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Turlock Irrigation District	)	
	)	
and	)	Project No. 2299
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Modesto Irrigation District	)	

2006 LOWER TUOLUMNE RIVER ANNUAL REPORT

Report 2006-8

Special Run Pool 9 and 7/11 Reach:
Post-Project Monitoring Synthesis Report

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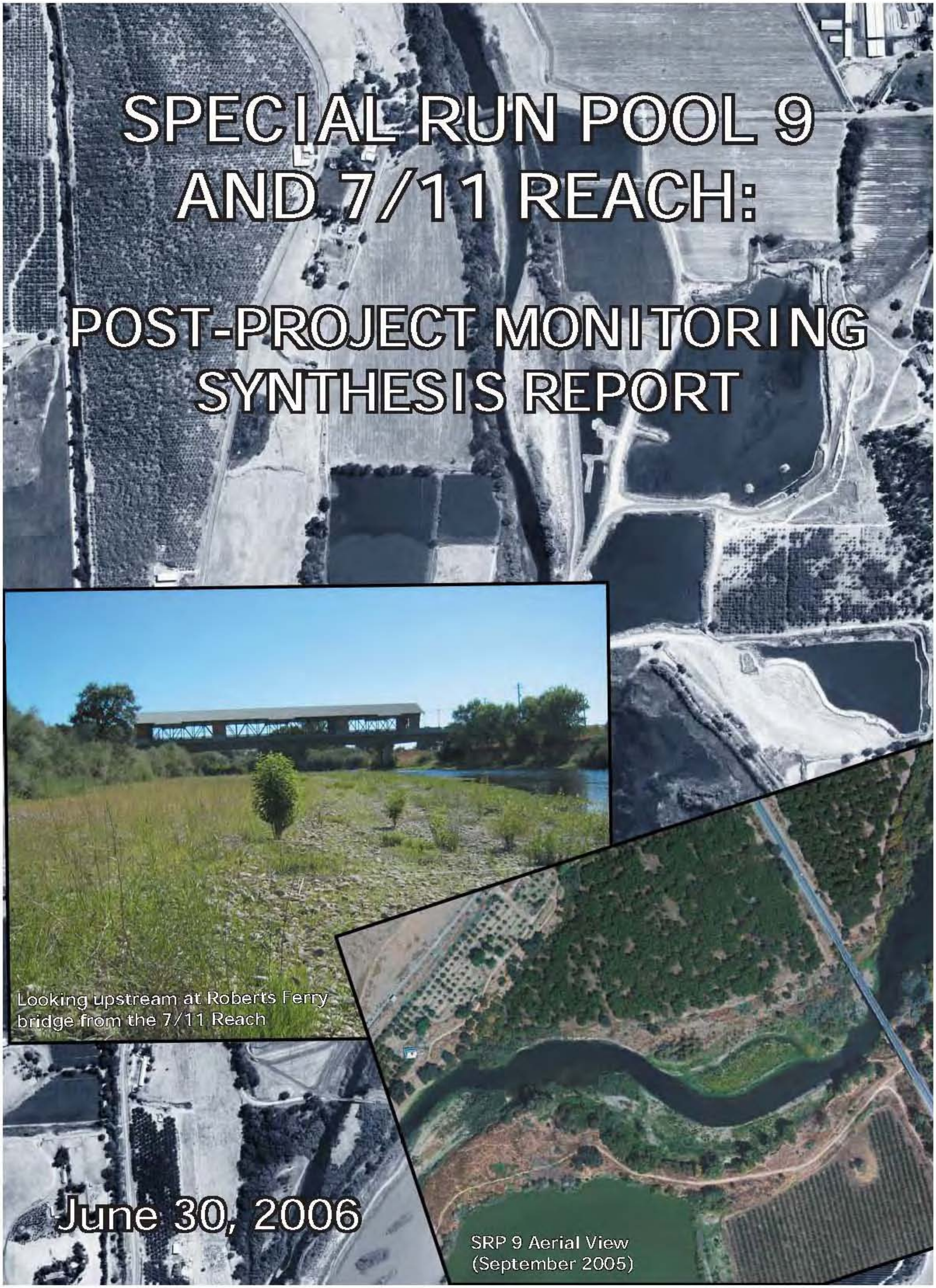
SPECIAL RUN POOL 9 AND 7/11 REACH:

POST-PROJECT MONITORING SYNTHESIS REPORT



Looking upstream at Roberts Ferry bridge from the 7/11 Reach

SRP 9 Aerial View (September 2005)

June 30, 2006

Special Run Pool 9 and 7/11 Reach: Post-project Monitoring Report

Prepared for:
The Tuolumne River Technical Advisory Committee
Turlock and Modesto Irrigation Districts
USFWS Anadromous Fish Restoration Program
California Bay-Delta Authority

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June 30, 2006

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The SRP 9 and 7/11 Reach projects extend over nearly three miles of the Tuolumne River and were implemented at a cost of more than $10 million. Design, permitting, and implementation of projects of this scale and complexity require collaboration between scientists, engineers, regulators, resource managers, environmental groups, and private landowners. Moreover, monitoring and adaptive management of these projects to ensure their success and their contribution to restoration science require long-term commitments from these contributing parties. Numerous parties contributed to the design, implementation, and monitoring of the SRP 9 and 7/11 Reach restoration projects. The projects and monitoring were funded by the U.S. Fish and Wildlife Service Anadromous Fish Restoration Program (AFRP), CALFED Ecosystem Restoration Program, Turlock Irrigation District, Modesto Irrigation District, and the City and County of San Francisco. Wilton Fryer, of the Turlock Irrigation District, is the project administrator and has shepherded these complex projects from concept through construction and monitoring. McBain & Trush developed conceptual designs, and HDR Engineering, Inc. developed construction designs. KSN Inc. conducted topographic and bathymetric surveys to support project design and record locations of monitoring cross sections. HDR Engineering, Inc. provided construction oversight and management. EDAW Inc. and the U.S. Fish and Wildlife Service prepared the environmental documents, with support from Stillwater Sciences and McBain & Trush.

McBain & Trush and Stillwater Sciences developed project monitoring plans, with significant input from the Tuolumne River Technical Advisory Committee Monitoring Subcommittee. CALFED and AFRP funded additional review of the projects and monitoring by the Adaptive Management Forum and review of Chinook salmon survival monitoring by an interdisciplinary peer review panel. Monitoring was conducted by McBain & Trush, Stillwater Sciences, S.P. Cramer and Associates, Turlock Irrigation District, and the California Department of Fish and Game. Electrofishing boats were provided by AFRP, S.P. Cramer and Associates, and the University of California – Davis.

Dominichelli and Associates (El Dorado Hills, CA.) conducted habitat suitability modeling for SRP 9 and control sites. Mark Gard, of the U.S. Fish and Wildlife Service, provided valuable expert advice on running the model and interpreting model results. Larry Brown and Dr. Michael Saiki, of the U.S. Geological Survey, provided comments to the bass habitat suitability criteria used in the model and factors that may affect bass in the river.

Finally, local property owners and mine operators provided site access for construction and monitoring. 7/11 Materials, Mr. William Streeter, Mr. Phil Short, and J.M. Keckler generously provided access through their properties to conduct monitoring. We sincerely appreciate the support of these landowners in gathering data to continue to improve the health of the river

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EXECUTIVE SUMMARY

Introduction

The *Habitat Restoration Plan for the Lower Tuolumne River Corridor* ("the Restoration Plan") identifies several channel-floodplain restoration projects, as well as subtle changes to flood control releases, to improve ecosystem health and increase salmonid carrying capacity and production in the Tuolumne River. The Tuolumne River Technical Advisory Committee (TRTAC) selected the Special Run Pools (SRPs) 9 and 10 and Gravel Mining Reach projects as high priority and to be among the first projects implemented as part of the Tuolumne River Restoration Program. The projects are being implemented in several phases. Construction at SRP 9 was completed in 2001. Construction of the 7/11 Reach of the Gravel Mining Reach project was completed in 2003.

This report presents results of as-built and post-project monitoring at the SRP 9 and the 7/11 Reach sites, including as-built topographic and bathymetric surveys, habitat mapping, fish population monitoring, and habitat suitability modeling. In this report, we also synthesize results from individual annual monitoring reports, present "lessons learned" from implementation and monitoring of these projects, recommend subtle alterations to the SRP 9 project to improve project effectiveness, and provide suggestions for improving future project designs. Because only limited future monitoring at the SRP 9 and 7/11 projects is currently funded, we also recommend future monitoring and adaptive management at these sites and for future projects.

With their large size and cost, the SRPs 9 and 10 and Gravel Mining Reach projects require thoughtful design, experimentation, and adaptive management to maximize their benefits both to the river and to restoration science. The long-term biological research and monitoring data available for the Tuolumne River, combined with the geomorphic studies conducted for the Restoration Plan, provide a solid foundation for hypothesis development, adaptive management, and learning. Tuolumne River project proponents have attempted to develop and implement comprehensive, hypothesis-driven monitoring plans for each restoration project. Effective adaptive management, however, requires long-term monitoring designs that have the capacity to detect change and identify causal linkages in a highly variable environment. Short-duration funding cycles for the restoration grants limit the duration of post-construction project monitoring to as little as one year. In addition to limits to project-specific monitoring, limited funding threatens continuation of long-term, river-wide monitoring programs that provide crucial population-level information needed to interpret project-specific results. In 2004, Turlock Irrigation District (TID), working with TRTAC participants, submitted a proposal to the California Bay-Delta Authority (CBDA) Ecosystem Restoration Program to fund project-specific and river-wide monitoring for an additional three years. The CBDA ranked the proposal as a high priority for immediate funding and, in September 2005, awarded $2.4 million to continue post-project and river-wide monitoring through 2009. Since that time, TID and the TRTAC have worked with California Department of Fish and Game — the grant administrator — to execute the grant agreement required to release funds and continue monitoring. As of the time of this report, a grant agreement had not been executed, and the schedule and process for executing an agreement have not been defined. Post-project monitoring will be delayed until these funds become available.

SRP 9 Project Description, Implementation, and Effectiveness

Project Description

The SRP 9 project extends from the Geer Road Bridge (RM 25.9) to RM 25.7. The primary goals of the SRP 9 project were to: (1) reduce habitat for largemouth bass, (2) improve bedload routing through the reach, and (3) construct a geomorphically functional channel and floodplain. Project objectives were presented in the Restoration Plan and reiterated in proposals to the CBDA to fund restoration implementation. These objectives were to:

- reduce/eliminate habitat favored by predatory bass species and replace it with high quality Chinook salmon habitat;
- restore channel and planform morphology scaled to contemporary and future sediment and hydrologic regimes;
- restore sediment transport continuity through the reach; and
- revegetate reconstructed floodplains and terraces with native woody riparian species planted on fluvial surfaces appropriate for each species life cycle.

The approach for the SRP 9 project was to import material to fill in the pit and construct a geomorphically functional channel and floodplain. The project designers considered reconstructing a portion of the channel between SRPs 9 and 10 to increase the channel gradient through SRP 9, but the concept was eliminated because it was considered too costly and was not expected to improve salmonid habitat or reduce bass habitat. As part of the SRP 9 project, a breach in the dike separating a floodplain mining pit ("the South Pit") from SRP 10 was also repaired.

After the conceptual design for the project was completed, several modifications were incorporated into the design, including:

- adding an infiltration gallery to the site that would facilitate shifting the point of up to 100 cfs of TID's diversion downstream to SRP 9, thus increasing flows in the 26 miles of river from La Grange Dam to the project site;
- lowering floodplain elevation and reducing the channel design capacity to 1,500 cfs to reduce the volume of fill required to construct the project and allow the project to be completed within the existing budget and work windows required by various permits; and
- adding high flow channels to constructed the floodplains on the left and right banks of the river to increase habitat diversity.

Project Implementation

The SRP 9 project was completed in 2001 at a cost of approximately $2.7 million. Grading extended from June 1 through October 15, 2001; all in-channel grading was completed by October 3, 2001. Planting was conducted from November 1 through December 31, 2001; irrigation and plant maintenance continued through September 2003.

The project was built consistent with the final designs, except for modification of the left bank floodplain channel which was extended further downstream. The final design, however, differed from the original concept in that the low-flow channel is wider.

Project Effectiveness

The monitoring plan for the restoration projects was developed to test specific hypotheses related to each project. Monitoring hypotheses are listed below. Monitoring to test each hypothesis and the status of monitoring for each project are shown in Table 3 in this report.

Monitoring hypotheses for SRP 9:

H1. The constructed channel conveys 1,500 cfs; flows exceeding 1,500 cfs spill onto the floodplain.
H2. The channel bed is mobilized at flows of 5,000 cfs.
H3. The constructed bankfull channel morphology is stable, where stable is defined as no net deposition or erosion in channel cross section and profile over the long term.
H4. The channel migrates under the current flow regime, although migration rates will be slow and magnitude will be small.
H5. The extent and quality of Chinook salmon spawning habitat is increased.

H6. The extent and quality of Chinook salmon rearing habitat is increased.
H7. Planted riparian vegetation becomes established on the constructed floodplain.
H8. Natural recruitment of native riparian plant species occurs on the constructed floodplain.
H9. Riparian vegetation does not encroach into the constructed channel.
H10. Elimination of the pits reduces habitat suitability for largemouth bass.
H11. Elimination of the pits results in reduction of largemouth bass abundance at the project sites and an increase in Chinook salmon outmigrant survival at the project sites.

Pre-project monitoring at SRP 9 was conducted in 1998 and 1999. Post-project monitoring extended through 2005 but was limited in scope after 2003 due to lack of monitoring funds. A pilot predation assessment was conducted in spring 2006. The results of the predation assessment will be provided in a separate report. Monitoring has not yet tested all relevant hypotheses for the project. Completed monitoring has, however, at least partially tested hypotheses related to a primary goal of the project – reducing largemouth bass habitat and increasing Chinook salmon outmigrant survival. Biological monitoring results and tools developed by this monitoring effort support recommendations for minor changes to the SRP 9 project and improvements to SRP 10 designs.

Geomorphic Processes (H1 through H4)

Geomorphic and hydraulic hypotheses have not been tested because flows sufficient to trigger post-project monitoring did not occur during the funded monitoring period. Completed as-built surveys and aerial photography will provide a baseline for evaluating the effects of high flows that occurred in 2005 and 2006.

Largemouth and Smallmouth Bass Abundance and Distribution (H11)

Monitoring of largemouth and smallmouth bass abundance at the project and control sites from 1998 through 2003 documented a pattern of population depletion following the 1997 flood and subsequent recovery during recent low water years. This finding is consistent with reproductive requirements for these species and river flows and temperatures from 1999 through 2003. From 1999 through 2003, low spring and summer flows in the river provided suitable spawning temperatures and flow velocities for these species. Abundance of both species increased throughout the reach, including at project and control sites, though largemouth bass were more abundant than smallmouth bass. In 2003, at least five cohorts for each species were present in the reach.

Comparing bass density between project and control sites, piscivore-sized largemouth bass densities were highest at SRPs 8 and 10, intermediate at SRPs 7 and 9, and lowest at Riffle 64 and Charles Road. This pattern did not change between pre- and post-project monitoring, indicating that the project was not successful in reducing largemouth bass linear density at SRP 9 during the initial low flow years following project construction.

Project effects on smallmouth bass are less clear. Monitoring did not identify any statistically significant trends in smallmouth bass linear density between the project and control sites. Although results were not statistically significant, increased smallmouth bass abundance was recorded at the site relative to pre-project conditions and other SRP sites. In 1998 and 1999 (i.e., pre-project) smallmouth bass density was low at all sites, but was highest at the channel control sites (Charles Road and Riffle 63). In 2003 (i.e., post-project), densities of piscivore-sized smallmouth bass at Riffle 64, SRP 9, and Charles Road, were not significantly different from one another but were significantly higher than at the SRP control sites. Increased smallmouth bass abundance should be expected when SRP units, which are characterized by deep, low-velocity flows, are replaced with shallower channels and increased flow velocities. Smallmouth bass prefer relatively swift water velocities, shallow depths, and steeper channel gradients.

Based on the results of the bass abundance monitoring, follow-up surveys were conducted at the Charles Road and Riffle 64 control sites, where largemouth bass abundance was consistently low over the monitoring period, to assess factors that might limit bass abundance at these sites. In addition, the River 2D model was used to assess largemouth and smallmouth bass habitat suitability at the Charles Road and Riffle 64 control sites and at SRP 9 for pre- and post-project conditions. Model results indicate that the project substantially reduced largemouth bass habitat at the site. For flows of 300 cfs (i.e., flows typical of the 1999 and 2003 monitoring), the project reduced largemouth bass primary habitat by 77% and secondary habitat by 90% compared to pre-project conditions. At higher flows the amount of suitable bass habitat is further reduced. Largemouth bass habitat at the site, however, remains well above that available at the channel control sites. The amount of largemouth bass habitat at SRP 9 (post-project) is 1.8 times greater than at the Charles Road control site and 3.6 times greater than at the Riffle 64 control site at a flow of 300 cfs. The difference between the amount of habitat at SRP 9 (post-project) and the channel control sites decreases with increasing flows and becomes indiscernible at flows exceeding 2,000 cfs.

The most important factor limiting the success of the SRP 9 project in reducing bass habitat and abundance seems to be flow velocity. Channel gradient at the Riffle 64 and Charles Road control sites is an order of magnitude steeper than at SRP 9, and the low-flow channel is 24% narrower. The steeper slope combined with narrower channel width at the channel control sites increases flow velocity relative to conditions at SRP 9. The results of the habitat model indicate that velocity is a key variable limiting largemouth bass habitat at the channel sites.

Chinook Salmon Survival (H11)

This restoration project was based largely on studies conducted in the Tuolumne River in the early 1990s that concluded that predation by largemouth and (to a lesser extent) smallmouth bass was a significant source of density-independent mortality for outmigrant Chinook salmon, particularly during drier year conditions. The most important goal of the project was to increase Chinook salmon outmigrant survival through reducing predation by largemouth bass. Effectiveness monitoring included mark-recapture studies to quantify Chinook salmon survival at the project and control sites. Survival monitoring was abandoned after two years because recapture conditions could not meet model assumptions, and the method could not reliably estimate survival rates over shorter project reaches.

Based on one year of post-project data, the project did not significantly reduce largemouth bass abundance at the site. Moreover, although the results were not statistically significant, the project may have increased in smallmouth bass abundance at the site. Smallmouth predation rates have been documented to be 2.5 times higher than for largemouth bass. If the SRP projects increase smallmouth bass abundance in the river, there is the potential that they could result in a net increase in predation pressure on juvenile Chinook salmon.

Despite the continued high abundance of smallmouth and largemouth bass at the SRP 9, the River 2D model provides a new conceptual model for identifying and testing the effects of projects such as SRP 9 on juvenile Chinook salmon outmigration success. The SRP 9 project replaced the wide, deep SRP 9 mining pit with a narrower and shallower channel and floodplain. By creating a smaller channel cross section, the project increased flow velocity relative to pre-project conditions. The River 2D model suggests that the SRP 9 project provides a "safe velocity corridor" for Chinook salmon outmigrants through the site during typical spring outmigration flows. Within this safe velocity corridor, higher flow velocities that exclude largemouth and smallmouth bass from the center of the channel segregate outmigrant salmon from these non-native predators and reduce bass predation efficiency. Based on the River 2D model for SRP 9, this safe velocity corridor is expected to occur at flows of 300 cfs and higher for post-project conditions, compared to 2,000 cfs and higher for pre-project conditions. If this hypothesis is correct, the channel reconstruction may have segregated largemouth and smallmouth bass from outmigrating juvenile salmon throughout the spring pulse flows of 2002 and 2003 (i.e., the post-project monitoring years). Understanding the role of flow velocity and temperature in spatially segregating largemouth and smallmouth bass from Chinook salmon outmigrants, therefore, is essential to understanding the potential effect of these projects on outmigrant survival and their role in restoring native fish populations in the river. The pilot predation study conducted in spring 2006 partially tested this hypothesis for high flow conditions.

Increased flow velocity in the reconstructed channel may also reduce energetic expenditure for outmigrating salmon. Assuming that salmon will shift from passive outmigration to active swimming when flow velocity is less than their sustained swimming speed, flow velocity can be a reasonable indicator of salmon swimming behavior and energy expenditure. Using flow velocity as an indicator and a sustained swimming speed of 1 ft/s, the River 2D model for SRP 9 predicts that that 1 ft/s threshold is passed at 300 cfs for post-project conditions but is not passed until 2,000 cfs under pre-project conditions. Conversion of SRPs to shallower, narrower channels, therefore, could reduce the energetic costs of outmigration by allowing Chinook salmon to passively migrate. Given the short length of the project, the project-scale benefit of this energy conservation is likely minor. The cumulative effects of restoring additional SRPs, however, could be substantial.

Chinook Salmon Rearing (H6)

The River 2D model was also used to compare Chinook salmon fry and juvenile habitat for pre- and post-project conditions over a range of flows. The restoration project increased Chinook salmon fry and juvenile habitat for all flows modeled, except fry habitat at 75 cfs. The increase in fry habitat was small for flows less than <1,000 cfs, but exceeded 180% for flows from 1,000 to 3,000 cfs. The project also substantially increased juvenile Chinook salmon habitat, with increases for flows < 1,000 cfs ranging from 46% to 121% and for flows > 1,000 cfs ranging from 50% to 392%.

The greatest benefits of the project for rearing salmon occur during flows ≥ 1,500 cfs, when rearing habitat becomes available on the floodplains and in the high flow channels. This benefit is a result of lowering the elevation of constructed floodplains to reduce the volume of fill needed to construct the project, and may come at the price of sacrificing geomorphic objectives, such as sediment transport capacity and channel migration. During the period for which the FSA flow schedule has been in place during the Chinook salmon rearing period (1997–2004), flows sufficient to inundate the SRP 9 constructed floodplain and provide rearing habitat occurred in all years from 1997 through 2000 but were rare during the drier period from 2001 through 2004. From 1997 through 2000, flows exceeded 1,500 cfs each year an average of 66 days (39% of total days) during the fry rearing period (January 1 through March 31) and 40 days (24% of total days) during the juvenile rearing period (April 1 through June 15). From 2001 through 2004, flows exceeded 1,500 cfs each year an average of only 4 days during the fry rearing period (January 1 through March 31) and never exceeded 1,500 cfs during the juvenile rearing period (April 1 through June 15). These results suggest that the site could provide valuable fry and juvenile rearing during wetter years. Moreover, the SNTEMP model developed for the Tuolumne River indicates that flows sufficient to inundate the floodplain should maintain temperatures suitable for salmon rearing at the site during May and June. Model results, however, should be interpreted with caution because they present 5-day average temperatures within the channel, which may not fully represent maximum temperature conditions on the construction floodplains.

Other Native Fish Species (Fish Community Species Composition)

Species composition can be an important indicator of ecosystem health, with dominance by native species indicating positive trends in health. The project monitoring reach is located at the transition from dominance by native to non-native fish species. Fish community composition patterns observed at the monitoring sites are consistent with previous studies, with the dominance of non-native fish increasing in lower flow years. The SRPs supported more non-native fish than native fish. In 2003, the ratio of non-native to native fish at the SRP sites for which abundance could be estimated (SRPs 9 and 10) was one-to-two orders of magnitude larger than at the channel sites. Non-native species at the SRP sites in all years were primarily centrarchids (sunfish and bass), cyprinids (goldfish and carp), and ictalurids (catfish). Centrarchids were consistently the most abundant family at the SRPs in all years. At the channel sites, native fish were more abundant than non-native fish in 1998 and 1999, but were less abundant than non-native fish following the low flows experienced from 2000 through 2003.

Fish community composition data from pre-project monitoring suggests that conversion of SRP 9 from a mined pit to a channel and floodplain would increase native fish abundance at the site. Native fish abundance and diversity at SRP 9, however, decreased relative to pre-project conditions and relative to SRP control sites. This reduction could be due to several factors, including (1) low reproductive success of native fish during low flow years since the project was completed, (2) lack of cover established at the newly constructed site, (3) predation by non-native fish at the site, (3) angling pressure (two dead suckers were observed on the banks during 2004 field surveys), and (4) low site gradient and extensive pool habitat provide poor habitat for native fish.

7/11 Reach Project Description, Implementation, and Effectiveness

Project Description

The 7/11 Reach is the first phase of the Gravel Mining Reach project, which extends from RM 40.3 to RM 34.4. The primary goal of the Gravel Mining Reach project is to establish a river channel and riparian floodway that will improve flood conveyance, geomorphic processes, and riparian and aquatic habitat throughout the reach. Project objectives are to:

- restore a floodway width that will safely convey at least 15,000 cfs;
- improve salmon spawning and rearing habitats by restoring an alternate bar (pool-riffle) morphology;
- prevent salmon mortality that results from frequent connection between the river and off-channel mining pits;
- restore native riparian vegetation communities on appropriate geomorphic surfaces within the restored floodway;
- restore habitats for native wildlife species (e.g., egrets, ospreys, and herons);
- allow the channel to migrate within the restored floodway to improve and maintain riparian and salmonid habitats;
- remove floodway constrictions created by unengineered dikes that fail during moderate flood flows; and
- decrease risk of flood damage to aggregate extraction operations, bridges, and other human structures.

The restoration approach for the Gravel Mining Reach attempts to restore a functional floodway capable of conveying a 15,000-cfs discharge through the project reach by acquiring control of the lands within the project footprint, isolating off-channel mining pits, constructing a functional channel and floodplain, and planting riparian vegetation on restored floodplain surfaces. The project requires importing large volumes of aggregate to construct the channel and floodplain and setback dikes that will protect adjacent properties from flooding. The design low-flow channel width is approximately 75 to 90 feet, and the design bankfull channel width is 175 to 200 feet. The bankfull channel is designed to convey 5,000 cfs (the post-dam Q_3), and flows exceeding 5,000 cfs will spill onto the floodplain and into high flow scour channels. Setback dikes are designed to be constructed at least 500 feet apart to define the floodway and riparian corridor for the reach. The top elevation of dikes will have at least two feet of freeboard during a 15,000-cfs flow as determined by hydraulic modeling results.

Major revisions to the 7/11 conceptual design incorporated following completion of the bid package included:

- modifying the 7/11 haul road bridge bypass channel;
- relocating the south bank dike at the downstream end of the project approximately 50 feet closer to the channel to reduce the volume of fill needed to complete construction;
- lowering of the floodplain adjacent to the relocated dike; and
- changing the haul road bridge from a span to a fill-and-culvert design.

Project Implementation

The 7/11 Reach was completed in 2003 at a cost of $7.5 million. The project was built consistent with the final designs, except for modifications to the left bank floodplain downstream of the 7/11 haul road bridge to reduce project cost. Grading occurred from April 2002 through March 2003, with in-channel grading limited to the summer work window defined by project permits. Planting was conducted from February through April 2003, with additional follow-up planting in January 2004. Irrigation and plant maintenance ended in September 2004.

Project Effectiveness

The monitoring plan for the restoration projects was developed to test specific hypotheses related to each project. Monitoring hypotheses are listed below. Monitoring to test each hypothesis and the status of monitoring for each project are shown in Table 4 in this report.

Monitoring hypotheses for the 7/11 Reach:

H1. The constructed channel conveys 5,000 cfs; flows exceeding 5,000 cfs spill onto the floodplain.
H2. The channel bed is mobilized at flows of 5,000 cfs.
H3. The constructed bankfull channel morphology is stable, where stable is defined as no net deposition or erosion in channel cross section and profile over the long term.
H4. The channel migrates under the current flow regime, although migration rates will be slow and magnitude will be small.
H5. The extent and quality of Chinook salmon spawning habitat is increased.
H6. The extent and quality of Chinook salmon rearing habitat is increased.
H7. Planted riparian vegetation becomes established on the constructed floodplain.
H8. Natural recruitment of native riparian plant species occurs on the constructed floodplain.
H9. Riparian vegetation does not encroach into the constructed channel.

Baseline (i.e., pre-project) monitoring was conducted in 1998 and 1999. As-built and post-project monitoring began in 2002. In 2005, one bed mobility experiment was conducted, and flow stage was monitored during flows of 5,690–8,400 cfs.

Geomorphic Processes (H1 through H4)

Since construction, geomorphic monitoring thresholds were not exceeded during the funded monitoring period but were exceeded for several months in 2005 and 2006. During flows of 5,690 cfs, most constructed floodplain surfaces were inundated, though the 7/11 haul road blocked flows from reaching the constructed floodplain downstream of the haul road crossing until flow exceeded 8,400 cfs. High flows in 2005 (peaking at approximately 8,410 cfs) also fully or partially mobilized the bed at monitoring sites.

As-built surveys and aerial photographs will provide baseline conditions for assessing the effects of 2005–2006 high flows on channel morphology. Additional topographic and bathymetric surveys and aerial photography from spring and summer 2005 are available from the Tuolumne River Coarse Sediment Management Project.

Chinook Salmon Spawning Habitat (H5)

The project increased Chinook salmon spawning habitat area by 22,100 ft^2 (172%). Assuming a defended redd size of 200 ft^2/redd for Chinook salmon, pre-project spawning habitat area could support 64 redds in the project reach (Roberts Ferry Bridge to the 7/11 haul road bridge). Post-project Chinook salmon spawning habitat area could support 174 redds. Currently available spawning data are not sufficient to assess project effects on Chinook salmon spawning use at the project riffles.

Chinook Salmon Rearing Habitat

The restoration project in the 7/11 Reach reduced Chinook salmon fry and juvenile rearing habitat area during low flows, but is expected to increase rearing area during high flows and increase habitat quality during both low and high flows. Pre-project Chinook salmon rearing habitat was mapped during flows of 254–265 cfs in 1999. Post-project habitat was mapped at flows of 185 cfs in 2002. Compared to 1999, Chinook salmon rearing habitat in 2002 was reduced by 150,700 ft^2 (64%) for fry and 494,500 ft^2 (47%) for juveniles. The observed reduction in fry and juvenile habitat area is likely partially attributable to the difference in flows between pre- and post-project monitoring. Fry habitat area is expected to increase with increasing flows as lateral bars become inundated at higher flows.

While an undetermined portion of the reduction in suitable juvenile habitat is likely attributable to the difference in flows during which pre- and post-project mapping was conducted, a large portion of the reduction is due to channel reconstruction. The majority of the reduction in juvenile rearing habitat occurred in the channel reconstruction reach upstream of Riffle 30B. In this reach, channel reconstruction reduced pool length and increased flow velocity, thus limiting suitable juvenile rearing habitat to channel margins. While the project reduced suitable rearing area, however, it likely increased rearing habitat quality by increasing food production area (i.e., riffles) and increasing the area of pool heads suitable for drift foraging. Moreover, during higher flows, the project is expected to increase juvenile rearing habitat area and quality relative to pre-project conditions by replacing steep banks that confined the floodway with gently sloping banks and a broad, vegetated floodplain. Rearing habitat during high flows has not been mapped.

Recommendations

<u>Design Review Process</u>

A more inclusive design review process would improve project designs and broaden the base of support for designs. Recommendations for improving interdisciplinary participation in project design and implementation are:

Conceptual Design Review: Provide a brief opportunity (such as a workshop and/or 2-week review period) for stakeholders to review and provide comments prior to completion of the conceptual design. Concurrently, obtain peer review from 1–3 professionals in relevant fields. Peer reviewers should be selected and scheduled prior to Step 3 below. The design schedule should allow 2–3 weeks for peer and stakeholder review. This step in the conceptual design process is intended to facilitate and incorporate where possible stakeholder and peer reviewer comments. The final conceptual plan should be the foundation and basis for the detailed construction plans and specifications and the associated monitoring program used to evaluate the effectiveness or success of the project. The final conceptual design should include: (1) quantitative objectives, (2) identification of site specific concerns to be addressed in the construction plans and specifications, such as grading methods and locations, access routes, and other construction features, (3) revegetation planting design features, including soil preparation, (4) detailed information on existing habitat conditions at the site and habitat conditions to be created, and (5) the objectives, elements, and methodologies to be included in a monitoring plan for the project.

Final Design Development and Review: To ensure that the conceptual design objectives are carried through to final design and implementation, the conceptual design team should have opportunities to review or collaborate on the construction designs at key milestones. At a minimum, the conceptual design team should review the 30% construction designs. Reviews can be formal or informal, as dictated by the design schedule and complexity, and should be scheduled to facilitate construction scheduling constraints.

Project Implementation: In addition to the construction management engineer, professionals such as a fisheries biologist, geomorphologist, and/or vegetation ecologist should be present during relevant construction phases to support the construction manager and help ensure that implementation best meets the project's geomorphic and biological objectives.

<u>Improvements to SRP 9 Implementation</u>

The SRP 9 project was implemented as a pilot to test the benefits of SRP restoration on geomorphic processes, fish communities, and riparian habitat. Though the project is still relatively young, it has provided important information for improving future SRP designs and the design of the SRP 9 project. Several measures for increasing flow velocity and reducing largemouth bass habitat at the site were considered, including: (1) removing the flow constriction at the upstream end of the site, (2) reducing channel width, (3) reducing pool depth at the meander apex to three feet or less, and (4) increasing channel slope. Narrowing the channel and reducing pool depth both conflict with the infiltration gallery and were determined to be infeasible. Given this constraint, we recommend removing the flow constriction to reduce the right-bank eddy at the upstream end of the site.

<u>Improvements to 7/11 Reach Implementation</u>

No corrective actions at the 7/11 Reach are recommended at this time. Corrective actions may be identified after further post-project monitoring. Management recommendations for the site are as follows:

- Use monitoring results from hypotheses H2 and H3 (see below) to identify long-term coarse sediment maintenance needs (volume and timing) for the project reach. In the long-term, this reach will likely require coarse sediment augmentation to maintain sediment supply and storage.
- Monitor and clear vegetation and debris from the culverts in the 7/11 haul road bridge and floodplain crossing to prevent clogging and ensure continued conveyance capacity.

<u>River-wide and Population-level Monitoring</u>

In the past, river-wide monitoring was funded by the Districts and CCSF (through the FSA) and CDFG. With its expiration in 2005, FSA river-wide monitoring funds have been fully expended and are no longer available. To continue gathering data needed to evaluate these restoration projects and other restoration actions, we recommend that the following river-wide monitoring be continued:

- juvenile Chinook salmon production and outmigration timing
- juvenile Chinook salmon and *O. mykiss* distribution, abundance, and size (winter and spring);
- juvenile Chinook salmon and *O. mykiss* distribution (summer);
- Chinook salmon adult escapement;
- *O. mykiss* adult distribution; and
- benthic macroinvertebrate composition, abundance, and diversity indices.

Improvements to SRP 9 Monitoring

Monitoring hypotheses for SRP 9 are listed above. Based on results from pre- and post-project monitoring, we recommend continued monitoring for several of these hypotheses. We also recommend revisions to portions of the existing monitoring, as well as additional monitoring to test new hypotheses. Revised hypotheses and new hypotheses are listed below. Recommended monitoring is shown in Table 37 in this report.

Revised monitoring hypotheses for SRP 9:

H6. The extent and quality of Chinook salmon rearing habitat is increased. Chinook salmon utilize the constructed floodplain at flows exceeding approximately 1,200 cfs. Rearing density on the SRP 9 floodplain during flows exceeding 1,200 cfs but less than 2,000 cfs is significantly greater than rearing density at the Charles Road seining monitoring site where floodplain rearing habitat is not available until flows exceed 2,000 cfs.

H8. Natural recruitment of native riparian plant species occurs on the constructed floodplain. Natural recruitment of native riparian vegetation on the floodplain is controlled primarily by: (1) spring and summer depth to groundwater, (2) spring and early summer surface water and groundwater drawdown rates, and (3) spring high flows during seed release by native riparian plants.

New monitoring hypotheses for SRP 9:

H12. During years with high spring flows, the abundance of non-native fish relative to native fish at SRP 9 is significantly lower relative to pre-project conditions and SRP control sites but higher than channel control sites.
This hypothesis can be tested using data from H10 and H6, above.

H11. Elimination of the pits results in reduction of largemouth bass abundance at the project sites and an increase in Chinook salmon outmigrant survival at the project sites.

H13. In SRP 9, habitat segregation between outmigrating Chinook salmon and foraging largemouth and smallmouth bass occurs at flows exceeding 300 cfs. Bass predation rates at flows $\geq$ 1,500 cfs are significantly less at SRP 9 than at SRP control sites. Predation rates by smallmouth bass are significantly higher than predation rates by largemouth bass.

H14. At flows exceeding 300 cfs, high flow velocity increases Chinook salmon migration rates relative to SRP control sites. At flows exceeding 300 cfs, juvenile Chinook salmon migration rates are significantly faster at SRP 9 than at the SRPs 7, 8, and 10. During these flows, juvenile Chinook salmon remain oriented facing upstream as they migrate through SRP 9 but orient facing downstream and must actively swim through SRP control sites.

Improvements to 7/11 Reach Monitoring

Monitoring recommendations for the 7/11 Reach project focus on continuation of existing monitoring, improvements in monitoring methods, and addition of one new monitoring hypothesis related to bird nesting in restored riparian stands. Recommended monitoring is shown in Table 38 in this report.

1 INTRODUCTION

The *Habitat Restoration Plan for the Lower Tuolumne River Corridor* ("the Restoration Plan") (McBain & Trush 2000) identifies several channel-floodplain restoration projects, as well as subtle changes to flood control releases, to improve ecosystem health and increase salmonid carrying capacity and production in the Tuolumne River. The Tuolumne River Technical Advisory Committee (TRTAC) selected the Special Run Pools (SRPs) 9 and 10 and Gravel Mining Reach projects as high priority and to be among the first projects implemented as part of the Tuolumne River Restoration Program. These projects are also identified as high priority in *Restoring Central Valley Streams: A Plan for Action* (California Department of Fish and Game [CDFG] 1993), the *Final Restoration Plan for the Anadromous Fish Restoration Program* (U. S. Fish and Wildlife Service [USFWS] 2001), and the *CALFED Ecosystem Restoration Program* (CALFED 2000).

The Restoration Plan's vision for restoring the lower Tuolumne River corridor is to utilize an integrative approach to re-establish critical ecological functions, processes, and characteristics under regulated flow and sediment conditions that best promote recovery and maintenance of a resilient, naturally reproducing Chinook salmon population. While the Restoration Plan and prior studies emphasized Chinook salmon (*Oncorhynchus tschawytscha*), rainbow trout/steelhead (*O. mykiss*)[1] is also an important management species in the river. With the 1998 listing of the Central Valley steelhead ESU as threatened under the federal Endangered Species Act, resource agencies increased their focus on *O. mykiss* in the Tuolumne River, and the TRTAC expanded its *O. mykiss* monitoring in the river. The SRPs 9 and 10 and Gravel Mining Reach projects contribute to the Restoration Plan's corridor-wide vision by restoring some of the most damaged sections of the river in a way that incorporates natural, dynamic processes into the restoration design and that relies on these processes (as opposed to continuous human intervention) to support and maintain ecological function at the project sites into the future.

Due to their size and complexity, SRPs 9 and 10 and the Gravel Mining Reach are being implemented as six separate projects. The SRP 9 project was completed in 2001, the 7/11 Reach of the Gravel Mining Reach was completed in 2003. Designs and permitting for the SRP 10 project and two of the remaining three projects in the Gravel Mining Reach are complete. Substantial funding has been secured for implementing the two Gravel Mining Reach projects but not for construction of SRP 10. The Gravel Mining Reach Projects have experienced significant complications and delays. The likelihood of and schedule for their implementation is uncertain.

The Restoration Plan recommends a two-tiered monitoring strategy for the river: (1) project-specific monitoring at individual restoration sites to measure progress toward achieving project objectives and provide information to improve restoration project design and implementation, and (2) river-wide monitoring to detect cumulative effects of the restoration projects and measure progress toward achieving the overall goals of the Restoration Plan. Project-specific monitoring at SRPs 9 and 10 and the Gravel Mining Reach was designed to assess: (1) whether the physical features were constructed as designed, (2) geomorphic and riparian vegetation responses to channel and floodplain reconstruction during high and low flows, and (3) changes in habitat suitability and utilization by target fish species.

While the Monitoring Plan specifies post-project monitoring of geomorphic processes, fish populations, and riparian vegetation continuing for several years after project construction, little post-project monitoring has occurred to date. Grants that funded project construction and as-built and

[1] Because it is not possible to determine whether a juvenile of this species will mature into a resident rainbow trout or an anadromous steelhead, both life history strategies are collectively referred to as "*O. mykiss*" in this report.

post-project monitoring were limited to a three-year duration. These grants funded monitoring through the 2003 completion of as-built surveys at both project sites and post-project predator abundance surveys at SRP 9. In 2004, Turlock Irrigation District (TID), working with TRTAC participants, submitted a proposal to the California Bay-Delta Authority (CBDA) Ecosystem Restoration Program to fund project-specific and river-wide monitoring for an additional three years. The CBDA ranked the proposal as a high priority for immediate funding and, in September 2005, awarded $2.4 million to continue post-project and river-wide monitoring through 2009. Since that time, TID and the TRTAC have worked with CDFG — the grant administer — to execute the grant agreement required to release funds and continue monitoring. As of the time of this report, a grant agreement had not been executed, and the schedule and process for executing an agreement have not been defined. Post-project monitoring will be delayed until these funds become available.

The purpose of this report is to:

- Discuss project implementation at SRP 9 and the 7/11 Reach (Section 1).
- Present pre-project, as-built, and post-project monitoring completed as of June 2006 at SRP 9 (Section 2) and the 7/11 Reach (Section 3).
- Discuss these results on the context of ongoing studies on the Tuolumne River (Section 4).
- Present recommendations for improving these projects and future project designs (Section 5).

1.1 Tuolumne River Background

The Tuolumne River, the largest of the three major tributaries to the San Joaquin River, drains a 1,960-square-mile watershed on the western slope of the Sierra Nevada Range. The river originates in Yosemite National Park and flows southwest to its confluence with the San Joaquin River (at San Joaquin river mile [RM] 83.7), approximately 10 miles west of the city of Modesto. The upper watershed is characterized by deep canyons and forested, mountainous terrain. Near the town of La Grange (RM 52), the river exits the Sierra Nevada foothills and flows through a gently sloping alluvial valley that is incised into Pleistocene alluvial fans. Within the alluvial valley, the river can be divided into two geomorphic zones defined by channel slope and bed composition: the gravel-bedded zone, which extends from La Grange Dam (RM 52) to below Geer Road (RM 24), and the sand-bedded zone, which extends from approximately RM 24 to the confluence with the San Joaquin River (RM 0) (Figure 1-1).

The lower Tuolumne River corridor, which extends 52.2 miles from La Grange Dam to the San Joaquin River, has been extensively altered by flow regulation and diversion, instream and floodplain gold dredging, instream and floodplain aggregate mining, and agricultural and urban development. Historical and contemporary conditions in the Tuolumne River are described in the *Habitat Restoration Plan for the Lower Tuolumne River* (“Restoration Plan”) (McBain & Trush 2000). Flow in the Tuolumne River is regulated by several dams that are owned and operated by TID, Modesto Irrigation District (MID), the City and County of San Francisco (CCSF). The New Don Pedro Project (NDPP), which includes New Don Pedro and La Grange Dams, is by far the largest water management project in the watershed. New Don Pedro Dam has a storage capacity of 2,030,000 acre-feet and provides approximately 900,000 acre-feet of water annually for irrigation and domestic use (575,000 acre-feet to TID and 310,000 acre-feet to MID).

Downstream of La Grange Dam, the river and its floodplain were dredged for gold in the early and mid-20th century. Dredging occurred primarily from the town of La Grange to approximately RM 40 near the Roberts Ferry Bridge. The gold dredges excavated channel and floodplain deposits to the depth of bedrock (approximately 25 feet) and often realigned the river channel. After recovering gold from the excavated alluvium, the dredges deposited the remaining tailings back onto the floodplain, creating long, cobble-armored piles that replaced the deep, rich soils of the alluvial valley floor. By the end of the gold mining era, 12.5 miles of river channel and floodplain (from RM 50.5 to RM 38) had been dredged and converted to tailings piles and much of the gravel-bedded zone of the river had been converted to long, deep dredger pools.

Large-scale aggregate mining in the river began in the 1930s and continues today. Historically, aggregate mines excavated sand and gravel directly from the river channel, creating large, in-channel pits now referred to as “special run-pools” (SRPs). These SRPs are as much as 400 feet wide and 35 feet deep and occupy 32% of the channel length in the gravel-bedded zone. Contemporary mining operations excavate sand and gravel from floodplains and terraces adjacent to the river, usually to a depth below the river’s thalweg elevation. These floodplain and terrace mining pits are typically separated from the river by narrow, unengineered dikes that consist of alluvium left in place during mining excavation. These dikes fail during even moderate flows (i.e., flows exceeding 8,000 cfs equivalent to the post-NDPP Q_6), resulting in connection of the pits to the river channel and/or capture of the river channel by the pits. The January 1997 flood (which peaked at 60,000 cfs downstream of the NDPP) breached nearly every mining pit dike along the river. After the flood, mine operators completed emergency repairs to separate some pits from the river and place the river back into its pre-flood channel. Most of these emergency repairs, however, were only temporary solutions.

These alterations to the river and its floodplain have reduced habitat quantity and quality for native salmonids (Chinook salmon and *O. mykiss*) and have contributed to declines in their populations. In 1995, through the FERC license amendment process for the New Don Pedro Project, TID, MID, and CCSF entered into a FERC Settlement Agreement (FSA) with USFWS, CDFG, California Sports Fishing Protection Alliance, Friends of the Tuolumne, San Francisco Bay Area Water Users Association, and Tuolumne River Expeditions. The FSA increased the minimum flow requirements for the Tuolumne River downstream of the NDPP and set forth a strategy for recovery of the lower Tuolumne River Chinook salmon population. Using adaptive management, the FSA goals are to: (1) increase the abundance of wild Chinook salmon in the Tuolumne River, (2) protect remaining genetic characteristics unique to the Tuolumne River Chinook salmon population, and (3) improve salmon habitat in the Tuolumne River. The TRTAC, composed of the Settlement Agreement signatories and other interested parties, was directed to coordinate, administer, and partially fund restoration and management activities within the lower Tuolumne River corridor. Section 12 of the FSA directed the TRTAC to identify ten priority habitat restoration projects, including a minimum of two SRP “pond isolation projects” (i.e., isolating in-channel gravel mining pits from the main channel), with the objective of implementing these projects by the year 2005. The SRPs 9 and 10 and four phases of the Gravel Mining Reach projects comprise six of these ten restoration projects.

1.2 Project Description and Implementation

1.2.1 Special Run Pool 9

The SRPs 9 and 10 projects (RM 25.9 to RM 25.0) are located near Geer Road at the transition from the gravel-bedded to the sand-bedded zone of the river (Figure 1-1). The SRPs are the legacy of past in-channel sand and gravel mining that excavated deep, lake-like pits in the river bed. At SRP 9, which extends from RM 25.9 to RM 25.7, the pre-project river channel was 400 feet wide and 6–19 feet deep. At SRP 10, which extends from RM 25.4 to RM 25.2, the river channel is 400 feet wide and 10–36 feet deep. The two SRPs are separated by a 2,000-foot-long channel reach that is relatively intact. At SRP 10, recent aggregate mining excavated a large pit on the south side of the river. The narrow dike that separated this floodplain pit from the river channel was breached by the 1997 flood.

The restoration approach for the SRP 9 project was to import material to fill the in-channel mining pit and construct a geomorphically functional channel and floodplain. The project also included repairing the dike at the floodplain mining pit at SRP 10. Project construction was completed in summer and fall 2001. Construction grading was completed from June 1 through October 15, 2001; all in-channel grading was completed by October 3, 2001. Riparian vegetation was planted from November 1 through December 31, 2001. Irrigation and plant maintenance continued through September 2003. The $2.7 million project cost was funded by the CBDA ($2,232,000), USFWS

Anadromous Fish Restoration Program (AFRP) ($271,000), and TID, MID, and CCSF ($227,000). Additional project design and implementation details can be found in the report *Tuolumne River Floodway Restoration: Project Design Approach and Rationale* (McBain & Trush 2004a).

1.2.1.1 Project Objectives

The primary objective of the SRPs 9 and 10 projects is to reduce habitat for largemouth bass (*Micropterus salmoides*) and, thus, increase Chinook salmon juvenile outmigrant survival from the river. The large, lake-like pits at SRPs 9 and 10 provide suitable habitat for non-native largemouth bass. Past studies of Chinook salmon population dynamics and outmigrant survival concluded that predation by largemouth bass in these and other SRP reaches is a significant factor limiting Chinook salmon production in the Tuolumne River, particularly during drier years (TID/MID 1992a). These studies also identified smallmouth bass (*M. dolomieu*) as a potentially important Chinook salmon predator. Although observed smallmouth bass predation rates on Chinook salmon were higher than observed rates for largemouth bass, smallmouth bass predation was considered to have a minor effect on Chinook salmon production due to the low abundance of this species throughout the river (TID/MID 1992a).

Additional project objectives presented in the Restoration Plan and reiterated in proposals to the CBDA and AFRP were to:

- Create a channel and floodplain with a morphology scaled to function within contemporary and future sediment and hydrologic regimes.
- Restore sediment transport continuity through the reach.
- Revegetate reconstructed floodplains and terraces with native woody riparian species planted on fluvial surfaces appropriate for each species life cycle.

1.2.1.2 Conceptual Design

The approach for the SRP 9 project was to import material to fill in the pit and construct a geomorphically functional channel and floodplain. The conceptual design presented in the Restoration Plan was to fill the SRP 9 pit with up to 21 vertical feet of aggregate and topsoil to construct a single-thread channel with vegetated floodplains on both the north and south banks. The conceptual channel and floodplain design was intended to allow: (1) scour and re-deposition of alluvial bars within the bankfull channel, (2) floodplain inundation and connection of the floodplain to the river channel, and (3) channel migration within the floodway. The channel was designed to convey 5,000 cfs (the post-dam Q_3), the maximum release through the NDPP turbines. On the constructed floodplains, riparian vegetation plantings were placed to coincide with specific inundation frequencies based on vegetation surveys conducted at control sites on the river.

After the conceptual design for the project was completed, TID developed plans to construct an infiltration gallery capable of diverting up to 100 cfs from the river at SRP 9 in conjunction with the restoration project. The pump station for the diversion has not been funded and was not included in the SRP 9 project. The gallery, as constructed, is described in the following section.

1.2.1.3 Final Design and Design Revisions

Final design for the SRP 9 project underwent significant revision less than four weeks before project construction. Final construction designs, drawings, and specifications for the project were developed by HDR Engineering and HART Restoration. This design package was released to solicit bids from a pre-qualified short-list of contractors eight weeks before the scheduled construction start date; bids were due four weeks later. All of the bids submitted exceeded the available construction budget.

Over a two-week period of negotiations with the low bidder, the project was quickly redesigned to reduce project cost to within available budget and allow construction to begin as scheduled, which was necessary to complete construction within the timeframe established by various permits. Project construction required large amounts of fill to be imported to the site, and fill handling and transport comprised the majority of the construction budget. Estimated fill volume to construct the project final design was 193,000 yd^3 (165,000 yd^3 of aggregate, 22,500 yd^3 of topsoil, 5,500 yd^3 of fill for the infiltration gallery), an increase of 47,000 yd^3 (32%) over the conceptual design estimate used to apply for project funding. The revised design reduced the fill volume by 24,000 yd^3 (12%) by lowering floodplain elevation on both sides of the channel by 1–3 feet and adding high flow scour channels to each floodplain (Figure 1-2). By lowering floodplain elevation, the revised design: (1) reduced bankfull channel depth by approximately two feet (from seven feet in the conceptual design to five feet in revised design), (2) reduced design channel conveyance by 70% (from 5,000 cfs [Q_3] in the conceptual design to 1,500 cfs [$Q_{1.3}$] in the revised design, and (3) increased the duration and frequency of floodplain inundation. Because the plants for the project had already been grown, the planting design was not substantially altered, except the high flow scour channels were planted with rushes and sedges. Additional details of the final and revised final designs are provided in Table 1.

This reduction in channel confinement and increased inundation of the floodplain could affect the performance of the project by:

- reducing flow depth at bankfull flows, thus reducing sediment transport and scour;
- causing inundation mortality of riparian plants, such as valley oak, that typically establish on higher elevation geomorphic surfaces;
- increasing natural regeneration of woody riparian species and associated understory plants because the lowered floodplain surface is closer to the summer baseflow groundwater table;
- increasing overbank inundation frequency and duration; and
- increasing the duration and frequency of salmon fry, juvenile, and smolt access to seasonally inundated rearing habitat on the floodplain and in floodplain scour channel.

The infiltration gallery was situated in the upstream third of the site. The gallery consists of 16 pipes extending from the left (south) bank and buried in the bed of the river (Figure 1-3). Rock revetment was installed on the left-bank to protect the infiltration gallery and diversion facilities. Revetment covers 625 feet (70%) of the left bank at the site. The diversion is not operational.

Table 1. SRP 9 project design elements.

Design Component	**Final Design**	**Revised Final Design**
Channel Reconstruction	• Reconstruct a low flow and bankfull channel from STN 14+50 to STN 3+00. Bankfull channel width is approximately 200 feet and flow conveyance is 5,000 cfs.	• Reconstruct a low flow and bankfull channel from STN 14+50 to STN 3+00. Bankfull channel width is approximately 160 feet and flow conveyance is 1,500 cfs.
Floodplain Regrading and Dike Construction	• Fill in the right (north) bank of the pit to create a floodplain up to 200 feet in width extending from STN 14+00 to STN 5+50. Floodplain elevation is approximately 5 feet above the low flow water surface. • Fill in the left (south) bank of the pit to create a floodplain up to 150 feet in width extending from STN 14+50 to STN 3+00. Floodplain elevation is approximately 5 feet above the low flow water surface. • Repair a 65-foot long breach in the dike at SRP 10, constructing the new dike section to have 2:1 side slopes on the mining pit and channel side. Armor dike side slopes with 25-pound rock slope protection with ½-ton boulders at the toe.	• Fill in the right (north) bank of the pit to create a floodplain up to 200 feet in width extending from STN 14+00 to STN 5+50. Floodplain elevation is approximately 2.5 feet above the low flow water surface. • Fill in the left (south) bank of the pit to create a floodplain up to 150 feet in width extending from STN 14+50 to STN 3+00. Floodplain elevation is approximately 2.5 feet above the low flow water surface. • Construct two high flow scour channels, one through the north floodplain and one through the south floodplain. Both high flow scour channels are connected to the main channel at both their upstream and downstream ends. • Repair a 65-foot long breach in the dike at SRP 10, constructing the new dike section to have 2:1 side slopes on the mining pit and channel side. Armor dike side slopes with 25-pound rock slope protection with ½-ton boulders at the toe.
Slope protection, culverts, and debris removal	• Install 25-pound rock slope protection with ½-ton boulders at the toe on the left bank from STN 12+50 to STN 6+25. • Install brush boxes and willow mats on north bank between SRP 9 and 10 to protect eroding orchard.	• No change
Infiltration Gallery	• From STN 13+00 to STN 11+00, install infiltration gallery consisting of four main laterals and 16 sub-laterals protruding from the left bank across the channel bed and buried in a select gravel envelope to a depth of five feet below the channel bed.	• No change
Revegetation	• Revegetate all floodplain surfaces constructed. Floodplain canopy species include cottonwood, willow, alder, and oak. Revegetation area = 5.5 acres.	• No change, except high flow scour channels planted with rushes and sedges.
Note that stationing in this table reflects project-specific stationing as depicted on the construction design drawings. STN 0+00 is the downstream boundary of the SRP 9 project site.		

1.2.2 Gravel Mining Reach

The Gravel Mining Reach (RM 40.3 to RM 34.4) is located near Roberts Ferry Bridge at the approximate mid-point of the gravel-bedded zone of the river (Figure 1-1). In-channel and floodplain mining have converted much of this reach to open-water pits. Mining continues in this reach outside the restoration area and will continue to convert the floodplain and terraces to open-water pits in the future. Within the Gravel Mining Reach, the river channel is bordered by eleven mining pits and one captured settling pond on the left (south) bank and three settling ponds on the right (north) bank. Mining pit dikes confine the river and riparian corridor. Dikes constitute 17,500 feet (55%) of the total length of the river's left bank and 735 feet (2%) of the right bank. Failure of the dikes separating the river channel from mining pits was a major impetus for restoration in this reach. These dikes have failed repeatedly during moderate-to-large floods, and the reach is particularly vulnerable to damage from large floods. The January 1997 flood caused extensive damage in the reach, including multiple dike failures, capture of the river channel by aggregate pits in the 7/11 Reach, loss of the M.J. Ruddy conveyor bridge, irreparable damage to the Roberts Ferry Bridge, and damage to other mine operation structures.

The restoration approach for the Gravel Mining Reach attempts to restore a functional floodway capable of conveying 15,000 cfs by acquiring lands or easements within the project footprint, isolating off-channel mining pits, constructing a functional channel and floodplain, and planting riparian vegetation on restored floodplain surfaces. Due to its length, the Gravel Mining Reach is being implemented as four projects from upstream to downstream: the 7-11 Reach (RM 37.7 to 40.3), M.J. Ruddy Reach (RM 36.6 to 37.7), Warner-Deardorff Reach (RM 35.2 to 36.6), and Reed Reach (RM 34.3 to 35.2) (Figure 1-4). The 7/11 Reach project was completed in 2003, with funding from the CBDA ($2,801,000) and AFRP ($4,196,000) and funding and in-kind contributions from TID, MID, and CCSF ($448,000). Construction grading was completed from April 2002 through March 2003, with in-channel grading limited to the summer work window defined by project permits. Riparian vegetation was planted from February through April 2003, with additional follow-up planting in January 2004. Irrigation and plant maintenance continued through September 2004.

1.2.2.1 Project Objectives

The primary goal of the Gravel Mining Reach project is to establish a river channel and riparian floodway that will improve flood conveyance, geomorphic processes, and riparian and aquatic habitat throughout the reach. Project objectives presented in the Restoration Plan and funding proposals to the CBDA are to:

- Restore a floodway width that will safely convey at least 15,000 cfs.
- Improve salmon spawning and rearing habitats by restoring an alternate bar (pool-riffle) morphology.
- Prevent salmon mortality that results from frequent connection between the river and off-channel mining pits.
- Restore native riparian vegetation communities on appropriate geomorphic surfaces within the restored floodway
- Restore habitats for native wildlife species (e.g., egrets, ospreys, and herons).
- Allow the channel to migrate within the restored floodway to improve and maintain riparian and salmonid habitats.
- Remove floodway constrictions created by unengineered dikes that fail during moderate flood flows.
- Decrease risk of flood damage to aggregate extraction operations, bridges, and other human structures.

1.2.2.2 Conceptual Design

The restoration approach for the Gravel Mining Reach attempts to restore a functional floodway capable of conveying a 15,000-cfs discharge through the project reach by acquiring control of the lands within the project footprint, isolating off-channel mining pits, constructing a functional channel and floodplain, and planting riparian vegetation on restored floodplain surfaces (Figure 1-5). The conceptual design presented in the Restoration Plan included setting back mine dikes to increase floodway width to 500 feet and importing fill to reconstruct portions of the channel and construct floodplains within the expanded floodway. The bankfull channel was designed to convey 5,000 cfs (the post-dam Q_3). The floodway was designed to convey 15,000 cfs with at least two feet of freeboard on the setback dikes. Design low-flow channel width was 75–90 feet; the design bankfull channel width was 175–200 feet. The 500-foot minimum floodway width was intended to allow scour and re-deposition of mobile alluvial bars within the bankfull channel, increase floodplain habitat area and connectivity of the floodplain to the channel, and provide room for channel migration within the floodway while reducing risk of the river being captured by aggregate mining pits and of damage to human structures. High flow scour channels on the floodplain provide topographic diversity, high flow refugia, and sites suitable for natural recruitment of riparian vegetation.

1.2.2.3 Final Design and Design Revisions

Final designs, construction drawings, specifications, and project cost estimates were developed by HDR Engineering (Figure 1-6). The final design replaced the original concrete ford crossing the floodplain at the 7/11 haul road bridge with a series of culverts. The haul road bridge went through several design iterations. Because the mine operator did not want the bridge to be moved or reconstructed, the original design included a concrete apron ford crossing on the south abutment that would convey flows above 5,000 cfs. Based on feedback from the operator, the apron design was replaced with a pre-cast bridge system in the 90% designs. In the final design, the bridge span was replaced with twelve culverts to reduce project cost (Figure 1-6). Additional detail on the final design is provided in Table 2.

Project construction was put out to bid to be constructed by a third-party contractor with construction management and inspection performed by HDR Engineering. During construction, the project design was modified to reduce fill volume. Final designs and specifications estimated that 420,000 yd^3 of fill would be required to construct the project. The contractor made a lump sum bid to build the project to the lines and grade presented in the bid package but found that construction required more fill than previously estimated. The contractor filed a claim against TID for the amount of the additional costs to complete the project as designed. To settle the claim, the design was revised to reduce fill volume and cost by: (1) shifting the dike at the downstream end of the project (from RM 37.7 to RM 37.8 50 feet toward the river, and (2) lowering the elevation of the adjacent floodplain. The design modifications reduced floodway width at the downstream end of the project by approximately 10% and reduced the threshold for floodplain inundation at the downstream end of the site from 5,000 cfs to 4,500 cfs.

Table 2. Construction design elements for the 7/11 Reach.

Design Component	**Description**
Channel Reconstruction	• Reconstruct channel from Roberts Ferry Bridge (STN 84+00) to STN 42+00. Bankfull channel width is approximately 175 feet and will convey 5,000 cfs. Top of bank elevation ranges from 108 feet to 110 feet at the upstream end of the site.
Floodplain Regrading and Dike Construction	• Remove dredger tailings and regrade floodplain on left bank upstream of Roberts Ferry Bridge (STN 121+66.07 to 104+00). • Construct dike on south side of left bank floodway (to isolate project from mining pit) from STN 121+23 to STN 101+01. • In conjunction with channel reconstruction, construct floodplain on left bank from STN 84+00 to STN 43+00. • Construct floodplain on left bank from STN 29+00 to STN 0+26, including filling the settling pond from STN 16+00 to STN 0+00. • Construct dike on south side of left bank floodway (to isolate project from mining pits) from STN 72+00 to STN 0+00. • Construct high flow scour channel on left bank floodplain beginning at STN 67+00 and joining the mainstem channel at STN 54+00. High flow scour channel is 2 feet deep at the upstream end, 3 feet deep at the downstream end, and 60 feet wide (top of bank).
Slope protection, culverts, and debris removal	• Install vegetated rock slope protection on right bank from STN 22+50 to STN 17+25 and on the left bank from STN 37+75 to STN 33+80. Vegetated rock slope protection consists of 15-pound rock with ½-ton boulders at toe and jute fabric overlay vegetated with sedge, alder and willow ballast buckets, creeping wild rye, coyote bush, box elder and valley oak. • Construct ford-type haul road crossing. Install ½-ton rock slope protection on slopes of haul road crossing and on right bank at STN 19+00. Actual installation was twelve 73 x 55-inch pipe arch culverts in crossing. • Install 25-pound rock slope protection with ½-ton boulders at toe on left bank STN 33+80 to STN 37+75. • Remove concrete and other debris from channel.
Revegetation	• Upstream of Roberts Ferry Bridge, vegetate floodplain surface. Canopy species include cottonwood, willow, and alder. Revegetation area = 21.8 acres. • Revegetate narrow band on south bank from STN 101 to STN 96+25. • Relocate elderberries to south bank from STN 96+25 to STN 89+00. • Revegetate south bank upstream abutment of Roberts Ferry Bridge. • Revegetate south bank floodplain surface described from STN 84+00 to STN 43+00. Canopy species include cottonwood, willow, alder, and valley oak. • Revegetate toe of dike and floodplain from STN 29+00 to STN 0+26. Canopy species include cottonwood, willow, alder, and valley oak. • Acquire approximately 8 acres of upland bench area on the south bank immediately upstream of the Roberts Ferry Bridge to be planted as valley oak savanna habitat.

Note that stationing in this table reflects project-specific stationing as depicted on the construction design. STN 0+00 is the downstream boundary of the reach.

1.3 Monitoring Plan Requirements and Implementation Status

The Monitoring Plan for the restoration projects was presented in the *Tiered Environmental Assessment and Initial Study/Mitigated Negative Declaration: Gravel Mining Reach and Special Run Pools 9 and 10 Restoration and Mitigation Projects* (USFWS and TID 1998) (see Appendix H). The plan was developed to test specific hypotheses related to each project (listed below).

<u>Monitoring hypotheses for SRP 9:</u>

H1. The constructed channel conveys 1,500 cfs; flows exceeding 1,500 cfs spill onto the floodplain.[2]
H2. The channel bed is mobilized at flows of 5,000 cfs.
H3. The constructed bankfull channel morphology is stable, where stable is defined as no net deposition or erosion in channel cross section and profile over the long term.
H4. The channel migrates under the current flow regime, although migration rates will be slow and magnitude will be small.
H5. The extent and quality of Chinook salmon spawning habitat is increased.
H6. The extent and quality of Chinook salmon rearing habitat is increased.
H7. Planted riparian vegetation becomes established on the constructed floodplain.
H8. Natural recruitment of native riparian plant species occurs on the constructed floodplain.
H9. Riparian vegetation does not encroach into the constructed channel.
H10. Elimination of the pits reduces habitat suitability for largemouth bass.
H11. Elimination of the pits results in reduction of largemouth bass abundance at the project sites and an increase in Chinook salmon outmigrant survival at the project sites.

<u>Monitoring hypotheses for the 7/11 Reach:</u>

H1. The constructed channel conveys 5,000 cfs; flows exceeding 5,000 cfs spill onto the floodplain.
H2. The channel bed is mobilized at flows of 5,000 cfs.
H3. The constructed bankfull channel morphology is stable, where stable is defined as no net deposition or erosion in channel cross section and profile over the long term.
H4. The channel migrates under the current flow regime, although migration rates will be slow and magnitude will be small.
H5. The extent and quality of Chinook salmon spawning habitat is increased.
H6. The extent and quality of Chinook salmon rearing habitat is increased.
H7. Planted riparian vegetation becomes established on the constructed floodplain.
H8. Natural recruitment of native riparian plant species occurs on the constructed floodplain.
H9. Riparian vegetation does not encroach into the constructed channel.

Monitoring metrics and status for each project are shown in Tables 3 and 4. Pre-project monitoring at the SRP 9 and 7/11 Reach projects was conducted in 1998 and 1999 and is reported in McBain & Trush and Stillwater Sciences (1999, 2000). As-built monitoring was conducted at SRP 9 in 2002–2005 and at the 7/11 Reach in 2003–2005. No additional funding is currently available for continued monitoring at these sites. Due to lack of funds for continued monitoring, post-project monitoring has been limited to stage observations at both sites and one bed mobility experiment at the 7/11 Reach conducted in 2005.

[2] H1 initially stated that the floodplain would be inundated by flows exceeding 5,000 cfs. This hypothesis was revised to address changes to the project design.

Table 3. SRP 9 monitoring metrics and status.

Topic (Hypothesis)	Metric	Status: Pre-project	Status: As-built	Status: Post-project	Comment
Channel morphology (H3, H7, H9)	Digital terrain mapping	●[1]	●[2]	N/A	[1] Prepared by EA Engineering. [2] October 2002.
	Cross section surveys and long profile	●[1]	●[2]	○[3,4]	[1] August 1998 (1,600 cfs) and July 1999 (265 cfs). [2] October 2002 (334 cfs). [3] LIDAR surveys of floodplain topography (2-ft contour interval) from La Grange to the San Joaquin River, September 2005.[a] [4] Monitoring Plan includes surveys after each of two high flow events exceeding 5,000 cfs (or if overbank flow > 1,500 cfs causes floodplain deposition).
	Aerial photography	●[1]	●[2]	◉[3,4]	[1] 1:2,000-scale Nov. 24, 1998 (354 cfs). [2] 1:1,200-scale Aug. 30, 2002 (76 cfs). [3] Digital orthophotographs (0.5-foot resolution), Sept. 21, 2005 (330 cfs).[a] [4] Monitoring Plan includes one survey after a high flow event exceeding 10,000 cfs.
Hydraulics (H1)	High flow stage	N/A	N/A	●[1]	[1] Surveyed for 1,030 cfs (April 23, 2003) and 2,200 cfs (February 21, 2005). Markers placed but not surveyed for 3,230 cfs (February 23, 2005) and 5,690 cfs (March 25, 2005).
Bed mobility (H2)	Tracer Rocks	N/A	N/A	○[1]	[1] Monitoring Plan includes tracer rock experiments for one high flow event.
Bass Habitat (H6, H10)	Habitat mapping and modeling	●[1,2]	N/A	●[2]	[1] Habitat mapping: Aug. 1998 (1,440–1,770 cfs) and July 1999 (265–287 cfs). [2] Habitat modeling.
Predator Abundance (H10, H11)	Electrofishing at project and control sites	●[1]	N/A	●[2]	[1] Sept. 1998 and Sept. 1999. [2] Sept.–Oct. 2003. Attempted Oct. 2004.
Juvenile salmon survival (H11)	Mark-recapture at rotary screw traps	●[1]	N/A	◉[2]	[1] Spring 1998 and 1999; discontinued. [2] Pilot predation study spring 2006.
Riparian vegetation (H7)	Plot-based survival, % cover, and growth	N/A	●[1]	○[2]	[1] As-built vegetation maps, 2002. [2] Monitoring Plan includes surveys in 2001–2003 and 2005 and/or following a high flow event exceeding 5,000 cfs.

Legend: ● = complete, ◉=begun but not complete, ○ = not begun
Footnote:
[a] Data acquired for and with funds from the Tuolumne River Coarse Sediment Transfusion Project.

Table 4. 7/11 Reach monitoring metrics and status.

Topic (Hypothesis)	Metric	Status			Comment
		Pre-project	As-built	Post-project	
Channel morphology (H3, H4, H7, H9)	Digital terrain mapping	●[1]	○[2]	◉[3]	[1] Pre-project digital terrain model prepared by KSN, Inc. [2] No post-project digital terrain model prepared. [3] Channel bathymetry (2-ft contour interval) surveyed from La Grange to the 7/11 haul road bridge, June 2005.[a] LIDAR surveys of floodplain topography (2-ft contour interval) from La Grange to the San Joaquin River, September 2005.[a]
	Cross section surveys and long profile	●[1]	●[2]	○[3,4]	[1] Aug. 1998 (944 cfs) and July–Aug. 1999 (254-277 cfs). [2] Oct. 2002 (338 cfs) and Nov. 2002 (185 cfs). [3] Channel bathymetry (2-ft contour interval) surveyed from La Grange to the 7/11 haul road bridge, June 2005.[a] LIDAR surveys of floodplain topography (2-ft contour interval) from La Grange to the San Joaquin River, September 2005.[a] [4] Monitoring Plan includes surveys after each of two high flow events exceeding 5,000 cfs.
	Aerial photography	●[1]	●[2]	◉[3,4]	[1] 1:2,000-scale Nov. 24, 1998 (354 cfs). [2] 1:1,200-scale Aug. 30, 2002 (76 cfs). [3] Digital orthophotographs (0.5-foot resolution), Sept. 21, 2005 (330 cfs).[a] [4] Monitoring Plan includes surveys after a high flow event exceeding 10,000 cfs.
Hydraulics (H1)	High flow stage	N/A	N/A	●[1]	[1] Surveyed for 1,030 cfs (April 23, 2003). Markers placed but not surveyed 5,690 cfs (March 25, 2005), 6,480 cfs (March 31, 2005), and 8,410 cfs (April 1, 2005).
Bed mobility (H2)	Tracer Rocks	N/A	N/A	◉[1]	[1] At cross sections 2214+50 and 2198+30 (Riffle 29B) for flows of 7,140 cfs (April 4, 2005).[b]
Bed Texture (H2, H5)	Pebble Counts	●[1]	●[2]	○	[1] August 1998, Aug. 1999 [2] Oct. 16, 2002 at cross sections 2214+50 and 2198+30 (Riffle 29B).
Salmonid Habitat (H5, H6)	Habitat mapping	●[1]	●[2]	N/A	[1] Aug. 1998 (1,050–1,680 cfs) and Aug. 1999 (254–265 cfs). [2] Oct. 2002 (331 cfs) and Nov. 2002 (185 cfs).
	Spawner surveys	●[1]	●[1]	◉[1]	[1] Conducted annually by CDFG.
Riparian vegetation (H7)	Plot-based survival, % cover, and growth	N/A	●[1]	○[2]	[1] As-built vegetation maps, 2003. [2] Monitoring Plan includes surveys in 2003–2005 and 2007 and/or following a high flow event exceeding 5,000 cfs.
Bioengineering (N/A)	Photomonitoring[1]	N/A	○[1]	○[1]	[1] Monitoring Plan includes photomonitoring in 2003–2005 and 2007 and/or following a high flow event exceeding 5,000 cfs.

Legend: ● = complete, ◉=begun but not complete, ○ = not begun

Footnote:

[a] Data acquired for and with funds from the Tuolumne River Coarse Sediment Transfusion Project.

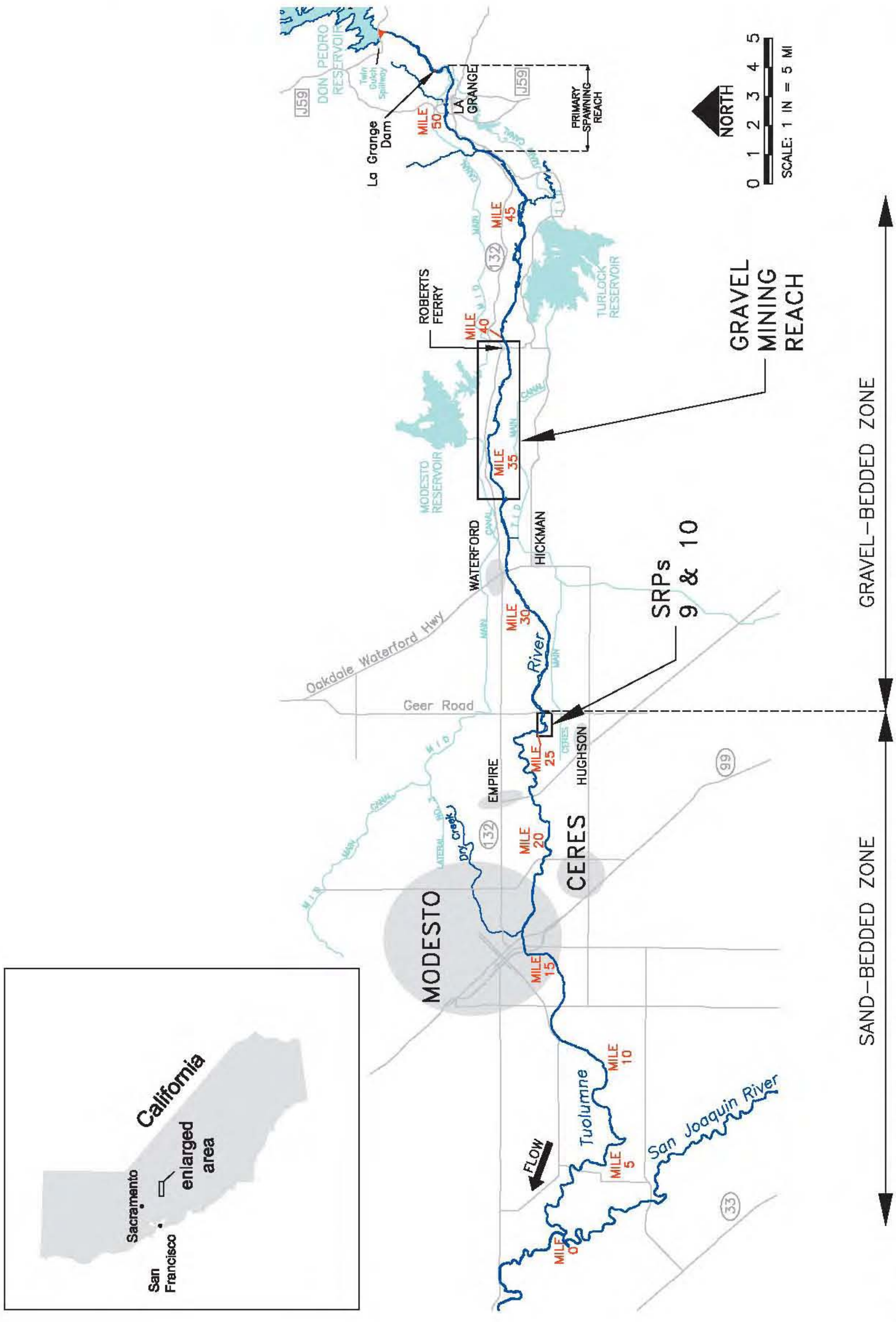

Figure 1-1. Lower Tuolumne River vicinity map.

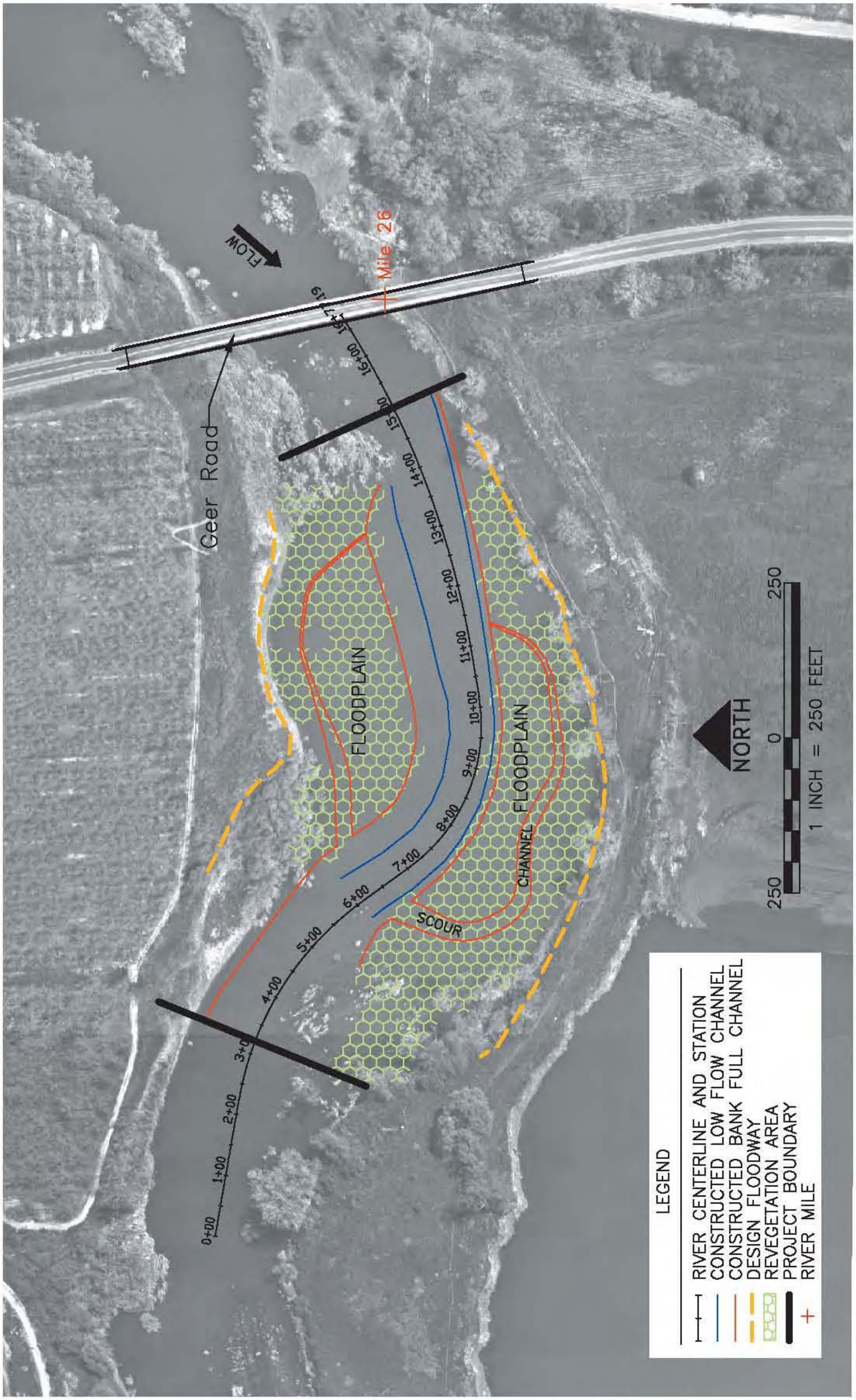

Figure 1-2. SRP 9 project final design.

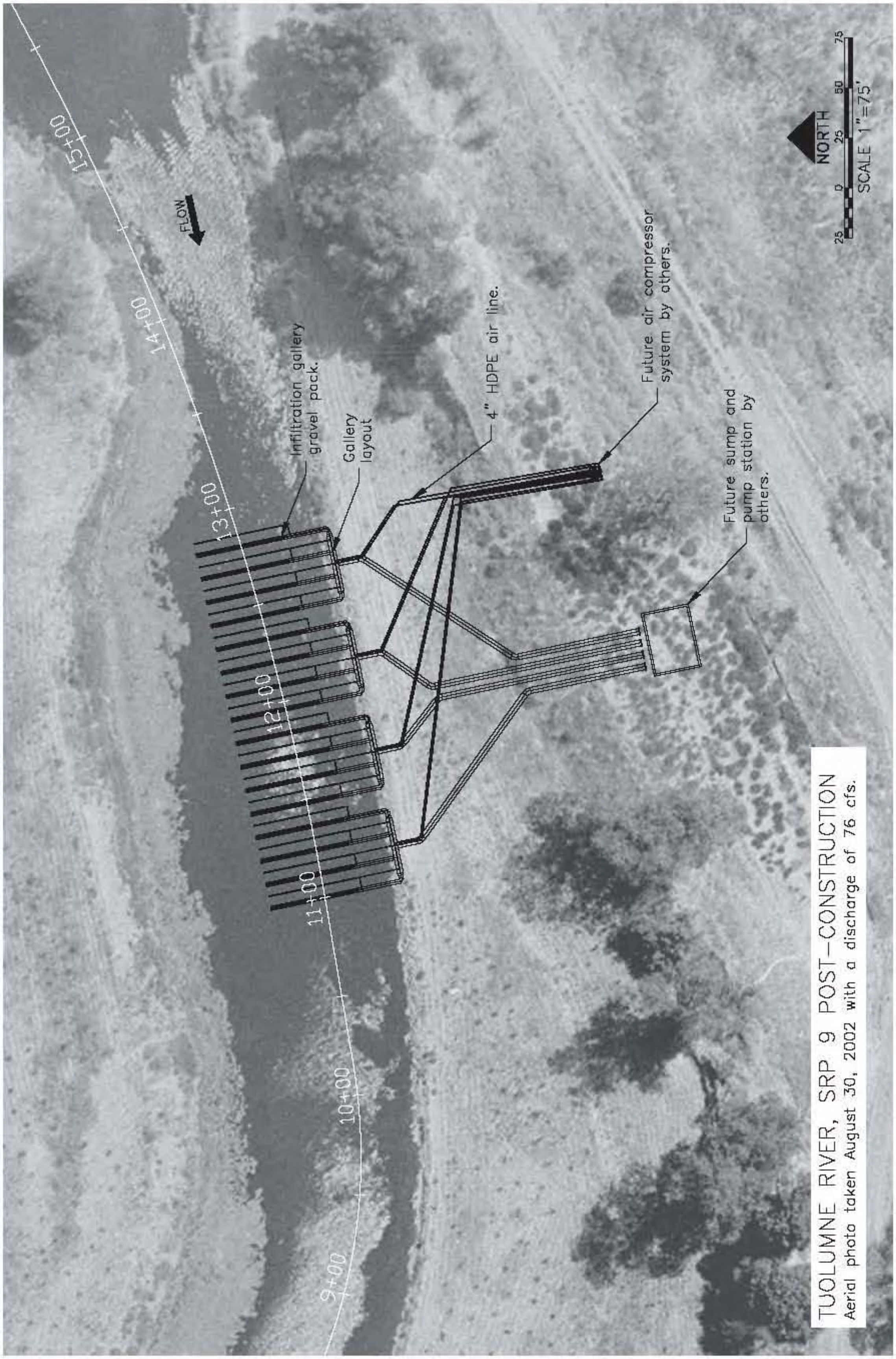

Figure 1-3. Schematic of infiltration gallery installed at SRP 9.

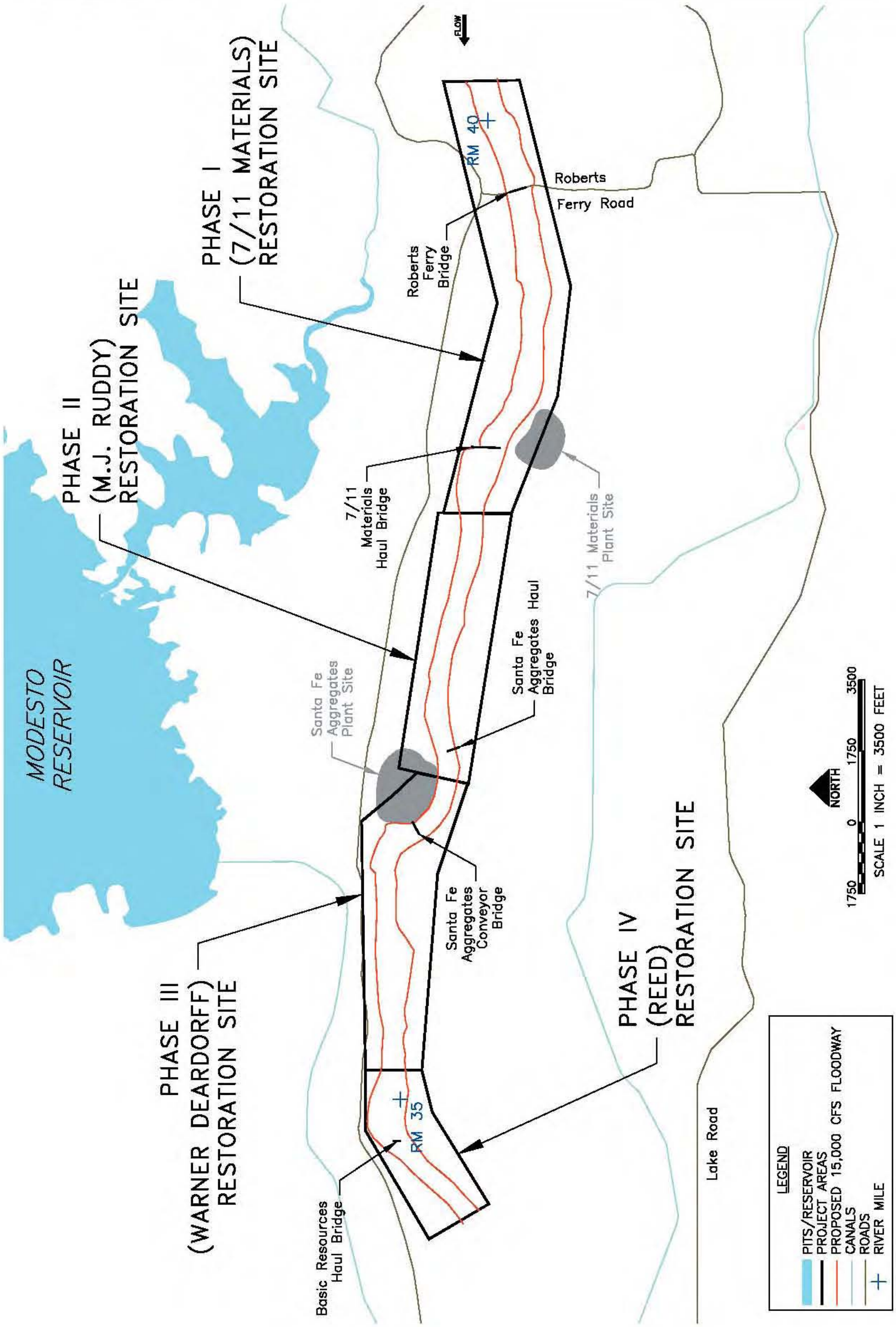

Figure 1-4. Gravel Mining Reach project boundaries: 7/11 Reach, M.J. Ruddy Reach, Warner-Deardorff Reach, and Reed Reach.

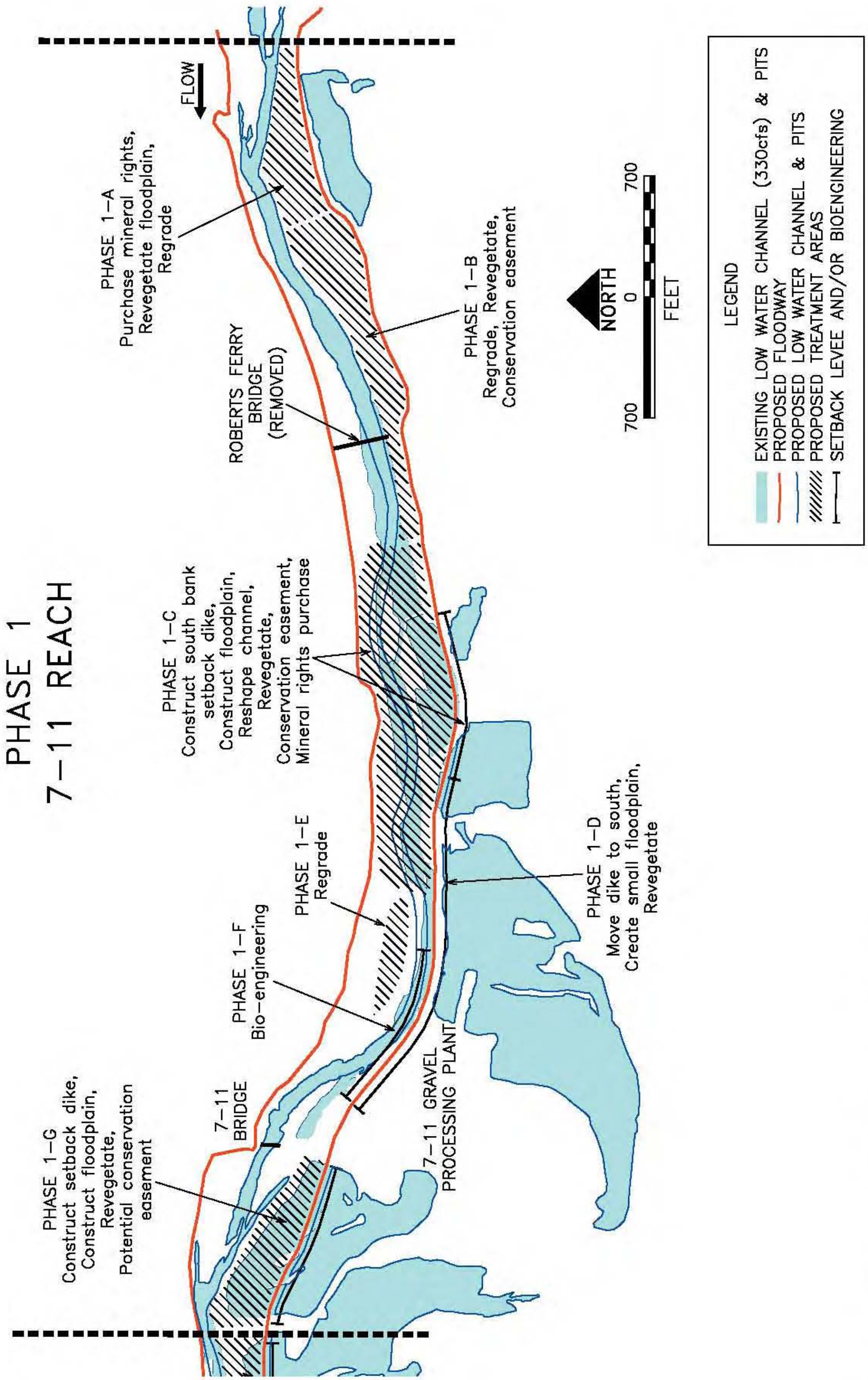

Figure 1-5. *7/11 Reach conceptual design.*

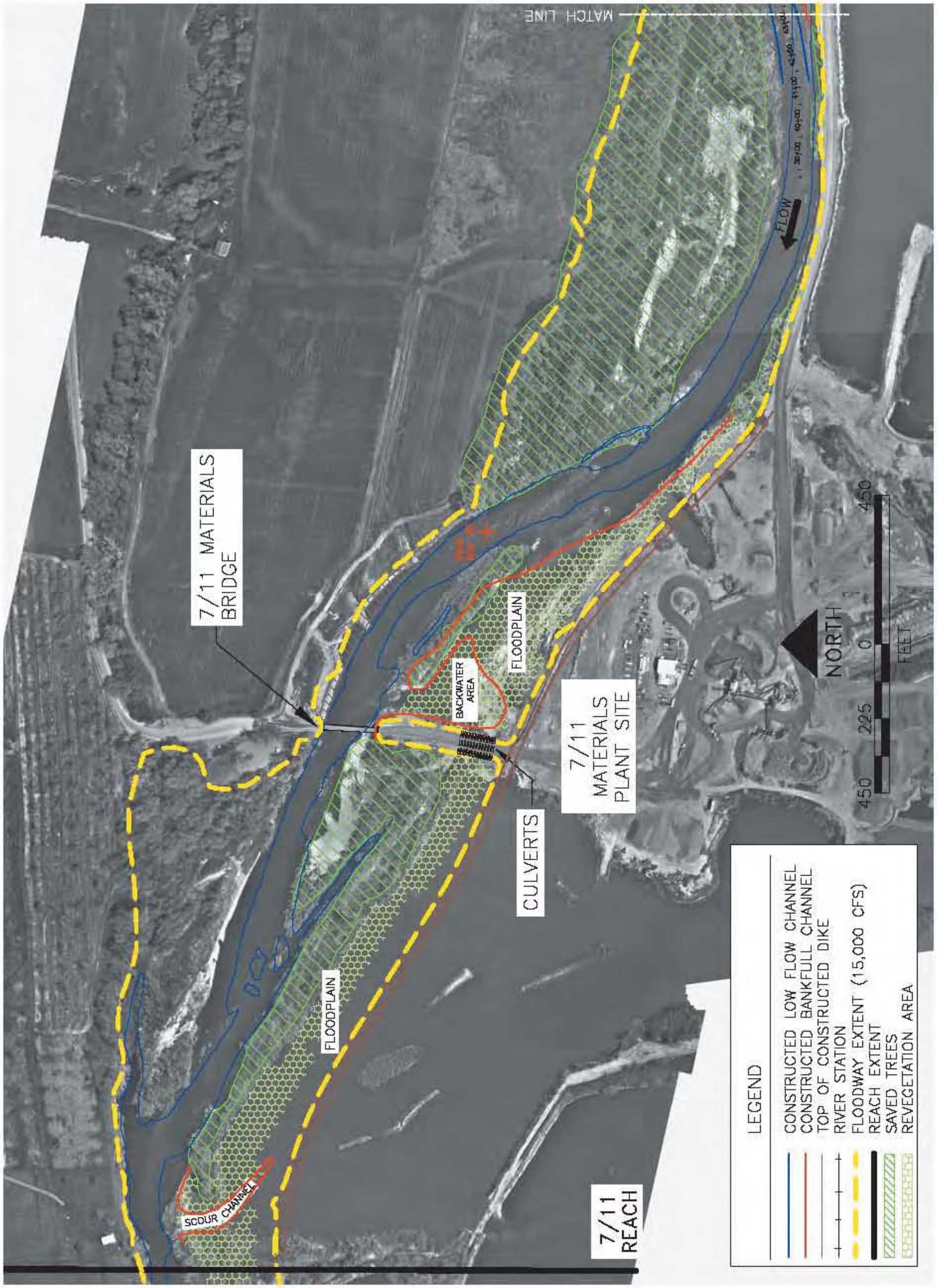

Figure 1-6. 7/11 Reach project final design.

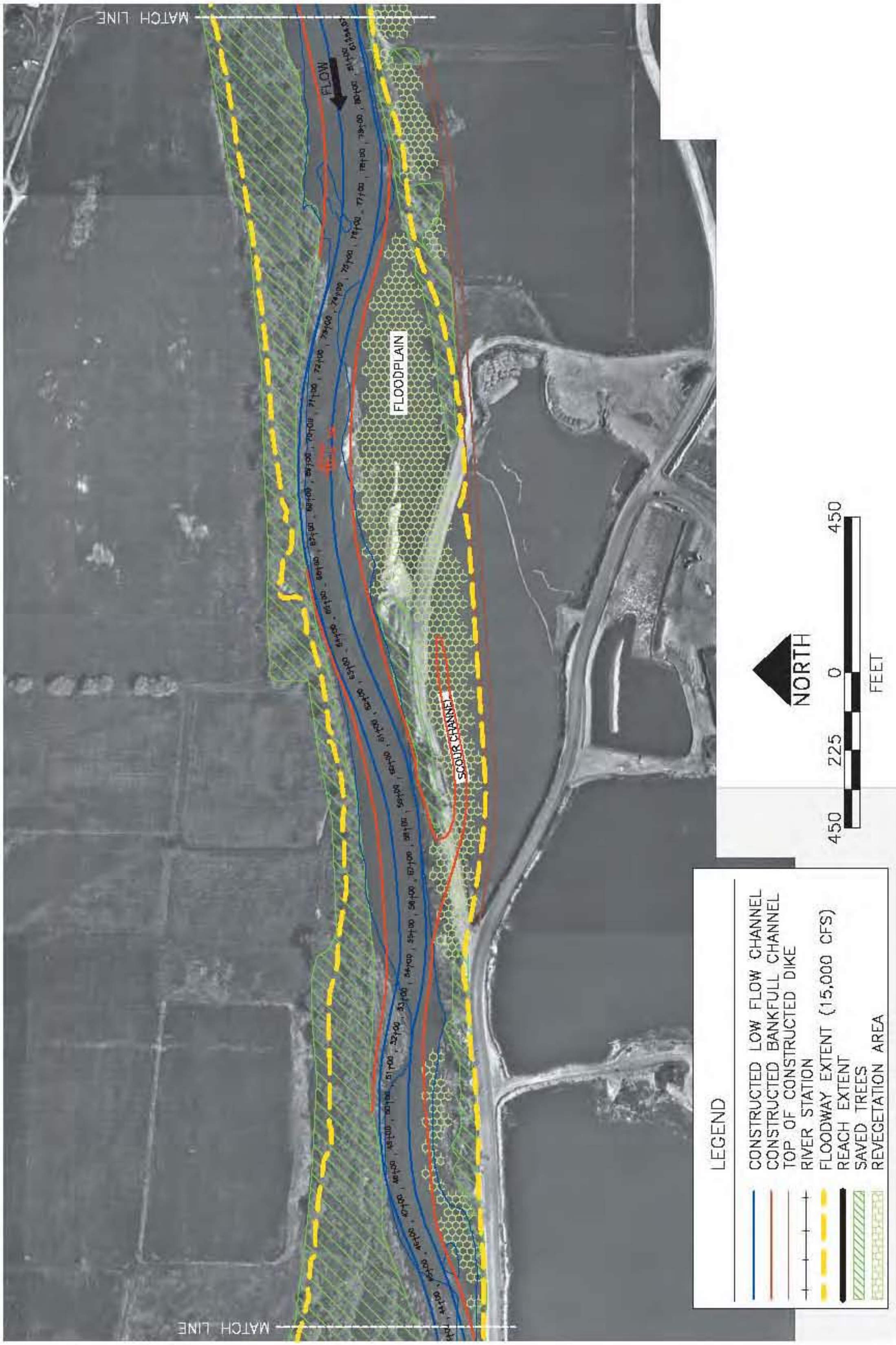

Figure 1-6. 7/11 Reach project final design, continued.

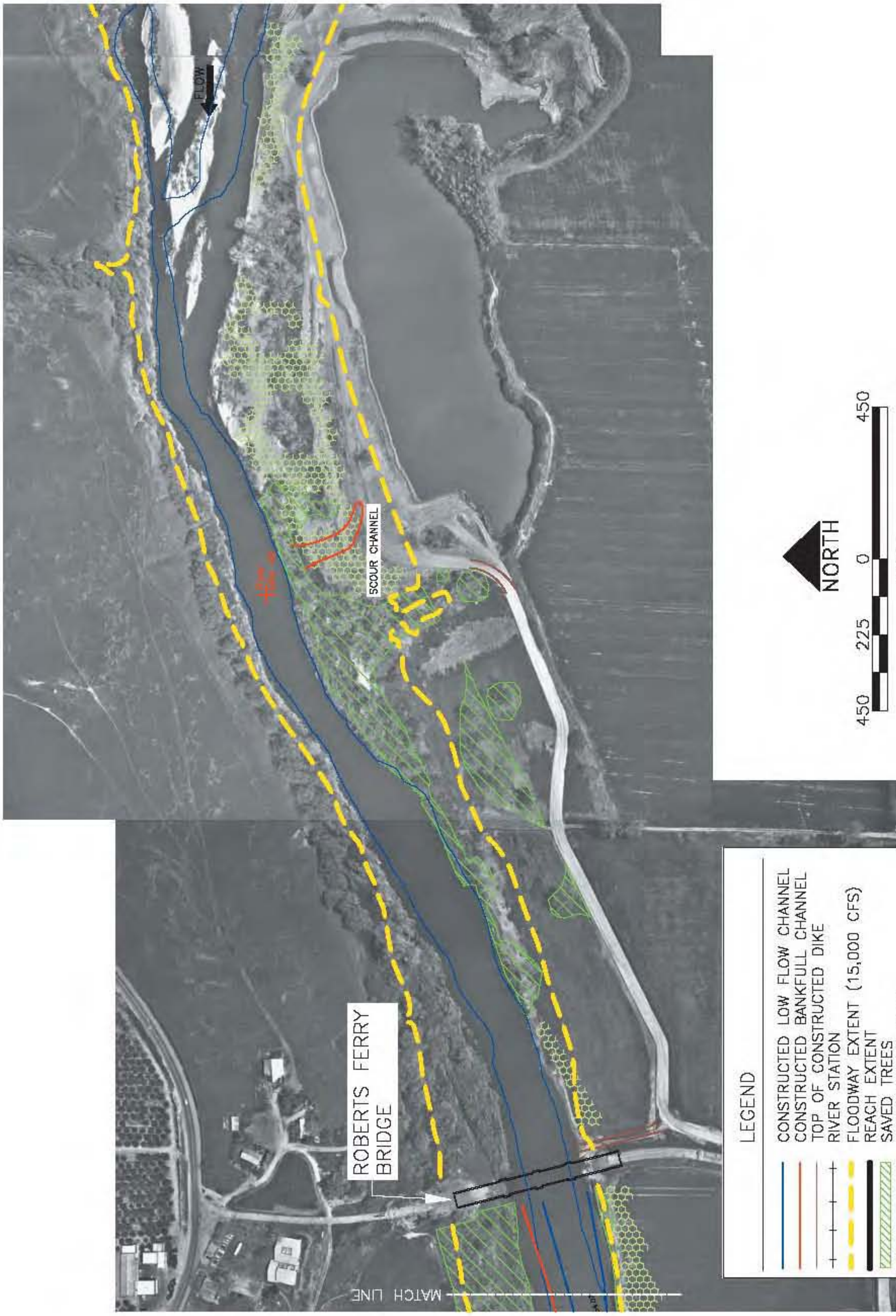

Figure 1-6. 7/11 Reach project final design, continued.

2 SPECIAL RUN POOLS 9 AND 10 MONITORING METHODS AND RESULTS

2.1 Flow Conditions since Project Construction

Tuolumne River flows and the timing of project construction and monitoring are shown in Figure 2-1. Water year conditions since project construction was completed were: Dry (WY 2002), Below Normal (WY 2003), Dry (WY 2004), and Wet (WY 2005 and 2006)[3]. In WY 2003–2004, flow in the river was maintained at or near minimum flows required by the FSA, and annual peak flows occurred during spring pulse released for outmigrating juvenile Chinook salmon. Annual peak flows during these years did not exceed the 1.6-year flood (post-NDPP recurrence interval). Peaks flows were 1,360 cfs ($Q_{1.2}$) in April 2002, 1,760 cfs ($Q_{1.3}$) in April 2003, and 3,100 cfs ($Q_{1.6}$) in March 2004)[4]. In WY 2005, daily average flows exceeded the 1,500-cfs monitoring threshold from mid-February through mid-July and exceeded 5,000 cfs on two occasions in late April and late May. Annual peak flow was 8,410 cfs (Q_{11}, April 1, 2005). In WY 2006, flow exceeded 1,500 cfs by late December and remained above 5,000 cfs as of late June 2006. Daily average flow in WY 2006 peaked at 8,850 cfs on May 7, 2006. The effects of flow on interpreting monitoring results are discussed in Section 4.

2.2 Hydraulics and Channel Morphology (H1, H2, H3)

2.2.1 Methods

Hydraulic and geomorphic monitoring at SRP 9 included low-altitude aerial photography, cross section and long profile surveys, digital terrain mapping, and flow stage monitoring during high flows (i.e., flows exceeding 1,500 cfs). Pre-project, as-built, and post-project aerial photographs are described in Table 3.

2.2.1.1 Channel and Floodplain Surveys

Pre-project channel and floodplain surveys were conducted in 1998 and 1999 (Table 5). Nine pre-project cross sections were established at SRP 9 and surveyed in August 1998 during flows of 1,600 cfs and July 1999 during flows of 265 cfs. Five cross sections were also established and surveyed in the reach between SRPs 9 and 10. Pre-project cross sections were surveyed using a level and stadia rod; horizontal stationing was determined using 300-foot tapes stretched across the channel. Seven as-built and post-project monitoring cross sections were established at the locations of pre-project cross sections in 2002 (Figure 2-2, Table 5). As-built channel and floodplain surveys were conducted on October 17, 2002 during a flow of 334 cfs using a total station. All cross section endpins were monumented with 1/2-inch rebar. As-built cross section endpin locations were also surveyed and mapped using survey-grade kinematic GPS. Cross section and endpin locations were incorporated into the Tuolumne River Geographic Information System (GIS) database.

Cross sections were identified by river station based on the channel centerline distance from the San Joaquin River. Stationing is presented in standard engineering format (i.e., STN 1464+75 is located 146,475 feet upstream from the San Joaquin River confluence). This stationing supersedes temporary stationing presented in project design documents, which was based on an arbitrary zero established at the downstream boundary of the project reach. Pre-project and as-built survey elevations are relative to the NGVD 1929 vertical datum. As-built surveys are relative to the NAD 83, California State Plane, Zone III coordinate system.

The pre-project digital terrain model was developed by EA Engineering; the date of this survey is not identified in available records. The as-built digital terrain model was generated from total station surveys of floodplain topography and channel bathymetry conducted in conjunction with the October

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[3] Water year classification as defined by the San Joaquin Valley Water Year Index (CDWR 2005).
[4] Annual flow maxima at the U.S. Geological Survey streamflow gage Tuolumne River below La Grange Dam near La Grange, Ca. (number 11289650).

2002 cross section surveys. Pre-project and as-built longitudinal profiles were extracted from the digital terrain models.

Table 5. Pre-construction and as-built cross sections at SRP 9

Cross Section	**Year Surveyed**		
	1998	**1999**	**2002**
1463+39			●
1464+75	●	●	●
1465+43	●	●	
1466+00	●	●	
1467+17	●	●	●
1468+07	●	●	
1469+05	●	●	●
1469+92	●	●	
1470+51			●
1471+25	●	●	
1472+08	●	●	
1472+52 (replaces 1471+25)			●
1473+21 (replaces 1472+08)			●

2.2.1.2 High Flow Stage

Water surface elevation was surveyed during flows of 1,030 cfs (April 23, 2003) and 2,200 cfs (February 21, 2005). For each flow, water surface elevation at the left bank of each cross section was surveyed using a level and stadia rod. All elevations are relative to the NGVD 1929 vertical datum.

Due to lack of funds to continue post-project monitoring, no additional high flow surveys were conducted in 2005 or 2006. High flow stage was marked opportunistically during flows of 3,230 cfs (February 23, 2005) and 5,690 cfs (March 25, 2005) when field crews were in the vicinity for other projects. Stage markers were nails driven into trees on or near each monitoring cross section. The installation date was written on survey flagging tied to each marker. Depending on the condition of the flagging, these markers could be surveyed if monitoring funds become available.

2.2.2 Results

Pre-project, as-built, and post-project aerial photographs and channel surveys will serve as the baseline for future post-project monitoring. Pre-project, as-built, and post-project aerial photographs are shown in Figure 2-3.

For most of the site, project construction adhered to the final design contours developed by HDR Engineering (Figures 2-4 and 2-5). The only major deviation from the design was the alignment of the left bank high flow channel. In the final design, this channel joins the mainstem river near Station 1464+00 (approximately 70 feet upstream of the project's downstream boundary). The constructed channel extends past the project boundary and joins an existing side channel downstream of the site. The final project design did not alter pre-project channel gradient through the site. Pre-project and as-built channel gradient (represented by low-flow water surface slope) is 0.00007 (Figure 2-6).

Post-construction partial floodplain inundation began at 1,030 cfs. At this flow, depth on inundated floodplain surfaces was less than 0.6 feet (Figure 2-5, Table 6). Flow depth in high flow scour channels on the left- and right-bank floodplains was approximately 1.4 feet. Site conditions during flows of 2,200 cfs, 3,230 cfs and 5,690 cfs are shown in Figures 2-7 and 2-8. At 2,200 cfs, all constructed floodplain surfaces were inundated. At monitoring cross sections, inundation depth was 0.78–2.69 feet (Table 6, Figure 2-5). Flow stage and inundation depth during flows of 3,230 cfs and 5,690 cfs were not measured.

Table 6. Post-construction floodplain inundation depth at SRP 9 for flows of 1,030 cfs and 2,200 cfs.

Cross Section	**Inundation Depth (ft)**			
	1,030 cfs		**2,200 cfs**	
	Left-bank Floodplain	**Right-bank Floodplain**	**Left-bank Floodplain**	**Right-bank Floodplain**
1463+39	NI	NI	0.78	1.60
1464+75	NA	NI	1.37	NA
1467+17	0.17	0.20	2.22	2.28
1469+05	0.63	NI	2.69	1.73
1470+51	NI	0.29	1.04	2.29
1472+52	NA	NA	NA	NA
1473+21	NA	NA	NA	NA

NI=not inundated
NA=no constructed floodplain at cross section

2.3 Bass Abundance (H10)

Bass abundance was monitored at SRPs 9 and 10 and four control sites using multiple-pass electrofishing depletion method (Moran 1951, Zippin 1956). Control sites were located upstream and downstream of SRPs 9 and 10 (from RM 30 to RM 24.8) and included two sites that represent SRP conditions (SRP 7 and SRP 8) and two sites that represent intact channel conditions (Charles Road and Riffle 64) (Figure 2-9). Control sites were chosen based on their proximity to the projects, channel morphology, and site accessibility. Pre-project monitoring was conducted in September 1998 and September 1999. Post-project monitoring was conducted in September–October 2003. Additional post-project monitoring was attempted in October 2004 but was halted (as required by CDFG permits) due to the presence of adult Chinook salmon in the river.

2.3.1 Field Methods

Electrofishing was conducted using a boat equipped with a Smith-Root electrofishing unit. Because electrofishing can not effectively sample the deep-water portions of the SRPs, sampling was conducted at night when adult bass are expected to be in their home territories in shallow water along the channel banks. Each survey began at the downstream of the site and continued upstream along one bank then downstream along the opposite bank. During each sampling pass, the boat was steered in a zigzag pattern through the shallow zone along each bank.

Several sampling criteria must be met to satisfy the assumptions of the multiple-pass depletion model. The model assumes that: (1) the sampled population is closed (i.e., there is no immigration or emigration during sampling), (2) sampling effort is the same for all passes at each site, (3) the probability of capture is the same for each individual in the sampled population, and (4) all captured individuals are removed from the sampling area upon capture. Field methods were selected to satisfy these assumptions. First, where possible, block nets were installed at the upstream and downstream ends of each site before sampling. Installing block nets was feasible at SRP 7, SRP 8, Charles Road, and Riffle 64. At SRPs 7 and 8, block nets did not span the entire channel cross section or depth, but the area not blocked by the nets was small relative to the total cross section. Block nets could not be installed at SRP 9 and SRP 10 due to high flow velocity at the riffles at the upstream and downstream ends of each site. However, we consider the closed-population assumption to be adequately met at these sites because: (1) the upstream and downstream ends of these sites comprise only a small portion of the total sample area (meaning that there was only a small area through which fish could enter or leave the sites), (2) high flow velocity would have prevented upstream movement and emigration from the upstream end of the site, and (3) the sites were sampled at night when largemouth and smallmouth bass are expected to be fairly stationary. To maintain uniform sampling effort, boat speed was kept as constant as possible within and among passes, and the power output of the electrofishing boat was held constant (5–6 amperes at 60 pulses/second) for all passes. The time required to complete each pass was recorded on data sheets to track sampling effort. Lastly, all captured fish were removed from the sampling area and kept in a live well or net pens. Fish captured on each pass were kept in separate pens and processed separately after all three sampling passes were completed. Captured bass were identified, counted, and measured. All other captured fish were identified and counted, and a subsample was measured.

2.3.2 Data Analysis

2.3.2.1 Fish Abundance and Density at Project and Control Sites

Abundance was estimated for largemouth and smallmouth bass and other fish species captured at each site. For largemouth and smallmouth bass, abundance was also estimated separately for the size range most likely to prey on juvenile salmon (180–380 mm FL), presented as "piscivore-size." The piscivore-size range was defined from probability analysis of stomach samples from largemouth bass collected at SRPs 7, 8, 9, and 10 in 1990 (TID/MID 1992a). From this study, largemouth bass in the 180–380 mm FL size range had the highest probability of having at least two Chinook salmon smolts in their stomach ($p \leq 0.03$; Figure 2-10). The most probable maximum number of smolts in the stomachs of smaller bass (≤ 180 mm FL) was 0.4 (95% variability range 0–0.7; Figure 2-10). This 180–380 mm FL size range also coincides with the findings of Vigg et al. (1991) for smallmouth bass, who observed that the rate of consumption of juvenile salmonids by smallmouth bass in the Columbia River was greatest for bass 200 mm in length. No similar studies could be found for largemouth bass, although Moyle (2002) states that largemouth bass larger than 100–125 mm standard length feed primarily on fish.

Abundance of largemouth and smallmouth bass and other fish species captured at the project and control sites was estimated using the multiple-pass depletion model (Moran 1951, Zippin 1956). The basic model is as follows:

$$pr(\{ n_i \}_{1\leq i\leq s} | N, p) = \binom{N}{\{ n_i \}_{1\leq i\leq s}} p^{\sum_{1\leq i\leq s} n_i} (1 - p)^{sN - \sum_{1\leq i\leq s} n_i - \sum_{1\leq i\leq s} (s-i) n_i}$$

where

N = the (unknown) population,
p = the (unknown) probability of capture,
s = the number of passes,
n_i = the number of individuals captured in pass $i, 1 \leq i \leq s$.

Two methods were applied to the model to estimate abundance: the "Carle-Strub estimator" (Carle and Strub 1978) and the "profile-likelihood estimator" (Seber 1982). The Carle-Strub estimator maximizes the posterior likelihood obtained by assuming a prior distribution for p of beta form. The uniform distribution on [0,1] was taken as the prior distribution for the analyses in this report. The profile-likelihood estimator solves for the p that maximizes the likelihood as an explicit function of N, substituting this into the likelihood function to obtain a profile likelihood function of N alone, and maximizing the latter as an integer.

While the profile-likelihood method has been shown to produce a well-defined estimator (Bedrick 1994), the Carle-Strub estimator is more robust to certain departures from assumptions of the multiple-pass depletion model, especially where capture numbers are not sufficiently reduced or actually increase between passes. Also, its expected bias and mean square error are small in the ranges of p and N encountered in this study. This estimator, however, is not applicable when fewer or an equal number of fish are captured in the first sampling pass than in the third pass (i.e., $n_1 \leq n_3$). Because it is more robust and its expected bias and mean square error are small, our analysis uses the Carle-Strub estimator whenever possible. Where capture rates do not satisfy model Carle-Strub assumptions (i.e., $n_1 \leq n_3$), the profile-likelihood estimator is used. Confidence intervals (95%) were computed using parametric bootstrapping.

To allow comparison among the project and control sites, total abundance was normalized by bank length and is reported as “linear density” for each species. A Before-After, Control-Impact (BACI) study design was used to discern trends from variations due to fluctuating environmental conditions. This design normalizes the population parameter of interest, in this case bass density, for each site relative to a single “control” site. By reducing the otherwise potentially confounding effects of inter-annual variability, this design facilitates unbiased comparison of bass density before and after treatment (i.e., reconstruction of SRP 9). To minimize the sample variance, the site with the largest estimated bass population was selected as the BACI control for that species. For largemouth bass, SRP 8 was used as the control site; for smallmouth bass, Charles Road was used as the control.

2.3.3 Results

2.3.3.1 Largemouth Bass Abundance and Density at Project and Control Sites

Largemouth bass were captured at all project and control sites sampled in 1998, 1999, and 2003 (Table 7, Figure 2-11). In 1998, largemouth bass abundance was low – 127 bass for all sizes combined and 49 bass for piscivore-sized only. From 1998 to 1999, largemouth abundance increased almost 1700% to 2,242 bass for all sites combined. During the same period, piscivore-size bass abundance increased 84% and totaled 90 bass for all sites combined in 1999. Increased largemouth bass abundance from 1998 to 1999 reflected increased abundance of young-of-the-year (YOY) (<120 mm FL [Moyle 2002]) and age 1+ (120–200 mm FL [Moyle 2002]) juveniles. In 1998, YOY and 1+ juveniles comprised 14% and 19% of all captured largemouth bass, respectively (Figure 2-12). In 1999, relative abundance of YOY and 1+ juveniles increased to 66% and 28% of all captures, respectively. From 1999 to 2003, abundance of all size classes combined declined 69% (to 685 bass). Piscivore-sized bass abundance increased 194%, to 265 bass for all sites combined. In 2003, YOY and 1+ juveniles were 35% and 18% of all captures, respectively (Figure 2-12).

In all monitoring years, the highest largemouth bass densities (for all sizes combined and piscivore-size) occurred at SRP sites, though the rank of each site varied among years (Tables 8 and 9). For all size classes combined, largemouth bass linear density was 7.8–14.8 bass/1,000 ft in 1998, 8.1–317.5 bass/1,000 ft in 1999, and 5.2–81.0 bass/1,000 ft in 2003 (Figure 2-11, Table 8). Linear density of piscivore-size bass was 0.7–6.0 bass/1,000 ft in 1998, 0.8–12.6 bass/1,000 ft in 1999, and 1.9–37.2 bass/1,000 ft in 2003 (Figure 2-11, Table 9).

Table 7. Largemouth bass abundance at project and control sites.

Location	Largemouth Bass Abundance (95% C.I.)					
	All Size Classes			180–380 mm FL		
	1998	1999	2003	1998	1999	2003
Project Sites						
SRP 9	19 (14-25)	165 (135-214)	60 (54-65)	4 (3-4)	7 (6-7)	24 (20-28)
SRP 10	37 (27-51)	179 (129-248)	149 (132-173)	15 (10-21)	23 (21-24)	93 (77-117)
Control Sites						
Riffle 64	NS	124 (75-206)	14 (12-15)	NS	2 (2-2)	5 (4-5)
SRP 7	30 (18-44)	767 (637-955)	205 (138-325)	12 (6-16)	18 (14-25)	48 (38-59)
SRP 8	41 (34-50)	1,007 (837-1,243)	257 (197-380)	18 (15-19)	40 (23-60)	95 (80-115)
Charles Rd	NE	24 (20-28)	40 (25-58)	0	3 (3-3)	16 (12-20)
Total						
All sites	127	2,242	685	49	90	265
Excluding Riffle 64	127	2,118	671	49	88	260

NE = Not estimable
NS = Not sampled

Table 8. Largemouth bass (all sizes combined) linear density at project and control sites.

Year	Largemouth Bass Linear Density (All Sizes) Ranking										
1998	SRP 10	>	SRP 8	>	SRP 9	>	SRP 7	>	Charles Rd		
	14.8		12.9		10.4		7.8		NE		
1999	SRP 8	>	SRP 7	>	SRP 9	>	SRP 10	>	Riffle 64	>	Charles Rd
	317.5		199.4		90.2		71.7		46.2		8.1
2003	SRP 8	>	SRP 10	>	SRP 7	>	SRP 9	>	Charles Rd	>	Riffle 64
	81.0		59.6		53.3		34.7		13.6		5.2

Table 9. Largemouth bass (180–380 mm FL) linear density at project and control sites.

Year	Largemouth Bass Linear Density (180-380 mm FL) Ranking										
1998	SRP 10	>	SRP 8	>	SRP 7	>	SRP 9	>	Charles Rd		
	6.0		5.7		3.1		2.2		0.0		
1999	SRP 8	>	SRP 10	>	SRP 7	>	SRP 9	>	Charles Rd	>	Riffle 64
	12.6		9.2		4.7		3.8		1.0		0.7
2003	SRP 10	>	SRP 8	>	SRP 9	>	SRP 7	>	Charles Rd	>	Riffle 64
	37.2		29.9		13.9		12.5		5.4		1.9

In all monitoring years, piscivore-size bass density was highest at SRPs 8 and 10, followed by SRPs 7 and 9, then Charles Rd., then Riffle 64 (Table 9, Figure 2-13). Density at the SRP sites was significantly greater than densities at the two channel control sites (Riffle 64 and Charles Road) in all years (Figure 2-13; densities differ significantly at the $\alpha = 0.05$ level if the 95% confidence bars do not overlap). The significance of differences in piscivore-size largemouth bass density among the SRP sites varied among years. In 1998 and 2003, largemouth bass density at SRP 9 was less than at SRP 8 and SRP 10 but was not significantly different from SRP 7. In 1999, largemouth bass density at SRP 9 was less than at SRP 8 but was not significantly different from SRP 7 and SRP 10. During the monitoring period, no change in piscivore-size largemouth bass density relative to SRP 8 was detected at SRP 7, SRP 9, SRP 10, and Riffle 64. The only statistically significant change was at Charles Rd., where piscivore-size largemouth bass density increased from 1999 to 2003.

2.3.3.2 Smallmouth Bass Abundance and Density at Project and Control Sites

Smallmouth bass were captured at SRPs 7 and 9, SRP 10, Charles Rd, and Riffle 64 in all monitoring years (Table 10, Figure 2-14). No smallmouth bass were captured at SRP 8 in 1998 or 1999. For all size classes combined, smallmouth bass abundance at the project and control sites totaled 30 bass in 1998 (excluding Riffle 64), 57 bass in 1999, and 466 bass in 2003. For piscivore-size only, smallmouth bass abundance totaled 5 bass in 1998 (excluding Riffle 64), 31 bass in 1999, and 119 bass in 2003. Increased smallmouth bass abundance from 1999 to 2003 reflected an increase in abundance of the YOY (<140 mm FL [Moyle 2002]) and 1+ juveniles (141–270 mm FL, [Moyle 2002]) (Figure 2-15).

Table 10. Smallmouth bass abundance at project and control sites.

Location	**Smallmouth Bass Abundance (95% C.I.)**					
	All Size Classes			**180–380 mm FL**		
	1998	**1999**	**2003**	**1998**	**1999**	**2003**
SRP 9	9 (7-10)	13 (12-13)	191 (107-298)	2 (1-2)	7 (6-7)	25 (16-37)
SRP 10	NE	20 (20-20)	14 (10-17)	0	9 (9-9)	7 (5-8)
Riffle 64	NS	NE	71 (58-90)	NS	1 (0-1)	49 (24-71)
SRP 7	6 (4-7)	1 (1-1)	102 (61-162)	1 (0-1)	1 (1-1)	12 (7-16)
SRP 8	NE	NE	2 (1-2)	0	0	2 (1-2)
Charles Rd	15 (14-16)	23 (18-29)	86 (58-130)	2 (2-2)	13 (11-15)	24 (16-33)
Total						
All sites	30	57	466	5	31	119
Excluding Riffle 64	30	37	381	5	21	63

NE = Not estimable

NS = Not sampled

The relative ranking of smallmouth bass density varied among years (Tables 11 and 12, Figure 2-14). For all sizes and piscivore-size, densities at SRP 9 and Charles Rd. were among the highest observed, and densities at SRP 8 were among the lowest observed in all three monitoring years. In 1998, density was 1.6–5.1 bass/1,000 ft for all sizes combined and 0.3–1.1 bass/1,000 ft for piscivore-size at the three sites where captures were sufficient to estimate density. In 1999, density was 0.3–8.0 bass/1,000 ft for all sizes combined and 0.3–4.4 bass/1,000 ft for piscivore-size at the four estimable sites. In 2003, density was 0.6–110.6 bass/1,000 ft for all sizes combined and 0.6–18.3 bass/1,000 ft for piscivore-size at the six sites combined.

Table 11. Smallmouth bass (all sizes combined) linear density at project and control sites.

Year	Smallmouth Bass Linear Density (All Sizes) Ranking										
1998	Charles Rd	>	SRP 9	>	SRP 7	>	SRP 10	>	SRP 8		
	5.1		4.9		1.6		NE		NE		
1999	SRP 10	>	Charles Rd	>	SRP 9	>	SRP 7	>	SRP 8	>	Riffle 64
	8.0		7.8		7.1		0.3		NE		NE
2003	SRP 9	>	Charles Rd	>	SRP 7	>	Riffle 64	>	SRP 10		SRP 8
	110.6		29.2		26.5		26.5		5.6	>	0.6

Table 12. Smallmouth bass (180–380 mm FL) linear density at project and control sites.

Year	Smallmouth Bass Linear Density (180-380 mm FL) Ranking										
1998	SRP 9	>	Charles Rd	>	SRP 7	>	SRP 10	>	SRP 8		
	1.1		0.7		0.3		0.0		0.0		
1999	Charles Rd	>	SRP 9	>	SRP 10	>	Riffle 64	>	SRP 7	>	SRP 8
	4.4		3.8		3.6		0.4		0.3		0.0
2003	Riffle 64	>	SRP 9	>	Charles Rd	>	SRP 7	>	SRP 10	>	SRP 8
	18.3		14.5		8.1		3.1		2.8		0.6

Few trends in piscivore-size smallmouth bass density were discernable among the sites over the monitoring period (Figure 2-16). In all monitoring years, piscivore-size smallmouth bass density at SRP 9 was significantly greater than at other SRP sites for which density was estimable, except SRP 10 in 1999. Compared to channel control sites, pre-project piscivore-size smallmouth bass density at SRP 9 was not significantly different from Charles Rd. but was significantly higher than Riffle 64. In 2003, smallmouth bass density at SRP 9, Charles Rd., and Riffle 64 was not significantly different, but density at all three sites was significantly greater than at all SRP sites. No temporal trends in density at the SRP sites (relative to Charles Rd.) were discernable. For instance, from 1999 to 2003, density increased at SRP 7, decreased at SRP 10, and remained relatively stable at SRP 9. No significant difference in pre-project versus post-project smallmouth bass density relative to Charles Rd. (piscivore-size) was detected at SRP 9.

2.3.3.3 Other Species Encountered at the Channel Restoration and Control Sites

At least 33 fish species, eleven native and 22 introduced, were captured at the project and control sites in 1998, 1999, and 2003 combined (Table 13). Lampreys and sculpins were not identified to species and thus the actual number of species in the project area may be higher. Six non-native species (carp, white catfish, bluegill, redear sunfish, largemouth bass, and smallmouth bass) and one native species (Sacramento sucker) were captured every year at all or nearly all sites. Chinook salmon and splittail, native species that were present in 1998 and 1999, were not captured in 2003. Abundance and density estimates for all fish species captured at the project and control sites in 2003 are provided in Appendix C.

The relative abundance of introduced fish to native fish could be computed for six monitoring sites for at least one monitoring year (Table 14). In all years, relative abundance of introduced fish was higher at the SRP sites than the channel control sites and was higher at Charles Rd. than at Riffle 64. Relative abundance of introduced fish at all sites increased from 1999 to 2003, reaching 98–99% at the SRP sites and 55–85% at the channel sites.

Table 13. Fish species captured at the project and control sites.

Species	Native or Introduced[1]	Site and Years Captured[2]					
		SRP 9	SRP 10	SRP 7	SRP 8	R64	Charles Road
Family Petromyzontidae							
lamprey (unidentified species)	N	a,b	c	b,c	b	b,c	b,c
Lampetra sp.							
Family Clupeidae							
American shad	I	b	b,c	b			b
Alosa sapidissima							
threadfin shad	I		b		a,b	b	
Dorosoma petenense							
Family Cyprinidae							
Carp	I	a,b,c	a,b,c	a,b,c	a,b,c	b,c	a,b,c
Cyprinus carpio							
mirror carp	I				a		
Goldfish	I	a,b	a,b	a,b	a,b,c		
Carassius auratus							
Sacramento blackfish	N		b,c	b	b		
Orthodon microlepidotus							
Hardhead	N	a,b		a,b	a	b,c	b
Mylopharodon conocephalus							
Hitch	N	b	b	b	b	b	b,c
Lavinia exilicauda							
Sacramento pikeminnow	N	a,b	a,c	b,c	a,b,c	a,b,c	a,b,c
Ptychocheilus grandis							
Sacramento splittail	N	b					
Pogonichthys macrolepidotus							
Family Catostomidae							
Sacramento sucker	N	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Catostomus occidentalis							
Family Ictaluridae							
channel catfish	I	c	a,b,c	a,b,c	b,c	b,c	a,b,c
Ictalurus punctatus							
black bullhead	I				c	b	
Ictalurus melas							
white catfish	I	a,b,c	a,b,c	a,b,c	a,b,c	b,c	a,b,c
Ameiurus catus							
brown bullhead	I		c	a,b,c	a,c	c	a,c
Ameiurus nebulosus							
Family Atherinidae							
inland silverside	I	b	b,c	b,c	b,c	a,b,c	b
Menidia beryllina							
Family Percichthyidae							

		Site and Years Captured[2]					
striped bass	I		b		a	a,c	a,c
Morone saxatilis							
Family Centrarchidae							
Bluegill	I	a,b,c	a,b,c	a,b,c	a,b,c	b,c	a,b,c
Lepomis macrochirus							
redear sunfish	I	a,b,c	a,b,c	b,c	a,b,c	a,b,c	a,b,c
Lepomis microlophus							
Pumpkinseed	I				c	c	
Lepomis gibbosus							
green sunfish	I	a,b,c	a,b,c	a,b,c	a,b,c	c	b,c
Lepomis cyanellus							
sunfish (unidentified species)	I	b	b	b	b		
Lepomis sp.							
Warmouth	I		c		a,c		c
Lepomis gulosus							
white crappie	I		b		b,c		
Pomoxis annularis							
black crappie	I		c	a	a,c		
Pomoxis nigromaculatus							
largemouth bass	I	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Micropterus salmoides							
smallmouth bass	I	a,b,c	a,c	a,b,c	b,c	b,c	a,b,c
Micropterus dolomieui							
Family Percidae							
bigscale logperch	I	c	a,b	b,c	c		
Percina macrolepida							
Family Cottidae							
prickly sculpin	N	b	b	b	b	b	b
Cottus asper							
riffle sculpin	N					b	
Cottus gulosus							
Sculpin	N	a,b	a,c	a,c	a,c	b,c	a,b,c
Cottus sp.							
Family Salmonidae							
chinook salmon	N	a	a			b	a
Oncorhynchus tshawytscha							

[1] N = native, I = introduced. Source: Brown and Ford (2002).
[2] a = captured in 1998; b = captured in 1999, c = captured in 2003

Table 14. Relative abundance of introduced to native fish abundance at project and control sites in 1998, 1999, and 2003.

Monitoring Site	Introduced Fish Abundance (% of total abundance)		
	1998	1999	2003
SRP Sites			
SRP 9	87	82	98
SRP 10	NE	72	99
SRP 7	5	44	NE
SRP 8	NE	70	NE
Channel Sites			
Charles Road	29	41	85
Riffle 64	NE	9	55

NE = Not estimable

2.4 Bass Habitat Suitability at SRP 9 (H10)

2.4.1 Methods

The Monitoring Plan specified habitat mapping to quantify changes in largemouth and smallmouth bass habitat area at SRP 9 pre- and post-project. Pre-project bass habitat was mapped during flows of 1,440–1,770 cfs (August 3–9, 1998) and 265–287 cfs (July 8–11, 1999). To allow comparison of pre-project and post-project bass habitat conditions over a broader range of flows (including both high and low flows), habitat mapping was replaced with 2-dimensional hydraulic and habitat modeling.

2.4.1.1 Habitat Mapping

Habitat mapping at SRP 9 used a combination of direct mapping of habitat features onto aerial photographs and extrapolation from cross sections. Habitat parameters included cover, substrate texture, flow depth and flow velocity. Cover and substrate texture were mapped onto laminated, orthorectified aerial photographs printed at a scale of 1 in = 50 ft. Mapped information included: location of wetted channel margins, delineation of substrate facies, in-channel and overhead cover, rooted and emergent macrophytic aquatic vegetation, overhead cover, location and dimensions of large and medium size woody debris. Flow depth and velocity were extrapolated from cross sections. Flow depth and velocity were measured at intervals across the nine pre-project cross sections, either by wading or from a boat. Depth was measured with a wading rod in shallow areas and a sonar depth sounder in deep water. Flow velocity was measured using a Marsh McBirney flow meter.

Habitat suitability criteria reported by for largemouth bass (Stuber et al. 1982) and smallmouth bass (Edwards et al. 1983) were used to define available habitat (Table 15). Mapped habitat characteristics were digitized in AutoCAD. Auto-CAD MAP was used to generate flow and depth contours and habitat polygons. Polygon boundaries were delineated by plotting areas corresponding to suitable conditions for each habitat parameter, then determining where polygons overlapped to provide the combination of suitable conditions. No extrapolation or modeling of these data for different flows was attempted, although the study plan previously acknowledged the need to collect habitat data at different flows.

Table 15. Largemouth and smallmouth bass habitat suitability criteria.

Criterion		**Largemouth Bass[1]**	**Smallmouth Bass[2]**
Velocity (ft/s)	(usable)	0-0.7	0-0.7
	(preferred)	0-0.2	0-0.3
Depth (ft)	(usable)	1.6-19.7	1.6-9.8
	(preferred)	3.3-19.7	3.3-9.8
Cover (%)	(usable)	20-80	25-100
	(preferred)	40-60	25-50
Predominant substrate	(usable)	coarse gravel/cobble	silt/sand
	(preferred)	silt/sand with gravel	gravel/boulder with interstitial spaces

[1]Stuber et al. (1982), [2]Edwards et al. (1983)

2.4.1.2 Habitat Modeling

The River 2D model (Steffler and Blackburn 2002) was used to predict pre-project and post-project bass habitat area and suitability for flows of 75 cfs, 150 cfs, 300 cfs, 500 cfs, 1,000 cfs, 2,000 cfs, and 3,000 cfs. The River 2D model uses a 2-dimensional, finite-element hydrodynamic model and PHABSIM sub-models combined with habitat suitability indices to predict usable habitat area.

Largemouth and smallmouth bass habitat suitability criteria included depth, velocity and cover. Two models were developed for each species using two suites of habitat criteria. The “primary habitat” model used depth, velocity, and cover criteria and represents the habitat suitable for adult home territories and foraging. The “secondary habitat” model used depth and velocity criteria only and represents the area suitable for foraging, but less suitable for ambush sites or other cover-dependent behaviors. The largemouth bass primary and secondary habitat models were applied to SRP 9 for pre- and post-project conditions. For smallmouth bass, the primary and secondary habitat models were applied for pre-project conditions only. The smallmouth bass primary habitat model could not be applied for post-project conditions because cover suitable for smallmouth bass was not mapped at SRP 9 after construction. Therefore, only the secondary habitat model was applied to post-project conditions.

Suitability criteria were derived from Habitat Suitability Index Models developed by the USFWS (Stuber et al. 1982, Edwards et al. 1983) (Table 15). Suitability criteria were developed for both “preferred” and “usable” habitats to represent the broad range of conditions that could support largemouth and smallmouth bass (Table 16). Conditions falling within the “preferred” range for each suitability criterion were assigned a suitability value of 1, and conditions in the “usable” range were assigned a suitability value of 0.5. Conditions outside of these ranges were assigned a suitability value of 0. For the primary habitat model, five suitability classes were possible (Table 16). For the secondary habitat model, four suitability classes were possible (Table 16). Using these criteria, the two suitability maps were generated for each flow, one representing primary habitat and one representing secondary habitat.

Table 16. Potential combined suitability index values for largemouth and smallmouth bass.

Combined Index Value		**Description**
Depth, Velocity, and Cover (Primary Habitat)	**Depth and Velocity (Secondary Habitat)**	
0	0	Unsuitable
0.125 [0.5*0.5*0.5]	0.25 [0.5*0.5]	Marginal
0.25 [1*0.5*0.5]	N/A	Usable
0.5 [1*1*0.5]	0.5 [1*0.5]	Suitable
1 [1*1*1]	1 [1*1]	Optimal

2.4.2 Results

2.4.2.1 Comparison of Model Predictions to Field Mapping

The model provided reasonable predictions of largemouth bass primary and secondary habitat compared to habitat mapped in the field. The model over-predicted suitable habitat area, but the distribution of predicted habitat was similar to field mapping. Pre-project habitat mapping identified 9,054 ft^2 of largemouth bass primary habitat and 271,414 ft^2 of secondary habitat at flows of 265–287 cfs (Table 17). At 273 cfs, the model predicted 18,840 ft^2 total habitat area and 16,137 ft^2 weighted usable area of primary habitat (108% and 78% more area than mapped in the field, respectively) and 275,489 ft^2 total habitat area and 239,741 ft^2 weighted usable area of secondary habitat (differing from mapped habitat by 2% and -12%, respectively) (Table 17). Mapped and predicted habitat distribution was similar. Mapped and predicted primary habitat was distributed in small patches around the perimeter of the SRP. Secondary habitat extended over the remainder of the SRP (Figures 2-17 and 2-18).

At 1,440–1,770 cfs, mapping identified 18,083 ft^2 of primary habitat and 225,789 ft^2 of secondary habitat (Table 17). The model predicted 20,912 ft^2 total habitat area and 12,778 ft^2 weighted usable area of primary habitat (differing from mapped habitat by 16% and 29%, respectively) and 169,554 ft^2 total habitat area and 111,231 ft^2 weighted usable area of secondary habitat (differing from mapped habitat by -25% and -51%, respectively) (Table 17). Mapped primary habitat occurred in a band along the right bank and a small patch on the left bank at the downstream end of the site (Figure 2-17). Secondary habitat extended over the remainder of the SRP, excluding a high-velocity zone along the left bank. Predicted habitat maps were generated for 1,000 cfs and 2,000 cfs. The spatial distribution of predicted habitat was similar to mapped habitat (Figures 2-17, 2-19, and 2-20).

For smallmouth bass, the predicted primary habitat area exceeded mapped habitat area by 1-2 orders of magnitude, and predicted secondary habitat area exceeded mapped habitat area by 160–430%. Pre-project habitat mapping identified 871 ft^2 of primary habitat and 19,373 ft^2 of secondary habitat at flows of 265–287 cfs (Table 17). The model predicted 16,668 ft^2 total habitat area and 14,731 ft^2 weighted usable area of primary habitat and 84,306 ft^2 total habitat area and 72,599 ft^2 weighted usable area of secondary habitat (Table 17). Mapped habitat was limited to a small patch of primary habitat and a narrow band of secondary habitat along the left bank of the SRP (Figure 2-21). The model predicted patches of primary habitat on both the left and right banks and a band of secondary habitat encircling the entire SRP (Figure 2-22).

Table 17. Comparison of pre-project largemouth and smallmouth bass habitat mapping and model predictions at SRP 9.

Flow (cfs)	Primary Habitat Area (ft^2)			Secondary Habitat Area (ft^2)		
	Mapping	Model		Mapping	Model	
		Total	WUA[a]		Total	WUA[a]
Largemouth Bass						
265–287	9,054	--	--	271,414	--	--
273	--	18,840	16,137	--	275,489	239,741
1,440–1,770	18,083	--	--	225,789	--	--
1,605		20,912	12,778		169,554	111,231
Smallmouth Bass						
265–280	871	--	--	19,373	--	--
273	--	16,668	14,731		84,306	72,599
1,440–1,770	629	--	--	22,977	--	--
1,605	--	13,104	9,467	--	51,458	37,514

[a]WUA = Weighted Usable Area

At 1,440–1,770 cfs, mapping identified 629 ft^2 of primary habitat and 22,977 ft^2 of secondary habitat (Table 17). The model predicted 13,104 ft^2 total habitat area and 9,467 ft^2 weighted usable area of primary habitat and 51,458 ft^2 total habitat area and 37,514 ft^2 weighted usable area of secondary habitat (Table 17). Mapped primary habitat was limited to a single patch at the upstream end of site (Figure 2-21). Predicted habitat occurred in patches along the right bank and at the downstream end of the left bank (Figures 2-23 and 2-24). Secondary habitat was mapped as a band along the left bank. Predicted secondary habitat extended along both banks and across the downstream end of the site at 1,000 cfs and along both banks at 2,000 cfs.

2.4.2.2 Comparison of Pre-project and Post-Project Predicted Habitat Area

After project construction, SRP 9 continued to provide suitable habitat for adult largemouth bass (see habitat suitability maps in Appendix E). During low flows (< 300 cfs), predicted suitable habitat occurred throughout most of the site, with optimal habitat occurring in the right bank eddy at the upstream end of the site (over the infiltration gallery) and the left bank of the pool at the mid-point of the site. Riffles at the upstream and downstream ends of the site were the only areas that did not provide suitable largemouth bass habitat at low flows. With increased flow, velocities in the center of the channel were too swift to be usable by largemouth bass, and usable habitat was restricted to the channel margins over the infiltration gallery and along the pool. As flows exceeded 1,000 cfs and began to inundate the floodplain, flow velocity in the entire channel was too swift to be usable, and usable habitat shifted to inundated floodplains on the right and left banks.

Although the site continues to provide suitable largemouth bass habitat, the project reduced predicted primary habitat area for all flows modeled and reduced secondary habitat for flows < 3,000 cfs (Figure 2-25). For flows exceeding 3,000 cfs, the project increased secondary habitat total usable area but reduced weighted usable area (Figure 2-25). For the range of spring rearing flows required by the FSA (150–300 cfs), the project reduced primary habitat by 21–42% (total usable area) and 73–78% (weighted usable area) (Table 18). For the same flows, the project reduced secondary habitat by 79–85% (total usable area) and 87–90% (weighted usable area) (Table 19). For higher flows, such as spring pulse flows (typically 1,000–3,000 cfs), the project reduced primary habitat by 67–85% (total usable area) and 87–92% (weighted usable area). For the same flows, the project reduced secondary habitat weighted usable area by 87–92%. Total usable area decreased 88% and 60% at flows of 1,000 cfs and 2,000 cfs, respectively, but increased 8% at 3,000 cfs.

Table 18. Pre-project and post-project predicted largemouth bass primary habitat area (depth, velocity, and cover).

Flow (cfs)	Total Area (ft^2)		Net Change (ft^2)	% Change	Weighted Usable Area (ft^2)		Net Change (ft^2)	% Change
	Pre-project	As-built			Pre-project	As-built		
75	16,185	14,336	-1,849	-11	13,945	4,496	-9,449	-68
150	17,735	13,928	-3,807	-21	15,414	4,237	-11,177	-73
300	19,088	11,018	-8,070	-42	16,299	3,552	-12,748	-78
500	19,935	11,202	-8,733	-44	16,296	3,630	-12,667	-78
1000	21,682	7,222	-14,460	-67	15,769	1,971	-13,797	-87
2000	20,410	3,243	-17,167	-84	10,826	921	-9,904	-91
3000	16,365	2,433	-13,932	-85	8,218	691	-7,527	-92
5000	9,781	774	-9,007	-92	5,146	258	-4,888	-95

Table 19. Pre-project and post-project predicted largemouth bass secondary habitat area (depth and velocity).

Flow (cfs)	Total Area (ft^2)		Net Change (ft^2)	% Change	Weighted Usable Area (ft^2)		Net Change (ft^2)	% Change
	Pre-project	As-built			Pre-project	As-built		
75	276,410	61,737	-214,673	-78	264,062	38,461	-225,601	-85
150	276,999	57,100	-219,899	-79	261,452	33,464	-227,988	-87
300	275,150	40,548	-234,602	-85	234,867	22,895	-211,972	-90
500	266,670	32,364	-234,306	-88	211,696	18,323	-193,373	-91
1000	220,254	27,185	-193,069	-88	158,698	13,830	-144,868	-91
2000	136,452	54,507	-81,945	-60	80,241	23,660	-56,581	-71
3000	98,427	106,648	8,221	8	59,256	35,750	-23,506	-40
5000	55,667	75,858	20,191	36	33,713	32,818	-896	-3

The extent and distribution of predicted adult smallmouth bass habitat was similar to largemouth bass (see habitat suitability maps in Appendix E). Optimal habitat occurred in the right bank eddy and on the left bank of the meander apex (i.e., the pool at the mid-point of the site) during flows < 1,000 cfs, then shifted onto the floodplain as flows exceeded 1,000 cfs. Compared to pre-project conditions, the project reduced smallmouth bass secondary habitat for flows <2,000–3,000 cfs (Figure 2-26). At higher flows, the project increased secondary habitat area. For spring rearing flows required by the FSA, the project reduced smallmouth bass secondary habitat by 36–55% (total usable area) and 52–64% (weighted usable area) (Table 20, Figure 2-26). For flows of 1,000 cfs, the project reduced secondary habitat total usable area by 55% and weighted usable area by 64%. During higher flows that inundate the floodplain, the project increased available habitat area. At 3,000 cfs, the project increased total usable area by 176% and weighted usable area by 56%.

Table 20. Pre-project and post-project predicted smallmouth bass secondary habitat area (depth and velocity).

Flow (cfs)	Total Area (ft^2)		Net Change (ft^2)	% Change	Weighted Usable Area (ft^2)		Net Change (ft^2)	% Change
	Pre-project	As-built			Pre-project	As-built		
75	91,896	52,038	-39,858	-43	81,879	37,699	-44,180	-54
150	89,164	57,099	-32,065	-36	78,493	37,711	-40,782	-52
300	83,215	37,548	-45,667	-55	71,276	25,606	-45,670	-64
500	75,940	32,364	-43,576	-57	61,702	21,651	-40,052	-65
1000	60,878	27,185	-33,693	-55	46,047	16,460	-29,588	-64
2000	45,308	52,007	6,699	15	31,943	25,920	-6,023	-19
3000	37,555	103,488	65,933	176	25,403	39,617	14,214	56
5000	26,203	70,670	44,467	170	17,855	35,145	17,290	97

2.4.3 Bass Habitat at Channel Control Sites

The primary goal of the SRP 9 project was to reduce bass abundance and thus increase Chinook salmon outmigrant survival at the project site. Project monitoring, however, detected no change in bass abundance at the site following the restoration project. After the project, largemouth bass density at SRP 9 remained similar to SRP 7 and was significantly greater than the Riffle 64 and Charles Rd. channel control sites. Smallmouth bass density at SRP 9 post-project was statistically the same as at Riffle 64 and Charles Rd. and greater than the three other SRP monitoring sites. The River 2D model was applied to the Charles Rd. and Riffle 64 sites to provide a comparison to SRP 9 and identify channel characteristics the limited largemouth bass abundance at these sites.

2.4.3.1 Methods

To obtain topographic and bathymetric data needed to construct the model, total station surveys were conducted at each control site in September 2004 during flows of 150 cfs. During each survey, smallmouth and largemouth bass primary habitat was mapped onto laminated aerial photographs, and pebble counts (Wolman 1954) were conducted to document bed texture. Flow was measured at the downstream end of each site using a Price AA flow meter and standard U.S. Geological Survey flow measurement protocols.

The River 2D model was applied at Charles Rd. and Riffle 64 using the same methods and criteria described in Section 2.4.1 for SRP 9. To compare habitat available at each site, predicted habitat area was normalized by total site length and is presented as “habitat density” (ft^2 of habitat/ft of channel).

2.4.3.2 Results

Low-flow and bankfull channel widths at the Charles Rd. and Riffle 64 control sites were narrower and channel gradient was steeper than at SRP 9 (Table 21, Figures 2-27 and 2-28). Low-flow channel width was 91 ft at Riffle 64 and 94 ft at Charles Rd., 36–39 ft (28–30%) narrower than at SRP 9. Bankfull channel width was 118 ft at Riffle 64 and 119 ft at Charles Rd, 51–52 ft (30%) narrower than at SRP 9. Channel gradient at the control sites was an order of magnitude steeper than at SRP 9 (Table 21, Figure 2-29). Bed texture at the channel control sites is shown in Table 22.

Compared to habitat mapped in the field, the model predicted similar habitat distribution but smaller total habitat area. The predicted distribution of primary habitat for largemouth and smallmouth bass at each site was similar to mapped habitat at each site was similar to mapped habitat at 150 cfs. At Riffle 64, mapped primary habitat occurred at the pool at the downstream end of the site, small areas

Table 21. Channel dimensions at SRP 9 and channel control sites.

Site	Low-flow Channel Width (ft)	Bankfull Channel Width (ft)	Channel Gradient
Riffle 64	91	118	0.0006[1]
Charles Road	94	119	0.0005[1]
SRP 9 post-project	130	170	0.00007

[1]150 cfs water surface elevation surveyed in September 2004.

Table 22. Bed texture in gravel facies at control sites.

Site	Particle Size (mm)		
	D_{31}	D_{50}	D_{84}
Charles Road (upstream riffle)	33	50	94
Riffle 64 (upstream)	26	44	69
Riffle 64 (downstream)	31	47	83

along channel margins, and vegetated backwaters (Figure 2-30). The model predicted habitat occurring at the downstream pool and along the channel margins but did not in the left-bank vegetated backwater (Figures 2-31 and 2-32). Total usable habitat area predicted by the model was 3,746 ft^2 (41%) less than habitat mapped for both species (Table 23). Predicted weighted usable habitat area was 6,623 ft^2 (73%) less than mapped habitat area for largemouth bass and 6,296 ft^2 (69%) less than mapped habitat area smallmouth bass (Table 23). At Charles Rd., mapped primary habitat occurred in the pool at the upstream end of the site and channel margins where large wood or other submerged cover was present (Figure 2-33). The model predicted habitat at the same locations, but at the downstream end of the site, the model predicted habitat extending across the channel where mapping identified habitat only along the right bank (Figures 2-34 and 2-35). Total usable habitat area predicted by the model was 582–583 ft^2 (2%) less than habitat mapped for both species (Table 23). Predicted weighted usable habitat area was 18,199 ft^2 (78%) less than mapped habitat area for largemouth bass and 15,718 ft^2 (54%) less than mapped habitat area smallmouth bass (Table 23).

Table 23. Predicted and mapped largemouth and smallmouth bass habitat area at Riffle 64 and Charles Rd.

Site	Mapping	Model			
		Primary Habitat Area (ft^2)		Secondary Habitat Area (ft^2)	
		Total	WUA	Total	WUA
Largemouth Bass					
Riffle 64	9,126	5,380	2,503	34,881	15,943
Charles Rd	24,345	23,762	5,446	35,874	17,499
Smallmouth Bass					
Riffle 64	9,126	5,380	2,830	34,881	17,983
Charles Rd	24,345	23,763	8,627	35,874	19,891

In summer 2003, daily flow averaged 241 cfs (June 1–September 30). Predicted habitat at each site for 241 cfs and bass density observed in 2003 are shown in Table 24. At these sites (the only sites for which habitat modeling and observed bass abundance data are available), total and weighted usable habitat area predicted by the largemouth bass primary habitat model was consistent with relative bass density observed at the sites (Table 24). For smallmouth bass, total area predicted by the secondary habitat model was consistent with relative bass density for all-sizes combined and piscivore-size only observed at the sites (Table 24). The remaining models did not accurately predict the rank order of observed abundance at the three sites.

Table 24. Predicted habitat area and observed bass density, 2003.

Site	Habitat Density (ft^2/ft)				Bass Density (fish/1,000 ft)	
	Primary		Secondary			
	Weighted Area	Total Area	Weighted Area	Total Area	Piscivore size	All sizes
Largemouth bass						
Riffle 64	1.2	2.9	8.6	18.7	1.9	5.2
Charles Rd.	2.4	10.1	8.0	15.8	5.4	13.6
SRP 9	3.8	12.3	27.1	47.1	13.9	34.7
Smallmouth bass						
Riffle 64	1.1	2.4	9.0	16.9	18.3	26.5
Charles Rd.	4.2	10.1	9.3	15.8	8.1	29.2
SRP 9	NA	NA	26.8	39.1	14.5	110.6

NA = Not modeled

Predicted largemouth bass habitat density at SRP 9 (post-project) exceeded habitat density at the channel control sites for all flows modeled, except 75 cfs at Charles Rd. and 5,000 cfs at Riffle 64 (Figure 2-36). For FSA spring flows, predicted largemouth bass primary habitat density at SRP 9 exceeded density at Charles Rd. by 6–35% (total usable area) and Riffle 64 by 314–342% (total usable area). For flows of 1,000–3,000 cfs, habitat density at SRP 9 exceeded density at Riffle 64 by 152–271% (total usable area) and at Charles Rd. by 65–212% (total usable area).

Smallmouth bass post-project primary habitat was not modeled at SRP 9; only secondary habitat can be compared among the sites. The magnitude of the difference between smallmouth bass habitat density at the two sites was much less than for largemouth bass. Predicted secondary smallmouth bass density at SRP 9 exceeded the channel control sites for all flows modeled (Figure 2-37). For FSA spring and summer flows, smallmouth bass habitat density at SRP exceeded density at Charles Rd. by 185% (total usable area) and 124–162% at Riffle 64 (total usable area).

2.5 Chinook Salmon Fry and Juvenile Habitat Suitability (H6)

2.5.1 Methods

The River 2D model was used to assess fry and juvenile Chinook salmon habitat for pre- and post-project conditions at SRP 9. Habitat suitability criteria (USFWS 1995) used for fry and juvenile Chinook salmon are shown in Table 25. Since the project sought to create the best habitat possible for Chinook salmon, only preferred habitat criteria were used in the model. Lower quality (i.e., usable) habitat is not represented.

Table 25. Suitability criteria used for juvenile Chinook salmon habitat modeling.

Life Stage	Criterion[a]	
	velocity (ft/s)	depth (ft)
Fry	0.0–1.2	0.2–2.0
Juvenile	0.1–2.2	0.5–6.5

[a] USFWS 1995

2.5.2 Results

Habitat modeling indicates that the project greatly increased Chinook salmon fry and juvenile rearing habitat (see habitat suitability maps in Appendices D and E). [Note that the River 2D model does not include temperature as a habitat parameter. Results, therefore, assume that temperature is suitable for rearing Chinook salmon.] Prior to construction, fry habitat at SRP 9 was limited to a narrow, discontinuous band along the margins of the pit. At low flows (<150 cfs), fry habitat was also found at the riffle that defines the downstream end of the site. As flows increase, fry habitat remained along the margins of the pit and shifted from the entire channel at the downstream riffle to the channel margins and eventually onto the left bank floodplain. For pre-project conditions, the extent of fry habitat remained relatively stable for the range of flows modeled (Table 26). Fry habitat area was greatest at 75 cfs, totaling 22,389 ft^2, and then fluctuated between 17,000 ft^2 and 21,300 ft^2 for flows of 150 cfs to 5,000 cfs (Table 26, Figure 2-38). Predicted juvenile Chinook salmon habitat was restricted to the riffles at the upstream and downstream ends of the site. As flows increased, juvenile habitat decreased at the upstream riffle (due to flow velocities) and expanded at the downstream riffle. At high flows, the pit margins also provided suitable juvenile habitat. For the range of flows modeled, predicted juvenile habitat area increased steadily from a low of 22,676 ft^2 at 75 cfs to 44,441 ft^2 at 2,000 cfs, then remained relatively stable through flows of 5,000 cfs (Table 26, Figure 2-38).

Table 26. Predicted Chinook salmon fry and juvenile rearing habitat at SRP 9 for pre- and post-project conditions.

Flow (cfs)	Fry Habitat				Juvenile Habitat			
	Predicted Area (ft^2)		Change in Area		Predicted Area (ft^2)		Change in Area	
	Pre-project	Post-project	ft^2	%	Pre-project	Post-project	ft^2	%
75	22,389	20,676	-1,713	-8	22,676	50,005	27,329	121
150	18,159	20,244	2,085	11	31,891	56,182	24,291	76
300	18,257	19,967	1,710	9	39,175	58,319	19,144	49
500	18,975	21,781	2,806	15	40,653	59,214	18,561	46
1,000	17,724	50,429	32,705	185	41,962	63,112	21,150	50
2,000	19,498	143,565	124,067	636	44,441	168,766	124,325	280
3,000	17,215	79,944	62,729	364	43,579	214,473	170,894	392
5,000	21,341	23,789	2,448	11	42,564	206,576	164,012	385

After project construction, fry habitat at SRP 9 is available along the gently sloping right bank of the channel and at the riffle at the downstream end of the site (see habitat suitability maps in Appendix E). As flows exceed 1,000 cfs, fry habitat becomes available in the high flow channels and on the left bank and right bank floodplains. As flows exceed approximately 2,000 cfs, flow velocity on the floodplain becomes too swift to be suitable for fry and the area of suitable habitat decreases. Juvenile Chinook salmon rearing habitat is available throughout the constructed channel, particularly at riffles, in the right bank eddy, and the head and tail of the pool. As flows exceed 1,000 cfs, juvenile habitat shifts to the left bank and right bank floodplains. By 2,000 cfs, the entire floodplain provides suitable rearing habitat, and the floodplains continue to provide suitable habitat up through the maximum flow for which modeling was conducted (i.e., 5,000 cfs).

Compared to pre-project conditions, the project increased fry habitat area for all flows except 75 cfs, with the largest increases occurring from 1,000 cfs through 3,000 cfs (Table 26, Figure 2-38). At 75 cfs, post-project fry habitat is 1,700 ft^2 (or 8%) less than under pre-project conditions. For flows from 150 cfs to 500 cfs, the project increased predicted fry habitat by 1,700 ft^2 to 2,800 ft^2, or 9% to 15%. For flows from 1,000 cfs to 3,000 cfs, the project increased predicted fry habitat by 33,000 ft^2 to 124,000 ft^2, or 185% to 636%. The predicted area of juvenile habitat increased for all flows modeled, with the largest increases occurring at flows exceeding 1,000 cfs (Table 26, Figure 2-38). For flows from 75 cfs to 1,000 cfs, the project increased predicted juvenile habitat by 18,600 ft^2 to 27,300 ft^2, or 46% to 121%. For flows from 2,000 cfs to 5,000 cfs, the project increased predicted juvenile habitat by 124,300 ft^2 to 164,000 ft^2, or 280% to 385%.

2.6 Chinook Salmon Survival (H11)

No Chinook salmon survival monitoring was conducted following project construction. Project construction, however, is expected to affect Chinook salmon outmigrant survival by increasing water velocities through the site and reducing interactions between bass and Chinook salmon. These potential effects on Chinook salmon survival are discussed in Section 4.

Quantifying Chinook salmon survival and bass predation through the project reach is fundamental to evaluating the SRP 9 project's effectiveness in achieving its primary goal (i.e., increasing juvenile salmon outmigrant survival) and testing the validity of the conceptual models upon which the project is based (i.e., whether converting the mining pits to geomorphically scaled channels and floodplains reduces largemouth bass abundance and whether reducing largemouth bass abundance increases Chinook salmon survival).

2.7 Riparian Vegetation (H7, H8, H9)

The Monitoring Plan includes plot-based surveys of species composition, survival and growth in the active channel, floodplain, and terrace. The monitoring schedule includes surveys in Years 0, 2, 3, and 5 or following a high flow event exceeding 5,000 cfs. Very little monitoring of riparian vegetation has occurred at SRP 9 to date. At this site, planting was conducted from November 1 through December 31, 2001; irrigation and plant maintenance continued through September 2003. HDR Engineering has developed as-built maps showing the locations and species of planted vegetation. Post-project monitoring of planted vegetation has been limited to quantifying survival of planted vegetation and replacing plants as stipulated in the construction contract. Percent cover and growth of planted vegetation has not been monitored. Recruitment of native vegetation on constructed surfaces (H8) and encroachment of riparian vegetation into the active channel (H9) also have not been assessed.

In December 2002, HDR Engineering conducted a brief survey of tree survival at the site. Survival of planted trees one year after planting was fairly high, exceeding 70% for most species (Table 27). Survival was higher on the north bank than the south bank due to human disturbance on the south bank. (The south bank is accessible via a trail from Fox Grove County Park.) Beaver damage to several trees was also noted. Survival has not been assessed since irrigation ended. Post-irrigation success of the riparian plantings, therefore, can not be determined.

Table 27. Vegetation survival at SRP 9 in 2002.

Species	**South Bank Floodplain**			**North Bank Floodplain**		
	No. Planted (2001)	**No. Live (2002)**	**% Survival**	**No. Planted (2001)**	**No. Live (2002)**	**% Survival**
White alder *(Alnus rhombifolia)*	9	6	66	9	5	55.6
Oregon ash *(Fraxinus latifolia)*	78	70	89.7	51	49	96
Black willow *(Salix gooddingii)*	49	31	63.3	55	42	76.4
Box elder *(Acer negundo)*	86	73	84.9	59	44	74.6
Fremont cottonwood *(Populus fremontii)*	106	98	92.5	126	123	97.6
Red willow *(Salix laevigata)*	33	20	60.6	15	12	80
Valley oak *(Quercus lobata)*	175	146	83.4	35	34	97.1
Yellow willow *(Salix lutea)*	22	10	45.5	10	7	70

Source: HDR Engineering (2002)

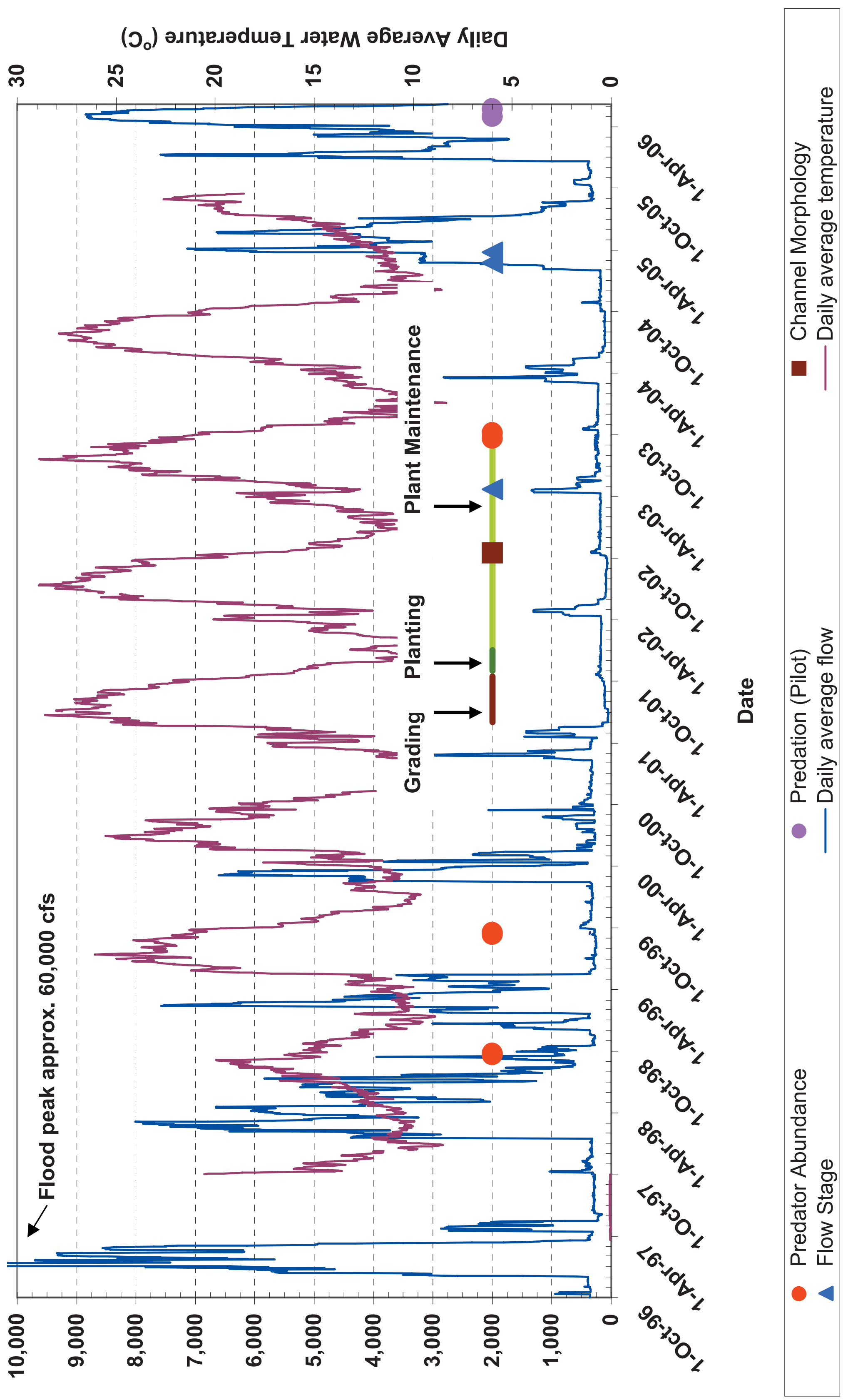


Figure 2-1. Tuolumne River flow and temperature conditions relative to SRP 9 construction and monitoring. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA. Temperature data are from RM 23.6 [1 Jan 97–1July03 and 6 Jan 04–26 Mar 05] and RM 3.4 [15July03–5Jan04 and 27 Mar 05–14 Sept 05], TID unpublished data).

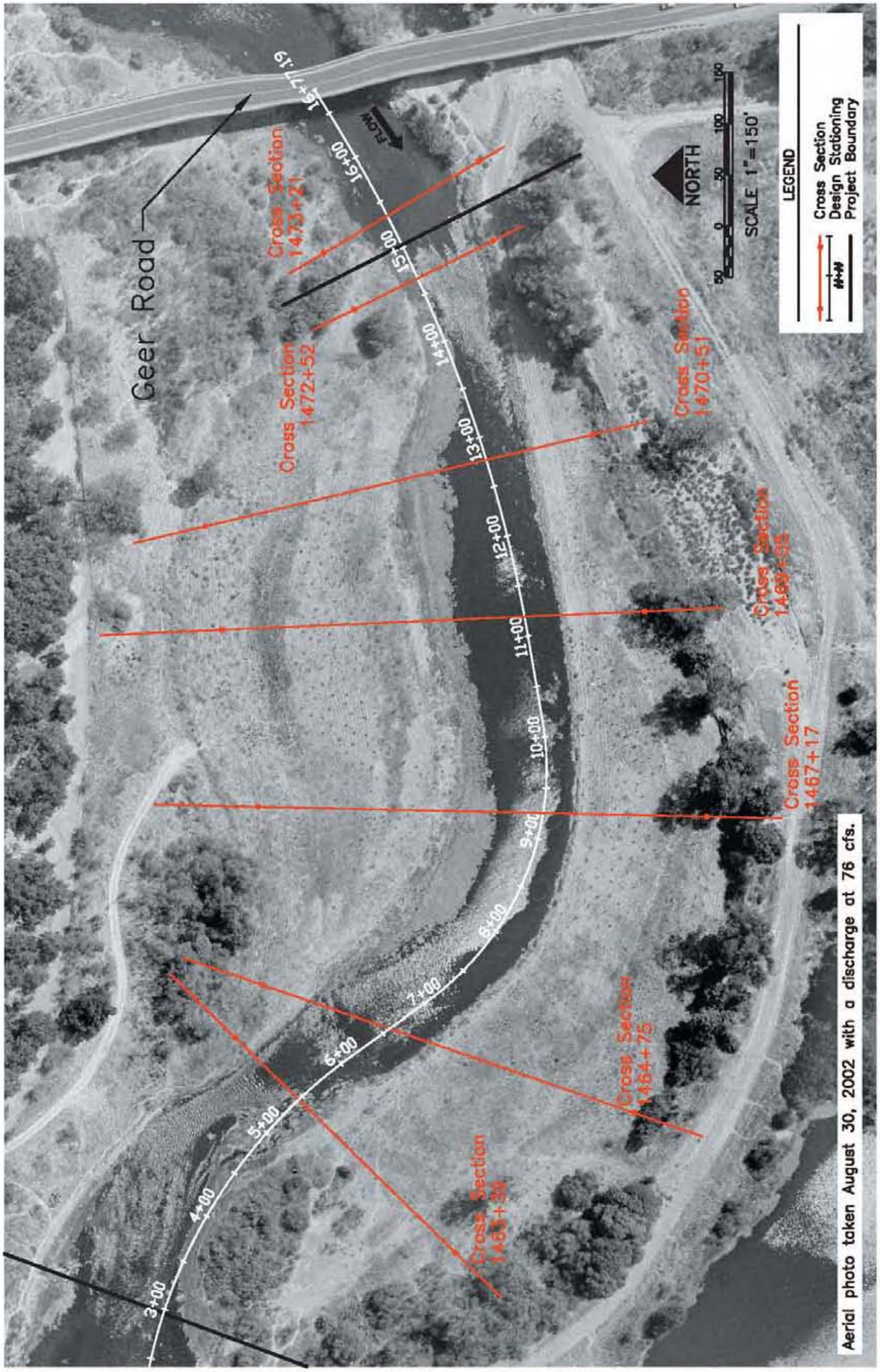


Figure 2-2. SRP 9 as-built and post-project monitoring cross section locations.

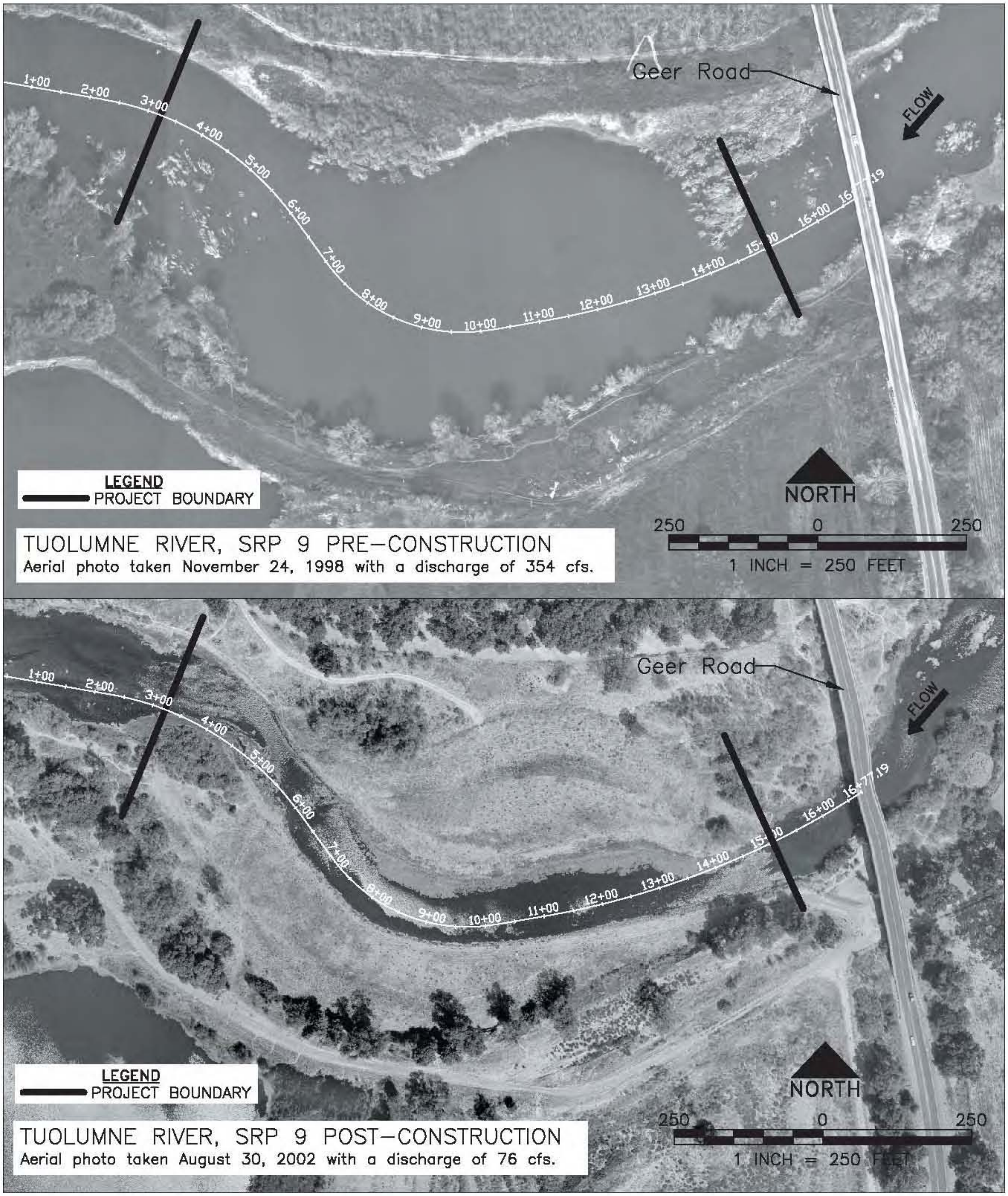


Figure 2-3. SRP 9 pre-project (1998), as-built (2002), and post-project (2005) aerial photographs.

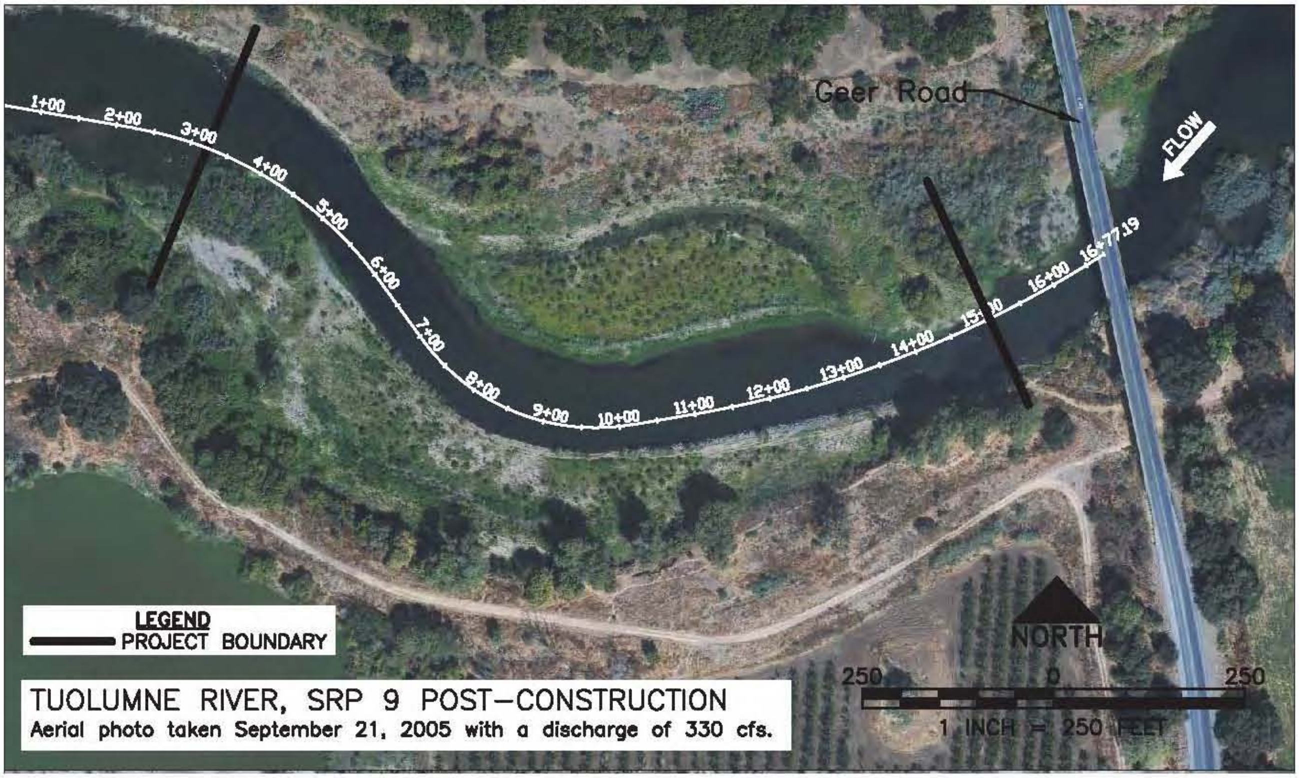


Figure 2-3. SRP 9 pre-project (1998), as-built (2002), and post-project (2005) aerial photographs, continued.

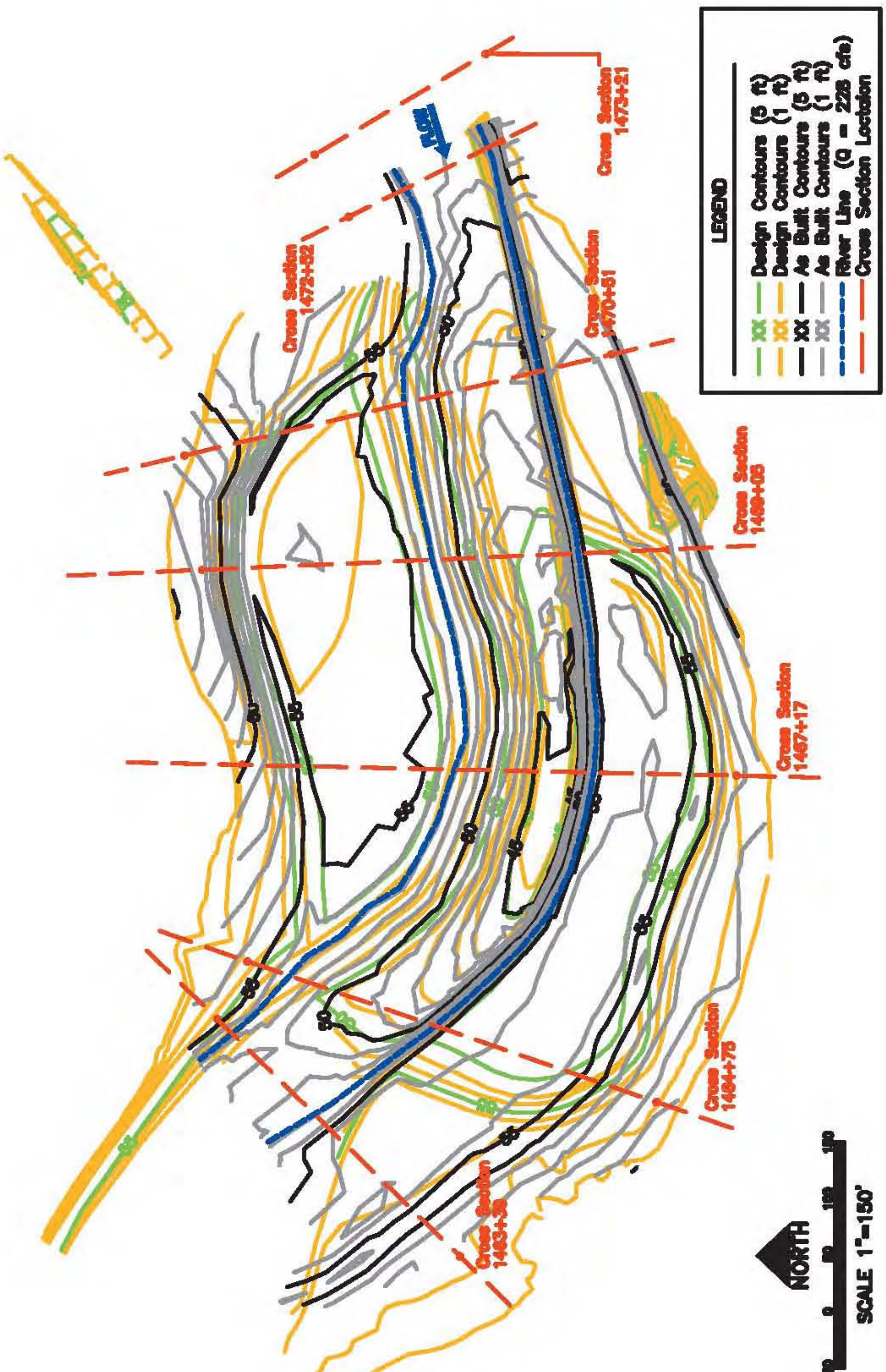
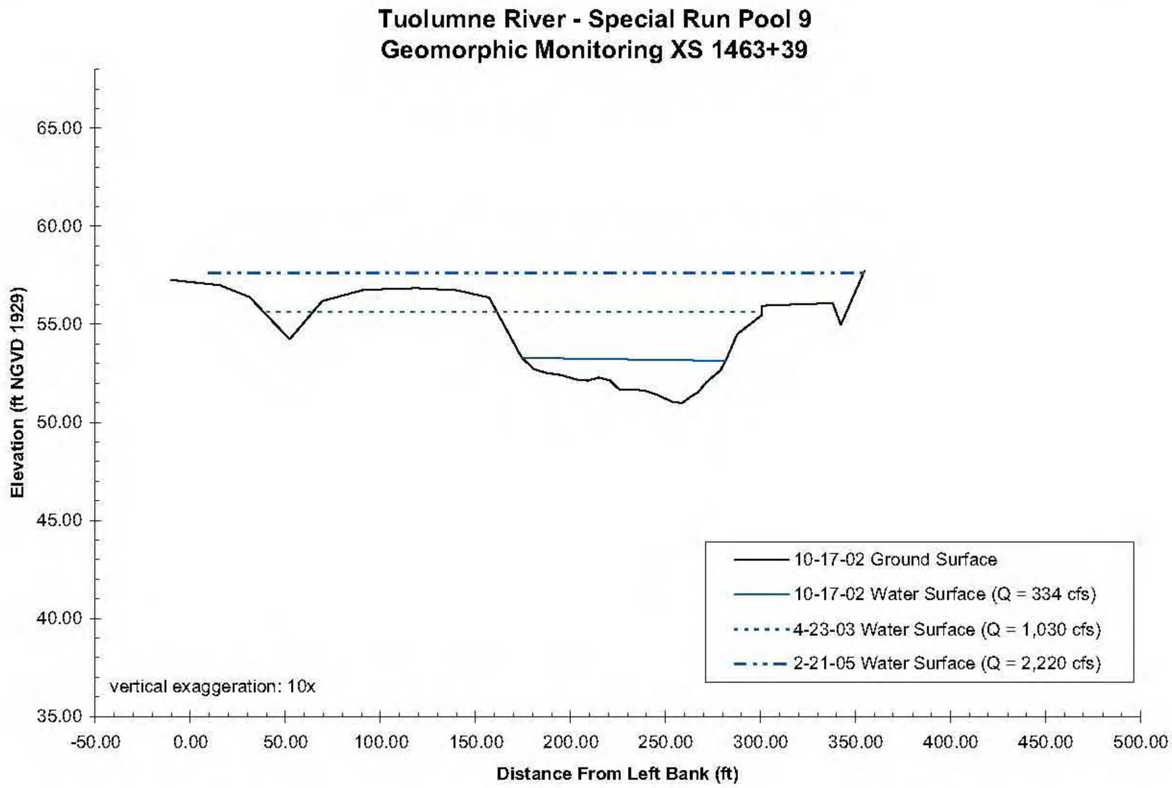


Figure 2-4. SRP 9 design and as-built channel and floodplain contours.



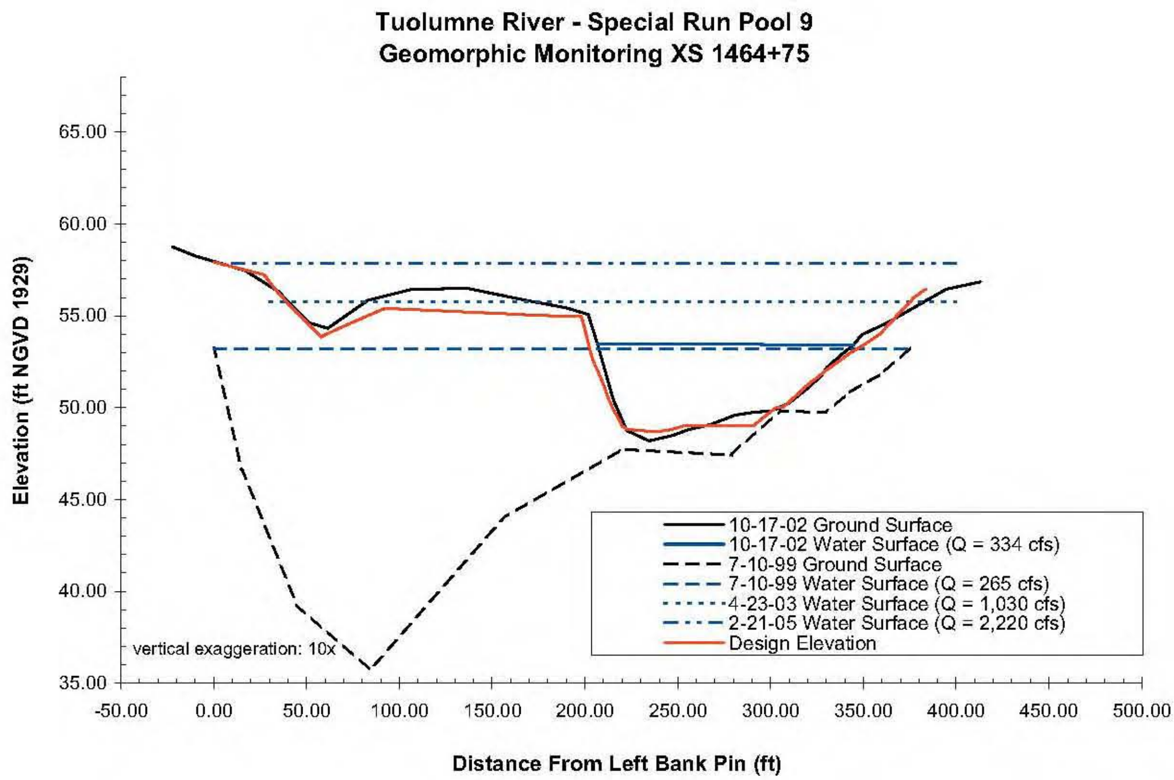
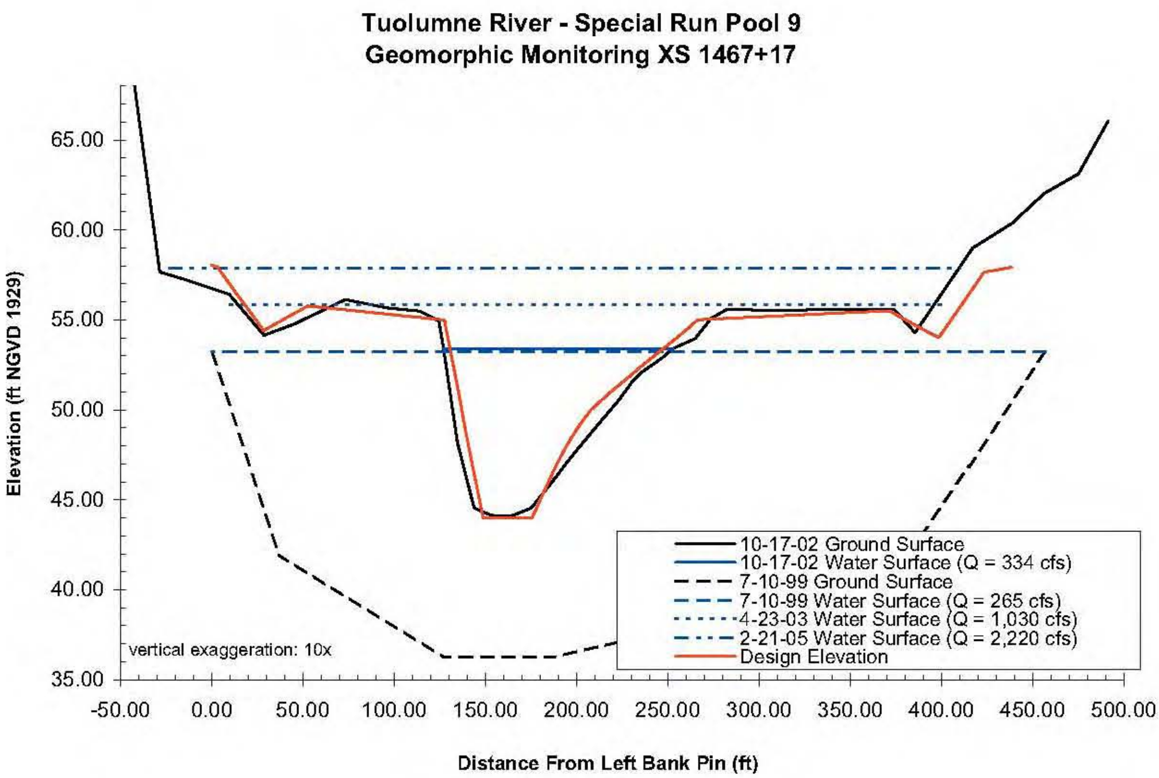


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface.



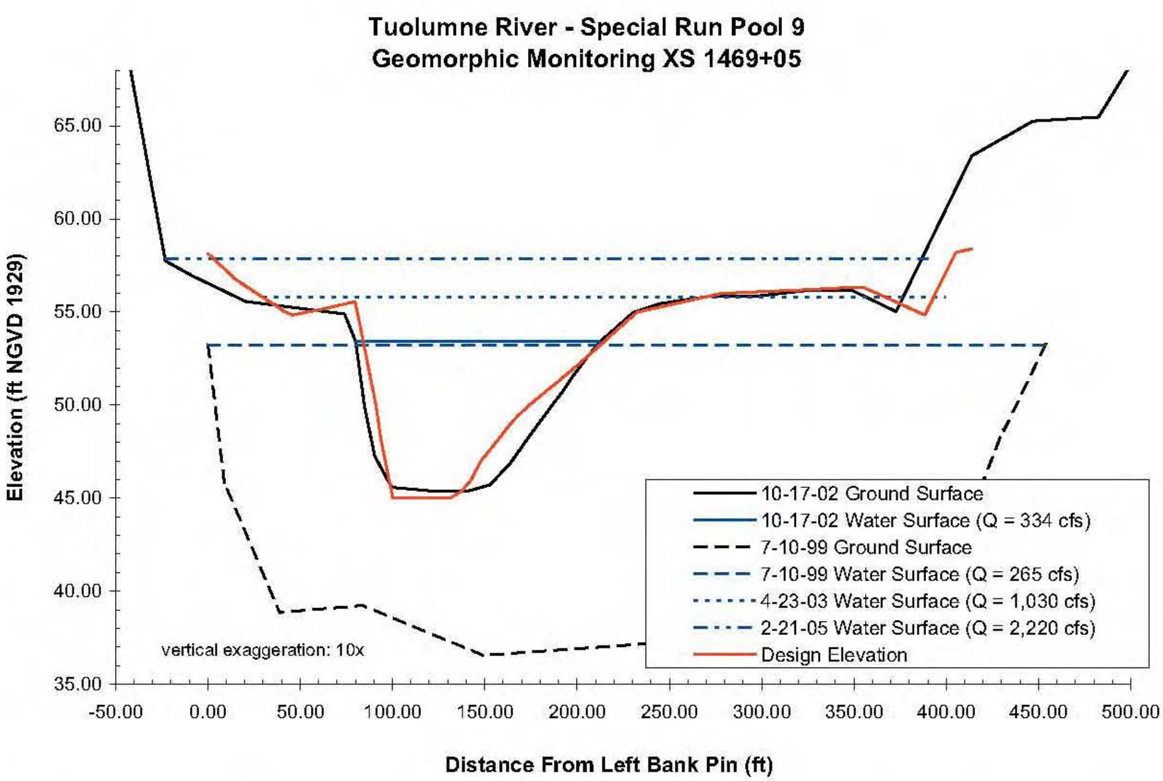
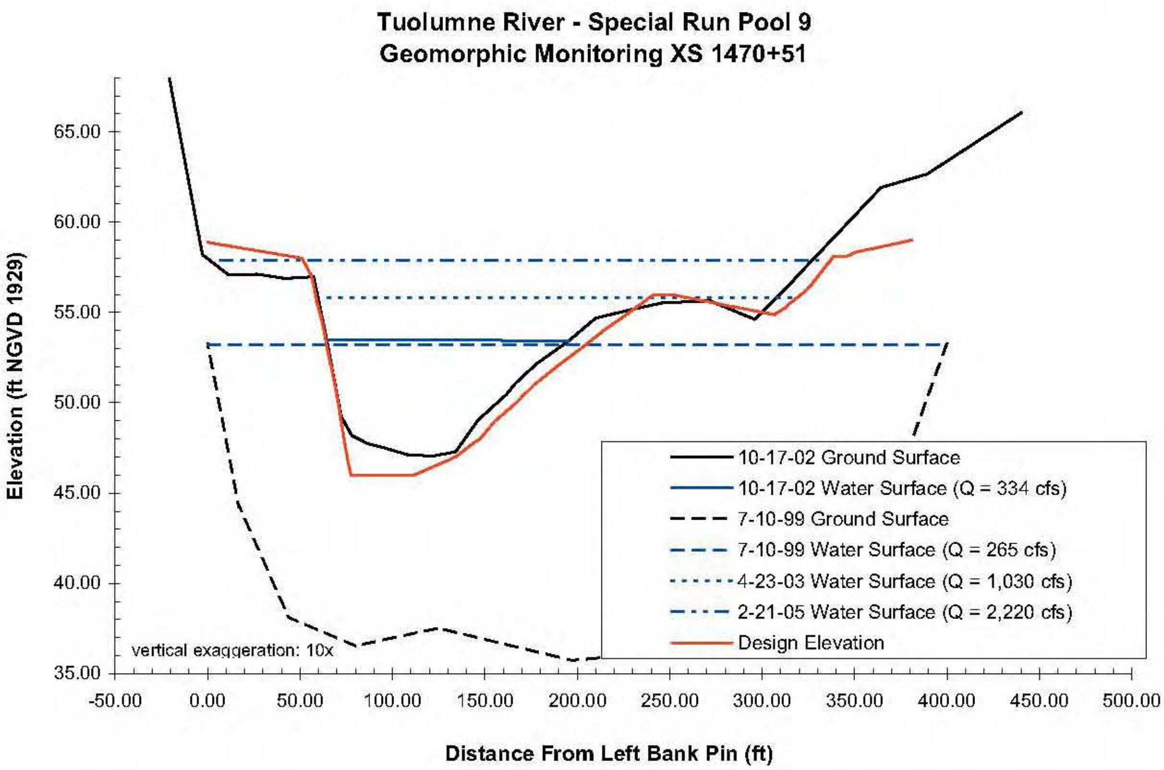


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface, continued.



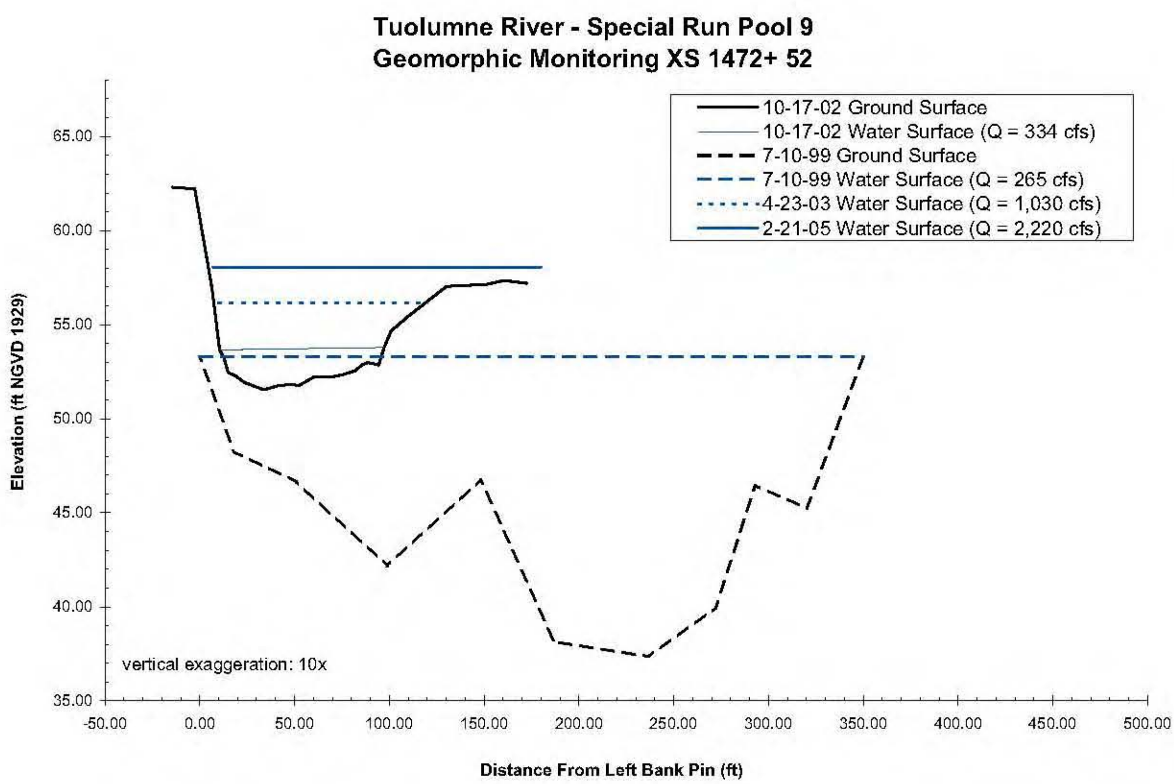


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface, continued.

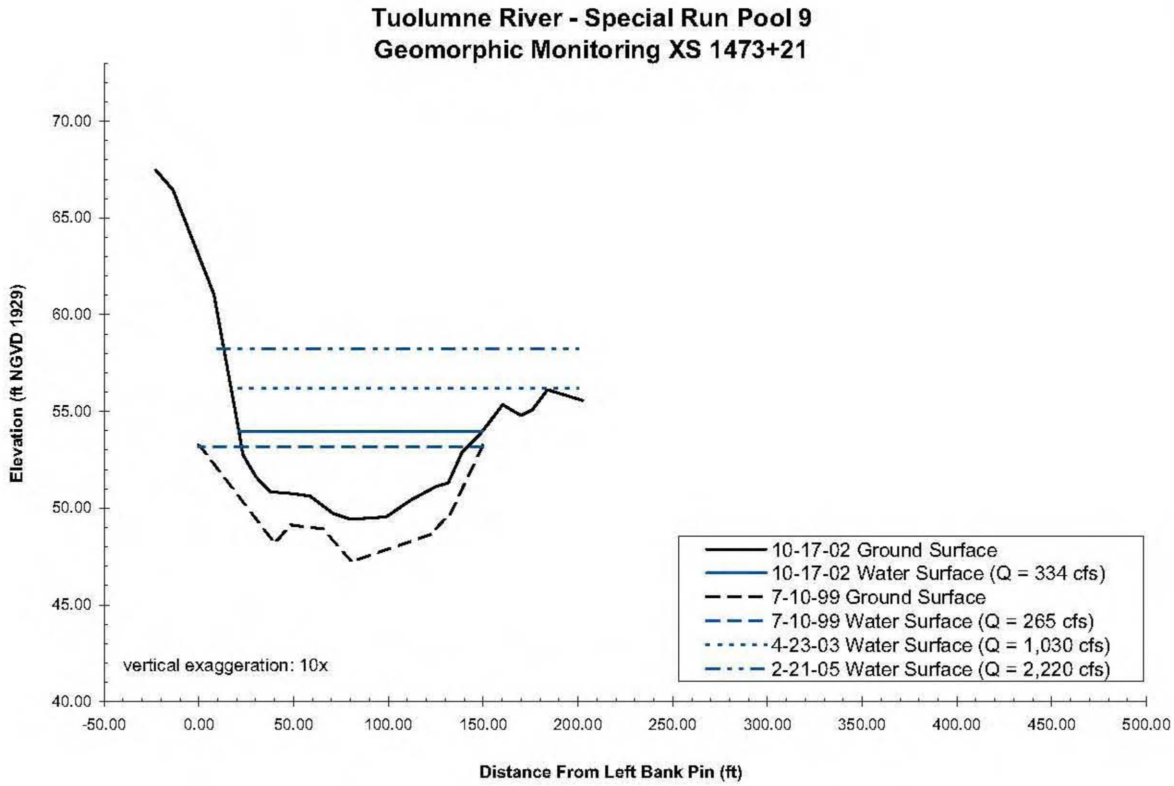


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface, continued.

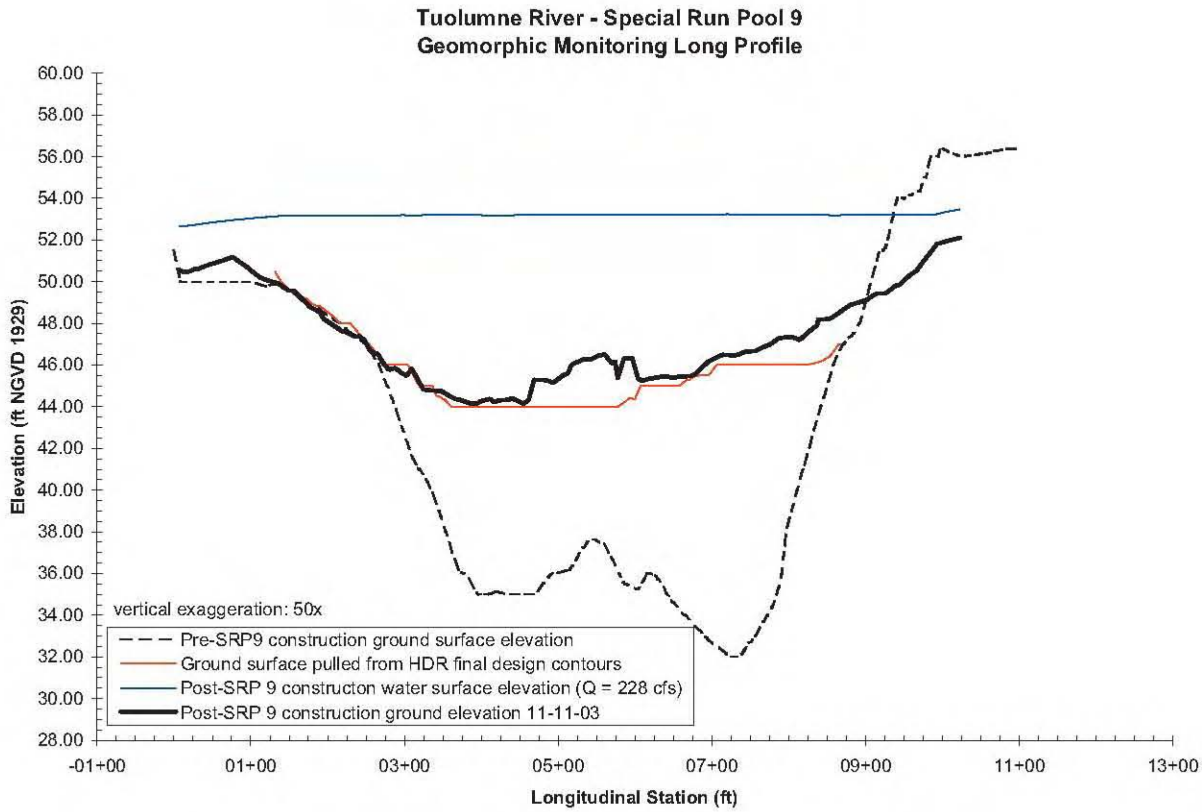


Figure 2-6. SRP 9 pre-construction, final design, and as-built channel thalweg profile.

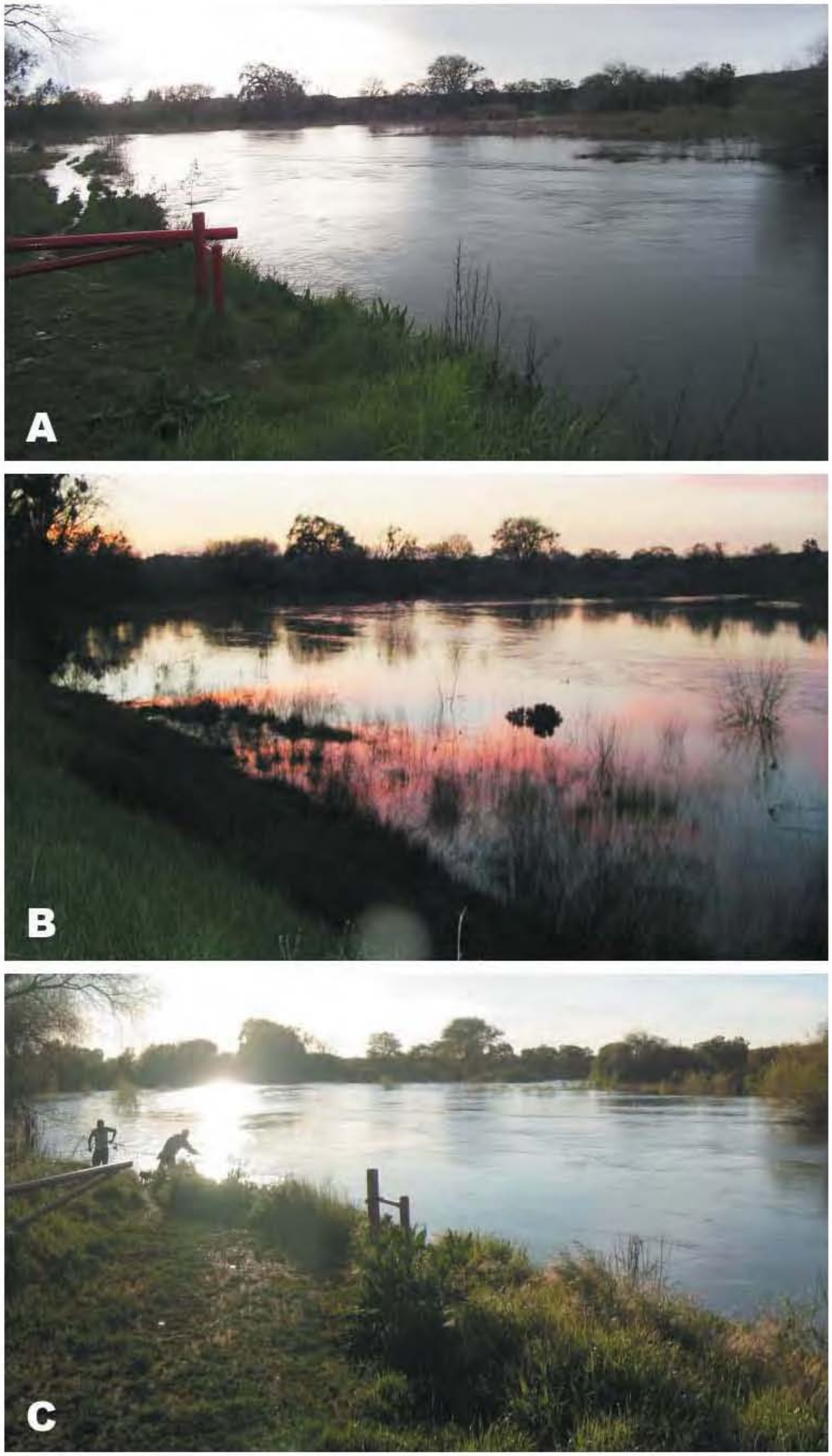


Figure 2-7. View from approximate location of cross section 1473+21 looking downstream during flows (A) 2,200 cfs [February 21, 2005], (B) 3,230 cfs [February 23, 2005], and 5,690 cfs [March 25, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.)

Figure 2-8. View of left bank floodplain from cross section 1464+75 looking upstream during flows of 2,200 cfs [February 21, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.)

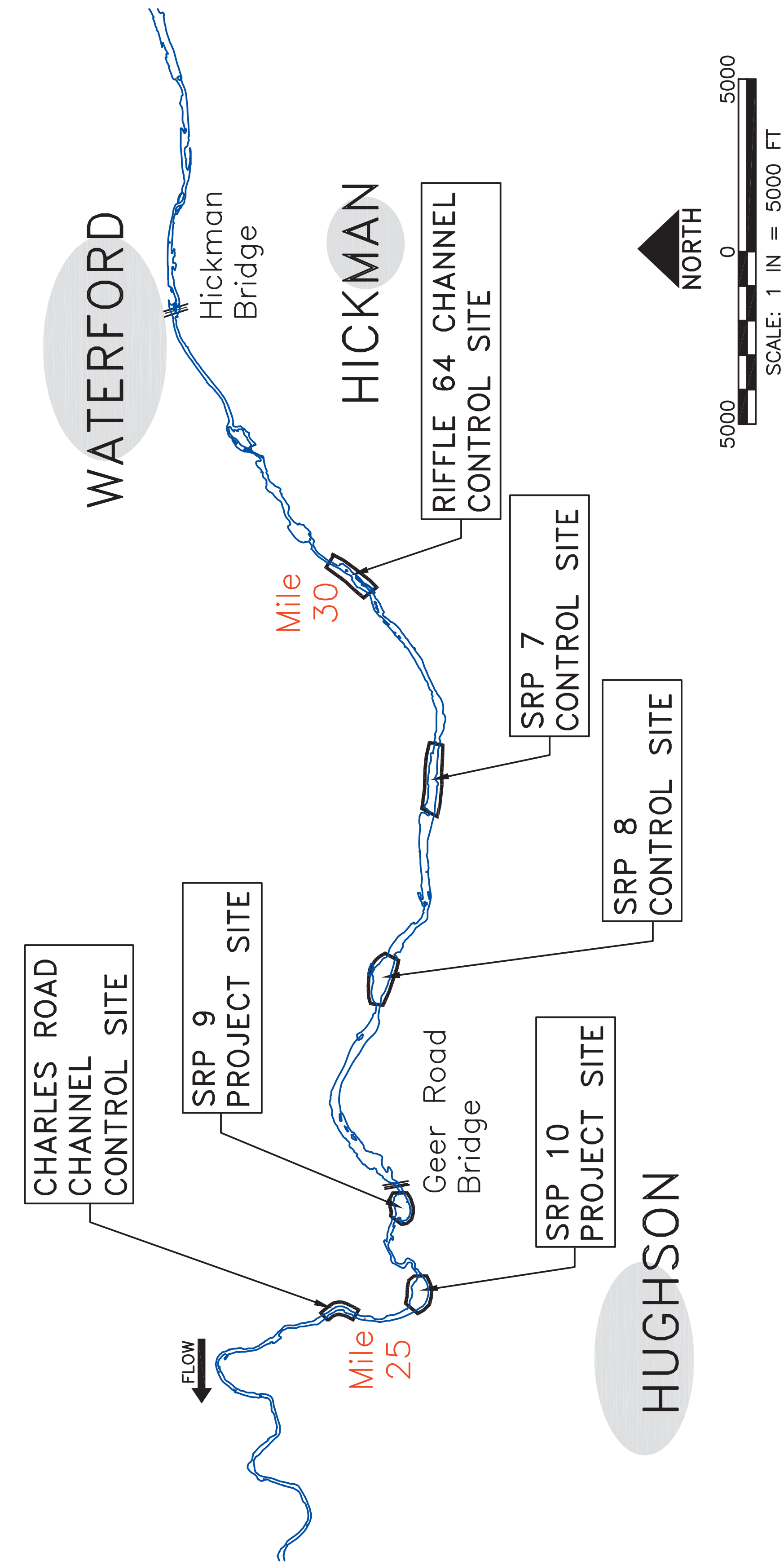


Figure 2-9. SRP 9 bass abundance monitoring sites.

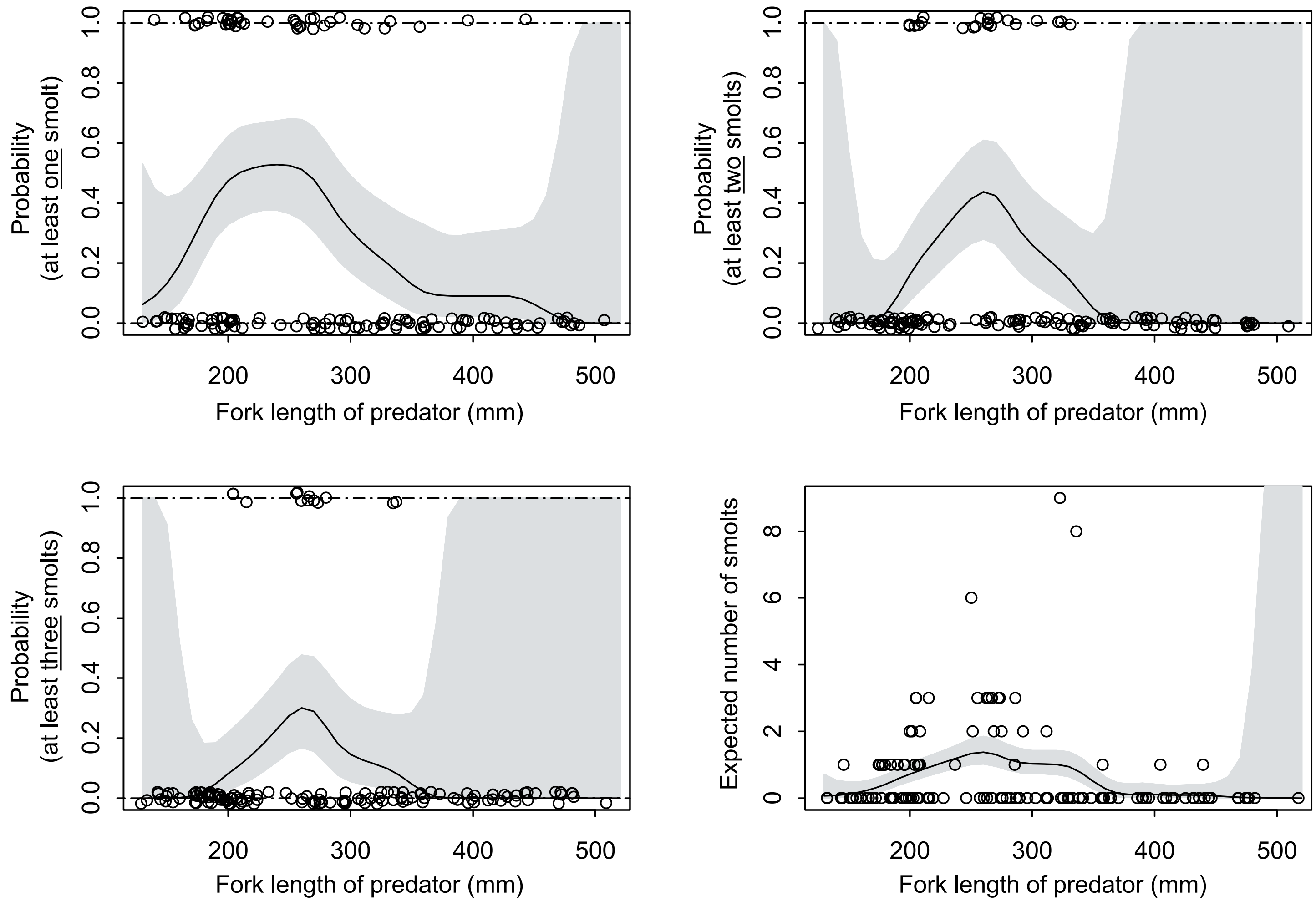
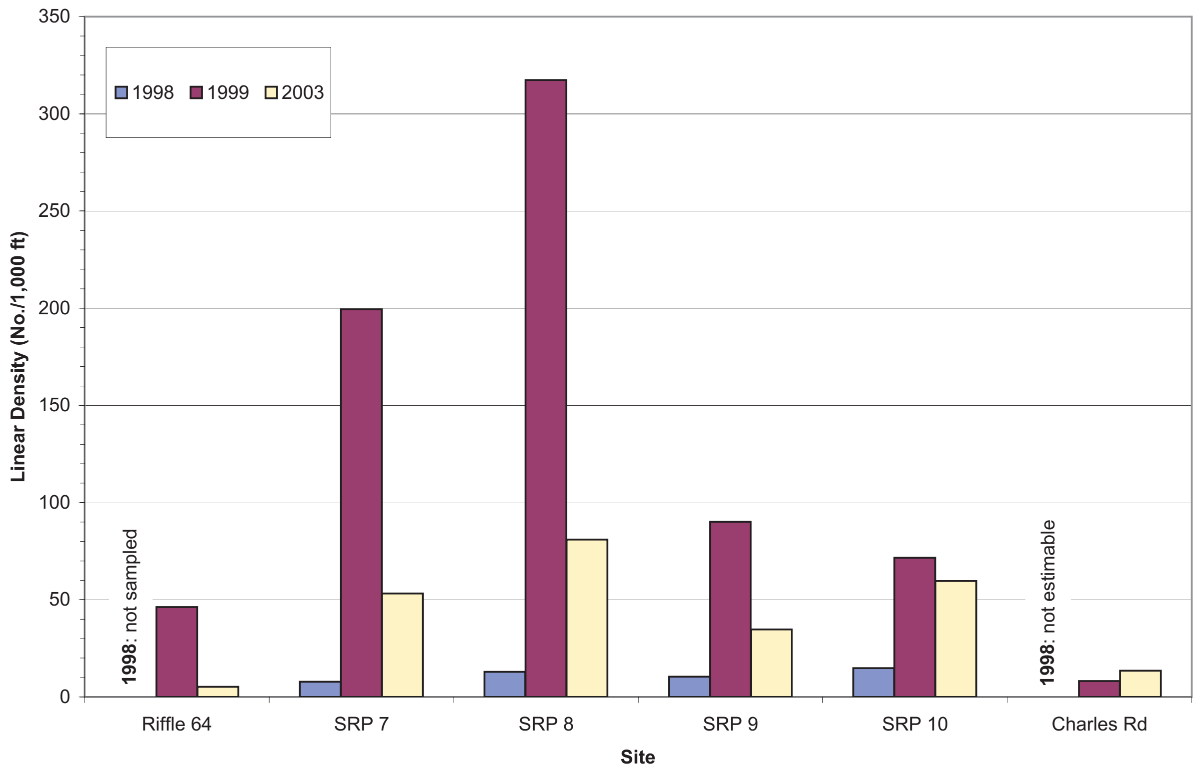


Figure 2-10. Chinook salmon found in stomachs of largemouth bass recovered by electrofishing in SRPs 7, 8, 9, and 10 from 2-4 May 1990, as part of the Lower Tuolumne River Predation Study (TID/MID 1992a). The figures at upper left, upper right, and lower left show probability of finding at least 1, at least 2, or at least 3 Chinook salmon smolts, respectively, in the stomach of an individual largemouth bass as a function of the predator's fork length. The figure at lower right shows an estimate of the expected number of smolts in the stomach of an individual largemouth bass as a function of the predator's fork length. The grey bands are approximate 95% variability bands.



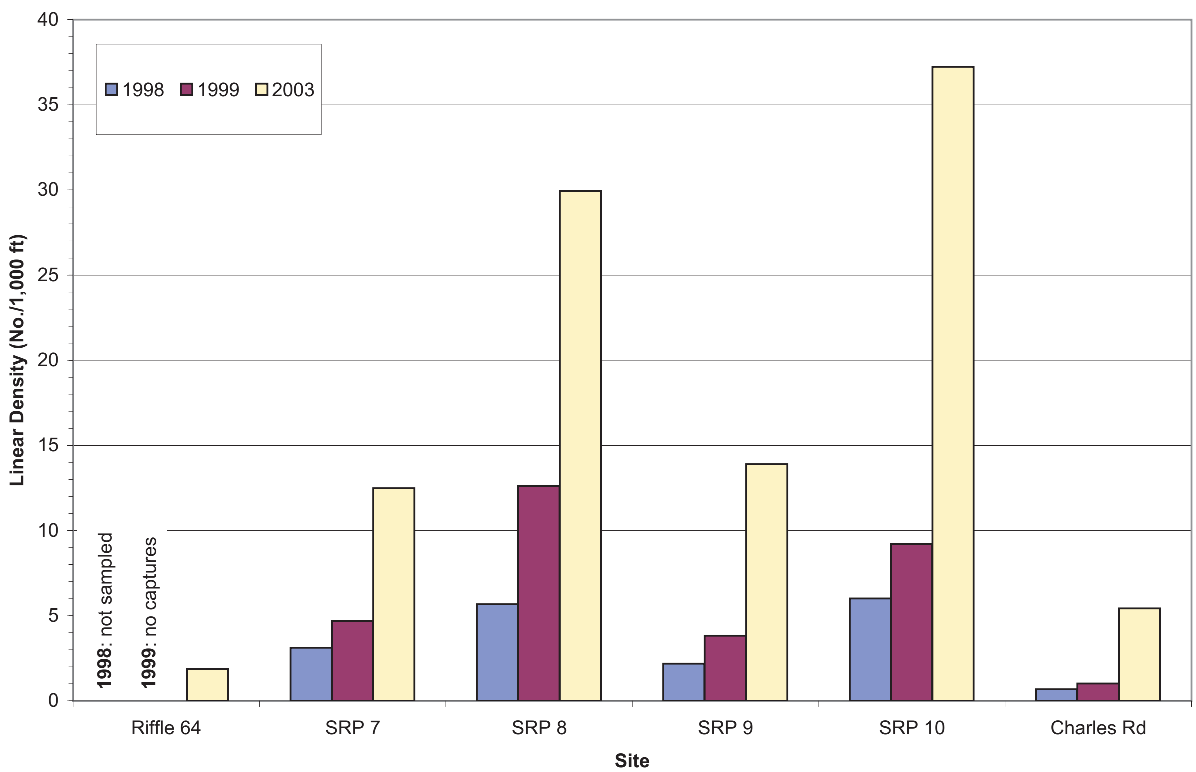


Figure 2-11. Largemouth bass linear density at project and control sites for all size classes combined (top) and piscivore-size only (bottom) –1998, 1999, and 2003.

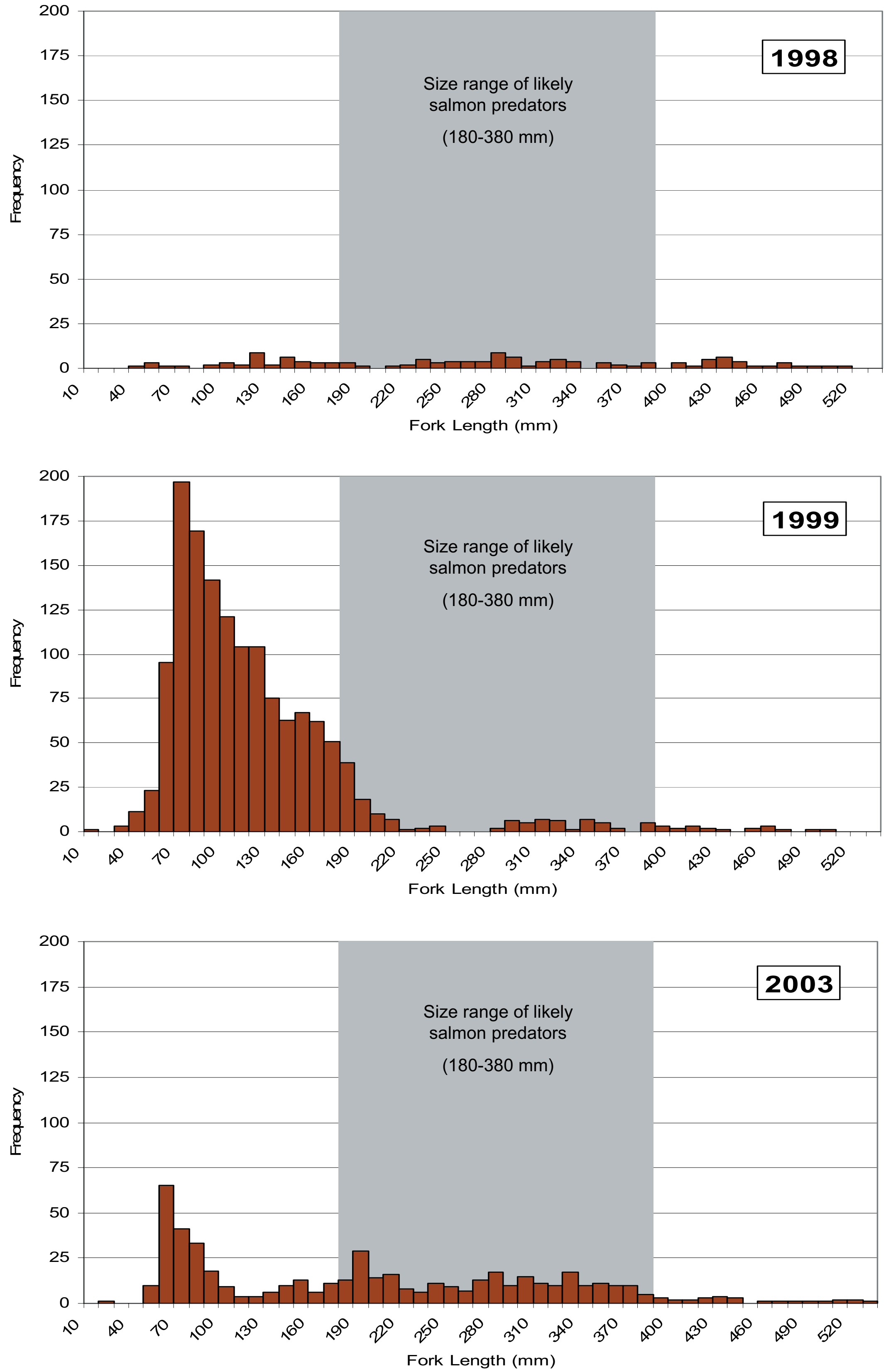


Figure 2-12. Length-frequency of largemouth bass captured at all project and control sites combined in 1998, 1999, and 2003.

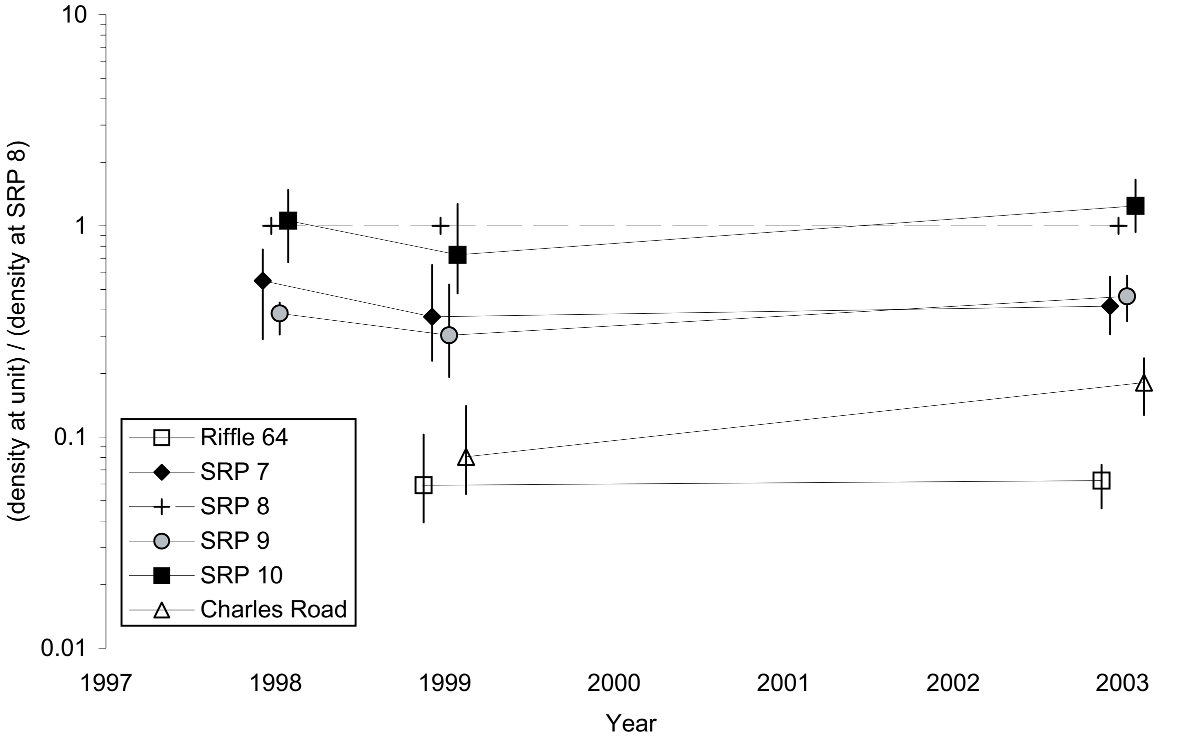
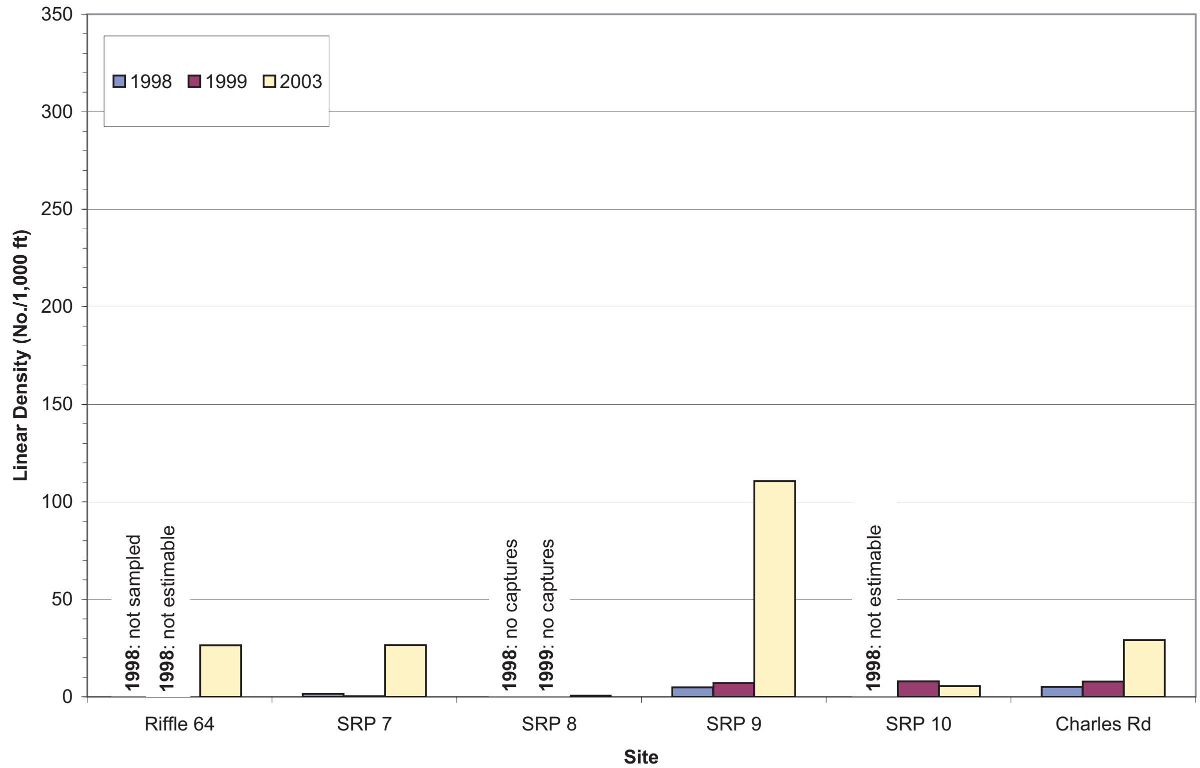


Figure 2-13. Before-After-Control-Impact trends for piscivore-sized largemouth bass. The plotted series are the ratios between the (linear) largemouth bass density at each project and control site to linear density at SRP 8. Vertical bars are 95% confidence intervals for these values.



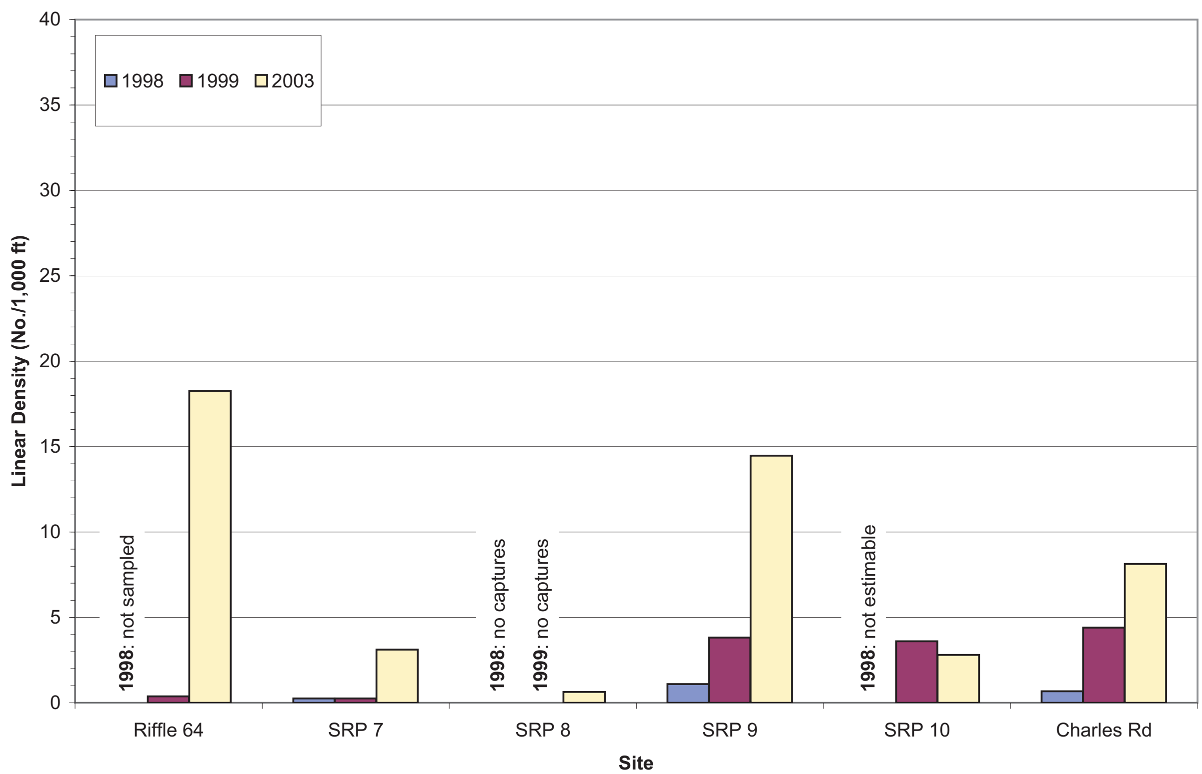


Figure 2-14. Smallmouth bass linear density at project and control sites for all size classes combined (top) and piscivore-size only (bottom) –1998, 1999, and 2003.

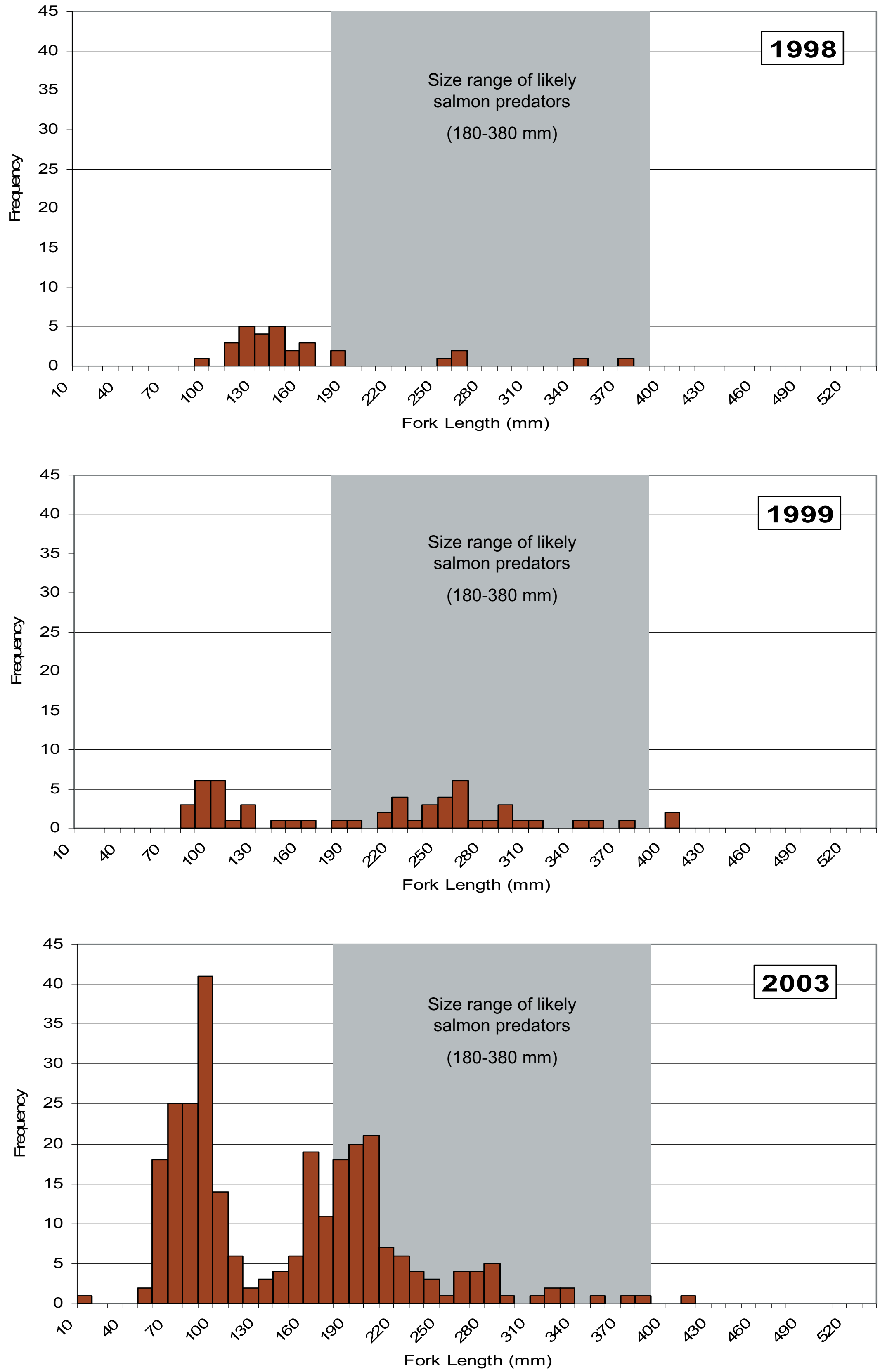


Figure 2-15. Length-frequency of smallmouth bass at all project and control sites combined in 1998, 1999, and 2003.

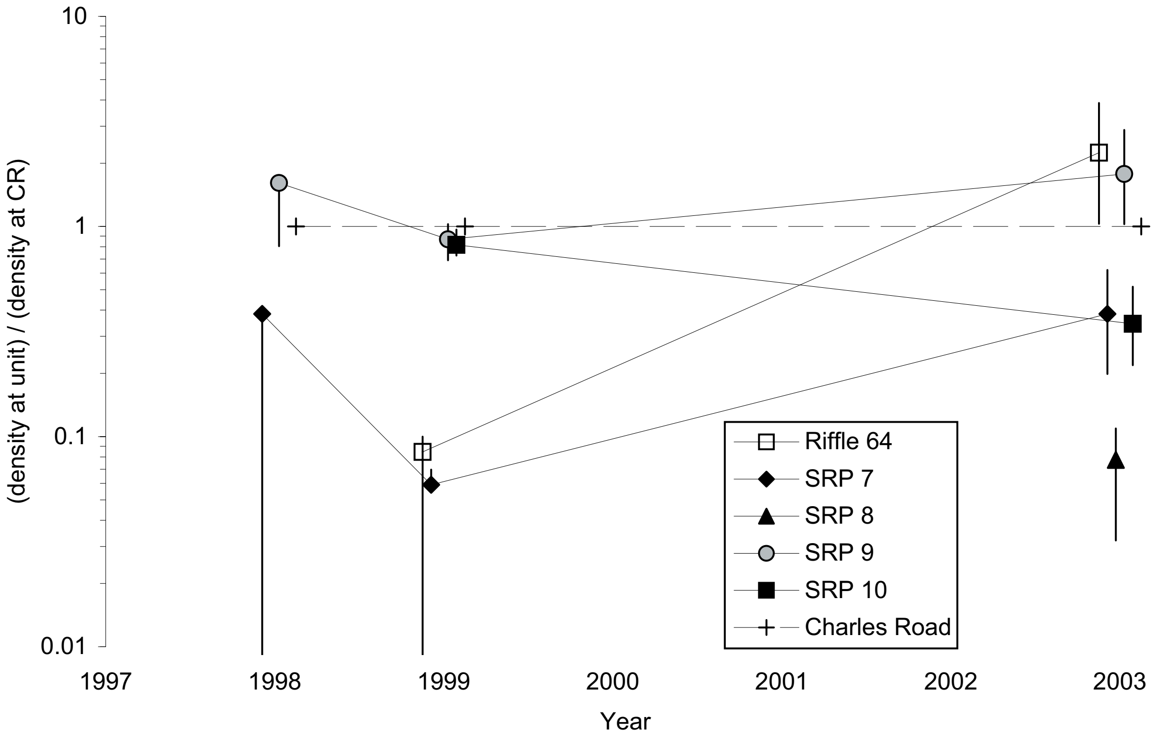


Figure 2-16. Before-After-Control-Impact trends for piscivore-sized smallmouth bass. The plotted series are the ratios between the (linear) largemouth bass density at each project and control site to linear density at Charles Rd. Vertical bars are 95% confidence intervals for these values.

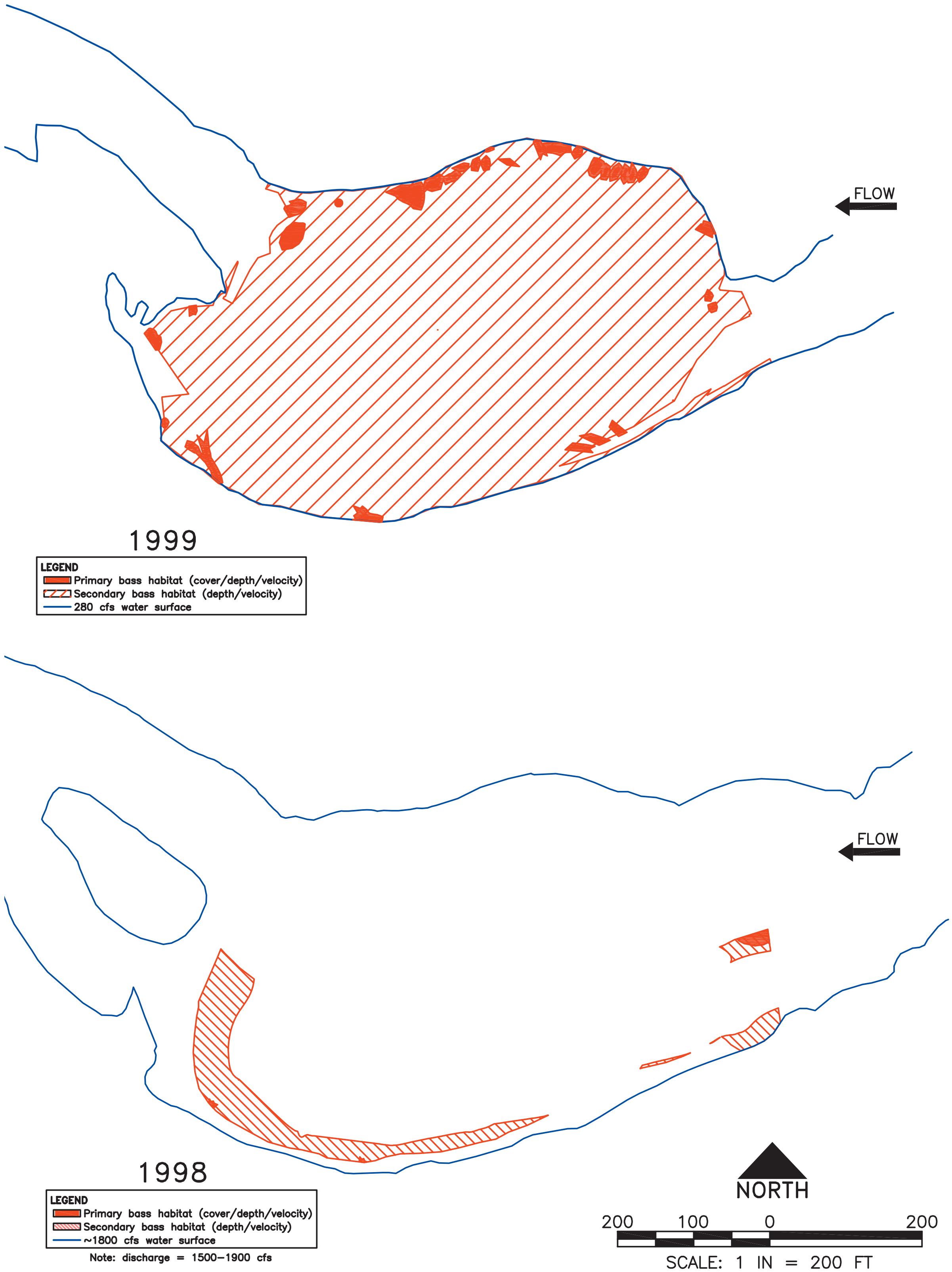


Figure 2-17. Largemouth bass primary and secondary habitat mapped at SRP 9 during flows of 265–287 cfs (August 1999) [top] and 1,440–1,770 cfs (August 1998) [bottom].

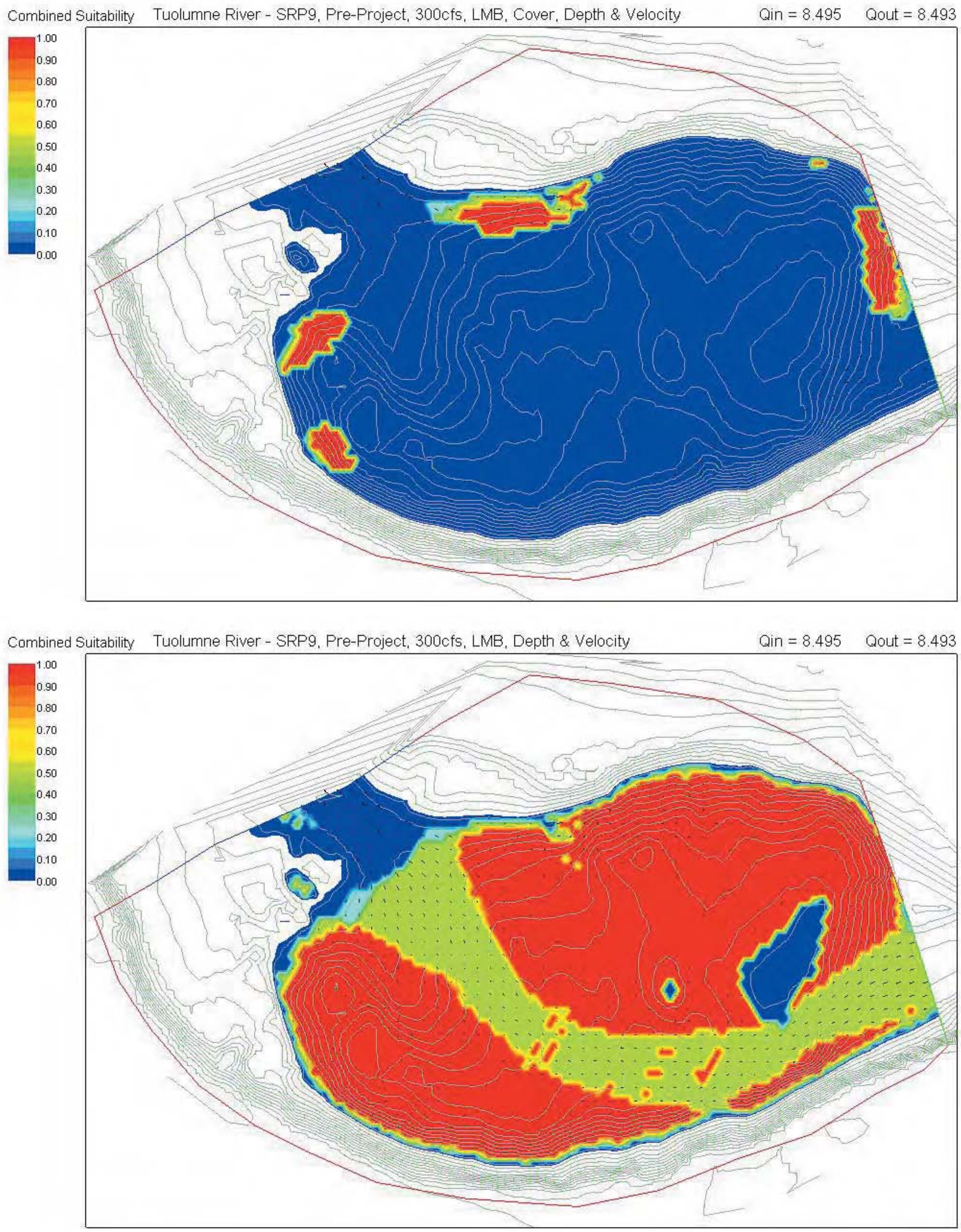
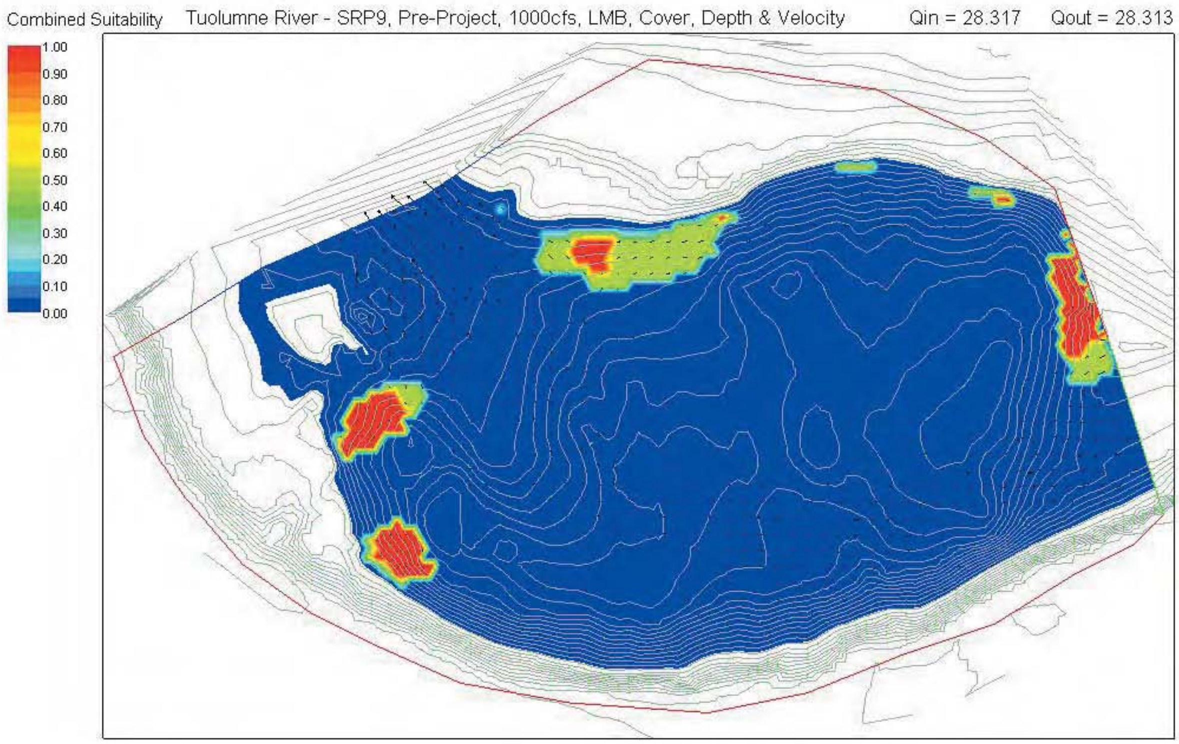


Figure 2-18. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 300 cfs.



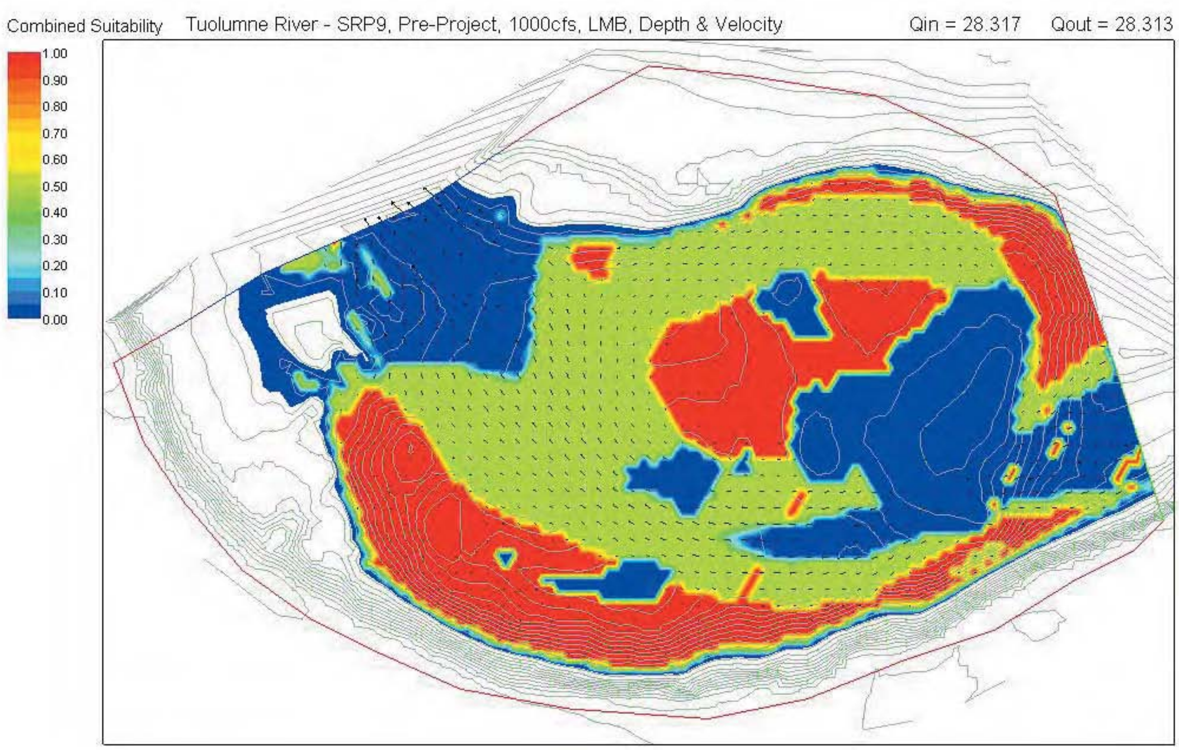


Figure 2-19. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 1,000 cfs.

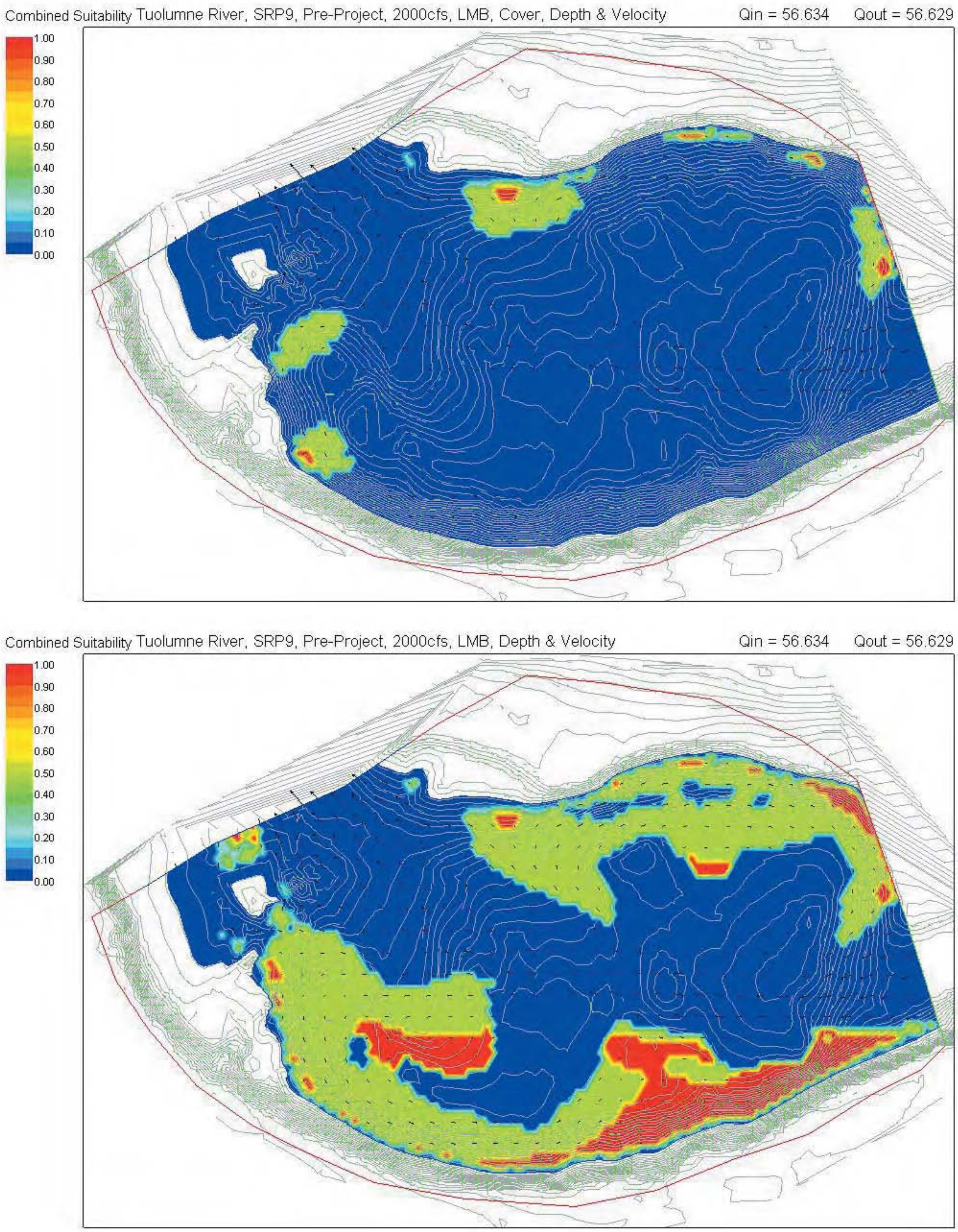


Figure 2-20. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 2,000 cfs.

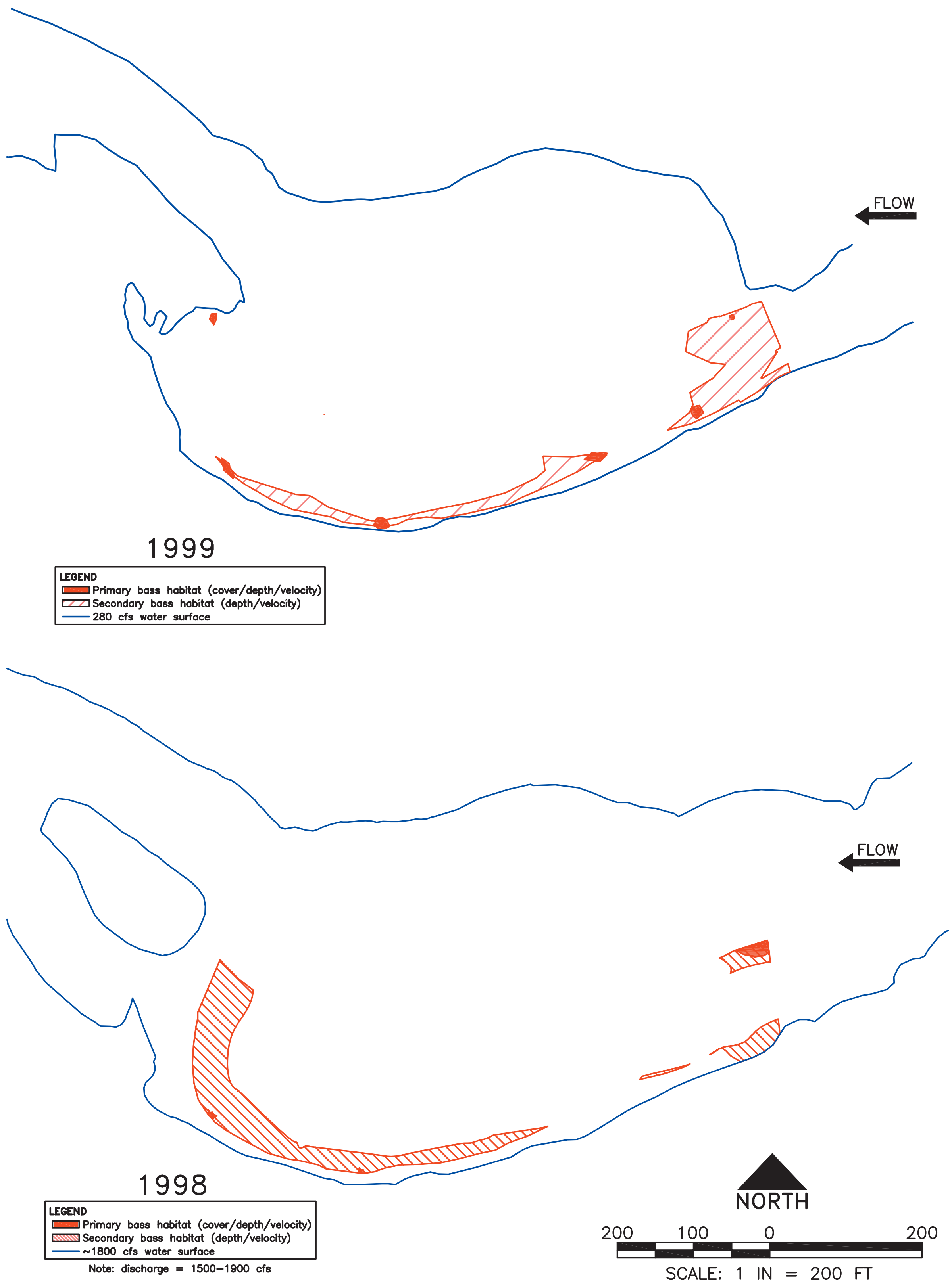
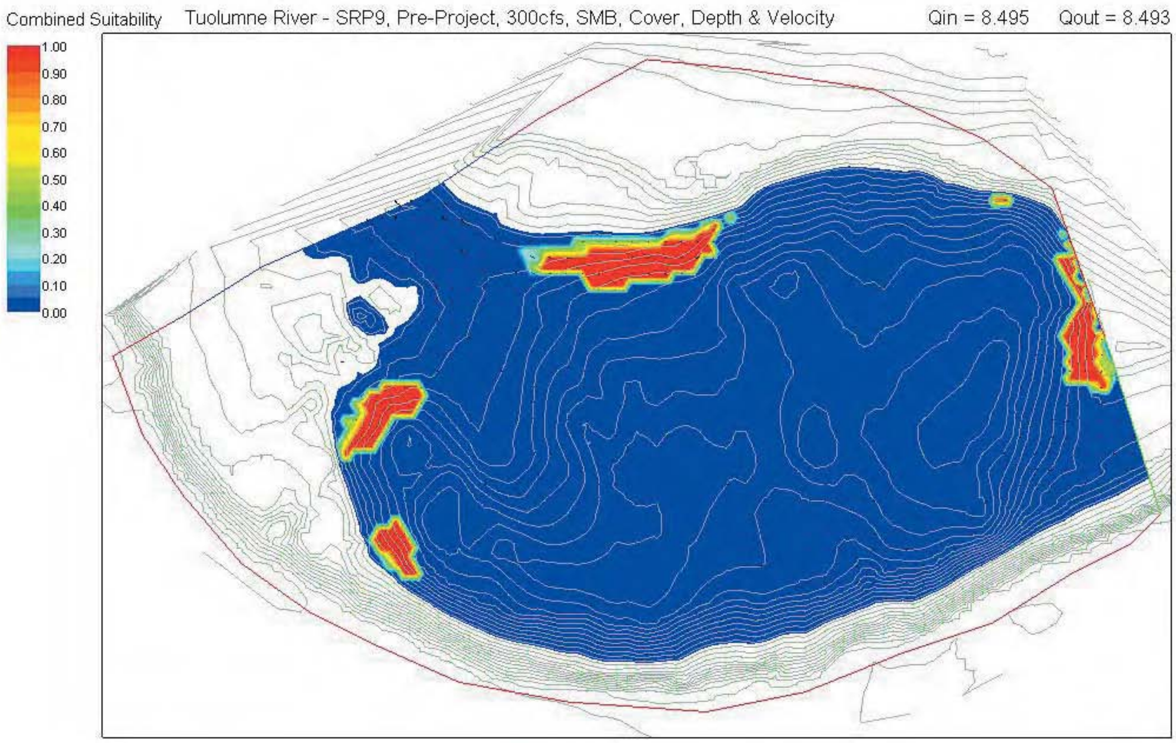


Figure 2-21. Smallmouth bass primary and secondary habitat mapped at SRP 9 during flows of 265–287 cfs (August 1999) [top] and 1,440–1,770 cfs (August 1998) [bottom].



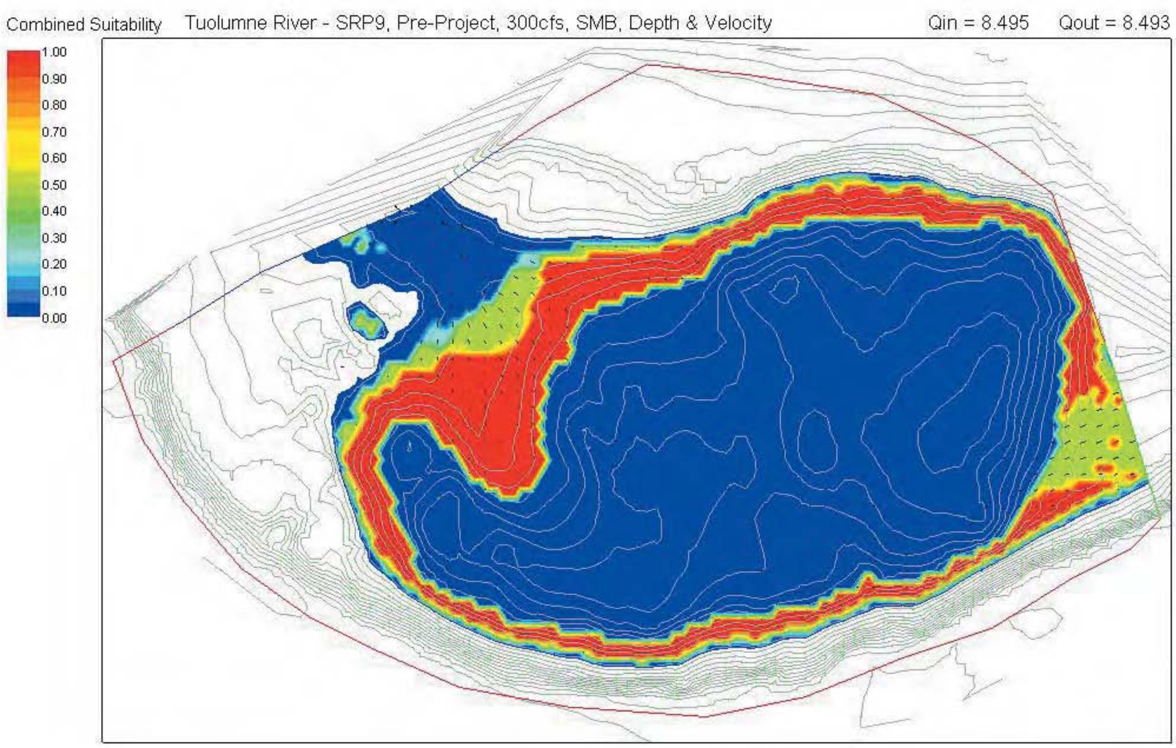


Figure 2-22. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 300 cfs.

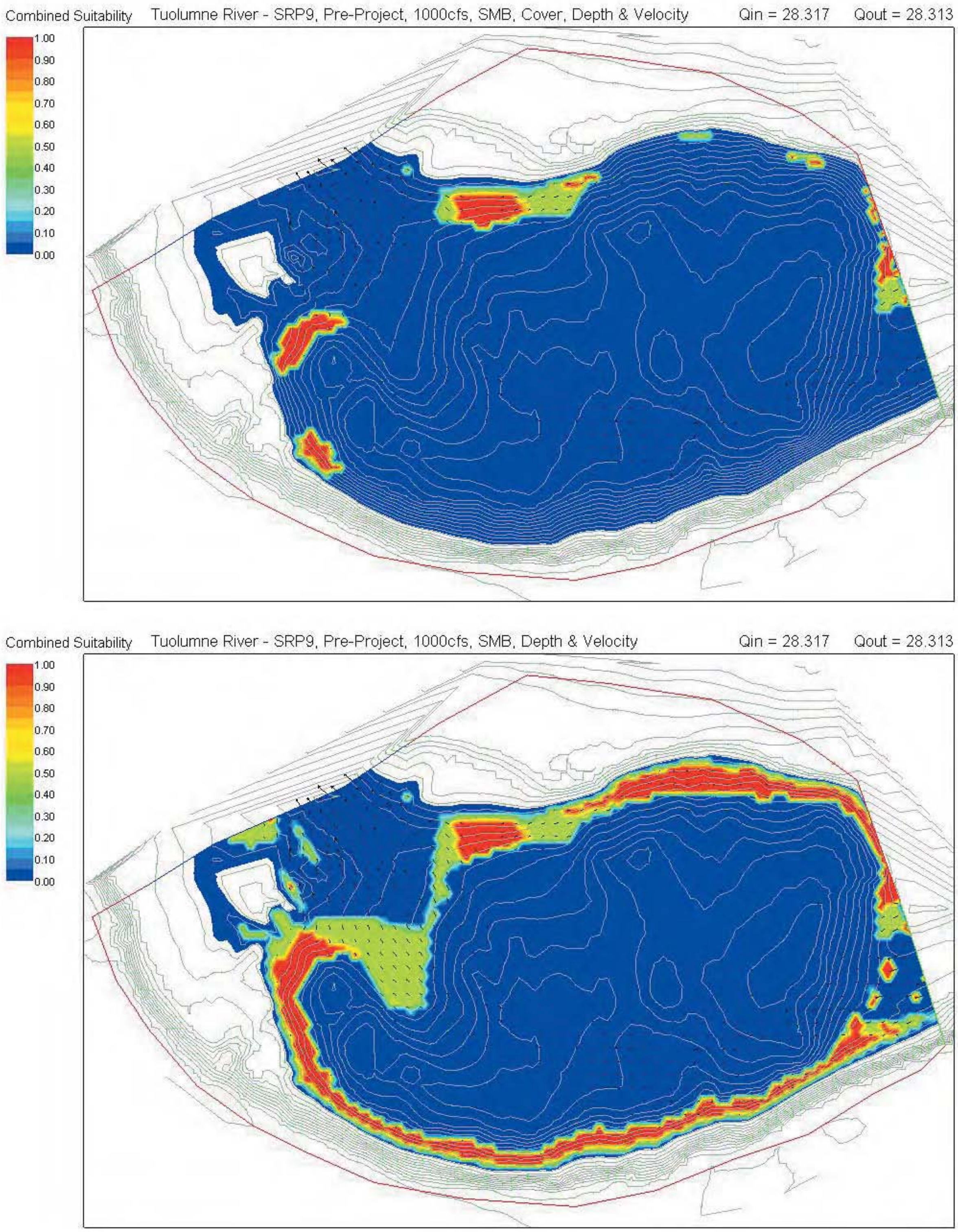


Figure 2-23. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 1,000 cfs.

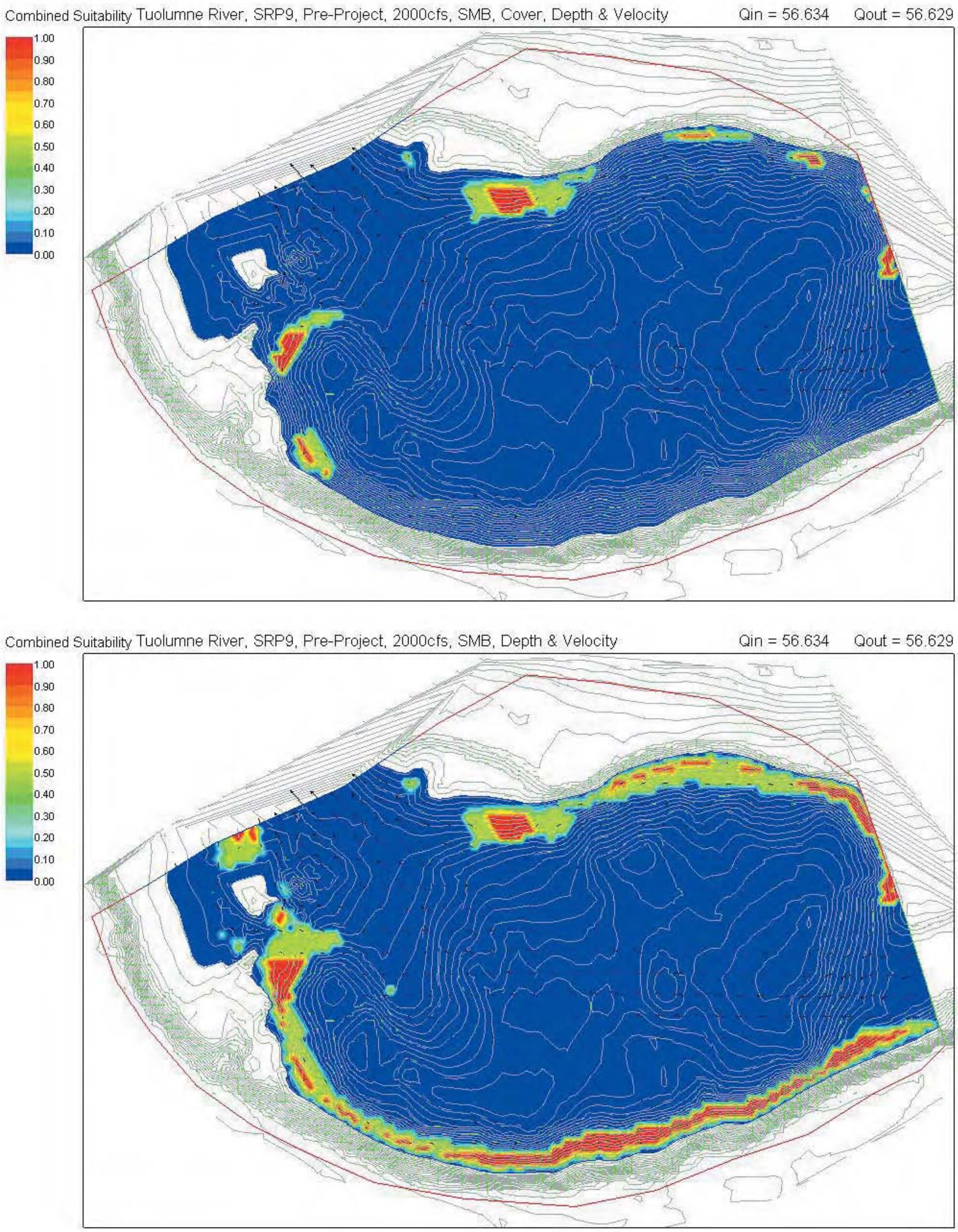


Figure 2-24. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 2,000 cfs.

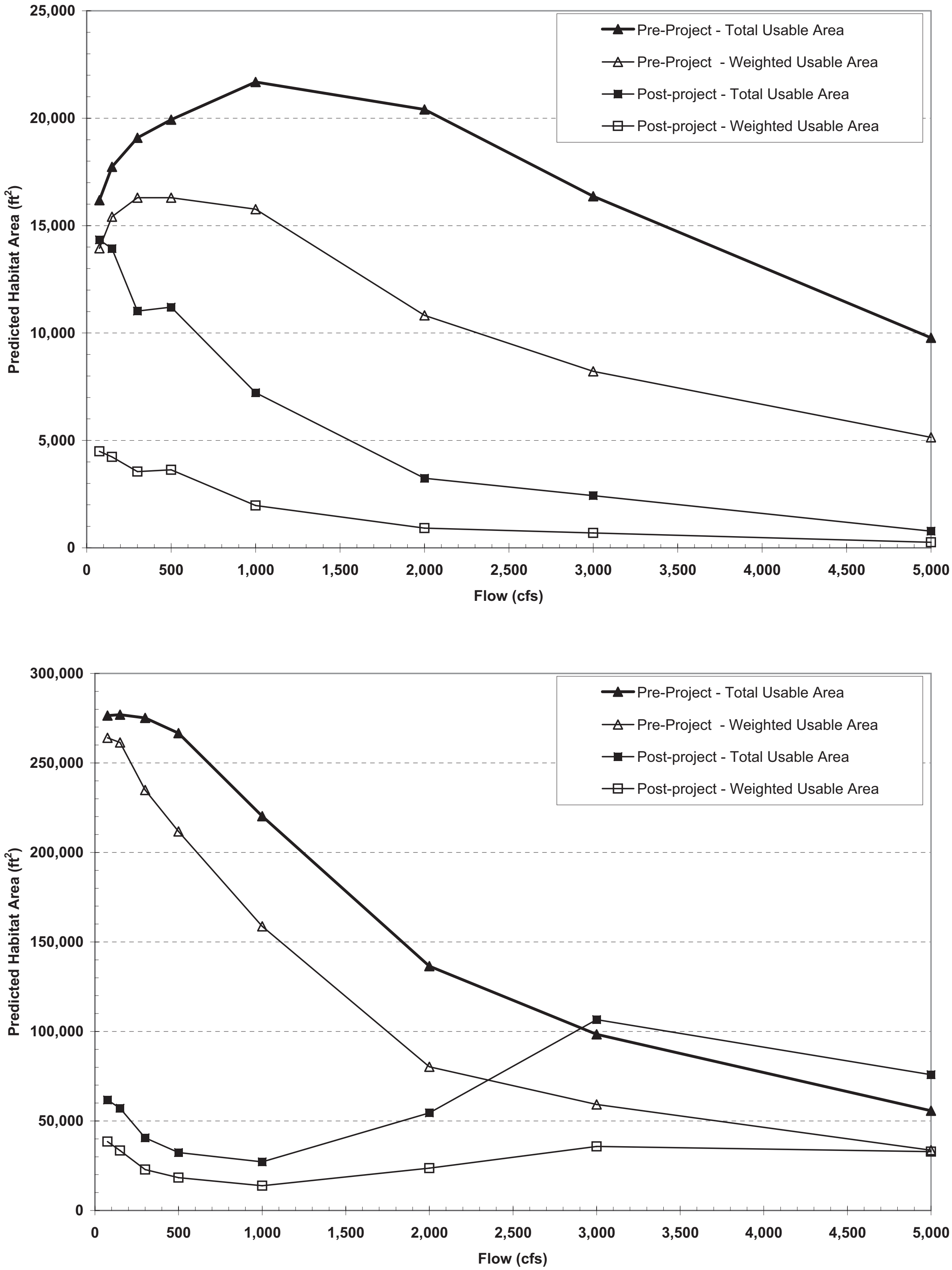
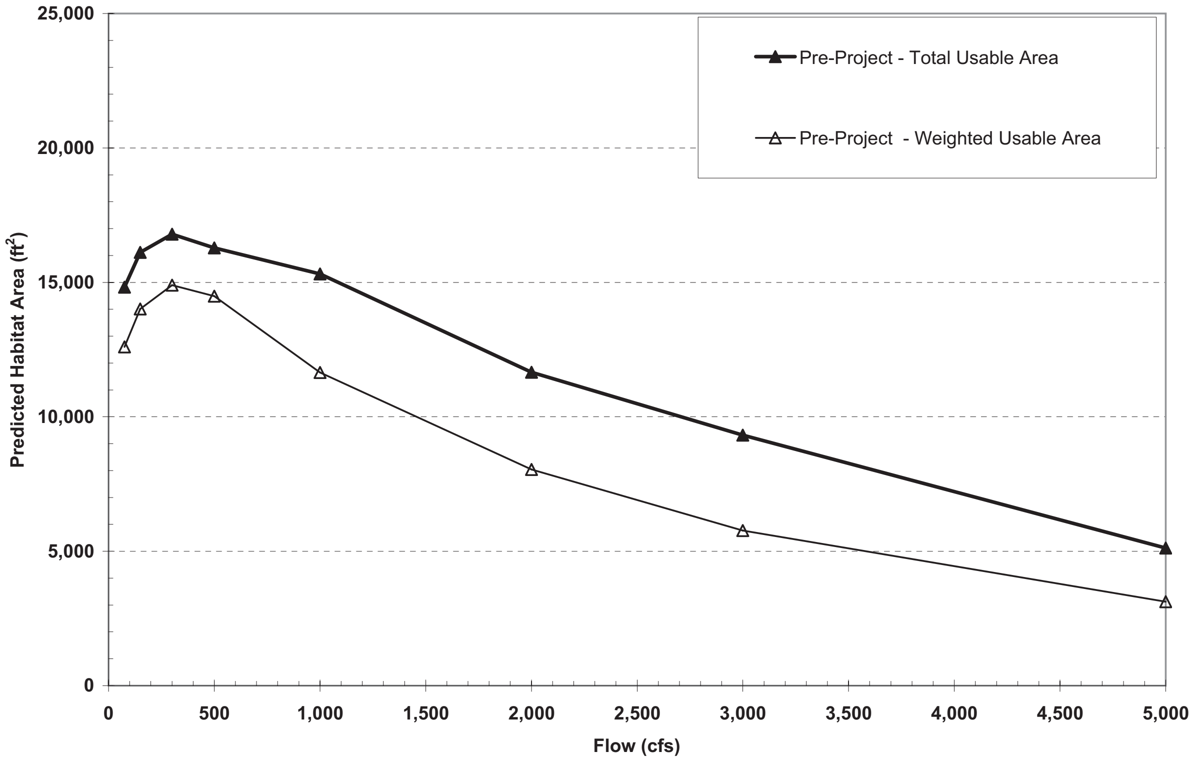


Figure 2-25. Predicted pre-project and post-project largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9.



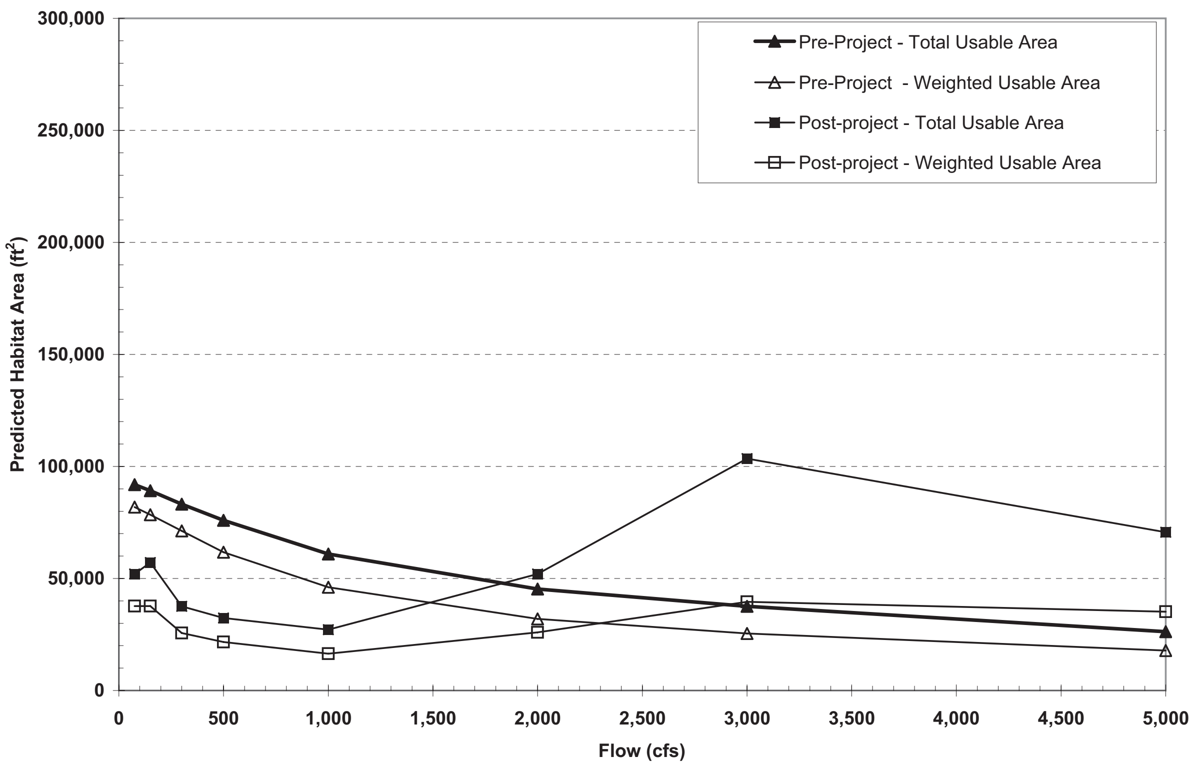


Figure 2-26. Predicted pre-project and post-project smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9.

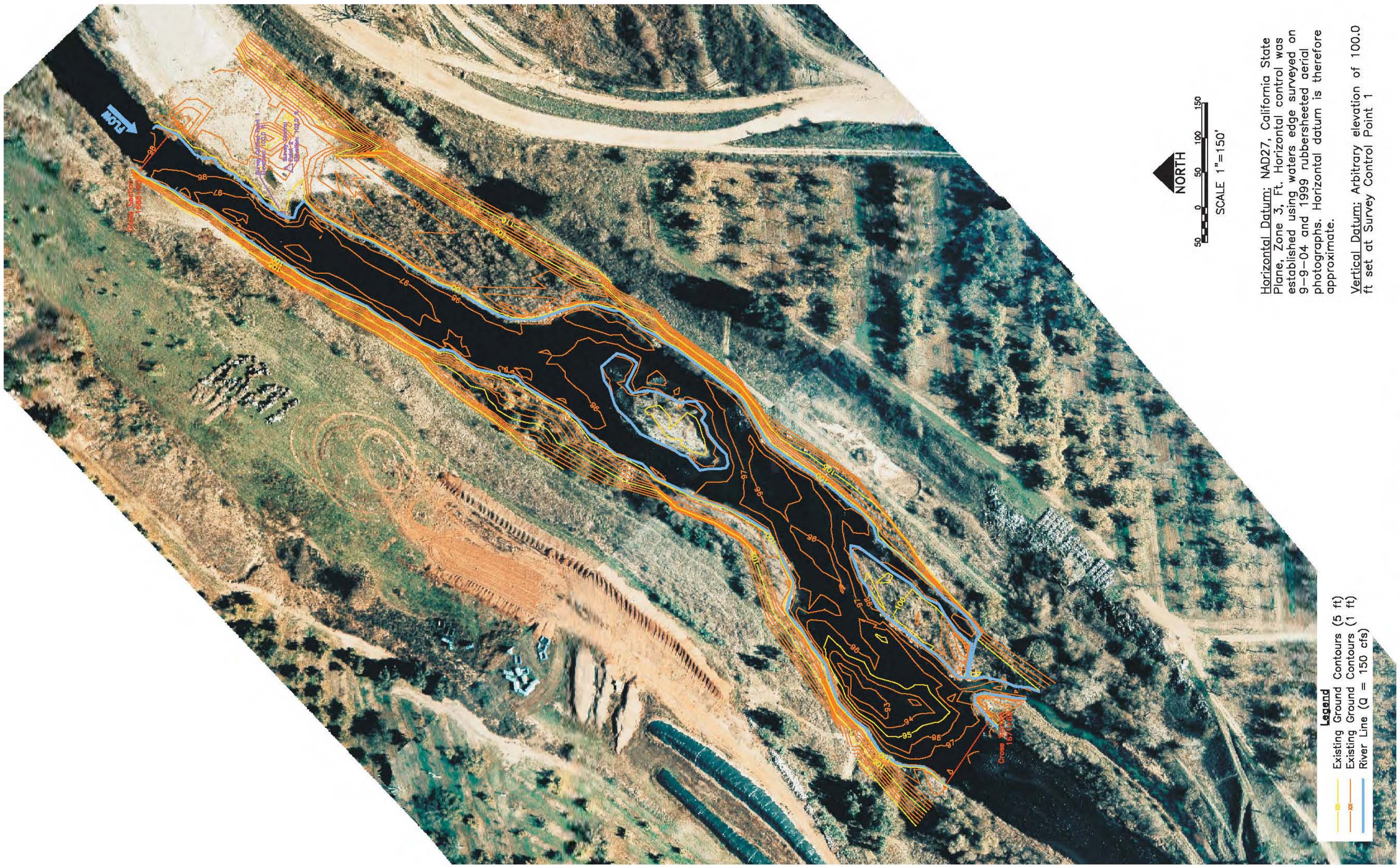


Figure 2-27. Floodplain topography and channel bathymetry at Riffle 64.

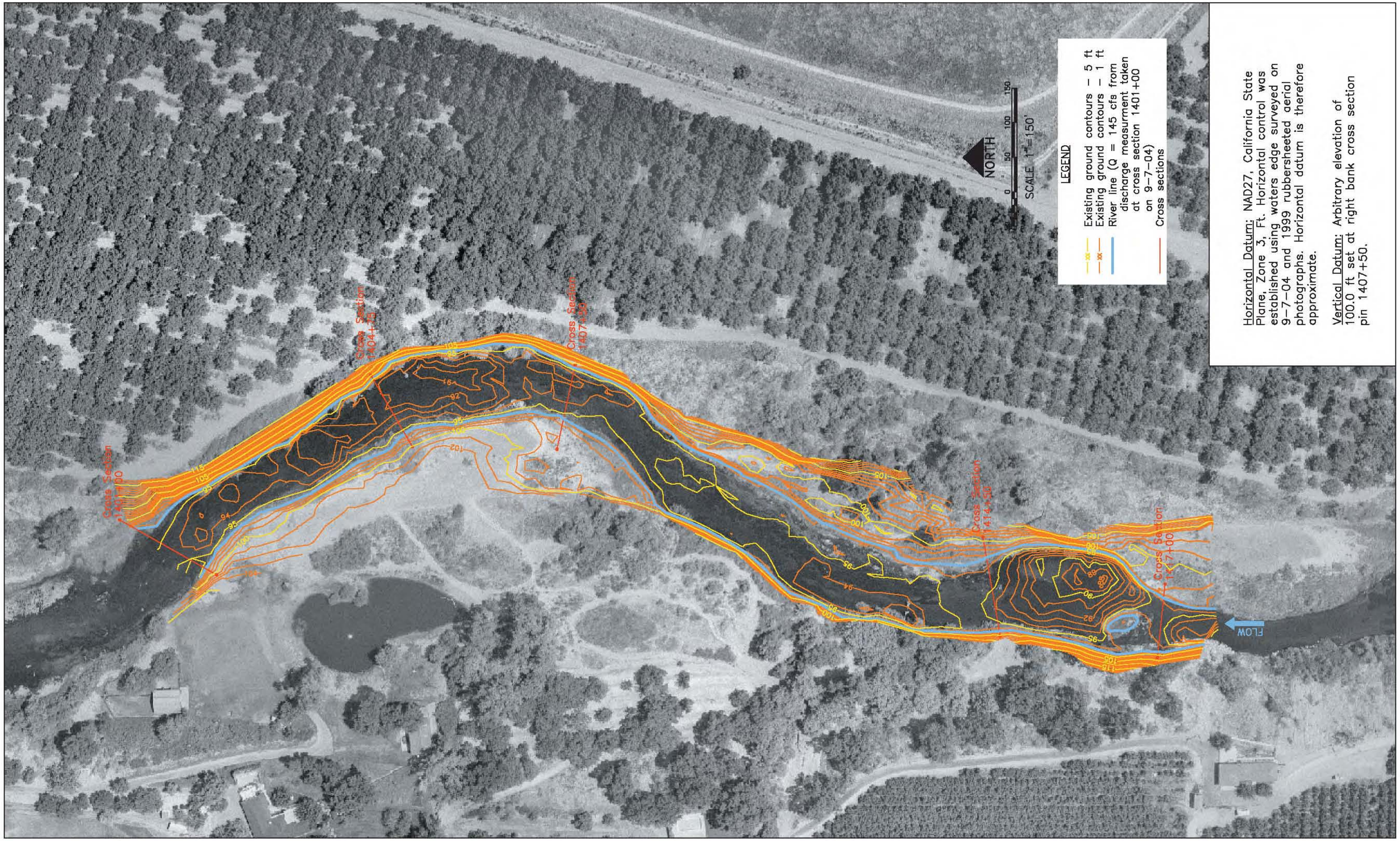
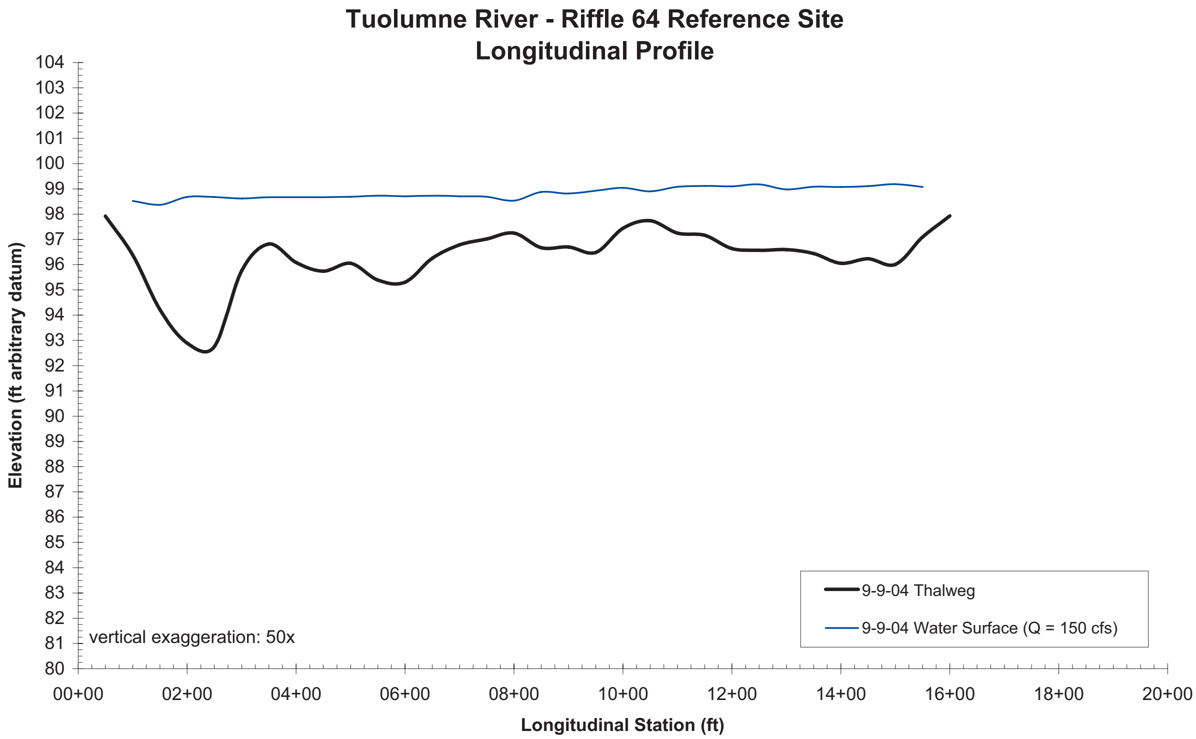


Figure 2-28. Floodplain topography and channel bathymetry at Charles Road.



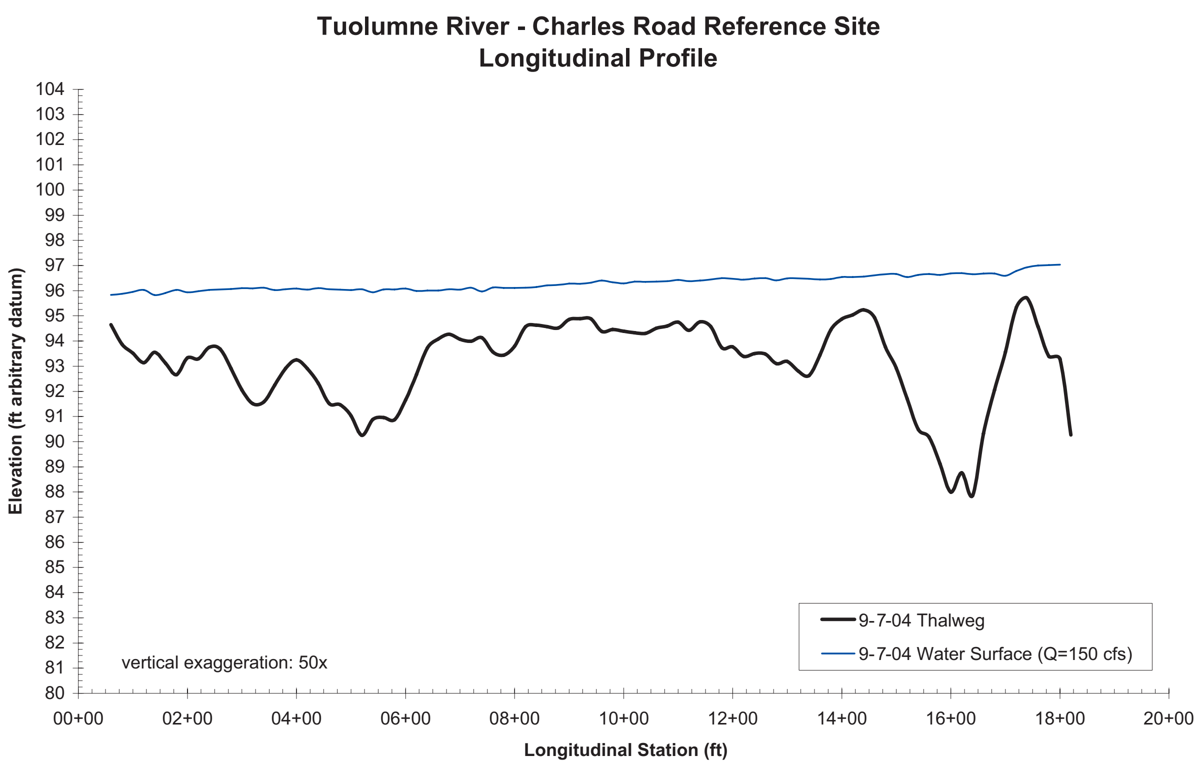


Figure 2-29. Thalweg and water surface profiles at Riffle 64 and Charles Road.

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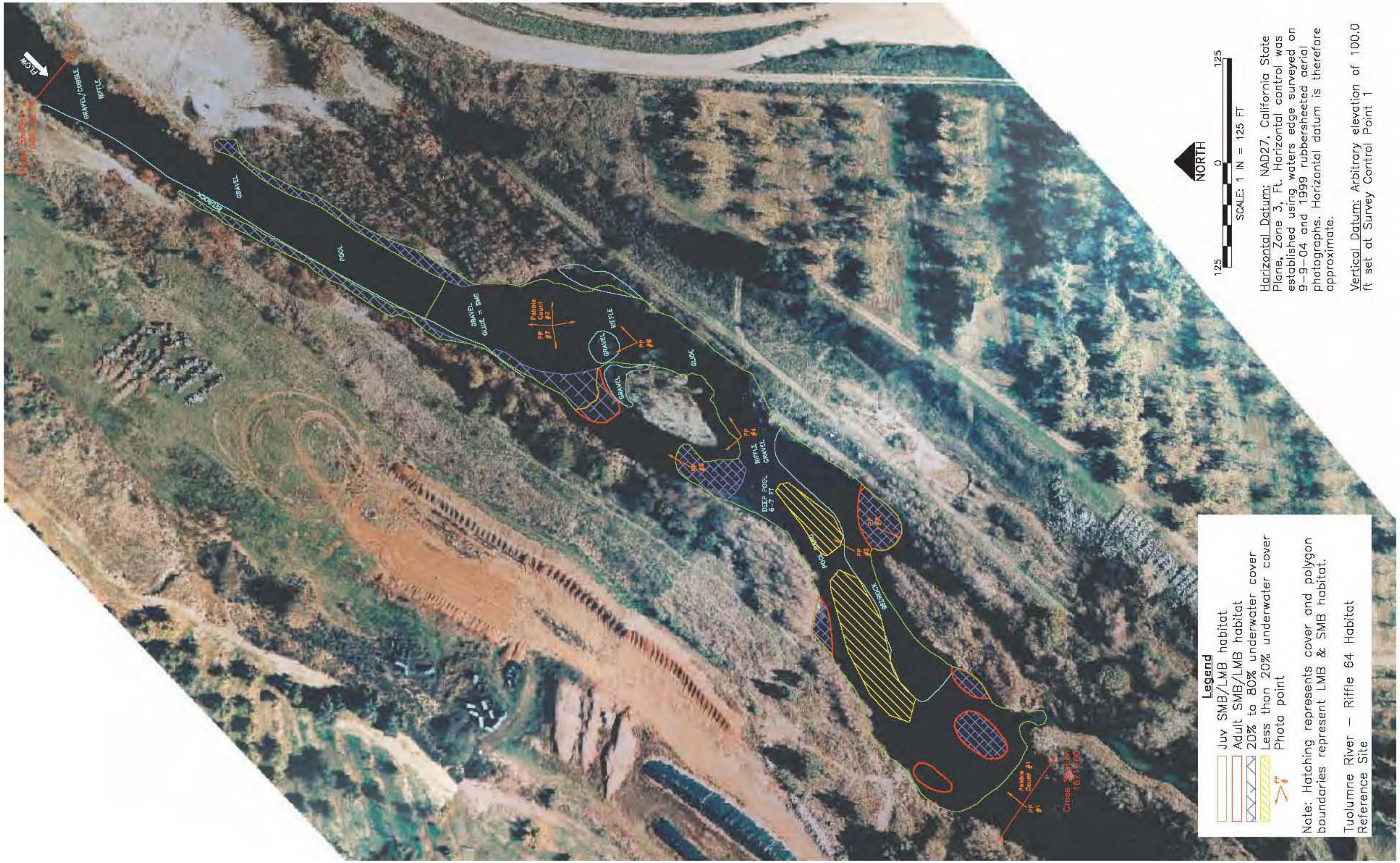

Figure 2-30. Largemouth and smallmouth bass habitat mapped at Riffle 64 during flows of 150 cfs (September 2004).

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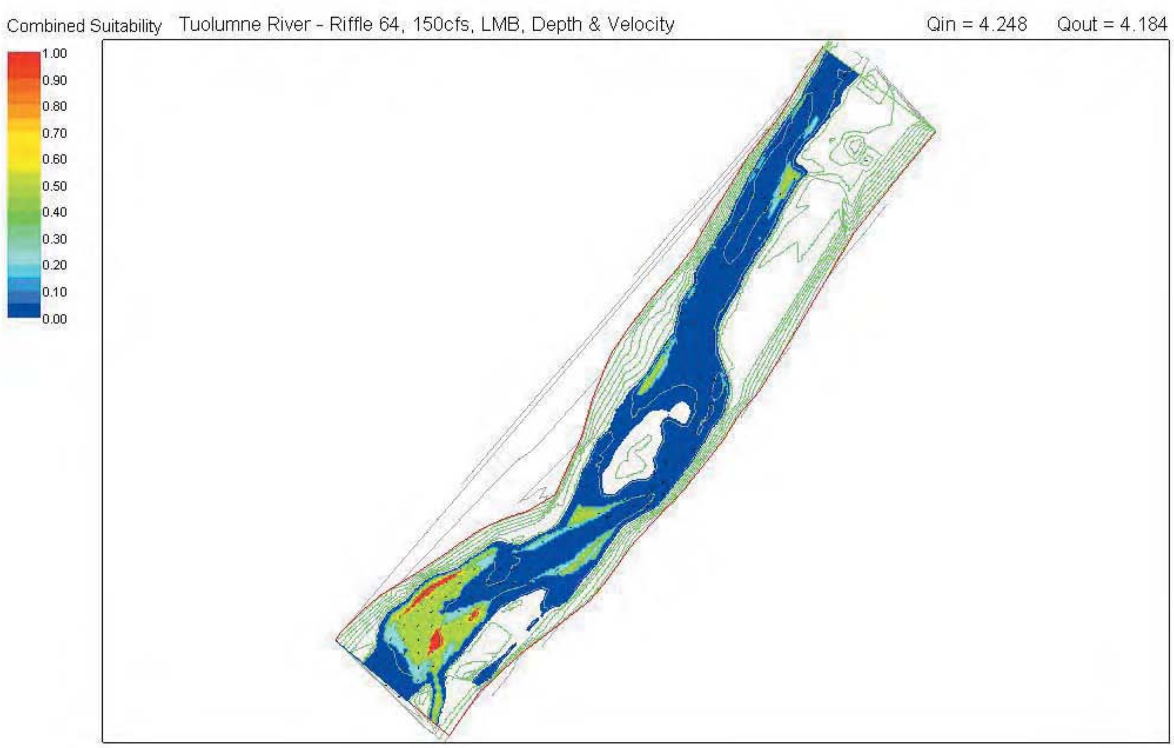
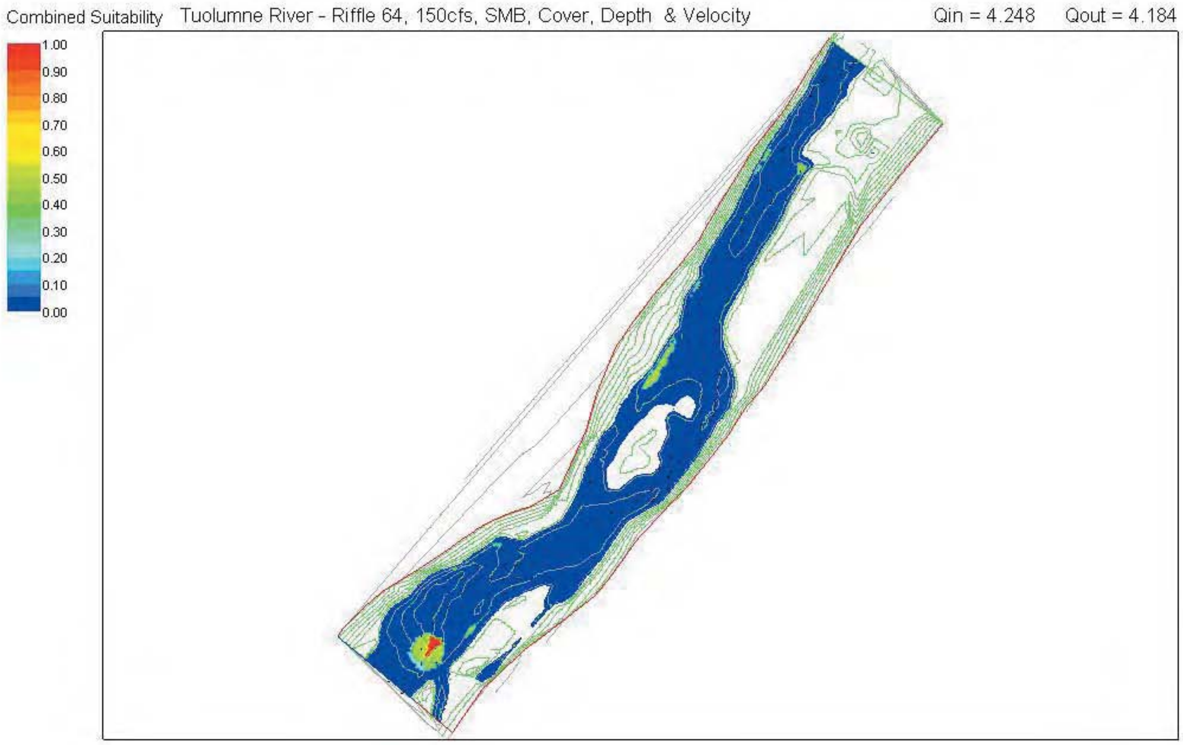


Figure 2-31. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at Riffle 64 for flows of 150 cfs.



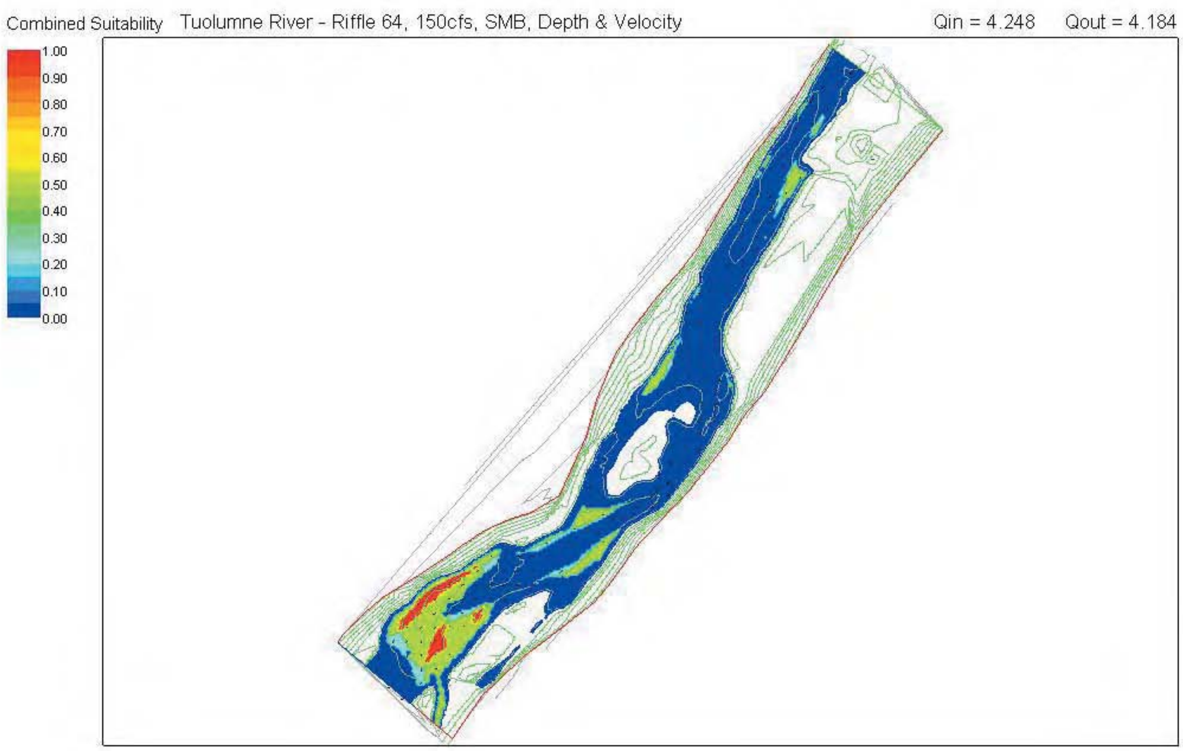


Figure 2-32. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at Riffle 64 for flows of 150 cfs.

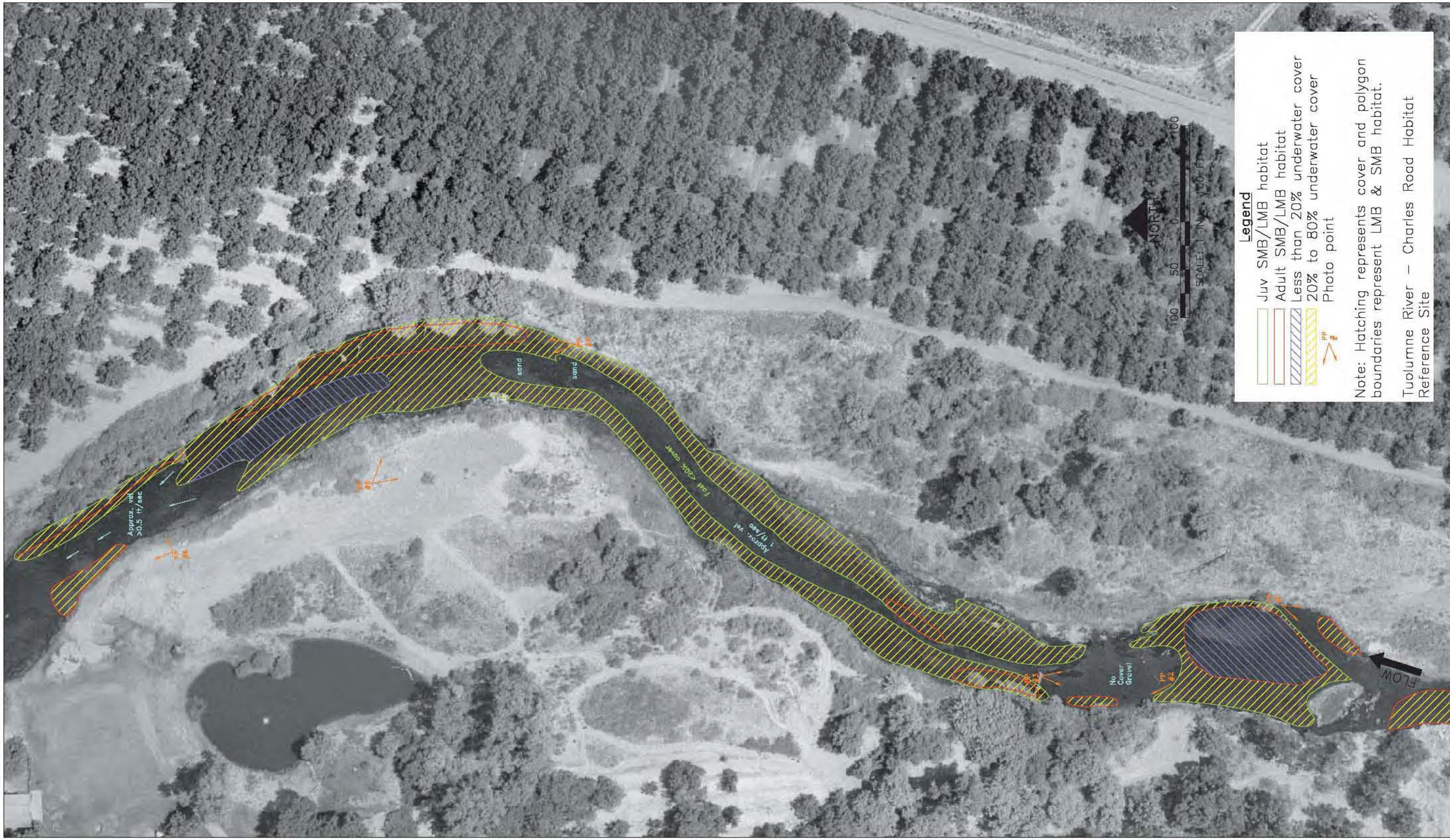


Figure 2-33. Largemouth and smallmouth bass habitat mapped at Charles Road during flows of 150 cfs (September 2004).

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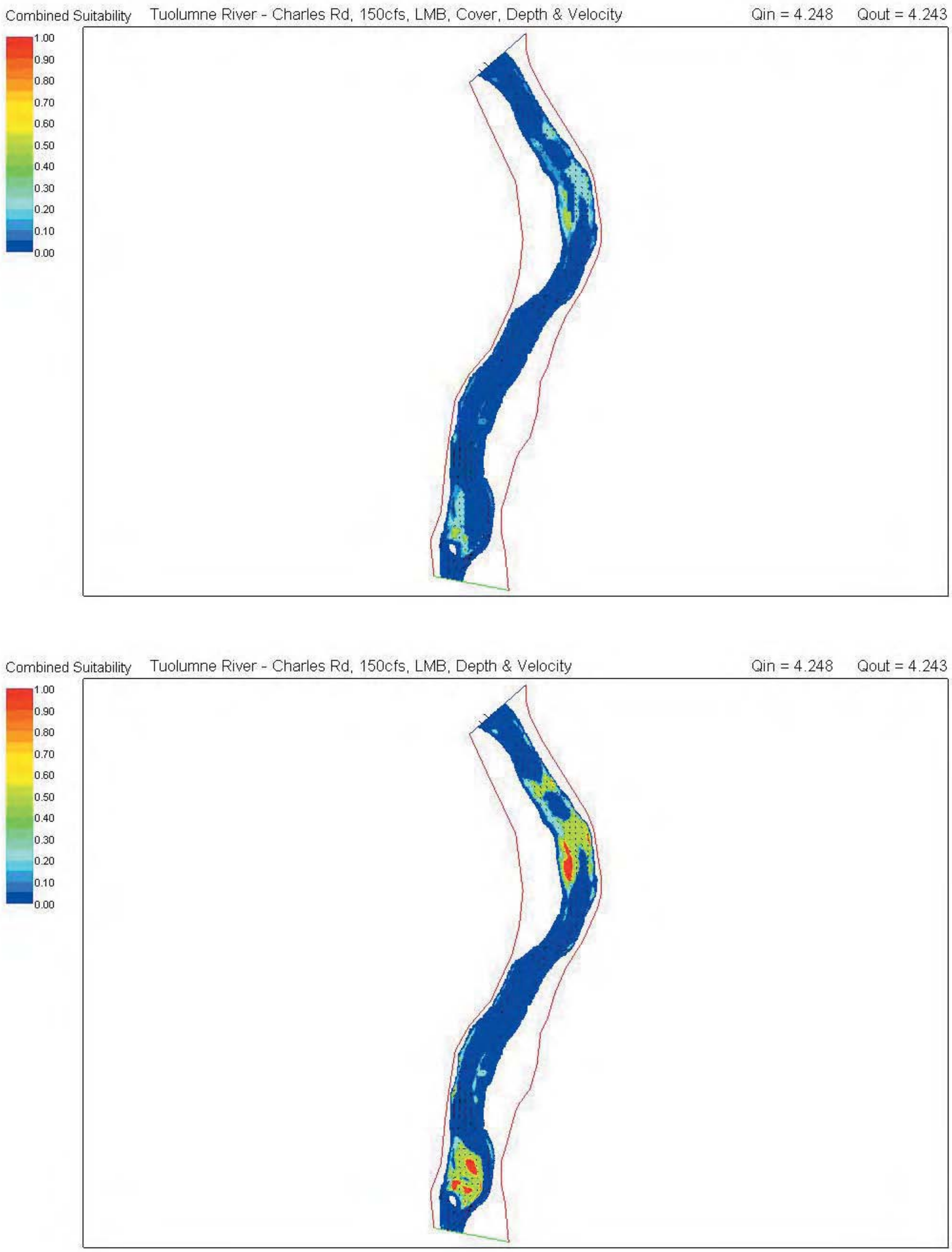
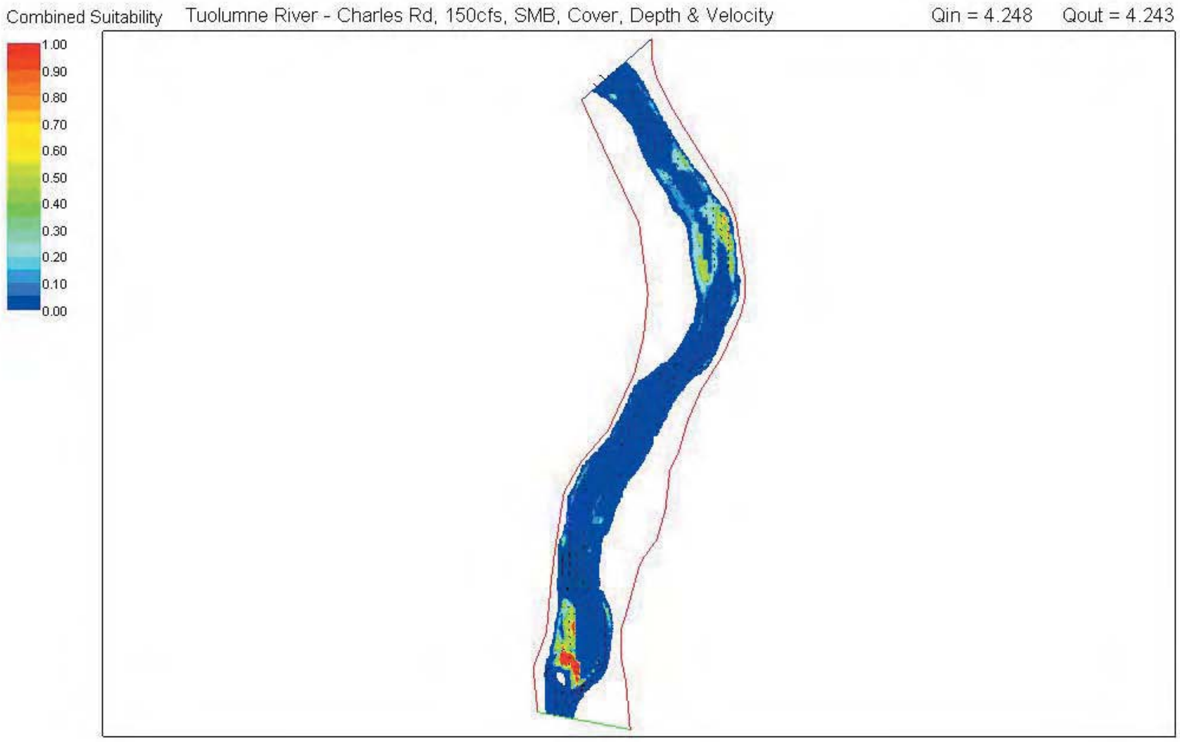


Figure 2-34. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at Charles Road for flows of 150 cfs.



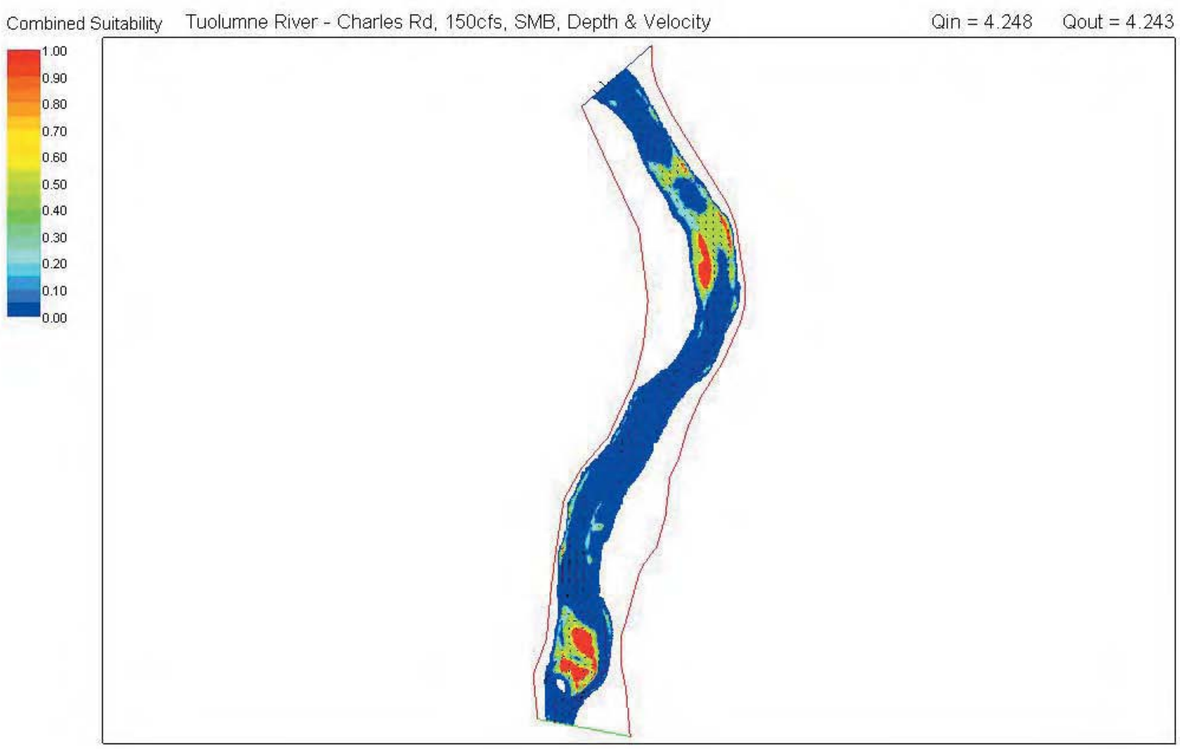
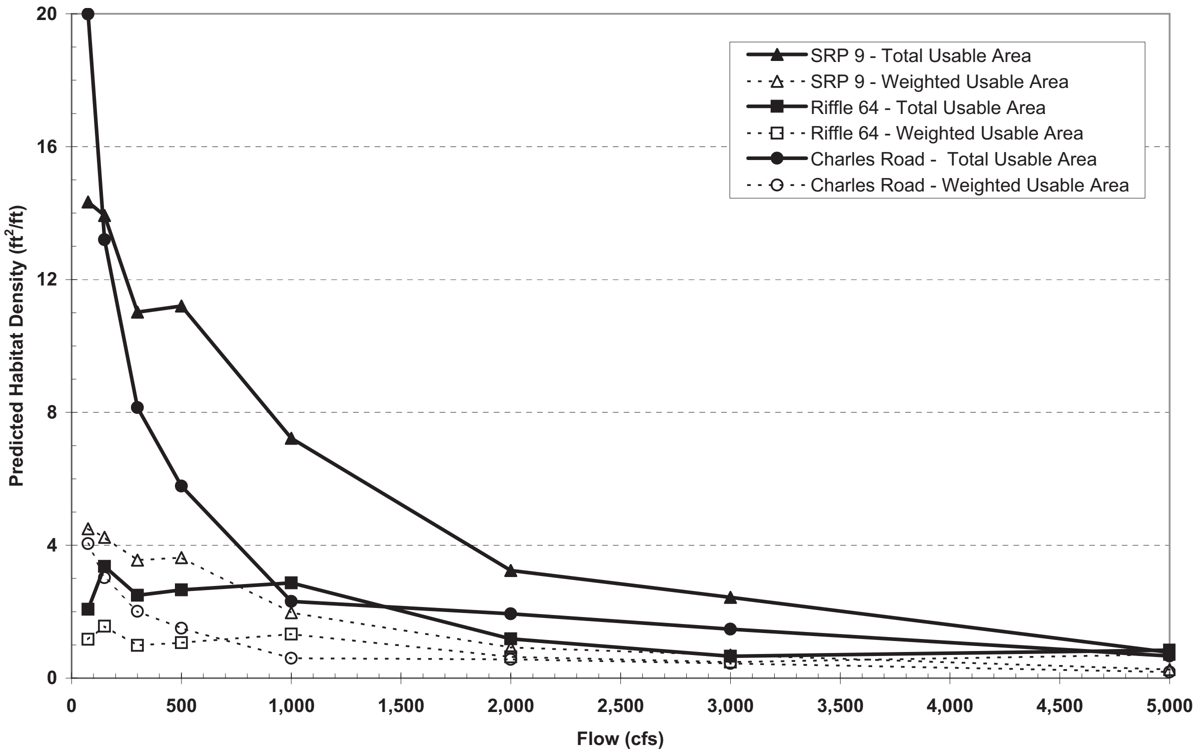


Figure 2-35. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at Charles Road for flows of 150 cfs.



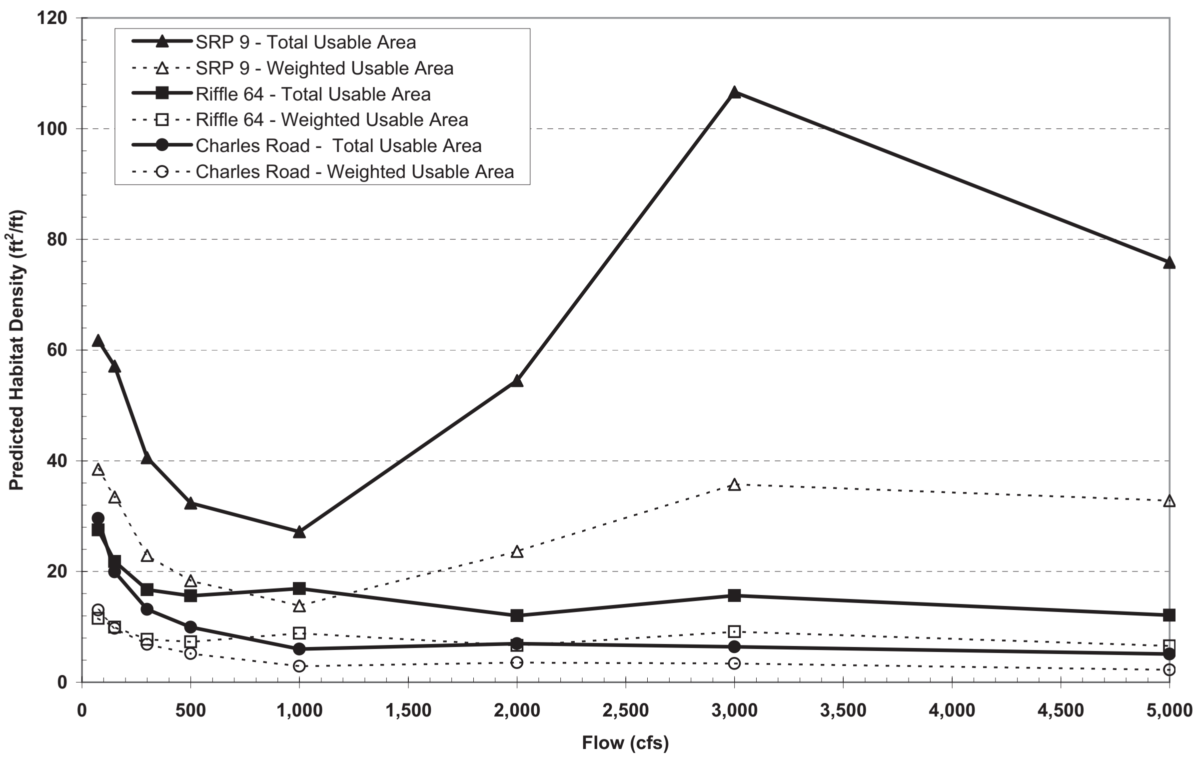
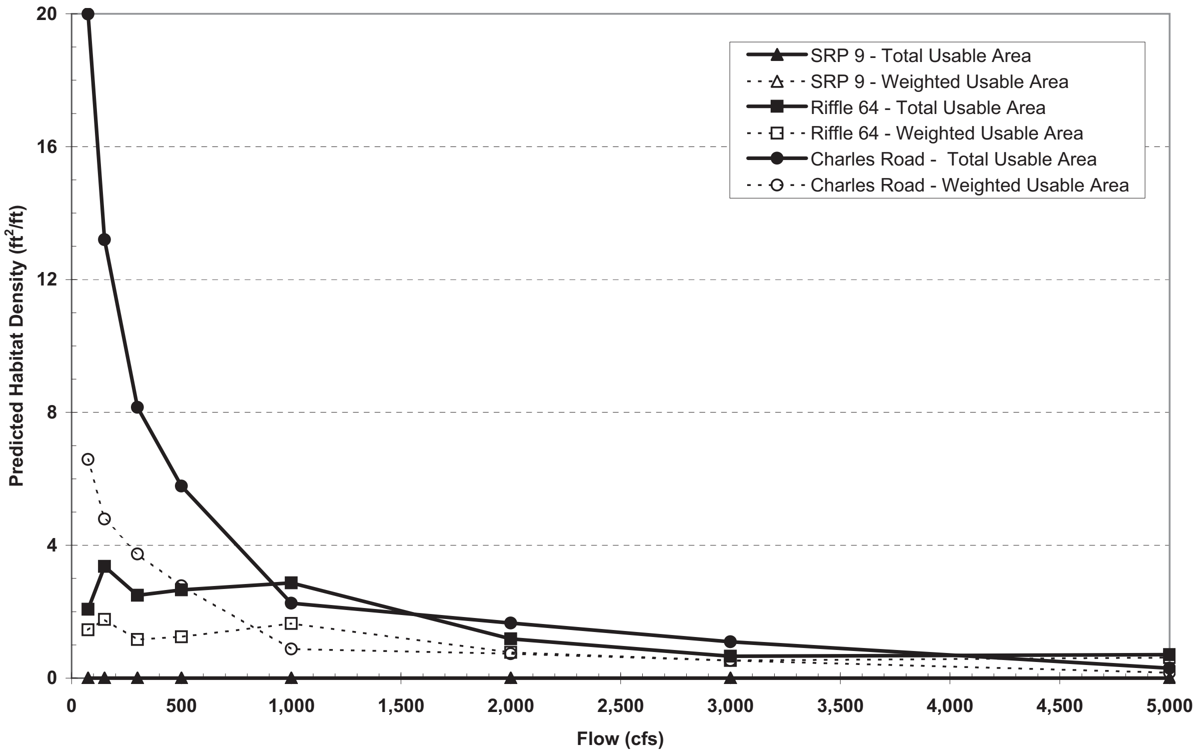


Figure 2-36. Comparison of predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at the SRP 9 project site and Charles Rd. and Riffle 64 reference sites.



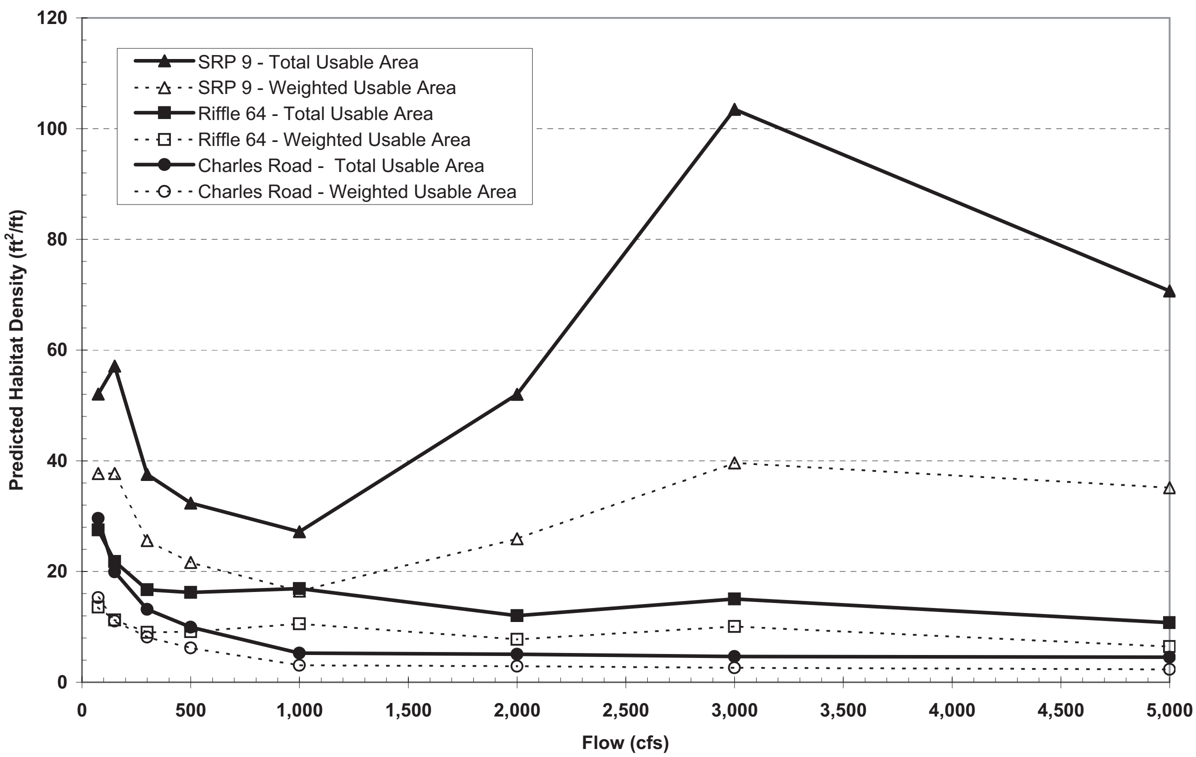


Figure 2-37. Comparison of predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at the SRP 9 project site and Charles Rd. and Riffle 64 reference sites.

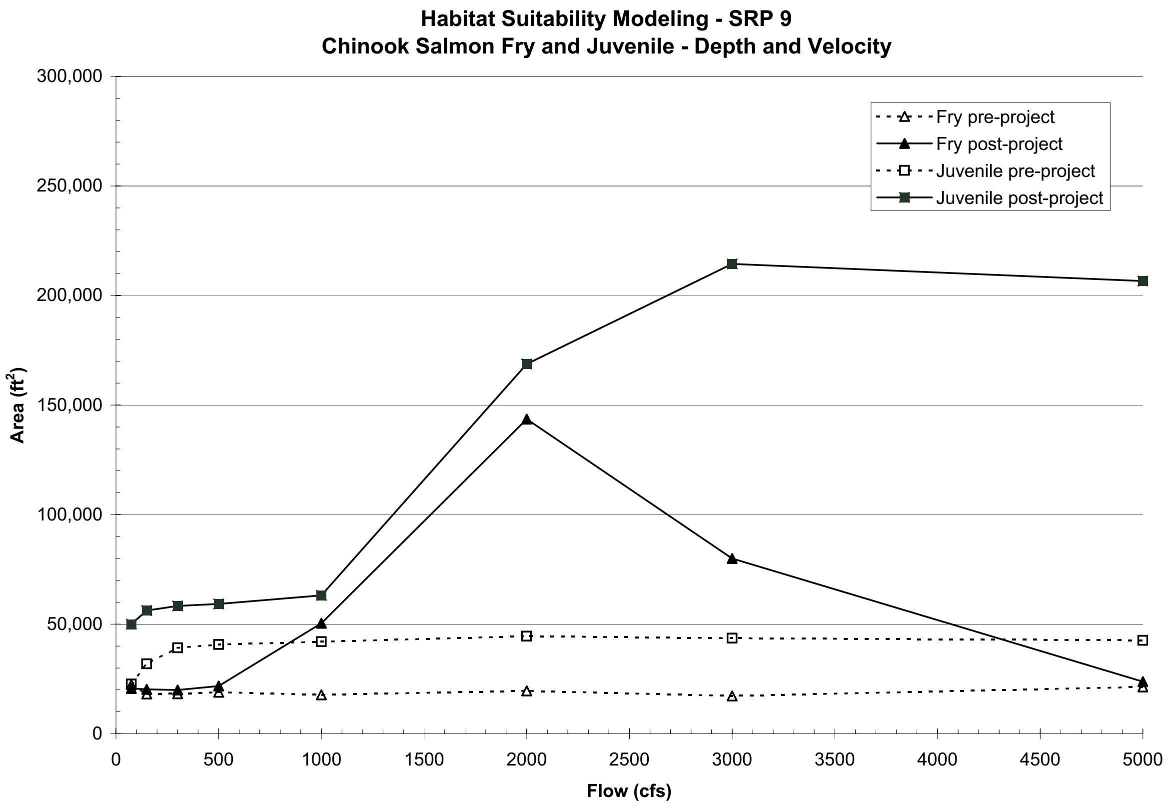


Figure 2-38. Predicted pre-project and post-project Chinook salmon fry and juvenile habitat at SRP 9.

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