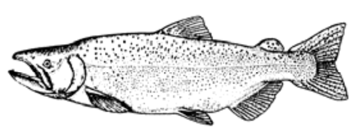
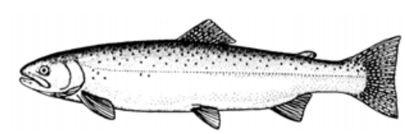
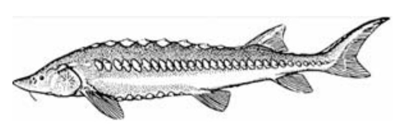
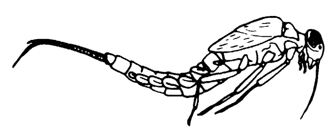
IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY OF CALIFORNIA AND FISHERIES INVESTIGATIONS

Annual Progress Report
Fiscal Year 2014

U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825

Prepared by staff of
The Restoration and Monitoring Program

PREFACE

The following is the Thirteenth Annual Progress Report, Identification of the Instream Flow Requirements for Anadromous Fish in the Streams within the Central Valley of California and Fisheries Investigations, prepared as part of the Central Valley Project Improvement Act (CVPIA) Instream Flow and Fisheries Investigations, an effort which began in October, 2001.[1] Title 34, Section 3406(b)(1)(B) of the CVPIA, P.L. 102-575, requires the Secretary of the Department of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Wildlife (CDFW). The purposes of this investigation are: 1) to provide scientific information to the Service's CVPIA Program to be used to develop such recommendations for Central Valley streams and rivers; and 2) to provide scientific information to other CVPIA programs to use in assessing fisheries restoration actions. The purpose of this report is to provide an update on the Monitoring and Restoration Program's CVPIA-funded activities and accomplishments during fiscal year 2014 to interested stakeholders. An in-depth presentation on the instream flow studies is given in the final reports for these studies. The annual reports serve as final reports for the fisheries investigation tasks.

The field work described herein was conducted by Mark Gard, Rick Williams, Harry Kahler, Amber Aguilera, Tricia Parker-Hamelberg and John Henderson.

Written comments or questions can be submitted to:

Mark Gard, Senior Biologist
Restoration and Monitoring Program
U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825

Mark_Gard@fws.gov

Electronic versions of our final reports and previous years' annual reports are available on our website:

http://www.fws.gov/sacramento/Fisheries/Instream-Flow/fisheries_instream-flow_reports.htm

[1] The scope of this program was broadened in FY 2009 to include fisheries investigations. This program is a continuation of a 7-year effort, titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

OVERVIEW

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring), steelhead trout, white and green sturgeon, American shad and striped bass. Between 2001 and 2013, the Service's Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch completed instream flow study reports on the Sacramento, Lower American, Yuba, Stanislaus and Tuolumne Rivers and Butte, South Cow and Clear Creeks. For Clear Creek, we worked with the USFWS Red Bluff staff in FY 2014 to revise a draft report that provides a synthesis of our four instream flow study reports, and sent the draft synthesis report to the Clear Creek Technical Team for their review. We will be issuing a final synthesis report in FY 2015.

In 2014, the following fisheries investigation tasks were selected for study: 1) American River gravel placement monitoring; 2) Stanislaus River floodplain area versus flow; 3) Stanislaus River floodplain restoration site identification; 4) Merced River floodplain area versus flow; 5) Yuba River floodplain area versus flow; 6) Yuba River Hammon Bar restoration project monitoring; 7) Yuba River Daguerre Alley restoration project monitoring; 8) South Fork Cottonwood Creek (Tehama County) habitat assessment; 9) Dry Creek habitat assessment; 10) Antelope Creek Lower Slab passage assessment and 11) Antelope Creek Bridge topographic survey.

We performed the following fisheries investigations to assess fisheries restoration actions:

1) In FY 2014, we completed modeling of the FY 2011 and 2012 gravel restoration projects on the American River.
2) We updated the Stanislaus River floodplain area versus flow relationship and conducted biological validation of this relationship in FY 2014.
3) We identified additional Stanislaus River floodplain restoration projects using the results of the updated Stanislaus River floodplain model.
4) We collected topographic and stage-discharge data to use in developing a Merced River floodplain area versus flow relationship. Further work on this task is dependent on the availability of funding in FY 2015.
5) We used an existing hydraulic model of the Yuba River to develop a floodplain area versus flow relationship for the Yuba River.
6) We modeled the amount of fall-run Chinook salmon and steelhead rearing habitat created by the second phase of the Yuba River Hammon Bar restoration project.
7) We completed data collection and modeling of the amount of fall-run Chinook salmon and steelhead rearing habitat created by the proposed Yuba River Daguerre Alley restoration project.
8) We conducted a fall-run Chinook salmon and steelhead habitat assessment in six miles of the South Fork of Cottonwood Creek as part of pre-project monitoring of the Hammer Dam removal restoration project.

9) We conducted a fall-run Chinook salmon and steelhead habitat assessment on the portion of Dry Creek within the Spenceville Wildlife Area to identify habitat restoration needs.
10) We collected data and started work on a hydraulic model at the Antelope Creek Lower Slab to assess at what flows this structure is a barrier to upstream passage of adult spring-run Chinook salmon. This task will be completed in FY 2015, with results presented in the FY 2015 annual report.
11) We conducted a topographic survey of the Antelope Creek bridge crossing to assess effects of high flow on this restoration project.

The results of these scientific investigations were provided to other CVPIA programs. The following sections summarize the eleven project activities that were performed between October 2013 and September 2014.

FISHERIES INVESTIGATIONS

American River Gravel Placement Monitoring

Methods

The purpose of this task was to complete hydraulic and habitat models of sites where gravel was placed in the American River above Sunrise Bridge in 2011 and at Lower Sailor Bar in 2012. The purpose of the models is to quantify the amount of spawning and rearing habitat that was created by the Above Sunrise restoration project and the amount of spawning habitat created by the Lower Sailor Bar project. High flows in 2006 resulted in downcutting of the main stream river channel at the upstream end of an island downstream of the 2011 site. As a result, a side channel that used to flow at a total American River flow of 800 cfs no longer had flow until the total American River flow reached an estimated 3,200 cfs. The 2011 gravel placement design consisted of both placement of spawning-sized material upstream of the island to create spawning habitat, and placement of larger material in the downcut main channel location to raise the water surface at this location, so that the side channel would once again flow at lower American River flows. The 2012 gravel placement design consisted of both placement of spawning-size material in the main channel and excavation of a side channel so it would flow at lower American River flows.

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated. The Physical Habitat Simulation (PHABSIM) transect at the outflow end of each site is calibrated to provide the water surface elevation (WSEL) at the outflow end of the site used by River2D. The PHABSIM transect at the inflow end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses

Table 1
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 – 1
1.2	Medium Gravel	1 – 2
1.3	Medium/Large Gravel	1 – 3
2.3	Large Gravel	2 – 3
2.4	Gravel/Cobble	2 – 4
3.4	Small Cobble	3 – 4
3.5	Small Cobble	3 – 5
4.6	Medium Cobble	4 – 6
6.8	Large Cobble	6 – 8
8	Large Cobble	8 – 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10 – 12

used by River2D are based on the observed substrate sizes and cover types (Tables 1 and 2), using the conversions in Table 3. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the inflow end of the site match the WSEL predicted by the PHABSIM transect at the inflow end of the site[2]. The River2D model is run at the flows at which the validation data set was collected, with the output used to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat. Spawning habitat was generated using habitat suitability criteria from the American River (U.S. Fish and Wildlife Service 1997), while rearing habitat was generated using the habitat suitability criteria developed for the Yuba River (U.S. Fish and Wildlife Service 2010a).

[2] This is the primary technique used to calibrate the River2D model.

Table 2
Cover Coding System

Cover Category	Cover Code
No cover	0.1
Cobble	1
Boulder	2
Fine woody vegetation (< 1" diameter)	3
Fine woody vegetation + overhead	3.7
Branches	4
Branches + overhead	4.7
Log (> 1' diameter)	5
Log + overhead	5.7
Overhead cover (> 2' above substrate)	7
Undercut bank	8
Aquatic vegetation	9
Aquatic vegetation + overhead	9.7
Rip-rap	10

Results

In FY 2014, we completed pre- and post-restoration hydraulic modeling for the post-restoration 2011 and pre and post-restoration 2012 sites. Pre and post-restoration habitat for the 2011 and 2012 sites is shown in Figures 1 through 8.

Discussion

The habitat effects of the 2011 project varied with flow, life stage and species, reflecting differing habitat requirements and changes in hydraulic conditions with flow. The 2011 project had the biggest benefit for spawning for flows less than 5,000 cfs, reflecting the focus of the project on creating spawning habitat and the design flow for the restoration project of 2,000 cfs. In general, the habitat benefits of the project can be tied to the three main hydraulic and structural effects of the project, namely rewetting the side channel at a lower flow, increasing the stage at a given flow in the upstream portion of the site, and adding additional spawning gravel.

Table 3
Initial bed roughness values

Substrate Code	Bed Roughness (m)	Cover Code	Bed Roughness (m)
0.1	0.05	0.1	0
1	0.1	1	0
1.2	0.2	2	0
1.3	0.25	3	0.11
2.3	0.3	3.7	0.2
2.4	0.4	4	0.62
3.4	0.45	4.7	0.96
3.5	0.5	5	1.93
4.6	0.65	5.7	2.59
6.8	0.9	7	0.28
8	1.25	8	2.97
9	0.05, 0.76, 2[3]	9	0.29
10	1.4	9.7	0.57
		10	3.05

At flows greater than 5,000 cfs, the side channel already had flow prior to the restoration project, and the increased side channel flows at these higher flows after construction of the restoration project results in velocities in the side channel that were higher than optimal velocities for spawning, reducing or cancelling out the benefits of the added gravel. Similarly, the reduced Chinook fry rearing habitat for flows greater than 6,000 cfs reflects less than optimal velocities in the side channel associated with increased side channel flow for high river flows. In contrast,

[3] For substrate code 9, we used bed roughnesses of 0.76 and 2, respectively, for cover codes 1 and 2, and a bed roughness of 0.05 for all other cover codes. The bed roughness value for cover code 1 (cobble) was estimated as five times the assumed average size of cobble (6 inches [0.15 m]). The bed roughness values for cover code 2 (boulder) was estimated as five times the assumed median size of boulders (1.3 feet [0.4 m]). Bed roughnesses of zero were used for cover codes 1 and 2 for all other substrate codes, since the roughness associated with the cover was included in the substrate roughness.

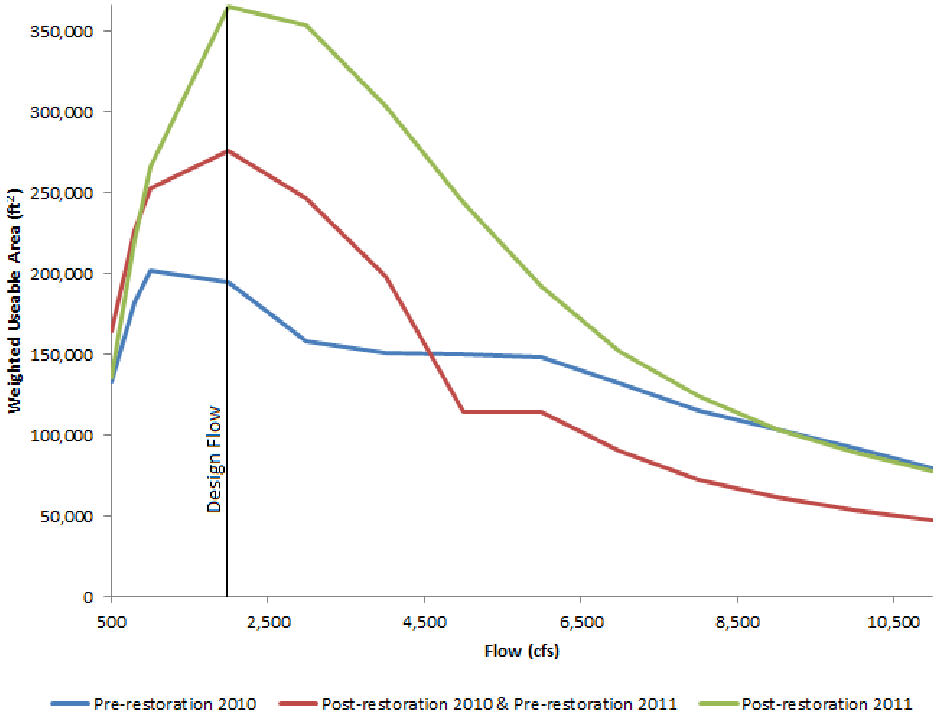


Figure 1

Fall-run Chinook salmon spawning flow-habitat relationships before and after construction of the 2010 and 2011 Above Sunrise sites

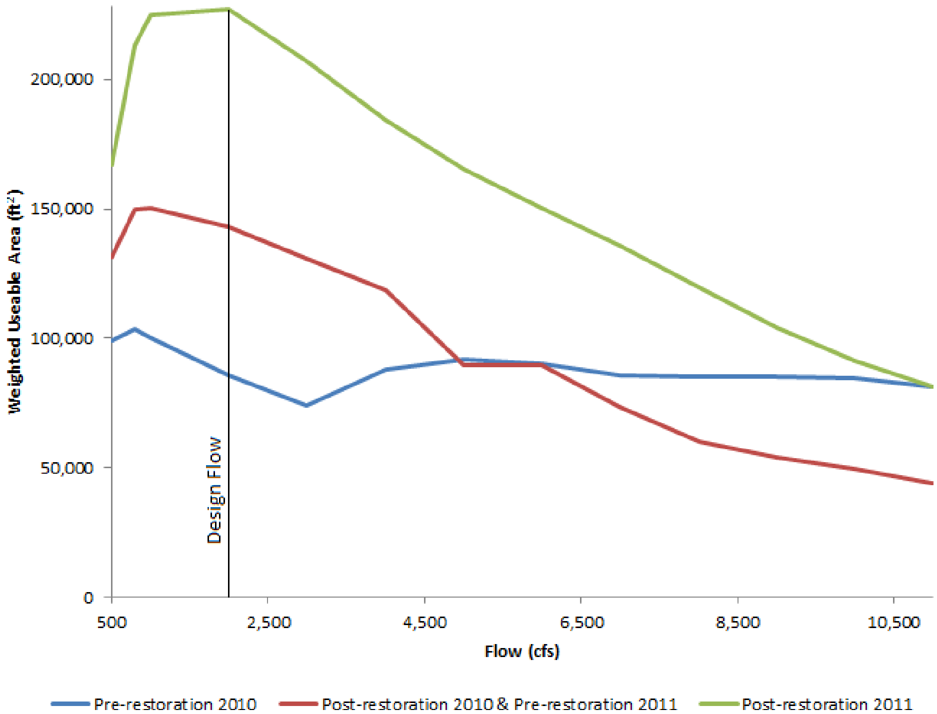


Figure 2

Steelhead spawning flow-habitat relationships before and after construction of the 2010 and 2011 Above Sunrise sites

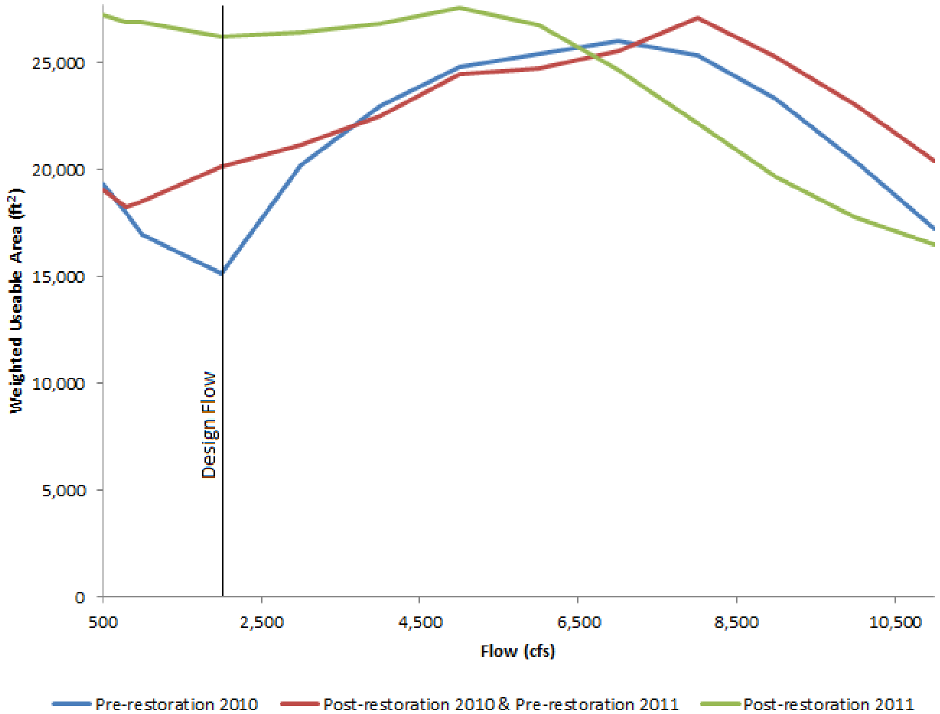


Figure 3

Fall-run Chinook salmon fry rearing flow-habitat relationships before and after construction of the 2010 and 2011 Above Sunrise sites

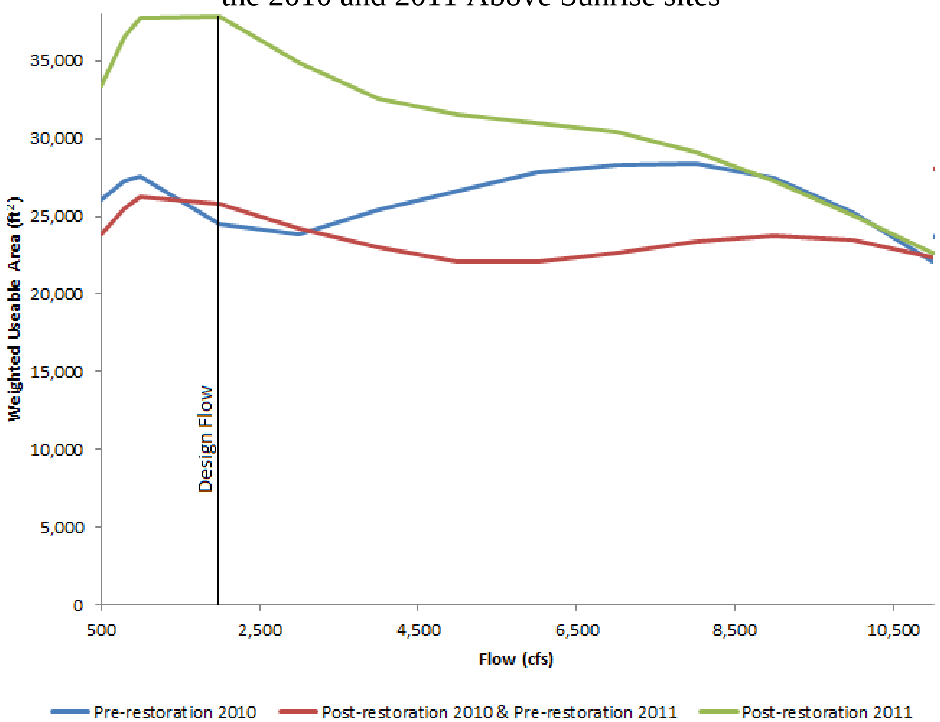


Figure 4

Steelhead fry rearing flow-habitat relationships before and after construction of the 2010 and 2011 Above Sunrise sites

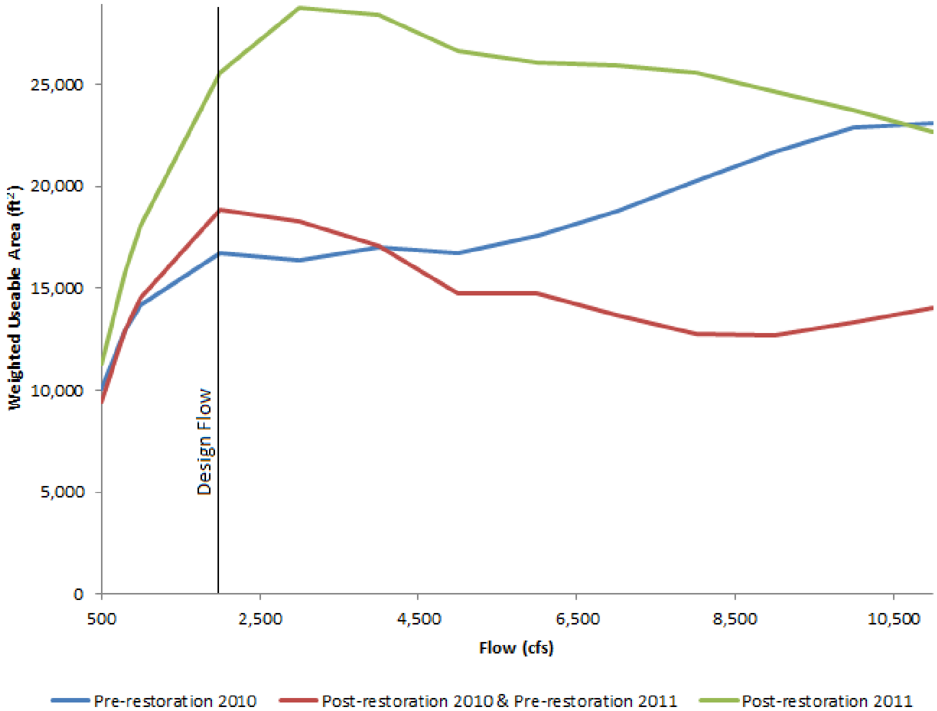


Figure 5
Fall-run Chinook salmon juvenile rearing flow-habitat relationships before and after construction of the 2010 and 2011 Above Sunrise sites

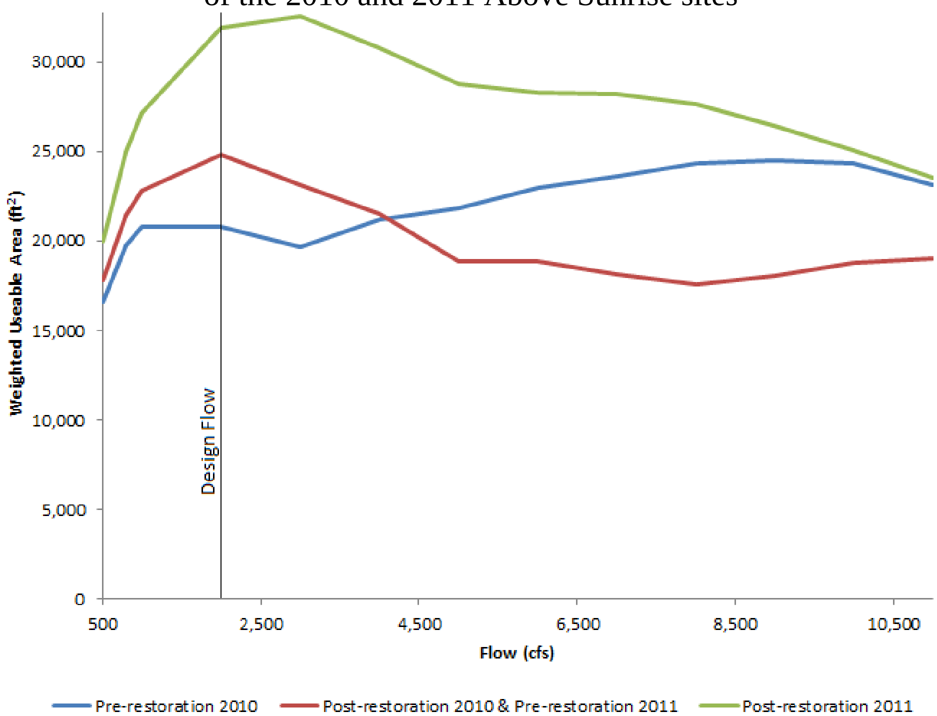


Figure 6
Steelhead juvenile rearing flow-habitat relationships before and after construction of the 2010 and 2011 Above Sunrise sites

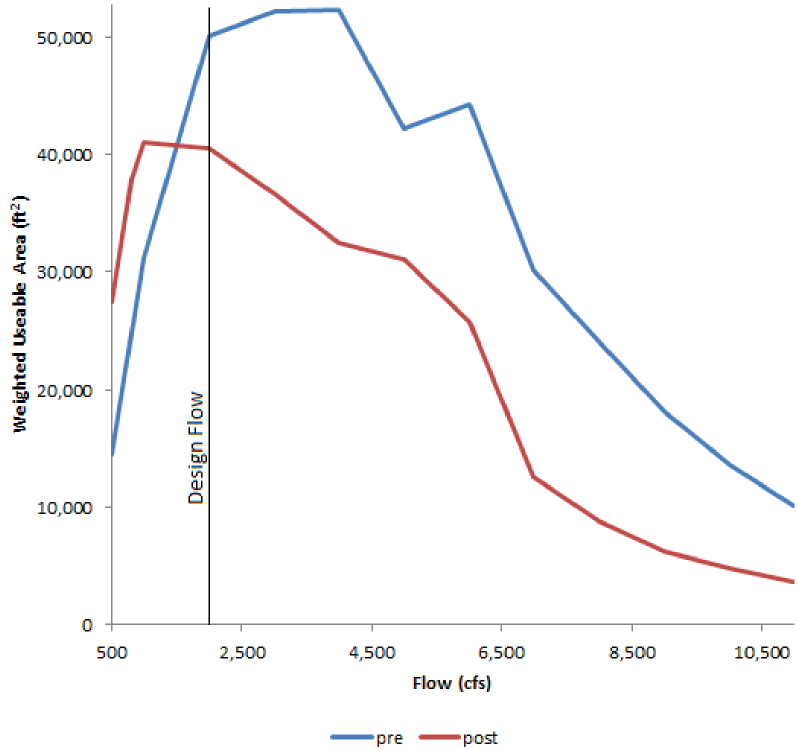


Figure 7

Fall-run Chinook salmon spawning flow-habitat relationships at the Lower Sailor Bar site

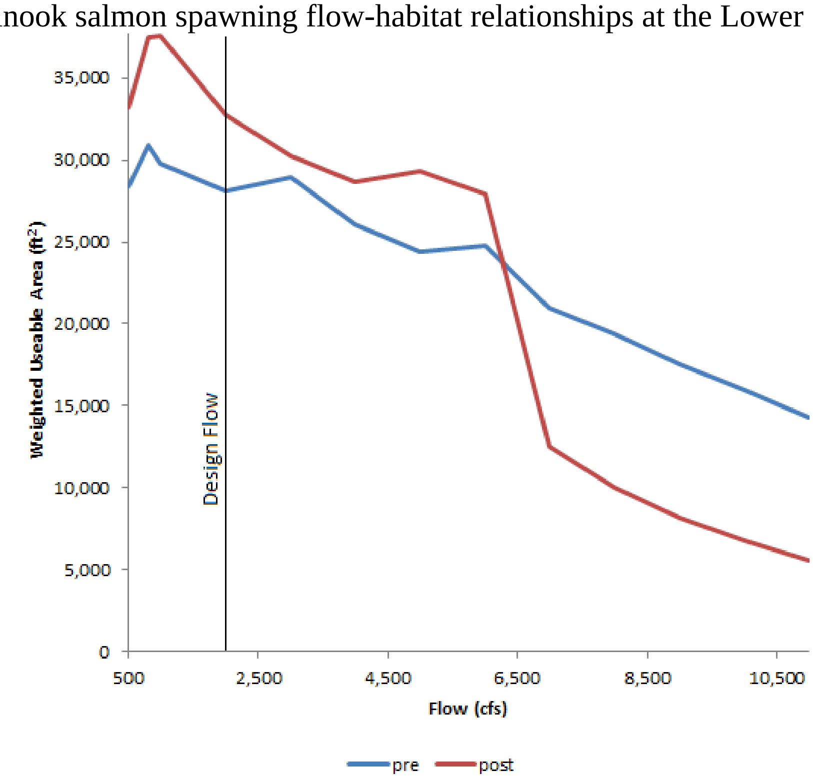


Figure 8

Steelhead spawning flow-habitat relationships at the Lower Sailor Bar site the effects of high velocities in the side channel at high river flows were much less for juveniles, which have optimal suitabilities at higher velocities. At lower flows, the larger increase in juvenile habitat is likely due to rewetting of the side channel at flows less than 3,200 cfs, as a result of project construction.

For Lower Sailor Bar, the decrease in the amount of fall-run Chinook salmon spawning habitat for flows greater than 1,500 cfs and for steelhead spawning habitat for flows greater than 6,000 cfs reflects the substantial proportion of the site that had suitable substrates prior to construction (Figure 9). Thus, spawning habitat changes associated with adding gravel were not associated with changes in substrate (Figures 9 and 10), but rather with increased velocities and shallower depths after gravel addition. The change in depths and velocities resulted in decreased combined suitabilities associated with higher than optimal velocities at higher flows, but increased combined suitabilities at lower flows as velocities increased to closer to optimal levels. The habitat predictions of this modeling are based on the assumption that pre-restoration substrates with suitable sizes were otherwise suitable for spawning, for example having sufficient intergravel velocities. Pre-restoration sampling by Sacramento State University could be used to test the validity of this assumption.

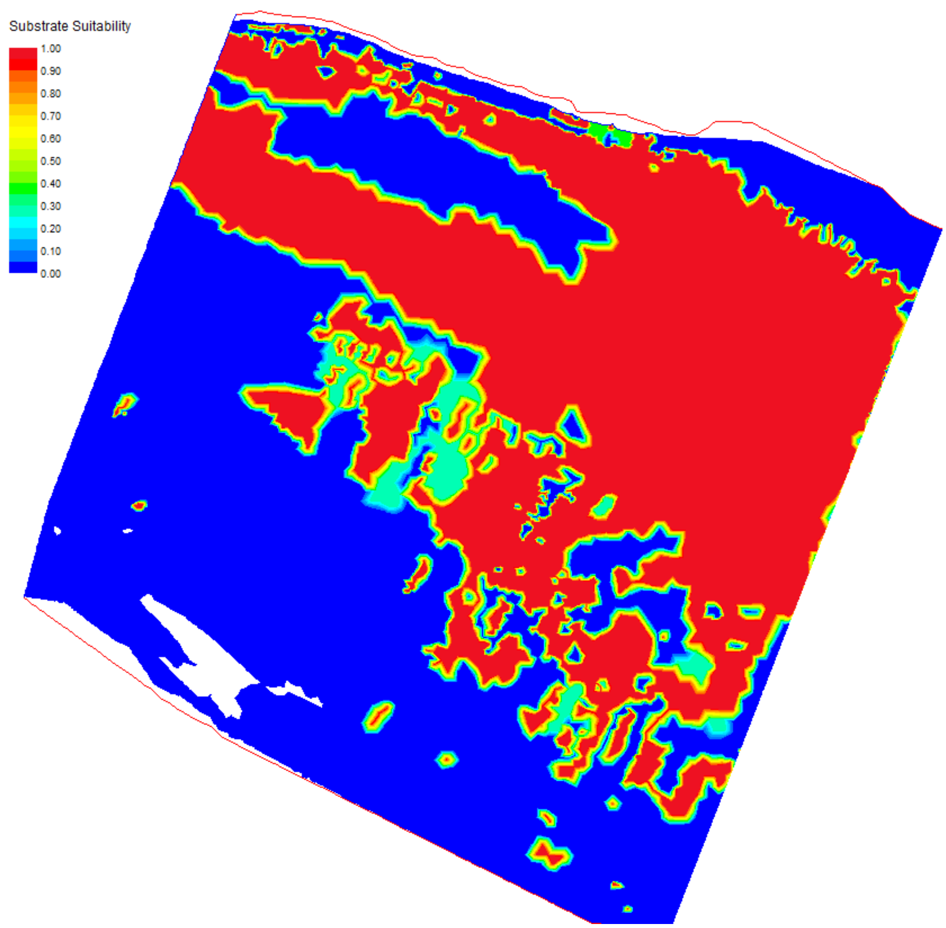


Figure 9
Lower Sailor Bar pre-restoration fall-run Chinook salmon spawning substrate suitability

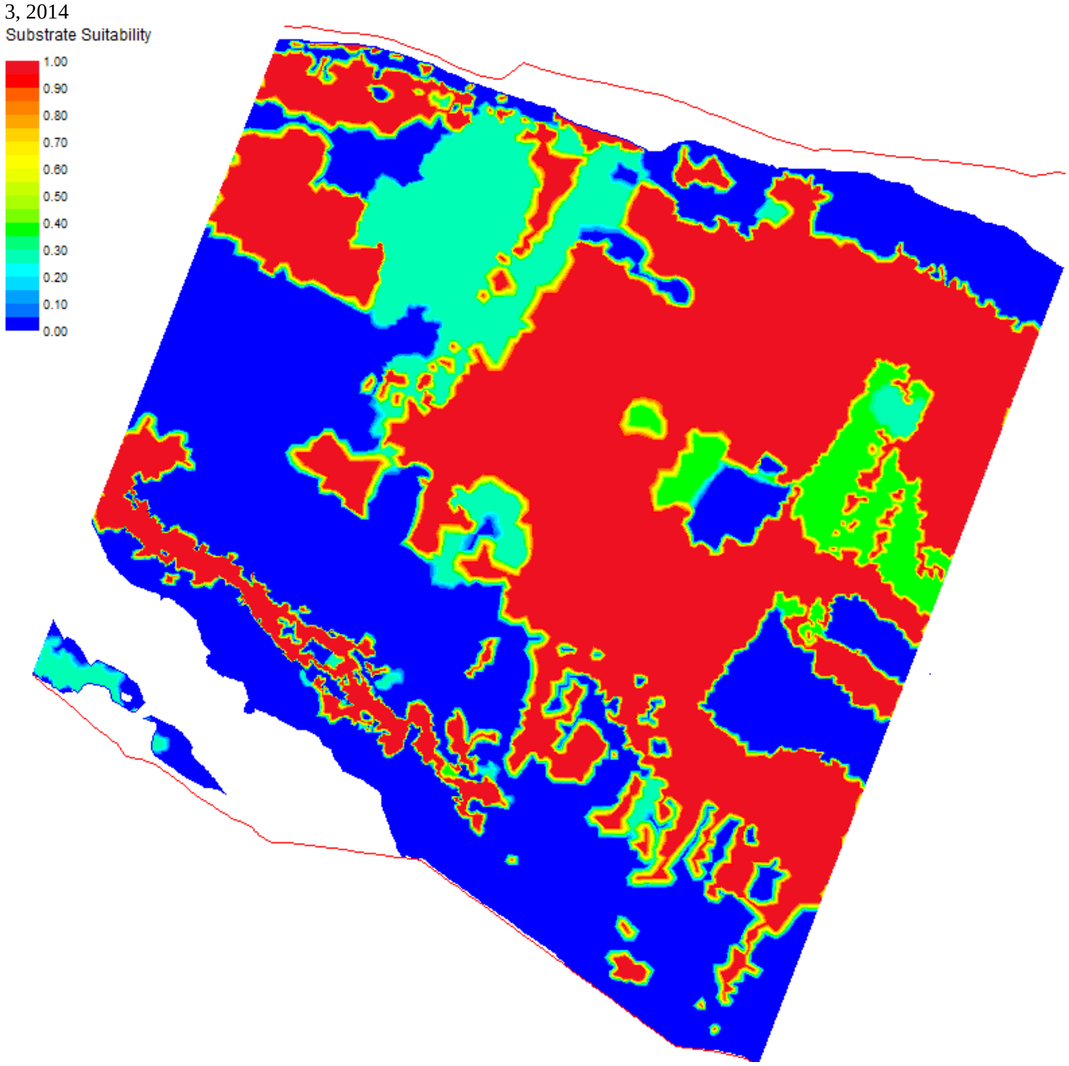


Figure 10
Lower Sailor Bar post-restoration fall-run Chinook salmon spawning substrate suitability

Stanislaus River Floodplain Versus Flow Relationships

Methods

The goal of this task was to use a refined two-dimensional hydraulic model of the Stanislaus River developed by NewFields to update the relationship between floodplain area and flow for the Stanislaus River presented in our FY 2013 annual report. The hydraulic model developed by NewFields differed from the model presented in our FY 2013 annual report in the following aspects: 1) the NewFields model used a more refined topographic and Manning's n dataset; 2) NewFields calculated the total wetted area for each flow in ArcMap, rather than using the Surface-water Modeling System (SMS) software; and 3) NewFields developed small and large active channel polygons to subtract from the total wetted area to calculate floodplain area, rather than subtracting the total wetted area at the flow where floodplain inundation starts. We reviewed the NewFields model and found it acceptable with two exceptions: 1) the NewFields model used an incorrect downstream boundary condition; and 2) the NewFields active channel did not include perenially-inundated off-channel areas, which would not be considered floodplain habitat. We reran the NewFields model with the correct downstream boundary condition, and conducted a sensitivity analysis of the model output to assess the relative effects of the differences between the NewFields and FWS models. We also used the total floodplain area from the NewFields model at flows of 250, 500, 750 and 1000 cfs as estimates of the area of perenially-inundated off-channel areas, and subtracted these values from the total floodplain area calculated from the NewFields model at higher flows to estimate the total floodplain area excluding perenially-inundated off-channel areas. We used the resulting relationship between flow and inundated floodplain area, based on the 250 cfs perenially-inundated off-channel area estimate, together with historical stream gage data for the Stanislaus River at Ripon (USGS Gage 11303000), to compute the number of acre-days of inundated floodplain for an appropriate period of each year, such as February 1 to June 15, for 1996 to 2009. We then used this metric in a regression analysis with annual average fall-run Chinook salmon juvenile survival estimates based on rotary screw trap data (from Zeug et al. 2014) to understand how inundated floodplain area affects juvenile survival.

Results

Figure 11 shows the results of the sensitivity analysis for the effects of the differences between the FWS and NewFields model: 1) the difference between the FWS and NewFields SMS curves reflect the more refined topographic and Manning's n dataset used in the NewFields model; 2) the difference between the NewFields SMS and Arcmap curves reflect the effect of calculating the total wetted area in SMS versus Arcmap; and 3) the difference between the Newfields Arcmap and Active Channel curves reflects using the delineated active channel polygon to define the floodplain, rather than subtracting the total area at the flow at which floodplain inundation starts. The difference between the Small Active Channel and Modified Active Channel curves shows the effect of excluding the area of perennially inundated off-channel areas from floodplain area estimates. Figure 12 shows the minimal effects of different estimates of the area of perenially-inundated off-channel areas. Overall, our analysis indicates that the results presented in our FY 2013 annual report underestimated the amount of floodplain area present in the Stanislaus River. There was a significant relationship between juvenile survival and floodplain area (Figure 13), with floodplain area explaining 77 percent of the year to year variation in juvenile survival.

Discussion

We conclude that the flow-floodplain area relationship shown in Figure 12 is robust, based on the similarities between the FWS and NewFields floodplain area-flow relationships. The biological validation of the floodplain area-flow relationship increases confidence in the applicability of the flow-floodplain relationship to evaluate survival of juvenile anadromous salmonids in the Stanislaus River. The relationship can be used in developing instream flow recommendations for outmigrant anadromous salmonids.

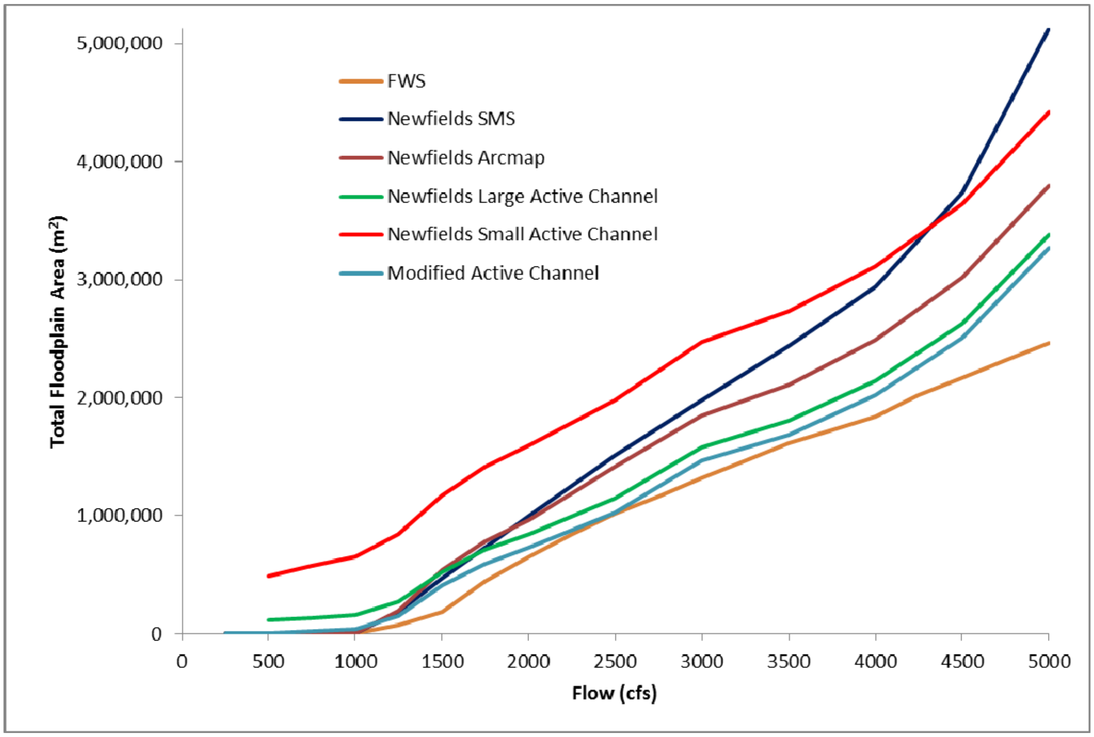


Figure 11
Floodplain versus flow relationships for the entire modeled portion of the Stanislaus River

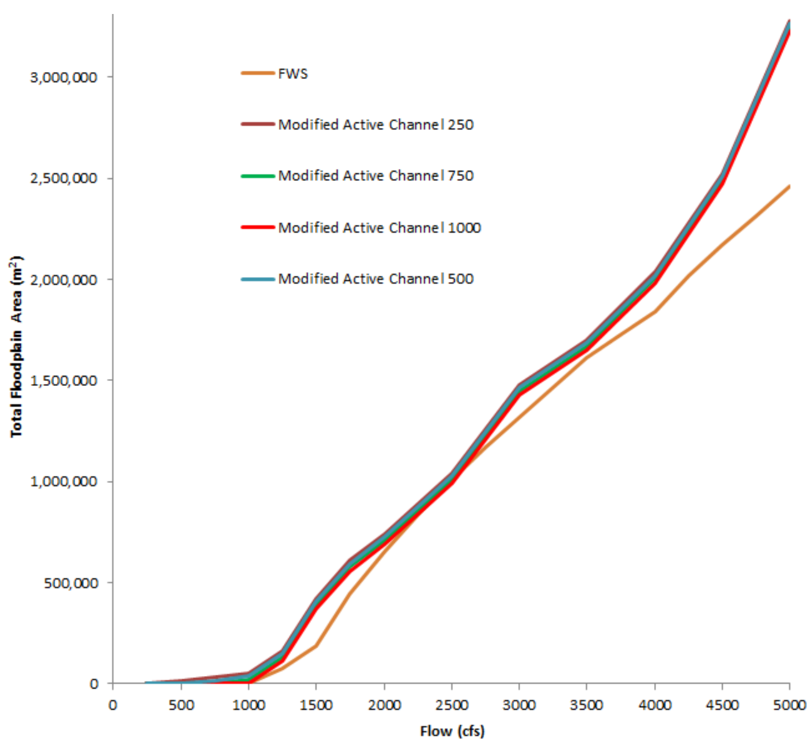


Figure 12
Effects of off-channel area estimates on Stanislaus River floodplain versus flow relationships

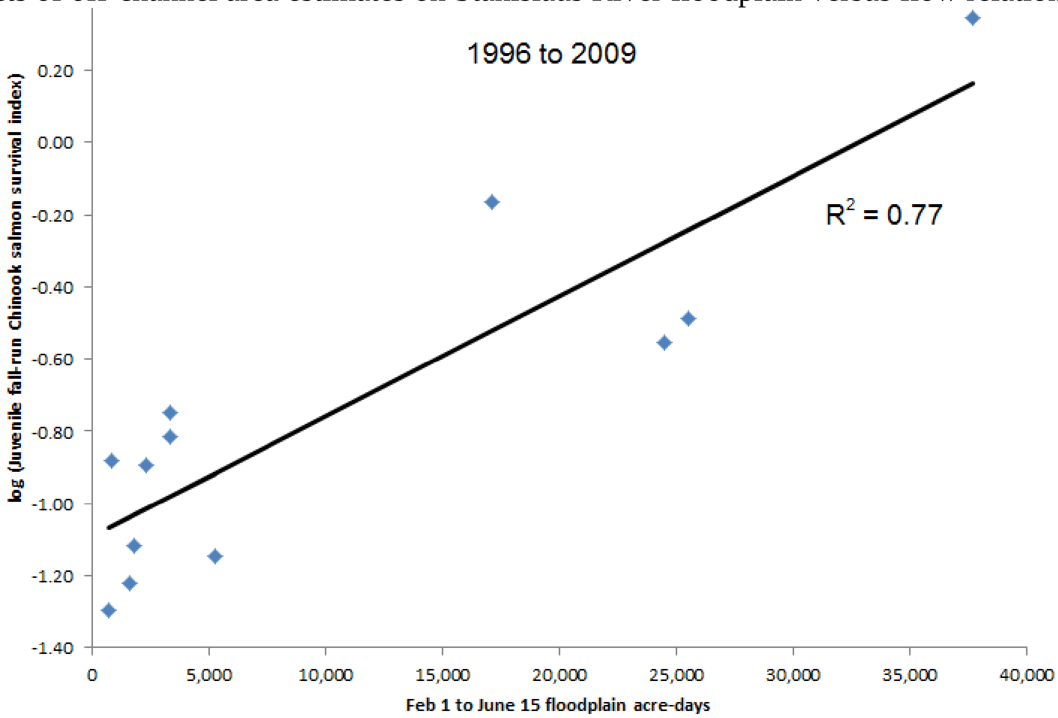


Figure 13
Relationship between juvenile survival and Stanislaus River floodplain area

Stanislaus River Floodplain Restoration Site Identification

Methods

This task involved applying the NewFields hydraulic model to identify potential floodplain restoration sites on the Stanislaus River between the mouth and Orange Blossom Bridge, a reach of the Stanislaus River where restoration projects have not yet been constructed. Polygons of each site were digitized in GIS using the terrain model used to develop the NewFields hydraulic model, with the resulting polygons used to calculate the area of each site. We ran the NewFields model at 650 cfs, and used the water surface elevation predicted at each site, minus 0.5 feet, to calculate the elevation that would have a depth of 0.5 feet at 650 cfs. This design elevation for each site was used, along with the terrain model, to estimate the cut volume (amount of earth that would need to be removed) for each site to have a uniform depth of 0.5 feet in each site at 650 cfs. We also identified the landowners and existing land uses, and evaluated the ease of access for each site.

Results

We identified 28 potential Stanislaus River floodplain restoration sites (Table 4) between the mouth and Orange Blossom Bridge.

Table 4
Potential Stanislaus River Floodplain Restoration Sites

Site	Area (m^2)	Cut Volume (m^3)
1	55,056	78,138
2	8,804	12,597
3	26,541	42,177
4	37,067	99,012
5	16,193	49,814
6	17,270	21,638
7	23,466	17,934
8	12,306	21,740
9	9,391	12,511
10	9,584	15,796
11	5,720	5,597
12	5,280	8,567
13	17,923	38,092
14	34,615	44,906
15	5,349	6,564
16	22,728	25,736
17	8,580	9,892
18	12,301	16,742
19	11,523	17,253
20	13,143	3,265
21	65,813	141,572
22	8,991	13,632
23	4,393	4,002
24	9,994	10,248
25	11,789	18,817
26	5,545	3,949
27	23,875	62,058
28	11,953	14,559

Discussion

The next step in developing restoration projects from the list in Table 4 would be to identify interested landowners. The terrain model can then be used to develop preliminary designs and cost estimates, as well as assessing feasibility. The list of potential sites in Table 4 represent a range of potential benefits in terms of floodplain areas, as well as a range of potential costs for projects that may be accomplished at a range of funding levels.

Merced River Floodplain Versus Flow Relationships

Methods

The goal of this task is to develop two-dimensional hydraulic models to quantify the relationship between floodplain area and flow for the following five reaches of the Merced River: 1) mouth of Merced River to Stevinson; 2) Stevinson to Cressy; 3) Cressy to Shaffer Bridge; 4) Shaffer Bridge to Snelling; and 5) Snelling to Crocker-Huffman (Figure 14), for flows ranging from 250 to 9,000 cfs. Topographic data were collected using a combination of an Acoustic Doppler Current Profiler (ADCP) and a survey-grade RTK GPS unit for the deeper portions. For each traverse with the ADCP, the RTK GPS was used to record the horizontal location and WSEL at the starting and ending location of each traverse, while the ADCP provided depths and distances across the traverse. The WSEL of each ADCP traverse is then used together with the depths from the ADCP to determine the bed elevation of each point along the traverse. For shallow areas, topographic data was collected while wading with the RTK GPS unit. There was only enough funding in FY 2014 for this task for four weeks of data collection. In addition to the above data, Light Detection and Ranging (LIDAR) and bathymetry cross-section data collected by the California Department of Water Resources and National Marine Fisheries Service, as well as 1.2 miles of topography data collected for the Merced Ranch and Henderson Park restoration projects, will be used as the topographic data source for the hydraulic model. We installed pressure transducers near the mouth of the Merced River to use to develop the downstream boundary condition for the hydraulic model of the mouth of Merced River to Stevinson reach. The data from these pressure transducers, together with stage and flow data from the Newman gage (CDEC Gage NEW), located on the San Joaquin River downstream from the mouth of the Merced River, and Merced River flows, will be used to develop a regression equation to predict the stage at the mouth of the Merced River from the Newman gage rating curve. The stage from the rating tables of the Stevinson (CDEC Gage MST), Cressy (CDEC Gage CRS), Shaffer Bridge (CDEC Gage MBN) and Snelling (CDEC Gage MSN) gages will be used as the downstream boundary conditions for the hydraulic models of the other reaches.

Results

In FY 2014, we obtained LIDAR and bathymetry data from the California Department of Water Resources. This data only covers the lower half of the Merced River below Crocker-Huffman Dam, and the bathymetry cross-section data was collected at too wide intervals to adequately define the in-channel portion of the topography. As a result, we collected topographic data to

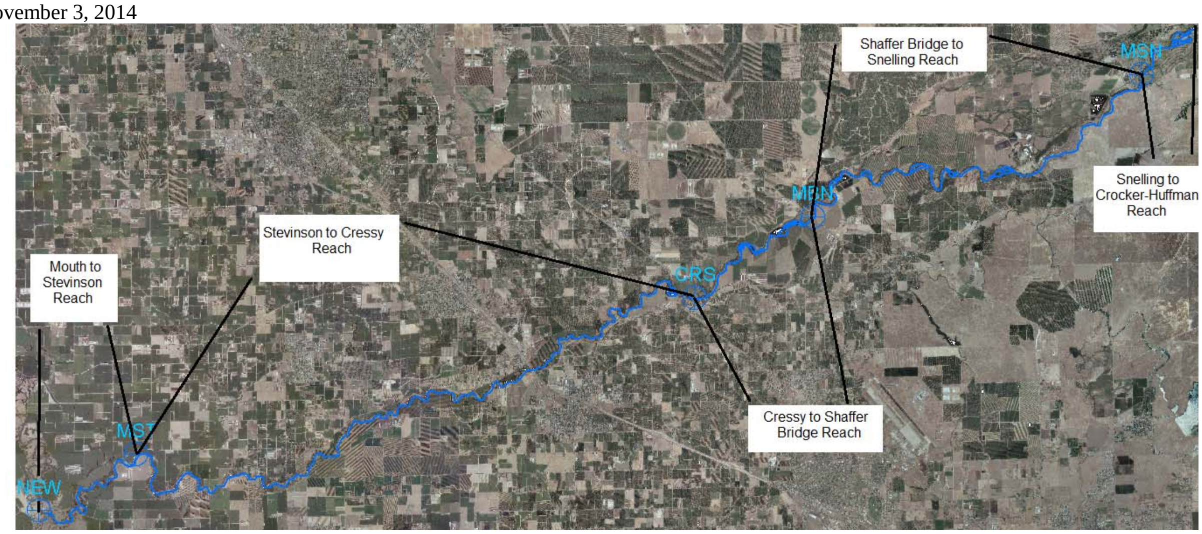


Figure 14
Merced River floodplain modeling reaches

supplement the California Department of Water Resources' bathymetry data in the lower half of the Merced River, and collected topographic data in the upper half of the Merced River, to use in developing the Merced River floodplain model. The National Marine Fisheries Service plans to collect LIDAR data for the upper half of the Merced River in the fall of 2014. Due to low-flow conditions in FY 2014 slowing our data collection efforts, we were only able to finish collecting topography data for 26.1 of the 52 miles of the Merced River between the mouth and Crocker-Huffman Dam. Completion of our data collection efforts and conducting modeling is dependent on the availability of funding in FY 2015.

Yuba River Floodplain Versus Flow Relationships

Methods

The goal of this task was to quantify the relationship between floodplain area and flow using Dr. Greg Pasternack's entire Yuba River hydraulic model (Pasternack 2012). In addition to the model runs provided by Pasternack, we also ran the model for the lower-most reach at flows of 84,400 and 110,400 cfs, using SRH-2D (USBR, Denver, CO). The model output was processed in SMS to compute the total wetted area at each flow. The resulting total wetted area versus flow graph was then examined to determine the flow at which floodplain inundation begins, as shown by an inflection point in the graph[4]. If an inflection point was detected, the total wetted area at higher flows was then subtracted from the total wetted area at which floodplain inundation begins to determine the inundated floodplain area at each flow.

[4] This methodology was applied because it had been successful in identifying the flow at which floodplain inundation starts on the Stanislaus and Tuolumne Rivers. We are not aware of any data to indicate whether inflection points would be expected in the hydrological analyses of most rivers, although the method has parallels to the field-based methods used to identify bank-full flow (Rosgen1996).

Results

None of the reaches showed an inflection point in the total wetted area versus flow graph. As a result, we examined the model output in SMS to visually identify the lowest flow at which any floodplain area was inundated (Figure 15). The overall floodplain area versus flow relationship is shown in Figure 16.

Discussion

The floodplain area estimates for 84,400 and 110,400 cfs are underestimates of the inundated floodplain area at those flows, as the entire inundated area for flows greater than 80,000 cfs was not included in the hydraulic model of the lower-most reach. The relationship in Figure 16 can be used in developing instream flow recommendations for outmigrant anadromous salmonids in the Yuba River.

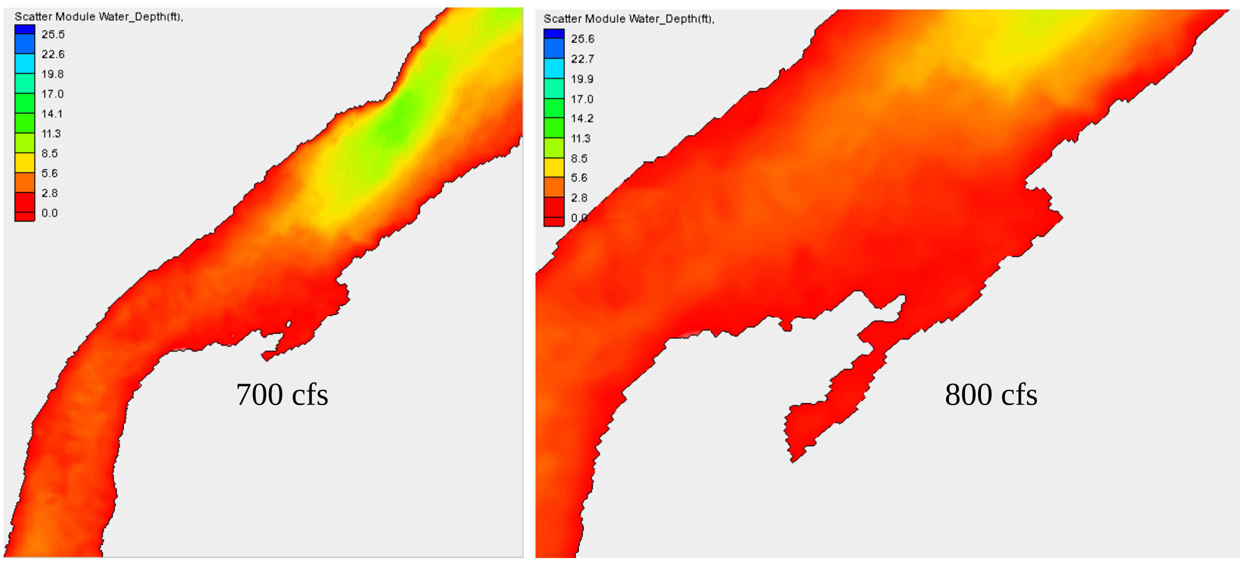
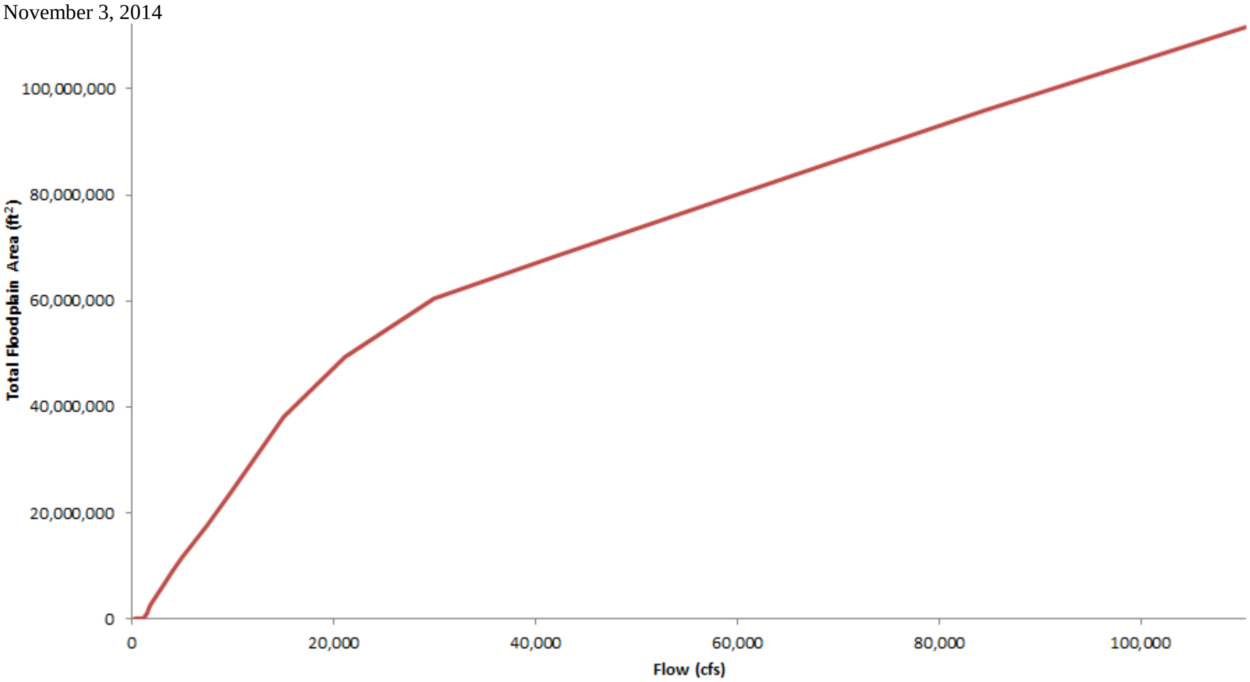


Figure 15
Example from Highway 20 to Narrows Reach of identification of floodplain area inundation



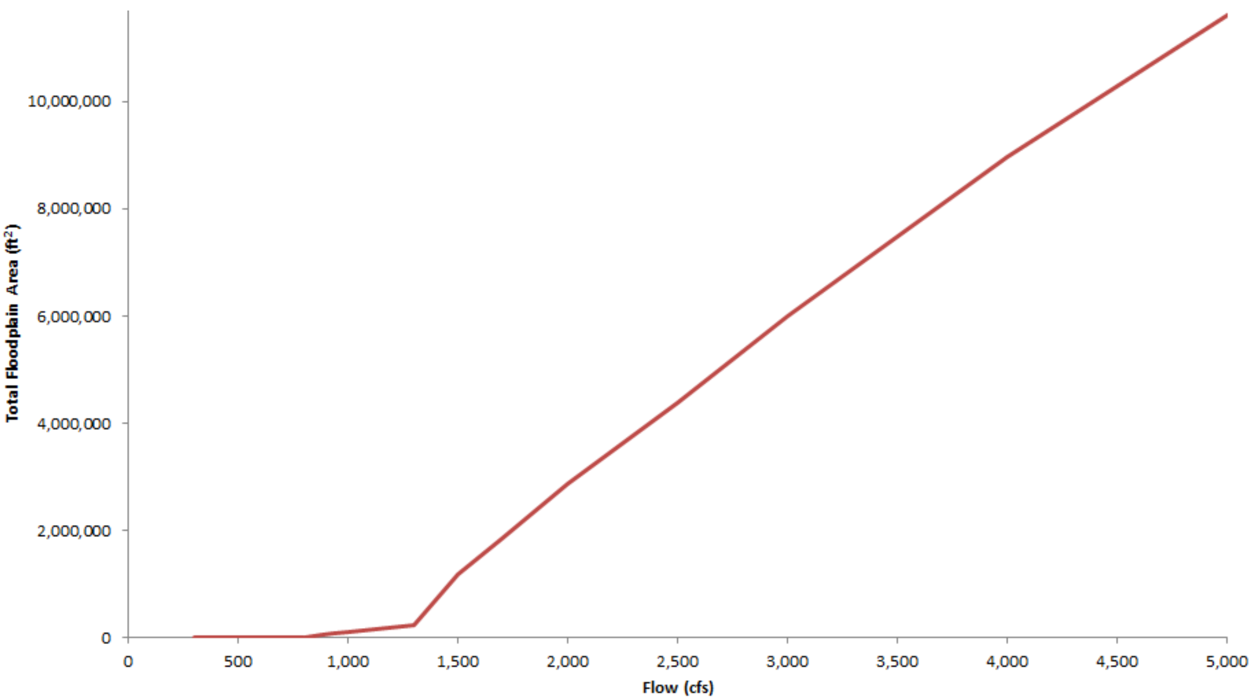


Figure 16
Yuba River floodplain area versus flow relationship

Yuba River Hammon Bar Restoration Project Monitoring

Methods

The goal of this task was to quantify the amount of juvenile anadromous salmonid rearing habitat created by the Hammon Bar restoration project. A six acre riparian restoration site was implemented at Hammon Bar on the Yuba River with funding from FWS. Riparian habitat can benefit anadromous fish by reducing velocities and providing woody cover. In January and February 2014, we collected topographic, substrate and cover data at the Hammon Bar second year riparian restoration site. Topographic data were collected using survey-grade RTK GPS units. We also collected substrate and cover data for each topographic point collected with the survey-grade RTK GPS unit. The RTK GPS data had an accuracy of 0.1 foot horizontally and vertically. We combined this data with topographic data we had collected in 2012 for the pilot phase of the Hammon Bar restoration site and additional topography data from Dr. Greg Pasternack, covering the areas we were unable to sample due to time constraints (primarily a downstream extension). The combined dataset was used to develop second year post-restoration and grow-out bed and mesh files, using the methods given above for the American River Above Sunrise and Lower Sailor Bar gravel projects. Grow-out conditions were simulated by assuming that the cover code for all of the planting locations would eventually either be 3.7 or 4.7, depending on the cover code present during data collection. The computation mesh was used in River2D, along with water surface elevations from Dr. Greg Pasternack's entire Yuba River hydraulic model (Pasternack 2012) (as the downstream boundary condition) to model fry and juvenile Chinook salmon and steelhead/rainbow trout habitat for flows ranging from 2,000 to 42,200 cfs[5], using the habitat suitability criteria from our Yuba River instream flow study (U.S. Fish and Wildlife Service 2010a), for second year post-restoration and grow-out conditions. Pre-restoration habitat was assessed using the pre-restoration River2D model we developed in FY 2013 for the pilot phase of the Hammon Bar project. During data collection, we discovered that the project area was actually larger than what we had assumed in our assessment of the pilot phase. As a result, we recalculated the habitat for the pre-restoration and post-restoration and grow-out conditions for the pilot project using the enlarged project area.

Results

The hydraulic model indicated that the plantings started to become inundated at a flow of 5,000 cfs and were fully inundated at a flow of 42,200 cfs. Results are shown in Figures 17 to 20. The largest increase in habitat, relative to pre-restoration conditions, was 56 percent for second-year grow-out for fall-run Chinook salmon fry at 25,000 cfs.

[5] A flow of 2,000 cfs is the flow at which the restoration site begins to be inundated, while 42,200 cfs is the highest flow simulated by Pasternack's model.

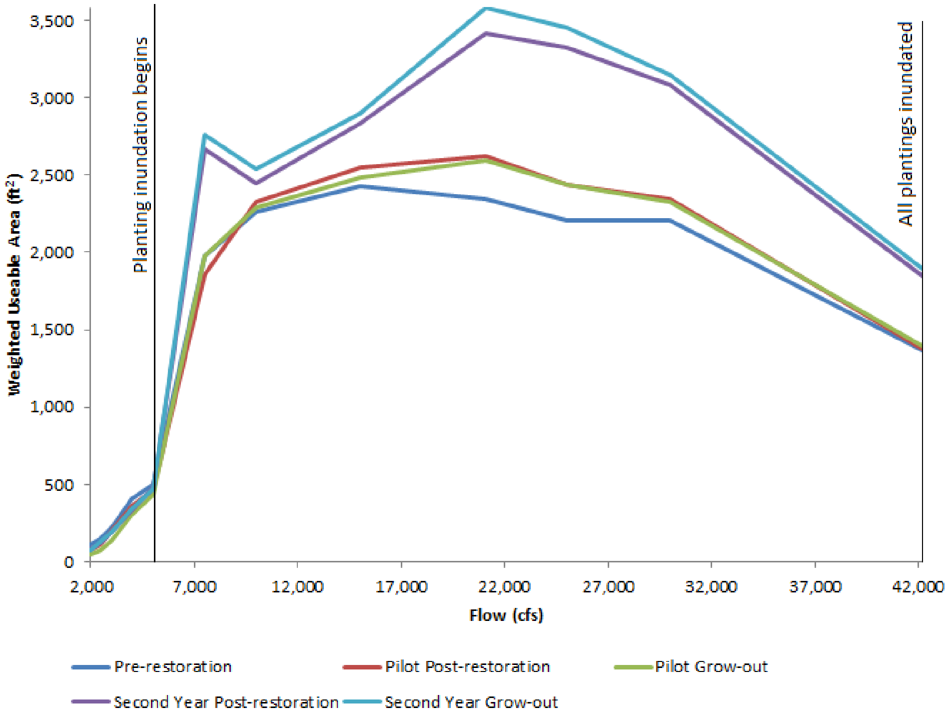


Figure 17
Fall-run Chinook salmon fry rearing flow-habitat relationships before, after and at grow-out of the pilot and second year riparian plantings at Hammon Bar

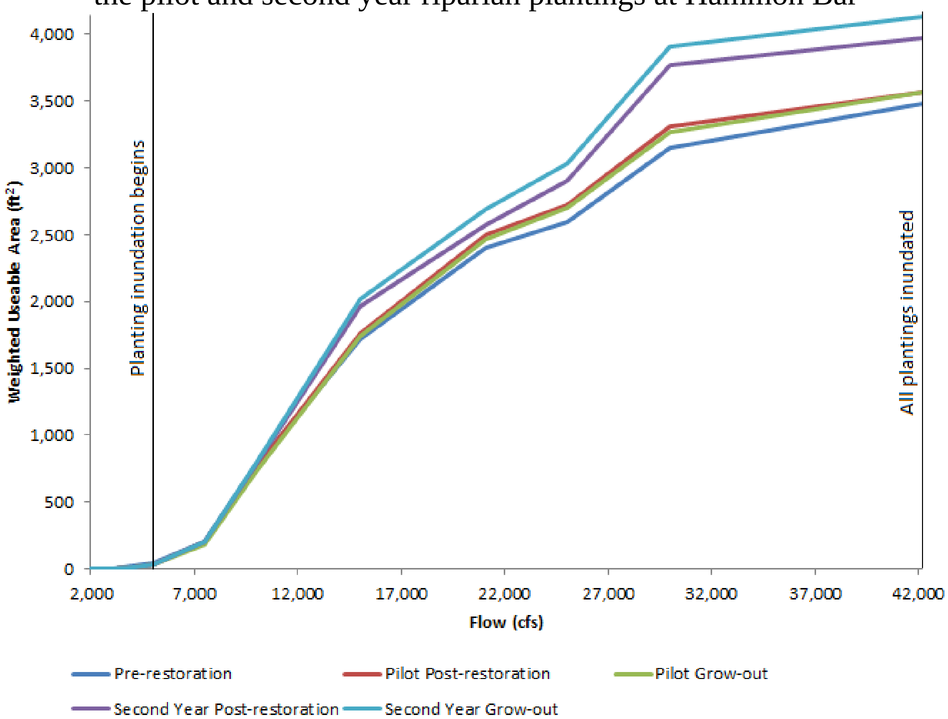


Figure 18
Fall-run Chinook salmon juvenile rearing flow-habitat relationships before, after and at grow-out of the pilot and second year riparian plantings at Hammon Bar

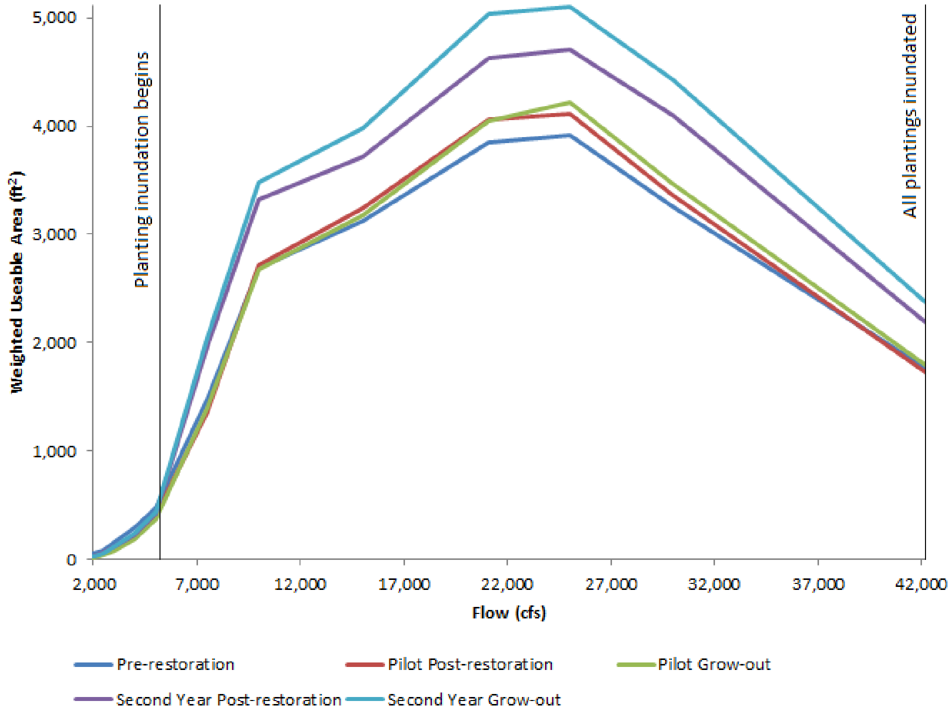


Figure 19
Steelhead fry rearing flow-habitat relationships before, after and at grow-out of the pilot and second year riparian plantings at Hammon Bar

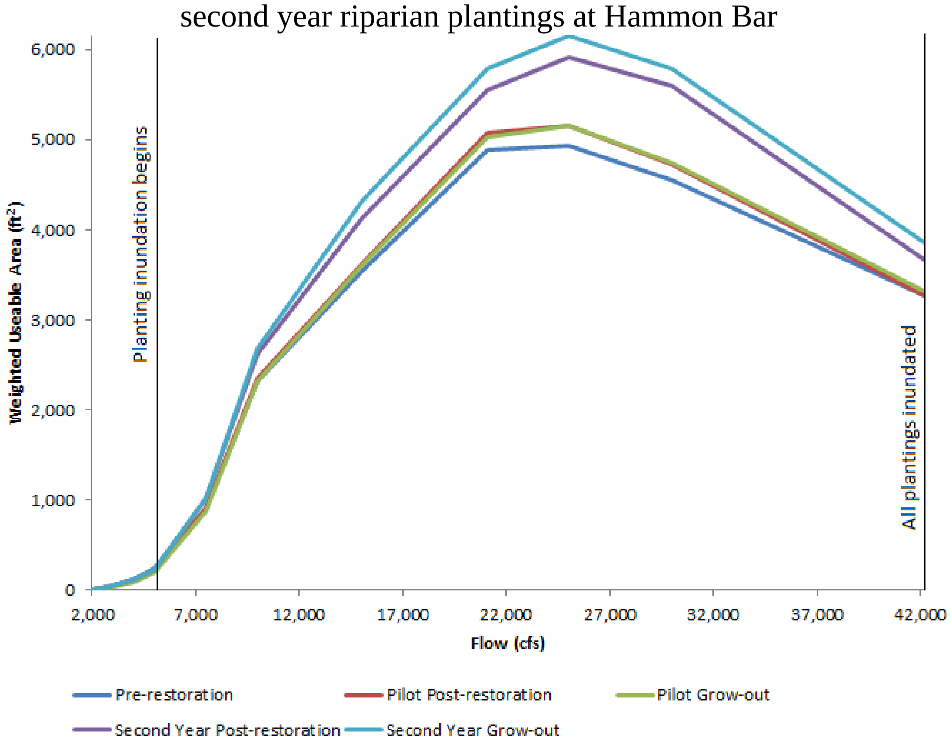


Figure 20
Steelhead juvenile rearing flow-habitat relationships before, after and at grow-out of the pilot and second year riparian plantings at Hammon Bar

Discussion

The increased fry and juvenile habitat caused by the riparian plantings is a combination of reduced velocities due to increased bed roughness from the plantings and the higher habitat suitability of the woody material comprising the plantings, versus the original largely unvegetated floodplain. The plantings show little to no benefit until flows reach 10,000 cfs, reflecting the relatively high elevations at which the plantings were made. The plantings show the greatest benefit for fall-run Chinook salmon fry rearing habitat, reflecting the lower velocity preference for fry, versus juvenile, and the lower preference for non-woody cover, versus steelhead.

Yuba River Daguerre Alley Restoration Project Monitoring

Methods

In October 2013 to February 2014, we completed collecting topography, cover and substrate data for the Daguerre Alley restoration project, using RTK GPS units for dry and shallow areas, using the methods described above for Hammon Bar, and a combination of ADCP and RTK GPS for deep areas, using the same methods described above for the Merced River. We mapped in substrate and cover polygons for the areas sampled with the ADCP; the vertices of these polygons were recorded with the survey-grade RTK GPS unit. We also installed pressure transducers at the upstream and downstream end of the Daguerre Alley project to determine if the stage-discharge relationships at these locations had changed since the data were collected to develop Pasternack's entire river model (Pasternack 2012). During data collection, we observed some flow in the lower portion of Daguerre Alley. We used a GPS unit to record the horizontal location of the source of this flow (seepage from levees on the southern side of Daguerre Alley), and measured the flow on June 17, 2014 using a tape, wading rod and Marsh-McBirney velocity meter.

Since Pasternack's entire river model indicated that flow into Daguerre Alley started at flows between 10,000 and 15,000 cfs, we ran Pasternack's model for the Daguerre Reach at 11,000, 12,000, 13,000 and 14,000 cfs. We combined the topographic data we collected with topography data from Pasternack, covering the areas we were unable to sample due to time constraints. The combined dataset was used to develop pre-restoration bed and mesh files, using the methods given above for the American River. The computation mesh was used in River2D, along with water surface elevations from Pasternack's entire Yuba River hydraulic model, modified based on our pressure transducer data (as the downstream boundary condition), and Daguerre Alley flow (calculated from depth and velocity output of Pasternack's entire Yuba River hydraulic model) to model fry and juvenile Chinook salmon and steelhead/rainbow trout habitat for flows ranging from 11,000 to 15,000 cfs, using the habitat suitability criteria from our Yuba River instream flow study, for pre-restoration conditions. For these runs, the upstream boundary of the River2D model was at the upstream end of Daguerre Alley. We also ran the River2D model using the seepage flow measured on June 17, 2014 and a seepage flow of 5 cfs, for Yuba River flows of 1,000 and 2,000 cfs[6]. For these runs, the upstream boundary of the River2D model was at the seepage location. We also simulated the habitat that would be produced from releasing 20 cfs from the Hallwood-Cordua Canal for Yuba River flows of 1,000 and 2,000 cfs. For these runs, the upstream boundary of the River2D model was at the location where the fish return pipe from the Hallwood-Cordua Canal fish screen passes under Daguerre Alley. The flow of 20 cfs represents the typical flow in the fish return pipe, which currently runs all the way to the main channel of the Yuba River.

Results

The seepage flow on June 17, 2014 was 0.3 cfs. Our pressure transducer data indicated that there had not been a change in the stage-discharge relationship at the upstream end of Daguerre Alley, indicating that the inflows to Daguerre Alley predicted by Pasternack's entire river model, which would be controlled by the hydraulic conditions at the upstream end of Daguerre Alley, would not have changed. Our pressure transducer data showed a significant downward shift in the stage-discharge relationship at the downstream end of Daguerre Alley, as compared to when the data was collected to develop Pasternack's model. Based on output from Pasternack's model and our pressure transducer data, we developed the following equation to adjust the water surface elevation at the downstream end of Daguerre Alley predicted by Pasternack's model:

$$\text{Log (rating curve shift in feet)} = -0.67 + 0.219 \times \log \text{(flow in cfs)}$$

We subtracted the rating curve shift, calculated from the above equation, from the water surface elevation predicted by Pasternack's model at the downstream end of Daguerre Alley to obtain the downstream boundary condition we used for our River2D model.

For higher areas, the elevations of topographic data from Pasternack's entire river model generally agreed with the elevations we measured. However, with the exception of the downstream-most deep area in Daguerre Alley, the elevations in deeper areas of the topographic data from Pasternack's model were consistently much higher than the elevations we measured. This likely indicates that the LIDAR data from these areas (used in Pasternack's model) were actually water surface elevations rather than bed elevations. Given that the deeper areas in Daguerre Alley are generally perennially inundated from seepage, this conclusion is consistent with what would be expected from LIDAR data in these areas. Based on the above, Pasternack's model would underestimate depths in most of the deeper areas in Daguerre Alley, and the topographic data from Pasternack's model for such areas should not be used in designing restoration projects in Daguerre Alley.

Results are shown in Table 5. The largest increase in habitat, relative to pre-restoration conditions, for a release of 20 cfs from the Hallwood-Cordua Canal to Daguerre Alley, was 309 percent for steelhead fry.

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[6] These flows were used to determine the downstream boundary condition for the Daguerre Alley River2D model.

Table 5. Weighted Useable Area Values (ft^2)

Yuba River Flow (cfs)	Seepage Flow (cfs)	H-C Canal Release (cfs)	Fall-run Chinook salmon Fry	Fall-run Chinook salmon Juvenile	Steelhead Fry	Steelhead Juvenile
11,000	0	0	263,217	11,088	121,961	22,769
12,000	0	0	293,410	35,190	179,200	62,303
13,000	0	0	306,984	45,431	197,428	75,667
14,000	0	0	316,372	65,634	218,547	92,281
15,000	0	0	324,683	76,465	227,381	109,444
1,000	0.3	0	48,232	1,390	16,830	2,783
2,000	0.3	0	61,764	2,602	23,797	4,427
1,000	5	0	48,428	1,416	16,896	2,803
2,000	5	0	44,979	1,307	15,817	2,485
1,000	0	20	136,551	3,087	52,068	7,500
2,000	0	20	108,058	2,130	39,162	5,176

Discussion

Since Yuba River flows are rarely greater than 10,000 cfs, the habitat associated with seepage flows is a better representation of typical pre-restoration habitat conditions in Daguerre Alley. The habitat values in Table 5 will provide a useful baseline habitat assessment to compare to various restoration options for Daguerre Alley, as well as an estimate of the benefits for anadromous salmonid rearing habitat that would result from releases of flow from the Hallwood-Cordua Canal to Daguerre Alley.

South Fork Cottonwood Creek Habitat Assessment

Methods

The goal of this task was to assess the quality of anadromous salmonid habitat in six miles of South Fork Cottonwood Creek as part of pre-project monitoring of the Hammer Dam removal restoration project. On November 5-6, 2013 and July 28-29, 2014, we hiked, wading and swam South Fork Cottonwood Creek between RM 43.5 and 49.5 (Figure 21). We conducted mesohabitat mapping, using the criteria in Table 6, and marked the ends of each mesohabitat unit with a Garmin GPS unit. The Rosgen channel type (Rosgen 1996) was recorded for each mesohabitat unit. In addition, the percentage of spawning gravel and percentage of bank with woody cover for each mesohabitat were recorded as metrics of habitat quality. In addition, for pools, the maximum pool depth, riffle crest depth, pool tail percent embeddedness and pool tail percent surface fines were recorded.

We also established 13 transects downstream of Hammer Dam to use as a baseline to assess potential channel changes from the removal of Hammer Dam, which was scheduled for summer-fall 2014 and occurred on September 19, 2014. Transect pins (headpins and tailpins) were marked on each creek bank above bank-full using rebar driven into the ground and/or lag bolts

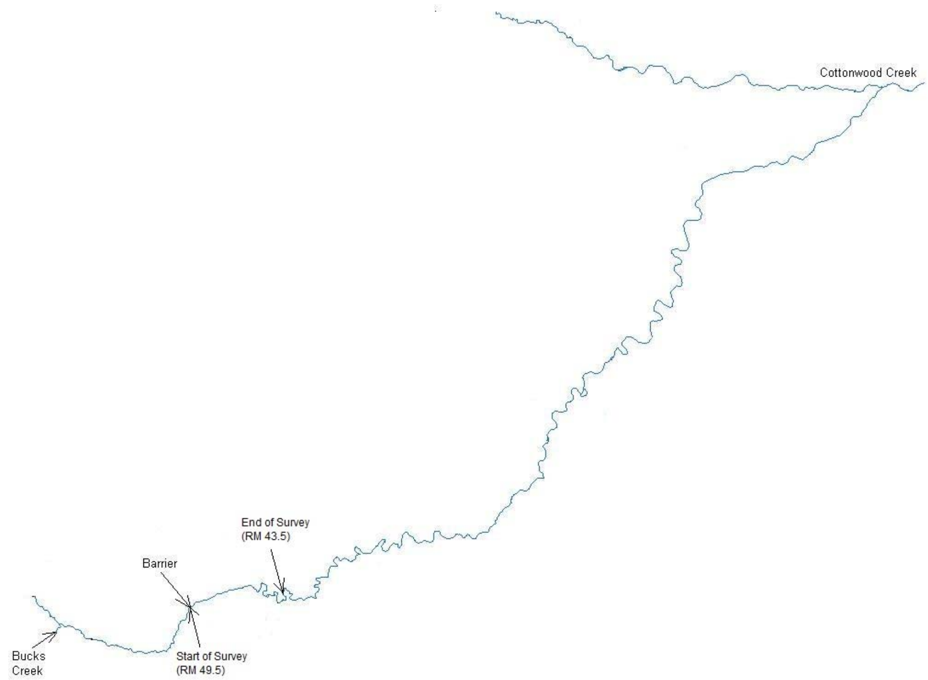

Figure 21
South Fork Cottonwood Study Area

Table 6. Mesohabitat type definitions (from Snider et al. 1992).

Habitat Type	Definition
Pool	Primary determinant is downstream control - thalweg gets deeper as go upstream from bottom of pool. Fine and uniform substrate, below average water velocity, above average depth, tranquil water surface. Depth is not used to determine whether a mesohabitat unit is a pool.
Glide	Primary determinants are no turbulence (surface smooth, slow and laminar) and no downstream control. Low gradient, substrate uniform across channel width and composed of small gravel and/or sand/silt, depth below average and similar across channel width, below average water velocities, width of channel tends to spread out, thalweg has relatively uniform slope going downstream.
Run	Primary determinants are moderately turbulent and average depth. Moderate gradient, substrate a mix of particle sizes and composed of small cobble and gravel, with some large cobble and boulders, above average water velocities, usually slight gradient change from top to bottom, thalweg has relatively uniform slope going downstream.
Riffle	Primary determinants are high gradient and turbulence. Below average depth, above average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable.

placed in tree trunks. Survey flagging was used to mark the locations of each pin. GPS coordinates were recorded for each pin using a survey-grade RTK GPS unit. Vertical benchmarks were established for each transect to serve as the vertical elevations to which all streambed elevations were referenced. Vertical benchmarks consisted of lag bolts driven into trees. Bed elevation profiles were measured for each transect using standard surveying techniques (differential leveling), and a tape to record stations.

The GPS data from the habitat mapping were put in GIS to make polyline shapefiles of the mesohabitat units, which were then used to calculate the length of each mesohabitat unit. Residual pool depths were computed by subtracting the riffle crest depth from the maximum pool depth. The transect data were entered into an Excel spreadsheet to generate bed elevation profiles.

Results

Of the six miles surveyed, five miles were upstream of Hammer Dam and one mile was downstream of Hammer Dam. The mesohabitat composition of the six miles of South Fork Cottonwood Creek was 39 percent pool, 9 percent glide, 12 percent riffle and 40 percent run, plus one cascade. The percent spawning gravel and percent of banks with woody cover, with the percentages of each mesohabitat unit weighted by the length of the mesohabitat units, were, respectively, 15 and 17 percent. We did not quantify the typical sizes of areas that could be considered suitable spawning habitat. The Rosgen channel types present in the six miles were B2 (moderate gradient boulder dominated), B3 (moderate gradient cobble dominated), C1 (low gradient bedrock dominated), C2 (low gradient boulder dominated), C3 (low gradient cobble dominated) and C4 (low gradient gravel dominated). The maximum pool depths ranged from 1.6 to 10 feet, with a mean of 3.6 feet. Residual pool depths ranged from 1.1 to 9.7 feet, with a mean of 3.2 feet. Riffle crest depths ranged from 0.2 to 1.1 feet, with a mean of 0.5 feet, reflecting the low flow conditions present during the surveys. The average pool tail embeddedness and percent surface fines were, respectively, 10 and three percent. Half and two-thirds of the pool tails, respectively, had zero embeddedness and zero percent surface fines.

Our surveys were conducted at the end of July in the 4^{th} year of the historic CA drought. Following protocol, we assessed the habitat with the stream conditions present during our presence. We observed a five foot waterfall with no downstream plunge pool (Figure 22) located at RM 48.76, 4.26 miles upstream of Hammer Dam. Given that there is no downstream plunge pool, this waterfall would be an upstream passage barrier for adult salmonids at all flows. We also observed a 3.2 feet tall waterfall with a one-foot deep downstream plunge pool located at RM 48.37, 3.87 miles upstream of Hammer Dam; a 3.1 feet waterfall with a three feet deep downstream plunge pool located at RM 47.97, 3.47 miles upstream of Hammer Dam; a 2.7 feet tall waterfall with a 1.7 foot deep downstream plunge pool located at RM 47.52, 3.02 miles upstream of Hammer Dam; and a 4.2 feet tall waterfall with a 1.1 foot deep downstream plunge pool located at RM 46.62, 2.12 miles upstream of Hammer Dam. These waterfalls are likely

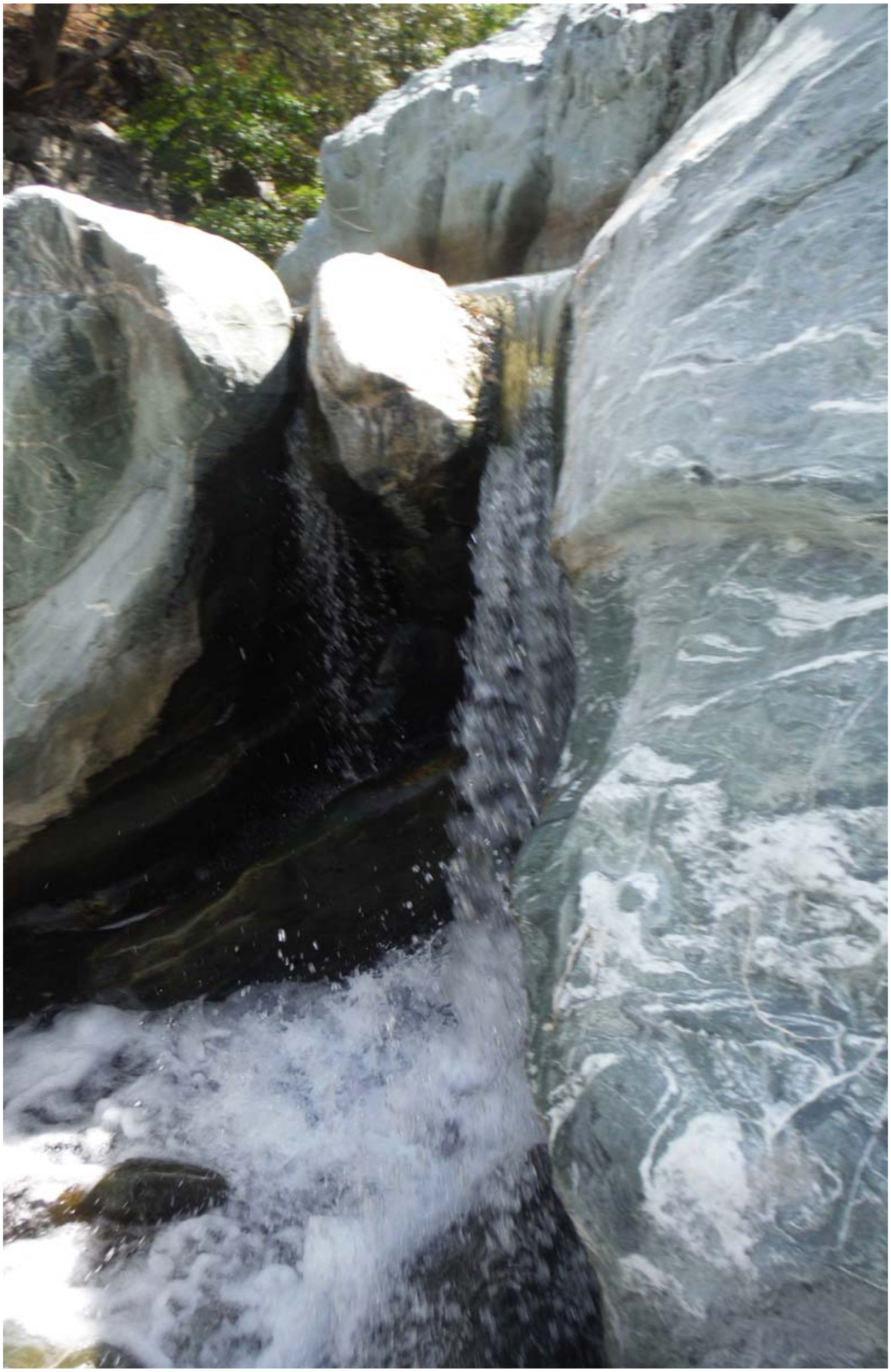

Figure 22
South Fork Cottonwood Creek Upstream Passage Barrier

only upstream passage barriers for anadromous salmonids at low flows[7]. All of the above waterfalls were observed on July 28-29, 2014, when South Fork Cottonwood Creek flows were around 2 cfs.

Pre-restoration cross-section profiles of the thirteen transects installed downstream of the Hammer Dam site (river mile 44.5) are shown in Figures 23 to 35.

Discussion

The results of our surveys indicate that there are only 4.26 miles of accessible anadromous salmonid habitat upstream of Hammer Dam, rather than the five miles previously identified. The percentages of spawning gravel and bank woody cover indicate that the habitat is capable of supporting a moderate density of anadromous salmonids. Surveys at higher flows would be useful to identify the flow range at which the other waterfalls identified are barriers to upstream passage. The data that we collected, together with the additional six transects surveyed by Northwest Hydraulic Consultants (located within 1000 feet of the Hammer Dam site), will serve as a good baseline to assess the effects of removing Hammer Dam. The plan is to re-measure these transects after the first, second and third high flows.

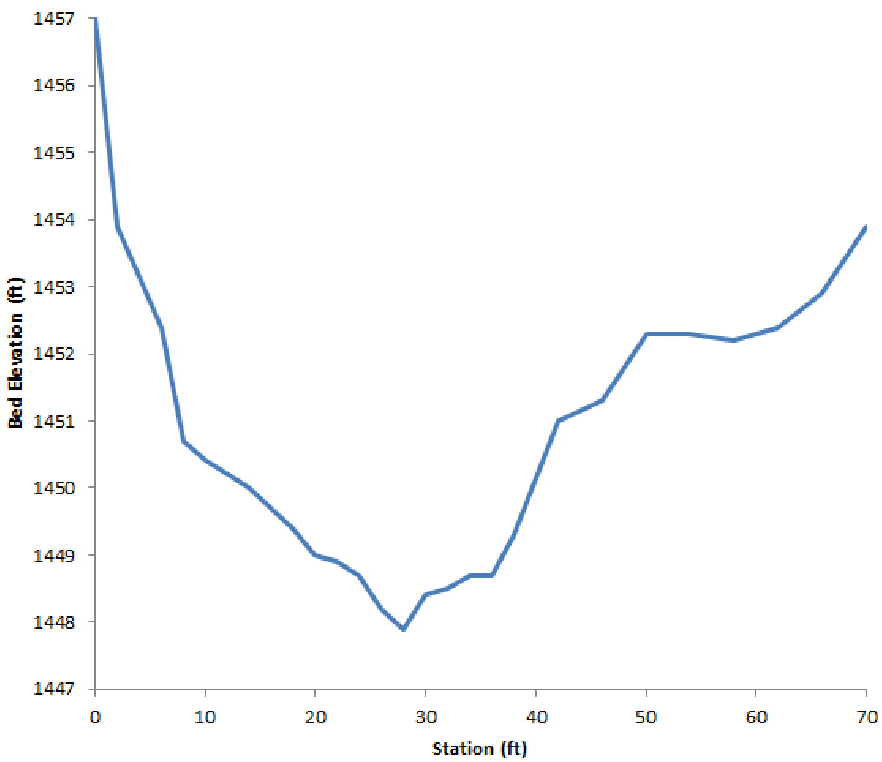

Figure 23
Hammer Cross-Section 1

[7] Per Gallagher (1999), waterfalls are considered to be a barrier to upstream passage when the depth of the plunge pool is less than 1.25 times the height of the waterfall.

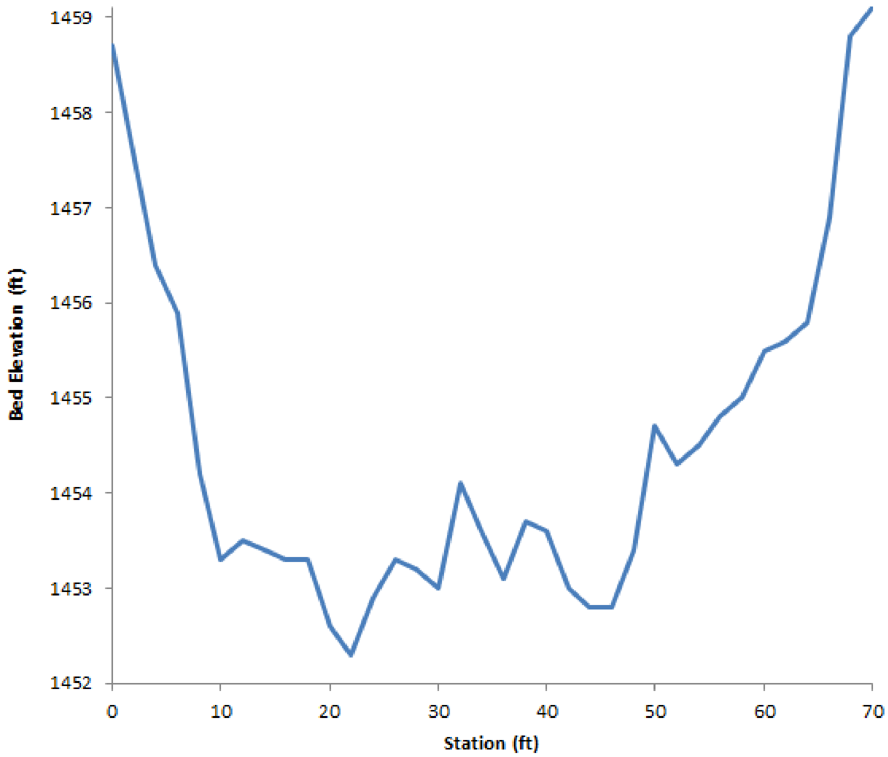

Figure 24
Hammer Cross-Section 2

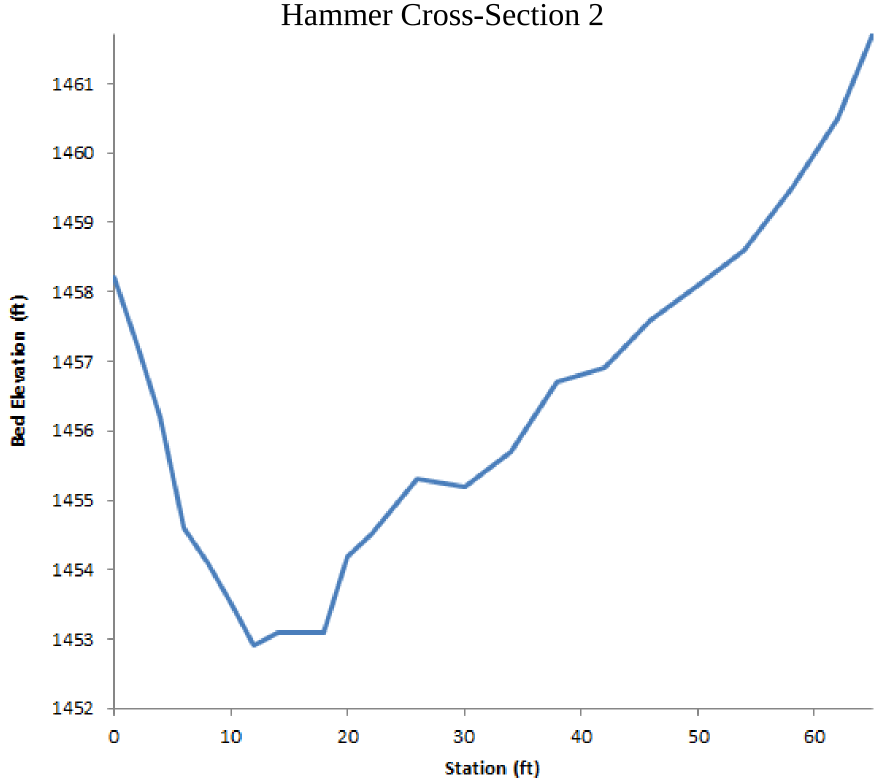

Figure 25
Hammer Cross-Section 3

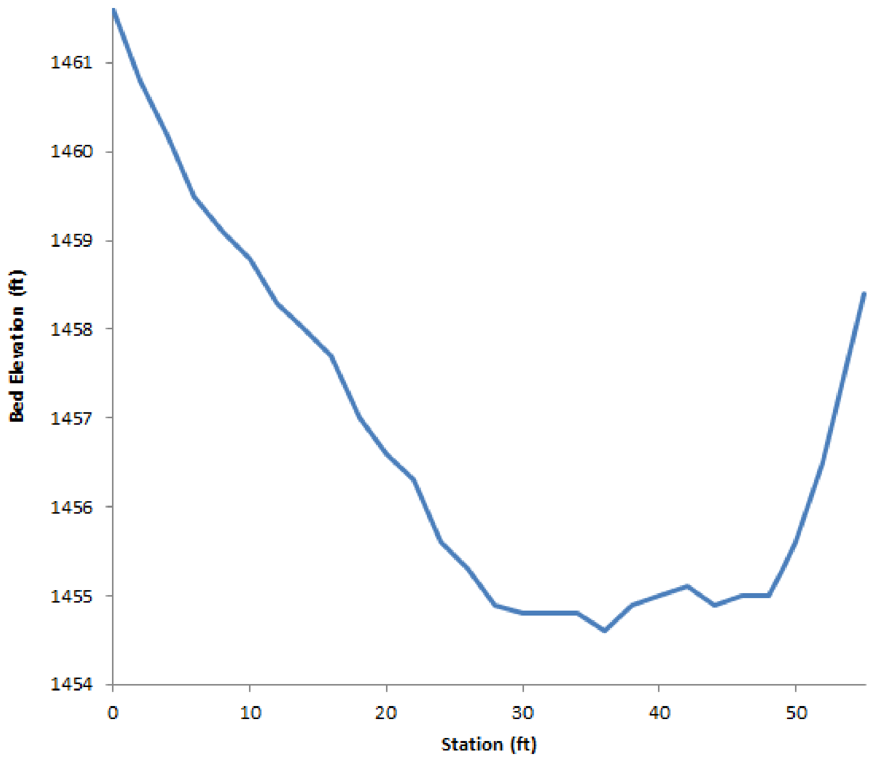

Figure 26
Hammer Cross-Section 4

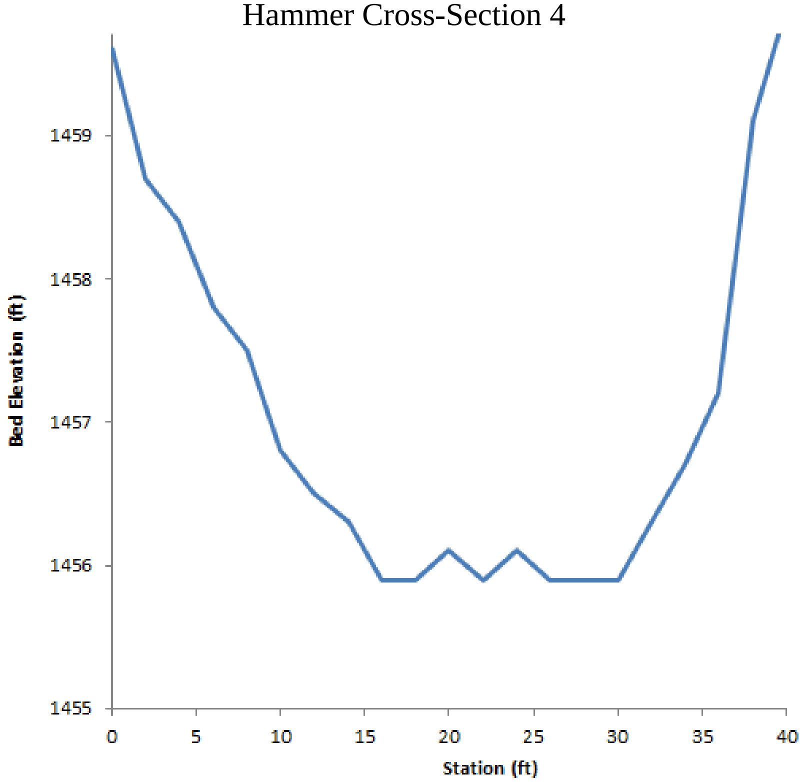

Figure 27
Hammer Cross-Section 5

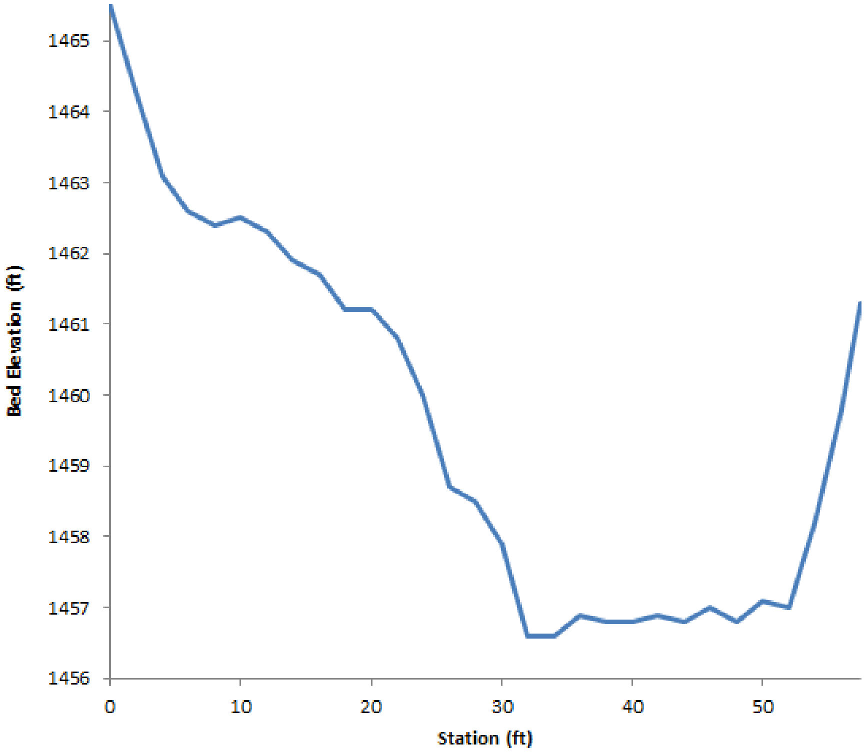

Figure 28
Hammer Cross-Section 6

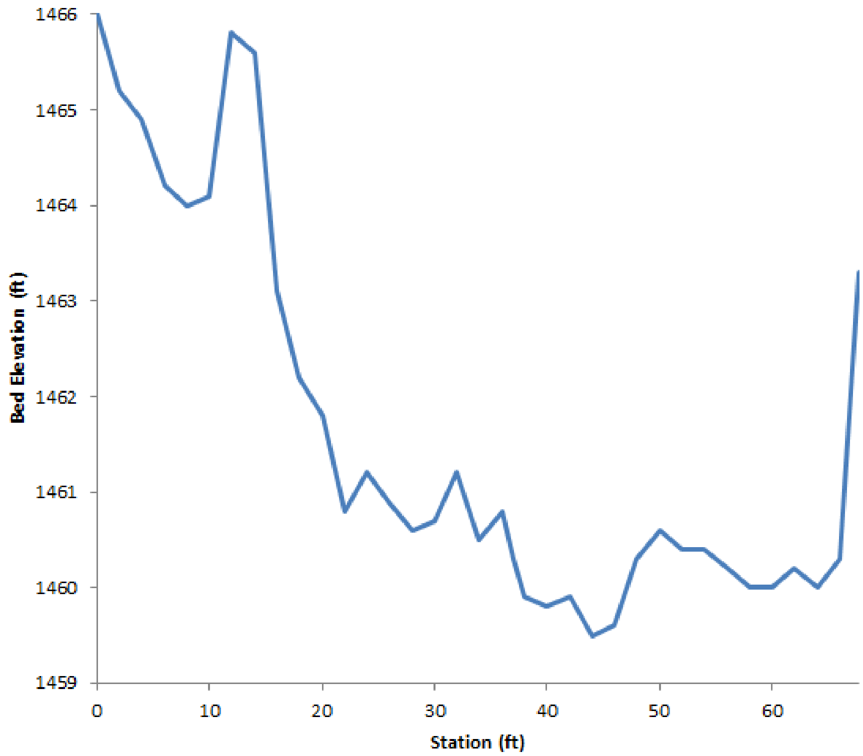

Figure 29
Hammer Cross-Section 7

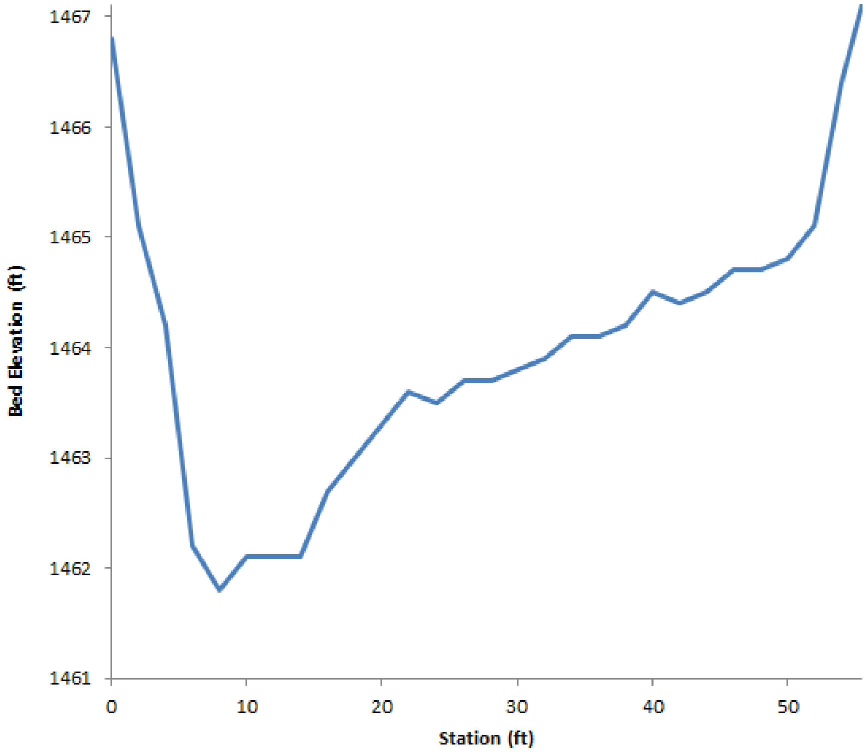

Figure 30
Hammer Cross-Section 8

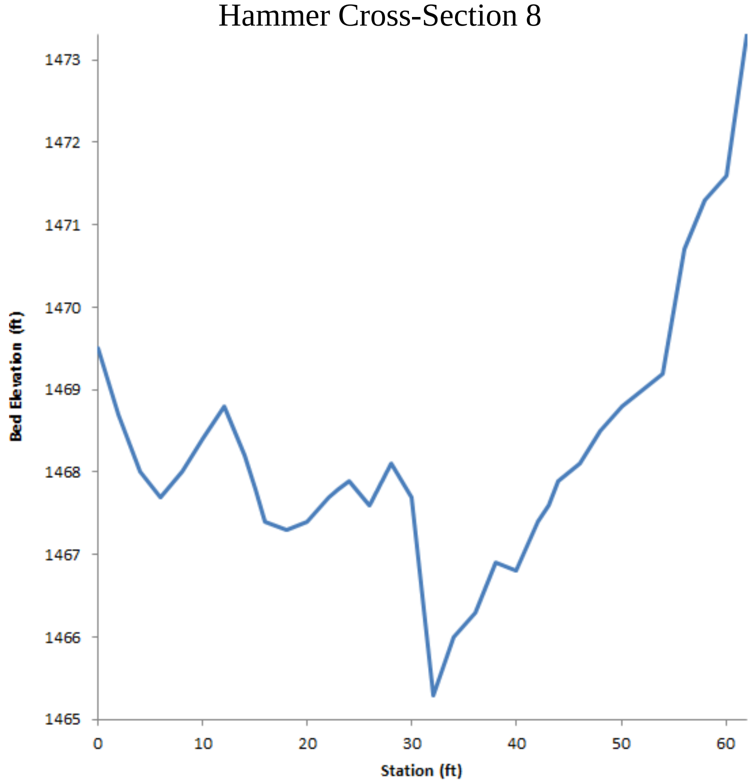

Figure 31
Hammer Cross-Section 9

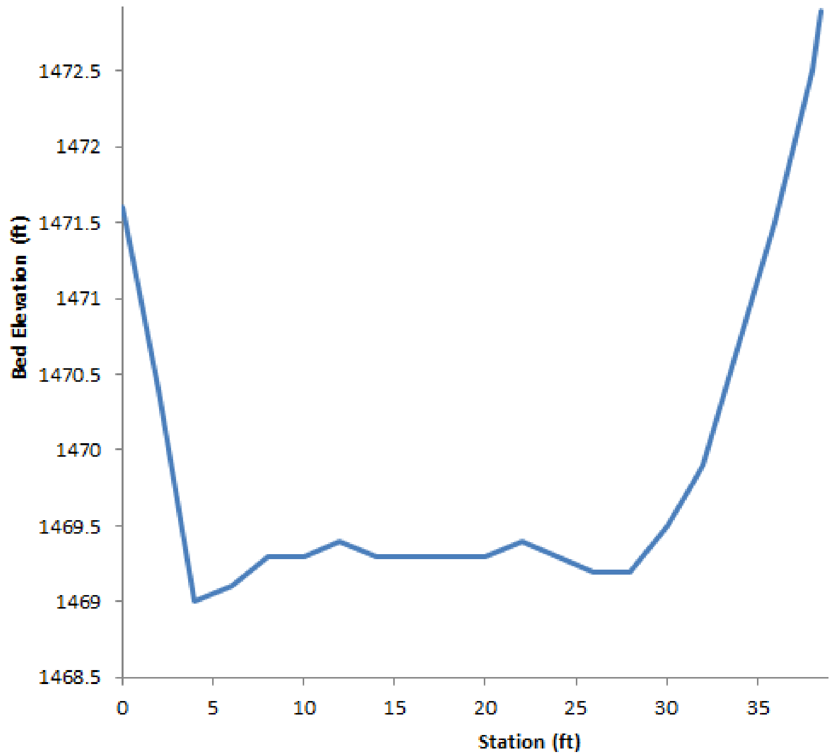

Figure 32
Hammer Cross-Section 10

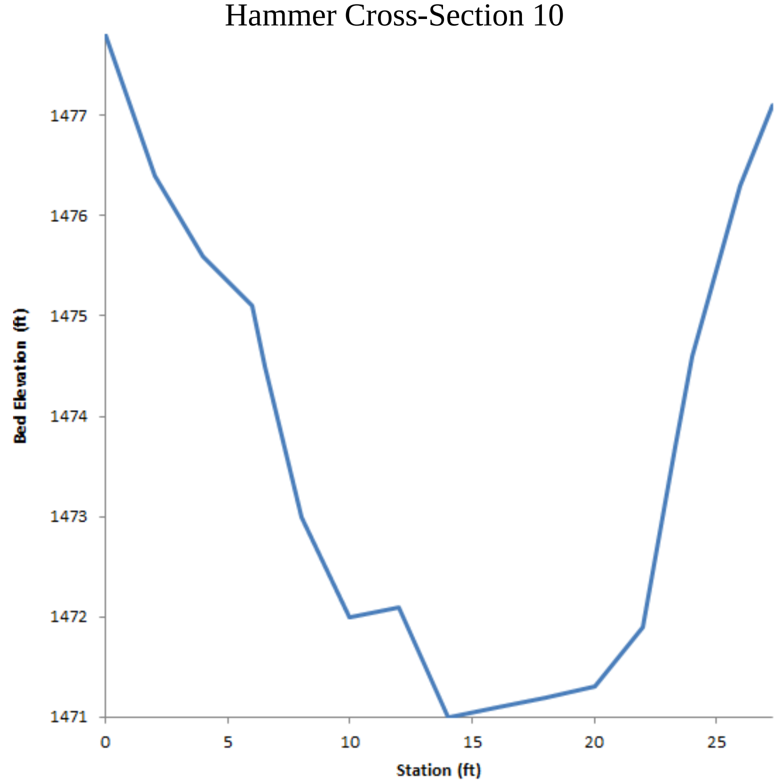

Figure 33
Hammer Cross-Section 11

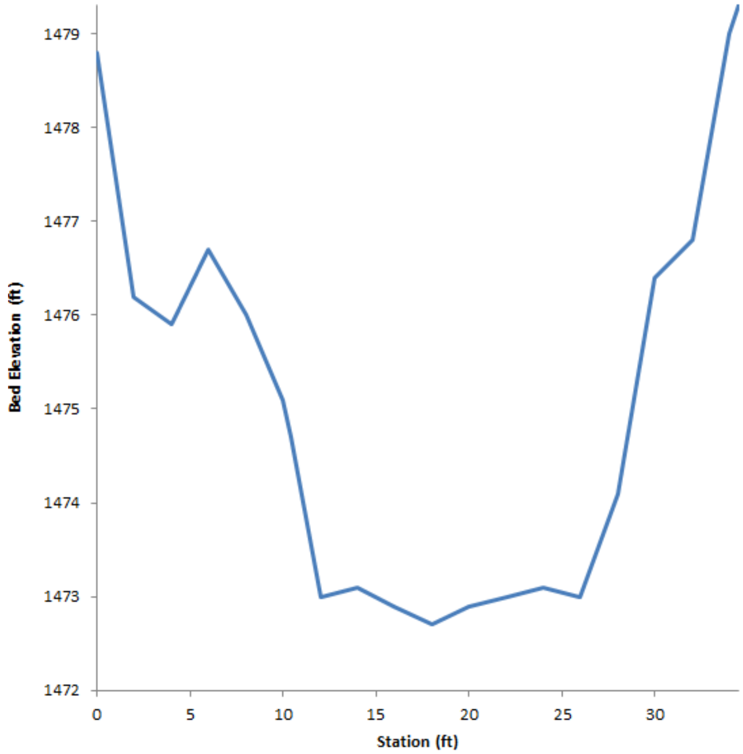

Figure 34
Hammer Cross-Section 12

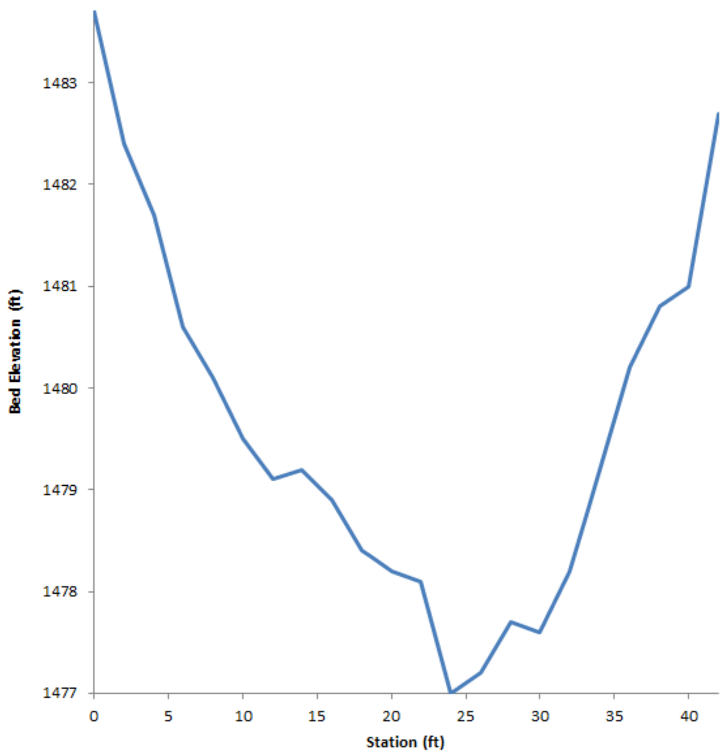

Figure 35
Hammer Cross-Section 13

Dry Creek Habitat Assessment

Methods

The goal of this task was to assess the quality of anadromous salmonid habitat and evaluate passage barriers in the portion of Dry Creek within the Spenceville Wildlife Area, from 220 to 500 feet elevation. On April 28 to May 1, 2014, we walked Dry Creek and conducted mesohabitat mapping, using the criteria in Table 6, and marked the ends of each mesohabitat unit with a Garmin GPS unit. The percentage of spawning gravel and percentage of bank with woody cover for each mesohabitat were recorded as metrics of habitat quality. In addition, for pools, maximum pool depth, riffle crest depth, pool tail percent embeddedness and pool tail percent surface fines were recorded. For riffles, the minimum thalweg depth was measured and recorded to assess the potential for low-flow barriers. Potential upstream passage barriers were assessed using the methods in Gallagher (1999) and Powers and Orsborn (1985), with the following parameters measured: 1) visual classification of the barrier as a fall, chute or cascade; 2) depth of pool below barrier (fish entrance zone) and pool above barrier (fish exit zone); 3) vertical distance from the falls crest to the water surface of the pool below the barrier; 4) depth of penetration of falling water into pool below barrier; 5) horizontal distance from the falls crest to the standing wave in the pool below the barrier; 6) for chutes, the depth of water in the chute; 7) width of barrier; and 8) velocity at top and bottom of barrier. Discharge was also measured using a tape, wading rod and Marsh-McBirney velocity meter. The GPS data were put in GIS to make polyline shapefiles of the mesohabitat units, which were then used to calculate the length of each mesohabitat unit.

Results

We surveyed 5.3 miles of Dry Creek, starting at the property line between Spenceville Wildlife Area and Beale Air Force Base going upstream. The mesohabitat composition of the 5.3 miles of Dry Creek was 44 percent pool, nine percent glide, 11 percent riffle and 36 percent run, plus two cascades with a total length of 163 feet. The percent spawning gravel and percent of banks with woody cover, weighted by the length of the mesohabitat units, were, respectively, 7 and 51 percent. The maximum pool depths ranged from 2.0 to 8.0 feet, with a mean of 4.3 feet. Residual pool depths ranged from 1.0 to 7.3 feet, with a mean of 3.2 feet. Riffle crest depths ranged from 0.5 to 2.3 feet, with a mean of 1.0 foot. The average pool tail embeddedness and percent surface fines were, respectively, 7 and 5 percent. Seventy eight percent and 81 percent of the pool tails, respectively, had zero embeddedness and zero percent surface fines. Fifty one percent of the riffles had minimum thalweg depths of less than 0.9 feet, ranging as low as 0.5 feet. The flow of Dry Creek during our survey was 44 cfs. We observed a 3.4 foot waterfall with no downstream plunge pool located 238 feet downstream of the upstream end of our survey (Figure 36). Given that there is no downstream plunge pool, this waterfall would be an upstream passage barrier for adult salmonids at all flows.

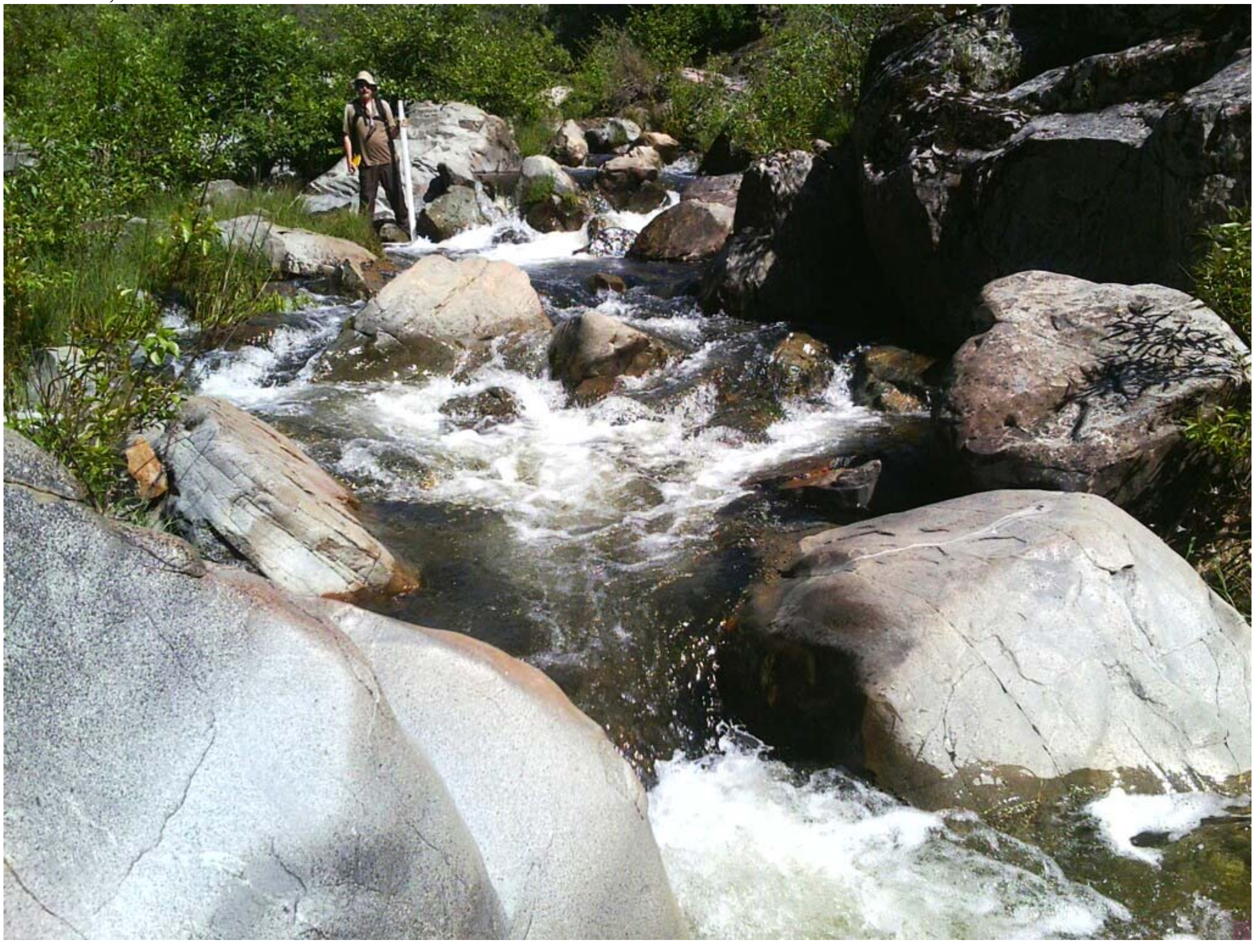

Figure 36
Dry Creek Upstream Passage Barrier

Discussion

The results of our surveys indicate that there are 5.25 miles of accessible anadromous salmonid habitat on Dry Creek within Spenceville Wildlife Area. The percentages of spawning gravel and bank woody cover indicate that spawning habitat is likely the limiting factor for anadromous fish in the portion of Dry Creek within Spenceville Wildlife Area. Based on our surveys of riffle minimum thalweg depths, flows of at least 120 cfs would be needed for upstream passage, suggesting that upstream passage of fall-run Chinook salmon would not occur until the first large rainfall event in the fall. Additional surveys at higher flows could refine the above flow estimate, but would be of limited value for developing restoration actions, given the lack of upstream diversions. The data that we collected will serve as a good baseline to develop restoration projects for the portion of Dry Creek within Spenceville Wildlife Area. For example, the results of our surveys suggest that spawning gravel addition might be the highest priority for restoring anadromous salmonid habitat in the portion of Dry Creek within Spenceville Wildlife Area.

Antelope Creek Lower Slab Upstream Passage Assessment

Methods

The goal of this task was to assess at what flows the Antelope Creek lower slab, also known as Facht's Place crossing, is a barrier to upstream passage of adult spring-run Chinook salmon. A PHABSIM transect was placed at the upstream and downstream end of the site. The downstream transect was modeled with PHABSIM to provide water surface elevations as an input to the 2-D model. The upstream transect was used in calibrating the 2-D model - bed roughnesses are adjusted until the water surface elevation at the top of the site matches the water surface elevation predicted by PHABSIM. Transect pins (headpins and tailpins) were marked on each bank above the 100 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. Vertical benchmarks were established to serve as the vertical elevations to which all elevations (streambed and water surface) were referenced. Vertical benchmarks consisted of lag bolts driven into trees. In addition, horizontal benchmarks (rebar driven into the ground) were established to serve as the horizontal locations to which all horizontal locations (northings and eastings) were referenced. The precise northing and easting coordinates and vertical elevations of two horizontal benchmarks were established using survey-grade Real Time Kinematic (RTK) Global Positioning System (GPS). The elevations of these benchmarks were tied into the vertical benchmarks using differential leveling. The data collected on the upstream and downstream transect included: 1) water surface elevations (WSELs), measured to the nearest 0.01 foot (0.003 m) at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bank-full discharge surveyed to the nearest 0.1 foot (0.031 m); 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification (Tables 1 and 2) at these same locations and also where dry ground elevations were surveyed.

Topographic data between the upstream and downstream boundaries of the site were collected using survey-grade RTK GPS units or a robotic total station and stadia rod. We also collected substrate and cover data for each topographic point collected with the survey-grade RTK GPS unit or total station and stadia rod. The RTK GPS and total station data had an accuracy of 0.1 foot horizontally and vertically.

A River2D model was developed for the site using the same methods described above for the American River. After calibration, the model will be run at flows ranging from 20 to 85.5 cfs to determine the flow at which the depth on the slab exceeds 0.9 feet for a continuous 3-foot width. The criteria that a total of at least 3 feet of the width must be contiguous for the minimum depth established for the target fish is based on WDFW (2009). The water depth criterion identified for protection of adult Chinook salmon passage is 0.9 ft (R2 Resources 2008). The passage criteria for adults are based upon a literature review conducted by R2 Resources (2008), and are intended to provide protective passage. Ideally, there should be sufficient clearance underneath the fish so that contact with the streambed and abrasion are minimized, which R2 Resources (2008) considered to be 0.1 ft. The flow that is determined from the River2D model will be compared to historical Antelope Creek gage records to see what percentage of the time during adult spring-run Chinook upstream passage (mid-February to the end of June) Antelope Creek flows exceed the flow from the River2D model.

Results

In FY 2014, we completed data collection and development of the River2D bed and mesh files. In FY 2015, we will complete the upstream passage assessment, with the results to be reported in our FY 2015 annual report.

Antelope Creek Bridge As-Built Survey

Methods

The purpose of this investigation was to conduct a survey of the topography of Antelope Creek in the vicinity of the Antelope Creek Bridge restoration to document the effect on the channel topography of high flows in December 2012. We used our survey grade RTK GPS units and total station to collect topography data on September 8-10, 2014.

Results

We collected a total of 2,800 topographic data points. The topography is shown in Figure 37, while the changes in topography after our as-built survey in November 2012 are shown in Figure 38. There were specific portions of the site that showed aggradation of up to two feet and erosion of up to three feet. However, the overall configuration of the site (a run underneath the bridge with upstream and downstream high gradient riffles) did not change, despite peak flows in December 2012 of around 6,900 cfs[8]. There were no areas of concern in relation to the scouring near the river left bridge abutment, since the scour hole is located six feet from the bridge abutment.

Discussion

Due to the large size of substrate at this site, the methods we used were unable to detect bed elevation changes of less than 0.5 feet. While there were areas of significant aggredation and erosion, the stream channel at the Antelope Bridge still provides unimpeded upstream passage for anadromous salmonids even at low flows, on the order of 20 cfs.

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[8] This flow estimate is based on the peak recorded flow in December 2012 for Deer Creek gage number 11383500 and the following equation from USFWS (2010b): Antelope Creek Flow = Max(0, -20.4 + 0.4977 x Deer Creek Flow).

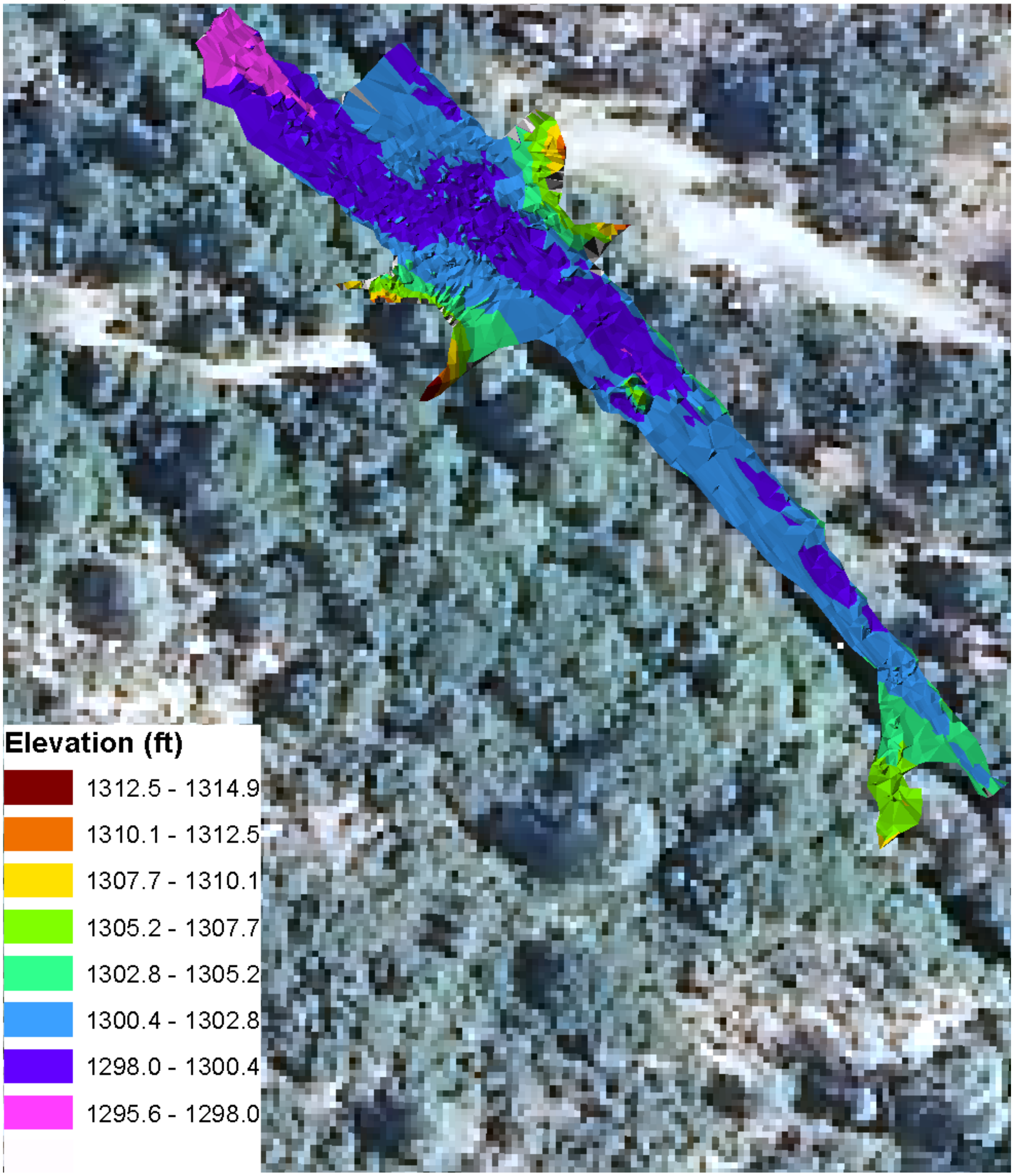

Figure 37
Antelope Creek Bridge Site 2014 Topography

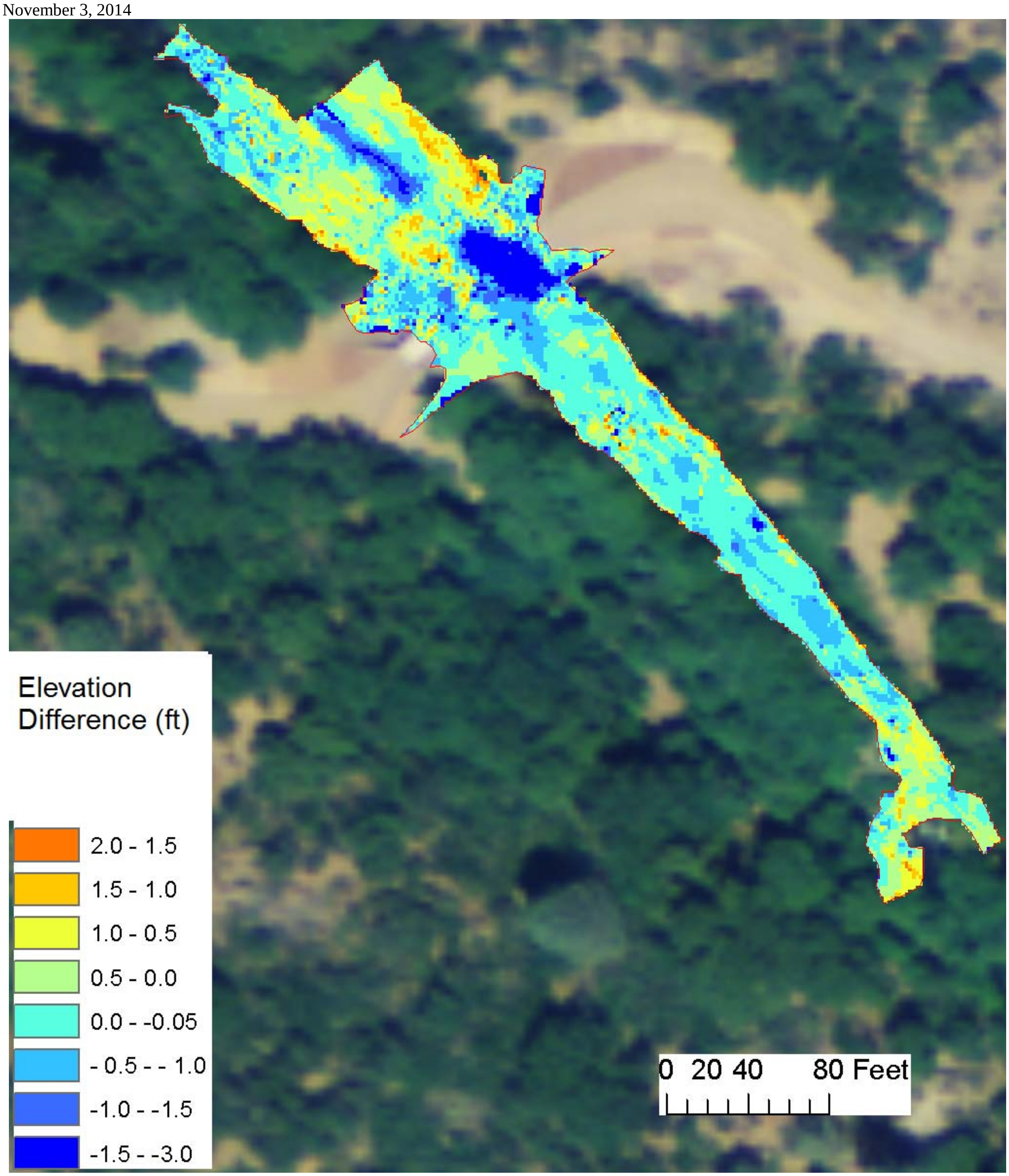

Figure 38
Changes in Antelope Creek Bridge Site Topography from 2012 to 2014

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