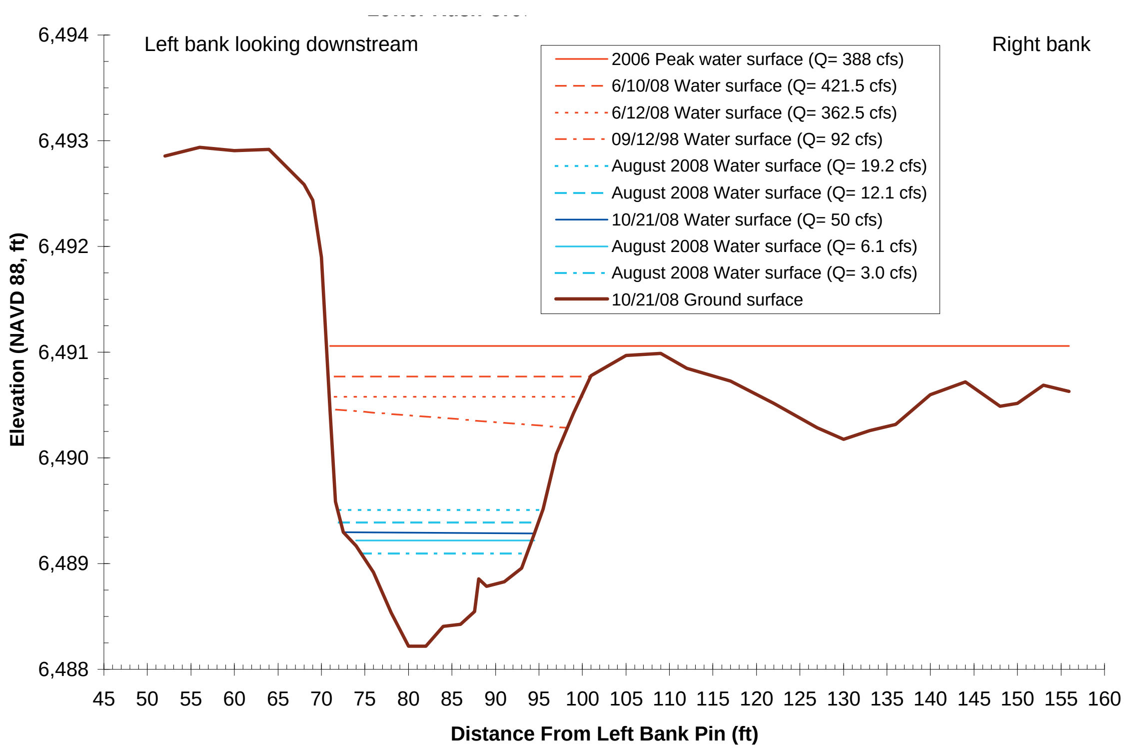

6,491
6,490
6,489
6,488
6,487
6,486
Elevation (NAVD 88, ft)
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Distance From Left Bank Pin (ft)
RY 1995 Peak water surface (Q= 548 cfs)
RY 1998 Peak water surface (Q= 387 cfs)
RY 2004 Peak water surface (Q= 241 cfs)
August 2008 Water surface (Q= 19.2 cfs)
August 2008 Water surface (Q= 12.1 cfs)
August 2008 Water surface (Q= 8.6 cfs)
August 2008 Water surface (Q= 6.1 cfs)
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface

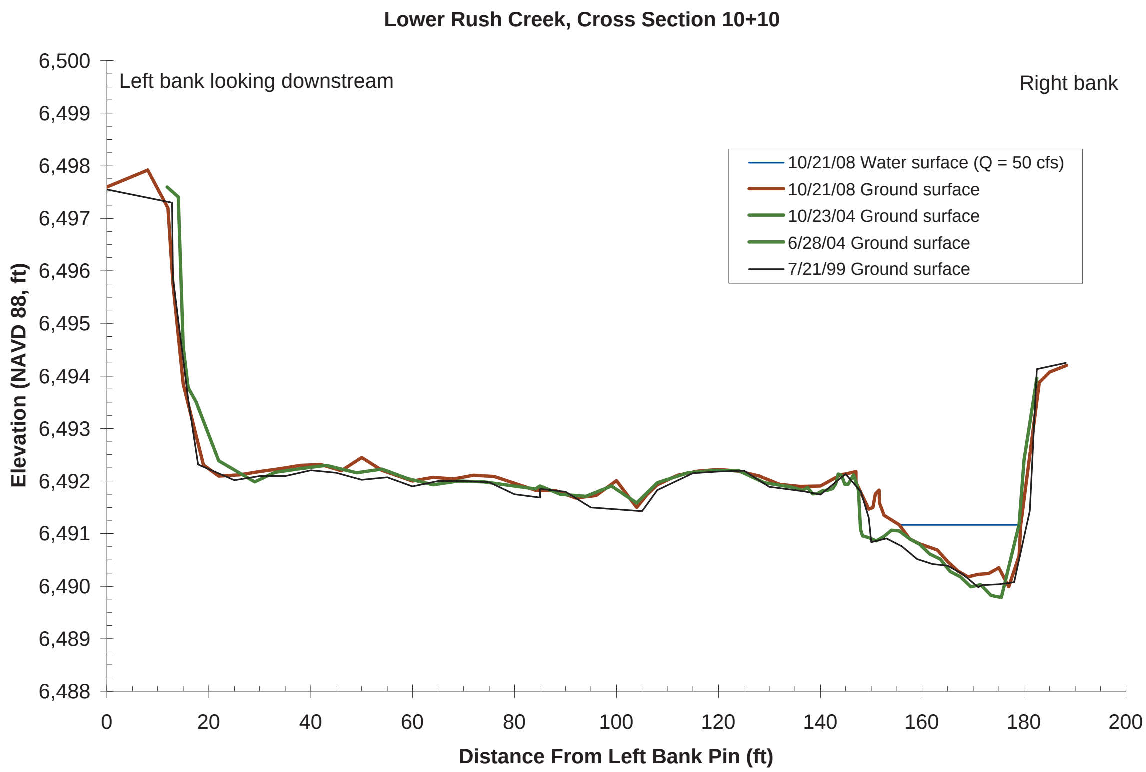
Lower Rush Creek, Cross Section 07+25

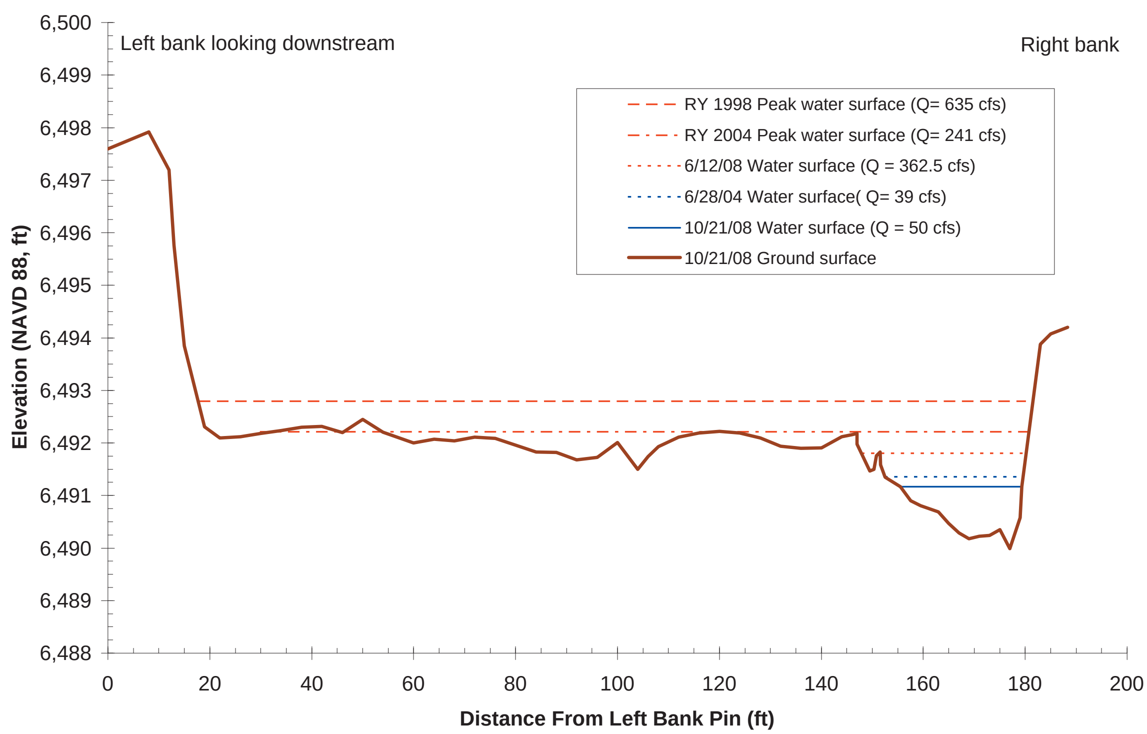


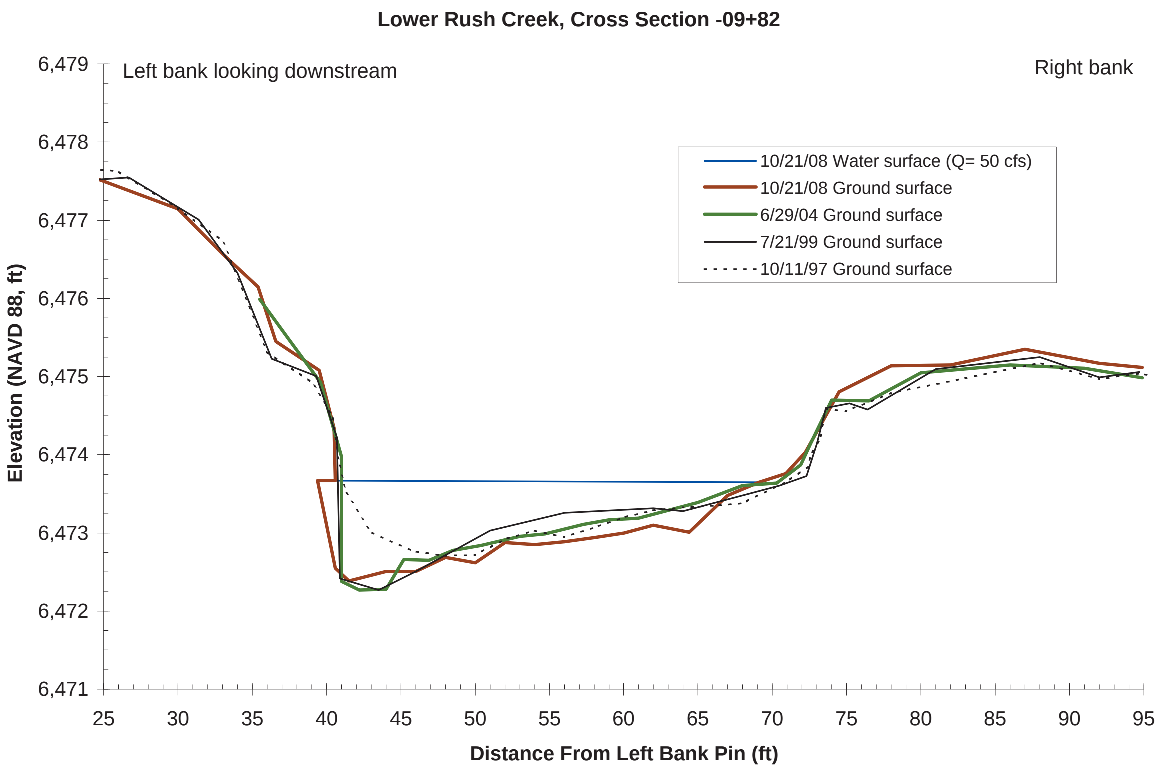


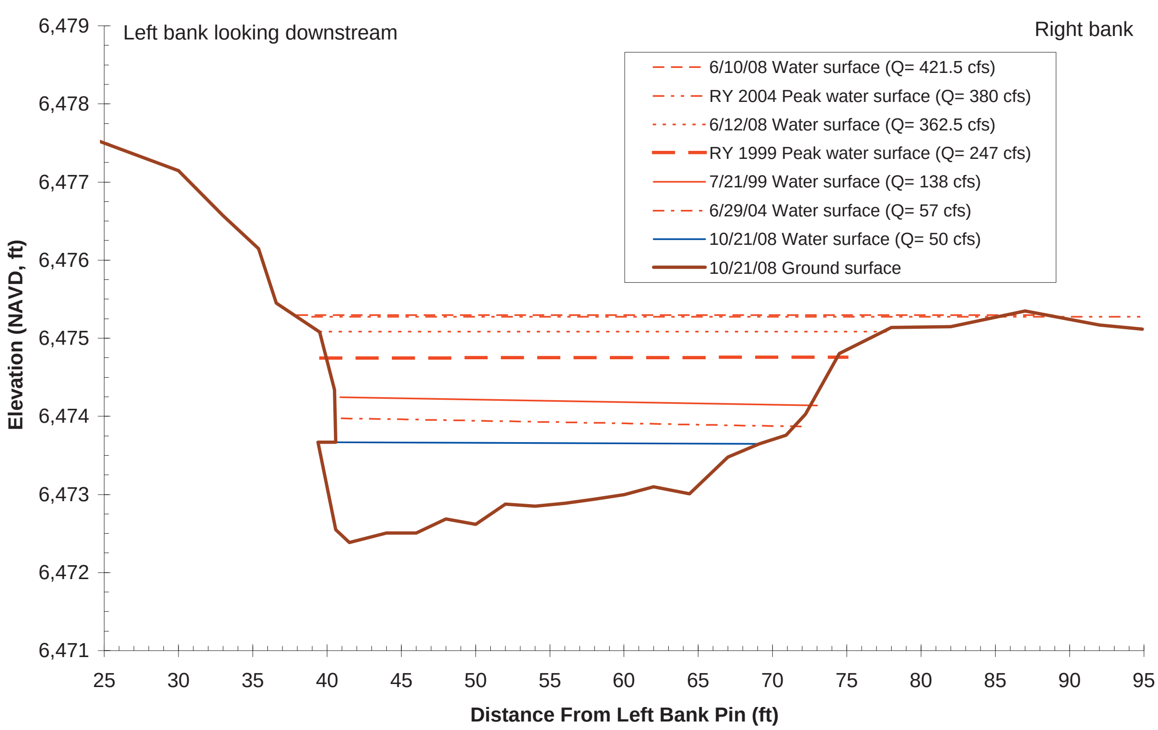

Lower Rush Creek, Cross Section 07+70
Left bank looking downstream
Right bank
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
7/8/04 Ground surface
10/2/97 Ground surface
Elevation (NAVD 88, ft)
6,497
6,496
6,495
6,494
6,493
6,492
6,491
6,490
6,489
6,488
6,487
45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160
Distance From Left Bank Pin (ft)

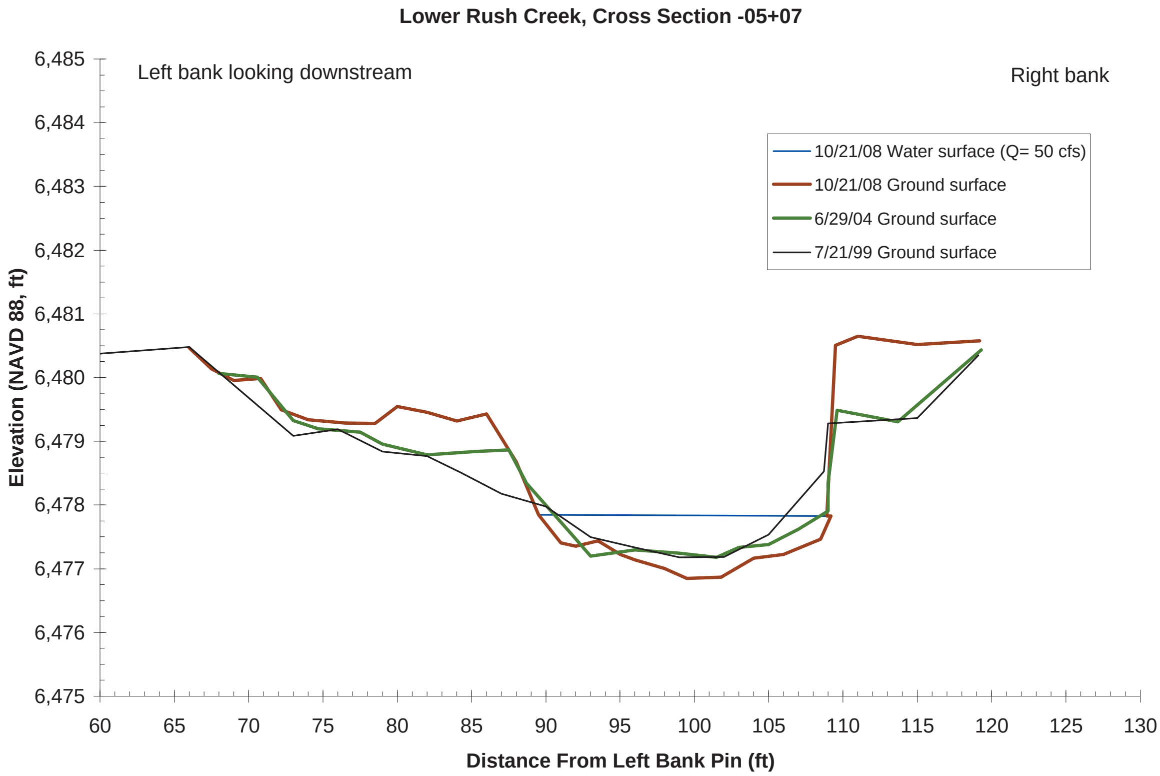

Left bank looking downstream
Right bank
2006 Peak water surface (Q= 388 cfs)
6/10/08 Water surface (Q= 421.5 cfs)
6/12/08 Water surface (Q= 362.5 cfs)
09/12/98 Water surface (Q= 92 cfs)
August 2008 Water surface (Q= 19.2 cfs)
August 2008 Water surface (Q= 12.1 cfs)
10/21/08 Water surface (Q= 50 cfs)
August 2008 Water surface (Q= 6.1 cfs)
August 2008 Water surface (Q= 3.0 cfs)
10/21/08 Ground surface
Elevation (NAVD 88, ft)
6,494
6,493
6,492
6,491
6,490
6,489
6,488
45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160
Distance From Left Bank Pin (ft)

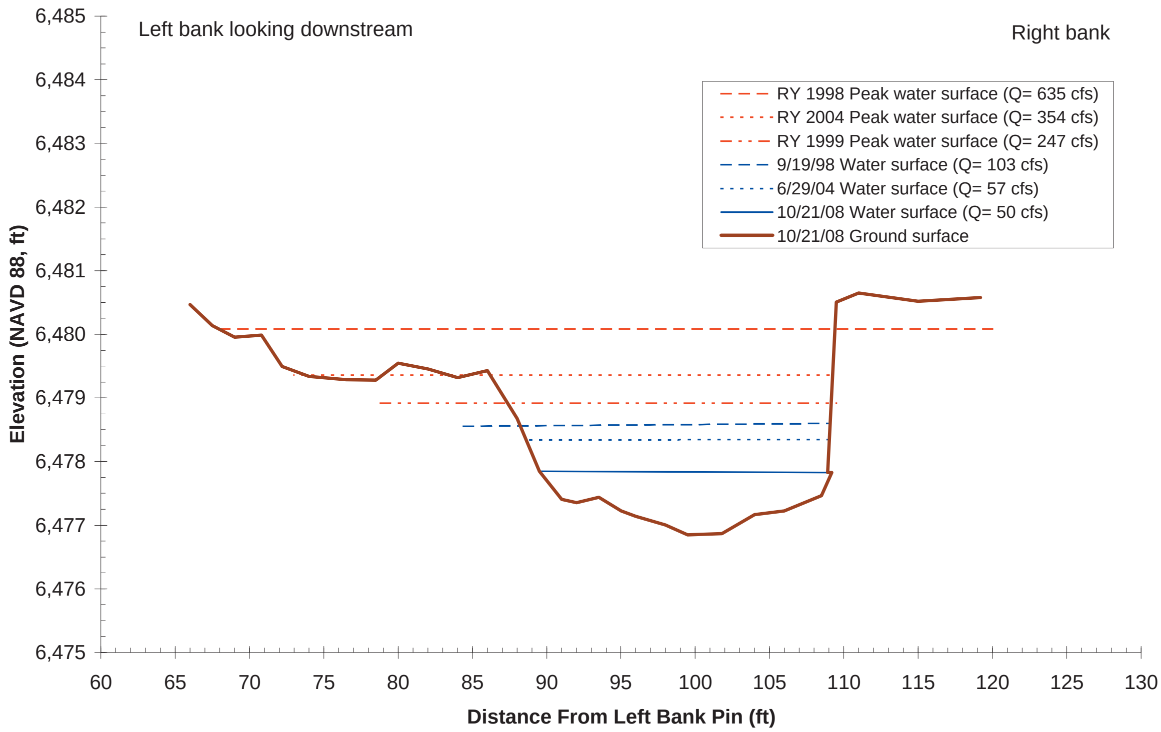

Lower Rush Creek, Cross Section 10+10
Left bank looking downstream
Right bank
10/21/08 Water surface (Q = 50 cfs)
10/21/08 Ground surface
10/23/04 Ground surface
6/28/04 Ground surface
7/21/99 Ground surface
Elevation (NAVD 88, ft)
6,500
6,499
6,498
6,497
6,496
6,495
6,494
6,493
6,492
6,491
6,490
6,489
6,488
0
20
40
60
80
100
120
140
160
180
200
Distance From Left Bank Pin (ft)

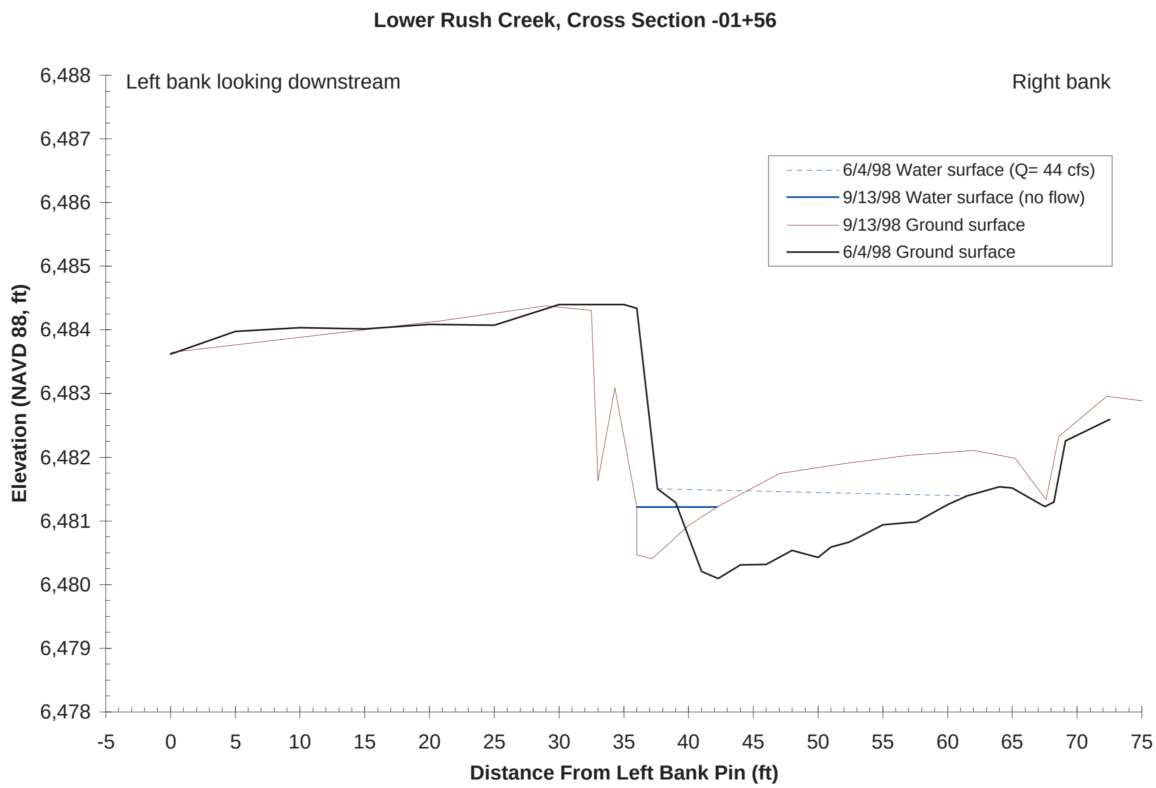

Left bank looking downstream
Right bank
RY 1998 Peak water surface (Q= 635 cfs)
RY 2004 Peak water surface (Q= 241 cfs)
6/12/08 Water surface (Q = 362.5 cfs)
6/28/04 Water surface(Q= 39 cfs)
10/21/08 Water surface (Q = 50 cfs)
10/21/08 Ground surface
Elevation (NAVD 88, ft)
6,500
6,499
6,498
6,497
6,496
6,495
6,494
6,493
6,492
6,491
6,490
6,489
6,488
0
20
40
60
80
100
120
140
160
180
200
Distance From Left Bank Pin (ft)

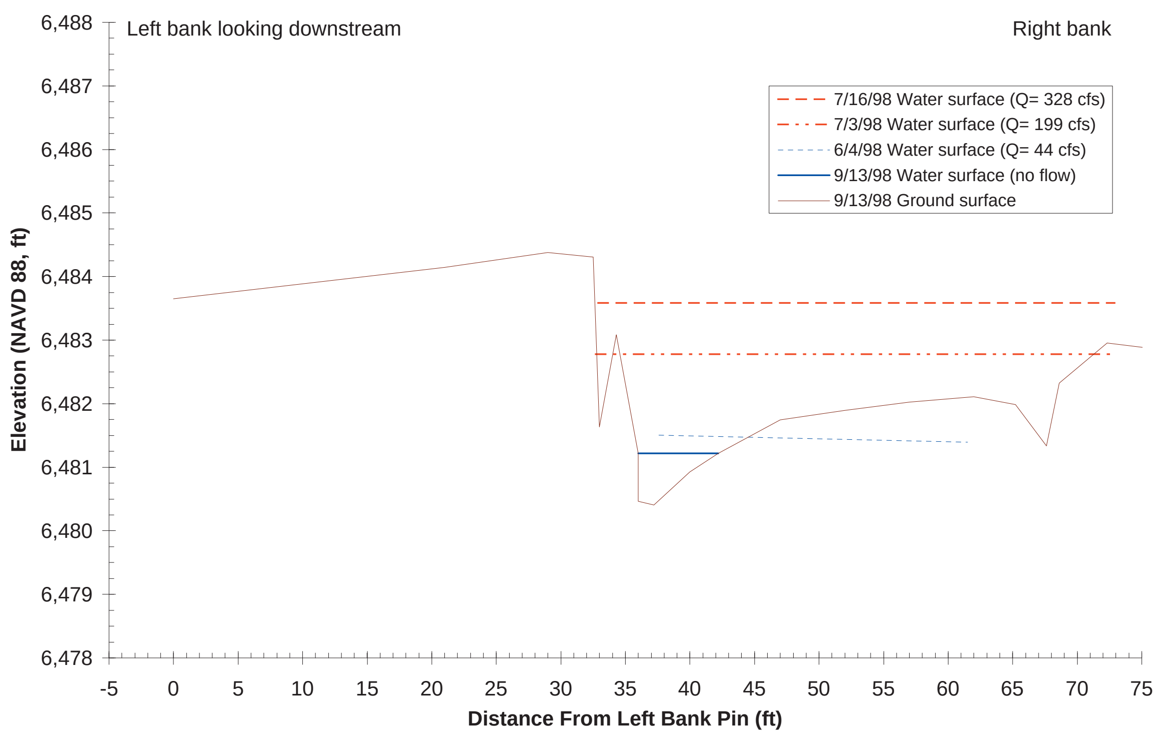

Lower Rush Creek, Cross Section -09+82
Left bank looking downstream
Right bank
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
6/29/04 Ground surface
7/21/99 Ground surface
10/11/97 Ground surface
Elevation (NAVD 88, ft)
6,479
6,478
6,477
6,476
6,475
6,474
6,473
6,472
6,471
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Distance From Left Bank Pin (ft)


Left bank looking downstream
Right bank
6/10/08 Water surface (Q= 421.5 cfs)
RY 2004 Peak water surface (Q= 380 cfs)
6/12/08 Water surface (Q= 362.5 cfs)
RY 1999 Peak water surface (Q= 247 cfs)
7/21/99 Water surface (Q= 138 cfs)
6/29/04 Water surface (Q= 57 cfs)
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
Elevation (NAVD, ft)
6,479
6,478
6,477
6,476
6,475
6,474
6,473
6,472
6,471
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Distance From Left Bank Pin (ft)

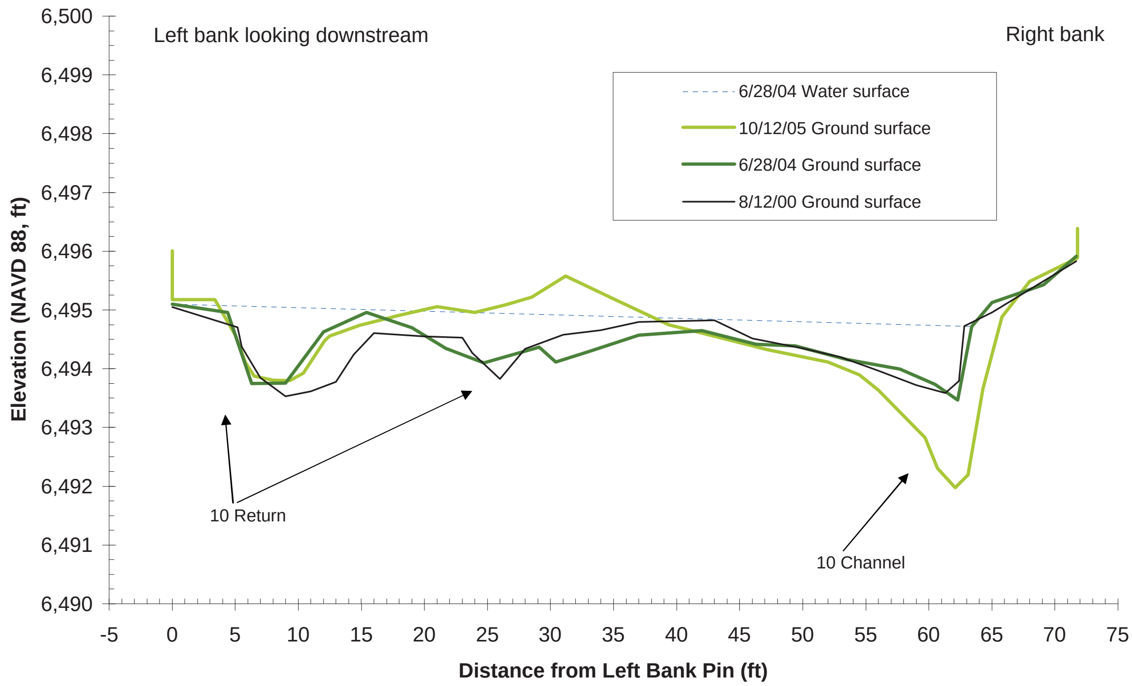

Lower Rush Creek, Cross Section -05+07
Left bank looking downstream
Right bank
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
6/29/04 Ground surface
7/21/99 Ground surface
Elevation (NAVD 88, ft)
6,485
6,484
6,483
6,482
6,481
6,480
6,479
6,478
6,477
6,476
6,475
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
Distance From Left Bank Pin (ft)

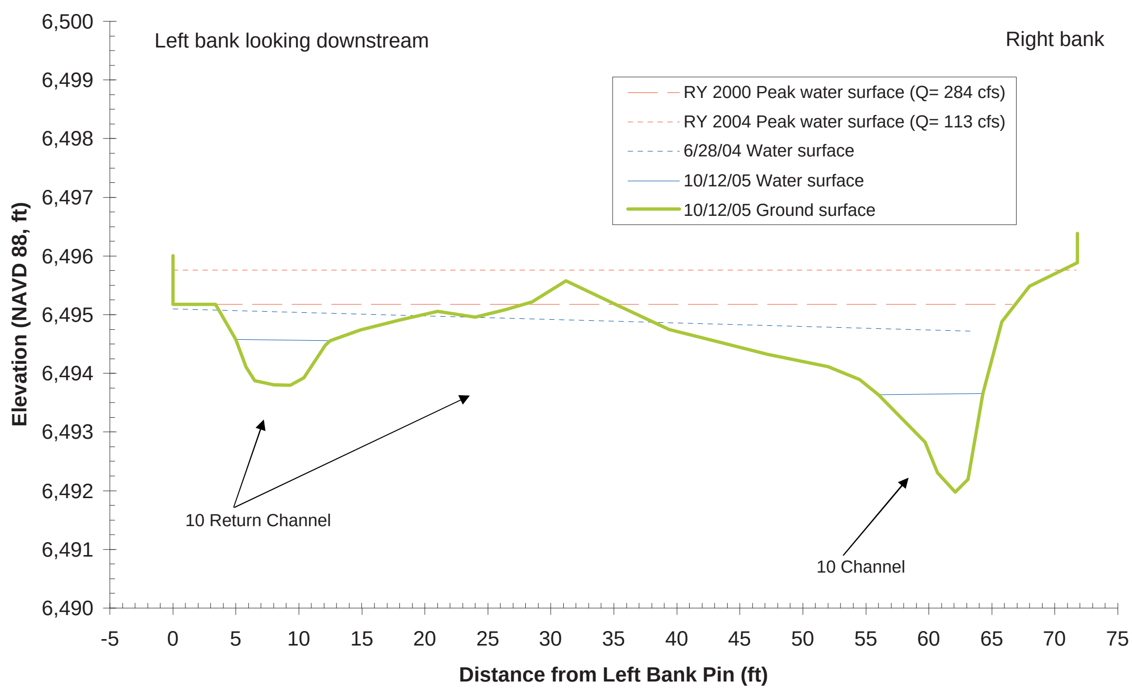

Left bank looking downstream
Right bank
RY 1998 Peak water surface (Q= 635 cfs)
RY 2004 Peak water surface (Q= 354 cfs)
RY 1999 Peak water surface (Q= 247 cfs)
9/19/98 Water surface (Q= 103 cfs)
6/29/04 Water surface (Q= 57 cfs)
10/21/08 Water surface (Q= 50 cfs)
10/21/08 Ground surface
Elevation (NAVD 88, ft)
6,485
6,484
6,483
6,482
6,481
6,480
6,479
6,478
6,477
6,476
6,475
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
Distance From Left Bank Pin (ft)

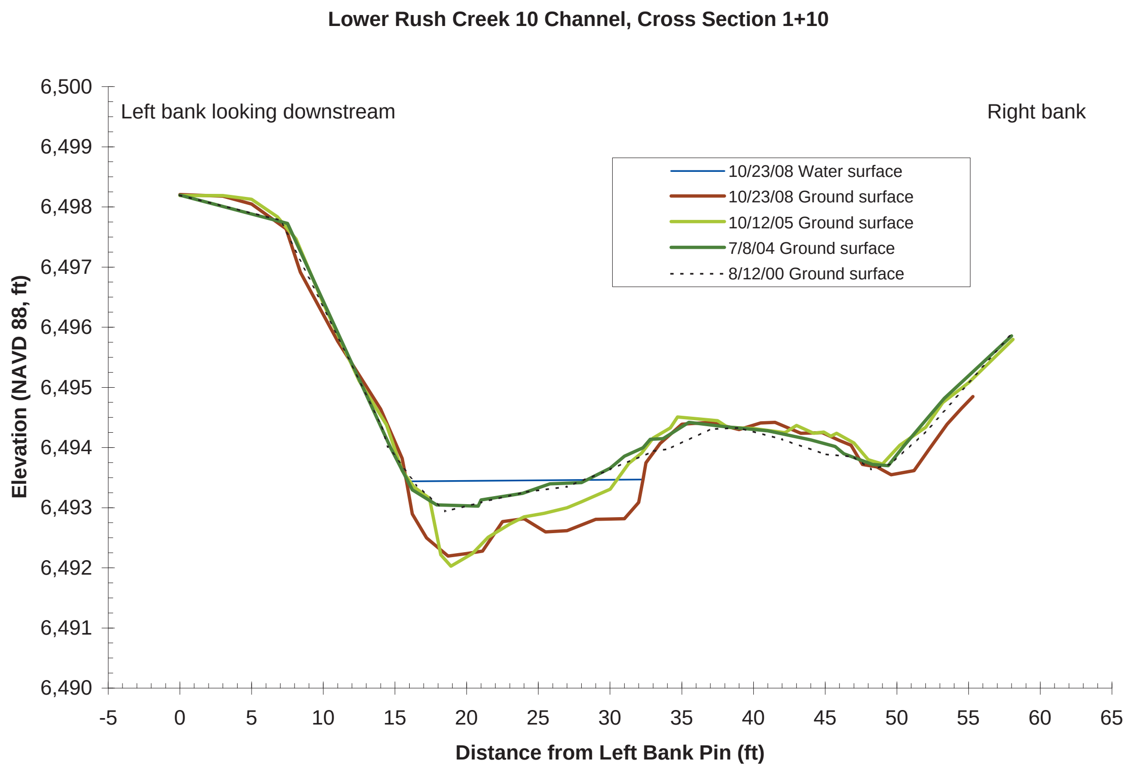

Lower Rush Creek, Cross Section -01+56
Left bank looking downstream
Right bank
6/4/98 Water surface (Q= 44 cfs)
9/13/98 Water surface (no flow)
9/13/98 Ground surface
6/4/98 Ground surface
Elevation (NAVD 88, ft)
6,488
6,487
6,486
6,485
6,484
6,483
6,482
6,481
6,480
6,479
6,478
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)

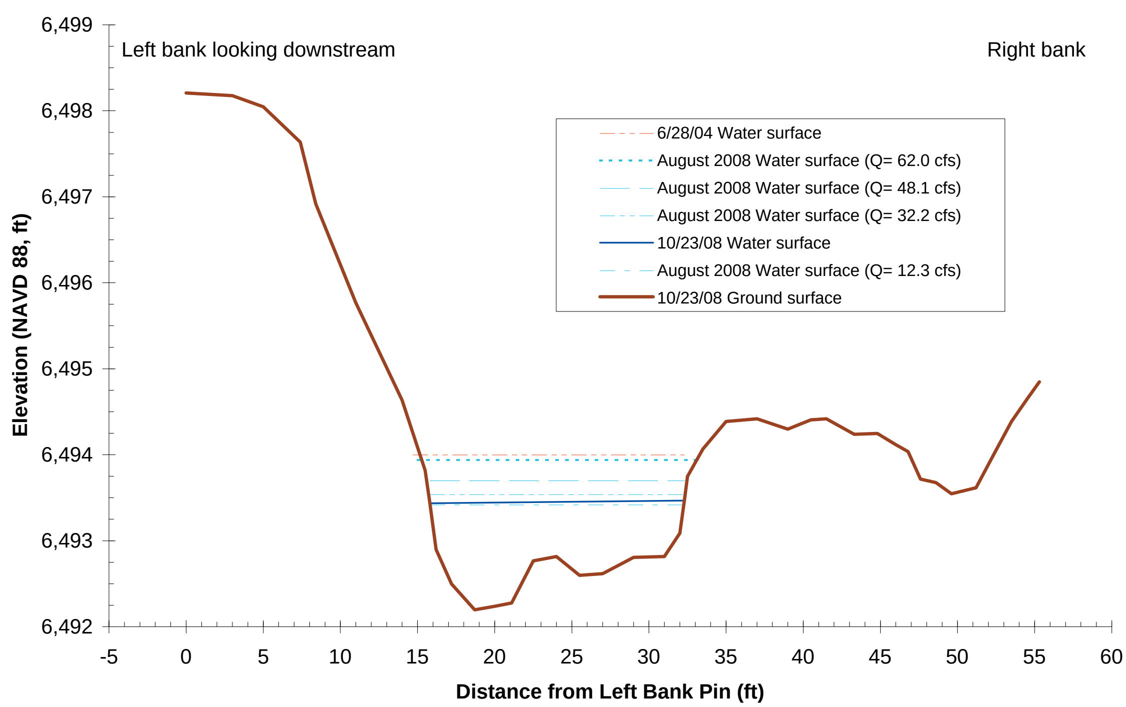

Left bank looking downstream
Right bank
7/16/98 Water surface (Q= 328 cfs)
7/3/98 Water surface (Q= 199 cfs)
6/4/98 Water surface (Q= 44 cfs)
9/13/98 Water surface (no flow)
9/13/98 Ground surface
Elevation (NAVD 88, ft)
6,488
6,487
6,486
6,485
6,484
6,483
6,482
6,481
6,480
6,479
6,478
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Distance From Left Bank Pin (ft)

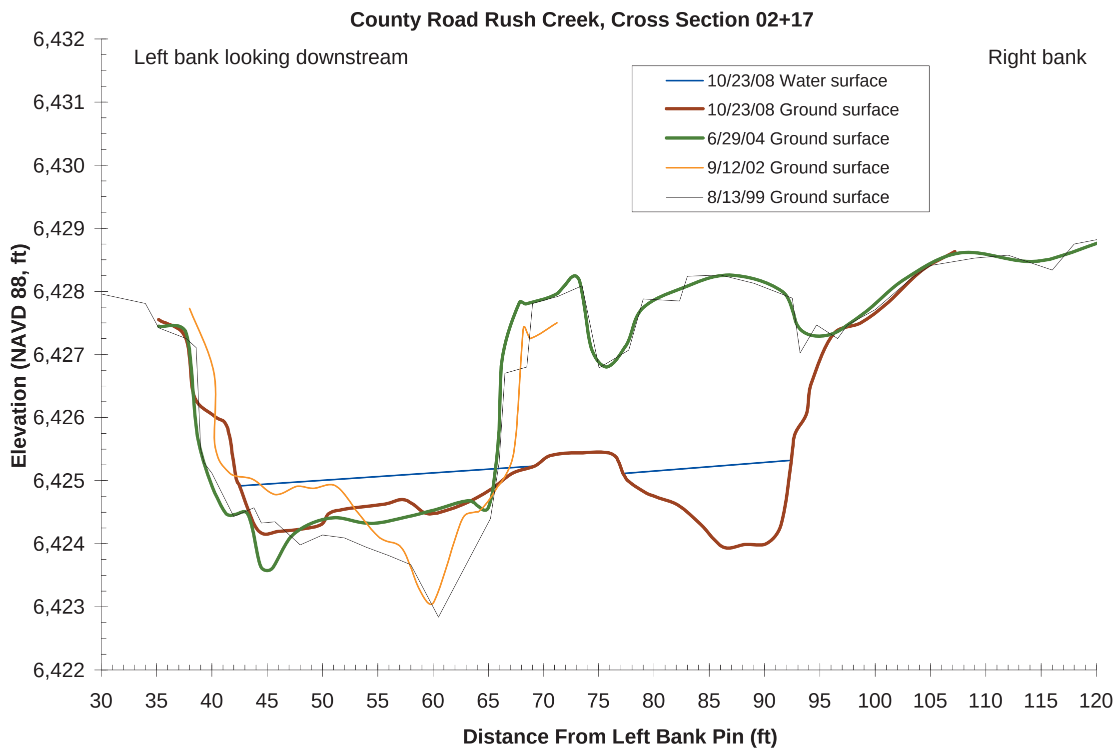
Lower Rush Creek 10 Channel, Cross Section 0+50

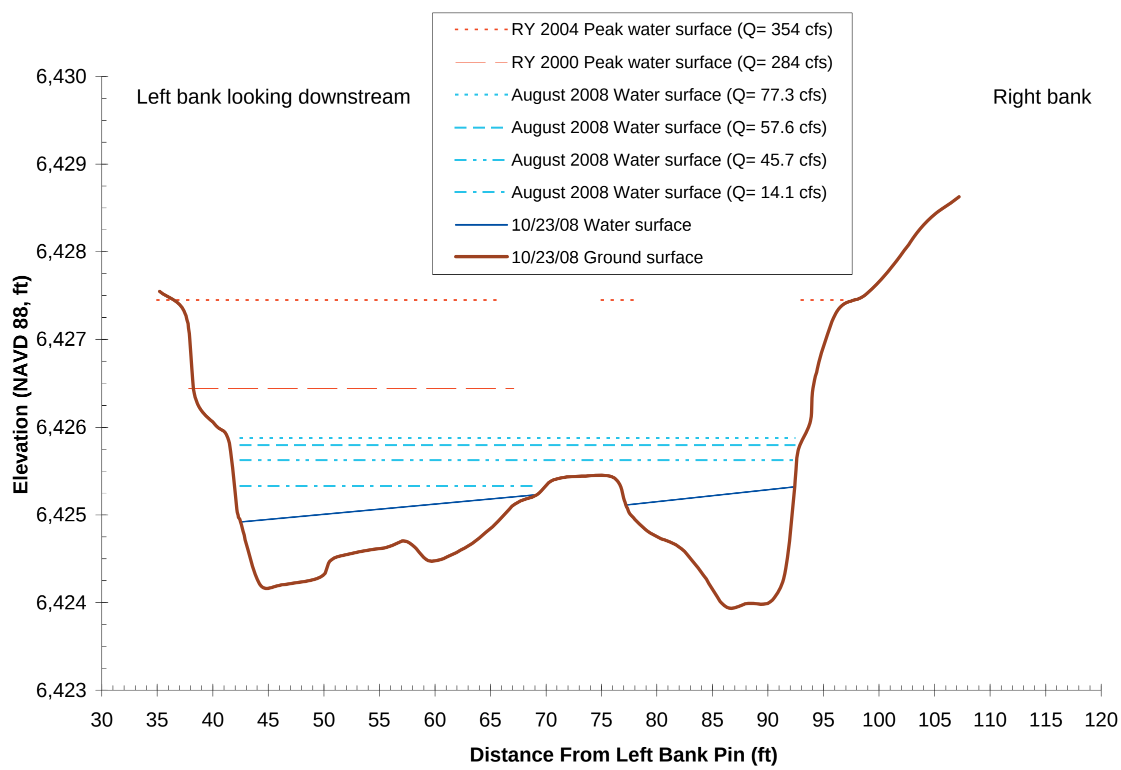




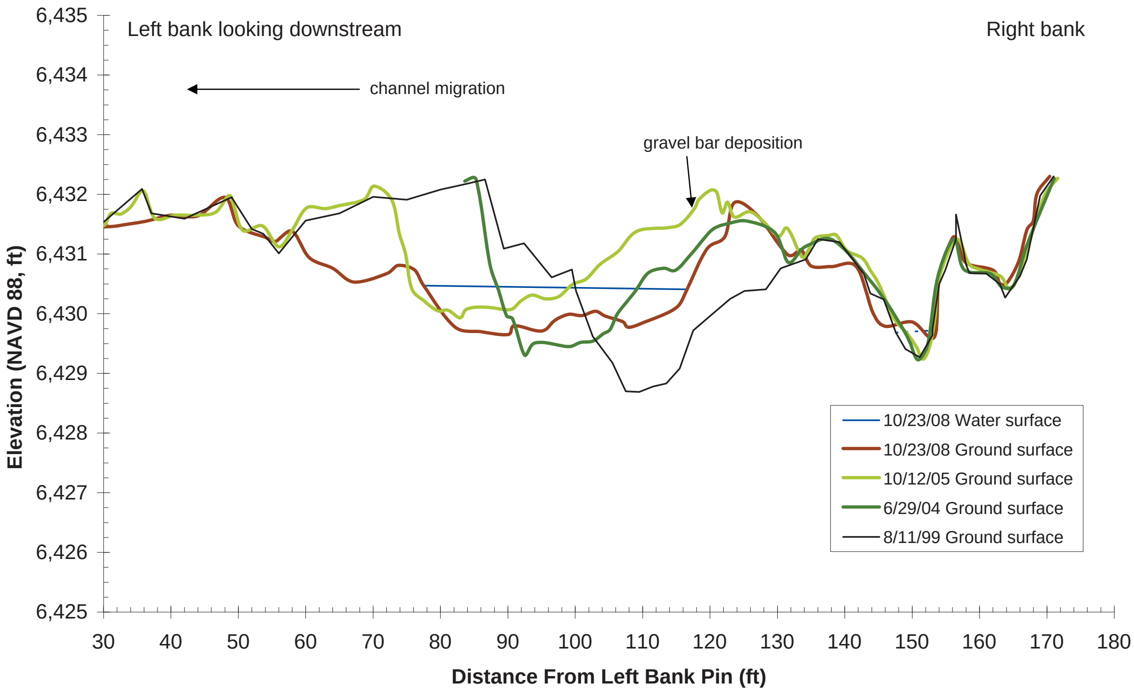

Lower Rush Creek 10 Channel, Cross Section 1+10
Left bank looking downstream
Right bank
10/23/08 Water surface
10/23/08 Ground surface
10/12/05 Ground surface
7/8/04 Ground surface
8/12/00 Ground surface
Elevation (NAVD 88, ft)
6,500
6,499
6,498
6,497
6,496
6,495
6,494
6,493
6,492
6,491
6,490
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Distance from Left Bank Pin (ft)

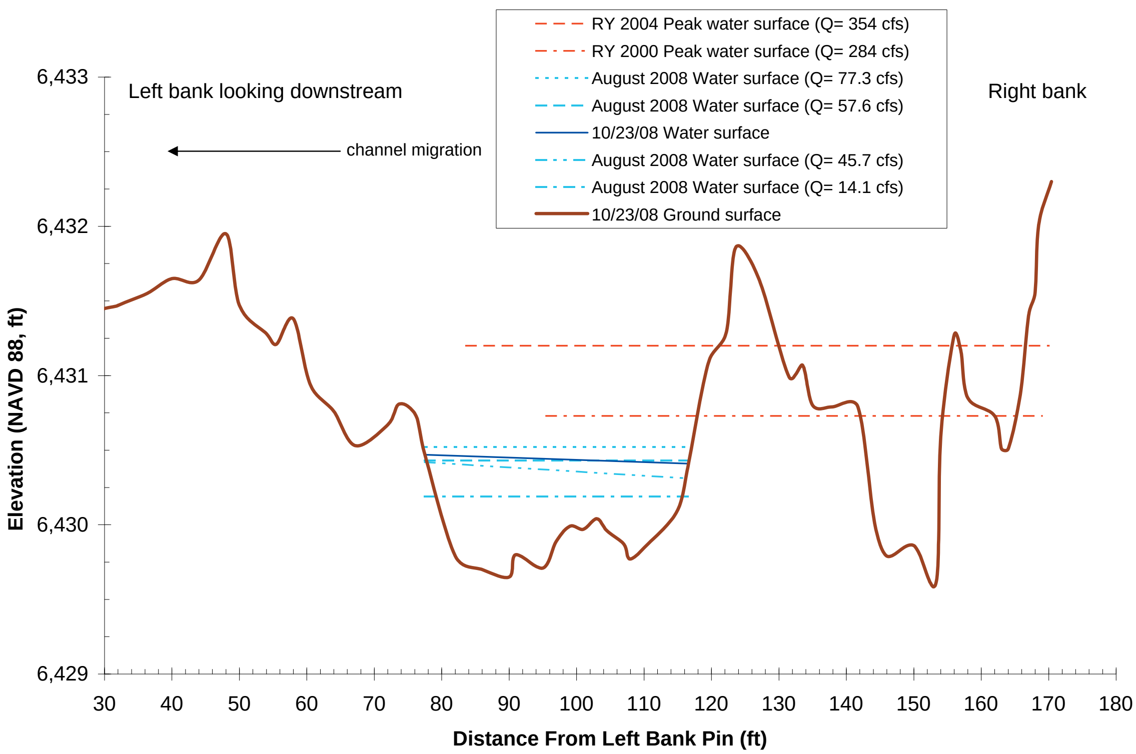

Left bank looking downstream
Right bank
6/28/04 Water surface
August 2008 Water surface (Q= 62.0 cfs)
August 2008 Water surface (Q= 48.1 cfs)
August 2008 Water surface (Q= 32.2 cfs)
10/23/08 Water surface
August 2008 Water surface (Q= 12.3 cfs)
10/23/08 Ground surface
Elevation (NAVD 88, ft)
6,499
6,498
6,497
6,496
6,495
6,494
6,493
6,492
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
Distance from Left Bank Pin (ft)

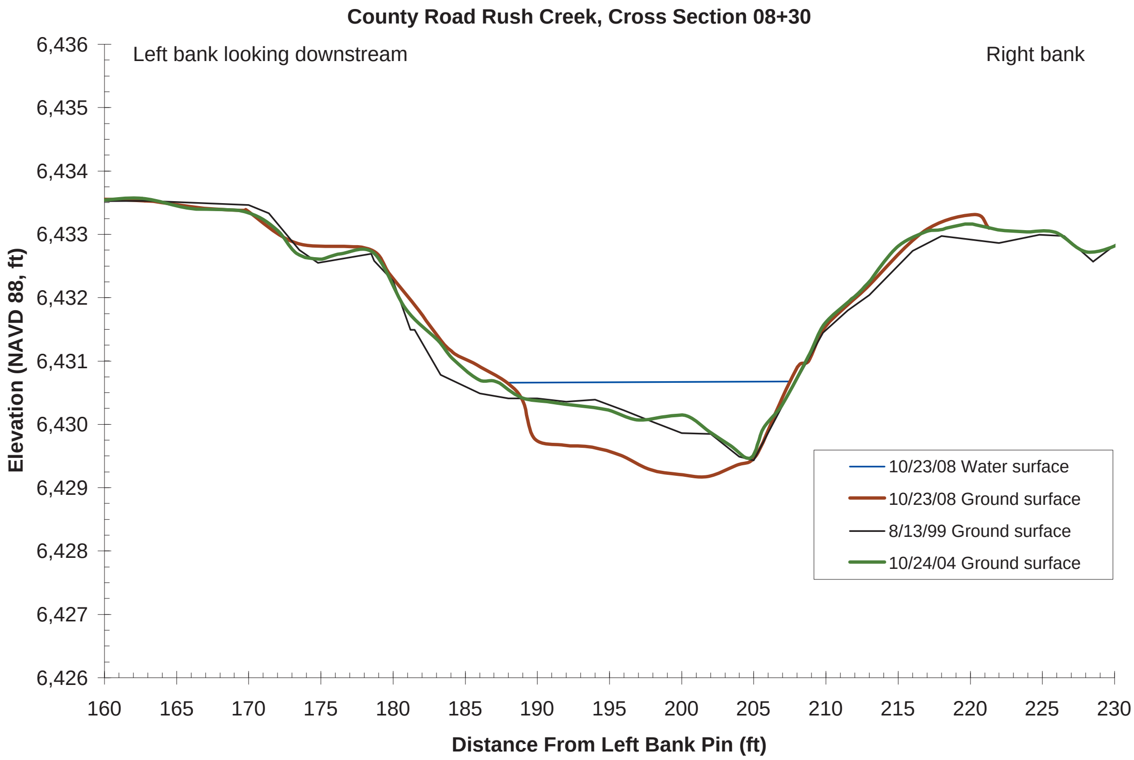

County Road Rush Creek, Cross Section 02+17
Left bank looking downstream
Right bank
10/23/08 Water surface
10/23/08 Ground surface
6/29/04 Ground surface
9/12/02 Ground surface
8/13/99 Ground surface
Elevation (NAVD 88, ft)
6,432
6,431
6,430
6,429
6,428
6,427
6,426
6,425
6,424
6,423
6,422
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
Distance From Left Bank Pin (ft)

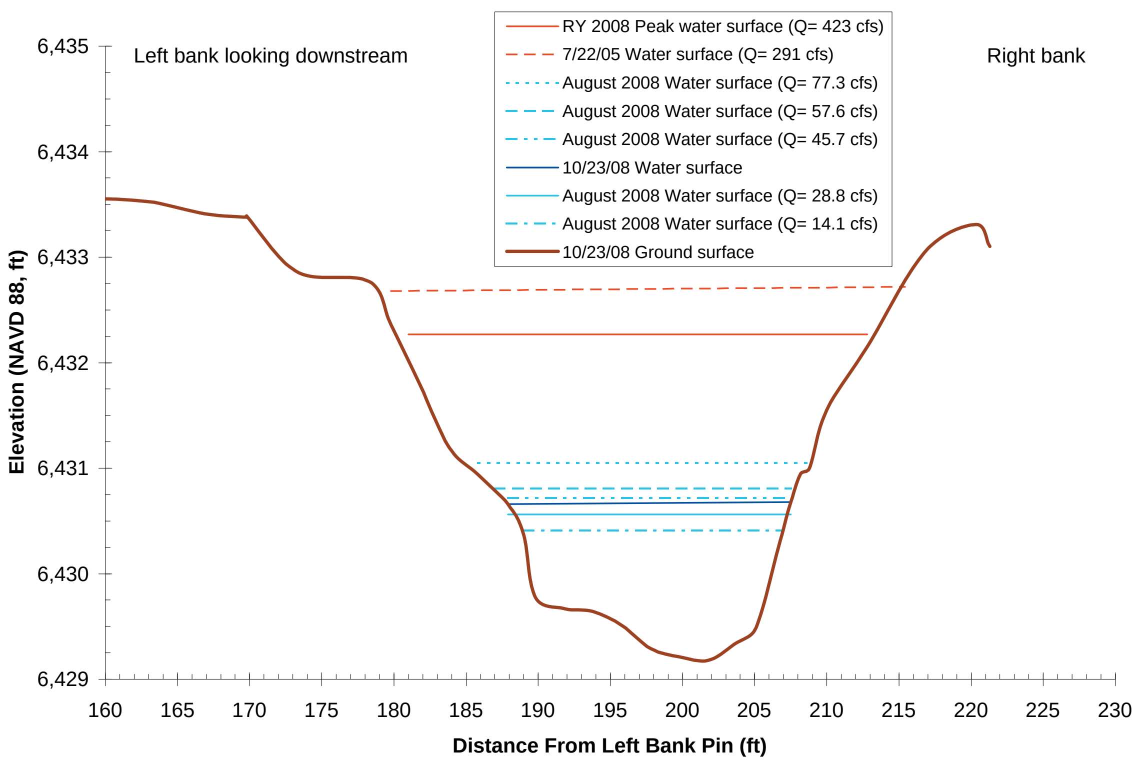

RY 2004 Peak water surface (Q= 354 cfs)
RY 2000 Peak water surface (Q= 284 cfs)
August 2008 Water surface (Q= 77.3 cfs)
August 2008 Water surface (Q= 57.6 cfs)
August 2008 Water surface (Q= 45.7 cfs)
August 2008 Water surface (Q= 14.1 cfs)
10/23/08 Water surface
10/23/08 Ground surface
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,430
6,429
6,428
6,427
6,426
6,425
6,424
6,423
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
Distance From Left Bank Pin (ft)

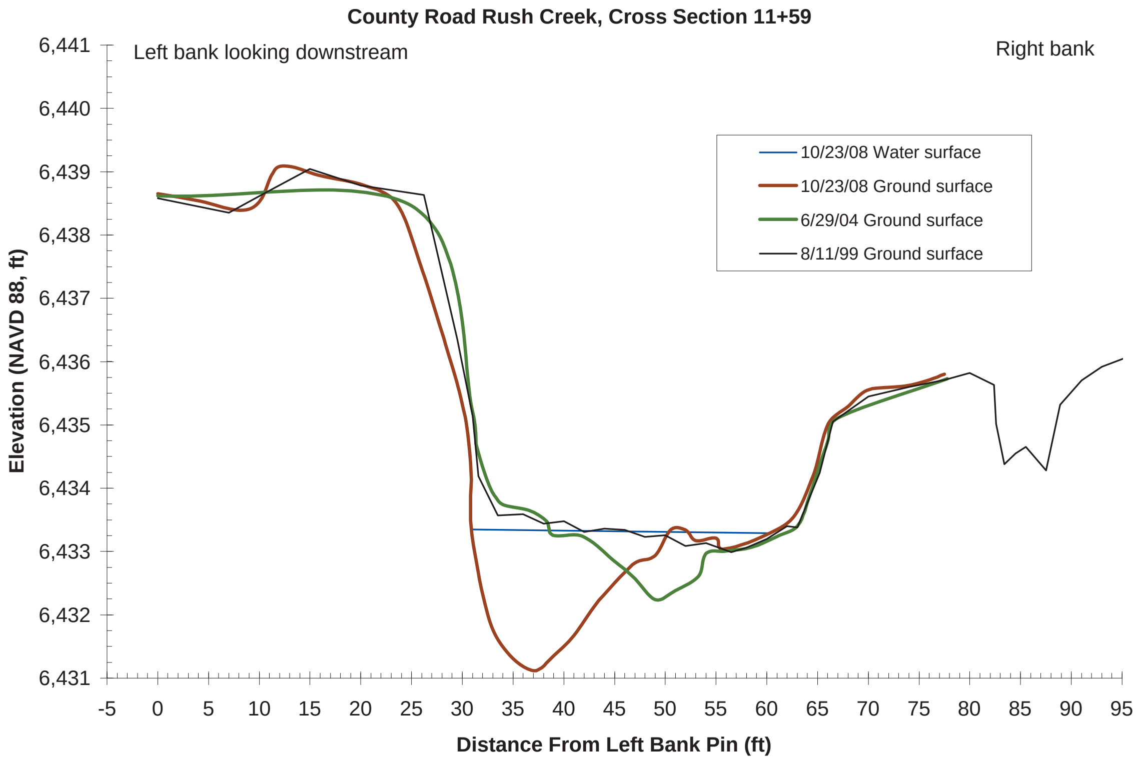
County Road Rush Creek, Cross Section 06+85

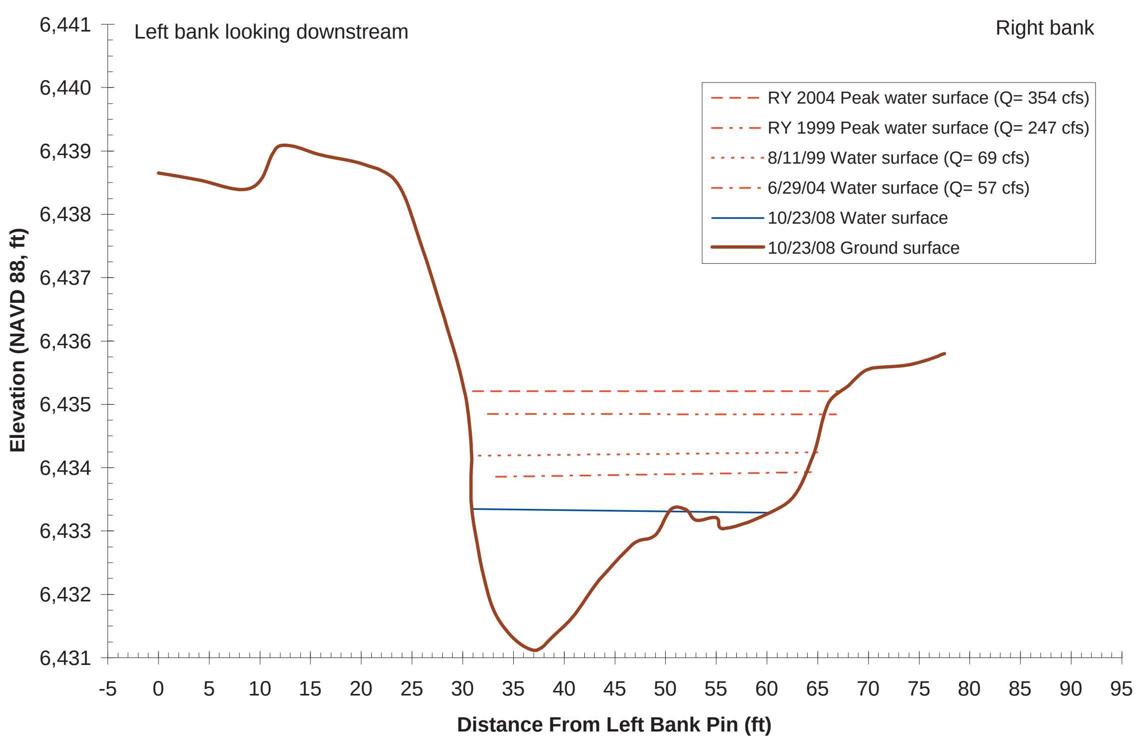


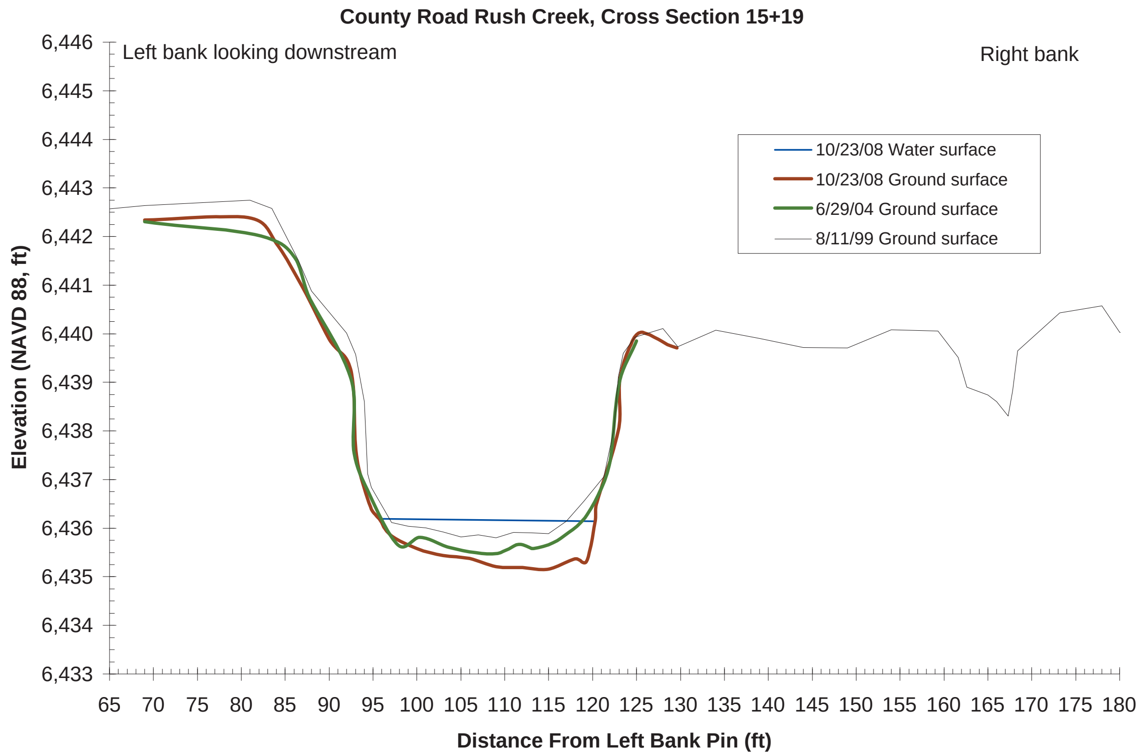


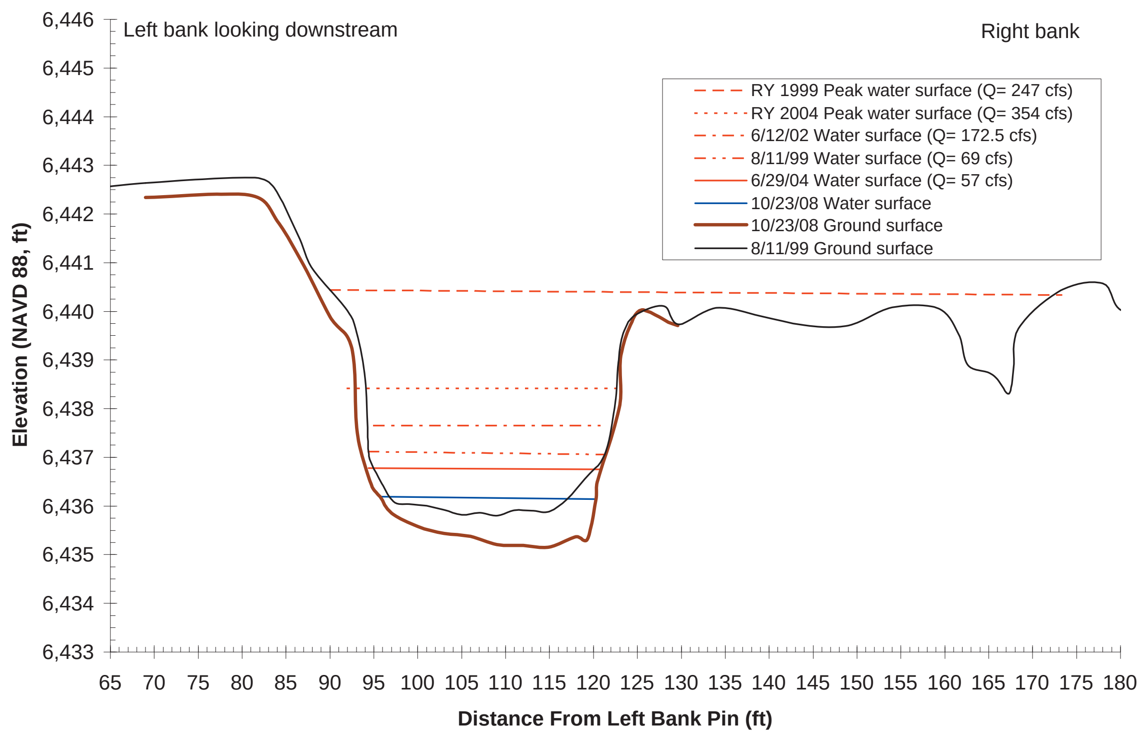

County Road Rush Creek, Cross Section 08+30
Left bank looking downstream
Right bank
Elevation (NAVD 88, ft)
6,436
6,435
6,434
6,433
6,432
6,431
6,430
6,429
6,428
6,427
6,426
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
Distance From Left Bank Pin (ft)
10/23/08 Water surface
10/23/08 Ground surface
8/13/99 Ground surface
10/24/04 Ground surface

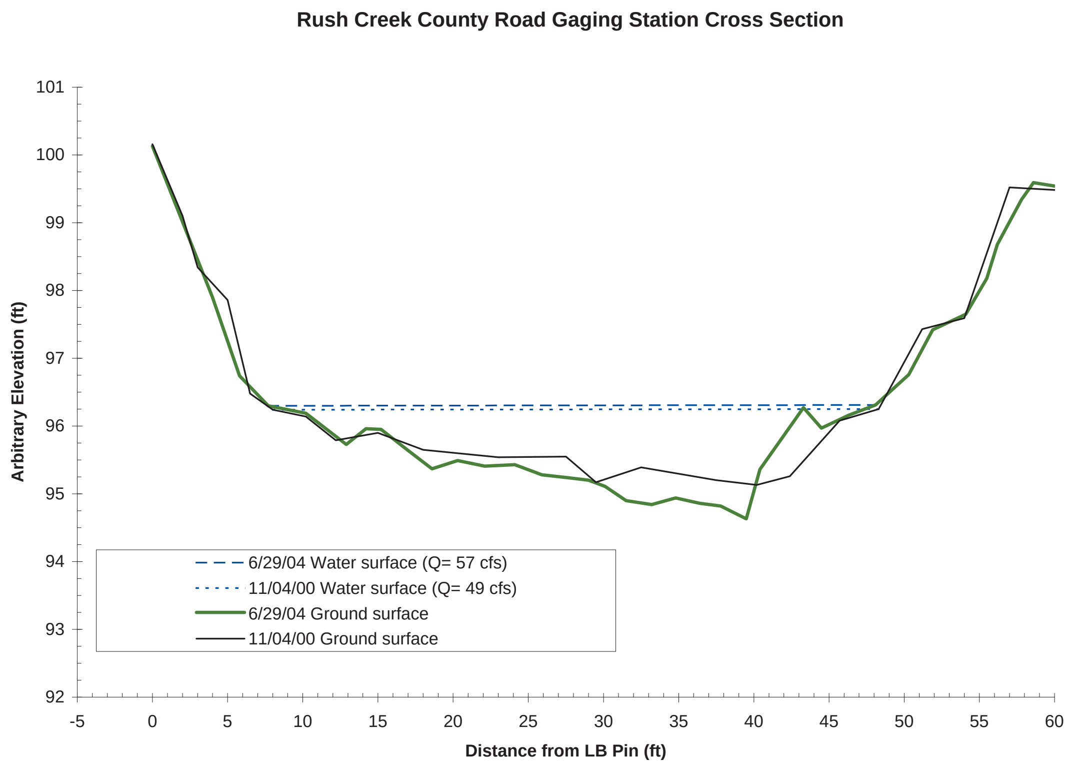

Left bank looking downstream
Right bank
RY 2008 Peak water surface (Q= 423 cfs)
7/22/05 Water surface (Q= 291 cfs)
August 2008 Water surface (Q= 77.3 cfs)
August 2008 Water surface (Q= 57.6 cfs)
August 2008 Water surface (Q= 45.7 cfs)
10/23/08 Water surface
August 2008 Water surface (Q= 28.8 cfs)
August 2008 Water surface (Q= 14.1 cfs)
10/23/08 Ground surface
Elevation (NAVD 88, ft)
6,435
6,434
6,433
6,432
6,431
6,430
6,429
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
Distance From Left Bank Pin (ft)


County Road Rush Creek, Cross Section 11+59
Left bank looking downstream
Right bank
10/23/08 Water surface
10/23/08 Ground surface
6/29/04 Ground surface
8/11/99 Ground surface
Elevation (NAVD 88, ft)
6,441
6,440
6,439
6,438
6,437
6,436
6,435
6,434
6,433
6,432
6,431
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
Distance From Left Bank Pin (ft)


Left bank looking downstream
Right bank
RY 2004 Peak water surface (Q= 354 cfs)
RY 1999 Peak water surface (Q= 247 cfs)
8/11/99 Water surface (Q= 69 cfs)
6/29/04 Water surface (Q= 57 cfs)
10/23/08 Water surface
10/23/08 Ground surface
Elevation (NAVD 88, ft)
6,441
6,440
6,439
6,438
6,437
6,436
6,435
6,434
6,433
6,432
6,431
-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
Distance From Left Bank Pin (ft)

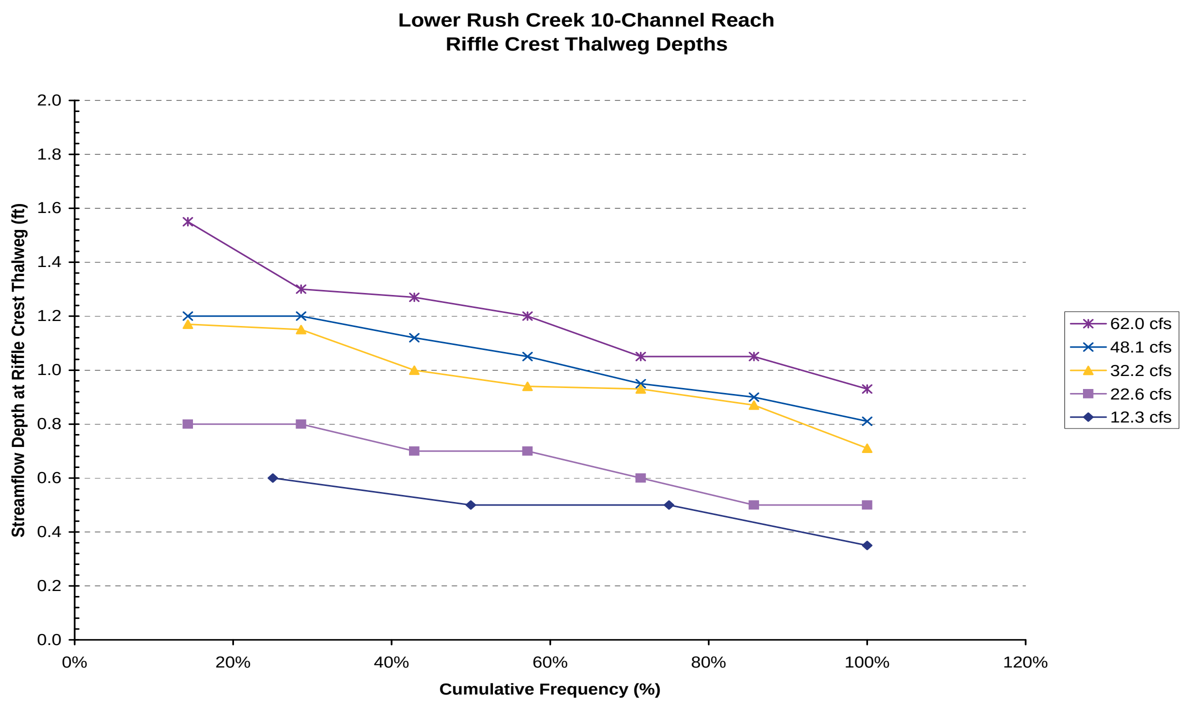

County Road Rush Creek, Cross Section 15+19
Left bank looking downstream
Right bank
10/23/08 Water surface
10/23/08 Ground surface
6/29/04 Ground surface
8/11/99 Ground surface
Elevation (NAVD 88, ft)
6,446
6,445
6,444
6,443
6,442
6,441
6,440
6,439
6,438
6,437
6,436
6,435
6,434
6,433
65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180
Distance From Left Bank Pin (ft)

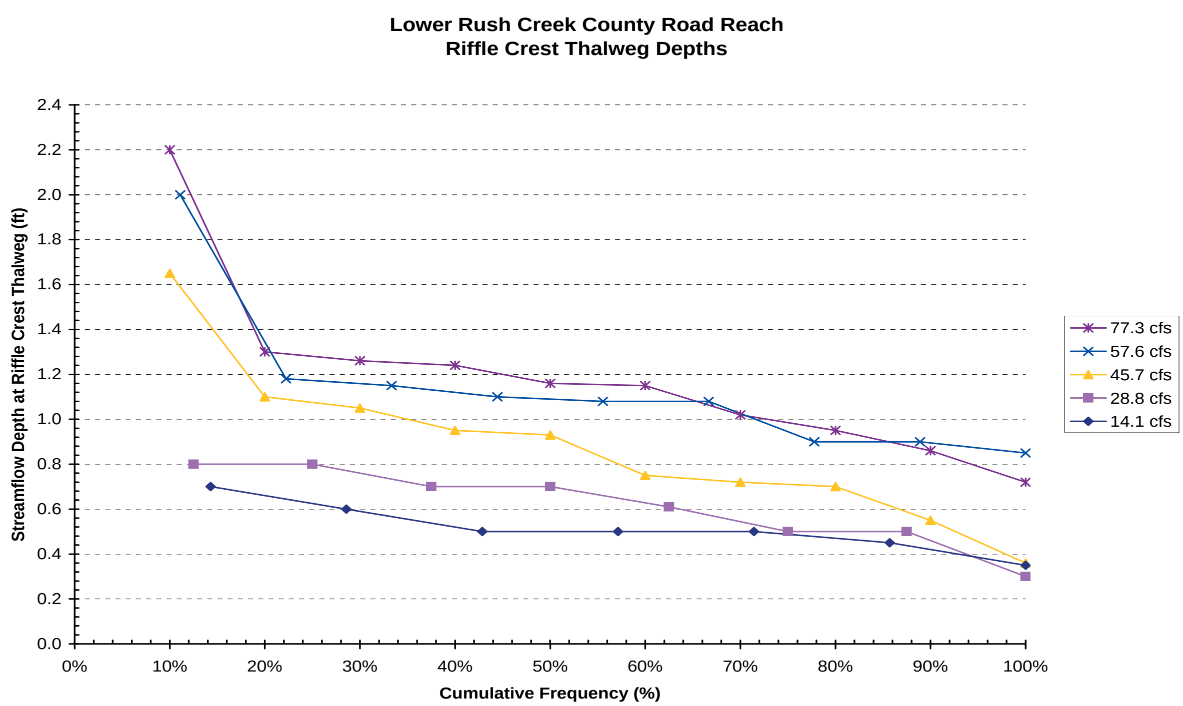

Left bank looking downstream
Right bank
RY 1999 Peak water surface (Q= 247 cfs)
RY 2004 Peak water surface (Q= 354 cfs)
6/12/02 Water surface (Q= 172.5 cfs)
8/11/99 Water surface (Q= 69 cfs)
6/29/04 Water surface (Q= 57 cfs)
10/23/08 Water surface
10/23/08 Ground surface
8/11/99 Ground surface
Elevation (NAVD 88, ft)
6,446
6,445
6,444
6,443
6,442
6,441
6,440
6,439
6,438
6,437
6,436
6,435
6,434
6,433
65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180
Distance From Left Bank Pin (ft)

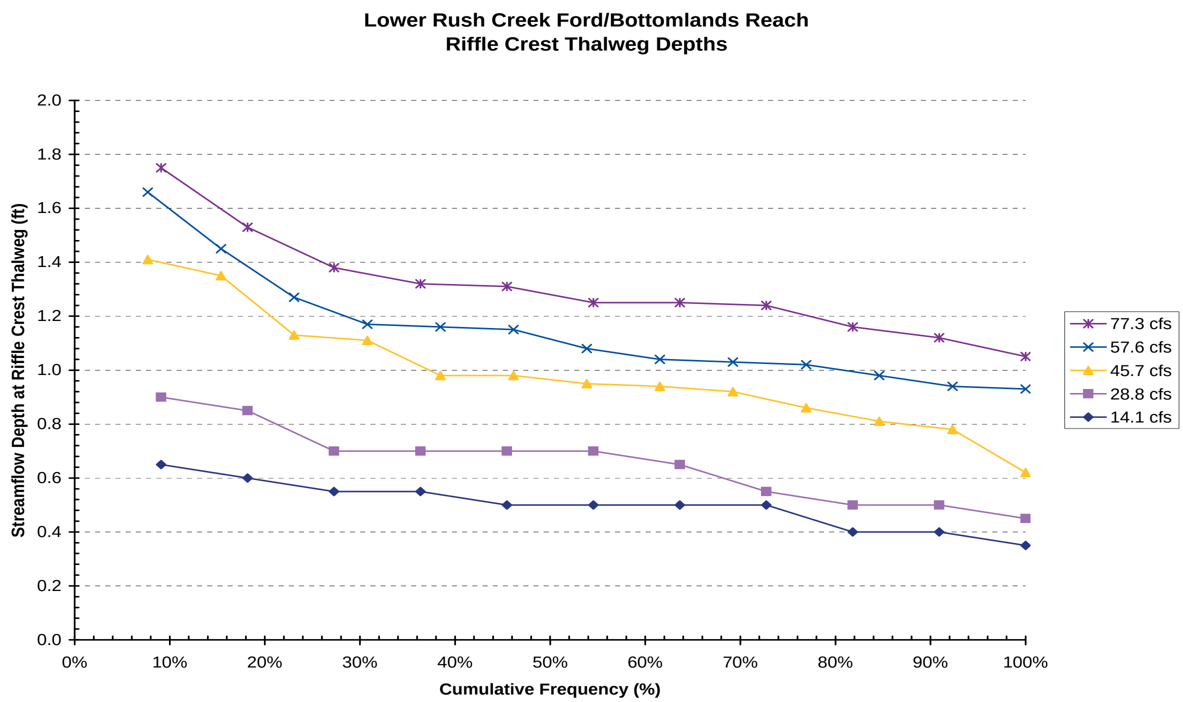

Rush Creek County Road Gaging Station Cross Section
101
100
99
98
97
96
95
94
93
92
Arbitrary Elevation (ft)
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
Distance from LB Pin (ft)
6/29/04 Water surface (Q= 57 cfs)
11/04/00 Water surface (Q= 49 cfs)
6/29/04 Ground surface
11/04/00 Ground surface

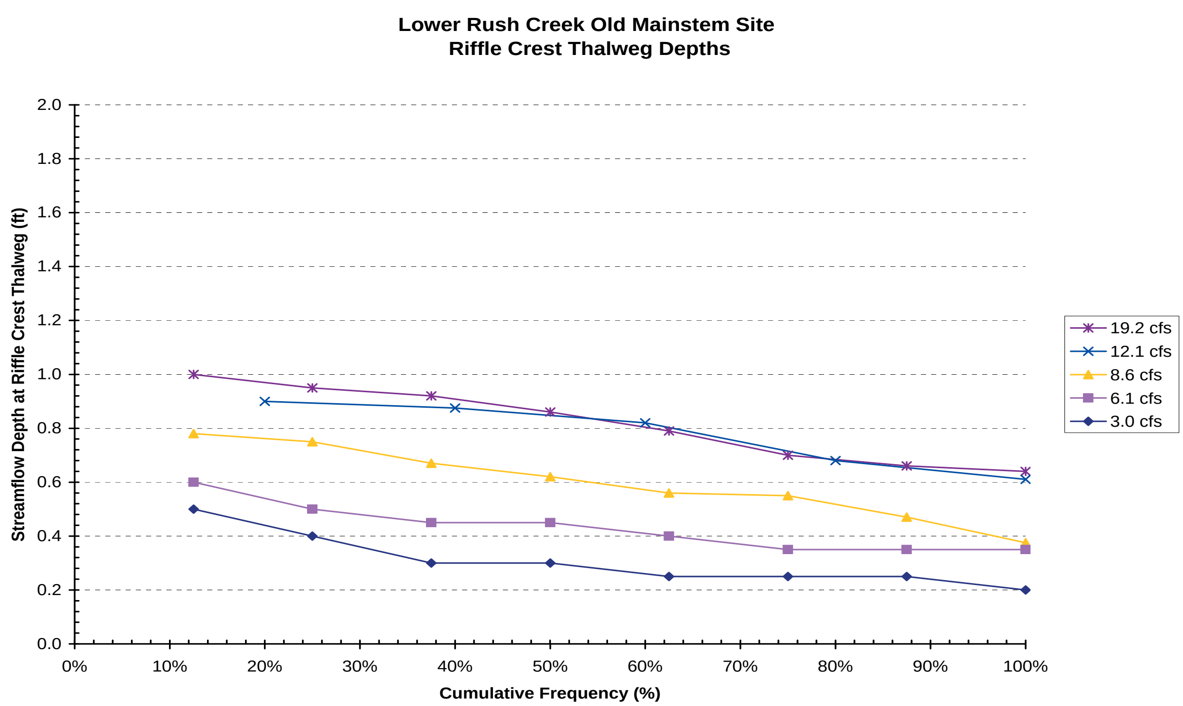
APPENDIX D

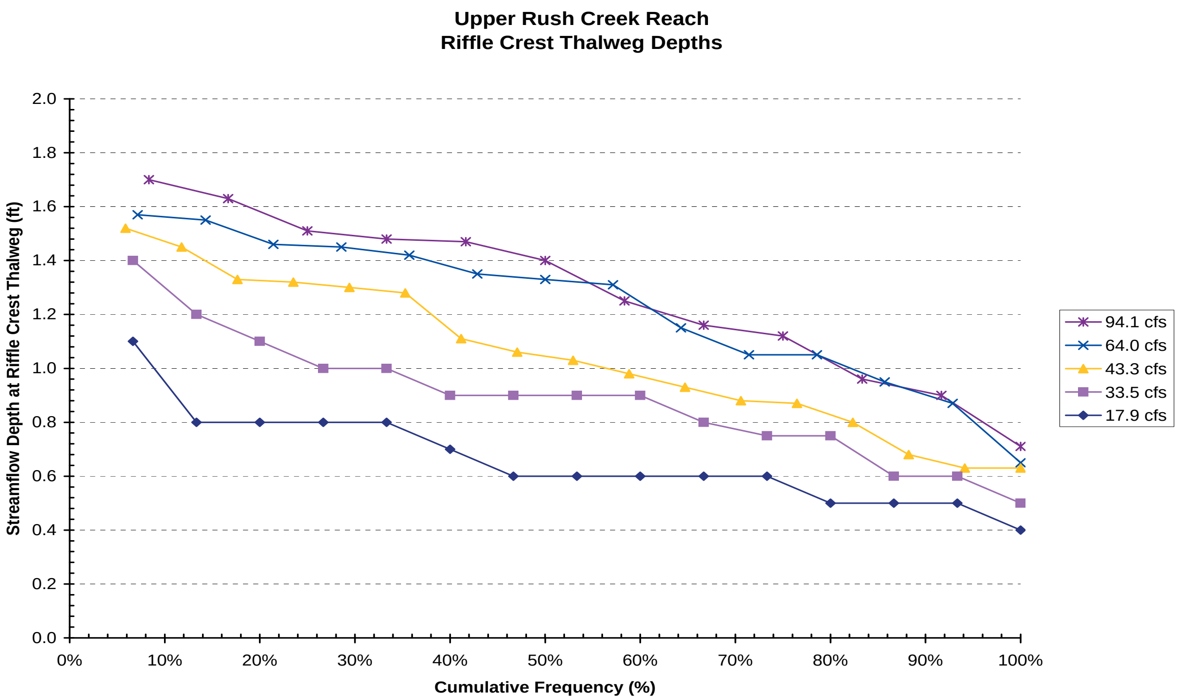
Rifflle Crest Thalweg Depth Surveys for Rush Creek
for Runoff Years 1995-2008


Lower Rush Creek 10-Channel Reach
Riffle Crest Thalweg Depths
Streamflow Depth at Riffle Crest Thalweg (ft)
Cumulative Frequency (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0%
20%
40%
60%
80%
100%
120%
62.0 cfs
48.1 cfs
32.2 cfs
22.6 cfs
12.3 cfs


Lower Rush Creek County Road Reach
Riffle Crest Thalweg Depths
Streamflow Depth at Riffle Crest Thalweg (ft)
Cumulative Frequency (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
77.3 cfs
57.6 cfs
45.7 cfs
28.8 cfs
14.1 cfs


Lower Rush Creek Ford/Bottomlands Reach
Riffle Crest Thalweg Depths
Streamflow Depth at Riffle Crest Thalweg (ft)
Cumulative Frequency (%)
77.3 cfs
57.6 cfs
45.7 cfs
28.8 cfs
14.1 cfs


Lower Rush Creek Old Mainstem Site
Riffle Crest Thalweg Depths
Streamflow Depth at Riffle Crest Thalweg (ft)
Cumulative Frequency (%)
19.2 cfs
12.1 cfs
8.6 cfs
6.1 cfs
3.0 cfs


Upper Rush Creek Reach
Riffle Crest Thalweg Depths
Streamflow Depth at Riffle Crest Thalweg (ft)
Cumulative Frequency (%)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
94.1 cfs
64.0 cfs
43.3 cfs
33.5 cfs
17.9 cfs