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Managing Water in the West

Technical Memorandum No. 86-68290-09-05

Klamath River Salmon Redd Scour Study, 2008–2009

U.S. Department of the Interior
Bureau of Reclamation

August 2009

Mission Statements

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photograph: Scour Chain at Willow Creek Confluence with Klamath River, December 16, 2008.

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Klamath Project, Oregon

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Abbreviations

cfs	cubic feet per second
cm	centimeter
ft	foot
GPS	Global Positioning System
km	kilometer
mm	millimeter
Reclamation	Bureau of Reclamation
RKM	river kilometer
USGS	U.S. Geological Survey
%	percent

Contents

	Page
Acknowledgements	iii
Abbreviations	v
Summary	1
Introduction	3
Study Area	3
Methods	8
Results and Discussion	8
Stream Flows	8
Comparison of Peak Flows	10
Redd Scour	14
Recommendations	15
References	19

Tables

		Page
1	Study locations for Klamath River scour study	4
2	Slope and discharge measurements for Klamath River scour study	13
3	Scour chain link results for Klamath River scour study	14
4	Scour chain elevations (feet) for Klamath River redd scour study	16

Figures

		Page
1	Study area for Klamath River redd scour study	4
2	Locations of redds in mainstem Klamath River at Klamath River Country Estates and Willow Creek (aerial photo top; topo map bottom)	5
3	Location of redd in mainstem Klamath River at Barkhouse Creek side channel (aerial photo top; topo map bottom)	6
4	Locations of redds in Horse Creek (aerial photo top; topo map bottom)	7

Figures (continued)

Page

5 Streamflows of the Klamath River measured at the gauging station below Iron Gate Dam 9
6 An index to the daily streamflows of the Klamath River at Barkhouse side channel..... 9
7 Annual maximum daily discharge measured at the gauge just below Iron Gate Dam for the period of record between 1961–2009 ... 11
8 Exceedence diagram for the maximum daily discharge for the Klamath River below Iron Gate Dam 11
9 Discharge in Klamath River at Iron Gate Dam (October–May) for water years 1997–2008..... 12
10 Discharge in Indian Creek (October–May) for water years 1997–2008 12
11 Available discharge in Indian Creek and water levels in Horse Creek during 2008–2009 redd scour study..... 13
12 Cross-sectional profiles at redd locations in Klamath River 17
13 Cross-sectional profiles at redd locations in Horse Creek 18

Summary

Within the Klamath River, the effect of flow on the potential for scouring of coho salmon redds has been identified as a data gap. To address this data gap, a better understanding on the relationships between flow, bed mobility, and scour depth in mainstem reaches utilized by spawning coho salmon is needed. During the 2008-2009 winter season, the Bureau of Reclamation continued a redd scour study, started the previous winter, to assess the potential impacts of scouring during high winter flows on the success of coho salmon redds within the mainstem of the Klamath River. Scour chains and cross-sectional profiles were measured at three documented coho spawning locations in the mainstem Klamath River and three redd locations in Horse Creek, a reference tributary. The maximum daily discharge (1,780 cubic feet per second [cfs]) occurred on March 5, 2009. This discharge has been exceeded during about 98 percent (%) of the years following completion of Iron Gate Dam in 1961. The 2007–2008 winter season was also relatively dry when no scouring was observed. The pattern of discharge (timing of high and low flows) was similar between Horse Creek and Indian Creek when comparing a stage recorder in Horse Creek with a stream gauge in Indian Creek. Scour chain exposed links and elevations showed little overall change between December 2008 and July 2009. Also, there was no evidence from the cross-sectional profiles that scouring had occurred at the redd locations. In fact, there was slight overall filling of redds with sand and small gravel which may have been just as detrimental to egg survival as scouring because of potential problems with oxygen for incubating eggs and emergence.

Introduction

A small proportion of coho salmon (*Oncorhynchus kisutch*) return to the Klamath River drainage to spawn in the mainstem of the Klamath River each year, but the origin of these fish and the survival of their eggs are unknown (Cramer Fish Sciences 2008). Between 2001 and 2005, a total of 46 coho salmon redds (ranging between 6 and 21 per year) were counted in the Klamath River mainstem (Magneson and Gough 2006). Most redds were concentrated within 20 kilometers (km) downstream from Iron Gate Dam (Magneson and Gough 2006). Cramer Fish Sciences (2007) suggested that coho salmon redds within the mainstem Klamath River likely are scoured by relatively high flows in some years, leading to negligible production potential of the mainstem. Thus, Cramer Fish Sciences (2008) recommended that studies are needed to determine whether mainstem coho salmon spawners are producing viable fry.

Most coho salmon spawn between November and January (Hassler 1987; Nickelson and Lawson 1998). Peak spawning in the mainstem Klamath River occurs around mid-December, coinciding with typical rise in river flows from storm events (Magneson and Gough 2006). Coho salmon eggs incubate for 8–12 weeks before hatching, with time inversely related to temperature (Moyle 2002). Coho salmon egg mean burial depths range from 12–25 centimeters (cm) between the overlying gravel and the top of the egg pocket (DeVries 1997). DeVries (1997) proposed preliminary coho salmon egg burial depth criteria of 15 to 35 cm below the original stream bed level for use in scour studies. These criteria were proposed as maximum depths of scour before initial (top) and total (bottom) egg loss (DeVries 1997). Hatchlings remain in the gravel until their yolk sacs have been absorbed, 4–10 weeks after hatching (Moyle 2002). Thus, for coho salmon spawning in January, time in the gravel potentially could extend to the end of May.

The objective of this ongoing study was to assess the potential impacts of scouring during high flows of the 2008–2009 winter season on the success of coho salmon redds within the mainstem of the Klamath River. This study initially was started during the 2007–2008 spawning season, a relatively dry water year that resulted in no observable scouring (Sutton and Milhous 2008).

Study Area

General geographic area is shown in figure 1. Three documented redd locations in the mainstem Klamath River were selected for this study (Magneson and Gough 2006) (table 1; figures 2 and 3). In addition, three reference redd locations were selected in one tributary (Horse Creek), determined after consultation with biologists from the Karuk Tribe (table 1; figure 4). Recently constructed redds were observed during the December survey at each location.

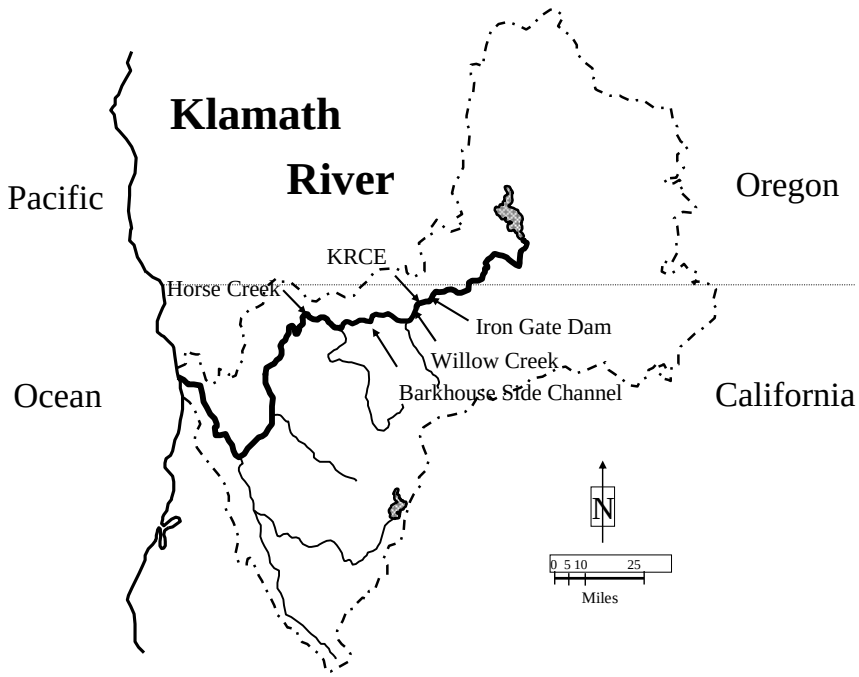


Figure 1. Study area for Klamath River redd scour study.

Table 1. Study locations for Klamath River scour study[1]

Location Description	RKM	Mesohabitat Type	GPS Coordinates	
			Latitude	Longitude
Mainstem Near Klamath River Country Estates (KRCE)	303.1	**Low slope**	**N41°53.734'**	**W122°29.074'**
Mainstem at Willow Creek mouth	302.0	**Low slope**	**N41°53.956'**	**W122°29.648'**
Mainstem at Barkhouse Creek Side Channel	256.7	**Pool**	**N41°49.863'**	**W122°50.720'**
Horse Creek – Lower Site	240.0	**Moderate slope**	**N41°50.397'**	**W123°01.077'**
Horse Creek – Middle Site	–	**Moderate slope**	**N41°50.496'**	**W123°01.413'**
Horse Creek – Upper Site	–	**Moderate slope**	**N41°50.515'**	**W123°01.441'**

[1] GPS = Global Positioning System; RKM = river kilometer.

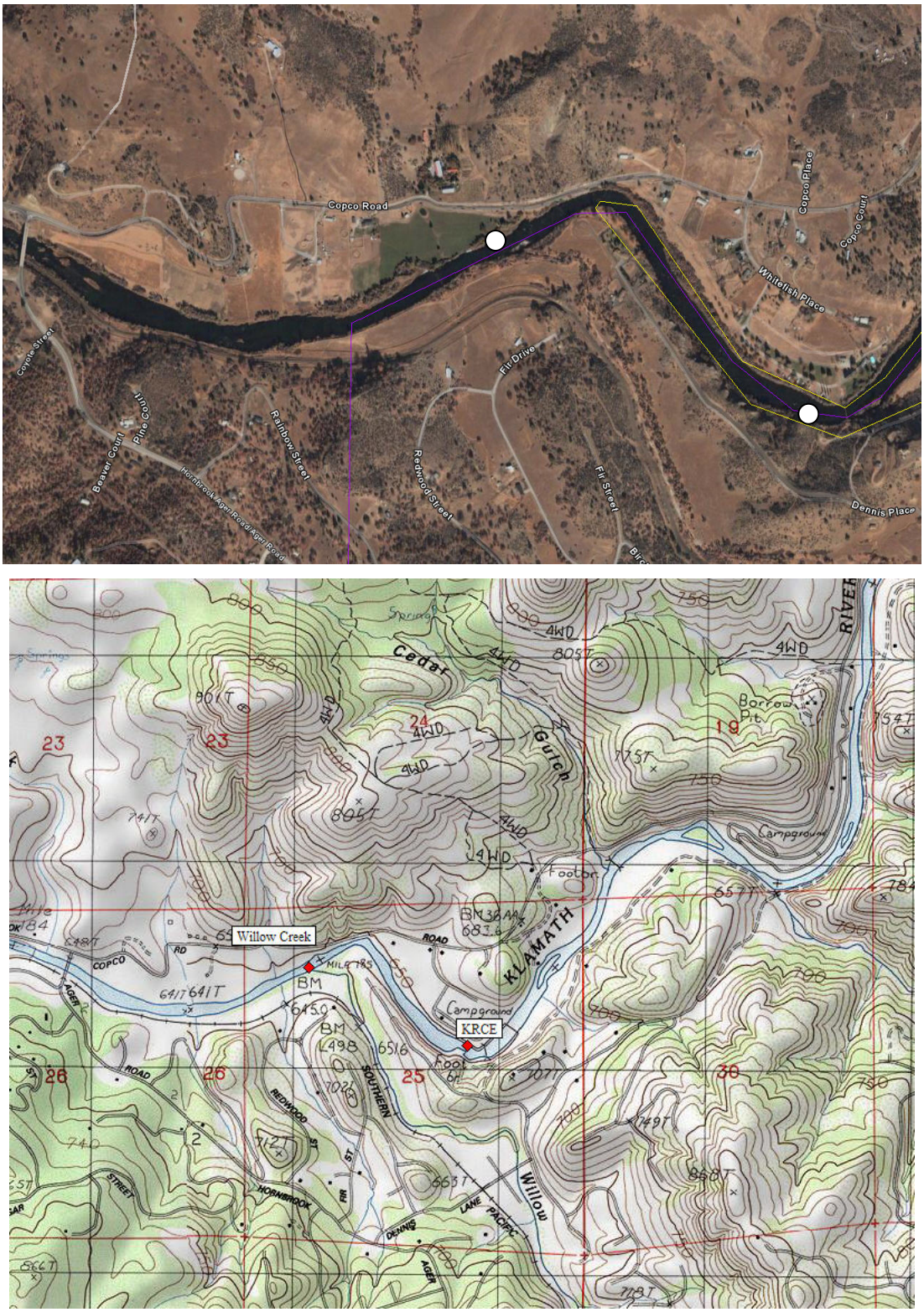


Figure 2. Locations of redds in mainstem Klamath River at Klamath River Country Estates and Willow Creek (aerial photo top; topo map bottom).

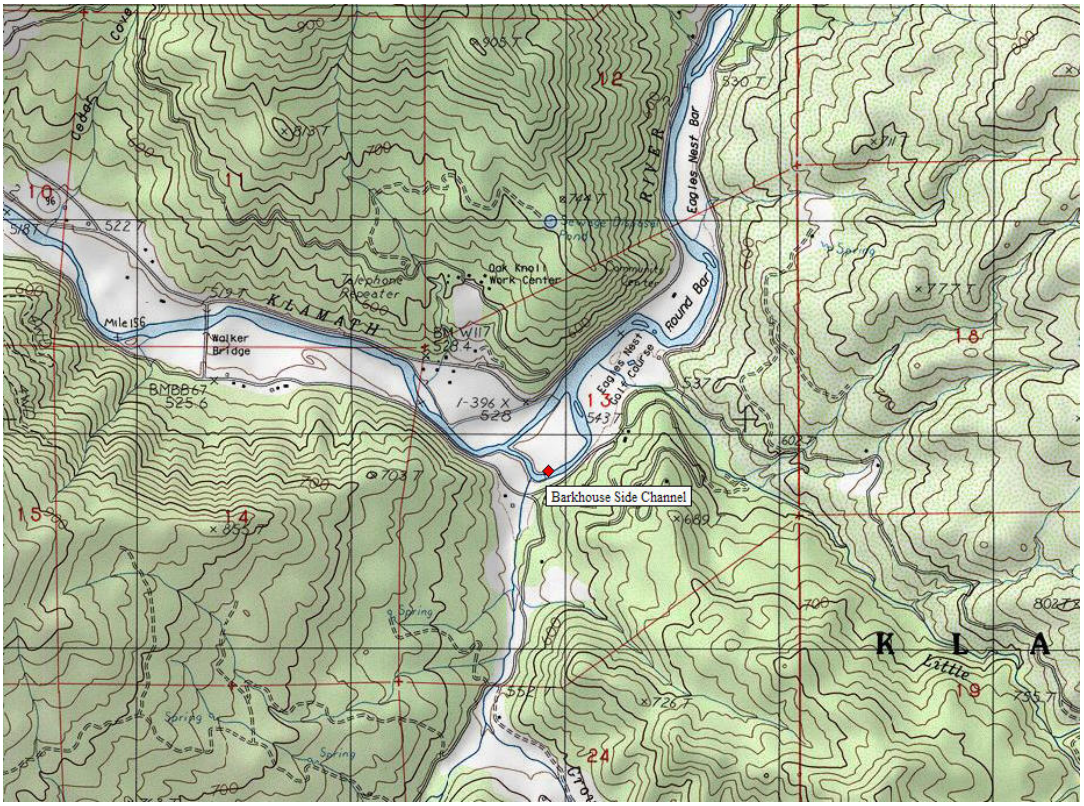


Figure 3. Location of redd in mainstem Klamath River at Barkhouse Creek side channel (aerial photo top; topo map bottom).

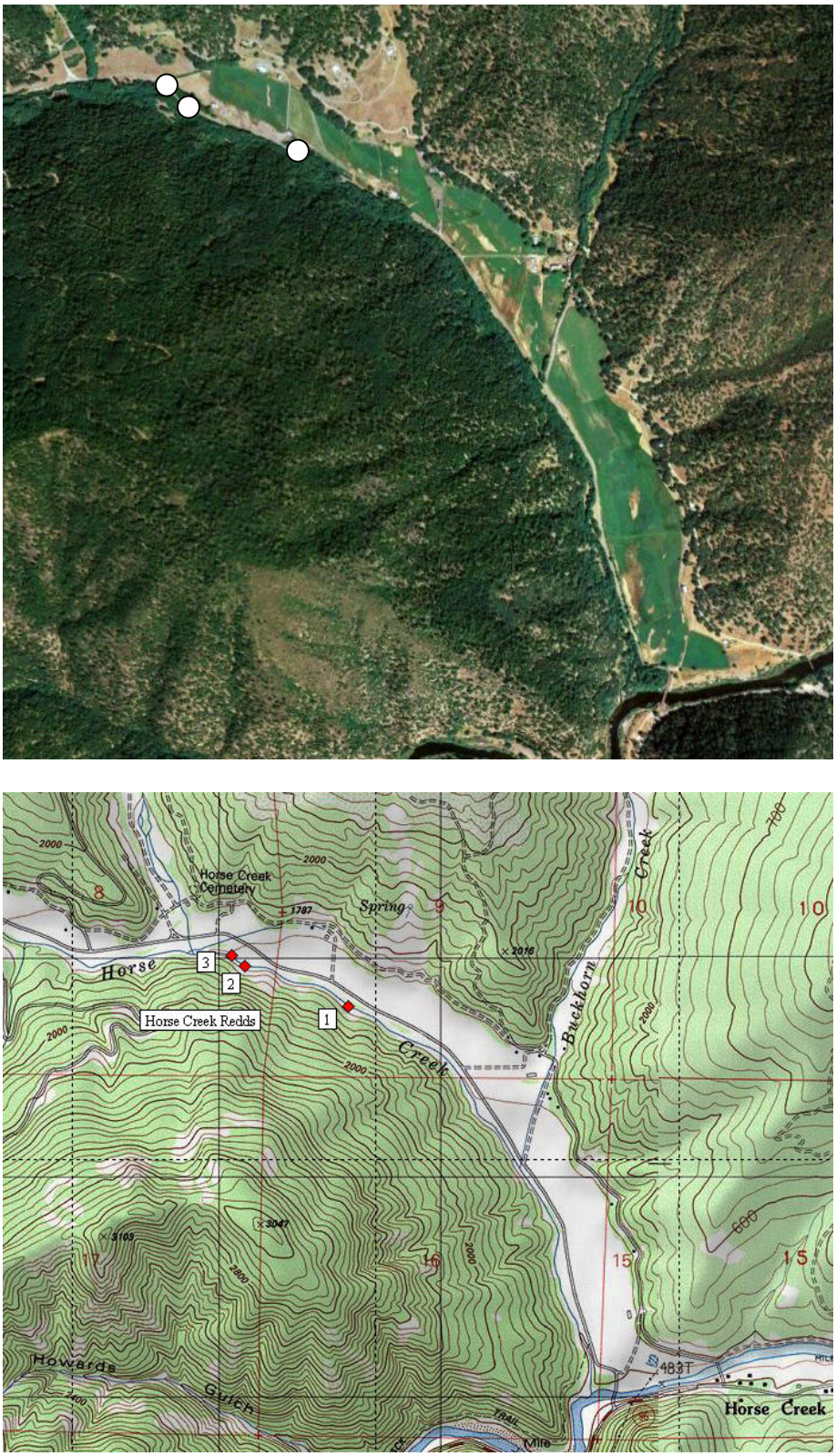


Figure 4. Locations of redds in Horse Creek (aerial photo top; topo map bottom).

Methods

Details on methods used for this study are described in Sutton and Milhous (2008). Initial transect survey and scour chain placements, timed to precede rising river flows, were conducted December 16, and 17, 2008. Survey dates were selected to reduce confounding effects caused by scour and fill with those caused by spawning adults digging redds. Each scour chain link was 35 millimeters [mm] long. Scour chains in Horse Creek were checked on March 27, 2009, prior to spring runoff. Transects were re-surveyed and scour chains checked a final time July 14, and 16, 2008, at a lower flow. Discharges from the nearest U.S. Geological Survey (USGS) gauges were documented through the study period to compare against historical flows, including a gauge from an unregulated stream (Indian Creek). In addition, an Onset® HOBO water level logger was deployed in lower Horse Creek on December 17, 2008, to record water levels every 15 minutes.

Results and Discussion

Stream Flows

Daily streamflows measured at the gauging station just below Iron Gate Dam (USGS station 11516530) are presented in figure 5. Also shown on the figure is the egg incubation period assumed for salmon from the middle of November through March. On December 16, 2008, the scour chains were placed in the mainstem at the Willow Creek and Klamath River Country Estates **(**KRCE) sites. Both sites were checked for scour and deposition on July 14, 2009. The date of the maximum daily discharge (1,780 cubic feet per second [cfs]) was March 5, 2009, which was also the date with the maximum daily discharge for the water year.

The third mainstem site, Barkhouse Side Channel, is downstream from the Shasta River confluence with the Klamath River. An index to the discharge was calculated by adding the daily discharge measured on the Shasta River on a given day to the discharge measured for the Klamath River just below Iron Gate Dam. As an example, the discharge measured on March 5, 2009, below Iron Gate Dam was 1,780 cfs. The daily discharge measure at the gauging station on the Shasta River near Yreka (USGS station 11517500) was 165 cfs on March 6, 2009. The index to the discharge for the Klamath River at Barkhouse on March 6, 2009, is then 1,780 cfs + 165 cfs = 1,945 cfs. This is an index to the discharge at Barkhouse and should not be considered the actual discharge. The calculated index mainstem discharge at the Barkhouse site is presented in figure 6. The maximum daily discharge in the Barkhouse Side Channel reach of the Klamath River was approximately 1,950 cfs.

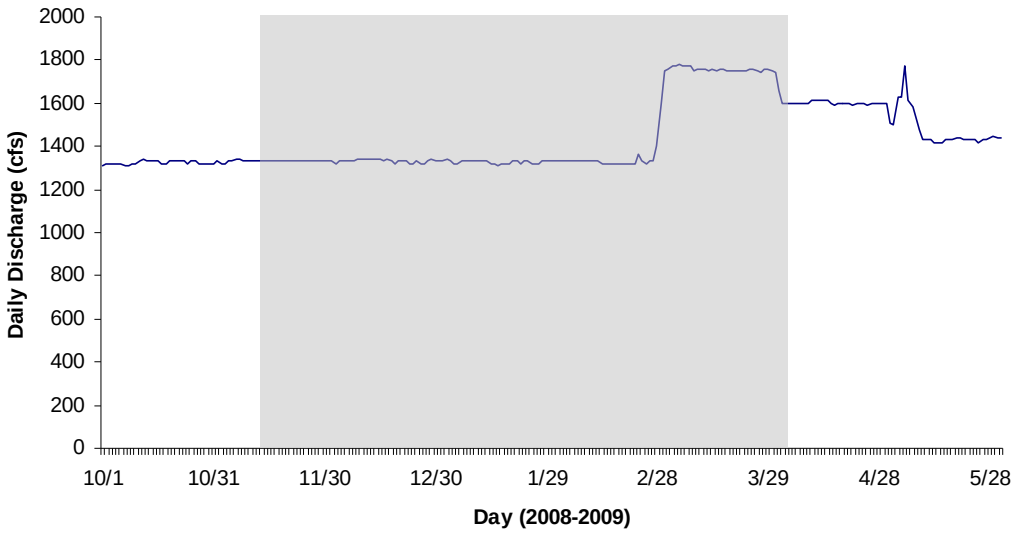


Figure 5. Streamflows of the Klamath River measured at the gauging station below Iron Gate Dam. Shaded area – egg incubation period, November 16–March 31.

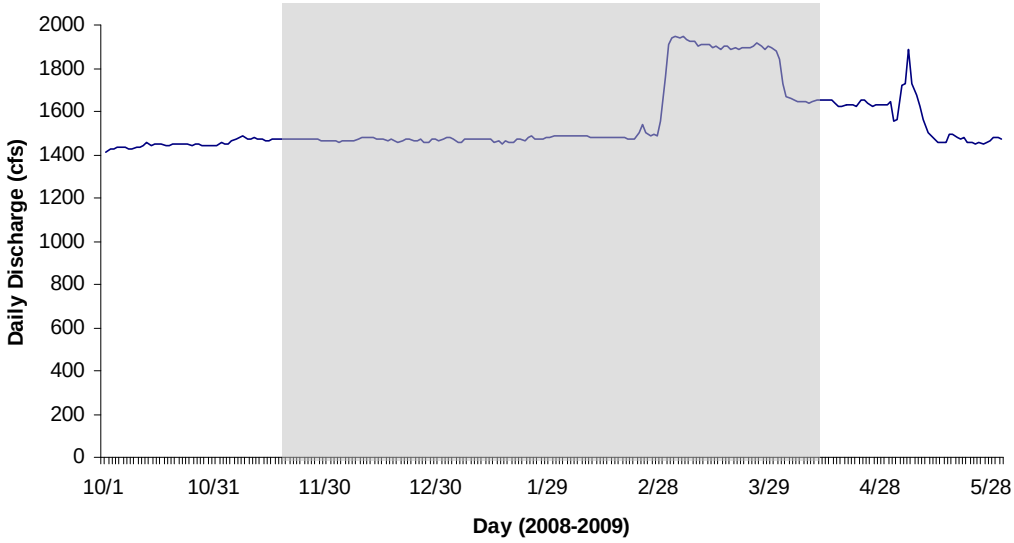


Figure 6. An index to the daily streamflows of the Klamath River at Barkhouse side channel. Shaded area – egg incubation period, November 16–March 31.

Comparison of Peak Flows

The maximum daily discharge that occurred in the Klamath River during the winter and spring of water year 2009 has been exceeded during 97.6 percent (%) of the years following completion of Iron Gate Dam in 1961. The annual maximum daily discharge for 1961–2009 is presented in figure 7. The same maximum daily discharge is shown as an exceedence diagram in figure 8. It is interesting to note that only 1 other year (1992) in the 49-year period of record was peak discharge below that measured in 2009 (1,780 cfs).

Daily mean average flows in the Klamath River at Iron Gate Dam between October 1 and May 31 are plotted in figure 9 for water years 1997–2009. The study period included March 5, 2009, the date with the maximum daily discharge (1,780 cfs) for the 2009 water year. This is substantially lower than the 3,310-cfs maximum flow during the previous year's study (Sutton and Milhous 2008). These plots show that flows in the Klamath River during this study were relatively low compared to many years since 1997—even lower than flows during the 2007–2008 winter/spring period when no redd scouring was observed (Sutton and Milhous 2008). No scouring was observed at the reference locations in 2008 or 2009. Thus, flows generally associated with redd scouring have not occurred in either study year.

Data from an unregulated stream (Indian Creek) were missing from October 2 through April 3 (figure 10). Available 2008–2009 flows were relatively low compared to flows since 1997. Particularly noticeable is the lack of discharge related to individual rainstorm events during 2008 and 2009. Figure 11 shows results from average daily water level monitoring in Horse Creek and compares these results to available Indian Creek discharge during the 2008–2009 scour study period. The pattern of discharge (high and low flows) was similar between streams ($r^2 = 0.88$).

Survey dates and slope and discharge measurements at each study site are summarized in table 2. Slopes ranged from 0.0004 (rise (feet [ft])/run [ft]) at KRCE on the mainstem Klamath River to 0.0090 at the upper Horse Creek site in December. Overall, slopes were lower in the mainstem Klamath River than Horse Creek.

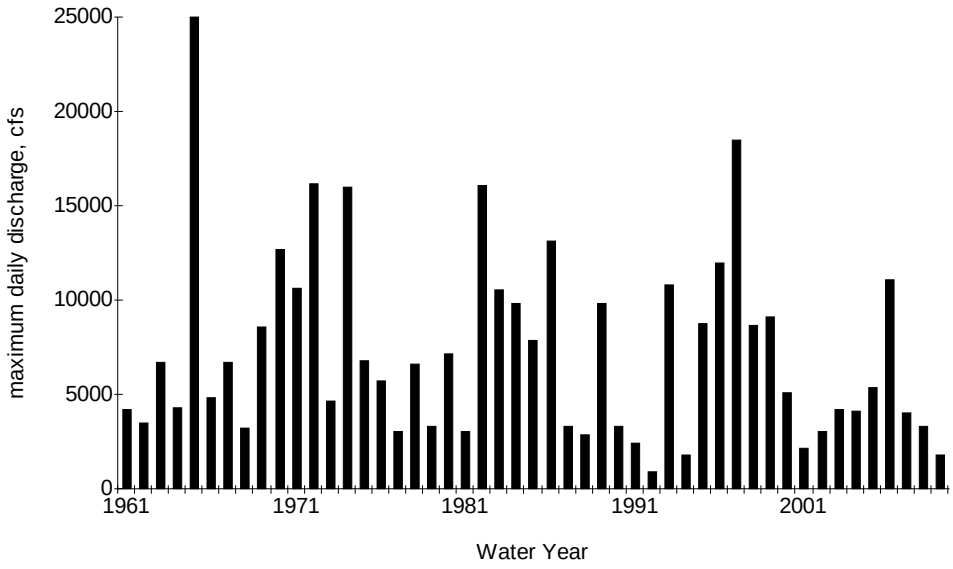


Figure 7. Annual maximum daily discharge measured at the gauge just below Iron Gate Dam for the period of record between 1961–2009.

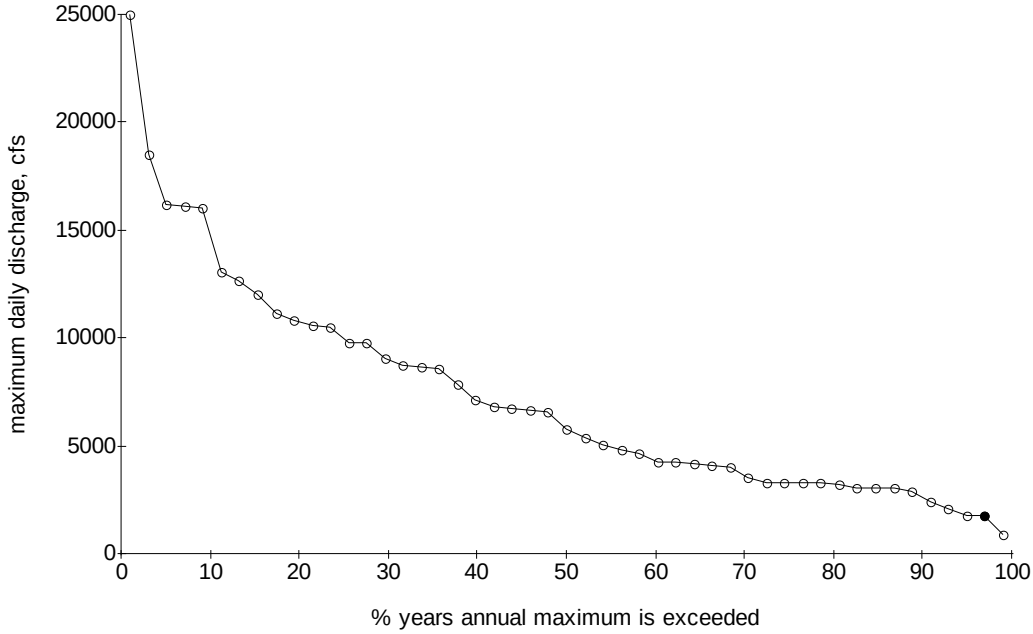


Figure 8. Exceedence diagram for the maximum daily discharge for the Klamath River below Iron Gate Dam. The maximum daily discharge for water year 2009 is shown as the solid point.

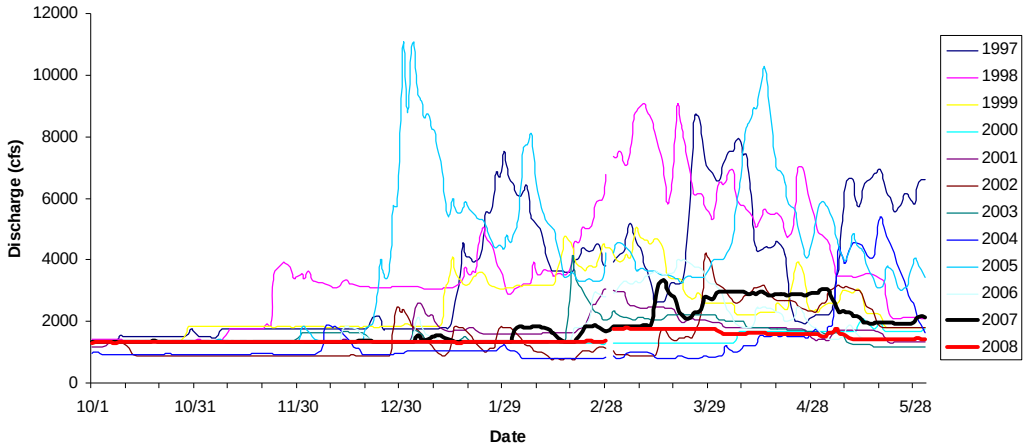


Figure 9. Discharge in Klamath River at Iron Gate Dam (October–May) for water years 1997–2008.
Source: USGS gauge at Iron Gate Dam at http://waterdata.usgs.gov/ca/nwis/uv?11516530.

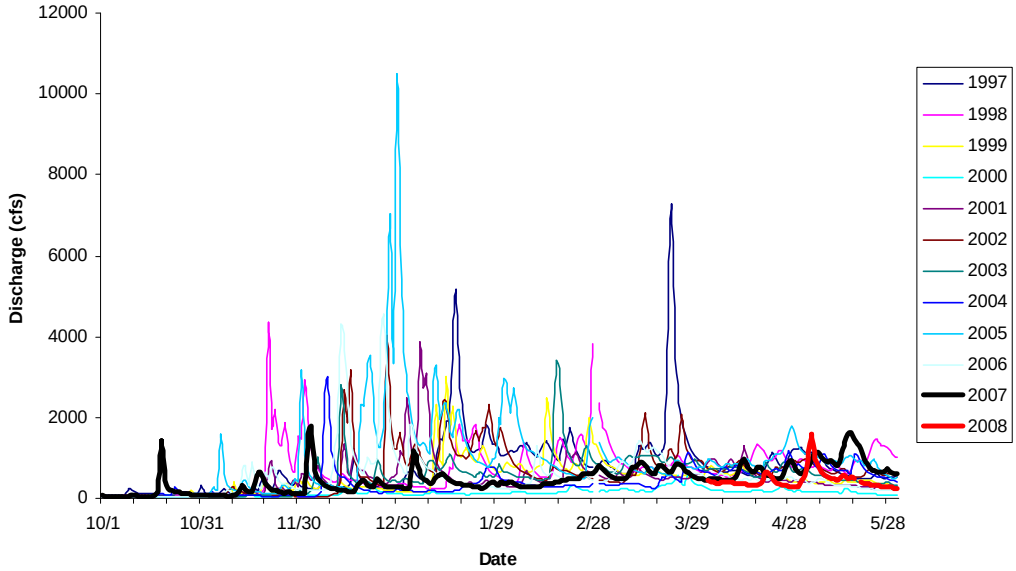


Figure 10. Discharge in Indian Creek (October–May) for water years 1997–2008.
Source: USGS gauge at Indian Creek at http://waterdata.usgs.gov/ca/nwis/uv/?site_no=11521500&PARAmeter_cd=00065,00060.

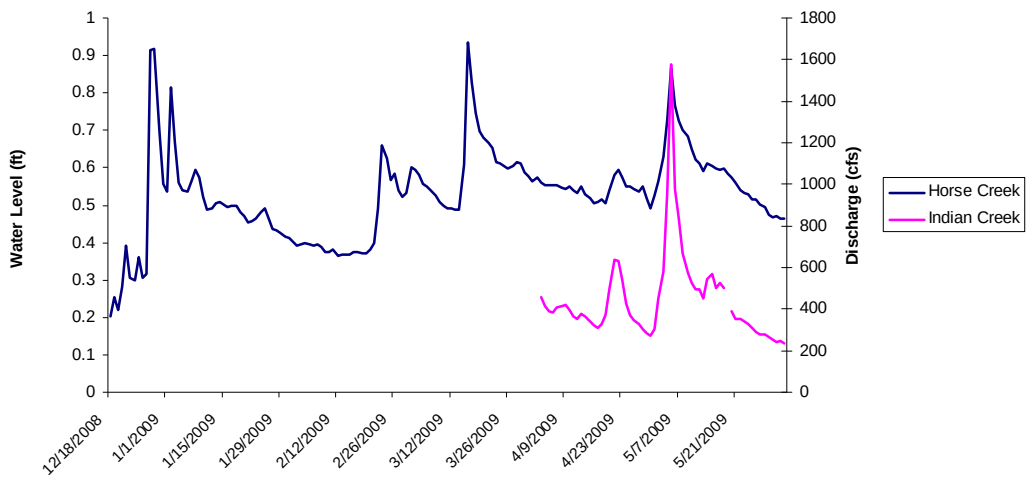


Figure 11. Available discharge in Indian Creek and water levels in Horse Creek during 2008–2009 redd scour study. Water levels of 0.2 and 0.6 ft equate to 7 and 36 cfs, respectively (see table 2).

Table 2. Slope and discharge measurements for Klamath River scour study

Location Description	Date	Slope (rise(ft)/run(ft))	Discharge (cfs)
Mainstem near KRCE	**December 16, 2008**	NA	[1]1,330
	July 14, 2009	0.0004	[1]1,030
Mainstem at Willow Creek mouth	**December 16, 2008**	NA	[1]1,330
	July 14, 2009	0.006	[1]1,030
Mainstem at Barkhouse Creek Side Channel	**December 16, 2008**	NA	98
Horse Creek – Lower Site	**December 17, 2008**	[2]0.0088	7 (0.2-ft water level height above logger)
	March 27, 2009	NA	36 (0.6-ft water level height above logger)
	June 23, 2009	NA	15
Horse Creek – Middle Site	**December 17, 2008**	[2]0.0132	6
	July 16, 2009	[3]0.0025	2
Horse Creek – Upper Site	**December 17, 2008**	[3]0.0030	6
	July 16, 2009	[3]0.0006	2

[1] Iron Gate Dam release.

[2] Upstream of redd.

[3] Downstream from redd.

Redd Scour

Table 3 summarizes scour chain link results (maximum scour) at each study site. Results indicated very little overall difference in chain links exposed between December 2008 and July 2009. The greatest difference occurred at the upper Horse Creek redd where a chain was completely buried (19 links) under small gravel. Of the 25 chains checked, including 7 from the 2007–2008 study, 11 showed fewer links exposed in March and July than December, suggesting some filling of sediment occurred (table 3). No change in exposed chain links was observed on two scour chains in lower Horse Creek. The chains with the highest sediment removal occurred at the Barkhouse side channel and lower Horse Creek where four additional links (14 cm) were exposed in March/July on one chain at each site (table 3). This was less than the proposed preliminary coho salmon egg burial depth criteria of 15 to 35 cm below the original stream bed level for use in scour studies (DeVries 1997).

Table 3. Scour chain link results for Klamath River scour study

Location Description	Date	Chain links exposed					
		SC1	SC2	SC3	SC4[1]	SC5[1]	SC6[1]
Mainstem KRCE	December 16, 2008	11	21	23			
	July 14, 2009	7	23	22			
	Difference (Dec–Jul)	4	-2	1			
Mainstem at Willow Creek mouth	December 16, 2008	23	24	22	11	8	
	July 14, 2009	20	11	21	14	11	
	Difference (Dec–Jul)	3	13	1	-3	-3	
Mainstem at Barkhouse Creek – Side Channel	December 16, 2008	14	23	22			
	July 16, 2009	16	24	26			
	Difference (Dec–Jul)	-2	-1	-4			
Horse Creek – Lower Site	December 17, 2008	26	26	27	8	8	7
	March 27, 2009	28	30	29	8	9	7
	July[2]	-	-	-	-	-	-
	Difference (Dec–Mar)	-2	-4	-2	0	-1	0
Horse Creek – Middle Site	December 17, 2008	27	27	26			
	March 27, 2009	29	0	23			
	July 16, 2009	-[3]	19	23			
	Difference (Dec–Jul)	-2[4]	8	3			
Horse Creek – Upper Site	December 17, 2008	19	24	20	11	11	
	March 27, 2009	0	11	19	9	13	
	July 16, 2009	0	21	21	5	10	
	Difference (Dec–Jul)	19	3	-1	6	1	

[1] Chains from 2007–2008 study.

[2] Not measured in July due to access difficulty.

[3] Missing chain.

[4] December – March.

Scour chain elevations also showed little overall change between December 2008 and July 2009 (table 4). The largest elevation change was a 6-cm increase (fill) at one chain at upper Horse Creek (table 4). No decreases in elevation were observed, indicating no scour. Also, cross-sectional profiles at each redd location between December 2008 and July 2009 (figures 12 and 13) did not provide any evidence of net redd scouring. If there was any effect, it involved slight overall filling of redds with sand and small gravel. Fill events may be just as detrimental to egg survival as scouring because of potential for suffocation of incubating eggs or fry prior to emergence. Based on these data, it appeared that no redd scouring occurred during the study period.

Recommendations

Based on the results of this survey, the following recommendations are suggested:

- Continue to monitor existing scour chains and measure cross-sectional profiles each July in the event that a high winter flow event occurs.
- Re-deploy a temporary stage recorder in Horse Creek to continue documenting discharge in this creek during egg incubation.
- Conduct further coho salmon spawning surveys to better understand where coho salmon spawn in the Klamath River.
- Investigate fry emergence success at coho salmon redds during dry years to determine potential effects of sedimentation on incubating eggs and fry prior to emergence.
- Quantify available spawning habitat in documented spawning areas through mapping (i.e., locations, numbers of spawning areas, total spawning area (square feet) relative to total river area).

Table 4. Scour chain elevations (feet) for Klamath River redd scour study

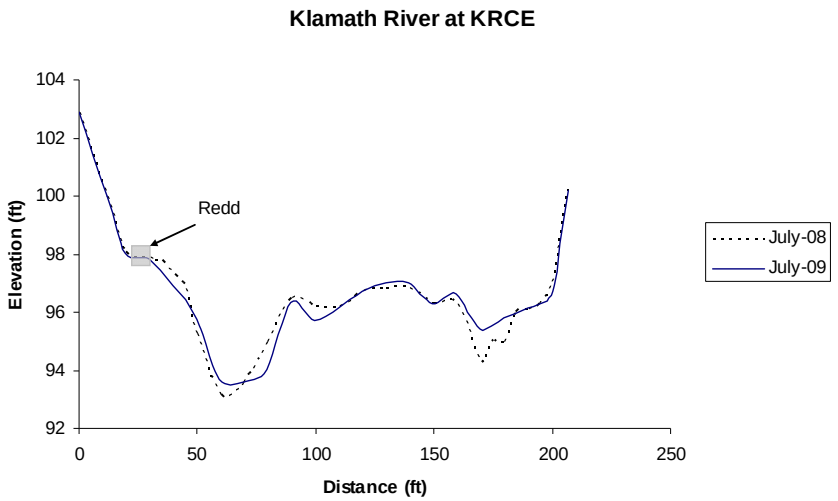
Chain location	December 2008	July 2009	Change
KRCE			
SC1	97.5	97.5	0
SC2	97.2	97.2	0
SC3	97.3	97.4	0.1
Mean			
Willow Creek			
SC1	96.6	96.7	0.1
SC2	96.7	96.8	0.1
SC3	96.7	96.8	0.1
SC4[1]	96.3	96.3	0
SC5[1]	96.5	96.6	0.1
Mean			
Barkhouse Creek			
SC1	98.4	-[2]	-
SC2	98.8	-	-
SC3	98.4	-	-
Mean			
Lower Horse Creek			
SC1	98.9	-	-
SC2	98.8	-	-
SC3	98.7	-	-
SC4[1]	99.5	-	-
SC5[1]	99.5	-	-
SC6[1]	99.6	-	-
Mean			
Middle Horse Creek			
SC1	94.8	[3]	
SC2	95.0	95.0	0
SC3	95.0	95.0	0
Mean			
Upper Horse Creek			
SC1	96.3	96.3	0
SC2	96.2	96.4	0.2
SC3	96.3	96.4	0.1
SC4[1]	96.2	[4]	-
SC5[1]	96.3	[4]	-
Mean	96.4	96.5	0.1

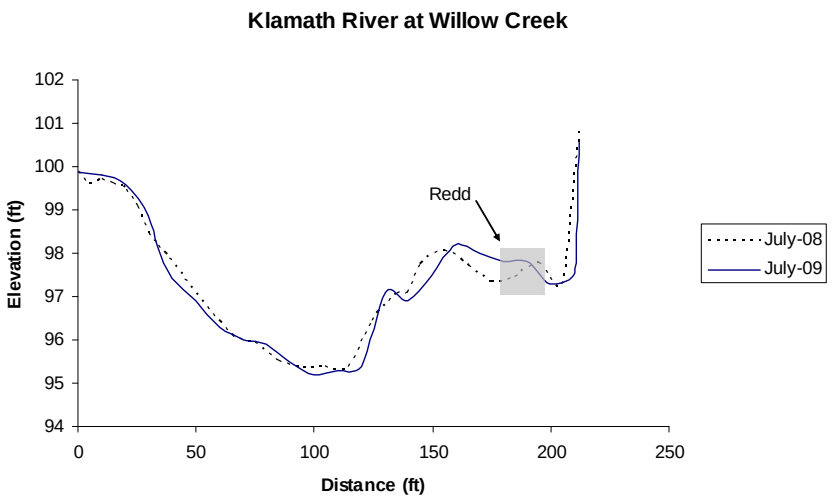
[1] Chain from 2007–2008 study (Sutton and Milhous 2008).

[2] "-" means elevations not measured due to access difficulty.

[3] Missing chain.

[4] Not measured.





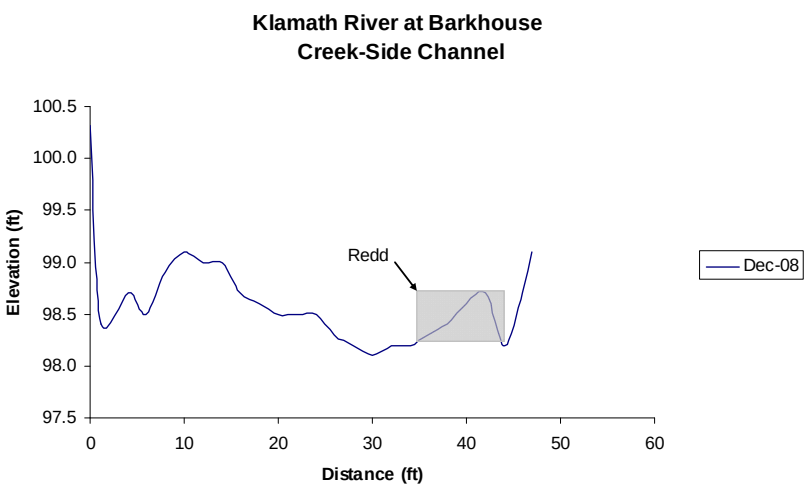


Figure 12. Cross-sectional profiles at redd locations in Klamath River. Note: July 2009 cross-section not measured at Barkhouse site due to access difficulty.

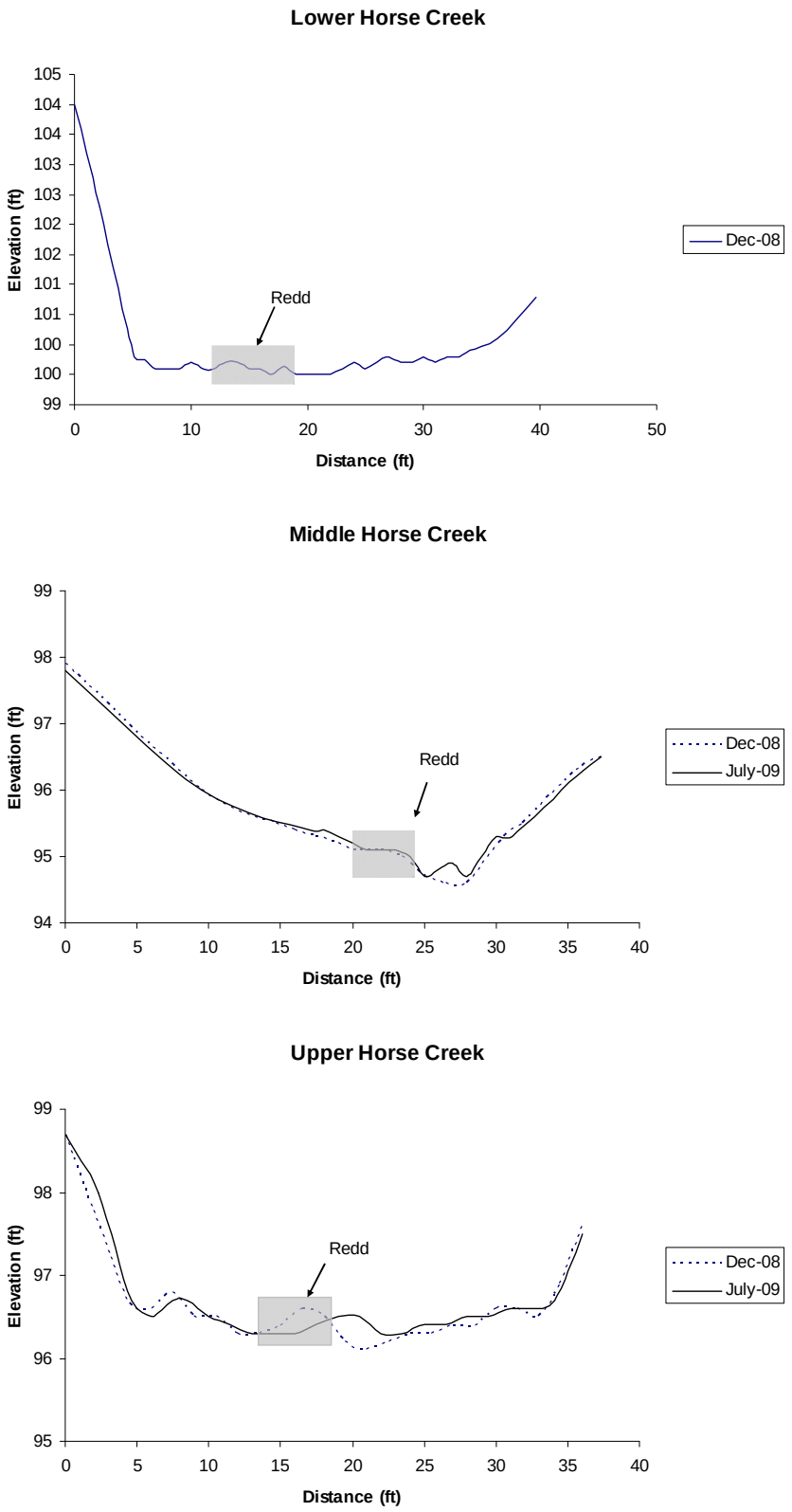


Figure 13. Cross-sectional profiles at redd locations in Horse Creek. Note: July 2009 cross-section not measured at lower Horse Creek due to access difficulty.

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