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Managing Water in the West



Evaluation of Hills Ferry Barrier Effectiveness at Restricting Chinook Salmon Passage on the San Joaquin River

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Fisheries and Wildlife Resources Group
Denver, Colorado

October 2011

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COVER PHOTOGRAPH

Bureau of Reclamation Fisheries Biologist, Eric Best, removes a Chinook salmon from the fish trap at the Hills Ferry Barrier, Newman, California.

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San Joaquin River Restoration Program

Evaluation of Hills Ferry Barrier Effectiveness at Restricting Chinook Salmon Passage on the San Joaquin River

by

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TABLE OF CONTENTS

	<i>Page</i>
Executive Summary	iv
Introduction.....	1
Materials and Methods.....	4
Fish Barrier	4
DIDSON Evaluation	6
Water Velocities and Bathymetry	7
Telemetry	8
Results	12
Fish Barrier	12
DIDSON Evaluation	13
Water Velocities and Bathymetry	17
Telemetry	25
Discussion.....	27
Conclusions and Recommendations.....	29
Acknowledgments	30
References	31

TABLES

<i>Table</i>	<i>Page</i>
1 Hydraulic Hydraulic data collected at Hills Ferry Barrier in October and November 2010. 1 foot = 0.3 meters.	18

FIGURES

<i>Figures</i>	<i>Page</i>
1 Hills Ferry Fish Barrier and fish trap on the San Joaquin River, California	2
2 Merced and San Joaquin River confluence near Newman, Californian.	3

Table of Contents – continued

3 Hills Ferry Barrier is a sliding pipe weir constructed of aluminum channel with 2.5-cm (1-inch) holes that allow 1.9-cm (.75-inch) electrical conduit to slide freely vertically in the corresponding holes and are pushed into the riverbed. 5

4 Fish trap retrofitted to the Hills Ferry Barrier sliding pipe weir design that consisted of a 1-m wide x 2-m long x 1-m high (3.28-ft x 6.56-long x 3.28-ft high) box frame with 2.5-cm (1-in) bars spaced at 2.5 cm (1 in) and a funnel opening to deter escapement. The net entrance led from the weir to the trap. 5

5 River-wide transects were recorded along the barrier to monitor scouring and passage issues along with fish behaviors using a DIDSON camera affixed to a transom mount of a jon boat and manually maneuvered across the channel directly adjacent the barrier. 6

6 Measuring river velocity and bathymetric transects utilizing the Acoustic Doppler Current Profiler. 7

7 Sonotronics model CT-82-1-I acoustic transmitter and acrylic rod used for esophageal tag insertion.. 9

8 Esophageal insertion of sonic transmitter into a Chinook salmon..... 9

9 Manual tracking of an acoustically-tagged Chinook salmon using a Sonotronics USR-5W wide band receiver with DH-4 directional hydrophone... 10

10 Stand-alone submersible ultrasonic receiver (Photo courtesy of Sonotronics Inc.)..... 11

11 Locations of fixed SUR-1-2D submersible ultrasonic receivers (SUR). 11

12 Gaps in the conduit pickets can provide passage for adult Chinook salmon beyond the Hills Ferry Barrier. 12

13 Bank erosion and scoring causes holes in the barrier which may provide upstream passage at the Hills Ferry Barrier..... 13

14 DIDSON image of a school of threadfin shad swimming along the upstream side of the Hills Ferry Barrier..... 14

15 Chinook salmon observed swimming directly downstream of the Hills Ferry Barrier searching for passage opportunity. 15

16 A carp observed swimming along the downstream of the Hills Ferry Barrier seeking passage opportunity, note the conduit pickets in the background. 16

17 River transect collected with an Acoustic Doppler Current Profiler at 9.1 m (30 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right..... 19

18 River transect collected with an Acoustic Doppler Current Profiler at 3.0 m (10 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right..... 20

Table of Contents – continued

19 River transect collected with an Acoustic Doppler Current Profiler at 1.5 m (5 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right..... 21

20 River transect collected with an Acoustic Doppler Current Profiler at 0.61 m (2 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right..... 22

21 River transect collected with an Acoustic Doppler Current Profiler at 0.61 m (2 ft) downstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right..... 23

22 River transect collected with an Acoustic Doppler Current Profiler at 1.5 m (5 ft) downstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right..... 24

23 River transect collected with an Acoustic Doppler Current Profiler at 3.0 m (10 ft) downstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right..... 25

24 Chinook salmon movement of fish tagged on November 17, 2010 at Hills Ferry Barrier. This fish did not re-ascend the San Joaquin River and eventually moved downstream out of detection by the submersible ultrasonic receivers (SUR)..... 26

25 Chinook salmon movement of fish tagged on Novemebr 18, 2010 at Hills Ferry Barrier. This fish did not re-ascend the San Joaquin River and eventually moved downstream out of detection by the submersible ultrasonic receivers (SUR)..... 27

EXECUTIVE SUMMARY

The California Department of Fish and Game (DFG) constructs the Hills Ferry Barrier (HFB) on the San Joaquin River (SJR) near Newman, California, in the fall to restrict passage of adult fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*Oncorhynchus mykiss*) upstream of the confluence of the Merced River where habitat and water quality may be unsuitable for these fish. The San Joaquin River Restoration Program will restore flows in the SJR from Friant Dam to the Merced River confluence and re-establish a self-sustaining population of Chinook salmon and other native fish. Beginning October 1, 2009, the San Joaquin River Restoration Program initiated a program of Interim Flows to collect relevant data on flows, temperatures, fish needs, seepage losses, recirculation, recapture and reuse. Public Law 111-11 Section 10004 (h)(4) requires that the Secretary of the Interior, in consultation with the California Department of Fish and Game, evaluate the effectiveness of the Hills Ferry Barrier in preventing the unintended upstream migration of anadromous fish in the San Joaquin River and any false migratory pathways.

Barrier physical characteristics, river hydrology and bathymetry, as well as fish behavior in proximity to the barrier were examined and evaluated in order to develop refined operating guidance and determine effectiveness of the barrier at preventing or reducing fish passage. Dual-frequency identification sonar underwater camera (DIDSON™), Acoustic Doppler Current Profiler (ADCP), and visual observations were used to identify problems and limitations of the barrier. Sand, silt, and clay river substrate eroded around the barrier's support structures, footings, base, and conduit panels. Scour holes underneath and at the terminal ends of the barrier develop from erosion and enable adult Chinook salmon to evade the barrier and swim upstream of this location. Upon detection, staff sandbagged scour holes and replaced or extended conduit pickets. Clearing floating hyacinth mats removed panels for cleaning and temporarily created gaps in the barrier. In November 2010, twenty-two fall-run Chinook salmon passed the barrier and were found upstream at Sack Dam, Mendota Pool, and upstream canals.

Information gathered from DIDSON™, ADCP, and visual accounts identified potential improvements to barrier design, operation, and location to improve barrier effectiveness including:

1. Locate the barrier downstream of the 2010 location for improved hydraulics
2. Improved debris removal procedures to avoid gaps from panel removal.

The long-term use of the HFB is unknown; however, it is anticipated it will be used to block anadromous fish species from moving upstream until the Restoration Area is considered ready for salmon reintroduction. This report discusses observations and near-term structural and non-structural modifications that can improve the effectiveness of the HFB.

INTRODUCTION

The San Joaquin River Restoration Program (SJRRP) is a long-term effort to restore flows to a 246-km-long (153-mi-long) stretch of the San Joaquin River below Friant Dam to the confluence with the Merced River and re-establish a self-sustaining Chinook salmon (*Oncorhynchus tshawytscha*) fishery in the river while reducing or avoiding adverse water supply impacts from Interim and Restoration Flows. Under the *NRDC, et al., v. Kirk Rodgers, et al. 2006 Settlement* two parallel goals were mandated: 1) a restoration goal to restore and maintain fish populations in “good condition” in the main stem San Joaquin River below Friant Dam to the confluence with the Merced River, including naturally reproducing and self-staining populations of salmon and other fish, and 2) a water management goal to reduce or avoid adverse water supply impacts to Friant Division Long-term Contractors that may result from the Interim and Restoration Flows provided for in the Settlement.

Public Law 111-11 Section 10004 (h)(4) states that the Secretary, in consultation with the California Department of Fish and Game (DFG), shall evaluate the effectiveness of the Hills Ferry Barrier (HFB) in preventing the unintended upstream migration of anadromous fish in the San Joaquin River and any false migratory pathways. If that evaluation determines any such migration past the barrier is caused by the introduction of the Interim Flows and that the presence of such fish will result in the imposition of additional regulatory actions against third parties, the Secretary is authorized to assist DFG in making improvements to the barrier. From funding made available in accordance with section 10009, if third parties along the San Joaquin River south of its confluence with the Merced River are required to install fish screens or fish bypass facilities due to the release of Interim Flows in order to comply with the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), the Secretary shall bear the costs of the installation of such screens or facilities if such costs would be borne by the Federal Government under section 10009(a)(3), except to the extent that such costs are already or are further willingly borne by the State of California or by the third parties. This report evaluates the effectiveness of the HFB at preventing unintended migration of anadromous fish.

HFB (Figure 1) is a sliding pipe weir located approximately 300 m (328 yd) upstream of the San Joaquin and Merced River confluence (Figure 2), 5.5 km (3.4 mi) east of Newman, California. The barrier is intended to impede passage of fall-run Chinook salmon from ascending the San Joaquin River above the confluence with the Merced River where habitat and water quality (temperature) are unsuitable for these fish. The HFB also blocks the Central Valley (CV) steelhead (*Oncorhynchus mykiss*) from moving upstream, although the HFB is not in place during the CV steelhead’s greatest potential to occur in the area (mid-December through mid-February). Identifying salmon, steelhead, and other native species use of the river is important to the SJRRP’s recovery program, and it is beneficial to determine fish species that are encountering the barrier. Information regarding the presence of non-native species such as catfish, carp, and striped bass may also be helpful but is a secondary priority.

In 1988, DFG began an adult trapping and egg salvage effort in the San Luis Canal at the Los Banos Wildlife Area which continued through 1991. Fish were spawned and the eggs were transported to the Merced River Hatchery near Snelling, California, for incubation and rearing. Fish trapping efforts continued with modifications in location and design through 1991. This approach was abandoned due to high egg and juvenile mortality. During spawning season of fall 1992, DFG tested an electrical fish barrier made by Smith-Root, Inc., just upstream of the confluence of the San Joaquin and Merced Rivers to restrict adult Chinook salmon passage. The electrical barrier was later determined to be ineffective for this particular application due to corrosion of electrode cables from high water conductivity. A physical barrier was placed 46 m (50 yd) upstream of the electrical barrier on the San Joaquin River to act as a backup during electrical barrier feasibility assessments. Following the limited success of the electrical barrier, a physical barrier has been used until present. Physical barriers of several variations (*i.e.*, Alaskan, resistance board, sliding pipe weirs) have been in place seasonally (September–December) since 1992. For a detailed history of the Hills Ferry Barrier operation see Gates (2011).



Figure 1.—Hills Ferry Fish Barrier and fish trap on the San Joaquin River, California.

The current design used since 2004 is a sliding pipe weir constructed with wooden tripod support structures and aluminum channel that have 2.5-cm (1-in) holes to allow pieces of 1.9-cm (.75-in) electrical conduit to slide into the riverbed. This type of weir has been

used every year at the confluence with minor changes in location due to bank erosion. In 2010 the barrier was moved upstream approximately 100 m (109 yd) to deeper water to allow for a fish trap to be retrofitted to the weir structure.

The alluvial river substrate of sand, silt, and clay poses a challenge to the integrity of the barrier throughout the season once it is installed. River hydraulics around weir support structures, barrier footings, base of conduit bars, and barrier panels cause substrate erosion resulting in scouring holes underneath the barrier and along the shoreline. DFG personnel fill these scour holes with sandbags on a daily basis to maintain a relatively “fish tight” barrier. This labor intensive activity is a challenge due the physical conditions at the site and the impermanence of the structure. Adult Chinook salmon have been observed in the past to take advantage of scour holes and elude the barrier. Others have been witnessed to pass during cleaning operations when excessive water hyacinth loads and vegetative debris become lodged against the sliding pipes requiring temporary removal of a panel of conduit pickets to allow the plant matter to travel downstream.



Figure 2.—Merced and San Joaquin River confluence near Newman, California.

An assessment of the HFB was performed to evaluate its effectiveness throughout the installation period and under a wide range of flows to understand the current limitations of the structure. An evaluation to inhibit the migration of Chinook salmon up the San Joaquin River was performed during fall 2010. Physical characteristics of the barrier and river were examined as well as fish behavior adjacent to the barrier. Dual-frequency identification sonar underwater camera (DIDSON) and an Acoustic Doppler Current Profiler (ADCP) were used to identify problems and limitations, and information will be used to recommend improvements with barrier design, operation, and location. Scour holes and gaps in the barrier can be found and possibly predicted using erosion depth and sediment transition behavior. The goal of this task is to evaluate the barrier effectiveness and develop refined operating guidance and data collection protocols.

MATERIALS AND METHODS

Fish Barrier

The HFB is a sliding pipe weir design used to exclude large migrating fish from swimming upstream while allowing water and other smaller species to pass. The barrier was installed August 31, 2010 and was removed December 9, 2010, which is the timeline of peak migration of fall-run Chinook salmon to Central Valley Rivers. The general principle of this type of weir is that an aluminum channel with 2.5 cm (1-in) holes allowed pieces of 1.9-cm (0.75-in) electrical conduit to slide freely vertically in the corresponding holes and can be pushed into the riverbed (Figure 3). The weir consisted of anchor points on each side of the river and a cable that spanned the river about 2–3 m (6.56–9.84 ft) above the water level. Eighteen, 2.5-m-high (8.20-ft-high) tripods spaced approximately 0.5 m (1.64 ft) apart at their base were tethered to the overhead cable. Two horizontal rows of aluminum channel with 2.5-cm (1-in) holes machined every 3.8 cm (1.5 in) were affixed to the tripods. The 1.9-cm (.75-in) electrical conduit pickets were then slid through these holes to make a fish tight weir. The fish trap that was retrofitted to the barrier consisted of a 1-m-wide x 2-m-long x 1-m-high (3.28-ft-wide x 6.56-ft-long x 3.28-ft-high) box frame with 2.5-cm (1-in) bars spaced at 2.5 cm (1 in) and a funnel opening to deter escapement once fish entered (Figure 4). The trap was suspended upstream of the barrier by two pontoons. An opening in the weir was made by removing conduit pickets and affixing a net-tube that led from the weir to the trap. The trap was checked for fish daily when in operation.



Figure 3.—Hills Ferry Barrier is a sliding pipe weir constructed of aluminum channel with 2.5-cm (1-in) holes that allow 1.9-cm (.75-in) electrical conduit to slide freely vertically in the corresponding holes and are pushed into the riverbed.



Figure 4.—Fish trap retrofitted to the Hills Ferry Barrier sliding pipe weir design that consisted of a 1-m-wide x 2-m-long x 1-m-high (3.28-ft-wide x 6.56-ft-long x 3.28-ft-high) box frame with 2.5-cm (1-in) bars spaced at 2.5 cm (1 in) and a funnel opening to deter escapement. The net entrance led from the weir to the trap.

DIDSON Evaluation

Barrier effectiveness at blocking migrating fish under a variety of flow conditions was evaluated by assessing the location and behavior of sediment scouring using a dual-frequency identification sonar underwater camera (DIDSON; Sound Metrics Corp., Chesapeake, Virginia). The near video quality images of the DIDSON allowed detailed underwater inspections of the barrier structure and substrate in turbid water. The DIDSON camera was also used to observe fish interactions with the weir and determine fish species that encounter the barrier. The DIDSON was configured with a remotely operated pan and tilt actuator that allowed a scan of the weir and river bottom. The DIDSON camera was affixed to a transom mount that allowed for easy attachment to a jon boat and manually maneuvered across the channel directly adjacent the barrier (Figure 5). River-wide transects recording barrier condition as well as fish behaviors were performed above and below the weir on September 21st, October 20th and November 18th.



Figure 5.—River-wide transects were recorded along the barrier to monitor scouring and passage issues along with fish behaviors using a DIDSON camera affixed to a transom mount of a jon boat and manually maneuvered across the channel directly adjacent the barrier.

Water Velocities and Bathymetry

River transects were measured upstream and downstream of the barrier with a Teledyne RD Instruments StreamPro Acoustic Doppler Current Profiler (ADCP; Teledyne RD Instruments, Poway, California) to map changes in bed elevations and velocity distributions and to identify scour and depositional zones during barrier operation (Figure 6). The StreamPro includes a 2.0 MHz ADCP with four transducers at a 20 degree beam angle mounted to a small float. The bottom-tracking capability of the StreamPro provides the ability to move the instrument continuously across the river. A tagline was set up at seven locations and the instrument was floated across the river at a velocity slower than the water velocity and raw data were processed with specialized StreamPro software. Velocity data were collected with a vertical cell size of 7.6–10.1 cm (0.25–0.33 ft) depending on the maximum water depth. Velocity resolution of the instrument is 0.1 cm/s (0.04 in/s). A handheld computer collected data via a Bluetooth transmitter and raw data were processed in specialized StreamPro software. River transects were collected 0.6, 1.5, 3.0, 9.1 m (2, 5, 10, and 30 ft) upstream of the barrier and 0.6, 1.5, 3.0, 9.1 m (2, 5, 10, and 30 ft) downstream of the barrier. Data were not collected 9.1 m (30 ft) downstream of the barrier since the 1.5-m (5-ft) and 3.0-m (10-ft) transects did not show significant changes in velocity or bed elevation during October. The river stage was recorded from USGS site 11273400 (San Joaquin R AB Merced R near Newman, California) staff gage directly upstream of the barrier. Data were collected on October 19–20, 2010 and November 16–17, 2010. Additional field trips were scheduled in December 2010 and January 2011, but field work was canceled due to very high river flows producing unsafe working conditions.



Figure 6.—Measuring river velocity and bathymetric transects utilizing the Acoustic Doppler Current Profiler.

Telemetry

Chinook salmon behavior was monitored on the downstream side of the Hills Ferry Barrier to measure the effectiveness of the barrier at inhibiting passage using ultrasonic telemetry. However, due to concerns of fall-run Chinook salmon passing the barrier, additional monitoring was performed on the upstream side of the barrier to Mendota Pool at the request of the SJRRP and DFG Management. Adult fall-run Chinook salmon were collected in a fish trap attached to the HFB and other collected along the weir with a dip net. Initial plans were to collect and tag up to 30 fall-run Chinook salmon distributed throughout their run that spans late September to early December, generally peaking in mid-November, to determine movements and behavior in the proximity of the HFB and San Joaquin-Merced River confluence. Collected fall-run Chinook salmon were measured (fork length), sexed, scale sampled from the dorsal area posterior to the adipose fin, and tissue sampled from the pectoral fin for DNA studies. Fish were implanted with ultrasonic transmitters (Sonotronics model CT-82-1-I, Sonotronics, Inc., Tucson, Arizona) that emit high frequency sound which propagated mechanically through the water. Fish that received a telemetry transmitter were secondarily tagged with a colored Floy tag to facilitate quick identification of recaptured fish in the trap and alert hatchery personnel if ultrasonically tagged fish were collected.

Esophageal implant of transmitters is the desired technique for tracking adult salmonids during migration (Burger *et al.* 1985, 1995; Eiler 1990; Ruggerone *et al.* 1990; Ramstad and Woody 2003). Utilizing the “two percent” rule for implanted telemetry tags (Winter 1983, 1996, 2000), it is recommended that the ratio of transmitter weight to body weight (in air) should be less than 2 percent. We determined that a 12-g transmitter (Sonotronics model CT-82-1-I, 38 mm x 15.6 mm (1.5 in x 0.61 in) with 60 day life span; Figure 7) was appropriate for fish larger than 600 g (1.32 lb) and would easily allow for tagging of any adult Chinook encountered in the trap. Fourteen frequencies were used (69–83 kHz) and each tag had a unique pulse code (*e.g.*, Code 234 would sound 2 pulses–pause, 3 pulses–pause, 4 pulses–pause, repeat). Transmitter detection range varied depending on conditions (*e.g.*, water turbulence, watercraft presence, and pump motor disturbance) with a maximum range of about 200 m (219 yards) under good conditions.

Tags were activated, coated with glycerin for lubrication, and pushed passed the aortic sphincter into the upper stomach of the fish using an acrylic rod similar in diameter to the tag (Figure 8). Fish were held by an assistant while the tag was inserted. The entire handling procedure was performed without the use of anesthetic and took less than 4 minutes. The fish was then cradled in the trap until recovered and normal swimming behavior obtained. An ultrasonic handheld receiver was used to check the acoustic frequency emission of the tag and the fish released.

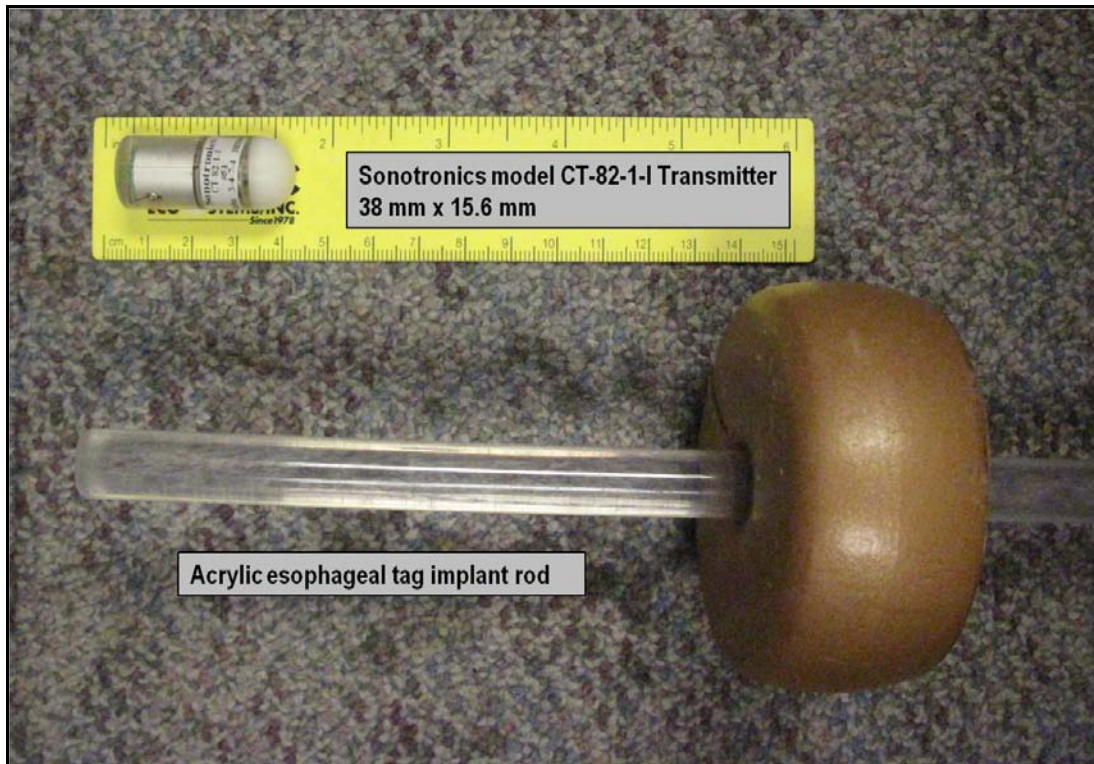


Figure 7.—Sonotronics model CT-82-1-I acoustic transmitter and acrylic rod used for esophageal tag insertion.



Figure 8.—Esophageal insertion of sonic transmitter into a Chinook salmon.

Manual tracking of acoustically-tagged fish was accomplished using a Sonotronics USR-5W wide band receiver with DH-4 directional hydrophone (Figure 9). Five SUR-1-2D submersible ultrasonic receivers (SUR; Figure 10) that allowed for fixed deployment and manual on-site download via laptop were strategically deployed. SURs are a stand-alone battery powered receiver that continuously scan for tags and can be deployed and stay unmaintained for months between downloads. Fixed deployment locations were SUR 1: ~180 m (~197 yd) upstream of HFB, SUR 2: attached to the HFB, SUR 3: ~220 m (~241 yd) below HFB, SUR 4: ~245 m (~268 yd) upstream of the San Joaquin-Merced River confluence in the Merced River, and SUR 5: ~540 m (591 yd) downstream of the San Joaquin-Merced River confluence in the San Joaquin River (Figure 11).



Figure 9.—Manual tracking of an acoustically-tagged Chinook salmon using a Sonotronics USR-5W wide band receiver with DH-4 directional hydrophone.



Figure 10.—Stand-alone submersible ultrasonic receiver (Photo courtesy of Sonotronics Inc.).

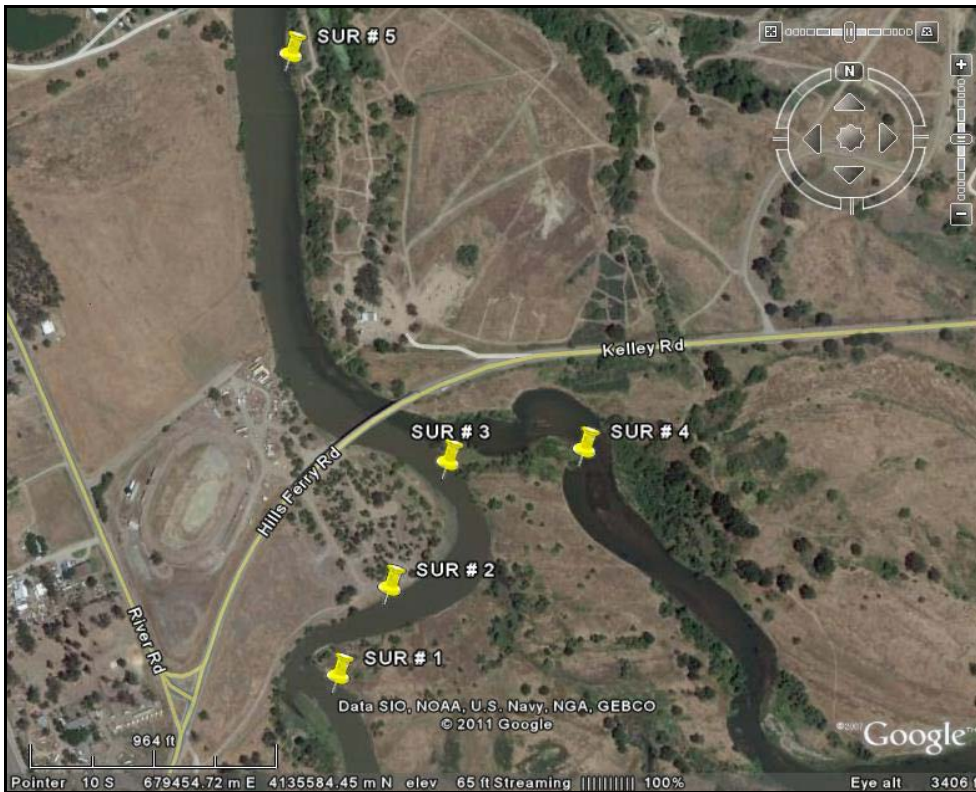


Figure 11.—Locations of fixed SUR-1-2D submersible ultrasonic receivers (SUR).

RESULTS

Fish Barrier

An assessment of the relative effectiveness of the current HFB at blocking native and non-native fish species was performed from August 31, 2010 until high flows caused the failure of the barrier and erosion of the river banks at the anchoring points on November 26, 2010. The HFB was removed for the season on December 6, 2010. Observations from the DIDSON camera, ADCP, and visual accounts identified problems and limitations with the structure in fall 2010. The location of scouring, gaps in the pickets, and openings in the barrier were discovered with these instruments along with visual observations (*i.e.*, Figures 12 and 13).



Figure 12.—Gaps in the conduit pickets can provide passage for adult Chinook salmon beyond the Hills Ferry Barrier.



Figure 13.—Bank erosion and scoring causes holes in the barrier which may provide upstream passage at the Hills Ferry Barrier.

DIDSON Evaluation

The near-video quality images of the DIDSON allowed detailed underwater inspections of the barrier and substrate; however the angle of the weir and the surface reflection posed some difficulties on the downstream side of the barrier. Carp (*Cyprinus carpio*), channel catfish (*Ictalurus furcatus*), white catfish (*Ameiurus catus*), striped bass (*Morone saxatilis*), threadfin shad (*Dorosoma petenense*), and Chinook salmon were identified, especially on the downstream side where the barrier was inhibiting their movement up-river and/or providing structure. Schools of threadfin shad swam freely on both sides of the barrier and occasionally passed through the conduit pickets (Figure 14). Chinook salmon and carp were observed to move along the barrier looking for holes for passage opportunity (Figures 15 and 16). The DIDSON provided an interesting observation of an unidentifiable species (most likely a carp), using its body to attempt to burrow under the conduit pickets in the substrate at the barrier's base, accelerating the erosion process. Acoustic images of missing pickets, scour holes, and eroded areas were also identified.

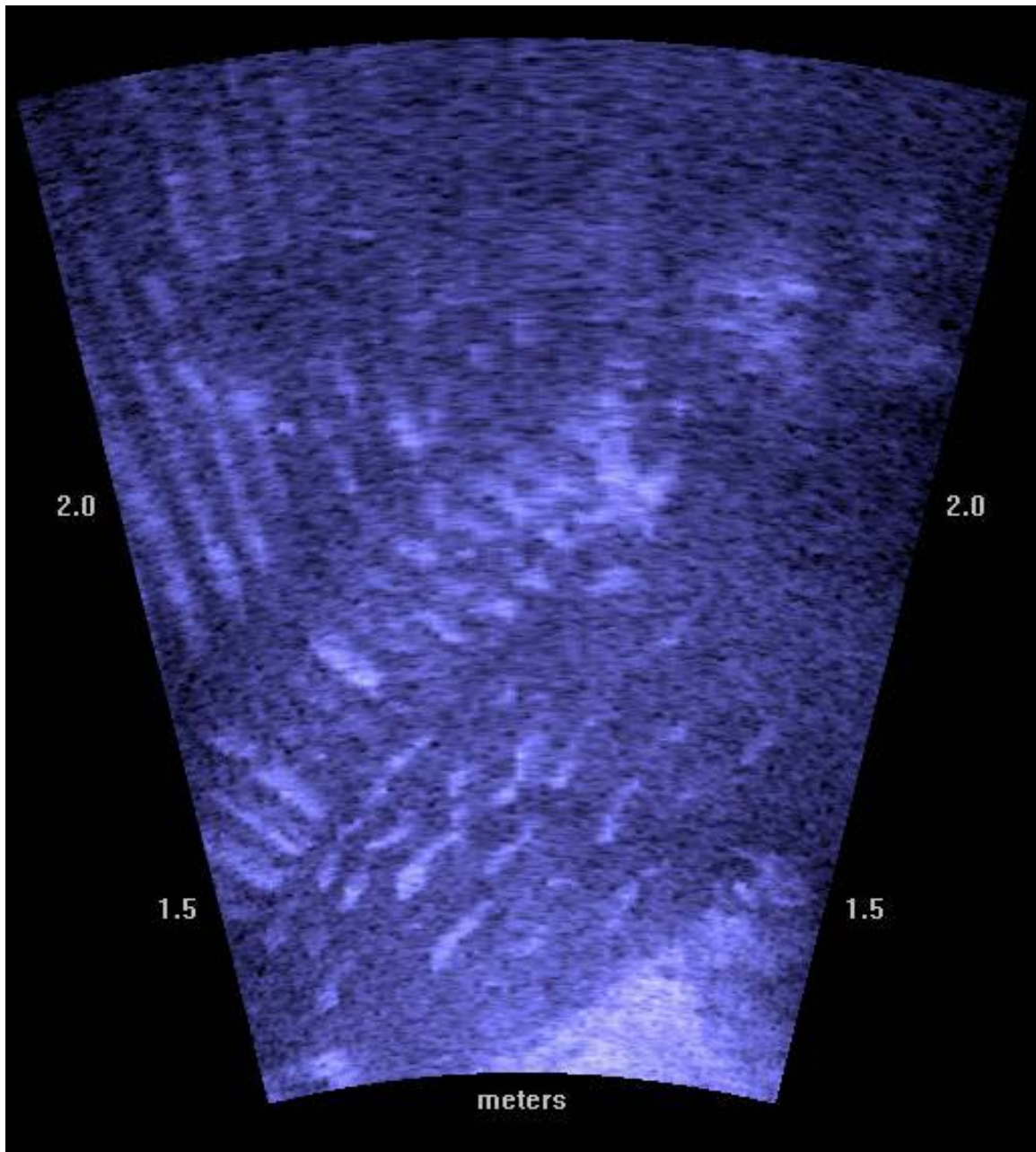


Figure 14.—DIDSON image of a school of threadfin shad swimming along the upstream side of the Hills Ferry Barrier.

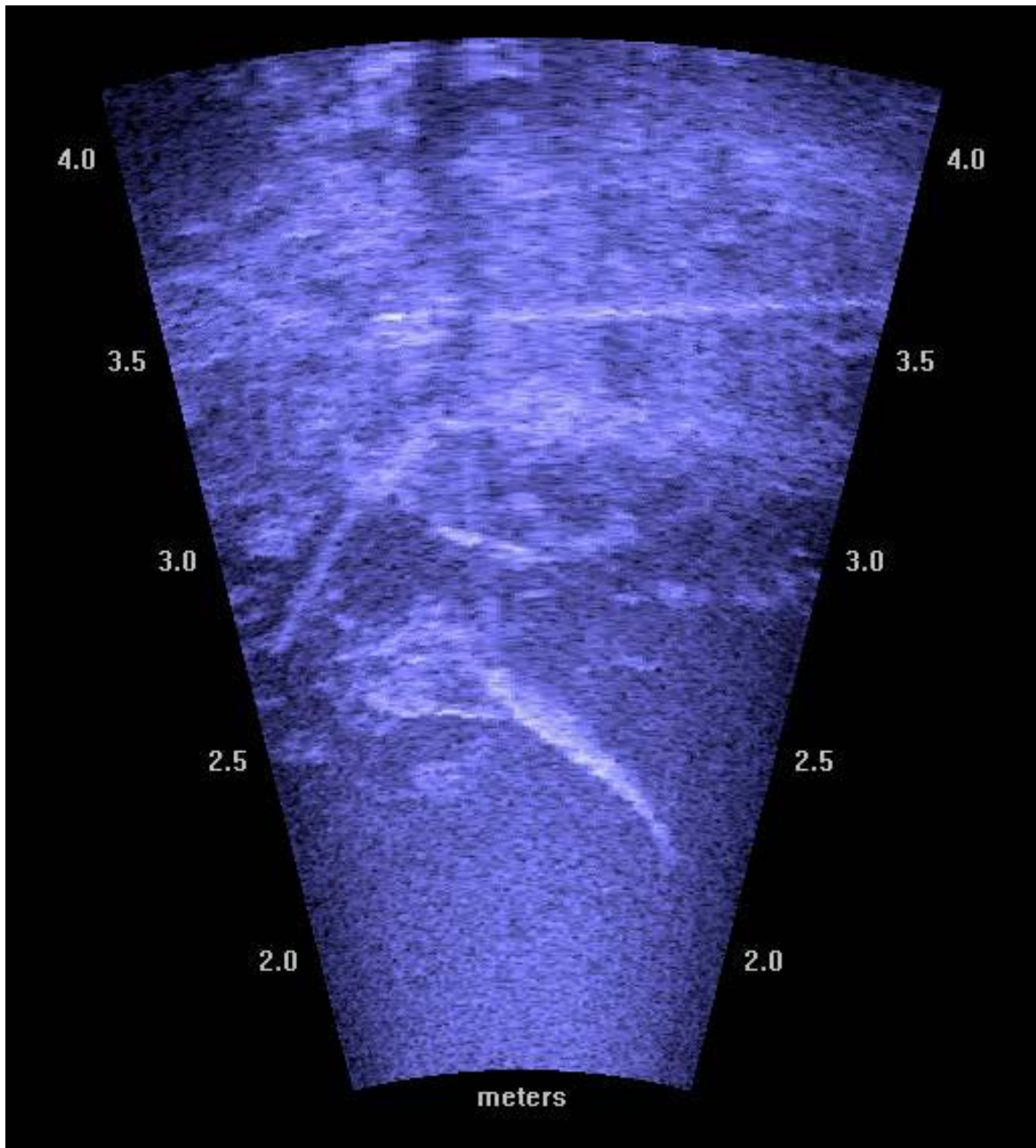


Figure 15.—Chinook salmon observed swimming directly downstream of the Hills Ferry Barrier searching for passage opportunity.

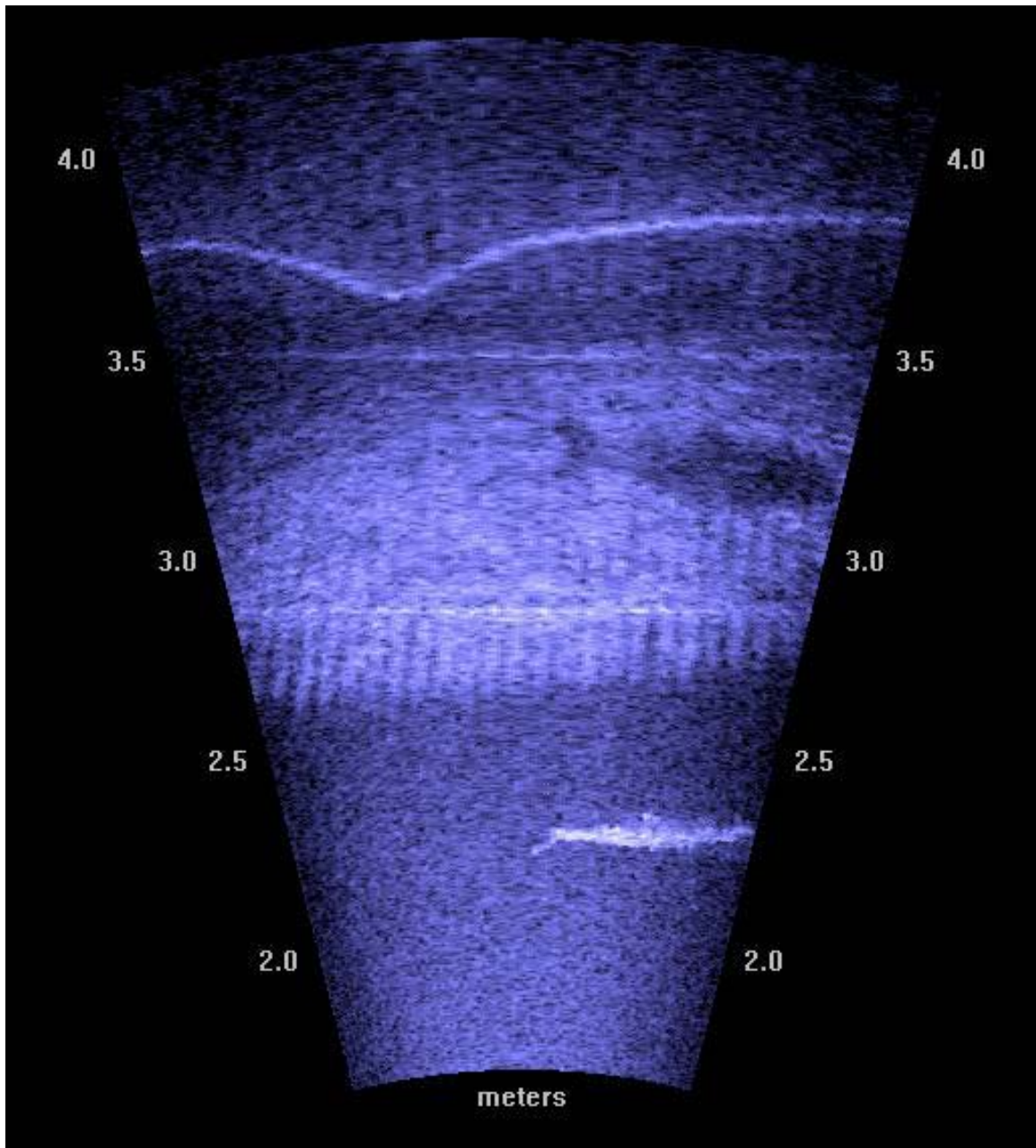


Figure 16.—A carp observed swimming along the downstream of the Hills Ferry Barrier seeking passage opportunity, note the conduit pickets in the background.

Water Velocities and Bathymetry

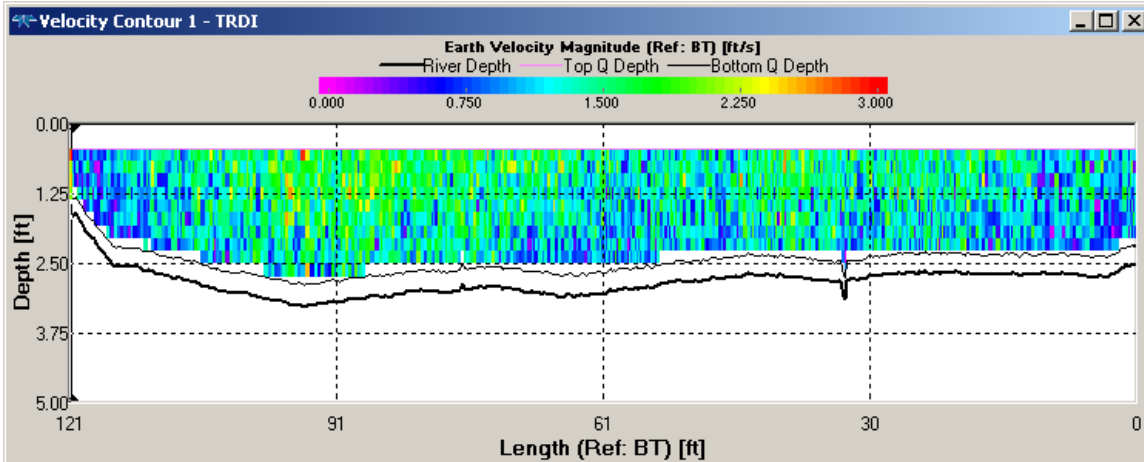
Data from the ADCP transects showed hydraulic conditions were similar in October and November with river flow rates slightly lower through mid-November (approximately 7 percent) and the water surface elevation approximately 0.61 m (2 ft) higher.

Comparative data between October 19 and November 16, 2010 transects are displayed in Figures 17–23. The velocity magnitude is shown on a scale of 0–0.9 m/s (0–3 ft/s) across the width of the river. On the upstream side of the barrier, flow was distributed fairly uniformly in October. At 9.1 m (30 ft) upstream of the barrier, the average channel velocity was 0.38 m/s (1.24 ft/s; Table 1, Figure 12). At 0.61 m (2 ft) upstream of the barrier, the velocity on the left side of the fish trap was 0.38 m/s (1.24 ft/s) and the velocity of the right side of the trap was 0.36 m/s (1.18 ft/s; Table 1, Figure 20). In November, flow was greatly skewed to the left side of the channel. At 3.1 m (30 ft) upstream of the barrier, the average channel velocity was 0.37 m/s (1.20 ft/s). Average velocities were 0.61 m at (2 ft) upstream of the barrier, 0.52 m/s (1.70 ft/s) on the left side and 0.23 m/s (0.74 ft/s) on the right (Figure 20).

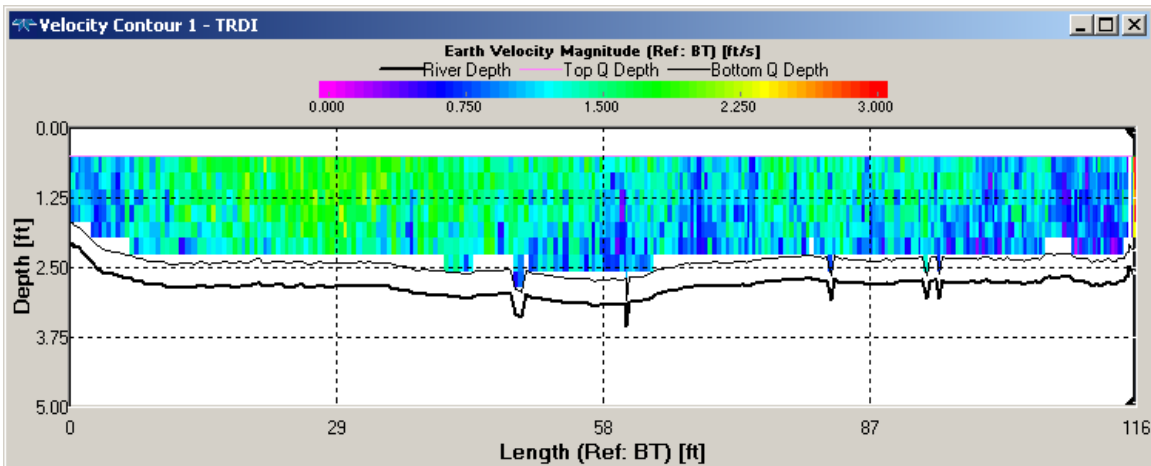
Deposition of loose fine material occurs on right river transect in November (Figures 19 and 20), while mid-channel scouring was occurring 0.61–3.0 m (2–10 ft) downstream of barrier between October and November (Figures 21–23). More aggressive scouring is noticeable 0.61 m (2 ft) downstream of barrier behind fish trap (Figure 21). The armored, riprap sill, upstream of the barrier on the left river bank remained stable throughout the evaluation period, and is seen as an elevation rise (Figures 18–20).

Table 1.—Hydraulic data collected at Hills Ferry Barrier in October and November 2010. 1 foot = 0.3 meters.

	Test Date	Flow Rate (ft ³ /s)	Average		
			Velocity (ft/s)	Flow Area (ft ²)	Water Surface Elevation (ft)
Upstream 30 ft Full Transect	10/19/2010	386.44	1.24	327.82	49.87
	11/16/2010	371.13	1.20	315.55	50.05
Upstream 10 ft Left of Trap	10/19/2010	124.28	1.22	108.89	49.87
	11/16/2010	172.48	1.68	108.82	50.05
Upstream 10 ft Right of Trap	10/19/2010	224.43	1.28	185.2	49.87
	11/16/2010	181.88	0.91	213.12	50.05
Upstream 5 ft Left of Trap	10/19/2010	125.29	1.24	107.34	49.87
	11/16/2010	189.42	1.77	110.5	50.05
Upstream 5 ft Right of Trap	10/19/2010	226.73	1.27	193.03	49.87
	11/16/2010	156.28	0.83	200.08	50.05
Upstream 2 ft Left of Trap	10/19/2010	132.87	1.24	114.12	49.87
	11/16/2010	203.47	1.70	125.21	50.05
Upstream 2 ft Right of Trap	10/19/2010	229.78	1.18	211.5	49.87
	11/16/2010	140.25	0.74	205.85	50.05
Downstream 2 ft Full Transect	10/19/2010	381.45	0.97	383.74	49.87
	11/16/2010	343.88	0.65	453.45	50.00
Downstream 5 ft Full Transect	10/19/2010	370.74	1.22	318.45	49.87
	11/16/2010	348.58	0.76	427.82	50.00
Downstream 10 ft Full Transect	10/19/2010	371.14	1.30	303.93	49.87
	11/16/2010	347.01	0.95	363.24	50.00

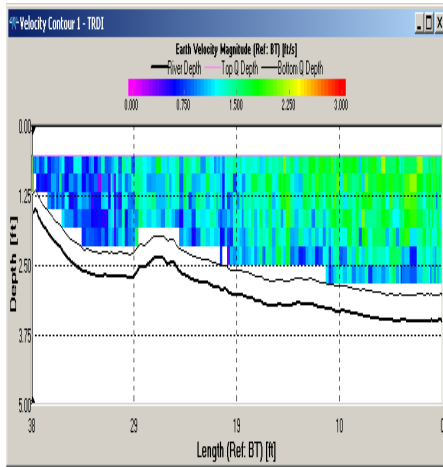


Full river transect collected October 2010. Flow rate 386.44 ft³/s, velocity 1.24 ft/s, flow area 327.82 ft².

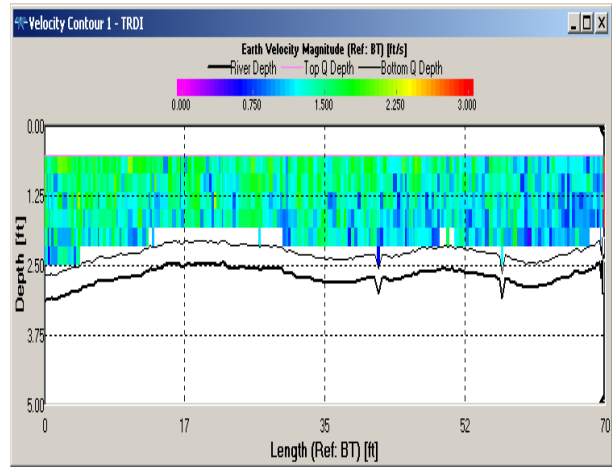


Full river transect collected November 2010. Flow rate 371.13 ft³/s, velocity 1.20 ft/s, flow area 315.55 ft².

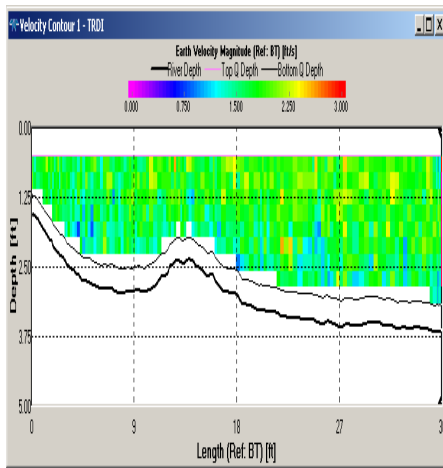
Figure 17.—River transect collected with an Acoustic Doppler Current Profiler at 9.1 m (30 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right. (0.3 m = 1 ft.)



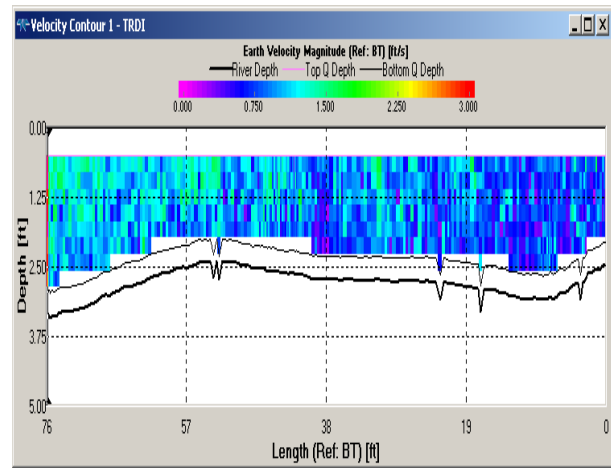
Left river transect collected October 2010. Flow rate 124.28 ft³/s, velocity 1.222 ft/s, flow area 108.89 ft².



Right river transect collected October 2010. Flow rate 224.43 ft³/s, velocity 1.28 ft/s, flow area 185.20 ft².

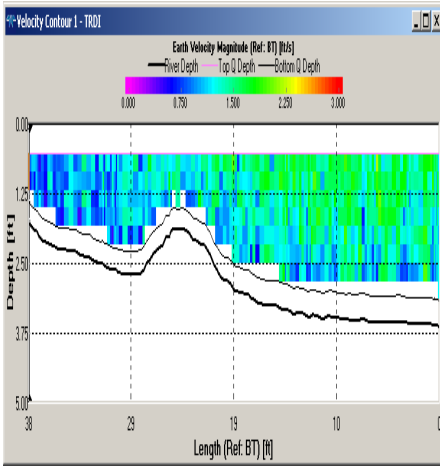


Left river transect collected November 2010. Flow rate 172.48 ft³/s, velocity 1.68 ft/s, flow area 108.82 ft².

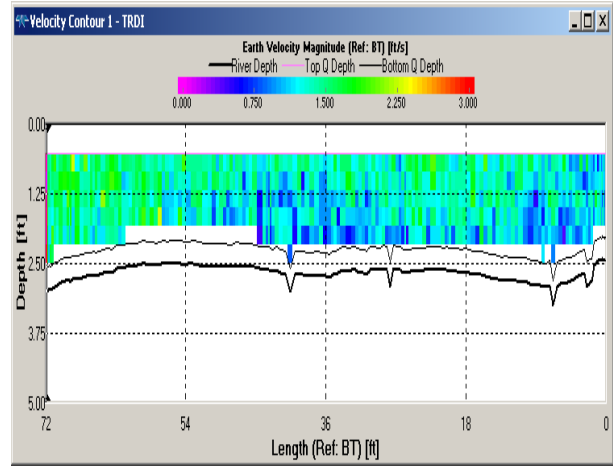


Right river transect collected November 2010. Flow rate 181.88 ft³/s, velocity 0.91 ft/s, flow area 213.12 ft².

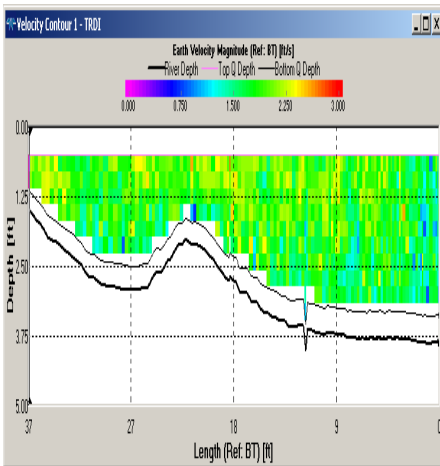
Figure 18.—River transect collected with an Acoustic Doppler Current Profiler at 3.0 m (10 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right. (0.3 m = 1 ft.)



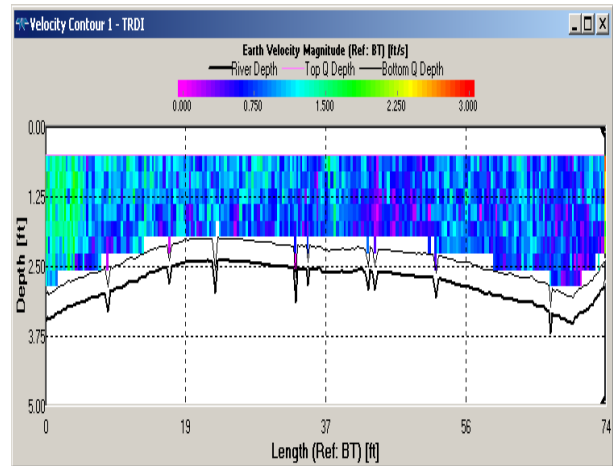
Left river transect collected October 2010. Flow rate 125.29 ft³/s, velocity 1.24 ft/s, flow area 107.34 ft².



Right river transect collected October 2010. Flow rate 226.73 ft³/s, velocity 1.27 ft/s, flow area 193.03 ft².

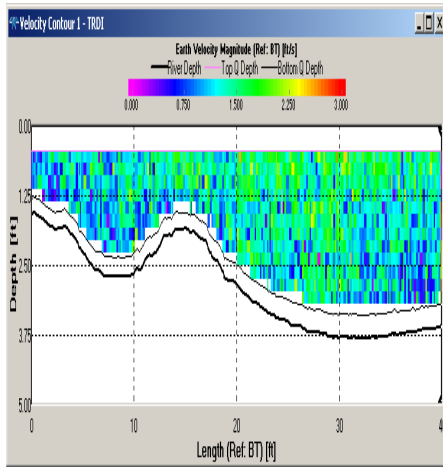


Left river transect collected November 2010. Flow rate 189.42 ft³/s, velocity 1.77 ft/s, flow area 110.50 ft².

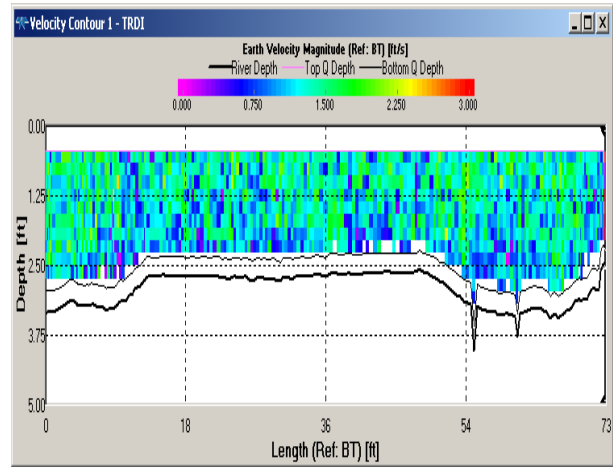


Right river transect collected November 2010. Flow rate 156.28 ft³/s, velocity 0.83 ft/s, flow area 200.08 ft².

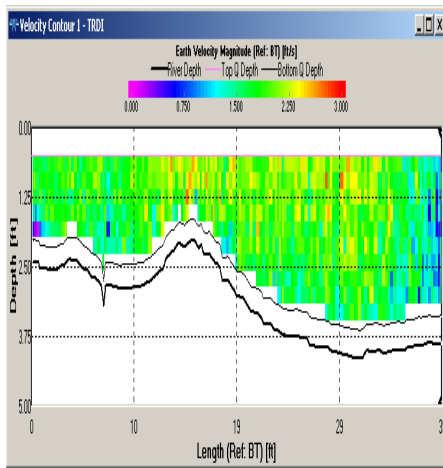
Figure 19.—River transect collected with an Acoustic Doppler Current Profiler at 1.5 m (5 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right. (0.3 m = 1 ft.)



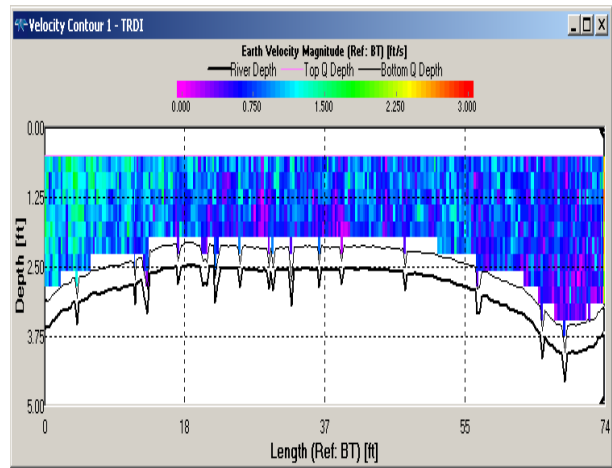
Left river transect collected October 2010. Flow rate 132.87 ft³/s, velocity 1.24 ft/s, flow area 114.12 ft².



Right river transect collected October 2010. Flow rate 229.78 ft³/s, velocity 1.18 ft/s, flow area 211.5 ft².

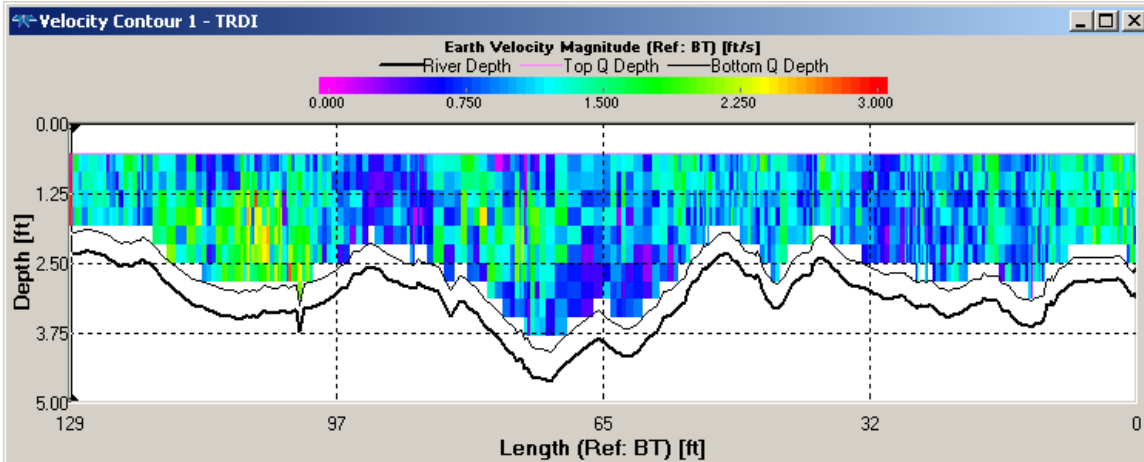


Left river transect collected November 2010. Flow rate 203.47 ft³/s, velocity 1.70 ft/s, flow area 125.21 ft².

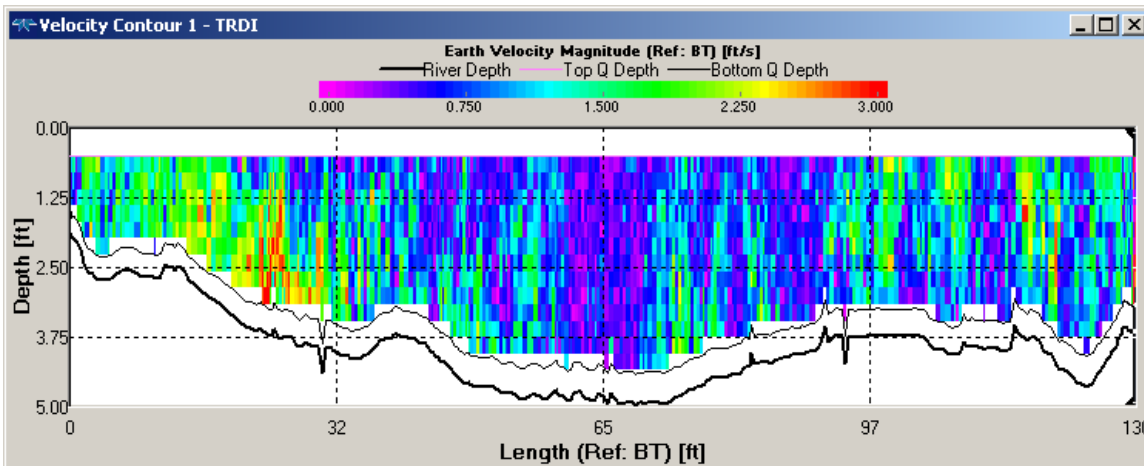


Right river transect collected November 2010. Flow rate 140.25 ft³/s, velocity 0.74 ft/s, flow area 205.85 ft².

Figure 20.—River transect collected with an Acoustic Doppler Current Profiler at 0.61 m (2 ft) upstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right. (0.3 m = 1 ft.)

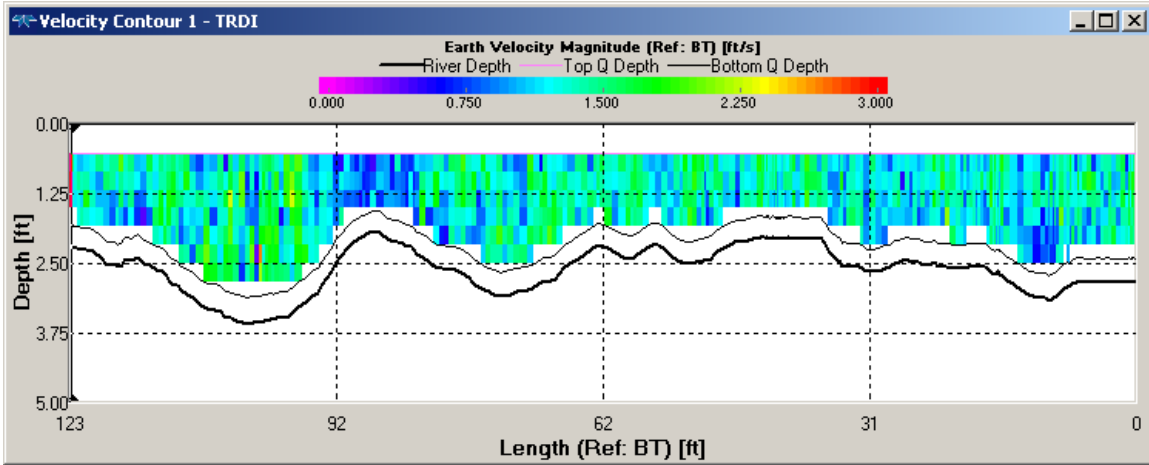


Full river transect collected October 2010. Flow rate 381.45 ft³/s, velocity 0.97 ft/s, flow area 383.74 ft².

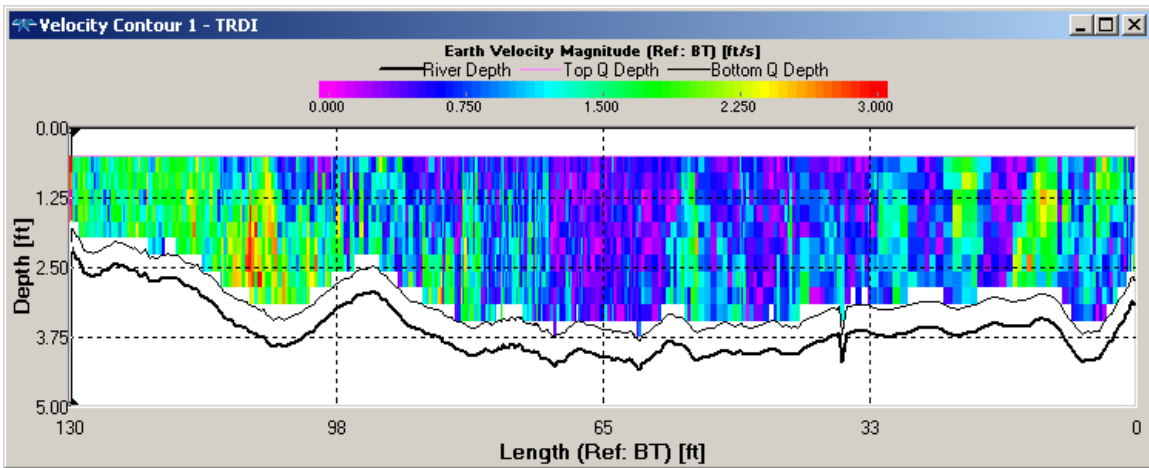


Full river transect collected November 2010. Flow rate 343.88 ft³/s, velocity 0.65 ft/s, flow area 453.45 ft².

Figure 21.—River transect collected with an Acoustic Doppler Current Profiler at 0.61 m (2 ft) downstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right. (0.3 m = 1 ft.)

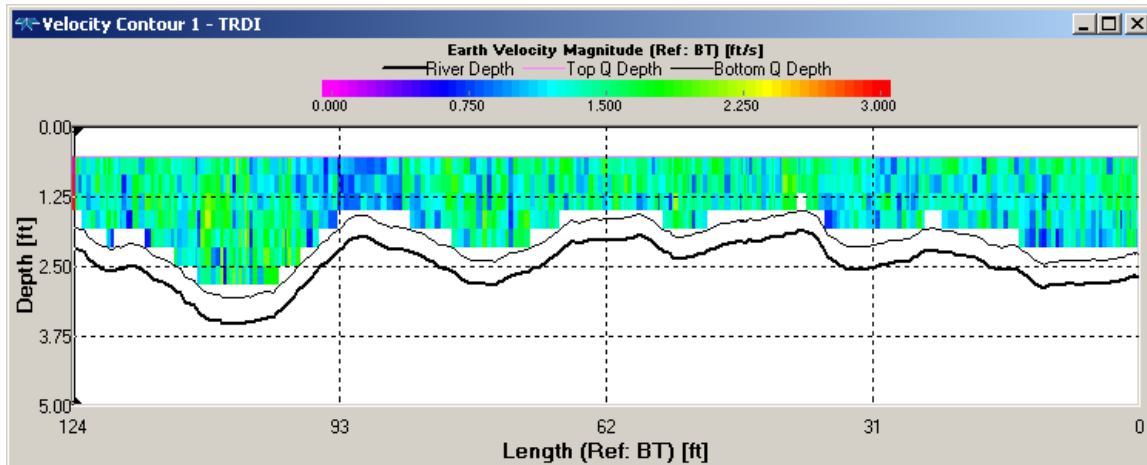


Full river transect collected October 2010. Flow rate 370.74 ft³/s, velocity 1.22 ft/s, flow area 318.45 ft².

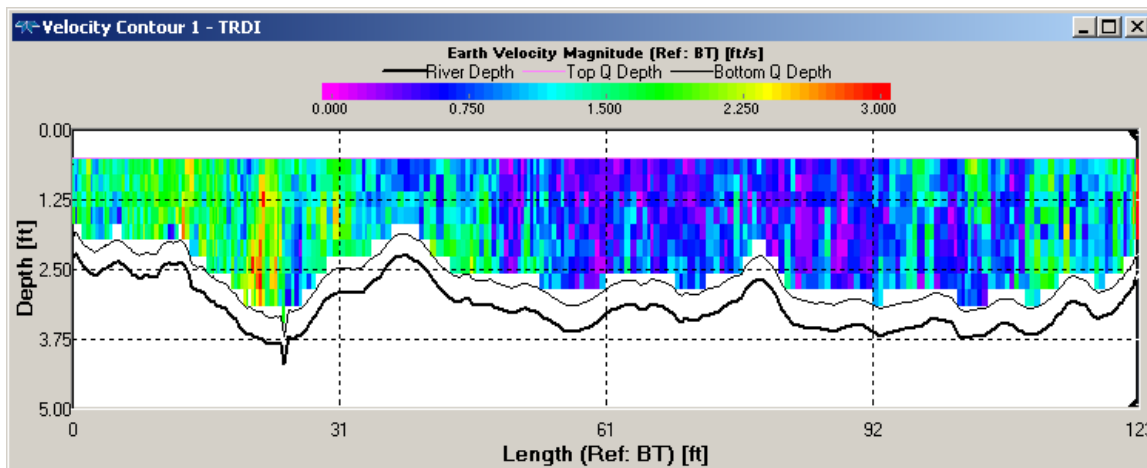


Full river transect collected November 2010. Flow rate 348.58 ft³/s, velocity 0.76 ft/s, flow area 427.82 ft².

Figure 22.—River transect collected with an Acoustic Doppler Current Profiler at 1.5 m (5 ft) downstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right. (0.3 m = 1 ft.)



Full river transect collected October 2010. Flow rate 371.14 ft³/s, velocity 1.30 ft/s, flow area 303.93 ft².



Full river transect collected November 2010. Flow rate 347.01 ft³/s, velocity 0.95 ft/s, flow area 363.24 ft².

Figure 23.—River transect collected with an Acoustic Doppler Current Profiler at 3.0 m (10 ft) downstream of the Hills Ferry Barrier for October (top) and November (bottom). West riverbank on left and east riverbank on right. (0.3 m = 1 ft.)

Telemetry

Adult Chinook salmon behavior was monitored using ultrasonic telemetry, primarily on the downstream side of the HFB to assist in determining the effectiveness of the barrier at inhibiting passage and movement patterns in the proximity of the HFB and San Joaquin-Merced River Confluence. The fish trap at HFB proved to be relatively ineffective at catching Chinook salmon but did capture carp and catfish daily. Only two salmon were captured in the trap during the study duration and were immediately released by DFG

without tagging due to fish condition and logistical restrictions. These fish were caught on October 13 and November 12, 2010, no data were made available. Salmon sightings at the barrier increased through the month of November, peaking mid-month. On November 17 and 18, 2010 two male Chinook (69.0 and 68.5 cm fork length, respectively) were netted along the upstream side of the barrier that apparently passed during cleaning, through scour holes, or barrier gaps along the shore. These two fish were attempting to find passage back downstream when they were captured and tagged with ultrasonic transmitters, and released downstream of the barrier where they were tracked with five pre-positioned receivers and a hand-held mobile receiver. They were detected only on receivers below the barrier and confluence, and did not re-ascend the San Joaquin or Merced Rivers (Figures 24 and 25).

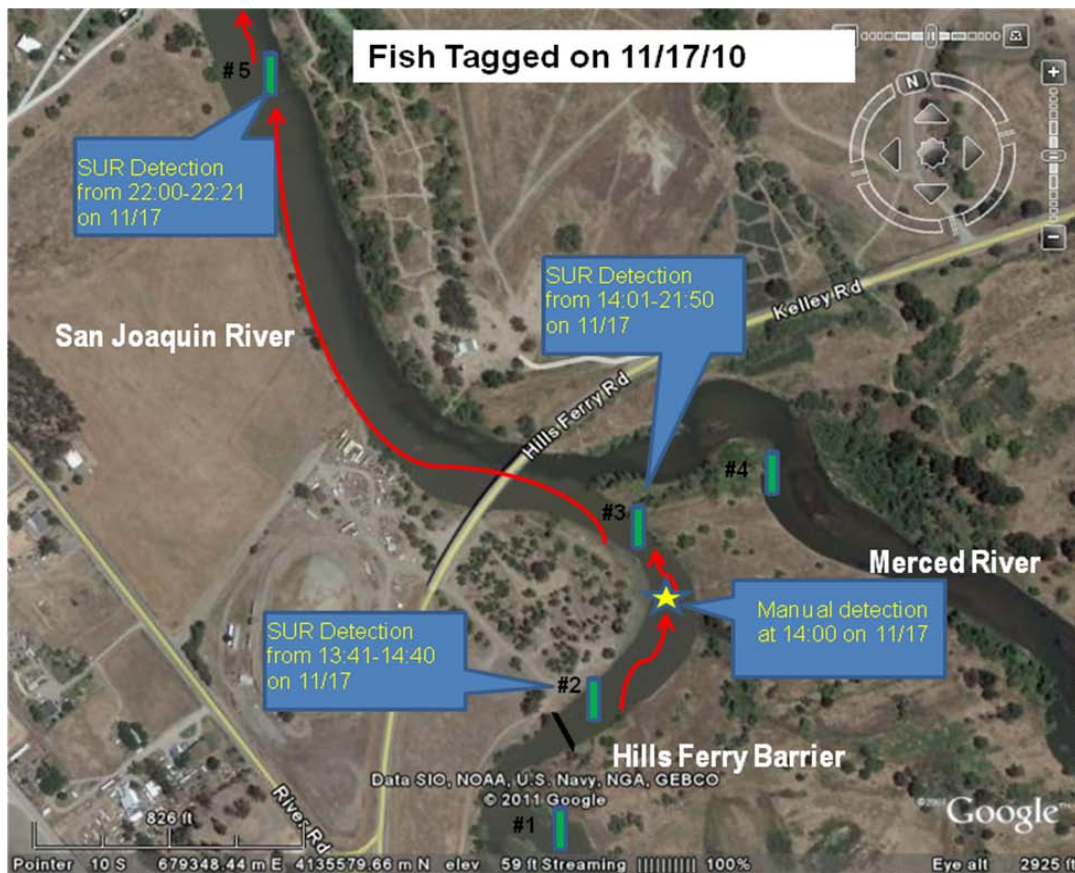


Figure 24.—Chinook salmon movement of fish tagged on 11/17/10 at Hills Ferry Barrier. This fish did not re-ascend the San Joaquin River and eventually moved downstream out of detection by the submersible ultrasonic receivers.

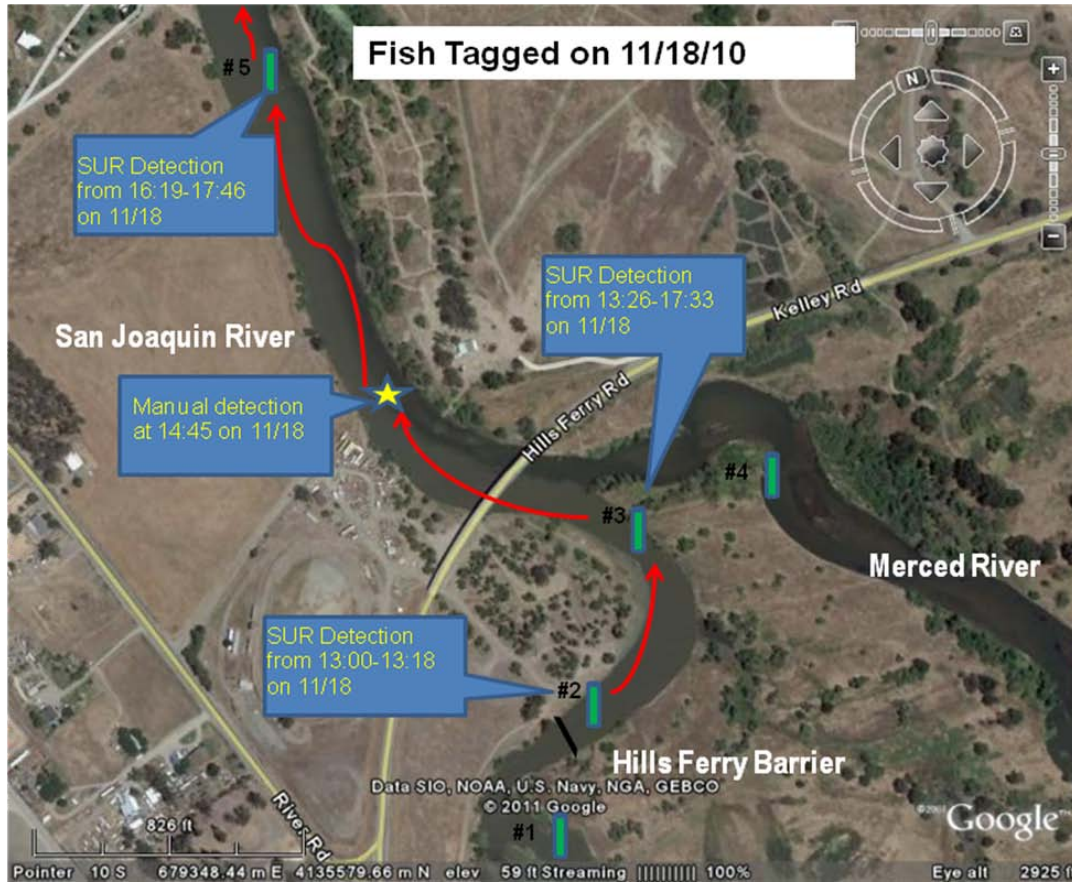


Figure 25.—Chinook salmon movement of fish tagged on 11/18/10 at Hills Ferry Barrier. This fish did not re-ascend the San Joaquin River and eventually moved downstream out of detection by the submersible ultrasonic receivers.

DISCUSSION

The SJRRP in its commitment to restore and maintain fish populations in the Restoration Area in accordance with the *NRDC, et al., v. Kirk Rodgers, et al. 2006 Settlement* and Public Law 111-11 Section 10004 (h)(4) has evaluated the effectiveness of the Hills Ferry Barrier in preventing the unintended upstream migration of anadromous fish in the San Joaquin River. HFB integrity was compromised under flooding and high flows which resulted in excessive bank erosion and river bed scouring. Observations from the DIDSON camera, ADCP, and visual accounts identified problems and limitations with the structure in fall 2010. Twenty-two fish passed the barrier location and migrated upstream to the Mendota and Sack dams, canals, and sloughs. HFB improvements are currently being considered for the fall 2011 season in order to improve opportunities for data collection, manage fish movement, better evaluate barrier effectiveness, and increase the rigidity and “fish tightness” of the structure. Operational changes may reduce the threat of Merced River fishery straying to unsuitable habitat on the San Joaquin River. The monitoring of fish species encountering the barrier and analyzing fish behavior under

different hydraulic conditions at this location may provide information and create indices to help ensure the success of the restoration goal.

The river substrate poses a challenge to the integrity of the barrier. Loose benthic material and river hydraulics around weir support structures, barrier footings, base of conduit bars, and barrier panels cause substrate erosion resulting in scouring holes along the barrier and shoreline destabilization. Scour holes and eroding banks are fortified with sandbags and conduit picket extensions are driven further into the substrate on a daily basis to maintain a relatively “fish tight” barrier. Adult Chinook salmon have been observed in the past to take advantage of scour holes and elude the barrier. DFG personnel, when alerted to failures in the barrier, promptly respond to the issues by sandbagging, replacing conduit pickets, and making other minor changes.

It is not clear why the river flow was skewed to the left side of the channel in November, we recommend further investigation before installing barrier at this location as this difference may cause increased erosion on this bank. Flow rates were slightly lower through mid-November and the water surface elevation approximately 0.61 m (2 ft) higher, which was most likely caused by the Merced River backing up into the San Joaquin River at the confluence. In November, scour was greater mid-channel, downstream of the barrier, particularly at the 0.61 m (2 ft) and 1.5 m (5 ft) transects (Figures 21 and 22). This erosion was exacerbated by eddy currents and hydraulic disturbances assumed to be caused by the fish trap. Velocities were reduced downstream of the barrier as cross sectional flow area increased. As a result, deposition of eroded material caused a rise in river bed beyond 3 m (10 ft) below the barrier. Additionally, we found that tying the jon boat to the barrier on the far left river bank caused downwelling eddies that scoured a large area of the substrate directly adjacent to the weir. Our water velocity and bathymetry information can be used to recommend improvements with barrier design, operation, and location. Scour holes and gaps in the barrier can be predicted using erosion depth and sediment transition behavior. Due to variable river flows and unstable river substrate at this site and the temporary nature of the barrier, erosion of the substrate will be a continuous problem unless redesigned.

Anecdotal information suggests that large fish pass through the barrier when excessive water hyacinth loads and vegetative debris become lodged against the sliding pipes and require a section of the barrier to be removed for a short period to allow the plant matter to travel downstream. The force created by the vegetative fouling on the pickets by water hyacinth and debris can cause weir failure if cleaning does not occur. Discussions to improve debris removal procedures are occurring to develop a strategy to maintain a “fish-tight” barrier design for fall 2011.

Monitoring Chinook salmon movements near the HFB and San Joaquin-Merced River confluence using ultrasonic telemetry was not successful due to only capturing two fish in good condition to tag and release. These two fish swam back down river never to return. The 2011 monitoring will increase the number of receivers downstream, increasing the detection area for future efforts. Also, at least ten adult Chinook salmon per month is recommended for future tagging and tracking to successfully monitor

migration and behavior at this site. This may be difficult to achieve due to the small quantity of fish that were caught in the past, however better traps and capturing techniques may increase capture success. Fall 2011 data will provide information regarding the “fish-tight” capability of the barrier, microhabitat utilization downstream of the barrier and at the confluence, and help improve knowledge on salmon migratory decision making when encountering the barrier inhibiting movement upstream in the San Joaquin River.

Numbers of salmon reported above the barrier were greater in 2010 than in recent years (Gates 2011), most likely the result of the barrier breach under high flows. Nevertheless, past data dwarfs these numbers and indicates that much great quantities of salmon once maneuvered past the HFB upstream on the San Joaquin River. Current understanding is that the HFB is operational at flows up to approximately 28.3 m³/s (1,000 ft³/s), however further investigation is needed to evaluate the effectiveness of the HFB during higher flows to understand the current limitations. San Luis Canal Company (SLCC) employees, Department of Water Resources (DWR) staff, and fishermen alerted Reclamation and Department of Fish and Game (DFG) biologists to four fish below Sack Dam where one female was later tagged by Reclamation biologists with an ultrasonic transmitter and released upstream of the dam. This fish was later tracked to a pool directly below the base of Mendota Dam (Eric Guzman, DFG, personal communication). SLCC staff reconfigured the stop logs in the Sack Dam fish ladder to allow passage of other salmon that evaded the HFB. Reclamation and DFG biologists later observed several salmon (12 or more) below the base of Mendota Dam and DFG sonically tagged a few females and released them into Mendota Pool. Two males were also captured at a later date and transported to the base of Friant Dam and released (Matt Bigelow, DFG, personal communication). The HFB did not restrict all passage to fall-run Chinook salmon during the fall 2010. Twenty-two fish were observed at Sack and Mendota dams, irrigation canals, and sloughs upstream of HFB during the later part of the barrier implementation season (Gates 2011).

CONCLUSIONS AND RECOMMENDATIONS

The long-term use of the HFB is unknown; however, it will be used to block anadromous fish species from moving upstream until the Restoration Area is considered ready for salmon reintroduction. After salmon reintroduction, it may be necessary to continue to utilize the HFB for fall-run Chinook salmon and steelhead actions. The HFB may potentially be operated as a control structure to minimize interactions between spring-run and fall-run Chinook salmon once populations are established. The barrier may function to minimize hybridization between spring-run and fall-run Chinook salmon.

Hybridization can reduce fitness parameters (*i.e.*, growth, survival, and reproduction). Excessive hybridization can result in outbreeding depression, degraded performance (*e.g.*, swimming performance, sexual maturity, and size), disrupt homing mechanisms, and lead to reduced survival and increased straying in fishes (Fish Management Plan 2010). HFB may also be used to reduce risk of redd superimposition among Chinook salmon runs.

Regardless of the future of the barrier, near-term structural and non-structural modifications are necessary. The location needs to be moved downstream towards the confluence where there is a reduced risk of overtopping and bank erosion because the river channel is wider and shallower. Barrier improvements may be necessary due to the Settlement's requirement of water releases (*i.e.*, Interim Flows and Restoration Flows) below Friant Dam, because these releases may potentially affect barrier performance if flows are greater than 28.3 m³/s (1,000 ft³/s). It is believed that the current barrier design cannot withstand high flows greater than this and substantial erosion will occur (Gates 2011). Long-term efforts may require a permanent concrete sill installed to stabilize erosion and provide a solid barrier foundation with suitable anchoring points.

Methods for successful removal of floating hyacinth mats may need to be incorporated in the barrier's future design. Water hyacinth buildup on the barrier compromises structure integrity and risk failure from the force of water held back once clogged with debris. Barrier effectiveness is also reduced when conduit picket panels are removed to float excessive quantities of hyacinth through the structure for cleaning. Conduit panels should never be removed for cleaning because it allows for gaping holes in the barrier for extended periods of time allowing passage opportunity. Cleaning the barrier twice daily is recommended to reduce the accumulation of vegetative debris collected on the upstream side of the structure.

Other passage locations upstream of HFB need to be considered and investigated. Open flow and exchange of water from the Merced River to the San Joaquin River through a small slough upstream of HFB that connects the rivers during high flows should be evaluated and a barrier installed if determined to allow potential migration. Fish that were found upstream of HFB in the fall of 2010 before the HFB failure in November may have passed using this opportunity.

Lastly, due to poor capture success of the barrier-incorporated trap design and increased erosion associated with the upstream placement of the trap, a new design is being proposed for the fall 2011 survey. A modified fyke net with wingwalls to guide fish to the trap opening, independent of the weir, will be used to collect salmon downstream of the barrier for use in telemetry experiments.

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