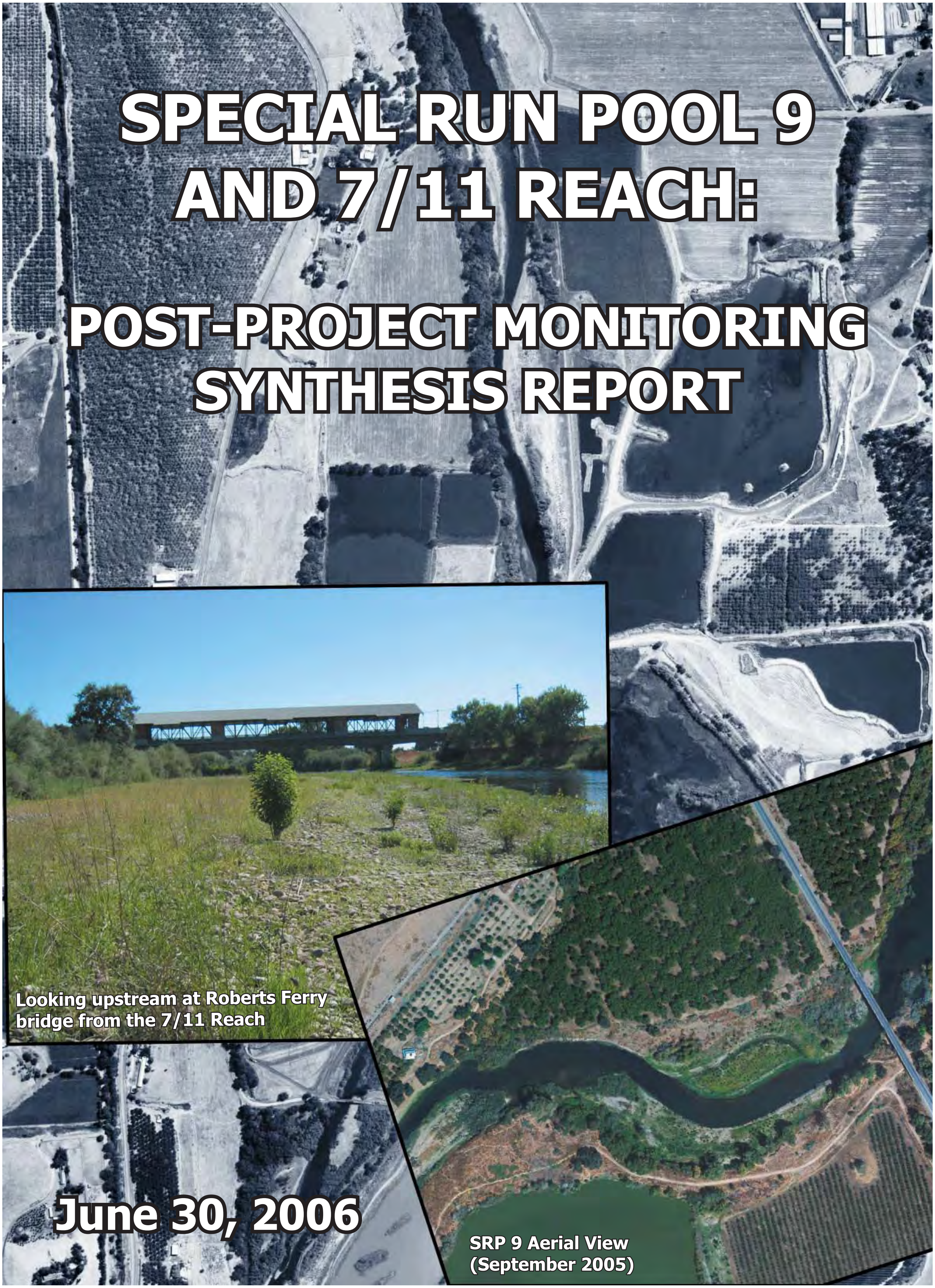
SPECIAL RUN POOL 9 AND 7/11 REACH:

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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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

Design Review Process

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.

Improvements to SRP 9 Implementation

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.

Improvements to 7/11 Reach Implementation

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.

River-wide and Population-level Monitoring

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

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[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).

Monitoring hypotheses for SRP 9:

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.

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.

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.

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[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			Comment
		Pre-project	As-built	Post-project	
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.

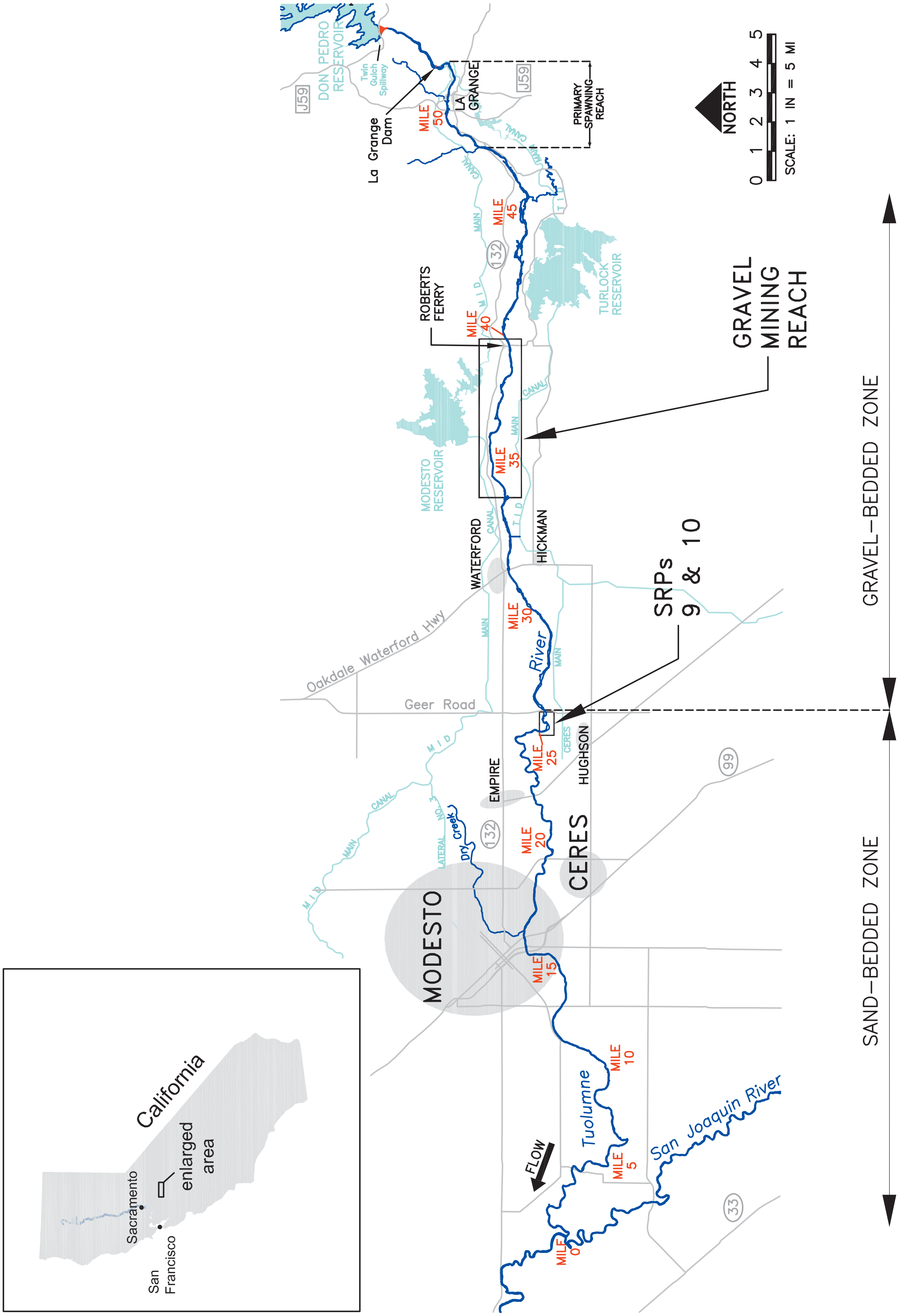

Figure 1-1. Lower Tuolumne River vicinity map.

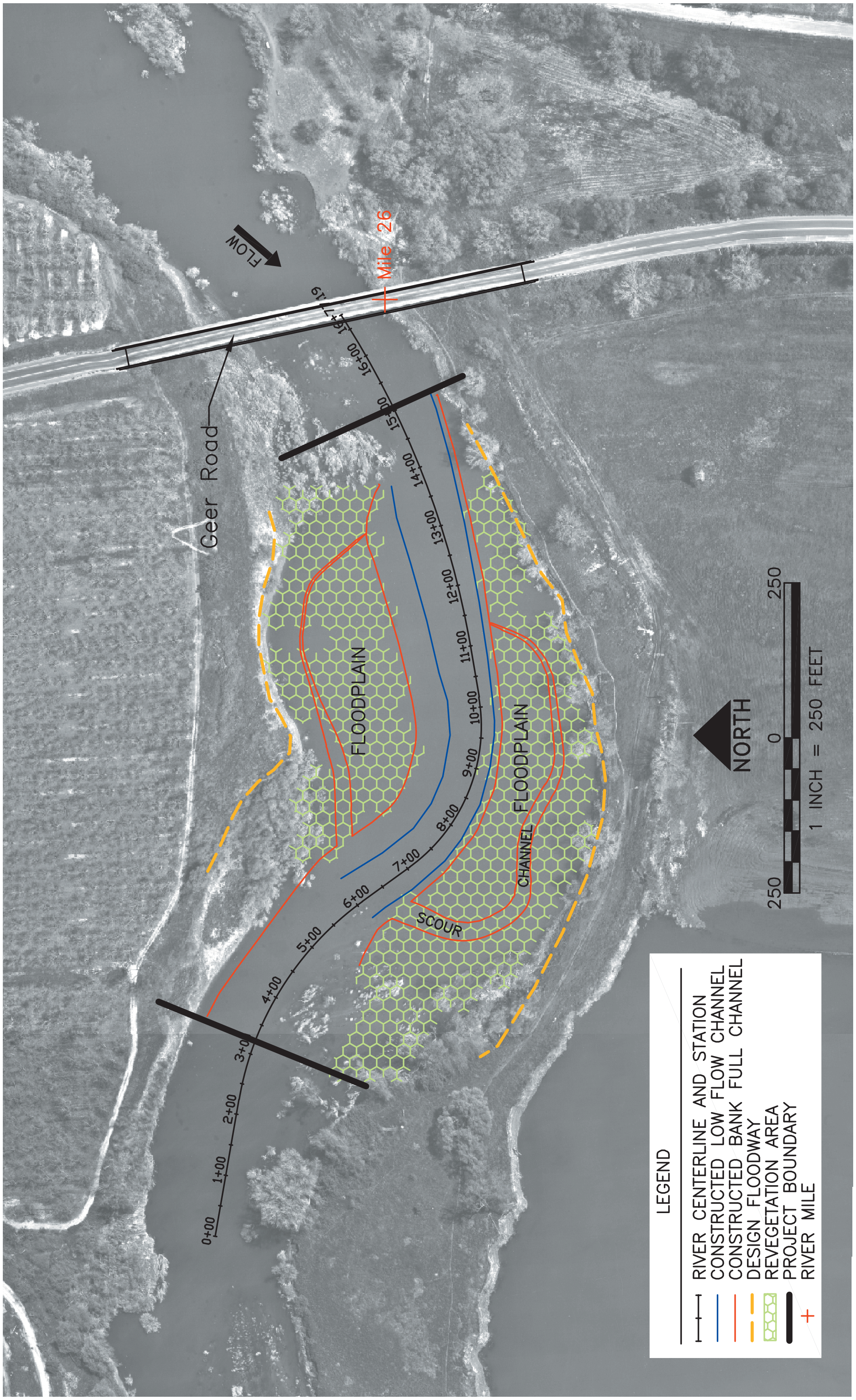

Figure 1-2. SRP 9 project final design.

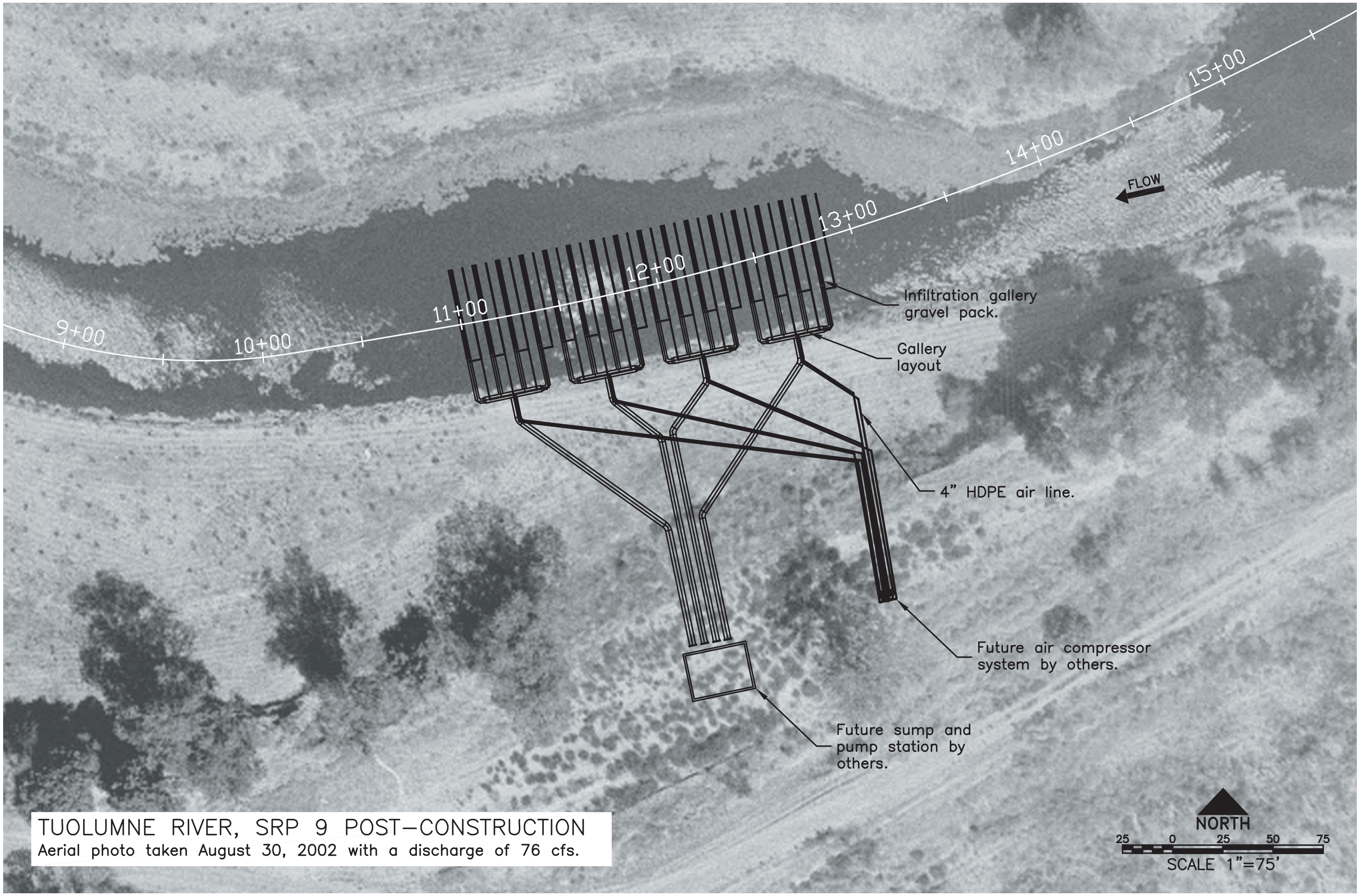

Figure 1-3. Schematic of infiltration gallery installed at SRP 9.

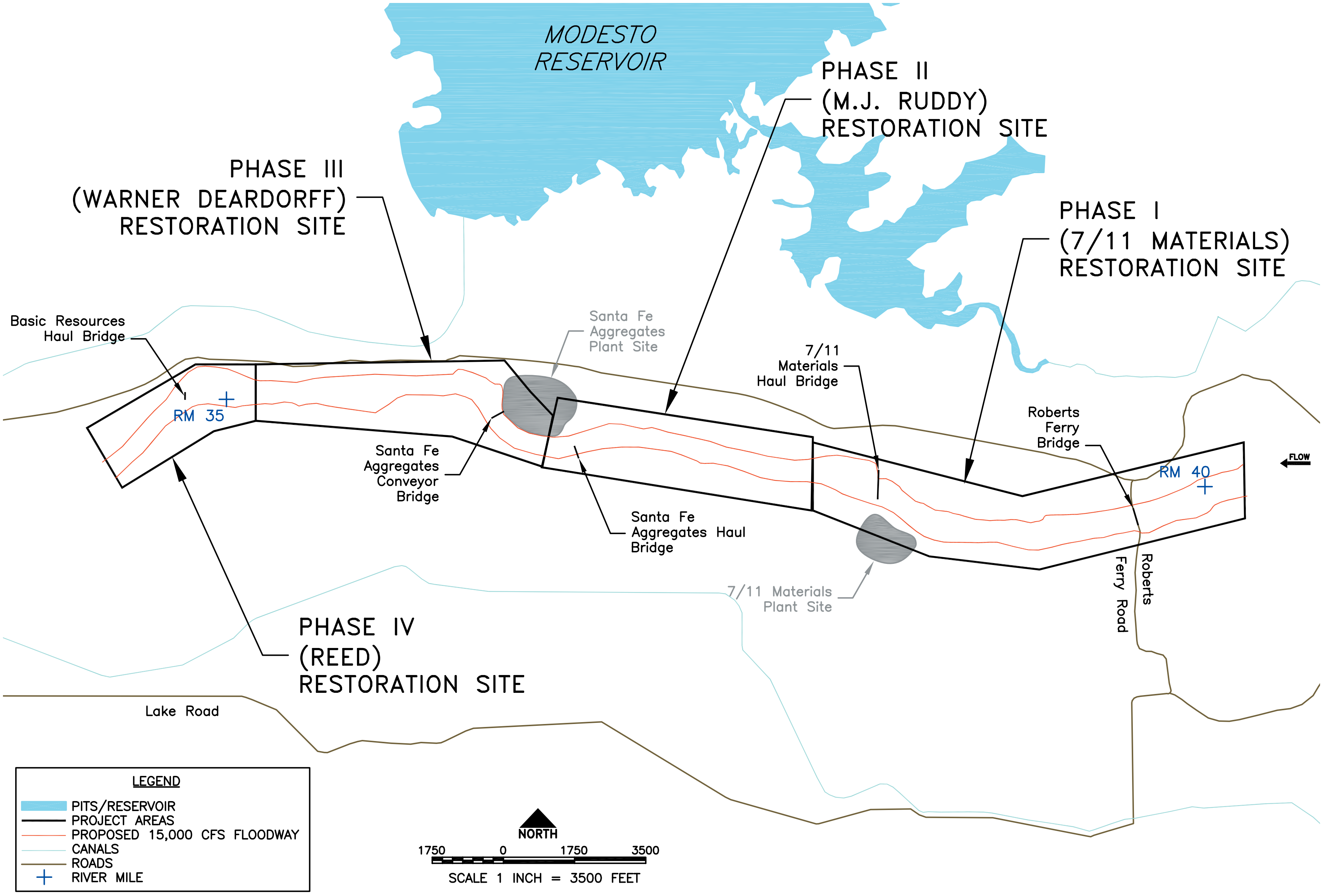

Figure 1-4. Gravel Mining Reach project boundaries: 7/11 Reach, M.J. Ruddy Reach, Warner-Deardorff Reach, and Reed Reach.

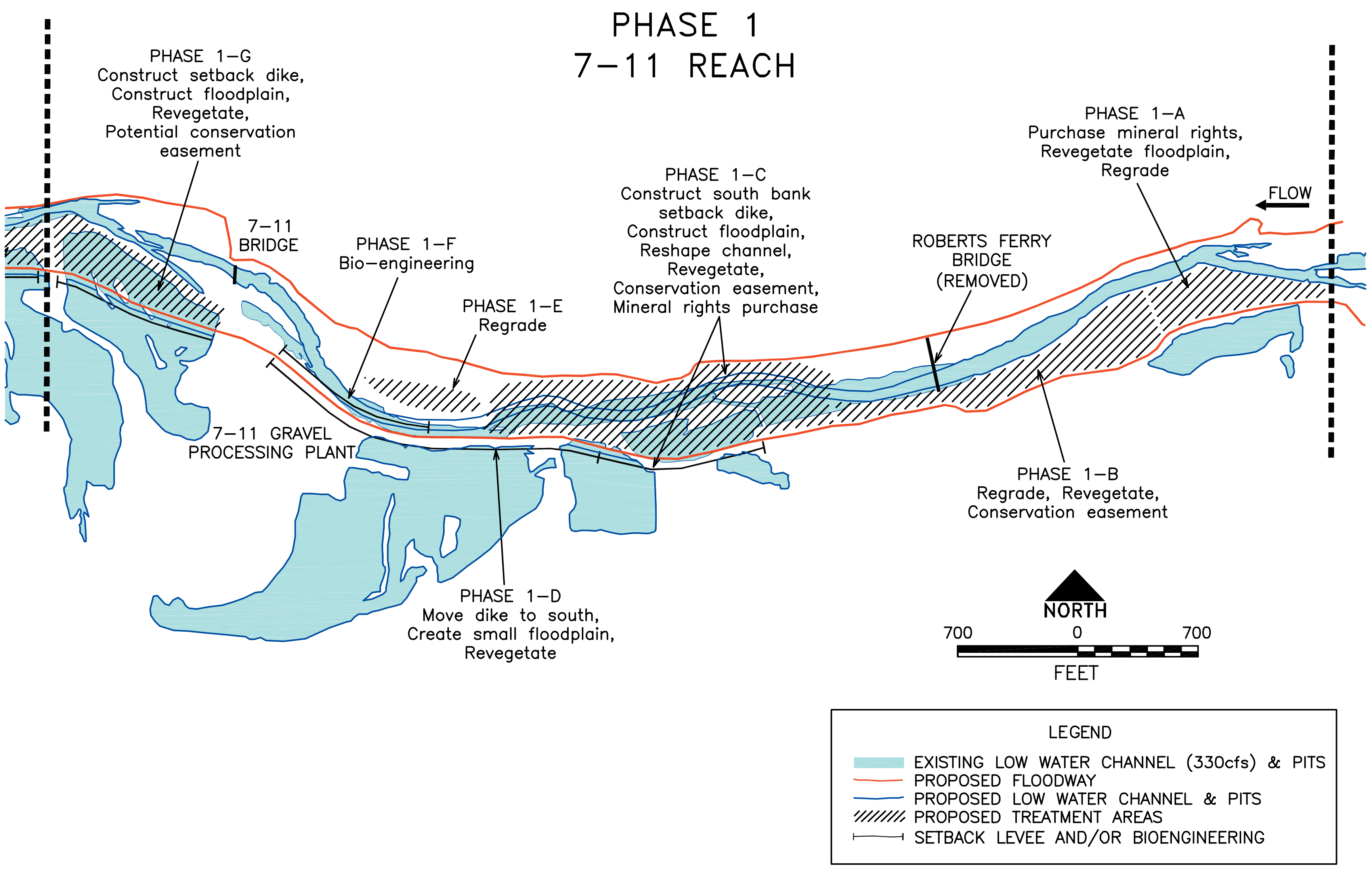

Figure 1-5. 7/11 Reach conceptual design.

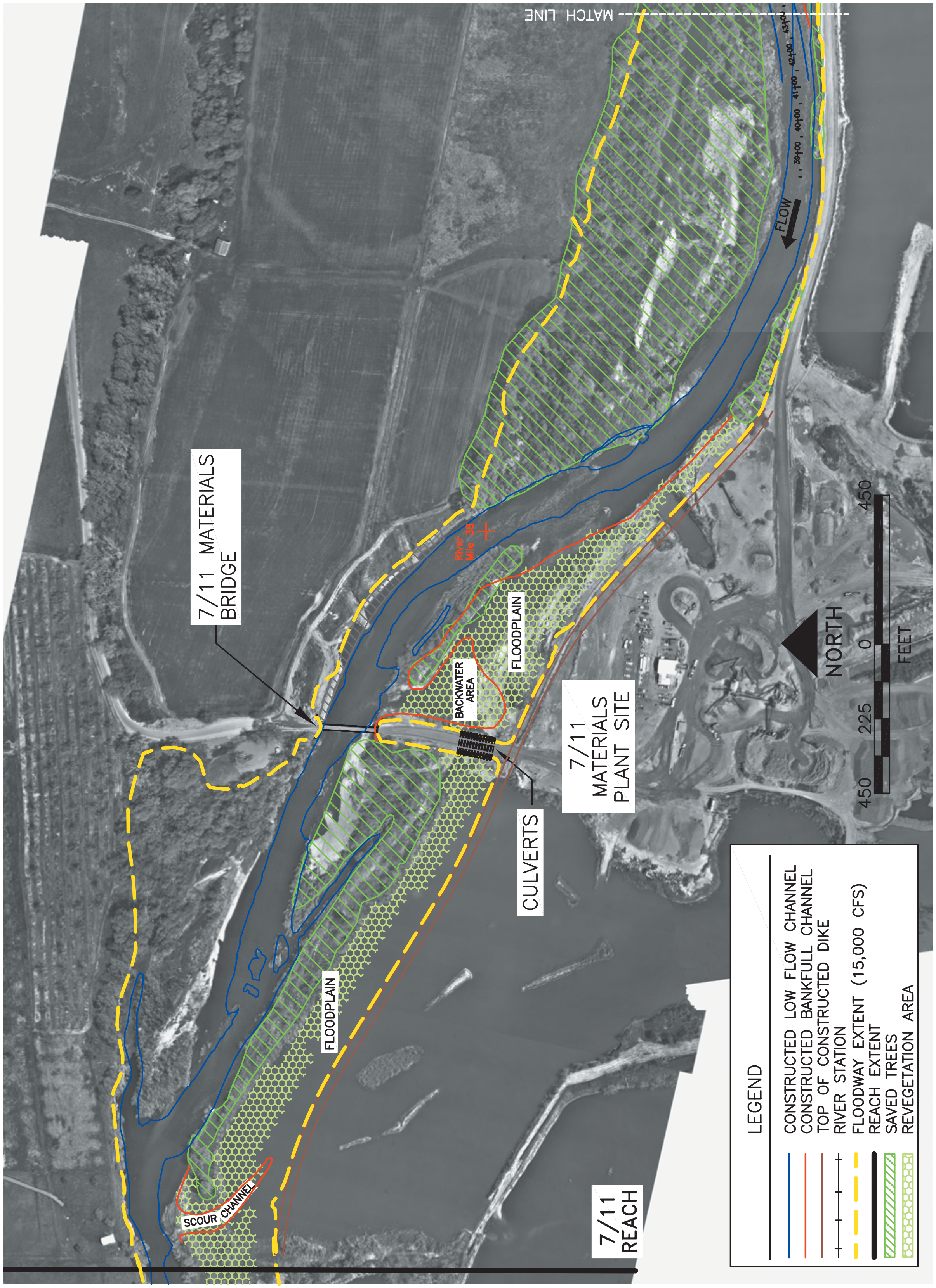

Figure 1-6. 7/11 Reach project final design.

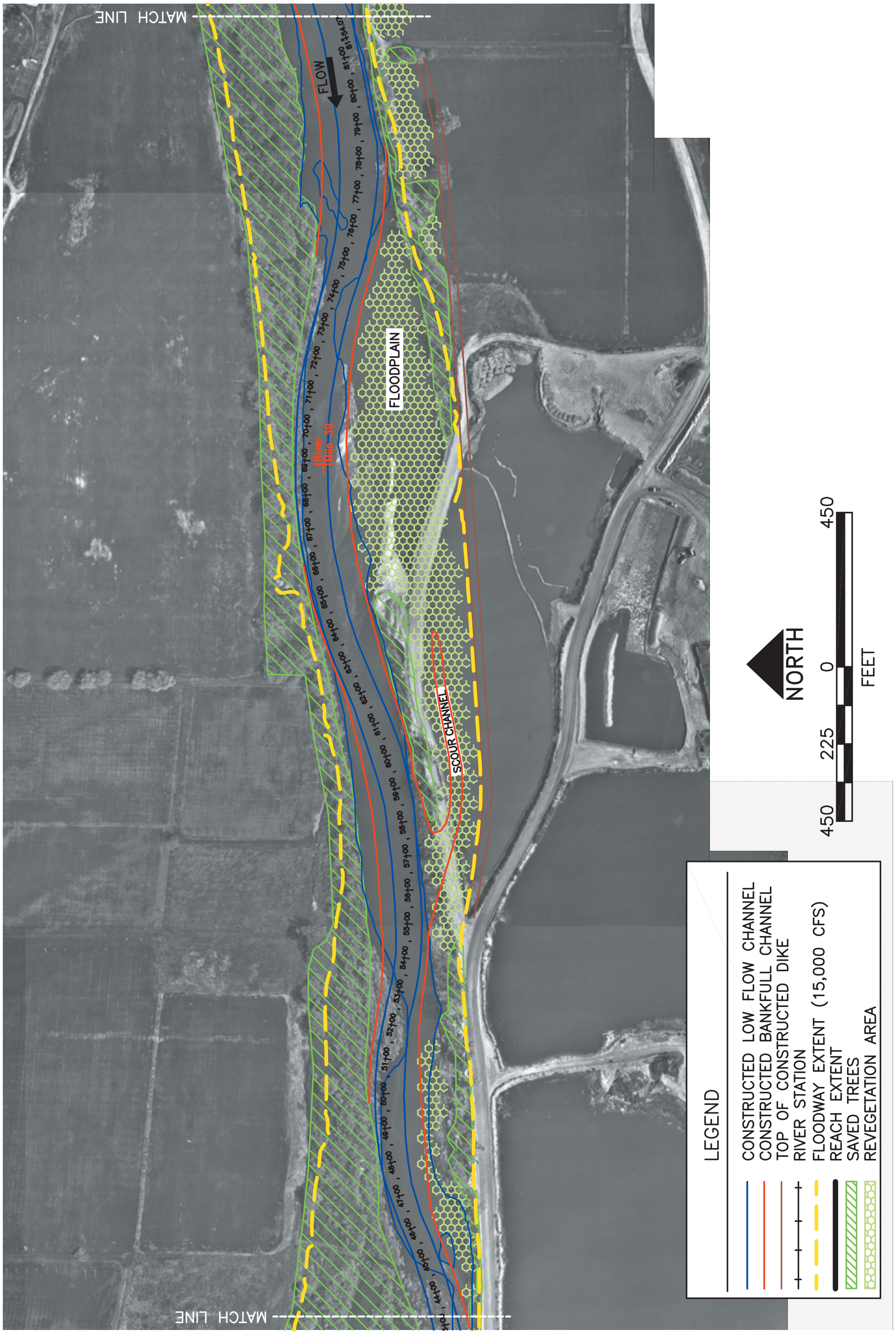

Figure 1-6. 7/11 Reach project final design, continued.

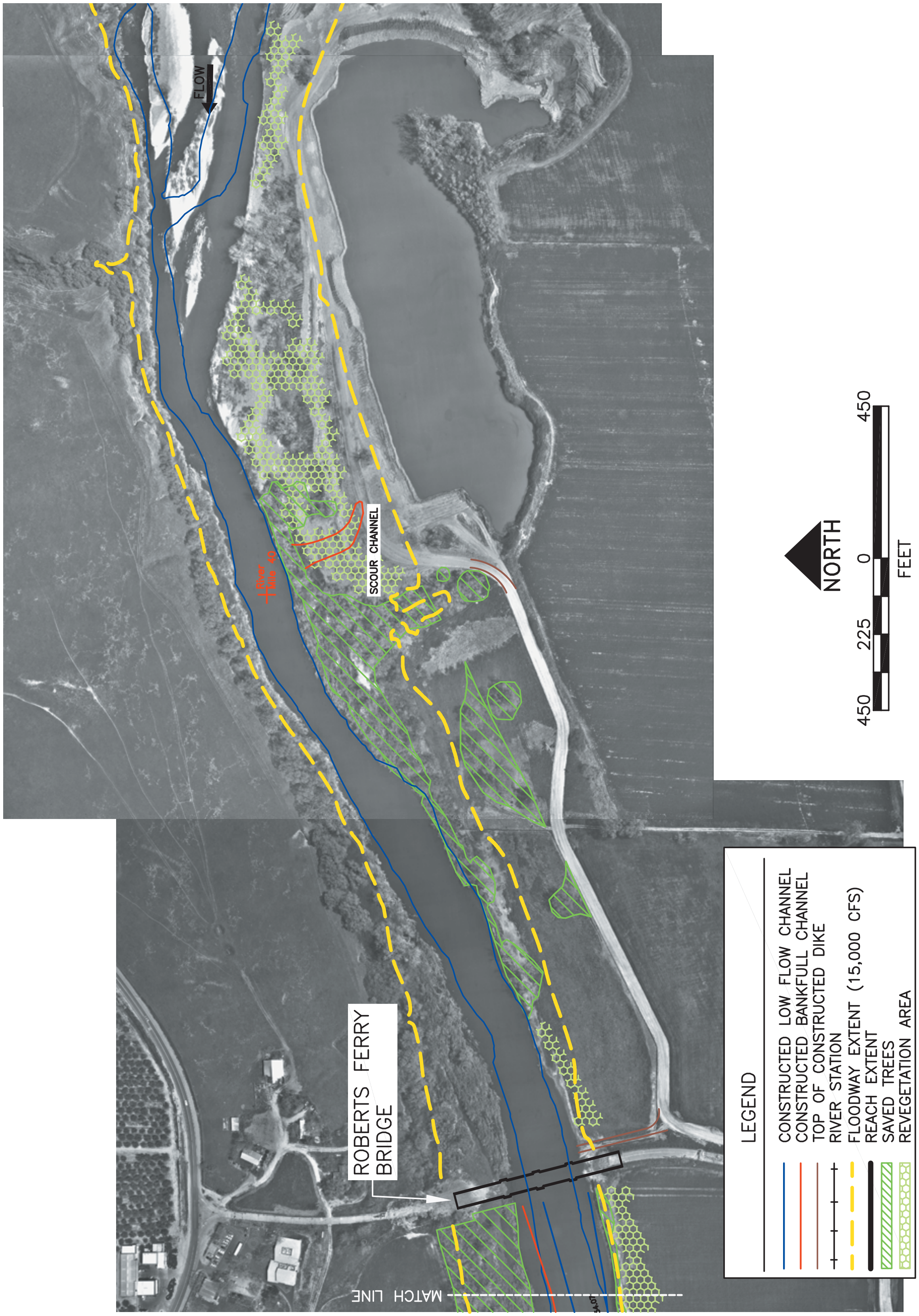

Figure 1-6. 7/11 Reach project final design, continued.

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:

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

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 14.8	>	SRP 8 12.9	>	SRP 9 10.4	>	SRP 7 7.8	>	Charles Rd NE		
1999	SRP 8 317.5	>	SRP 7 199.4	>	SRP 9 90.2	>	SRP 10 71.7	>	Riffle 64 46.2	>	Charles Rd 8.1
2003	SRP 8 81.0	>	SRP 10 59.6	>	SRP 7 53.3	>	SRP 9 34.7	>	Charles Rd 13.6	>	Riffle 64 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 6.0	>	SRP 8 5.7	>	SRP 7 3.1	>	SRP 9 2.2	>	Charles Rd 0.0		
1999	SRP 8 12.6	>	SRP 10 9.2	>	SRP 7 4.7	>	SRP 9 3.8	>	Charles Rd 1.0	>	Riffle 64 0.7
2003	SRP 10 37.2	>	SRP 8 29.9	>	SRP 9 13.9	>	SRP 7 12.5	>	Charles Rd 5.4	>	Riffle 64 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)

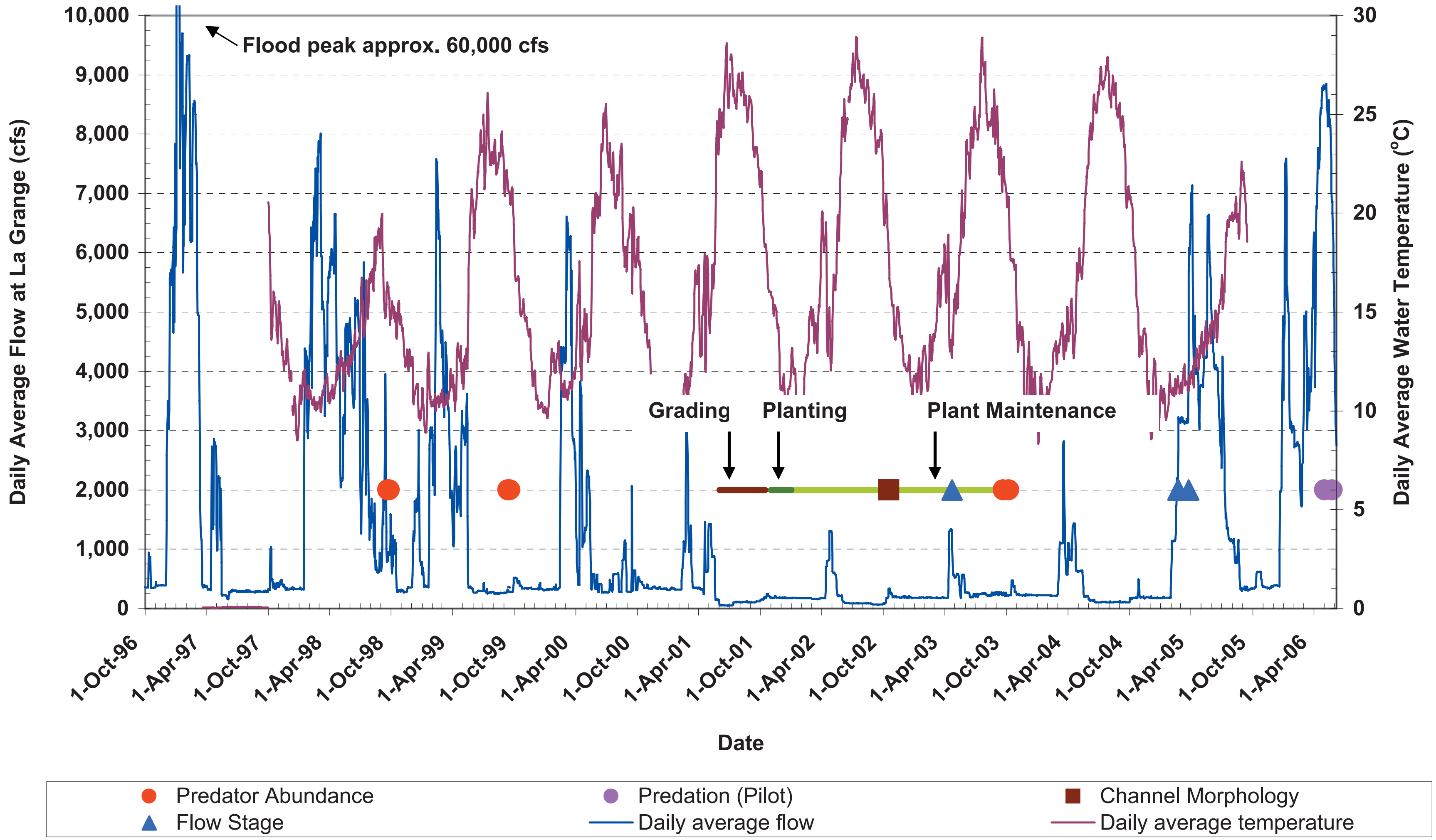
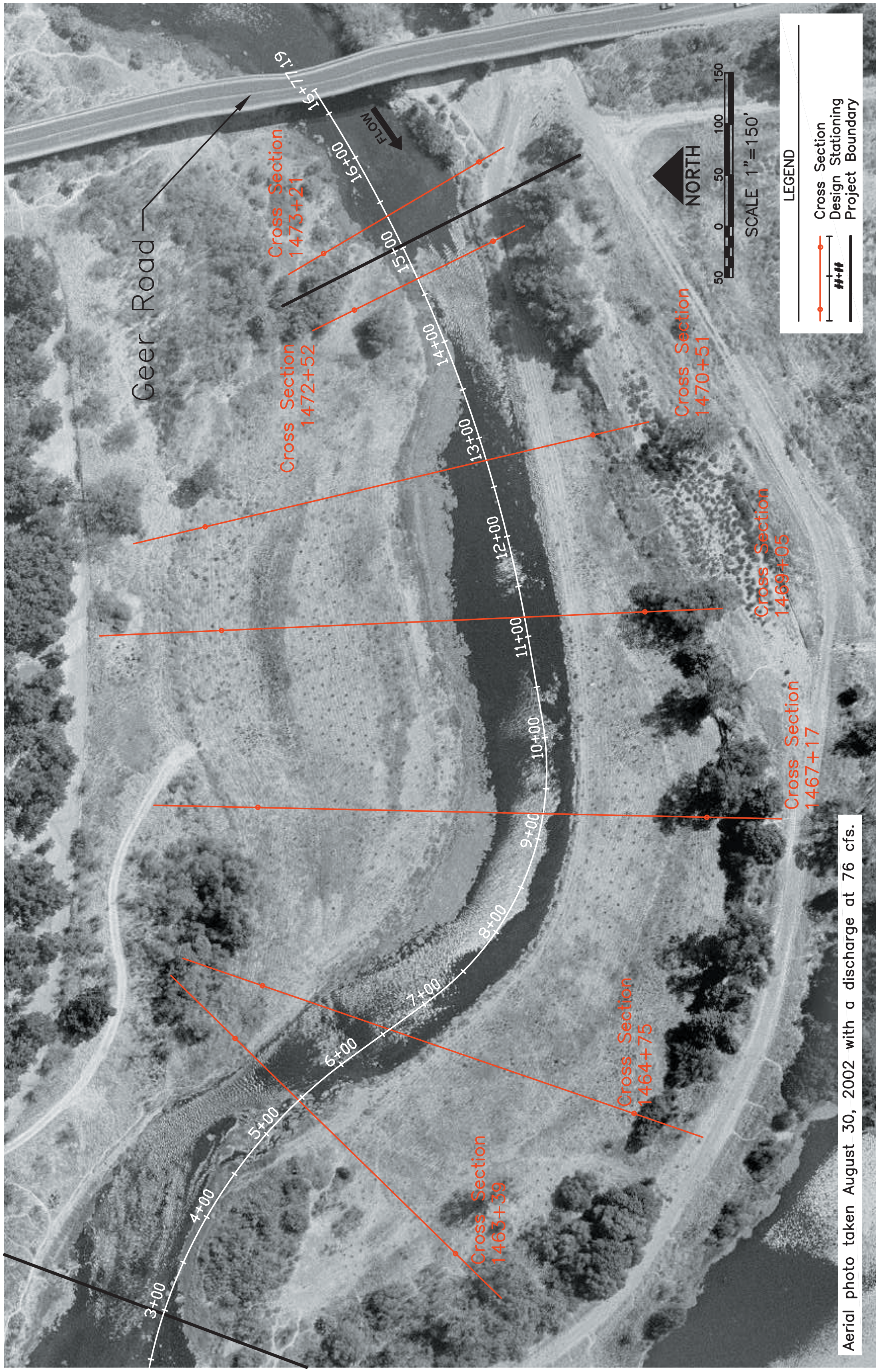


Figure 2-1. Tuolumne River flow and temperature conditions relative to SRP 9 construction and monitoring. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA. Temperature data are from RM 23.6 [1 Jan 97–1July03 and 6 Jan 04–26 Mar 05] and RM 3.4 [15July03–5Jan04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



Aerial photo taken August 30, 2002 with a discharge at 76 cfs.

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

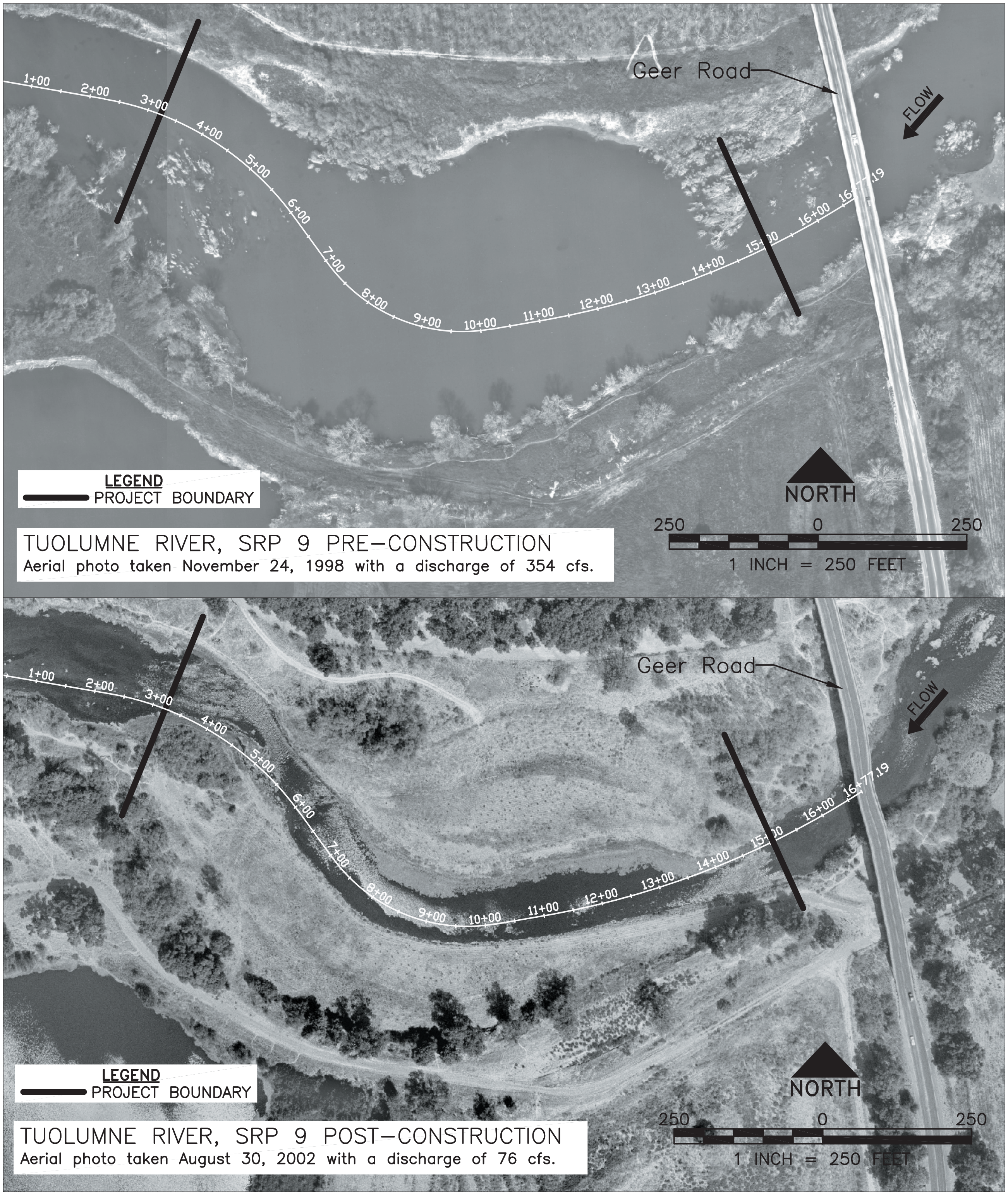


Figure 2-3. SRP 9 pre-project (1998), as-built (2002), and post-project (2005) aerial photographs.

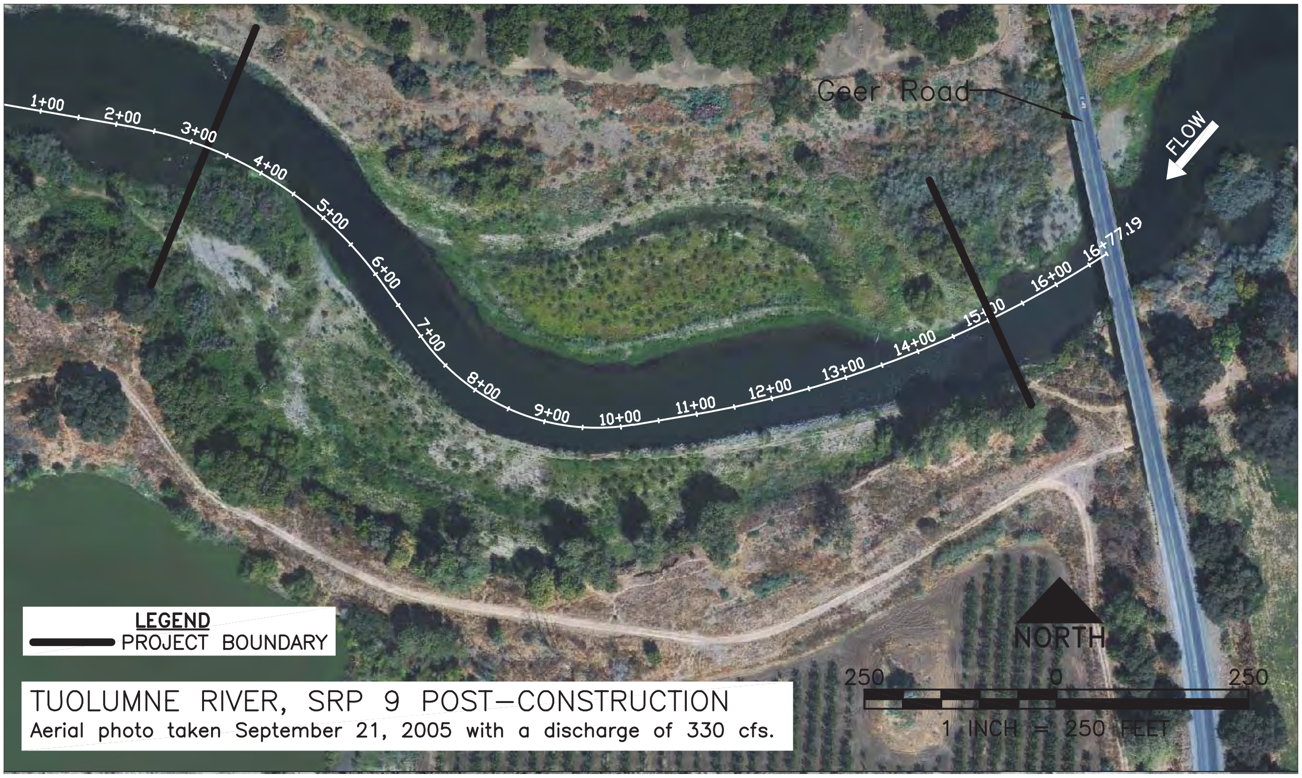


Figure 2-3. SRP 9 pre-project (1998), as-built (2002), and post-project (2005) aerial photographs, continued.

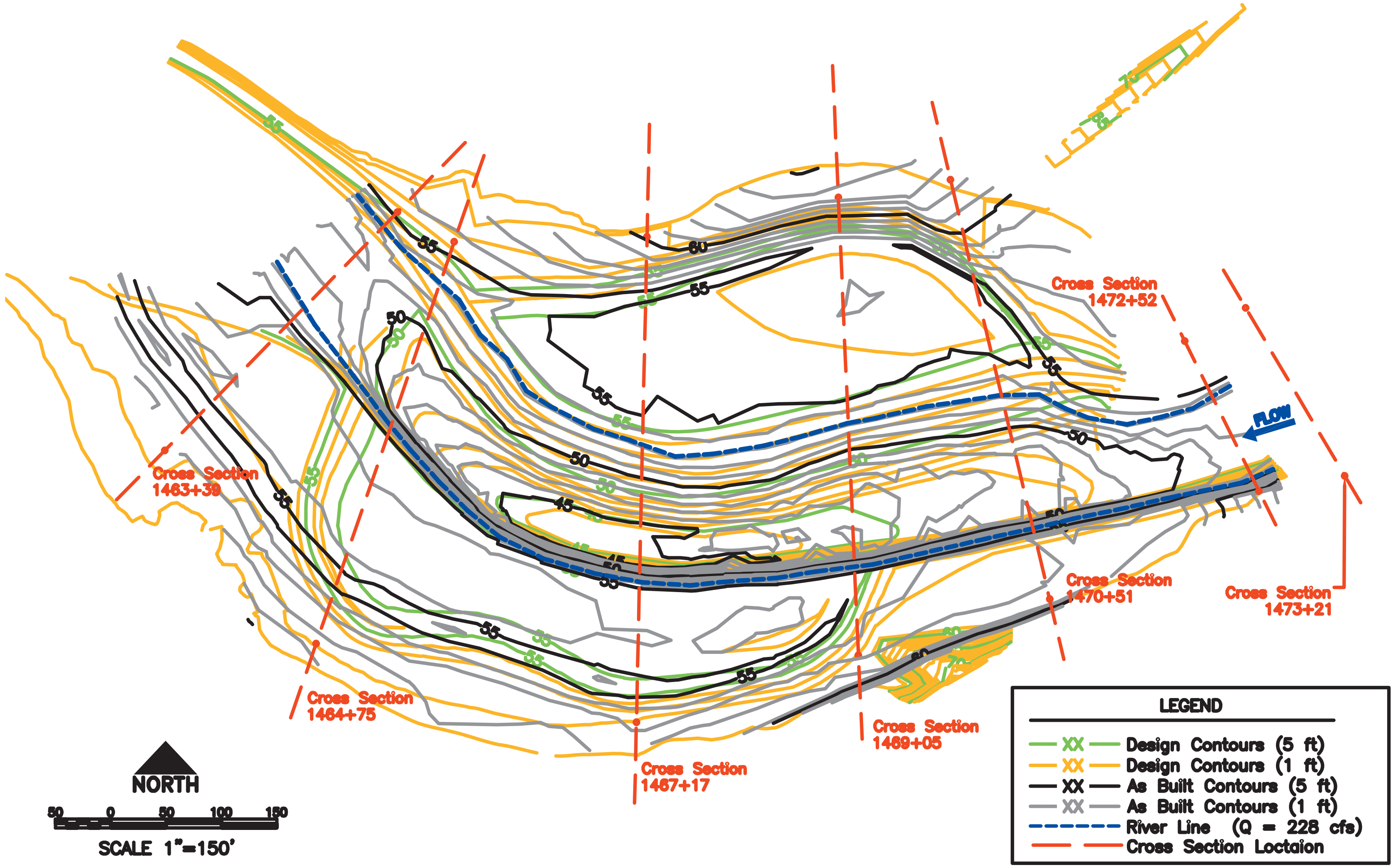


Figure 2-4. SRP 9 design and as-built channel and floodplain contours.

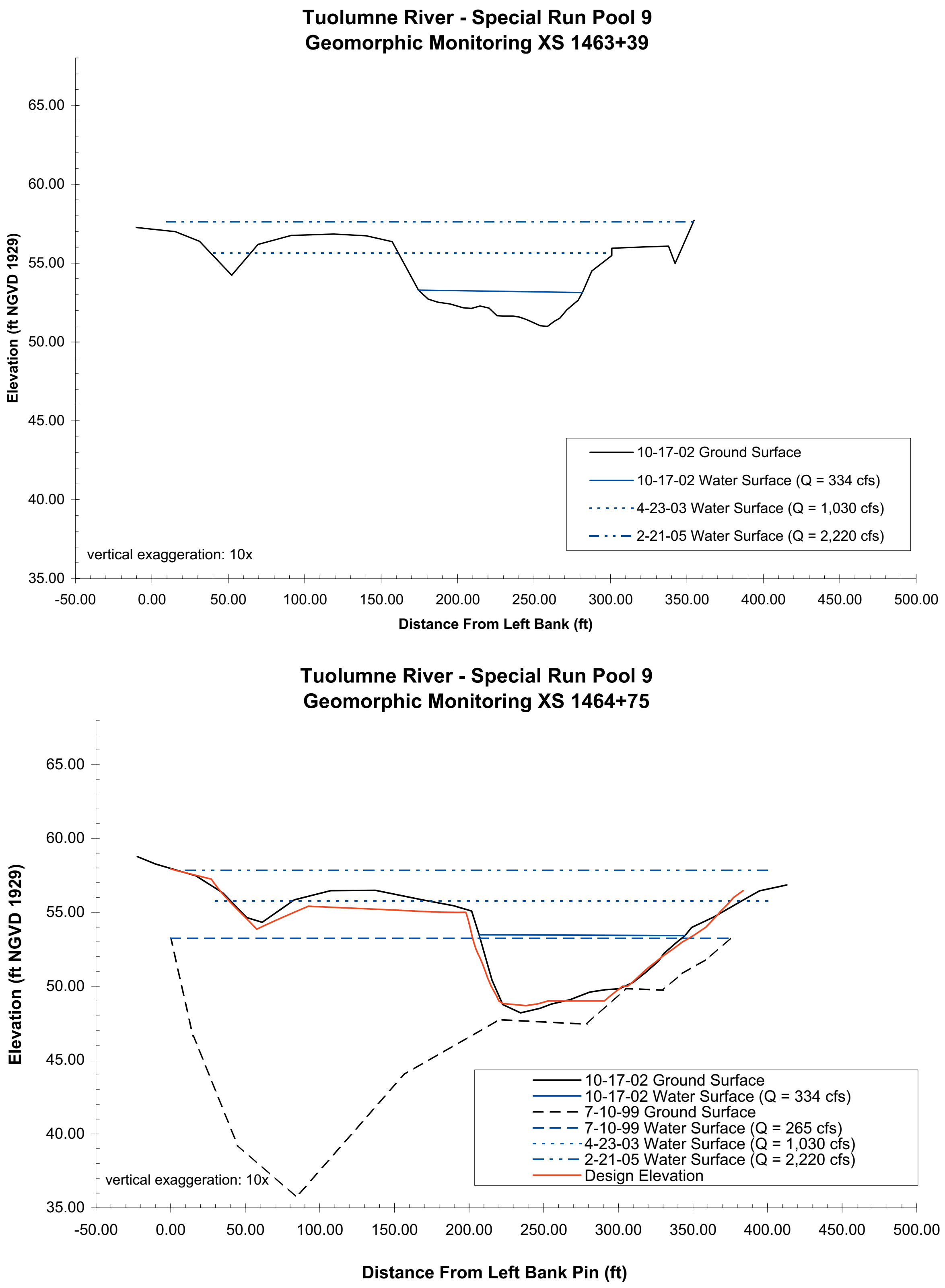
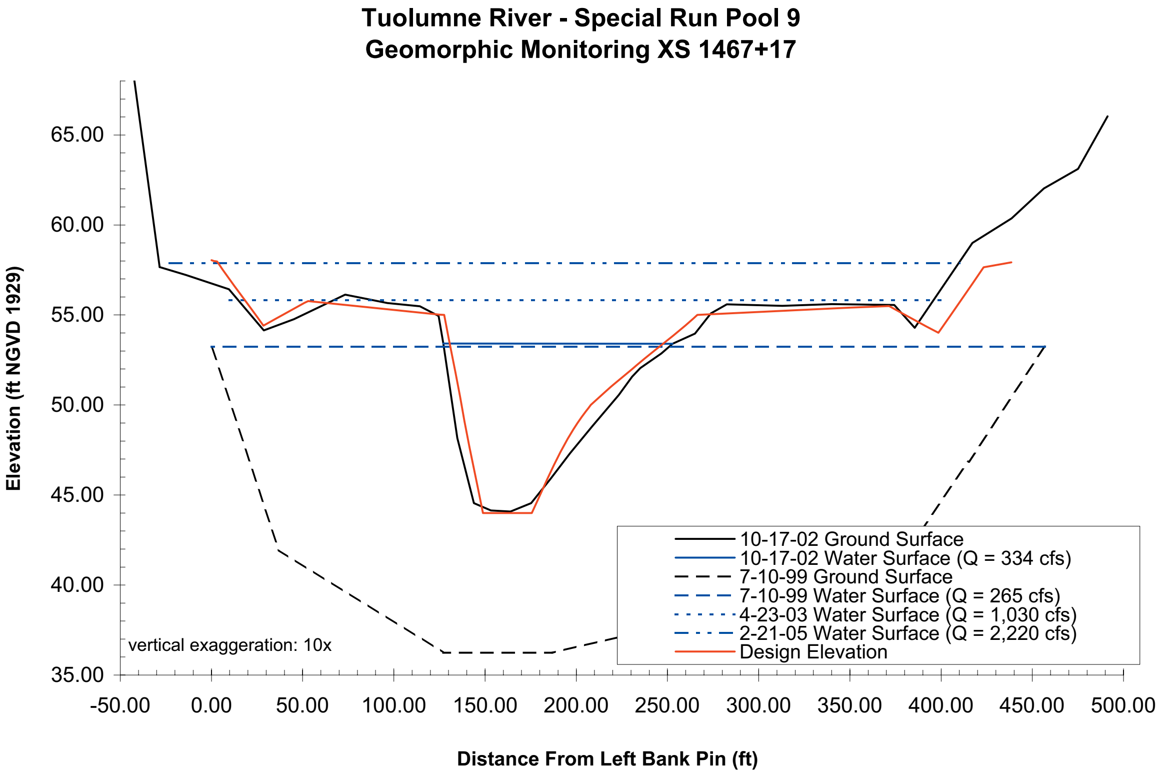


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface.



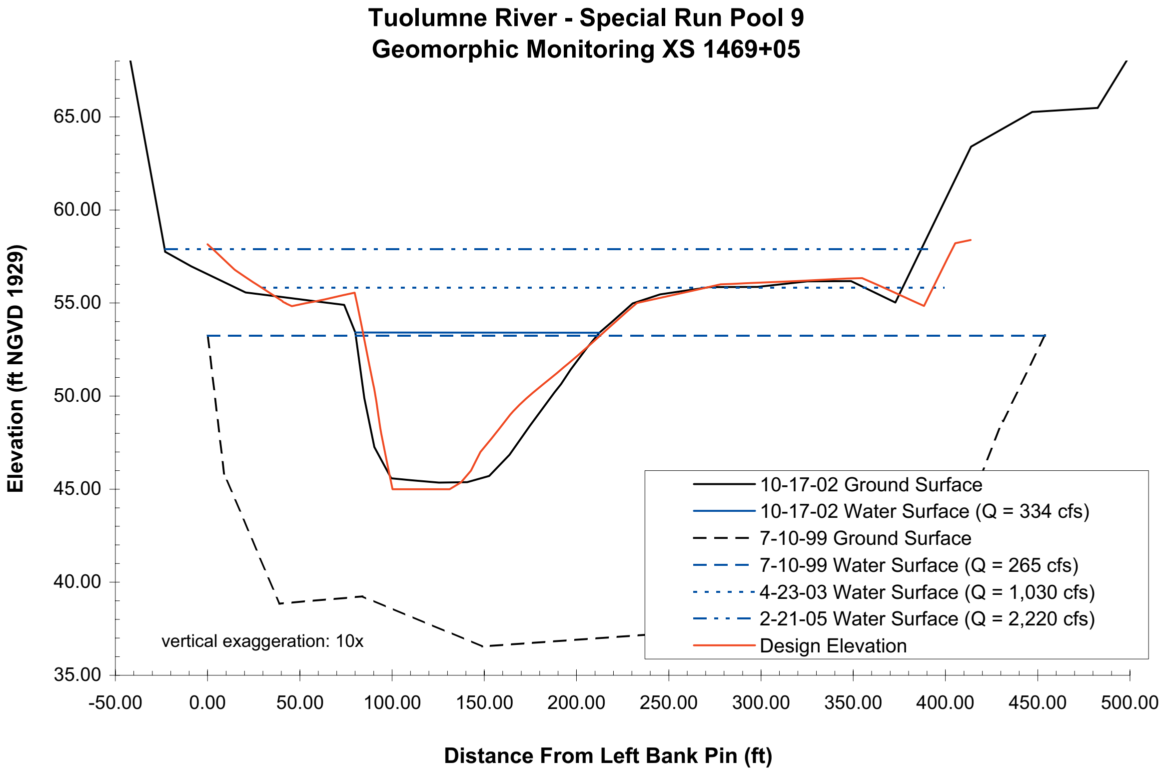
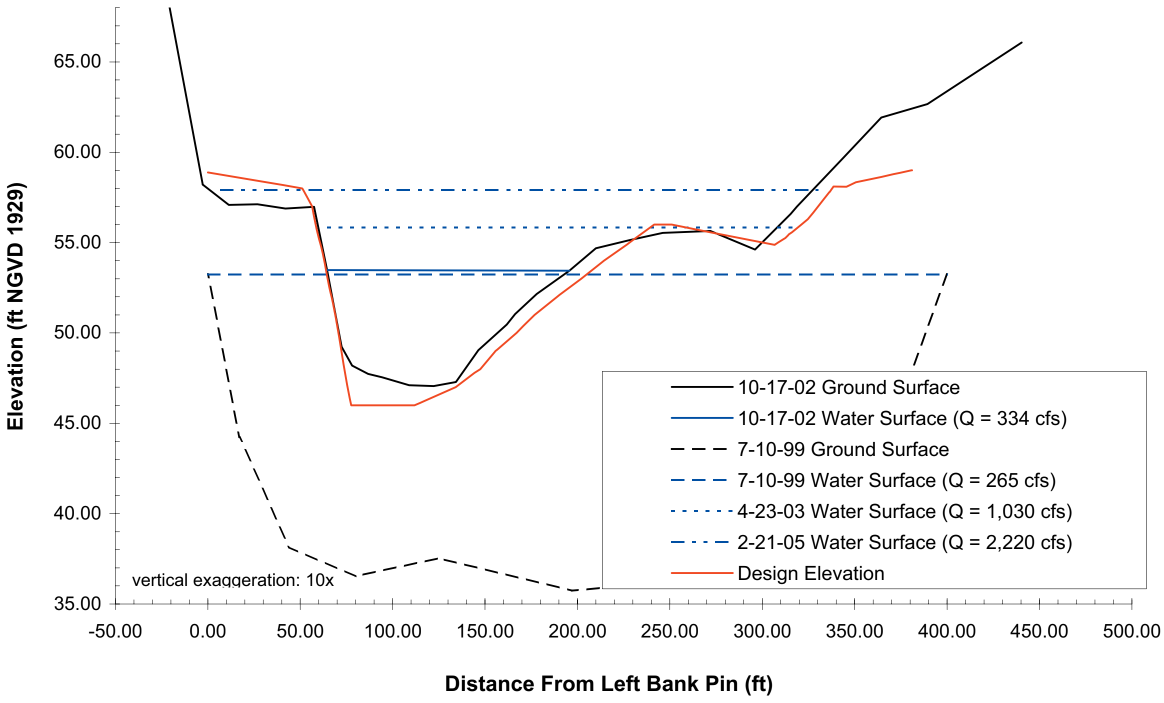


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface, continued.

Tuolumne River - Special Run Pool 9
Geomorphic Monitoring XS 1470+51



Tuolumne River - Special Run Pool 9
Geomorphic Monitoring XS 1472+ 52

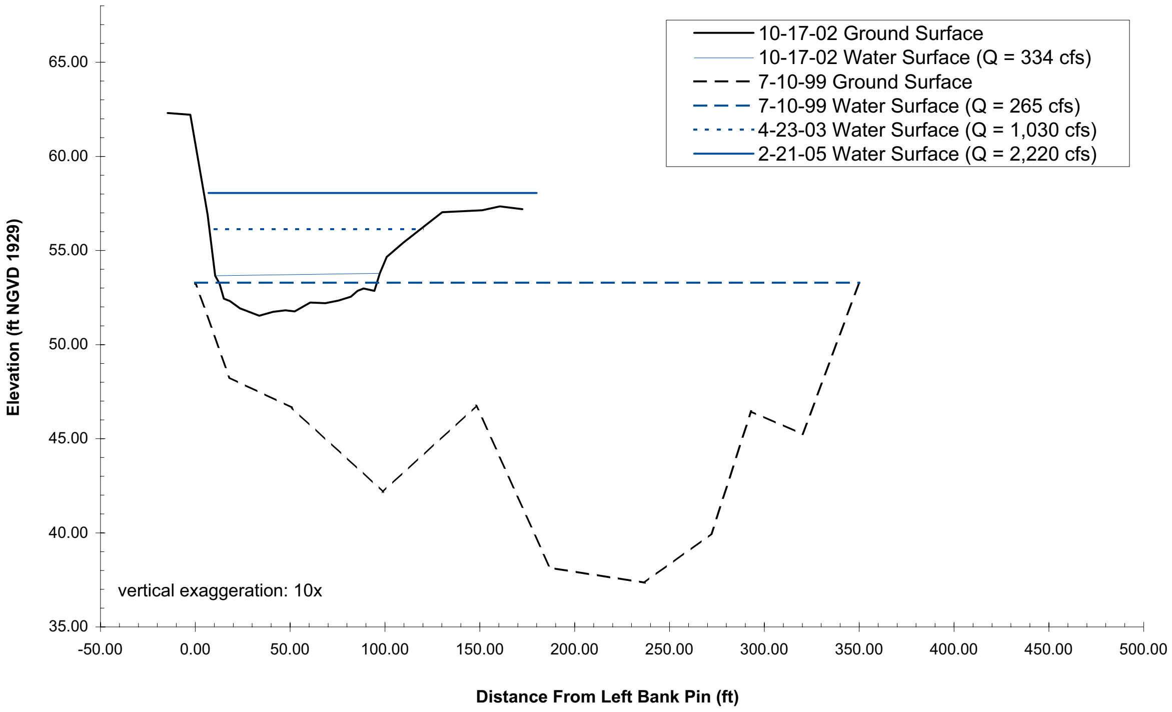


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface, continued.

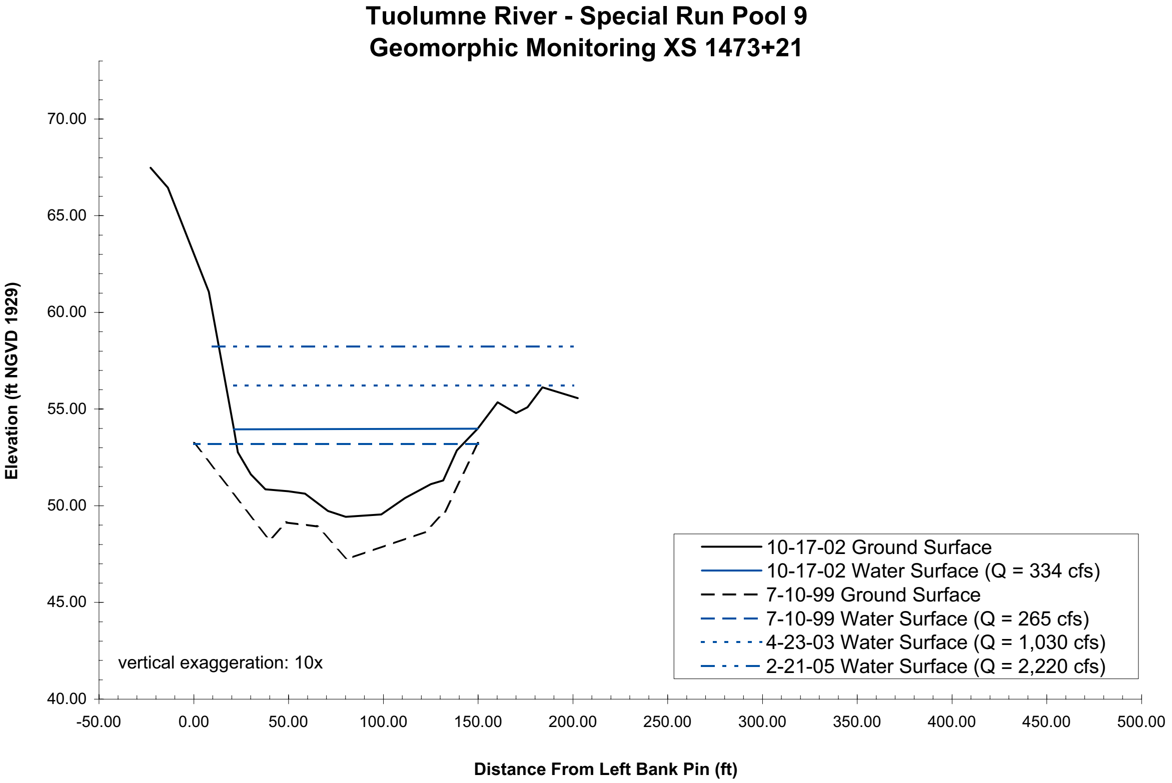


Figure 2-5. SRP 9 monitoring cross sections showing pre-project, final design, and as-built ground surface and pre-project and post-project water surface, continued.

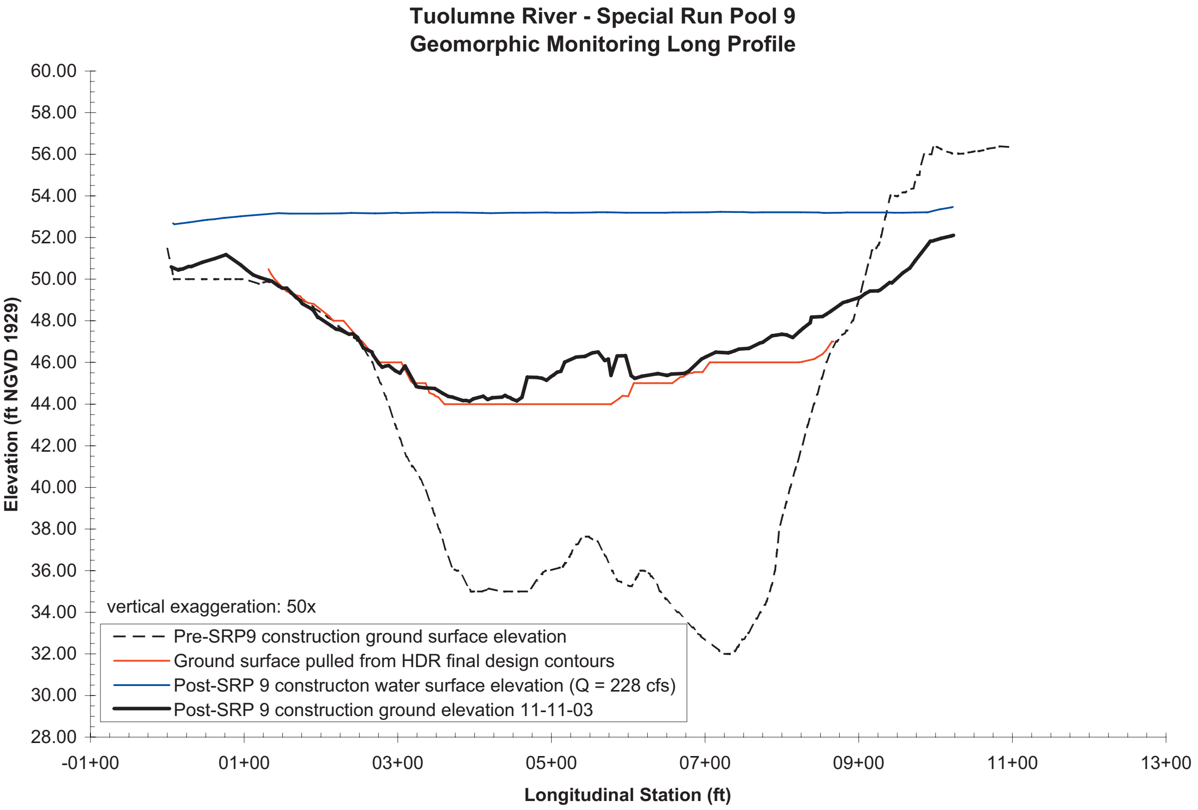


Figure 2-6. SRP 9 pre-construction, final design, and as-built channel thalweg profile.

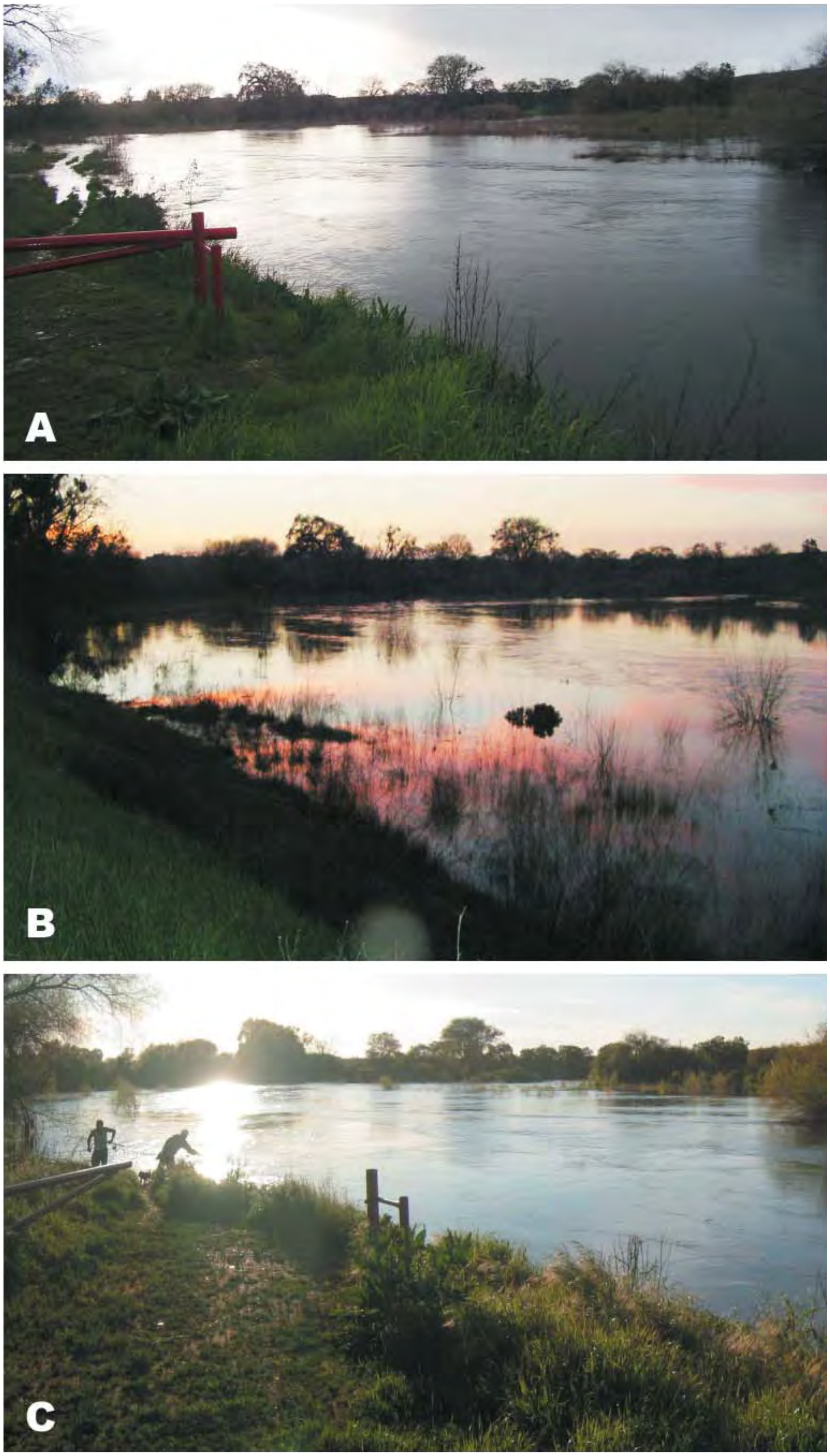


Figure 2-7. View from approximate location of cross section 1473+21 looking downstream during flows (A) 2,200 cfs [February 21, 2005], (B) 3,230 cfs [February 23, 2005], and 5,690 cfs [March 25, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.)

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.)

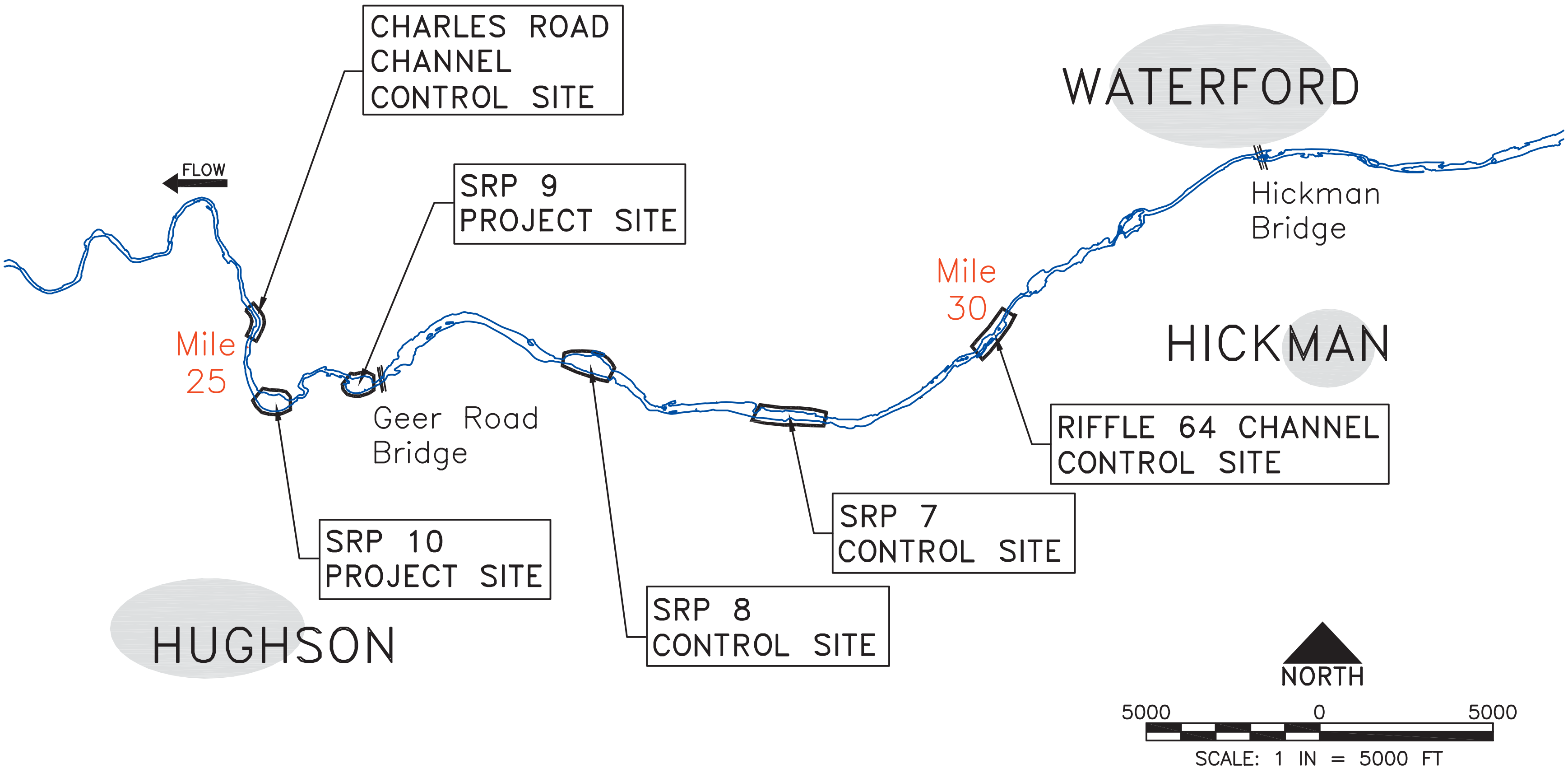


Figure 2-9. *SRP 9 bass abundance monitoring sites.*

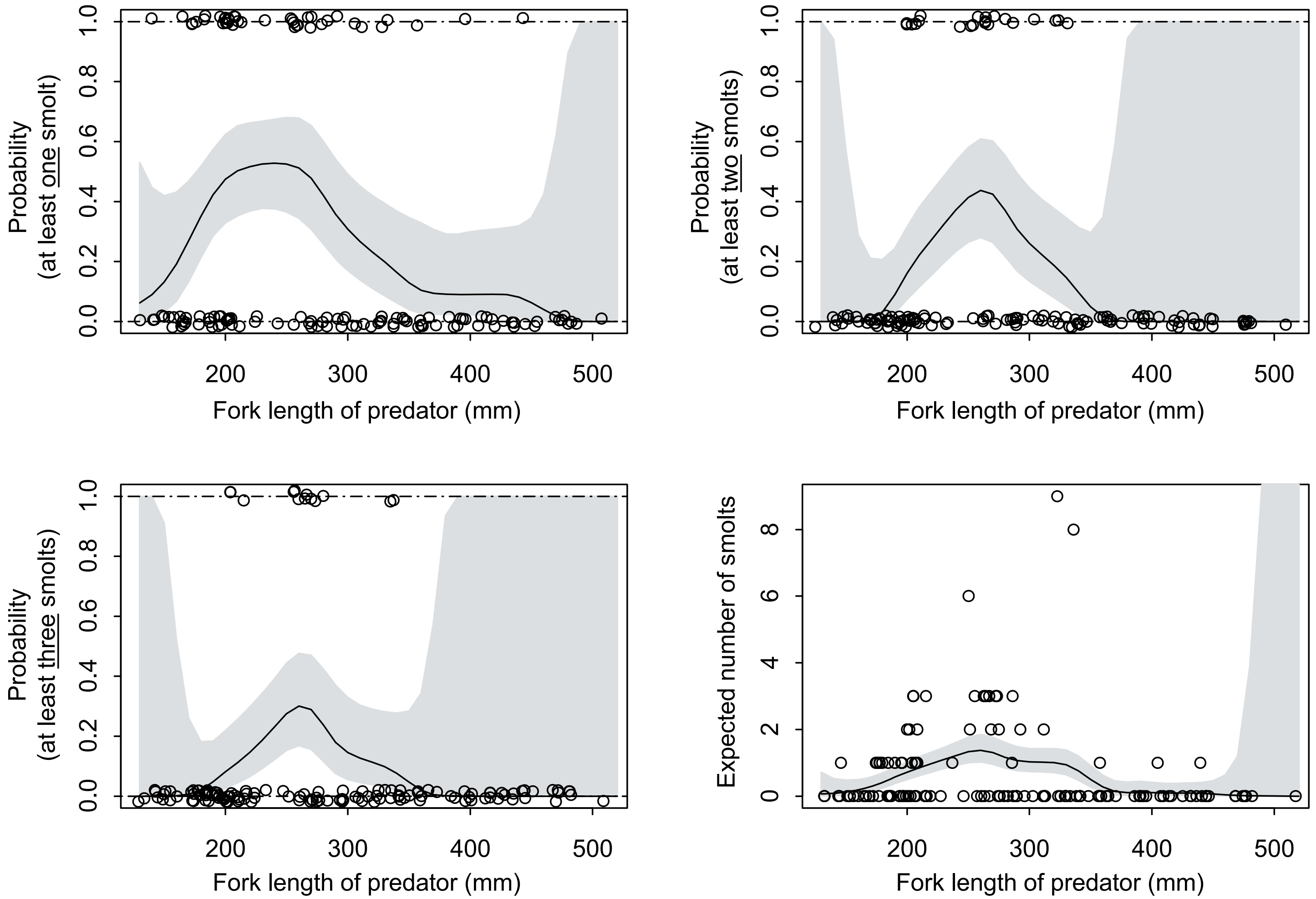
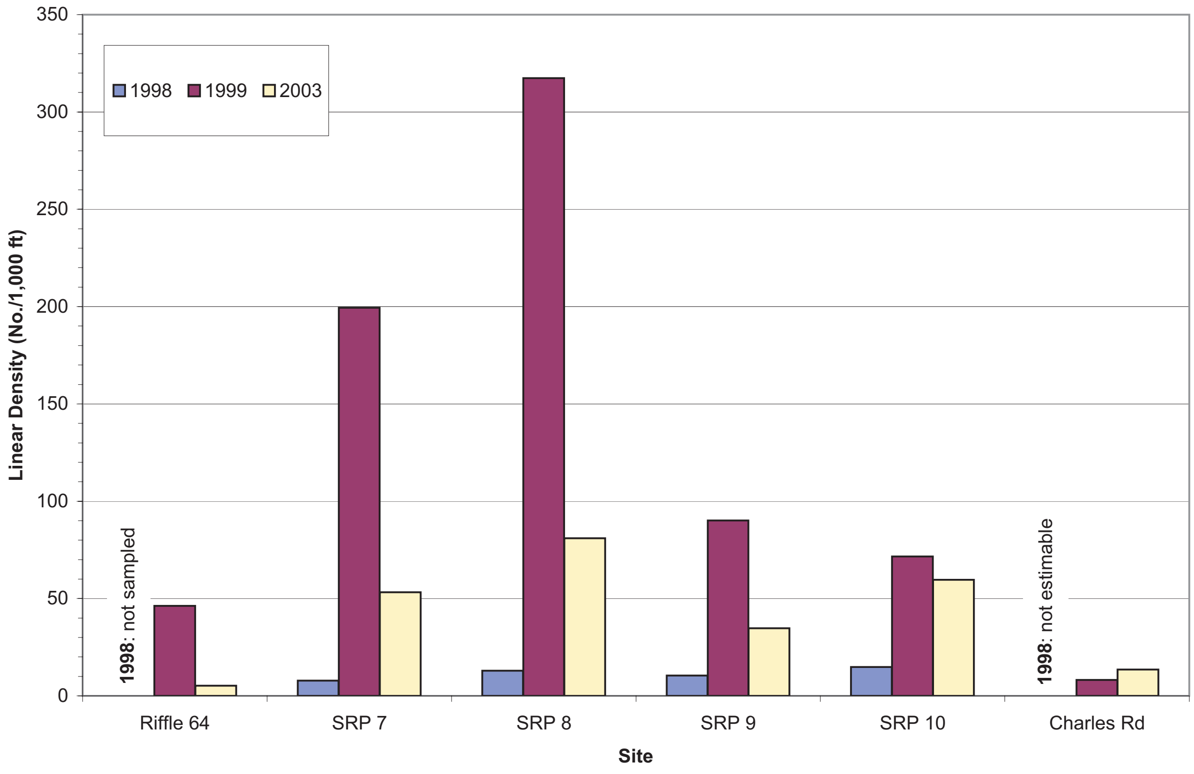


Figure 2-10. Chinook salmon found in stomachs of largemouth bass recovered by electrofishing in SRPs 7, 8, 9, and 10 from 2-4 May 1990, as part of the Lower Tuolumne River Predation Study (TID/MID 1992a). The figures at upper left, upper right, and lower left show probability of finding at least 1, at 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.



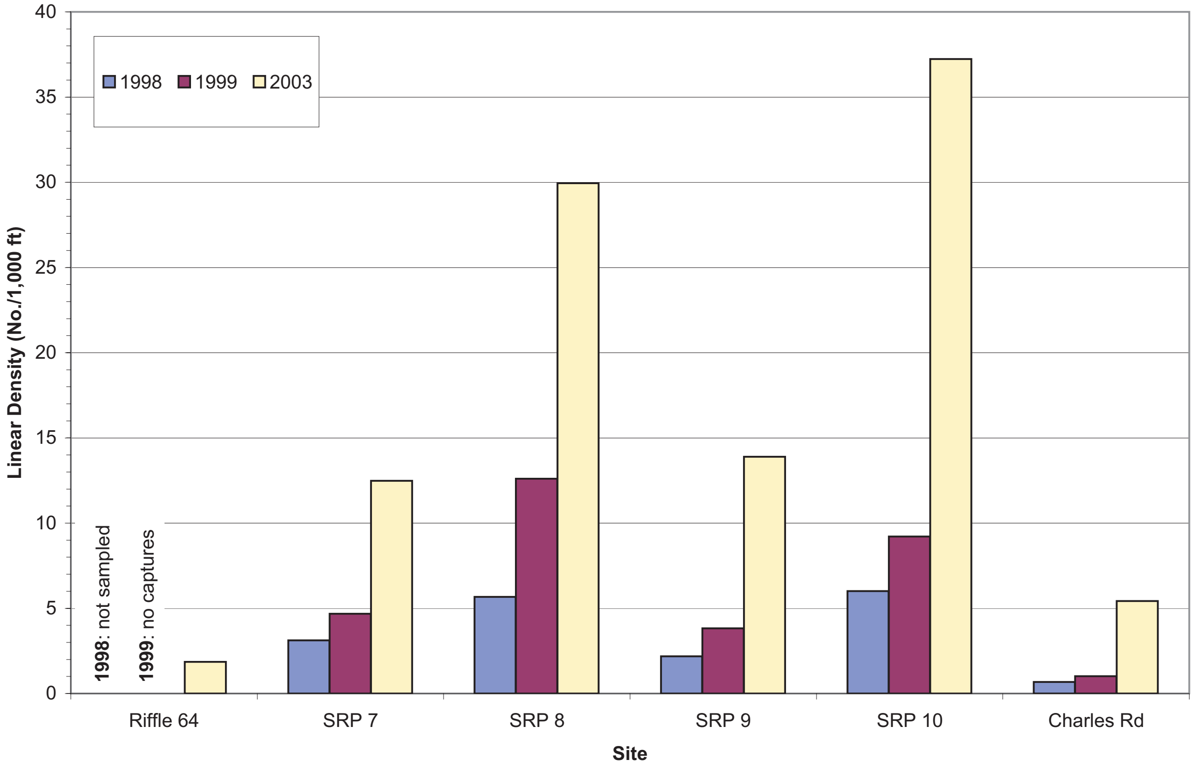


Figure 2-11. Largemouth bass linear density at project and control sites for all size classes combined (top) and piscivore-size only (bottom) –1998, 1999, and 2003.

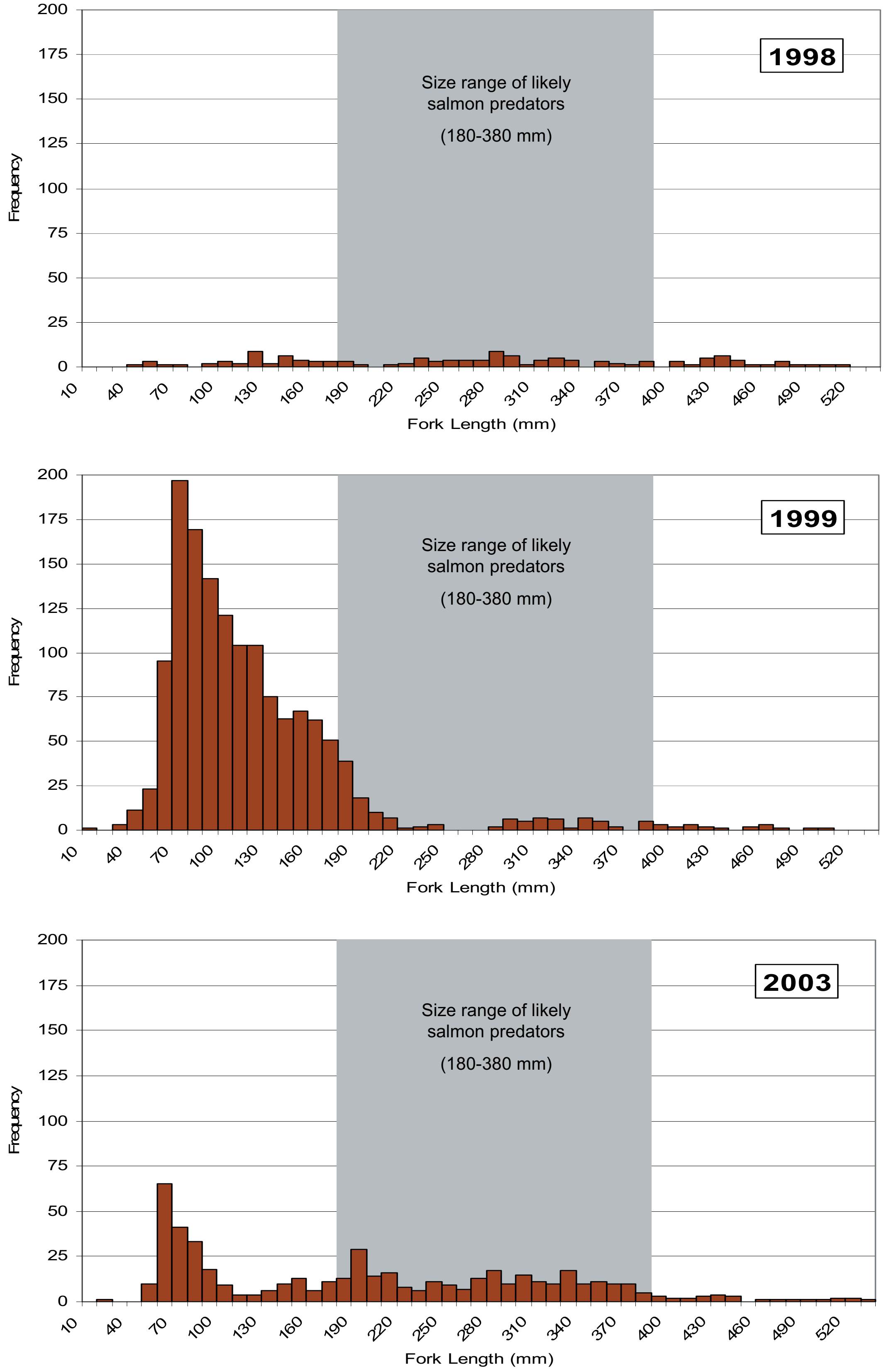


Figure 2-12. Length-frequency of largemouth bass captured at all project and control sites combined in 1998, 1999, and 2003.

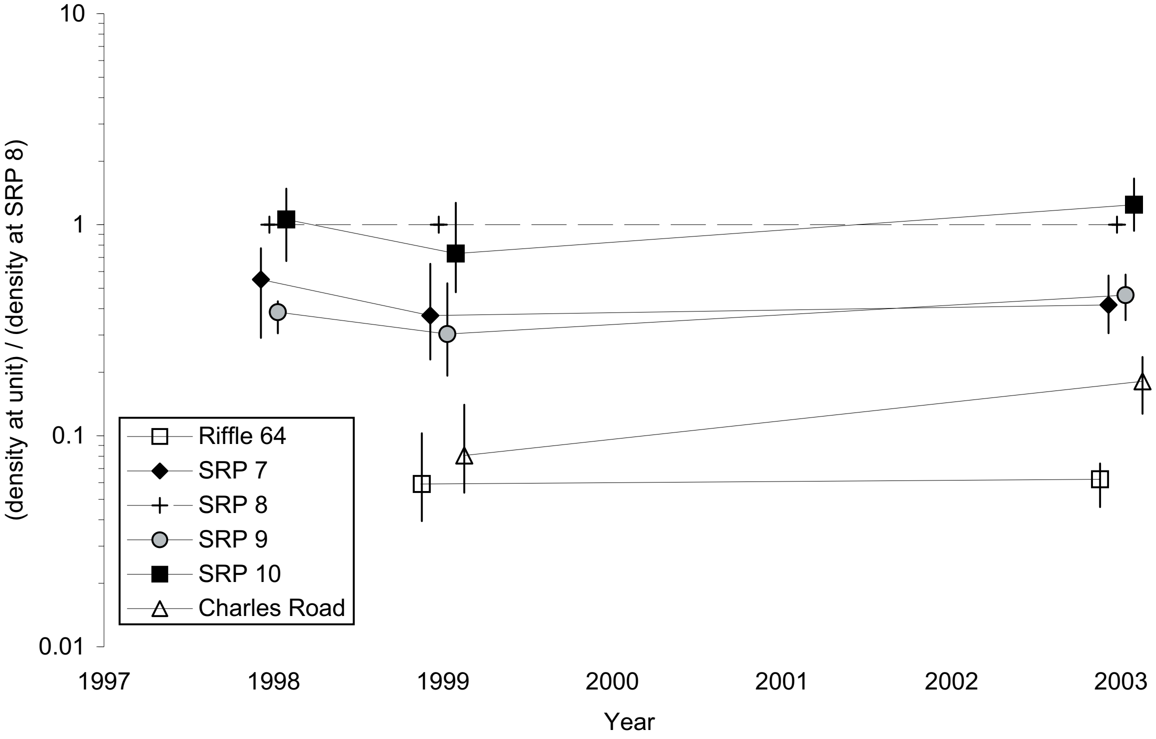
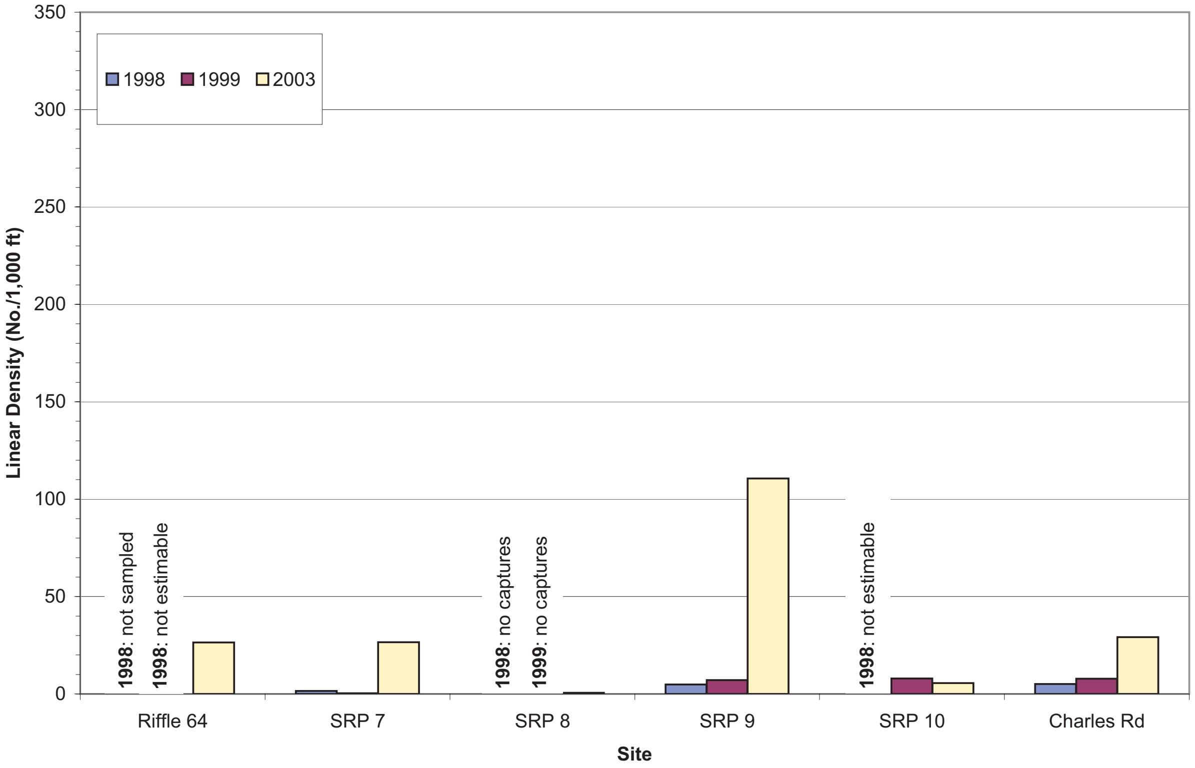


Figure 2-13. Before-After-Control-Impact trends for piscivore-sized largemouth bass. The plotted series are the ratios between the (linear) largemouth bass density at each project and control site to linear density at SRP 8. Vertical bars are 95% confidence intervals for these values.



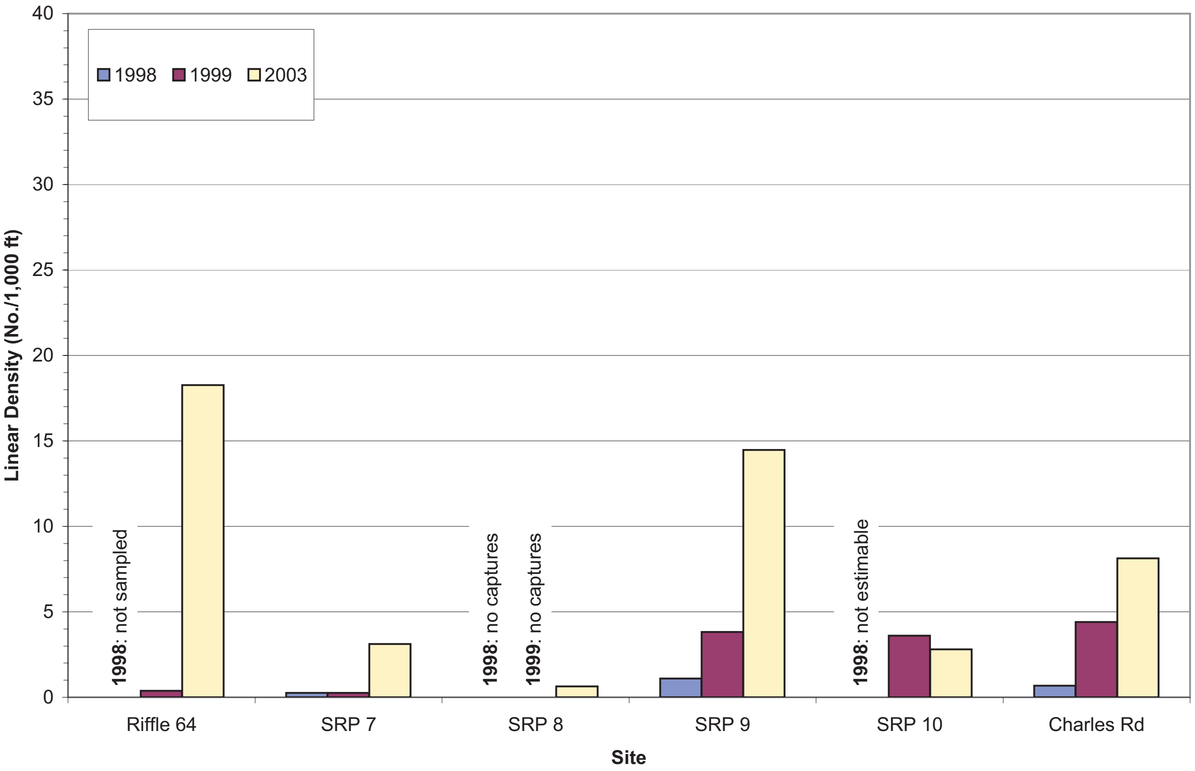


Figure 2-14. Smallmouth bass linear density at project and control sites for all size classes combined (top) and piscivore-size only (bottom) –1998, 1999, and 2003.

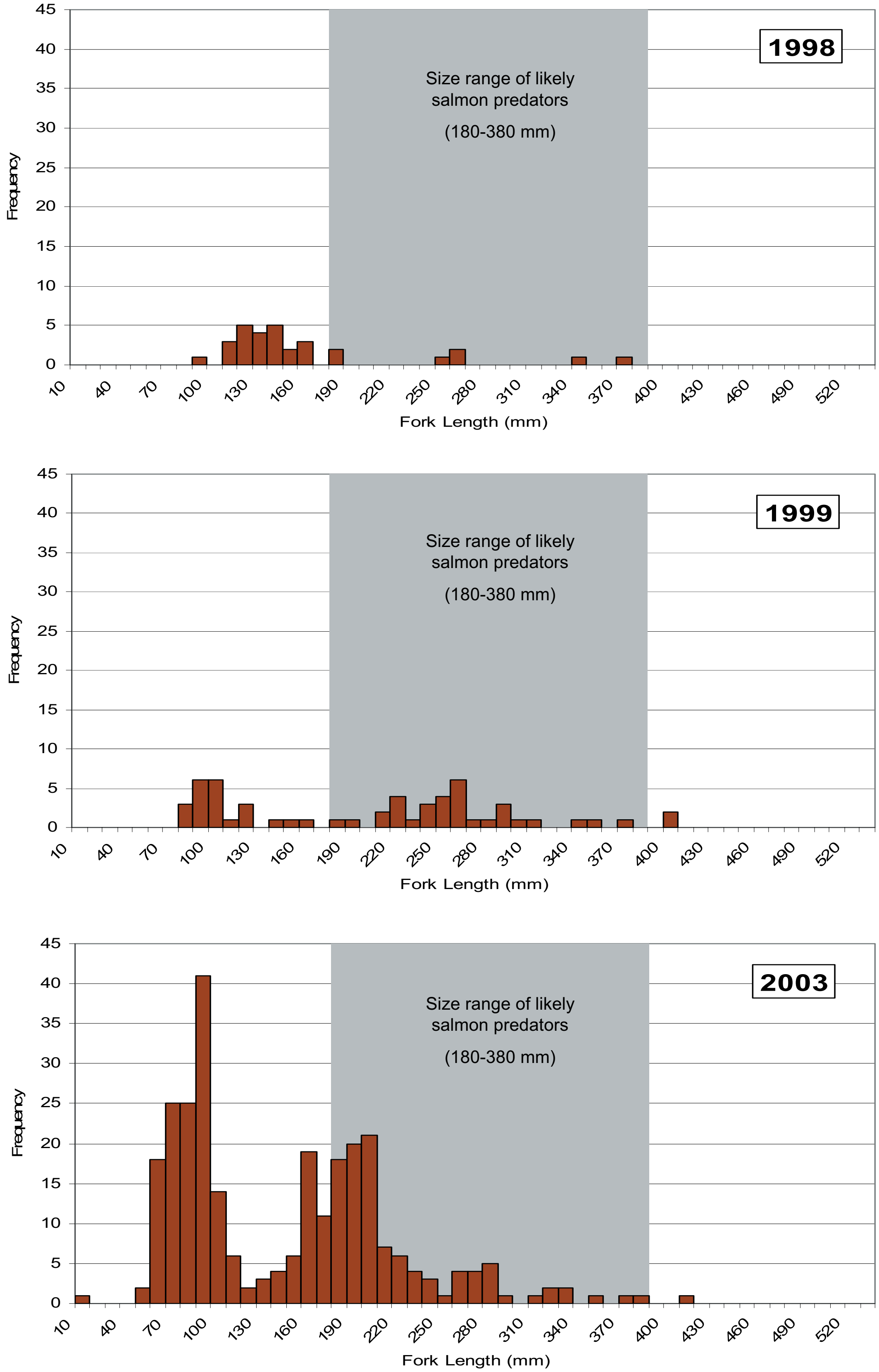


Figure 2-15. *Length-frequency of smallmouth bass at all project and control sites combined in 1998, 1999, and 2003.*

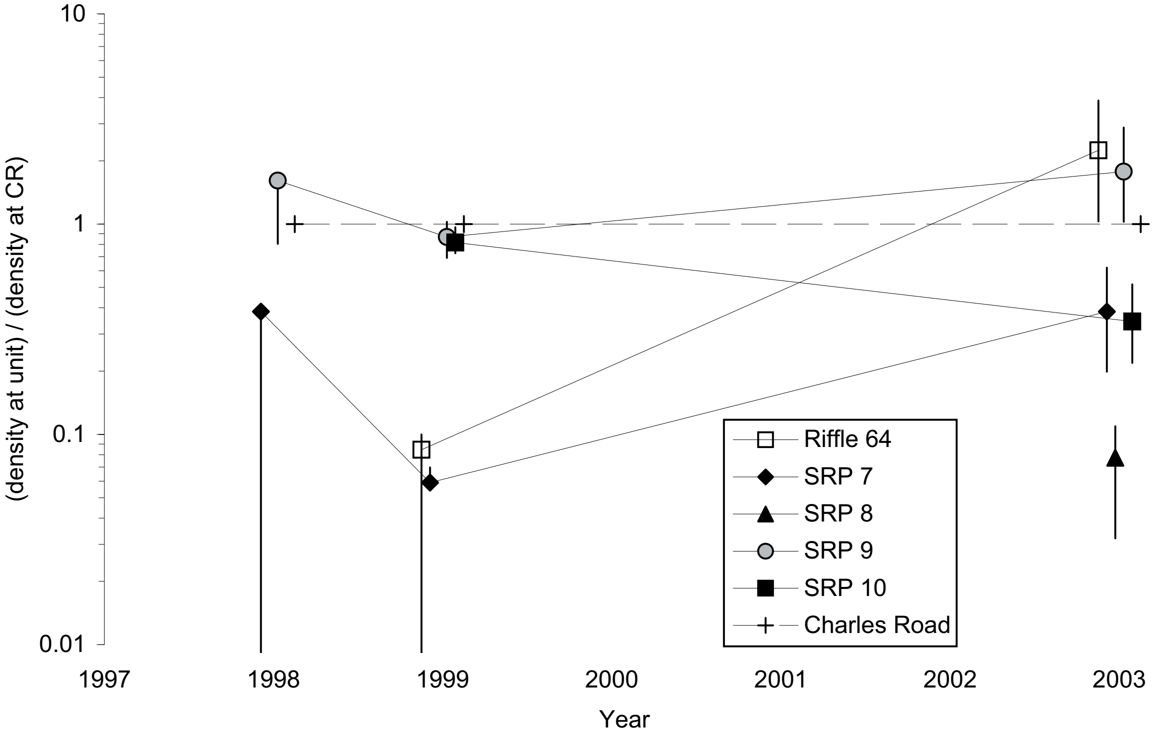


Figure 2-16. Before-After-Control-Impact trends for piscivore-sized smallmouth bass. The plotted series are the ratios between the (linear) largemouth bass density at each project and control site to linear density at Charles Rd. Vertical bars are 95% confidence intervals for these values.

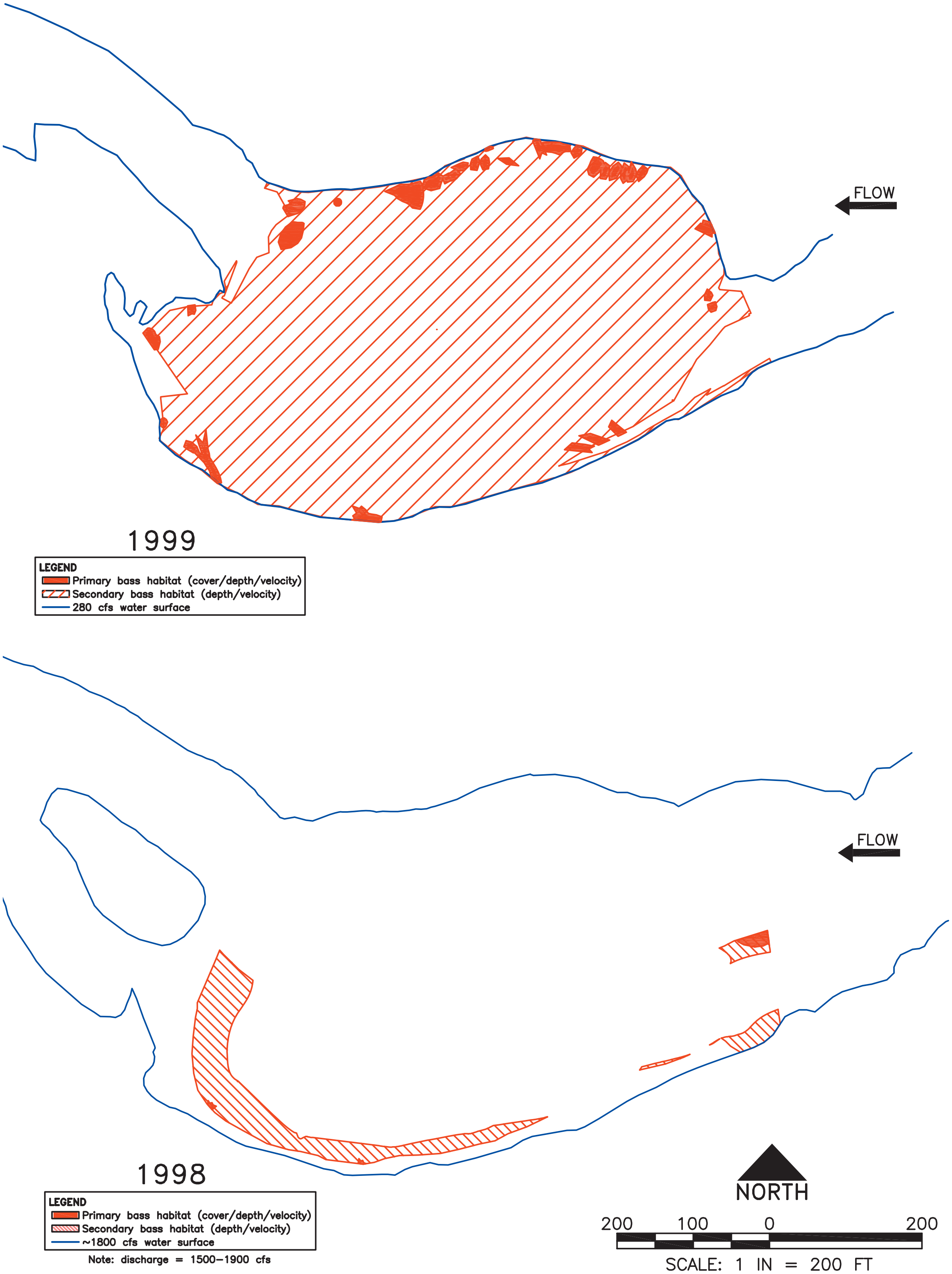


Figure 2-17. Largemouth bass primary and secondary habitat mapped at SRP 9 during flows of 265–287 cfs (August 1999) [top] and 1,440–1,770 cfs (August 1998) [bottom].

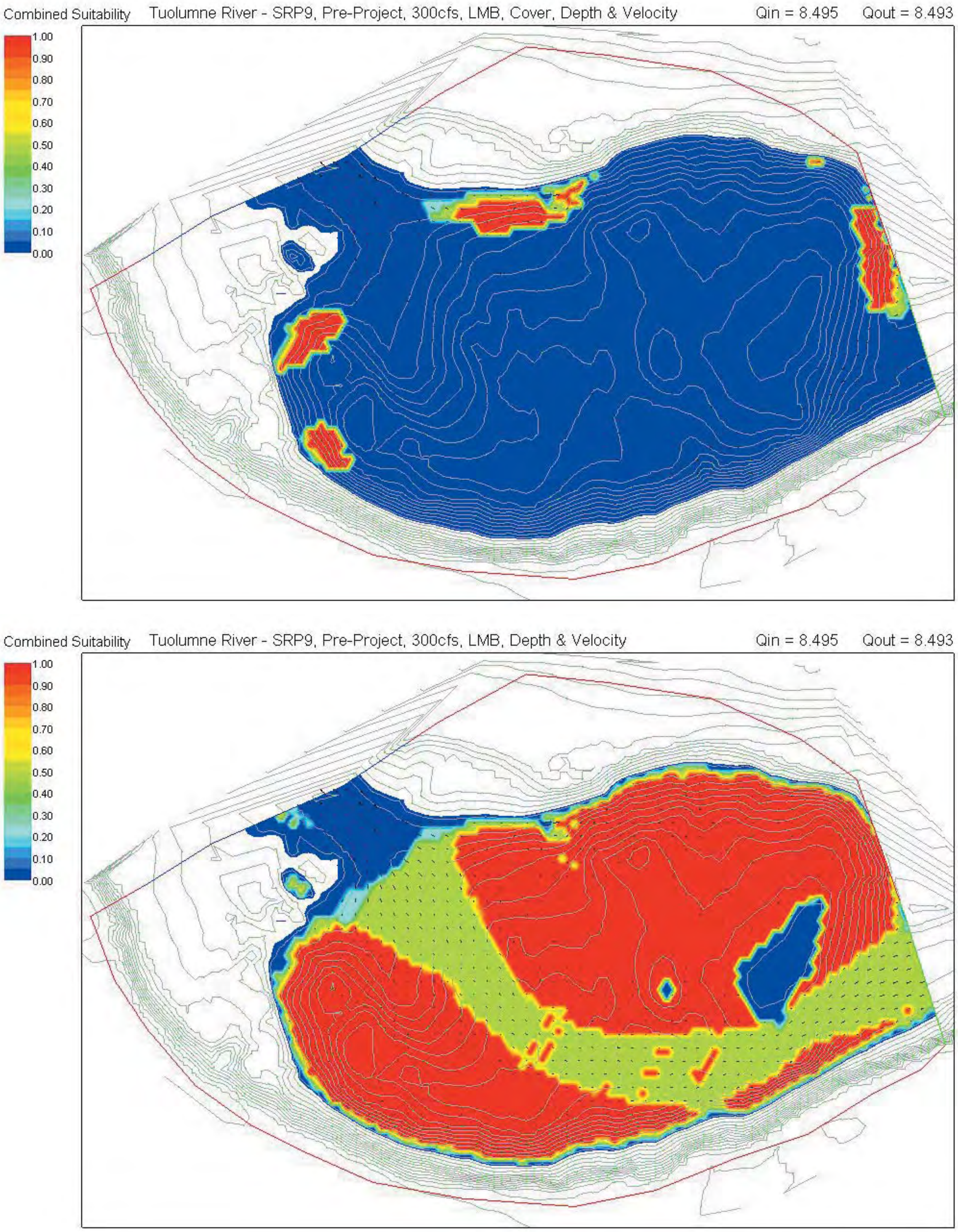


Figure 2-18. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 300 cfs.

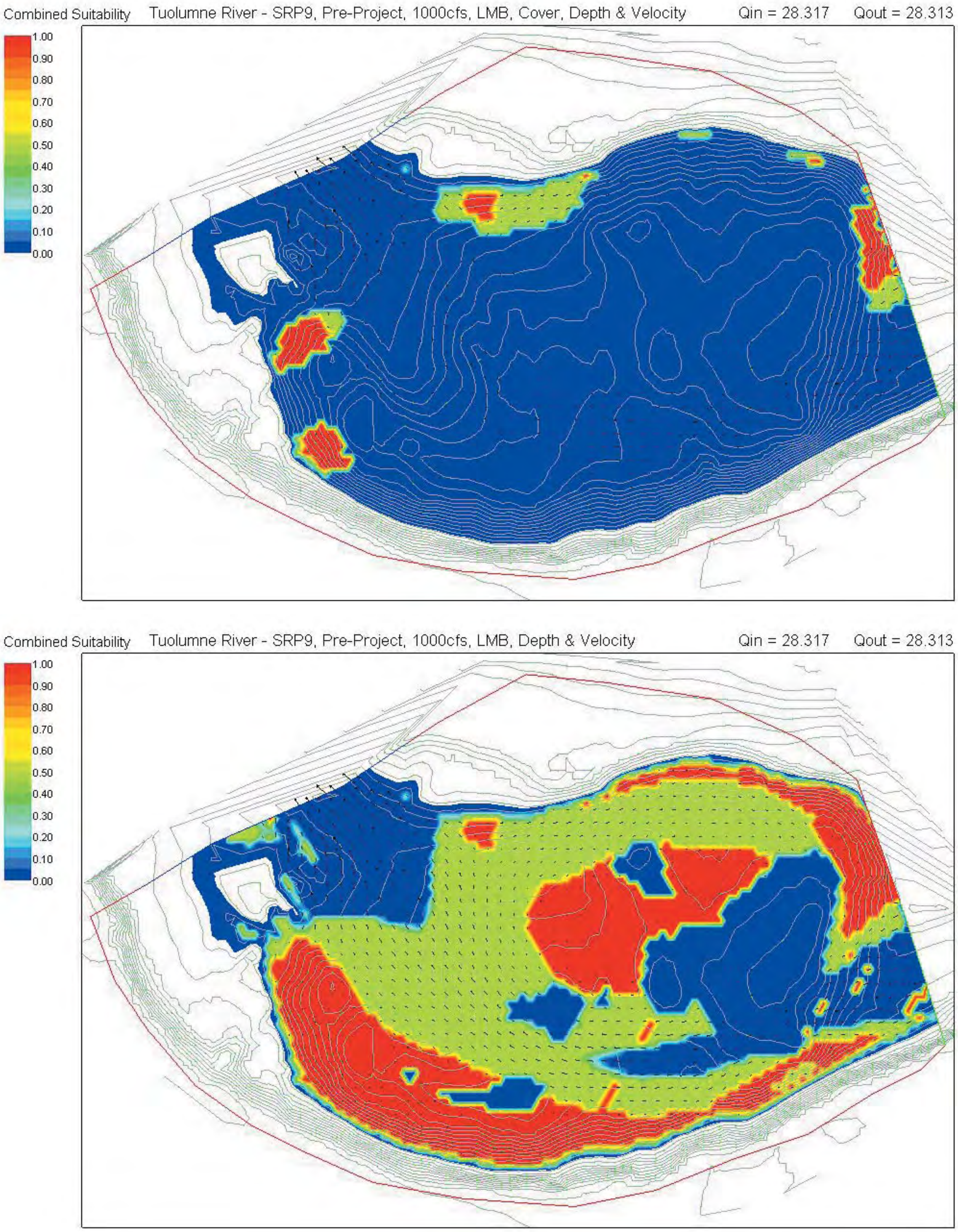


Figure 2-19. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 1,000 cfs.

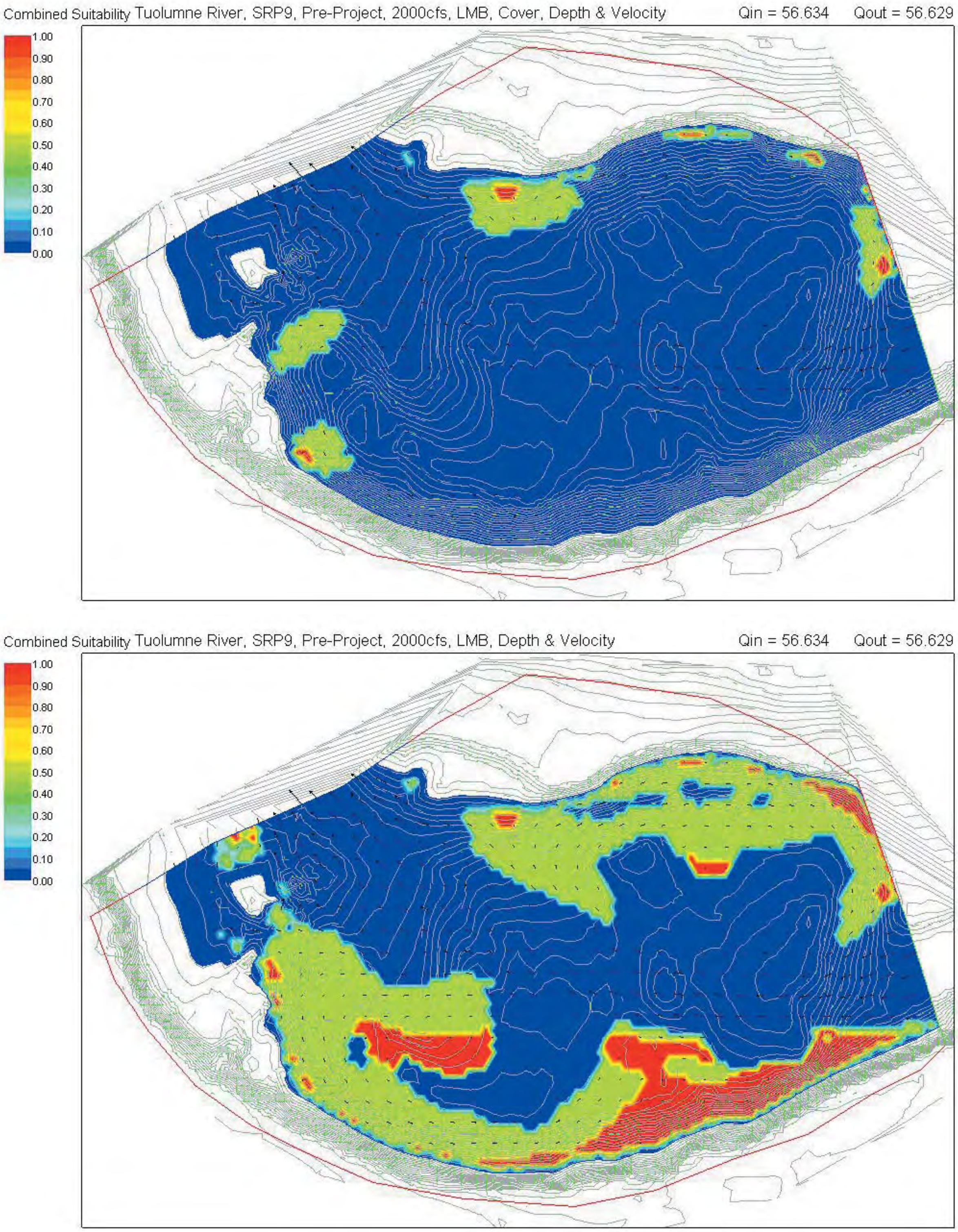


Figure 2-20. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 2,000 cfs.

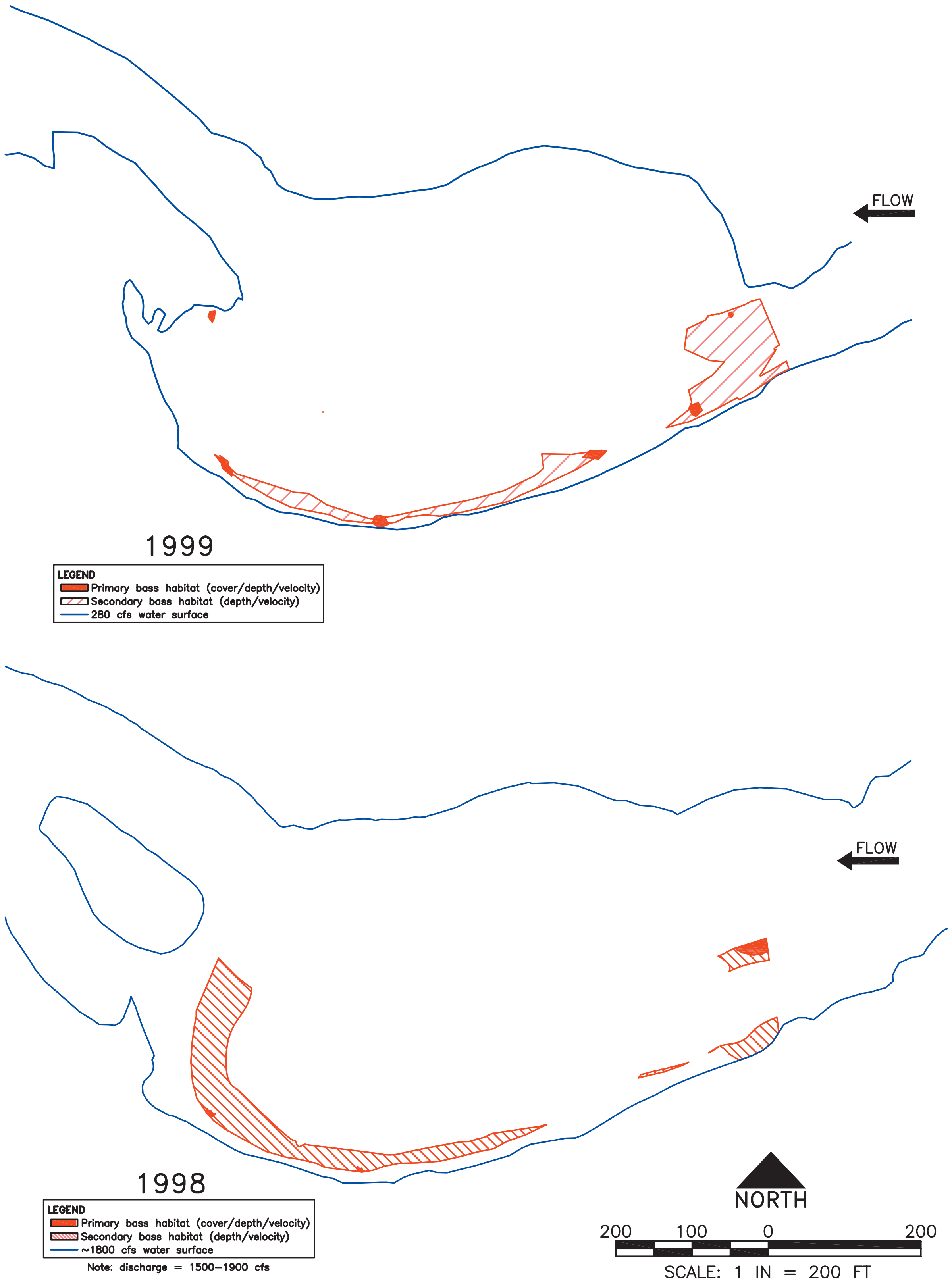


Figure 2-21. Smallmouth bass primary and secondary habitat mapped at SRP 9 during flows of 265–287 cfs (August 1999) [top] and 1,440–1,770 cfs (August 1998) [bottom].

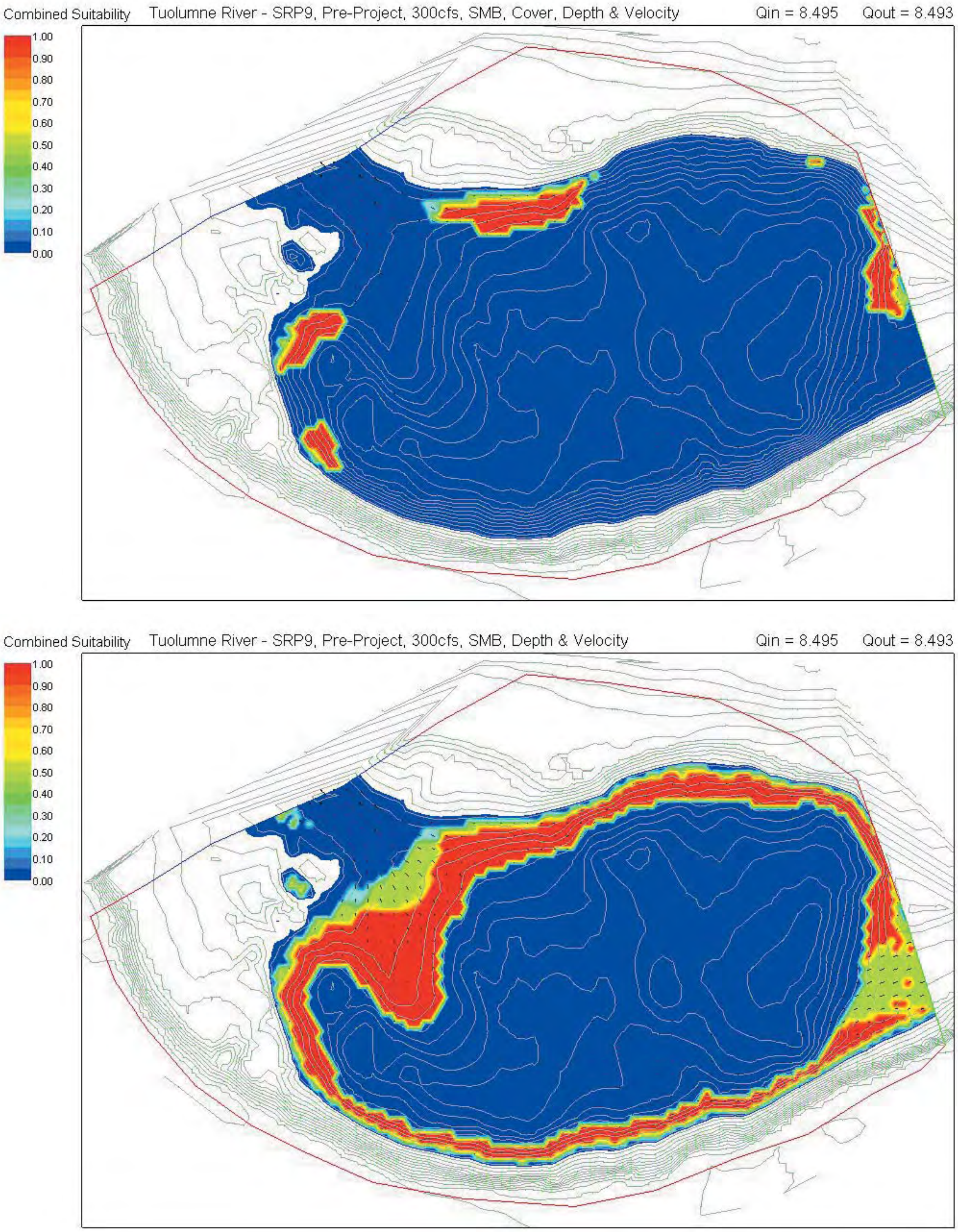


Figure 2-22. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 300 cfs.

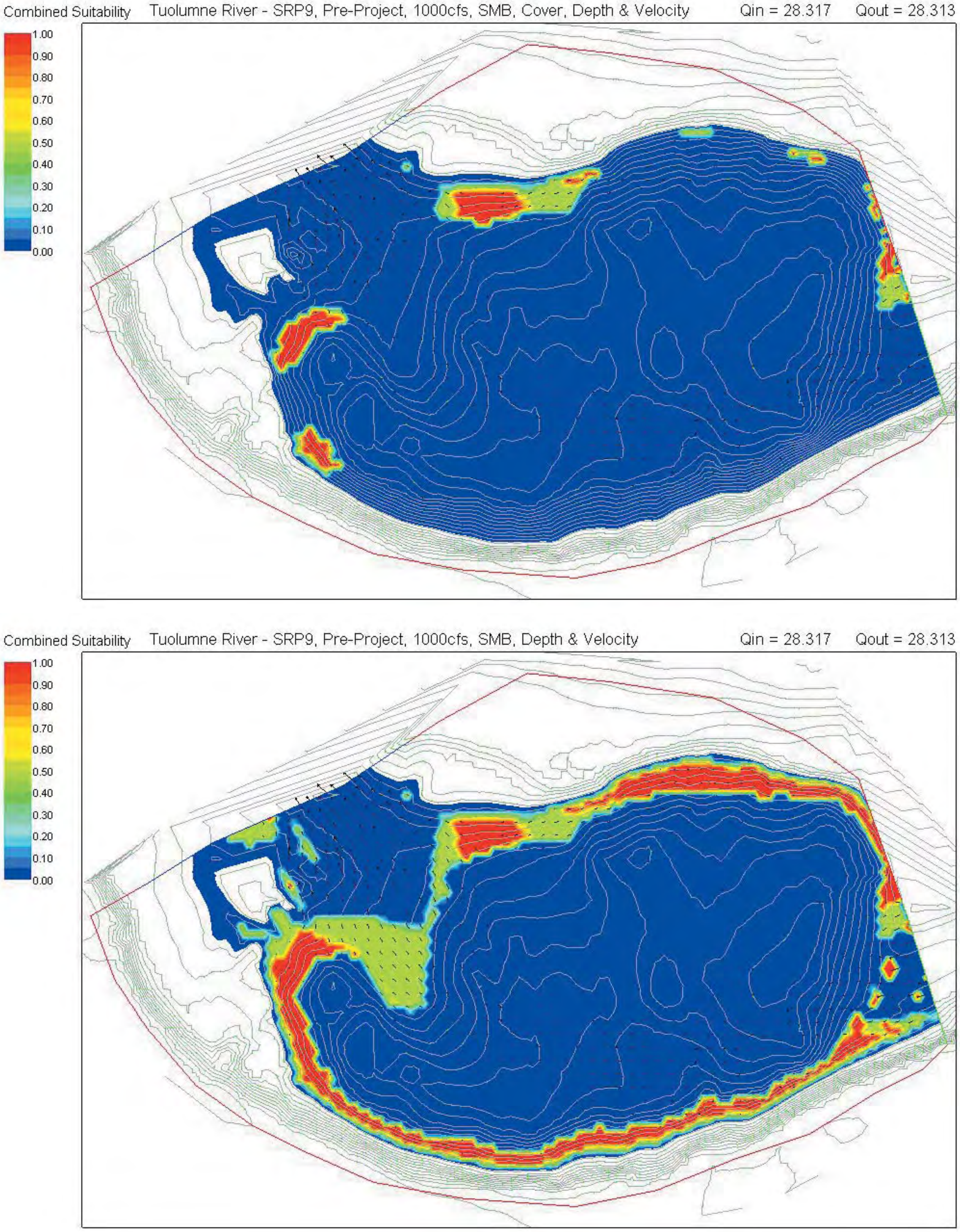
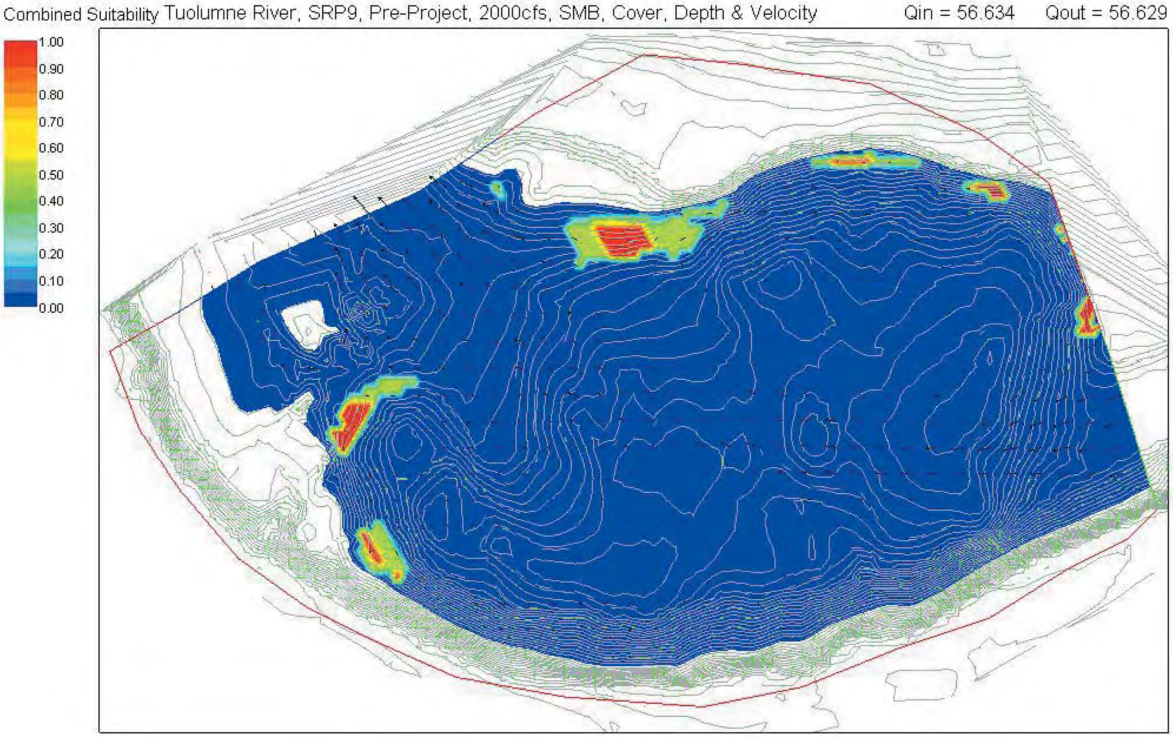


Figure 2-23. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 1,000 cfs.



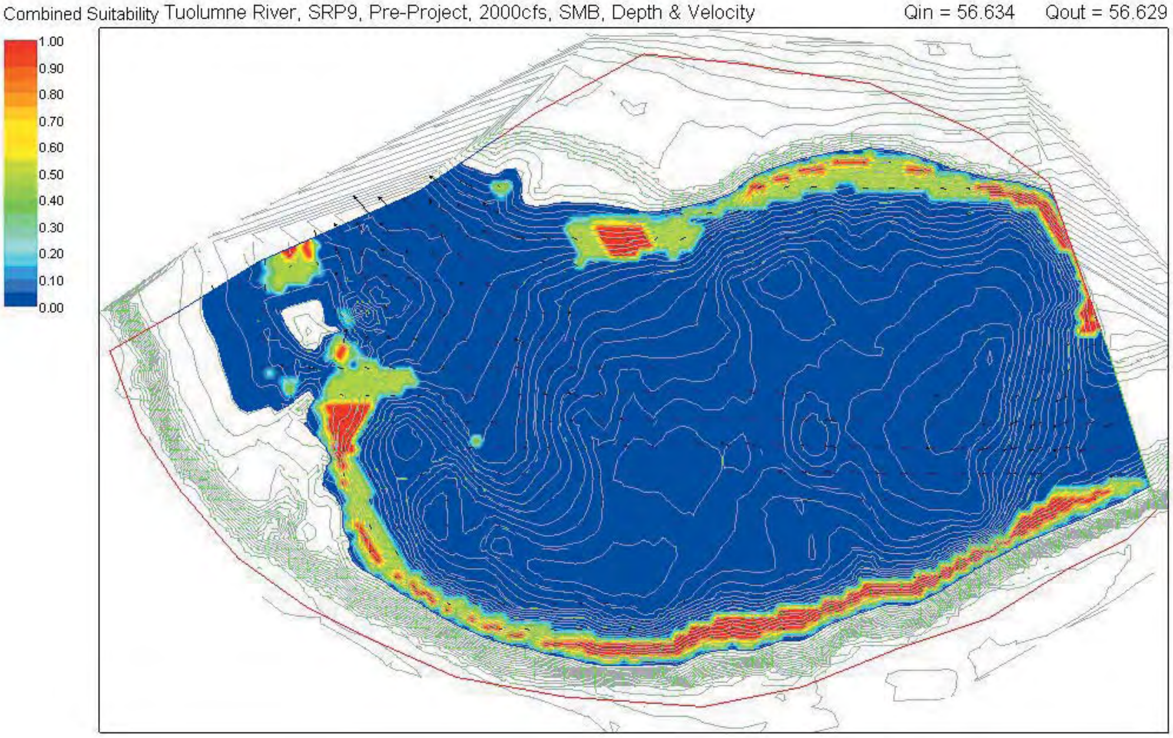
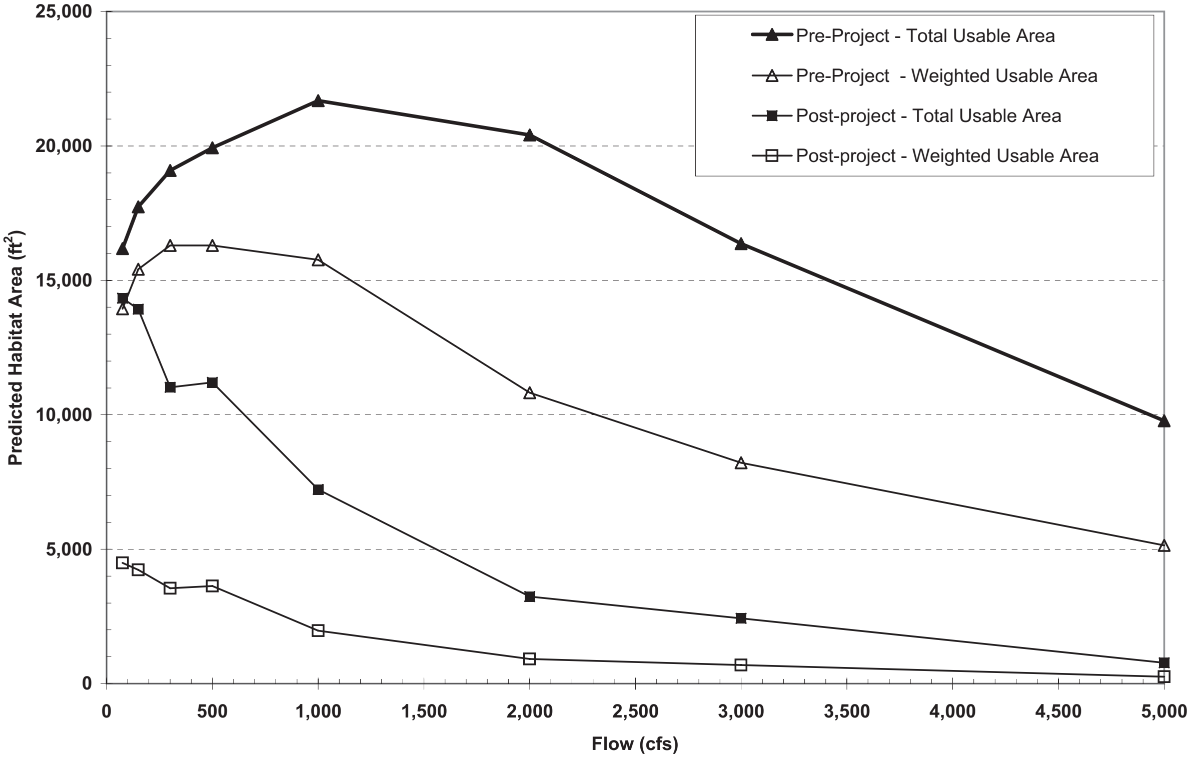


Figure 2-24. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9 for flows of 2,000 cfs.



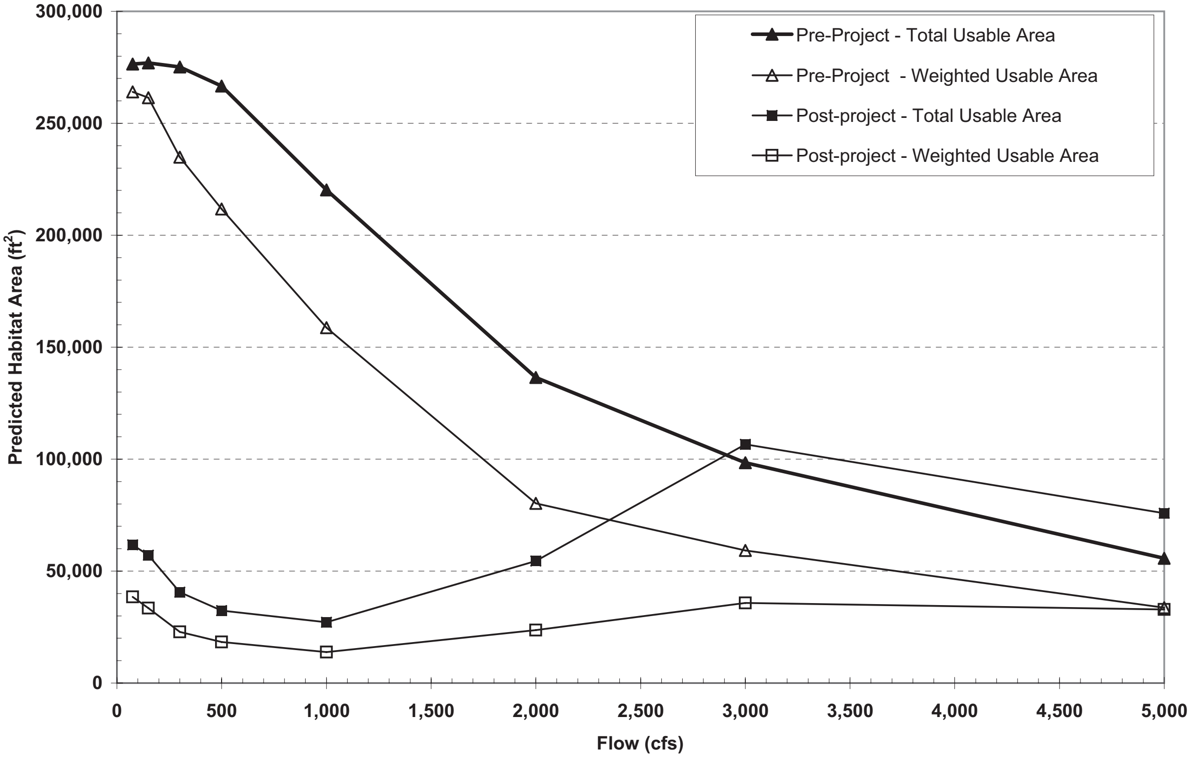
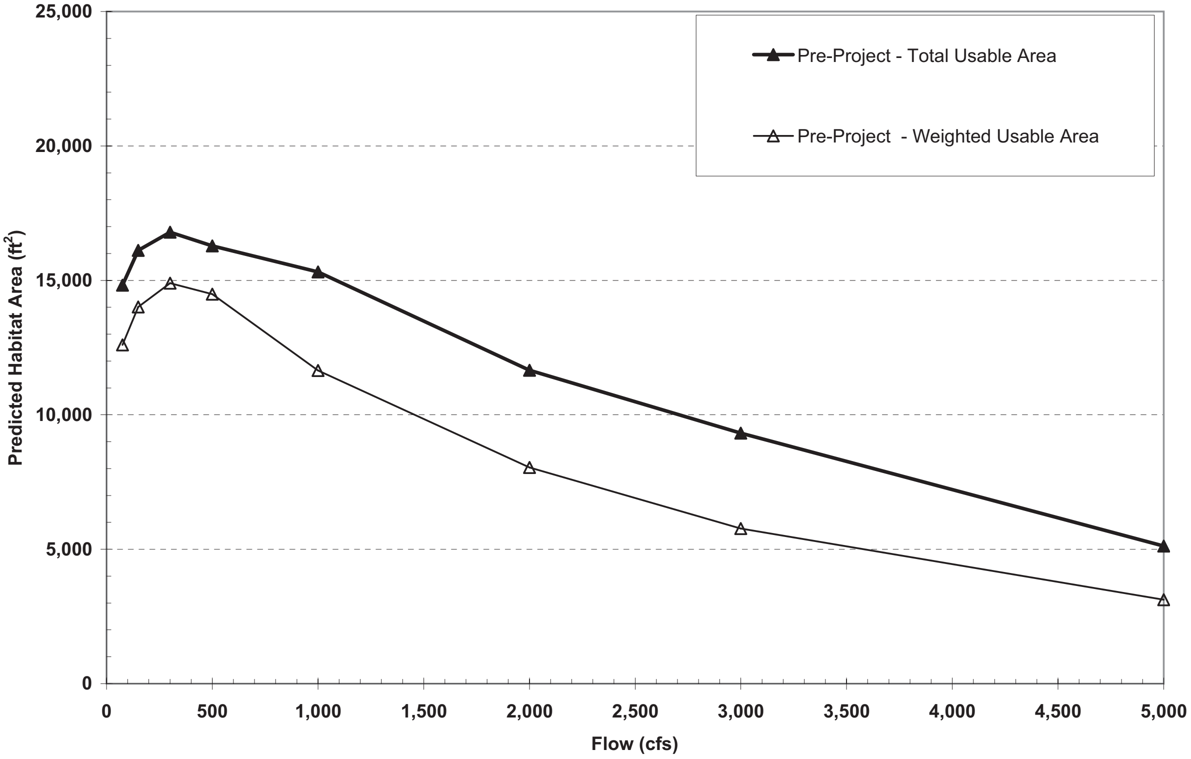


Figure 2-25. Predicted pre-project and post-project largemouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9.



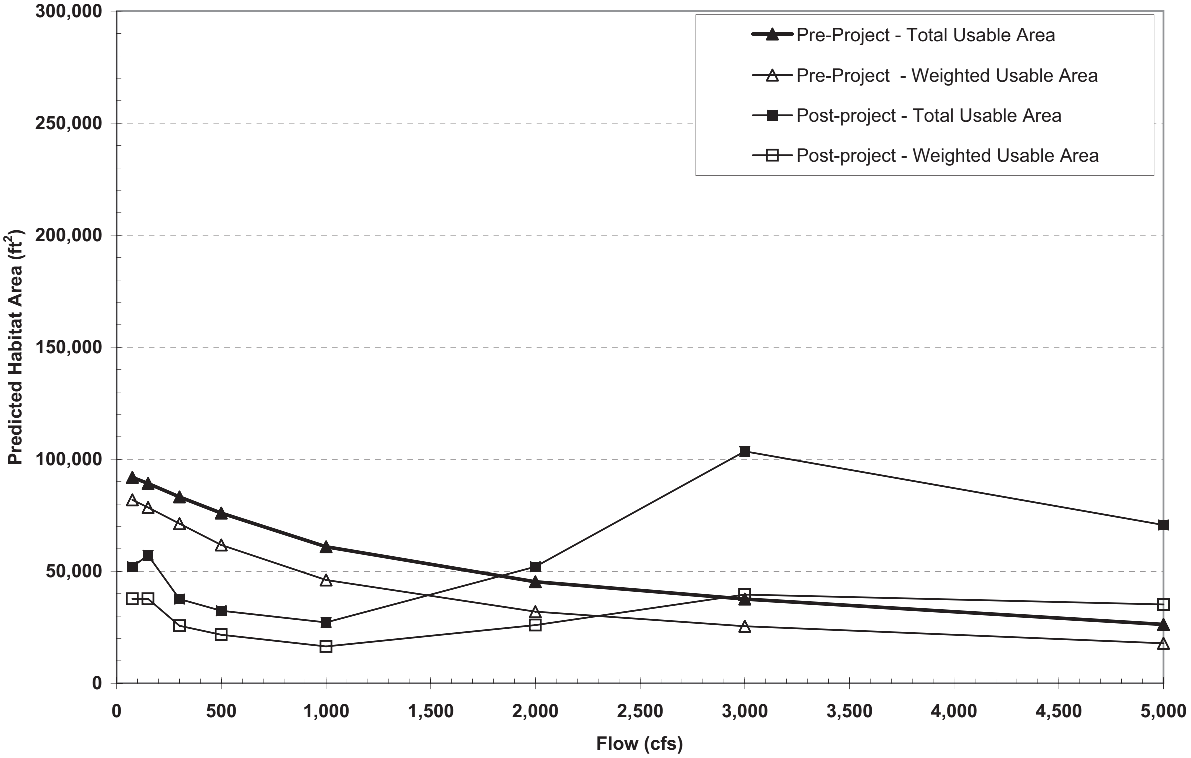
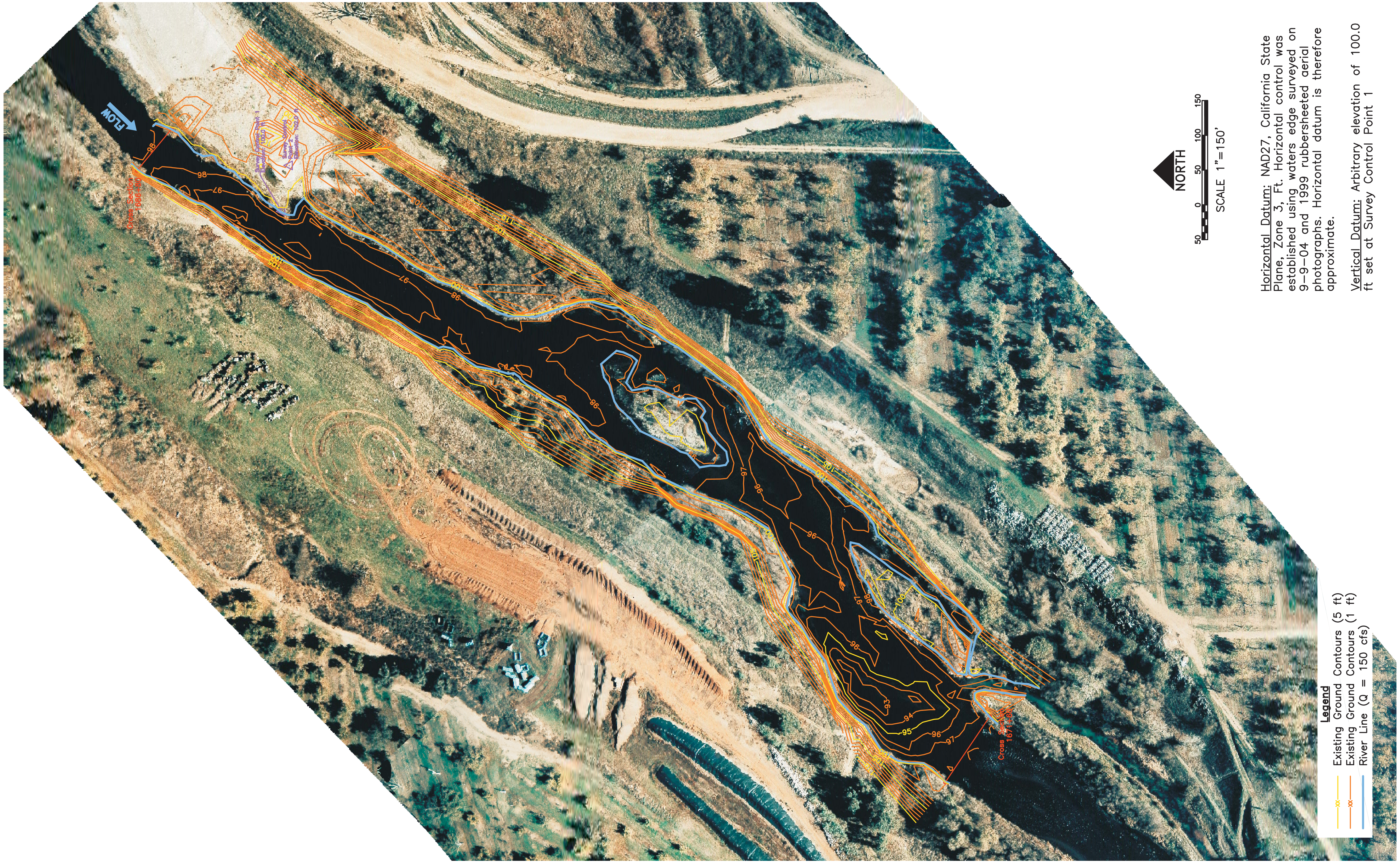


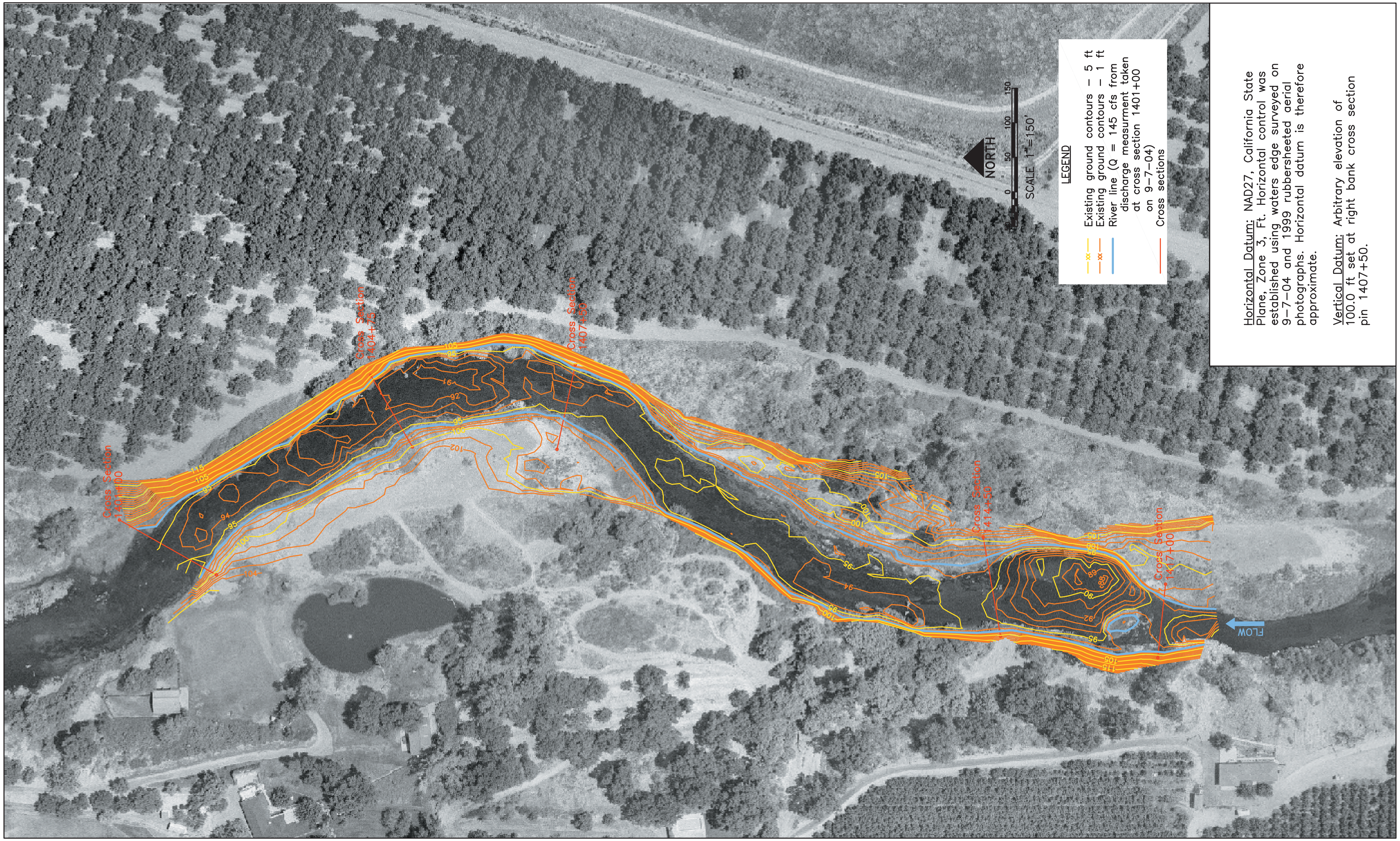
Figure 2-26. Predicted pre-project and post-project smallmouth bass primary habitat (top) and secondary habitat (bottom) at SRP 9.



Horizontal Datum: NAD27, California State Plane, Zone 3, Ft. Horizontal control was established using waters edge surveyed on 9-9-04 and 1999 rubbersheeted aerial photographs. Horizontal datum is therefore approximate.

Vertical Datum: Arbitrary elevation of 100.0 ft set at Survey Control Point 1

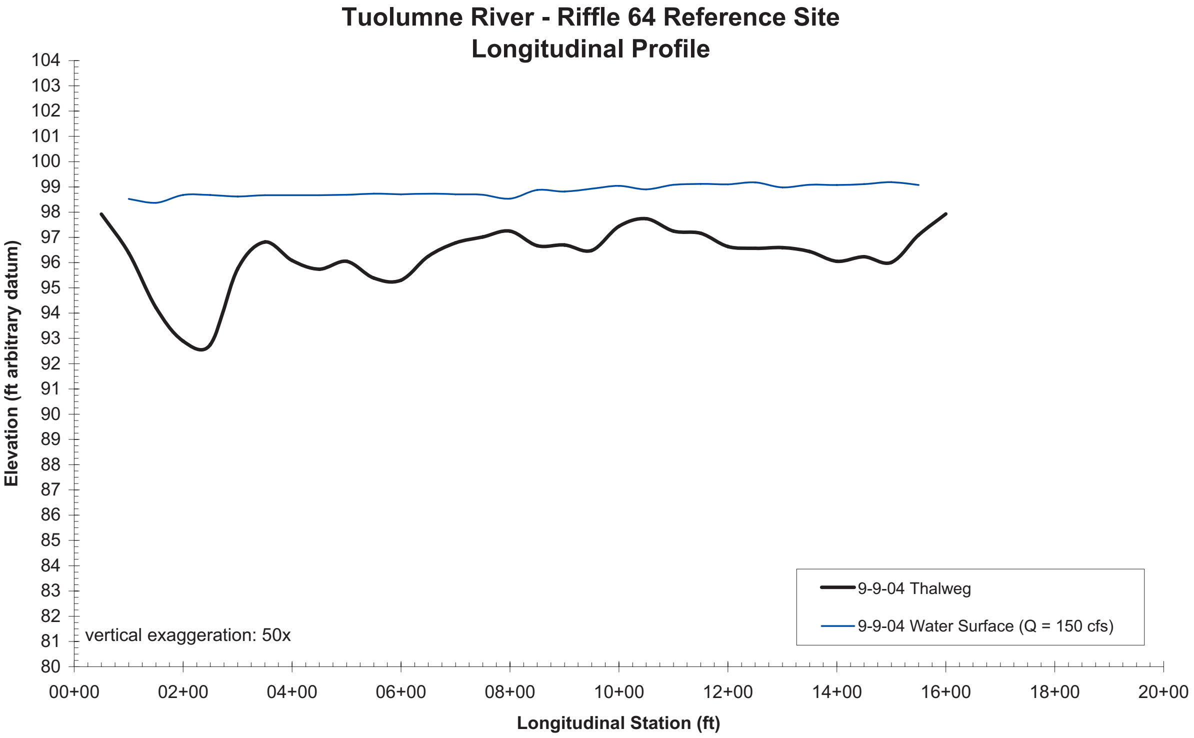
Figure 2-27. Floodplain topography and channel bathymetry at Riffle 64.



Horizontal Datum: NAD27, California State Plane, Zone 3, Ft. Horizontal control was established using waters edge surveyed on 9–7–04 and 1999 rubbersheeted aerial photographs. Horizontal datum is therefore approximate.

Vertical Datum: Arbitrary elevation of 100.0 ft set at right bank cross section pin 1407+50.

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



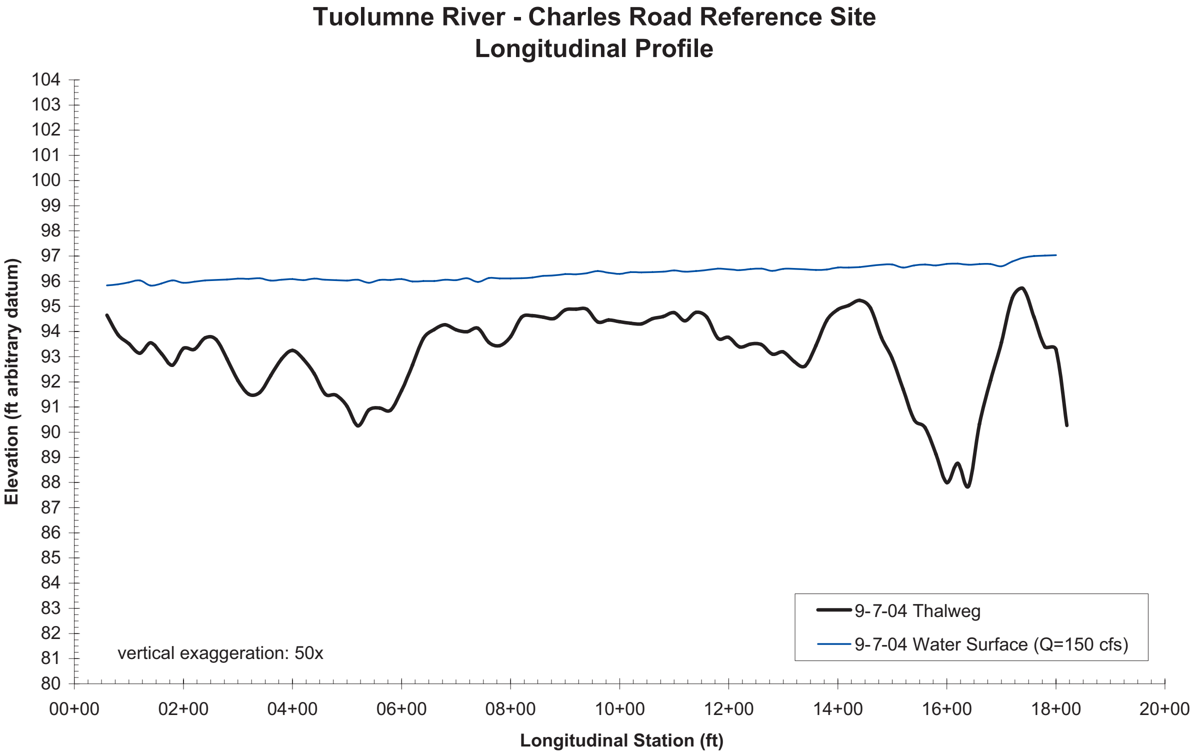


Figure 2-29. Thalweg and water surface profiles at Riffle 64 and Charles Road.

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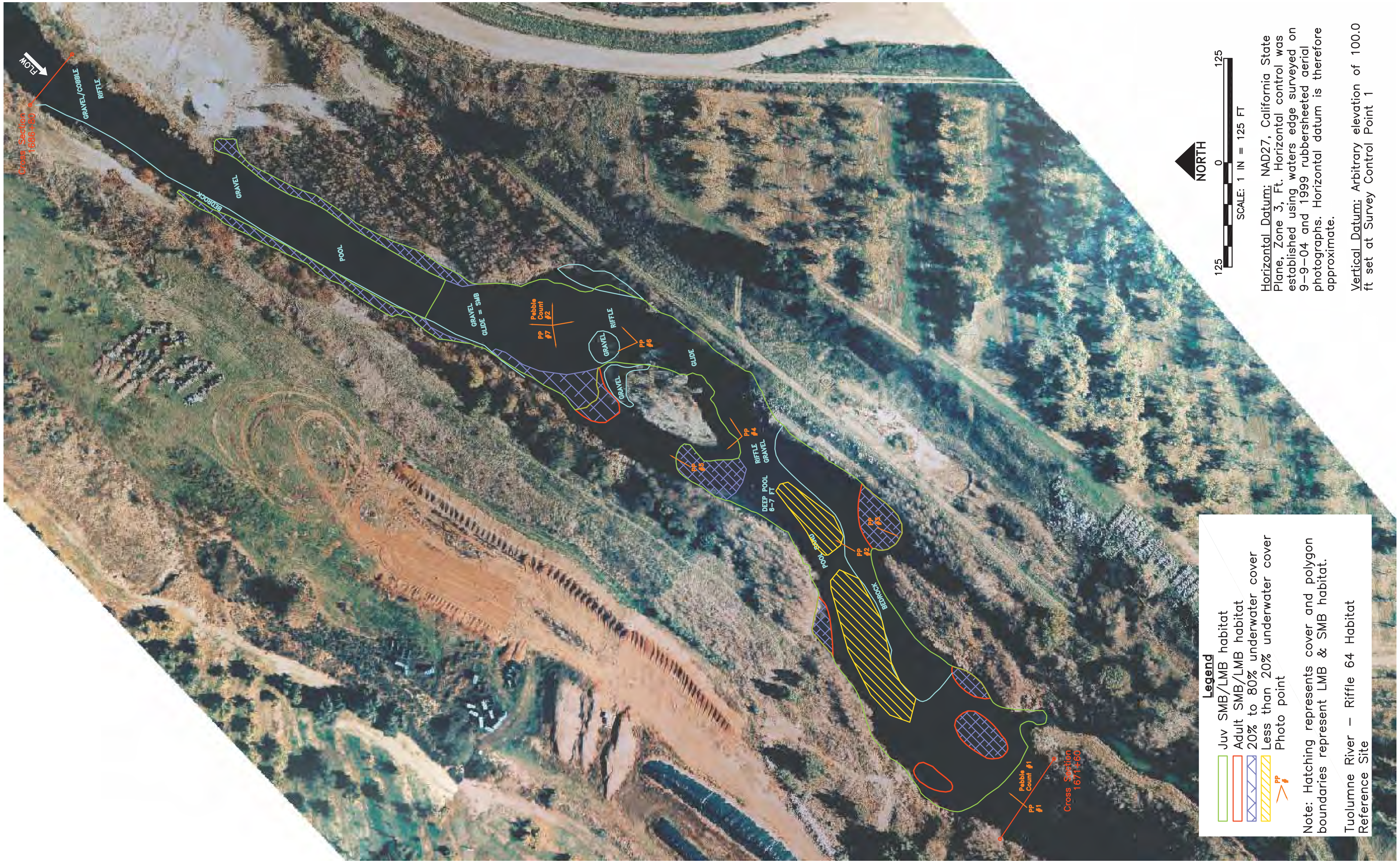

Figure 2-30. Largemouth and smallmouth bass habitat mapped at Riffle 64 during flows of 150 cfs (September 2004).

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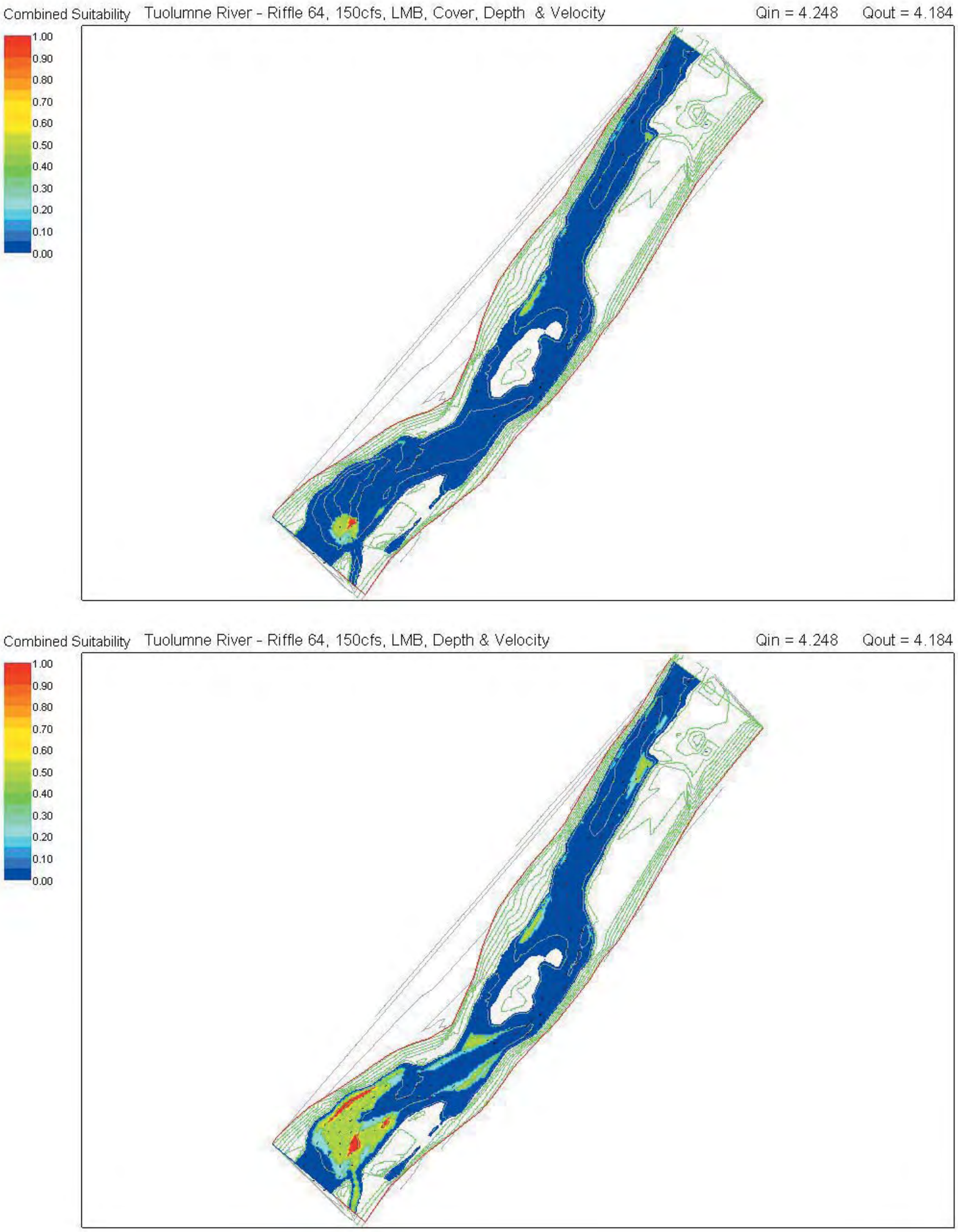

Figure 2-31. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at Riffle 64 for flows of 150 cfs.

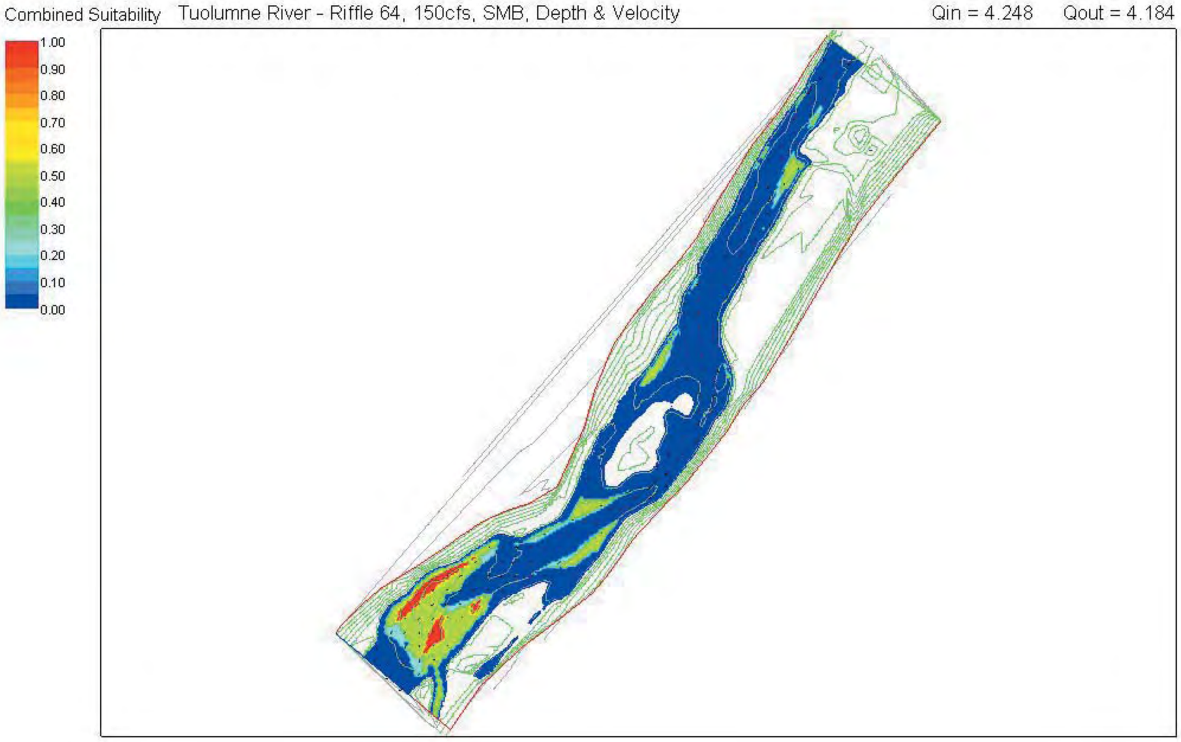

Figure 2-32. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at Riffle 64 for flows of 150 cfs.

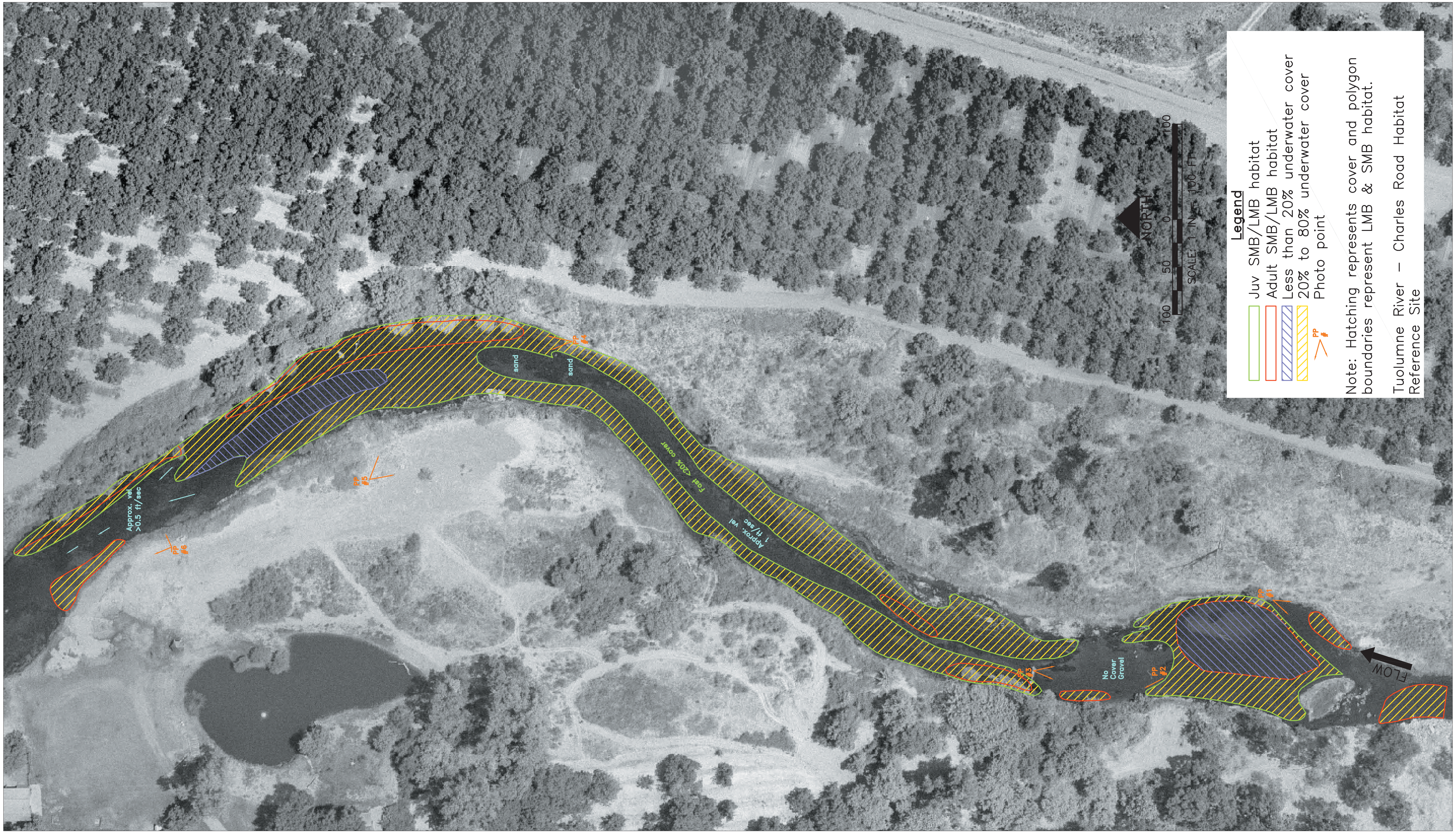

Figure 2-33. *Largemouth and smallmouth bass habitat mapped at Charles Road during flows of 150 cfs (September 2004).*

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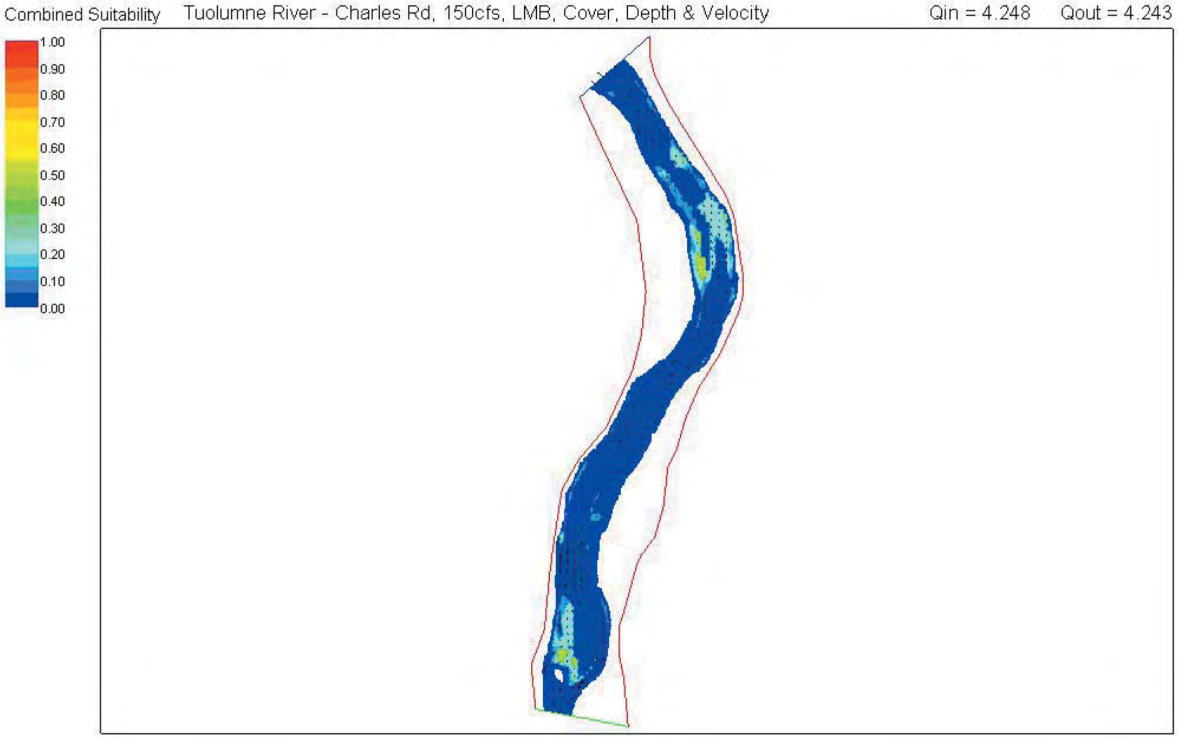


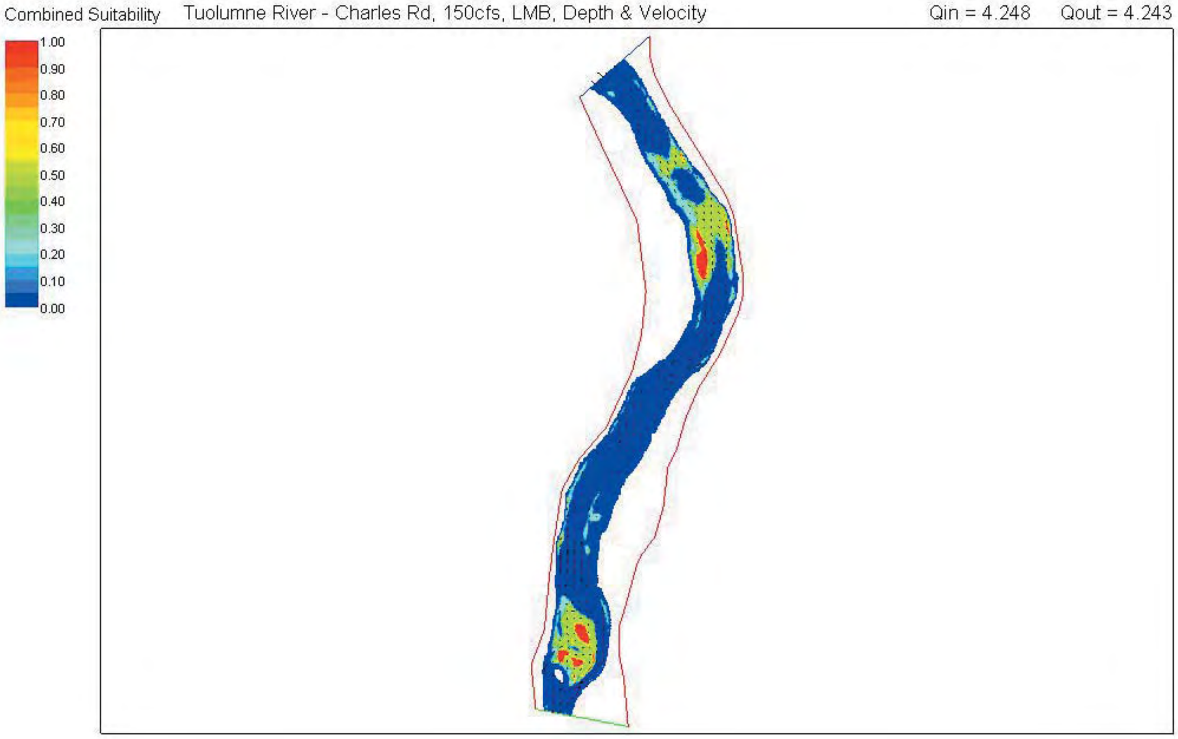
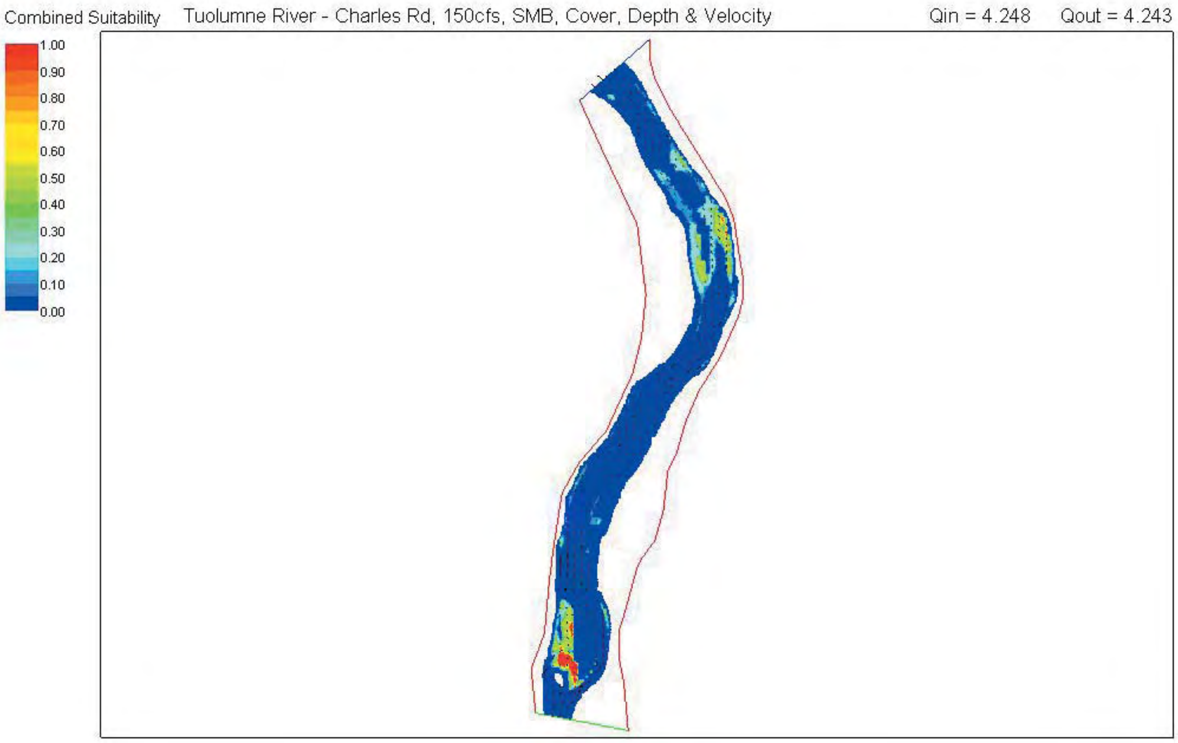


Figure 2-34. Predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at Charles Road for flows of 150 cfs.



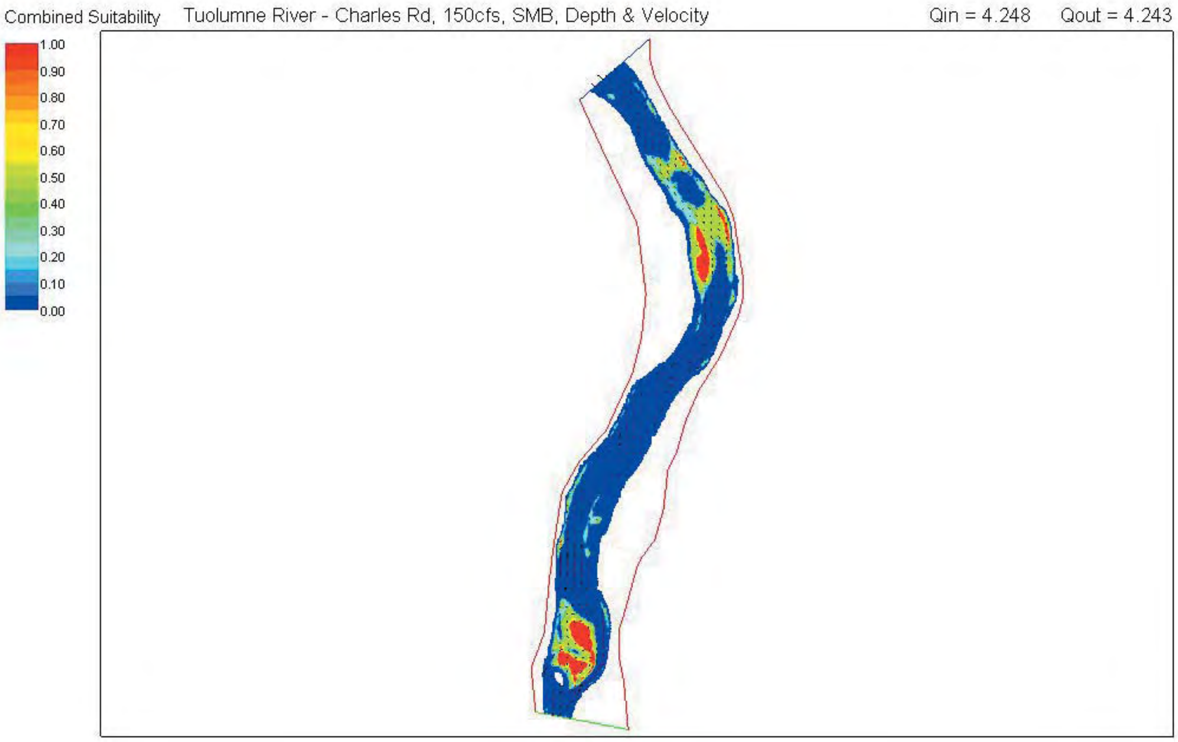
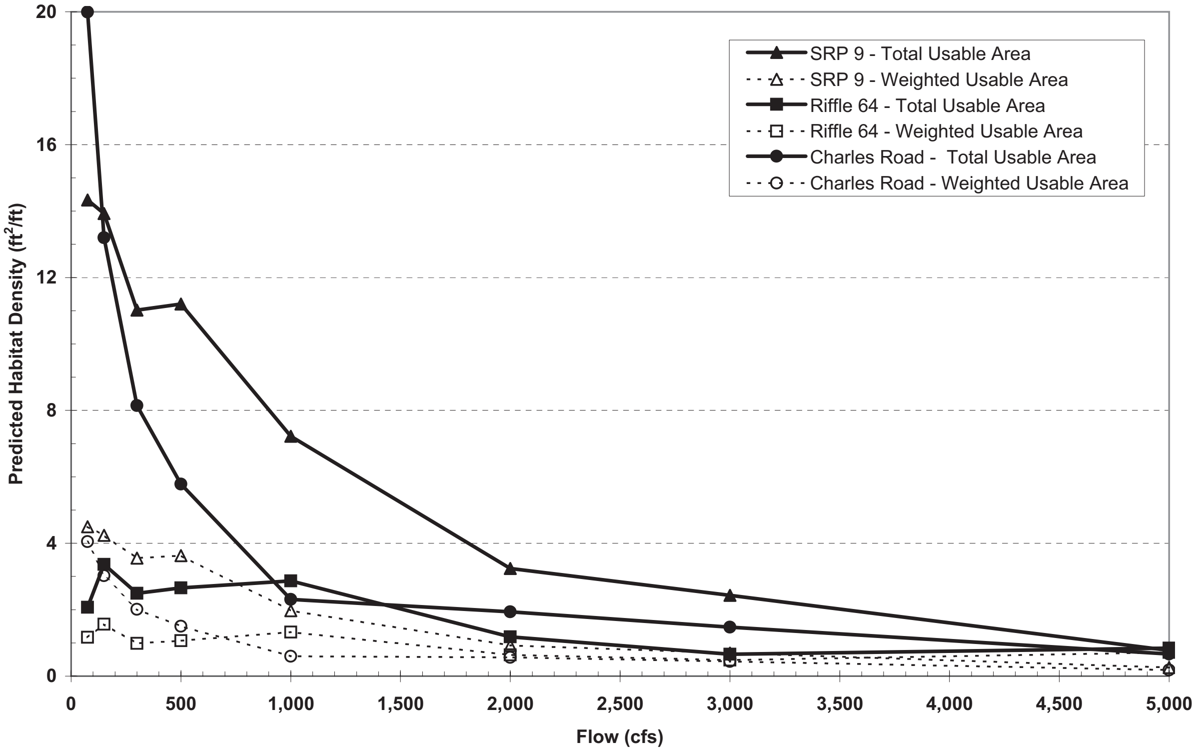


Figure 2-35. Predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at Charles Road for flows of 150 cfs.



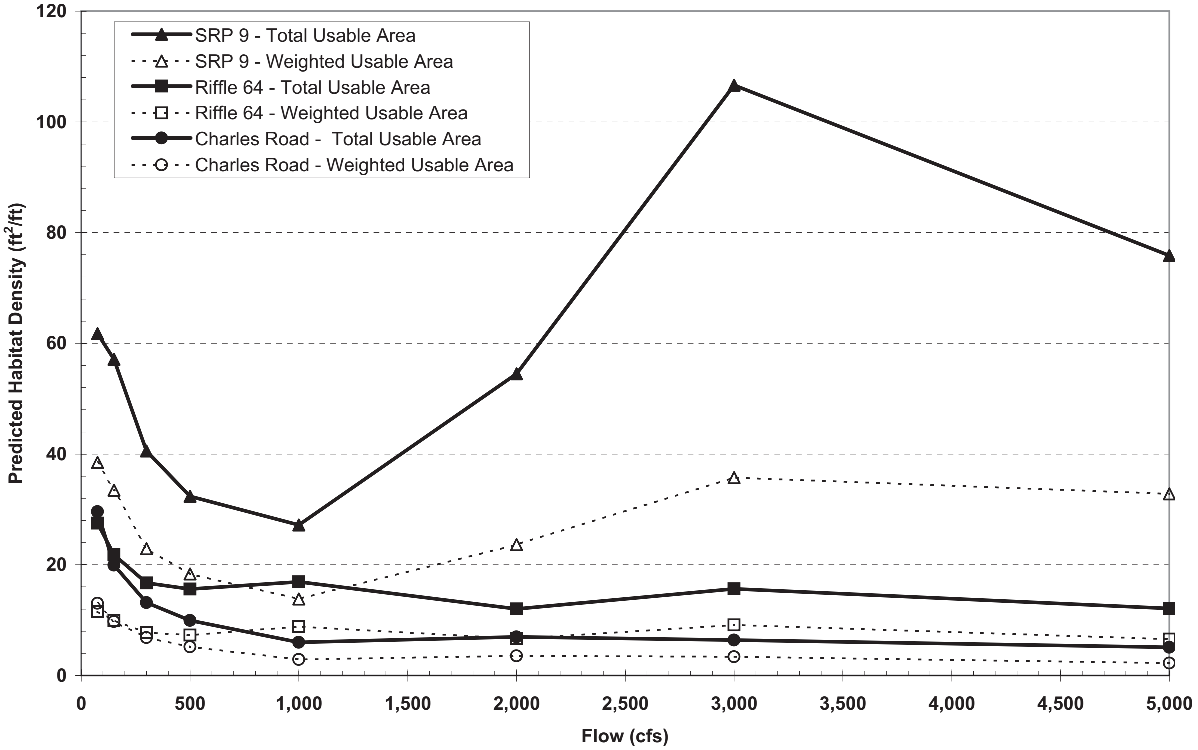
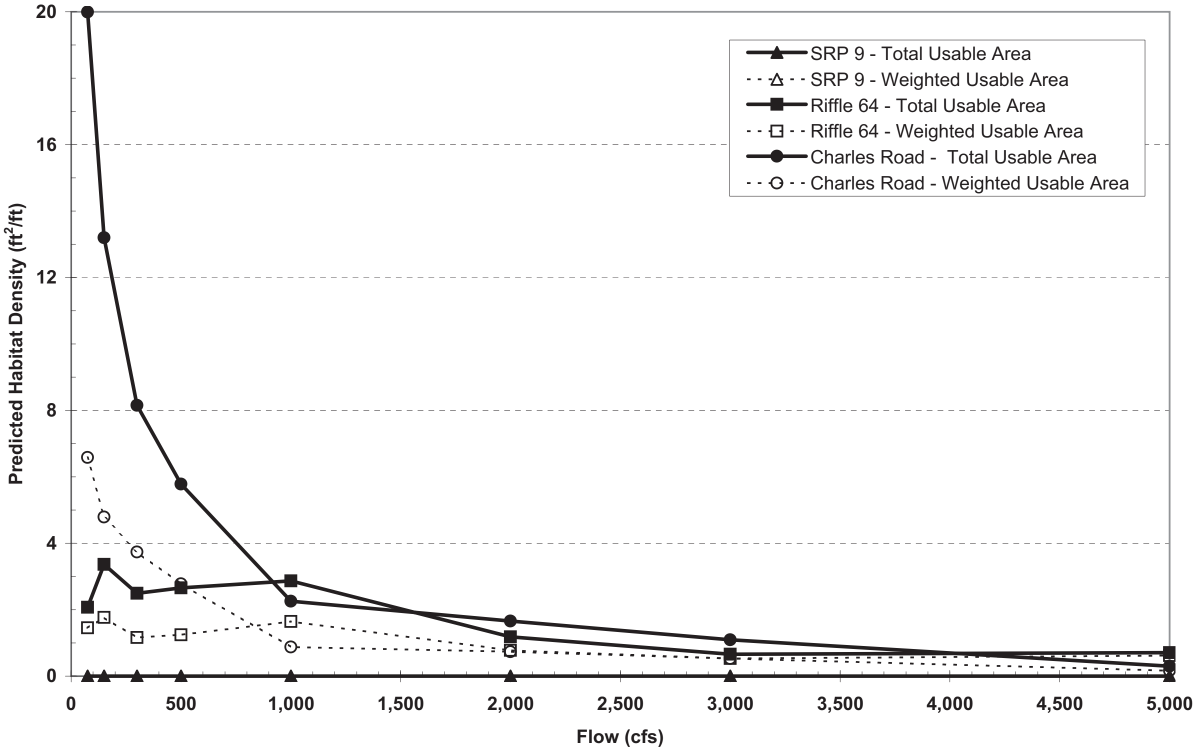


Figure 2-36. Comparison of predicted largemouth bass primary habitat (top) and secondary habitat (bottom) at the SRP 9 project site and Charles Rd. and Riffle 64 reference sites.



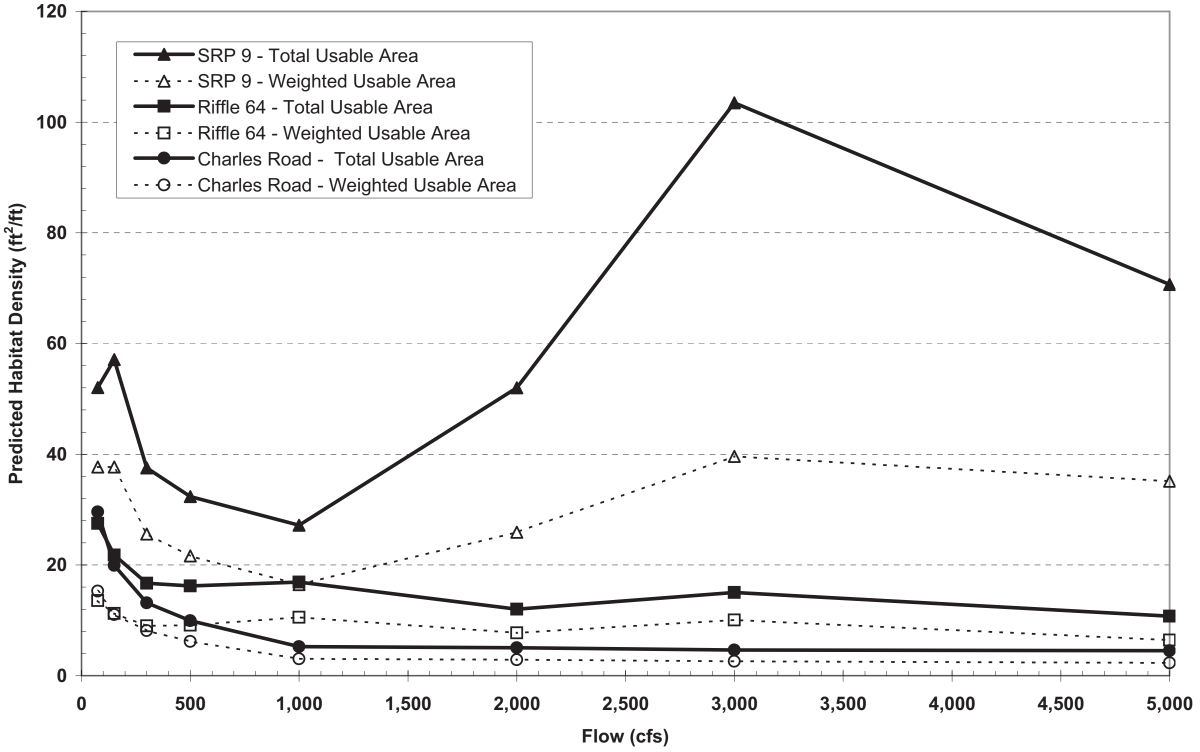


Figure 2-37. Comparison of predicted smallmouth bass primary habitat (top) and secondary habitat (bottom) at the SRP 9 project site and Charles Rd. and Riffle 64 reference sites.

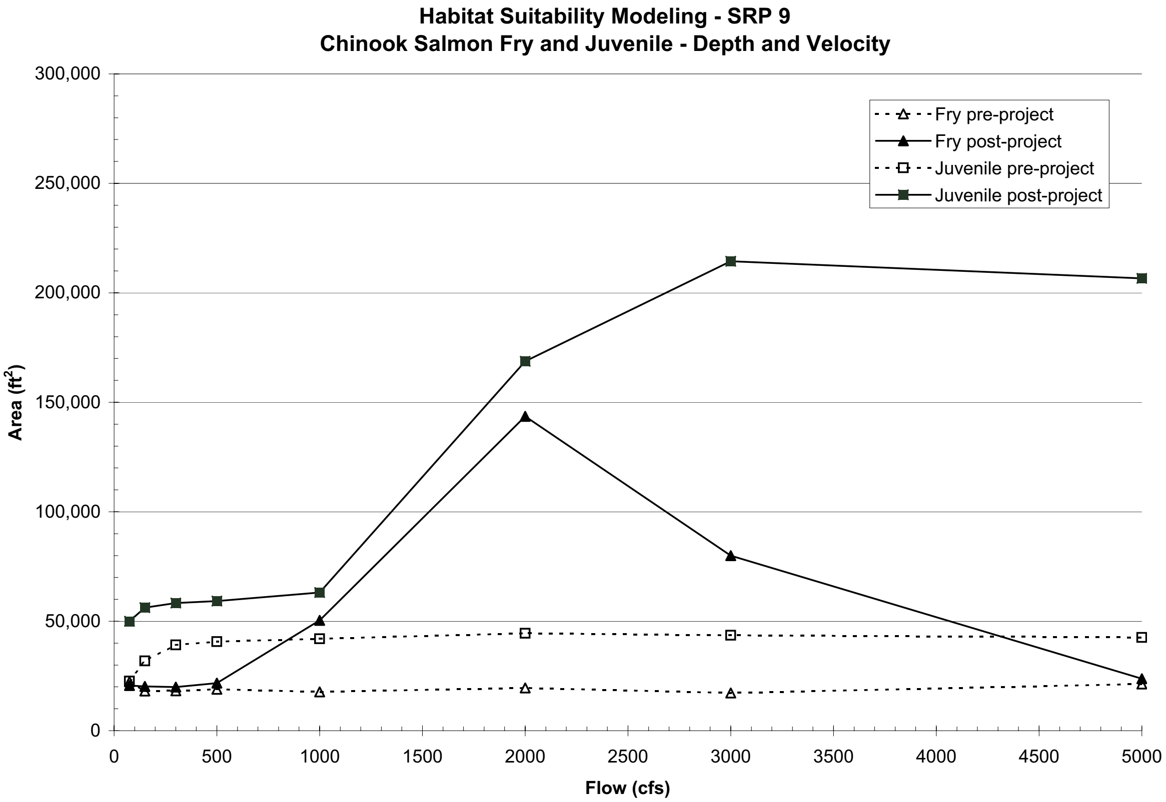


Figure 2-38. Predicted pre-project and post-project Chinook salmon fry and juvenile habitat at SRP 9.

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3 7/11 MINING REACH METHODS AND RESULTS

3.1 Flow Conditions since Project Construction

Tuolumne River flows and the timing of project construction and monitoring are shown in Figure 3-1. Water year conditions since project construction was completed were Below Normal (WY 2003), Dry (WY 2004), and Wet (WY 2005 and 2006). In WY 2003 and WY 2004, flow in the river was maintained at or near minimum flows required by the FSA, and annual peak flows occurred during spring pulses released for outmigrating juvenile Chinook salmon. Annual peak flows[5] 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 and did not exceed the 5,000-cfs threshold for post-project monitoring. In WY 2005, daily average flow exceeded 5,000 cfs for 27 days March–May[6]. Annual peak flow was 8,410 cfs (Q_{11}) (April 1, 2005). As of June 25, 2006, daily average flow in WY 2006 flow exceeded 5,000 cfs for 86 days, including 12 days in January and 74 days March–June. Flows are expected to continue to exceed 5,000 cfs into the summer 2006. Daily average flow peaked at 8,850 cfs on May 7, 2006. The effects of flow on interpreting monitoring results are discussed in Section 4.

3.2 Hydraulics and Channel Morphology (H1, H2, H3, H4)

3.2.1 Methods

Hydraulic and geomorphic monitoring 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 4.

3.2.1.1 Channel and Floodplain Surveys

Pre-project channel morphology was surveyed in 1998 and 1999. On August 10–11, 1998, twelve cross sections were established and surveyed during flows of 944 cfs (Table 28). Cross sections were resurveyed July 28-August 3, 1999, during flows of 254-277 cfs. Cross section elevation was surveyed using an auto-level and stadia rod; horizontal stationing was determined using a 300-foot tape stretched across the channel. Nine as-built cross sections (six pre-project and three newly installed) were surveyed on October 18, 2002, during a flow of 338 cfs (Figure 3-2, Table 28). The as-built thalweg longitudinal profile was surveyed on November 12, 2002, during a flow of 186 cfs. As-built cross sections and channel profile were surveyed using a total station.

All surveys are relative to the NGVD 1929 vertical datum. Post-construction total station surveys and end pin locations are also referenced to the NAD 83, California State Plane, Zone III coordinate system. Cross section endpoints were marked with 1/2-inch rebar. As-built cross section endpoints were also mapped by KSN Engineering using survey-grade kinematic GPS. Cross section naming follows the same stationing described for SRP 9 (Section 2.2.1).

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[5] Annual flow maxima at the U.S. Geological Survey streamflow gauge Tuolumne River below La Grange Dam near La Grange, Ca. (number 11289650).

[6] May 2005 high flows were released for bedload transport monitoring for the Tuolumne River Coarse Sediment Transfusion Project.

Table 28. 7/11 Reach pre-construction and as-built cross sections and years of survey.

Cross Section	**Year Surveyed**		
	1998	**1999**	**2002**
2141+60	●	●	
2147+00		●	
2162+20	●	●	●
2168+40	●	●	●
2176+00	●	●	
2181+00	●	●	●
2194+00	●	●	
2198+30			●
2199+20	●	●	●
2207+00	●	●	●
2208+60			●
2214+50	●	●	●
2221+10			●
2233+00	●	●	
2247+00	●	●	

Flow did not exceed the 5,000-cfs monitoring threshold during the funded monitoring period. Flow stage was surveyed at 1,030 cfs on April 23, 2003, the highest flow during the funded monitoring period. In 2005, flow stage was marked at each cross section in the project reach during flows released to monitor bedload transport for the Coarse Sediment Transfusion Project. Daily average flow during stage observations was 5,690 cfs on March 25 and 6,480 cfs on March 31. On April 1, stage was marked for a flow of approximately 8,400 cfs. Flow at La Grange on this date varied from 6,500 cfs to 8,410 cfs. Stage observations at the 7/11 Reach were timed to coincide with the peak release. Stage was marked with nails driven into trees on or near the cross section (left bank) and/or wooden stakes driven into the floodplain surface. Where possible, stage was measured at cross sections end pins, providing a stage elevation relative to NGVD 1929. Stage markers were not surveyed due to lack of monitoring funds. If funds become available, intact markers could be surveyed to determine stage elevation.

3.2.2 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 3-3. Pre-project, design, and as-built channel cross sections and channel profile are shown in Figures 3-4 and 3-5, respectively. Post-project aerial photographs, channel bathymetry, and floodplain topography data are available from work completed for the Tuolumne River Coarse Sediment Transfusion Project, including ½-ft resolution aerial photographs taken on September 21, 2005, during a flow of 330 cfs, 2-ft contour channel bathymetry surveyed in July 2005, and 2-ft contour interval floodplain topography constructed from LIDAR surveys conducted in September 2005. These 2005 data have not been analyzed due to lack of monitoring funds.

At 1,030 cfs, flow began to inundate lower portions of constructed lateral bars within the bankfull channel (cross sections 2214+50 and 2281+00) and was 3–4 feet below the constructed floodplain surface that extends from Station 2211+00 to Station 2190+00 (Figure 3-4). Stage was not recorded upstream of Roberts Ferry Bridge or downstream of the 7/11 haul road bridge.

The project constructed floodplains at four locations on the left bank in the project reach. The bankfull channel was designed to convey 5,000 cfs, with higher flows spilling over onto constructed floodplains. At 5,690 cfs, the floodplain upstream of Roberts Ferry Bridge (intersected by cross section 2247+00) was inundated to a depth of approximately 0.5 feet (Figure 3-6). Inundation depth increased to approximately 0.7 feet at 6,500 cfs and 1.6 feet at 8,400 cfs.

The constructed floodplain intersected by cross sections 2198+30 and 2208+60 was inundated during each of the three high flows observed. At 5,690 cfs, inundation extended across the floodplain to the base of the setback dike (Figures 3-7 and 3-8). Inundation depth at cross section 2208+60 was 0.7 feet. Inundation depth at cross section 2208+60 increased to 2.0 feet at 6,500 cfs and 2.5 feet at 8,400 cfs. In the high flow scour channel near cross section 2198+30, inundation depth was 2.5 feet during flows of 5,690 cfs.

The constructed floodplain on the upstream side of the 7/11 haul road was not inundated during flows of 5,690 cfs or 6,500 cfs (Figure 3-9). At 5,690 cfs, the margin of the floodplain was inundated, but most of the surface remained 1–3 feet above the flow stage. At 8,400 cfs, the surface was inundated and water was flowing through the culverts in the reconstructed haul road. Flow depth in the culverts was 0.2 feet (on the downstream side).

The floodplain downstream of the 7/11 haul road was constructed by setting back the dike that isolated a mining pit from the river channel and by filling the portion of the pit on the river-side of the setback dike. Riparian vegetation along the channel was left in place. The constructed floodplain is approximately two feet lower than the riparian berm and connects to the river channel through a breach in the berm at the downstream end. For the flows observed, the floodplain was inundated as flow backed up through the breach. At 5,690 cfs, only the downstream end of this floodplain was inundated; depth was not recorded (Figure 3-10). At 8,400 cfs, inundation extended upstream to the 7/11 haul road.

3.3 Bed Texture and Mobility Thresholds (H2, H5)

3.3.1 Methods

In 1998, bed texture was mapped throughout the reach, and pebble counts were conducted at five locations, including two riffles and three lateral bars, to describe gravel and coarser facies units (Figure 3-2). In 1999, additional pebble counts were conducted at four riffles in the project reach (Figure 3-2). As-built bed texture was not mapped. As-built pebble counts were conducted in 2002 at two locations: cross section 2198+30 (Riffle 29B) and the constructed right bank lateral bar downstream of Roberts Ferry Bridge (cross section 2214+50). The as-built pebble count at Riffle 29B is represents texture of constructed riffles. The as-built pebble count on the lateral bar represents texture of constructed bars.

The Monitoring Plan specifies that tracer rock experiments be installed immediately following construction of each of the Gravel Mining Reach phases and monitored after each high flow event until mobilization is observed, with monitoring of up to three additional flow events to document sediment routing through pools. Tracer rocks experiments were installed on the left-bank bar at cross section 2198+30 (Riffle 29B) and the right bank bar at cross section 2214+50 in January 2005. Tracer rocks were grouped into “sets,” with each set consisting of the D_{84}, D_{50}, and D_{31} particle sizes of the bar surface as determined by the pebble counts at each location. The D_{84} represents the idealized bed framework (Church et al. 1987). The D_{50} and D_{31} represent finer framework particles. Marked rocks were painted yellow and placed at 3-foot intervals along each cross section. Rocks were placed into the bed surface to simulate the surrounding particle embeddedness. Marked rocks were recovered in September 2005; peak flow during the experiment was 8,410 cfs (April 1, 2005).

3.3.2 Results

Pre-project and as-built pebble counts are summarized in Table 29 and Figure 3-11. Complete results from pebble counts are shown in Figure 3-12. Average pre-construction D_{31}, D_{50}, and D_{84} at reconstructed riffles for which pebble counts were conducted (Riffles 30B and 29) were 35 mm, 47 mm, and 86 mm, respectively. As-built D_{31}, D_{50}, and D_{84} at Riffle 29B (a new riffle constructed by the project) was 26 mm, 34 mm, and 58 mm, respectively. Assuming that the texture of the constructed Riffle 29B is representative of riffle texture throughout the reconstructed reach, the project reduced D_{31}, D_{50}, and D_{84} by 9 mm (25%), 13 mm (28%), and 28 mm (32%), respectively, at constructed or reconstructed riffles relative to pre-project riffle texture. Texture at the constructed bar at cross section 2214+50 was coarser than the riffle texture. As-built D_{31}, D_{50}, and D_{84} were 27 mm, 38 mm, and 68 mm, respectively. Prior to construction, alluvial bars in this reach were extremely limited. No pre-project bar texture data are available. The 1998 facies map identifies the only pre-project bar in the reach (a mid-channel bar at Riffle 29) as “medium gravel.”

The *Coarse Sediment Management Plan for the Lower Tuolumne River* (McBain & Trush 2004b) recommends using two spawning substrate mixtures for coarse sediment augmentation – a standard mix that is suitable for Chinook salmon spawning and a finer mix that is suitable for both Chinook salmon and *O. mykiss* (Table 30). Coarse sediment used to construct riffles in the project reach (represented by texture at Riffle 29B) was consistent with these recommended mixtures, though the D_{31} was slightly coarser than both mixtures, and the D_{50} was slightly coarser than the finer mixture (Figures 3-11 and 3-12).

“Significant” particle mobilization is considered to have occurred when more than 80% of the D_{84} rocks are mobilized from the cross section. At cross section 2214+50 on the right bank bar , more than 93% of the marked rocks in each size class were mobilized by the 8,410-cfs flow, indicating significant mobilization of the bar (Table 31). At cross section 2198+30, only partial mobilization was observed for the same flow. At this cross section, 53% of the D_{50}, 73% of the D_{31}, and 20% of the D_{84} rocks were mobilized (Table 31). Increased floodplain width in this portion of the project reduces flow depth and bed shear stress during high flows, thus increasing flow magnitude required to mobilize the bed surface.

Table 29. 7/11 Reach pre-construction and as-built pebble count locations.

Station (feet)	**Riffle No.**	**Bed Texture (mm)**									**Comment**
		1998			**1999**			**2002**			
		D_{31}	**D_{50}**	**D_{84}**	**D_{31}**	**D_{50}**	**D_{84}**	**D_{31}**	**D_{50}**	**D_{84}**	
2135+00	R33B				46	62	95				on riffle
2141+60	R33A				40	71	105				on riffle
2147+00	N/A	33	55	101							on left bank bar
2162+20	R31B	33	43	77							on right bank bar
2162+20	R31B	55	69	99							on left bank bar
2171+00	R31				46	67	99				on riffle
2181+00	R30B	47	54	94							on riffle
2181+00	R30B				31	41	76				on riffle
2198+30	R29B							26	34	58	on riffle
2207+00	R29	30	48	81							on riffle
2207+00	R29				30	46	91				on riffle
2214+00	N/A							27	38	68	on left bank bar

Table 30. Recommended salmonid spawning gravel texture for coarse sediment augmentation.

Mixture	**Particle Size (mm)**		
	D_{31}	**D_{50}**	**D_{84}**
Standard Mix	25	37	77
Finer Mix	22	32	77

Table 31. Marked rocks mobilized in the 7/11 Reach in 2005.

Size Class	**% Mobilized**	
	XS 2198+30	**XS 2214+50**
D_{84}	20	93
D_{50}	53	100
D_{31}	73	100

3.4 Chinook Salmon Spawning and Rearing Habitat (H5, H6)

3.4.1 Methods

Habitat mapping recorded three categories of successively more detailed information: (1) mesohabitat based on the classification system developed by Snider et al. (1992), (2) microhabitat features such as flow depth and velocity, substrate facies, wetted channel boundaries, woody debris, and submerged and overhead cover, and (3) Chinook salmon spawning and rearing habitat boundaries. Mesohabitat classification system included four levels of spatial resolution, as follows (Table 32):

- **Level-1** (study reach) consists of the seven Tuolumne River subreaches described in the Restoration Plan.
- **Level-2** (major channel features) includes bar complexes, flatwater areas, and off-channel areas.
- **Level-3** (channel feature types) includes 10 channel types tiered hierarchically from level-2 categories.
- **Level-4** (habitat units) describes mesohabitat units typically found along the Tuolumne River corridor, including: pools (pool head, body, and tail, where distinguishable), riffles, glides, runs, deep and shallow backwaters, side-channels, Special Run Pools (SRPs), and off-channel gravel mining pits (assessed from photographs only).

Mesohabitat was mapped onto laminated aerial photographs. All mesohabitat polygons were digitized and entered into the Tuolumne River GIS. In-channel mesohabitat units were assigned unique identifiers based on their longitudinal distance from the San Joaquin River confluence rounded to the nearest 100 feet. For example, a riffle located 213,527 feet upstream of the San Joaquin confluence (i.e., Station 2135+27) was rounded to Station 2135+00 and named “2135” (the last two digits were dropped).

Chinook salmon spawning and rearing habitat was identified based on the meso- and micro-habitat conditions and habitat suitability criteria developed by the USFWS (1995) (Table 25). Depth and velocity criteria with suitability indices greater than 0.1 were used to define suitable spawning and rearing conditions. All substrate types had suitability indices of 1.0 for juvenile rearing habitat. Substrate type, therefore, was not used as a criterion for defining rearing habitat. Different field methods were used in 1998 and 1999/2002 to quantify Chinook salmon habitat in the project reach. In 1998, Chinook salmon spawning and rearing habitat area was extrapolated from measurements at 12 cross sections in the project reach. Flow depth and velocity were measured at each cross section, and habitat suitability was determined based on the criteria shown in Table 25. Habitat area was then extrapolated between the cross sections. In 1999 and 2002, the cross section approach was abandoned, and habitat was mapped for the entire reach. In 1999, habitat was mapped onto laminated aerial photographs using the criteria in Table 25. The boundaries of each habitat polygon were defined by measuring depth and velocity. Once boundaries were identified, each polygon was mapped by hand onto the aerial photograph map base. The same method was used in 2002, except a total station was used to map polygon boundaries rather than hand mapping onto aerial photographs. For each year, habitat polygons were entered into the Tuolumne River GIS and used to produce a set of habitat maps for the project reaches.

Pre-project habitat was mapped in August 1998 and August 1999 during flows of 1,050–1,680 cfs and 254–265 cfs, respectively. As-built habitat was mapped in October 2002 during a flow of 331 cfs and November 2002 during a flow of 187 cfs.

Table 32. Mesohabitat classification system used to map project reaches. Definitions are based on Snider et al. (1992) with some modification where needed to accommodate Tuolumne River conditions.

MESOHABITAT TYPE (Level)	**DEFINITION**
BAR COMPLEXES (2)	
Island Complex (3)	Stable island located in main channel; supports established riparian vegetation.
Mid-Channel Bar (3)	Temporary island located in main channel; generally lacks established riparian vegetation.
Lateral Bar (3)	Contiguous with one main-channel bank, does not span channel; less built up than island complex; lacks established riparian vegetation.
Channel-Spanning Bar (3)	Spans entire channel at approximate right angle.
Transverse Bar (3)	Spans entire channel at approximate acute angle.
FLATWATER (2)	
Channel Bend (3)	Main channel primarily curved.
Straight Channel (3)	Main channel primarily without curvature.
Split Channel (3)	Main channel split into two or more channels.
OFF-CHANNEL (2)	
Contiguous (3)	Off-channel area contiguous with main channel.
Non-Contiguous (3)	Off-channel area not contiguous with main channel.
HABITAT UNITS (4)	
Pool Head (4)	Transition area from fast water unit to a pool; water surface slope decreases and bed slope increases.
Pool Body (4)	Very slow velocity; generally contains deepest portion of pool.
Pool Tail (4)	Transition area into fast water unit; depth decreases and velocity increases.
Glide (4)	Relatively low gradient and below average depths and velocities; no turbulence.
Run (4)	Moderate gradient with above average depths and velocities; low to moderate turbulence.
Riffle (4)	Relatively high gradient with above average velocities, below average depths; surface turbulence and channel controls.
Backwater (4)	Low-velocity areas not contiguous with the main channel; often associated with downstream ends of lateral bars, often shaded by riparian vegetation. Can be designated Shallow or Deep Backwater.
Side-channel (4)	Small channel connected to the main channel, often formed as lateral scour channel on backside of gravel bars. Generally shallow depths and velocities, but distinct from backwaters by having some flow velocity.
Special Run Pool (4)	SRPs are in-channel aggregate extraction pits generally located in Subreach 4.
Off-Channel Pond (4)	Off-channel aggregate extraction pits isolated from the main channel by dikes or berms; generally located in Subreach 5.

3.4.2 Results

Habitat was mapped at similar flows in 1999 and 2003 and thus provides a suitable comparison of pre- and post-project conditions (Figure 3-13). Overall, project effects on mesohabitat were (Table 33 and Figure 3-14):

- reduced active channel area by 250,400 ft^2 (14%) by increasing channel confinement;
- reduced pool area from 71% of the reach (pre-project) to 60% of the reach (as-built);
- increased lateral bar area by 508,100 ft^2 (500%);
- increased riffle area by 30,200 ft^2 (62%);
- reduced shallow backwater area by 73,200 ft^2 but replaced this backwater with a high-flow channel on the floodplain;
- reduced mid-channel bar area by 66,600 ft^2 (72%); and
- increased floodway width to 450–500 feet and floodplain area (i.e., the area of floodplains inundated at 4,500–5,000 cfs) by 40 acres by setting back dikes that isolate aggregate mining pits from the river and filling mining pits within the floodway.

Table 33. 7/11 Reach pre-construction and as-built mesohabitat.

	1999[1]		**2002[1]**	
UNIT	**Area (ft^2)**	**%**	**Area (ft^2)**	**%**
Mid-channel Bar	92,155	5.0	25,556	1.6
Lateral Bar	1,162	0.1	509,285	32.2
Pool	1,298,877	70.9	941,168	59.5
Run	29,257	1.6	--	0.0
Riffle	48,862	2.7	79,071	5.0
Glide	289,672	15.8	27,733	1.8
Shallow Backwater	73,203	4.0	--	0.0
Total Mapped Channel	**1,833,189**	**100.0**	**1,582,812**	**100.0**

[1] In-channel habitat areas represent the reach from the upstream end of the project reach to the 7/11 haul road bridge. As-built in-channel habitat downstream of the 7/11 haul road bridge was not mapped.

Pre-project habitat mapping identified 236,274 ft^2 of Chinook salmon fry rearing habitat and 1.04 million ft^2 of Chinook salmon juvenile rearing habitat during a flow of 254–265 cfs (Table 34, Figure 3-15). Fry rearing habitat occurred along the margins of glides and pools and in shallow backwaters. Juvenile rearing habitat occurred in pools and along pool margins throughout the project reach. The only areas of the channel not mapped as suitable for juvenile rearing were the center of the channel between Riffle 29 and Riffle 30B, a portion of the pool downstream of Riffle 30B, and portions of Riffles 31B and 32.

During flows of 185 cfs, post-project habitat mapping identified 85,567 ft^2 of Chinook salmon fry rearing habitat and 549,737 ft^2 of juvenile Chinook salmon rearing habitat, 64% and 47% less than pre-project mapped habitat, respectively (Table 34, Figures 3-15 and 3-16). Post-project fry habitat extended in a continuous band along the wetted channel margin throughout the project reach, excluding the bioengineered bank revetment upstream of the 7/11 haul road bridge. Juvenile habitat occurred along the margins of the pool upstream of Riffle 29 and throughout pools and glides downstream of Riffle 29 (Figure s 3-15 and 3-16).

The reduction in low-flow Chinook salmon rearing habitat area may be misleading. The approach to the 7/11 Reach project was to: (1) setback mine-pit dikes from the river to increase floodway width, (2) replace long dredger pools with a more functional channel morphology by constructing riffles and lateral bars, and (3) construct floodplains long the left bank of the channel to increase bankfull

Table 34. Pre- and post-construction fry and juvenile rearing habitat area.

Habitat Type	**Habitat Area (ft²)**[1]		**% Change**
	1999 (254–265 cfs)	**2002 (185 cfs)**	
Fry Rearing	236,274	85,567	-64
Juvenile Rearing	1,044,253	549,737	-47
Total	1,280,527	635,305	-50

[1] In-channel Chinook salmon habitat areas represent the reach from the Roberts Ferry Bridge to the 7/11 haul road bridge. As-built Chinook salmon habitat was not mapped upstream of the Roberts Ferry bridge or downstream of the 7/11 haul road bridge, where project construction was limited to dike setbacks and floodplain grading.

channel confinement and improve high-flow habitat. By replacing pool area with lateral bars, riffles, and floodplains, the project reduced the total area mapped as suitable juvenile habitat but increased habitat quality. A complex riffle-pool morphology provides higher quality rearing habitat than continuous, long pools by increasing macroinvertebrate production and macroinvertebrate drift available to rearing juveniles. The habitat mapping methods used can quantify change in total habitat area but cannot assess change in habitat quality or carrying capacity. Also, the project is expected to increase fry and juvenile rearing area during flows that inundate constructed lateral bars and floodplains. Habitat mapping during flows of 185 cfs could not detect this effect.

The project increased Chinook salmon spawning habitat area by approximately 22,100 ft^2, or 172% (Table 35, Figure 3-16). Pre-project spawning habitat mapped in 1999 during flows of 254–265 cfs totaled 12,814 ft^2 and was limited to small patches at Riffles 29, 30B, 31A, and 32 (Table 35, Figure 3-15). Riffles 29 and 30 provided limited spawning habitat due to steep riffle slope and high water velocity. At Riffles 31A and 31B, flow depth and velocity were suitable for spawning, but riffle substrate was embedded and poor quality for spawning and incubation.

The project constructed two new riffles (Riffles 28C[7] and 29B), modified two existing riffles (Riffles 29 and 30B), and altered flow depth and velocity by increasing channel confinement at four riffles (Riffles 31, 31A, 31B, and 32). The project also attempted to reconstruct Riffle 30A, which was removed by the 1997 flood. Coarse sediment was added to the channel at the Riffle 30A location, but channel slope was not adequate to form a riffle. Post-project spawning habitat mapped in 2002 during flows of 187 cfs totaled 34,875 ft^2 and occurred at five riffles in the project reach (Table 35, Figure 3-15). All riffles in the project reach, except Riffle 32, provided suitable Chinook salmon spawning depths and velocity. Constructed riffles also provided clean (i.e., unembedded) spawning substrates. Slope at constructed riffles, however, was steeper than at heavily used spawning riffles near La Grange. Typical slope during spawning flows (~ 300 cfs) at project riffles was 0.005–0.01 compared to 0.0035 and 0.0009 at Riffles A7 and 1A, respectively (Figure 3-17).

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[7] Stanislaus County placed 200 yds^3 of spawning gravel at Riffle 28C as part of the Roberts Ferry Bridge reconstruction in September 1999 (Dennis Blakeman, CDFG, pers. comm. 2005). The restoration project reconfigured this riffle.

Table 35. Pre-construction and post-project spawning habitat area.

Riffle	Habitat Area				Project Action
	1999 (254–265 cfs)		2002 (185 cfs)		
	Riffle Area (ft^2)	Spawning Area (ft^2)	Riffle Area (ft^2)	Spawning Area (ft^2)	
28C	0	0	11,795	9,060	created riffle
29	8,059	2,526	9,421	5,262	modified riffle
29B	0	0	8,772	4,158	created riffle
30B	4,595	2,792	8,311	2,757	modified riffle
31A	7,049	4,508	11,674	7,130	None
31B	24,461	0	21,227	6,508	None
32	4,734	2,988	7,869	0	None
Total (Entire Project Reach)	**48,898**	**12,814**	**79,069**	**34,875**	

3.5 Spawning Counts

3.5.1 Methods

CDFG monitors Chinook salmon escapement each fall and winter. During the upstream migration and spawning period (mid-October through early January), CDFG conducts weekly surveys to count and tag carcasses, count live fish, and count redds at each riffle. For the survey, the river is divided into four reaches, and redds are counted from a drift boat by CDFG staff. The annual maximum redd count (i.e., the peak number of redds counted at each riffle during a single survey over the duration of each spawning season) was compiled from CDFG redd count data for project and control riffles for the period 1997–2005. Riffles 25, 26, 27, and 28A (all located upstream of the project) were used as controls.

3.5.2 Results

Considering only the reach in which riffles were added or reconstructed, the project appears to have nearly doubled Chinook salmon spawning use in the channel reconstruction reach (Table 36). From Roberts Ferry Bridge to Riffle 30B (i.e., at new and reconstructed riffles), the ratio of the number of redds (annual maximum redd count) to upstream control riffles increased from an average of 0.24±0.09 SE pre-project (1997–2001) to 0.43±0.01 SE post-project (2002–2005) (Table 36). For the entire project reach (i.e., Riffle 28C to Riffle 32), however, no significant difference in spawning use at project riffles relative to control riffles was detected. For the entire reach, the ratio of redds at project and control riffles averaged 0.76±0.26 SE pre-project (1997–2001) to 0.88±0.14 SE post-project (2002–2005) (Table 36).

These results should be interpreted with caution. While these redd counts provide important reach-scale data for assessing spawning distribution, differences in riffle naming systems and potential inaccuracy of the rapid drift boat counts make these data less usable at the individual riffle-scale. The redd counts are from drift boat surveys conducted by various CDFG staff over several years. CDFG recently compared their drift boat counts to site-intensive redd counts and concluded that drift boat surveys can severely undercount redds (CDFG 2004a). At low spawning densities, as occurred in the project reach, CDFG considers the drift counts to be fairly accurate (CDFG 2004b). Detailed redd counts and redd mapping at project and control riffles would provide a more accurate and robust assessment of Chinook salmon spawning. The Washington Salmon Recovery Board (2004) has developed a protocol for this type of monitoring that could be applied to the project with some modifications.

Table 36. Maximum weekly redd counts at project and control riffles.

Riffle No.[a]	**Peak Weekly Redd Count**								
	Pre-project					**Post-project**			
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Control Riffles									
25 [K2]	13	15	6	27	21	13	11	9	8
26 [L1]	11	12	6	30	19	9	6	5	8
27 [L2]	9	9	2	28	20	12	6	6	2
28A,B [L3]	0	4	1	20	7	0	4	8	5
New or Reconstructed Riffles									
28C [M1]						1	1		
29 [M2]	6	7	3	11	14	4	2	7	4
29B [N1]							3		
30A, B [N/A, N2]	6	5	0	5	0	10	5	5	6
Other Project Riffles									
31A, 31B [N3, N4]	11	10	9	19	47	17	7	8	3
32 [O1]	6	2	1	7	10	0	5	2	1
Reconstructed:Control	0.36	0.30	0.20	0.15	0.21	0.44	0.41	0.43	0.43
Project Reach:Control	0.88	0.60	0.87	0.40	1.06	0.94	0.85	0.79	0.61

[a] Riffle numbers use the "traditional" numbering system used on the Tuolumne River. Revised riffle numbers used by CDFG in 2002–2005 are shown in [brackets].

3.6 Riparian Resources

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 the 7/11 Reach to date. At this site, planting was conducted from February through April 2003, with additional follow-up planting in January 2004. Irrigation and plant maintenance ended September 30, 2004. 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 replacement of 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) have not been assessed.

The portion of the 7/11 floodplain that was lowered to be inundated at 4,500 cfs could provide a good opportunity to observe floodplain evolution (deposition, inundation frequency and duration, and riparian revegetation response) to compare evolution between the reaches. No monitoring is currently funded to test the effects of this change in floodplain design on riparian vegetation recruitment and establishment.

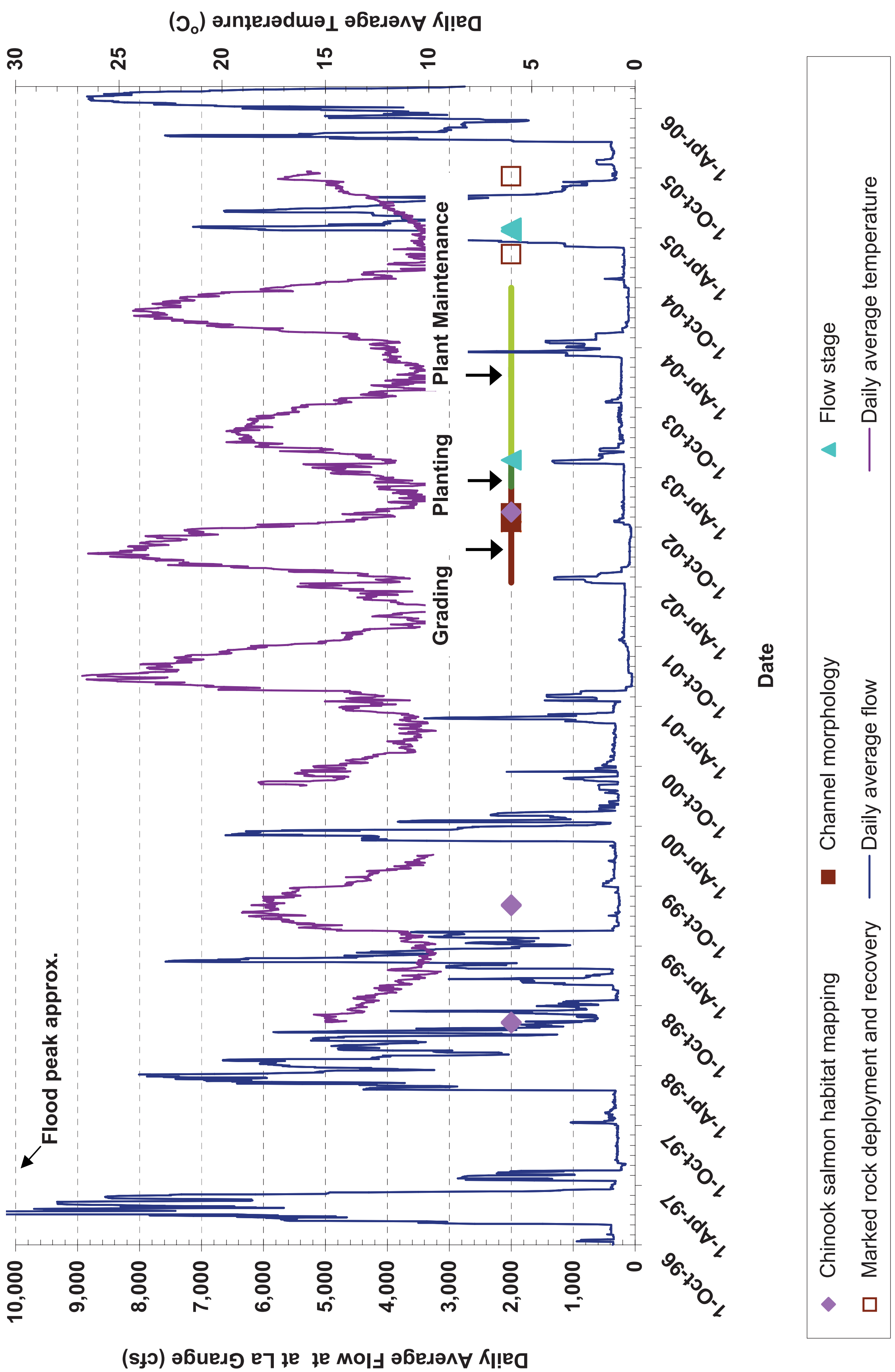

Figure 3-1. *Flow and temperature conditions relative to construction and monitoring at the 7/11 Reach. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA. Temperature data are from RM 39.5, TID unpublished data).*

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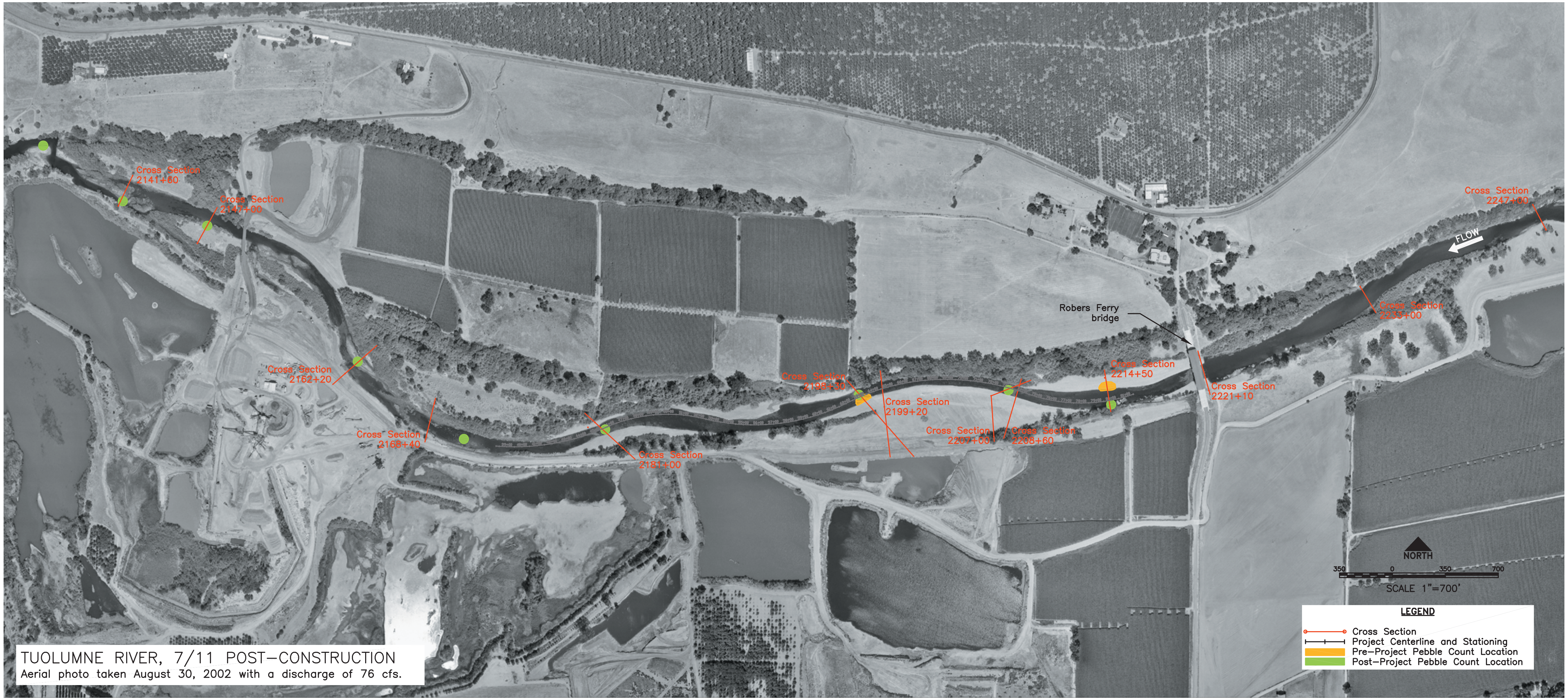

Figure 3-2. 7/11 Reach as-built and post-construction monitoring cross section locations.

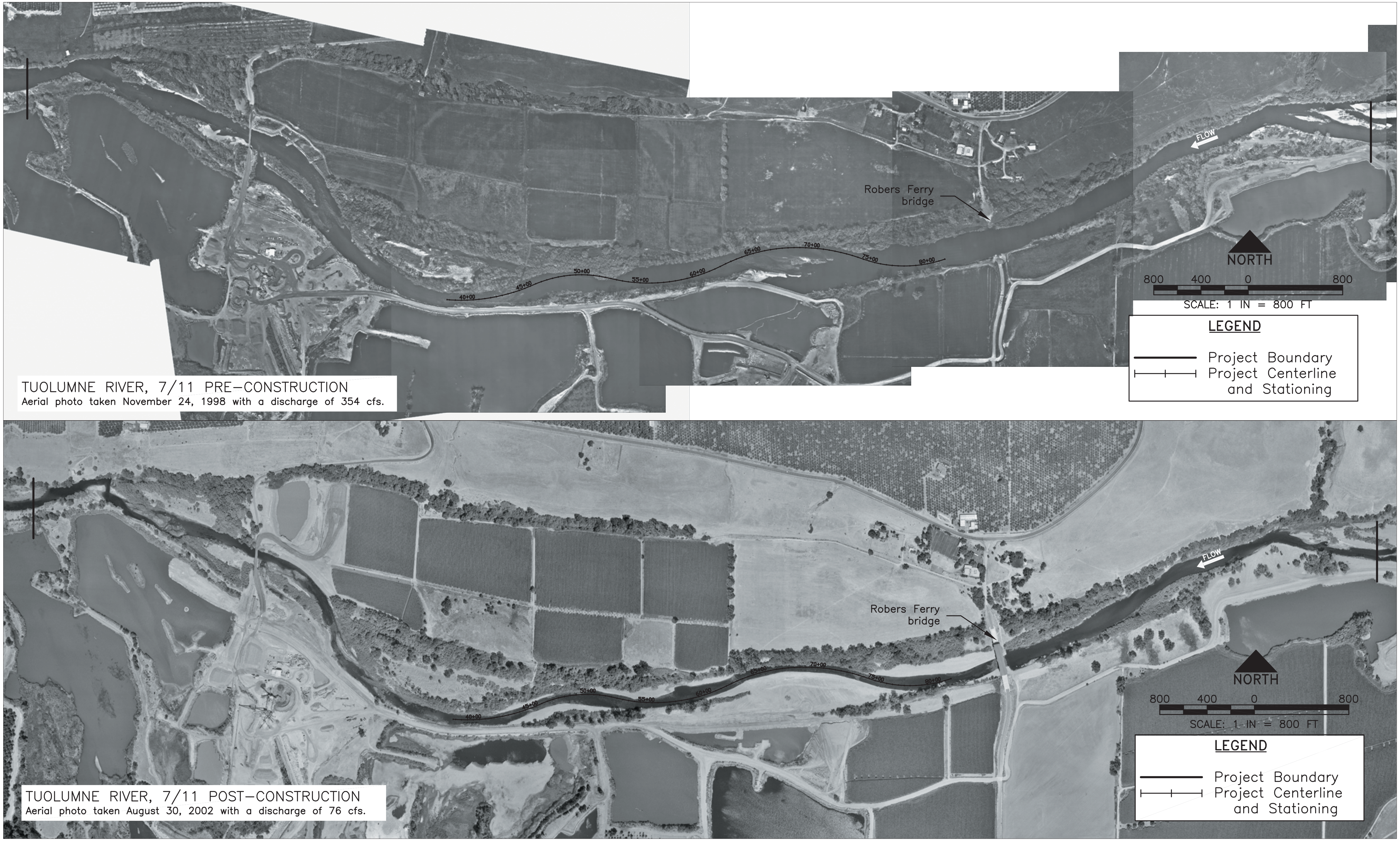

Figure 3-3. 7/11 Reach pre-project (1998), as-built (2002), and post-project (2005) aerial photographs.

Figure 3-3. 7/11 Reach pre-project (1998), as-built (2002), and post-project (2005) aerial photographs, continued.

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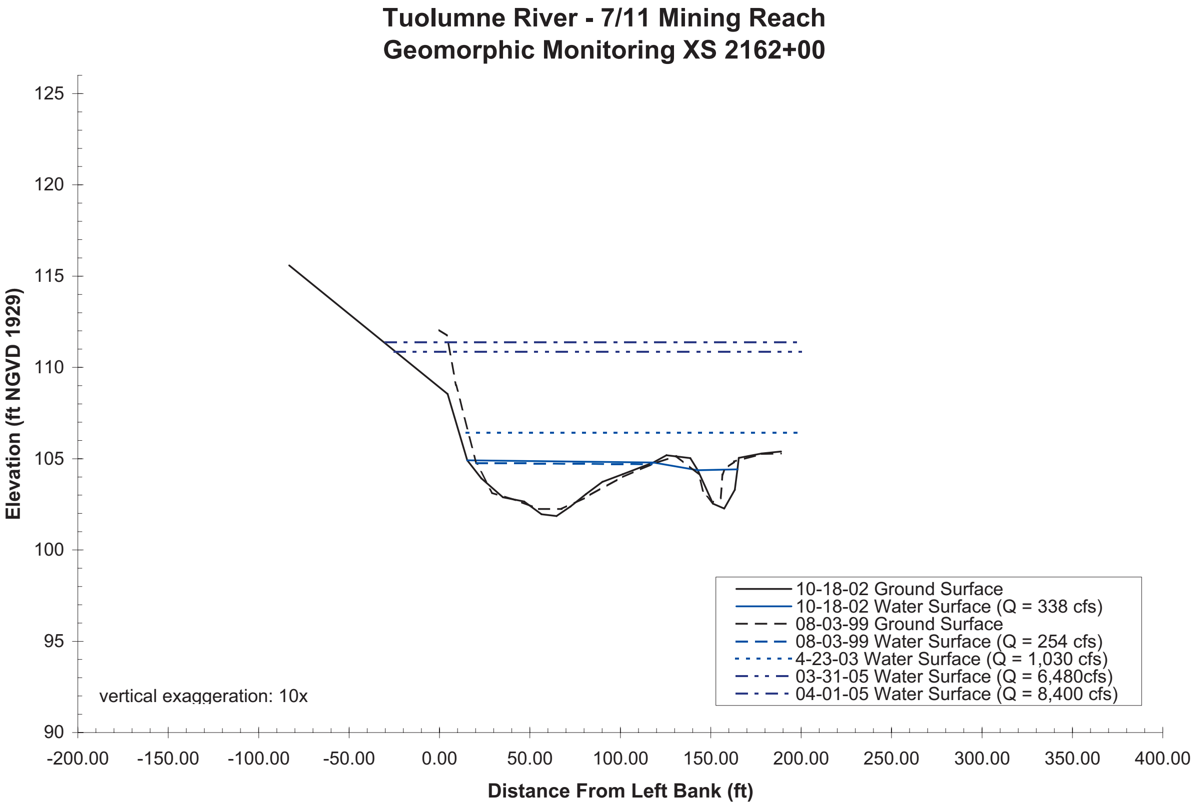


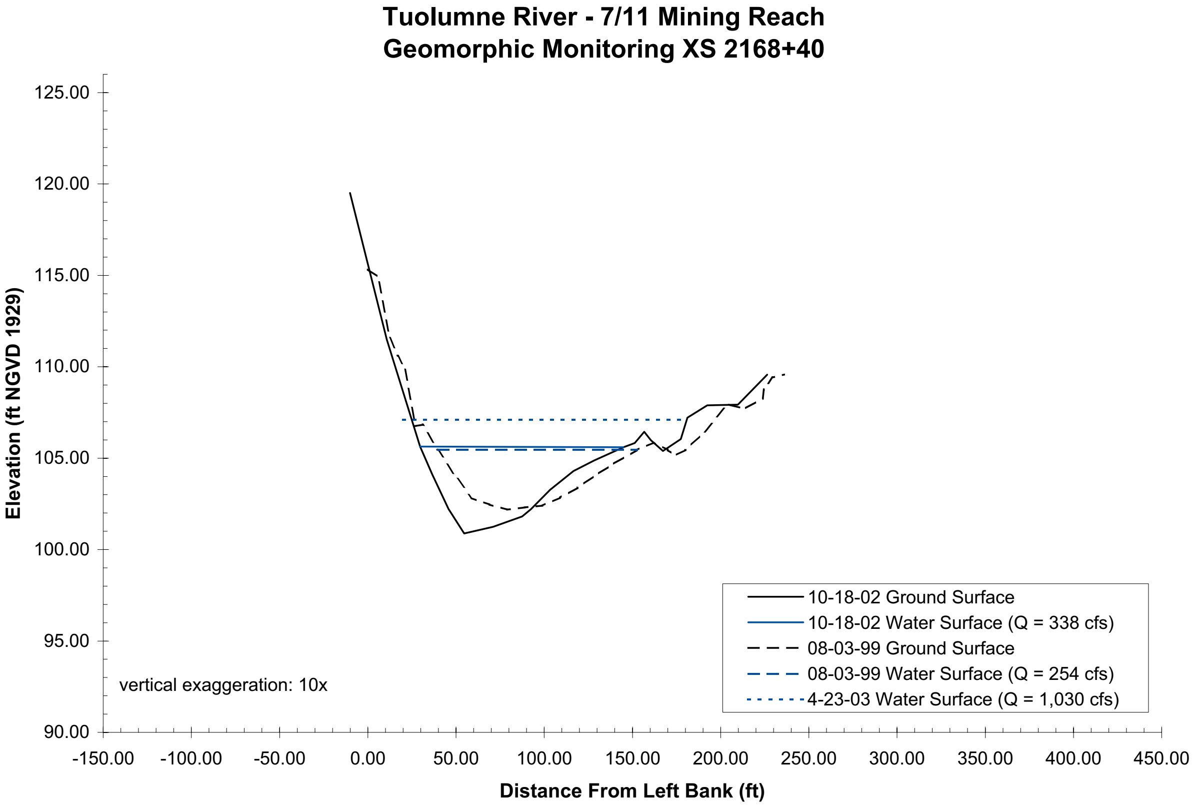
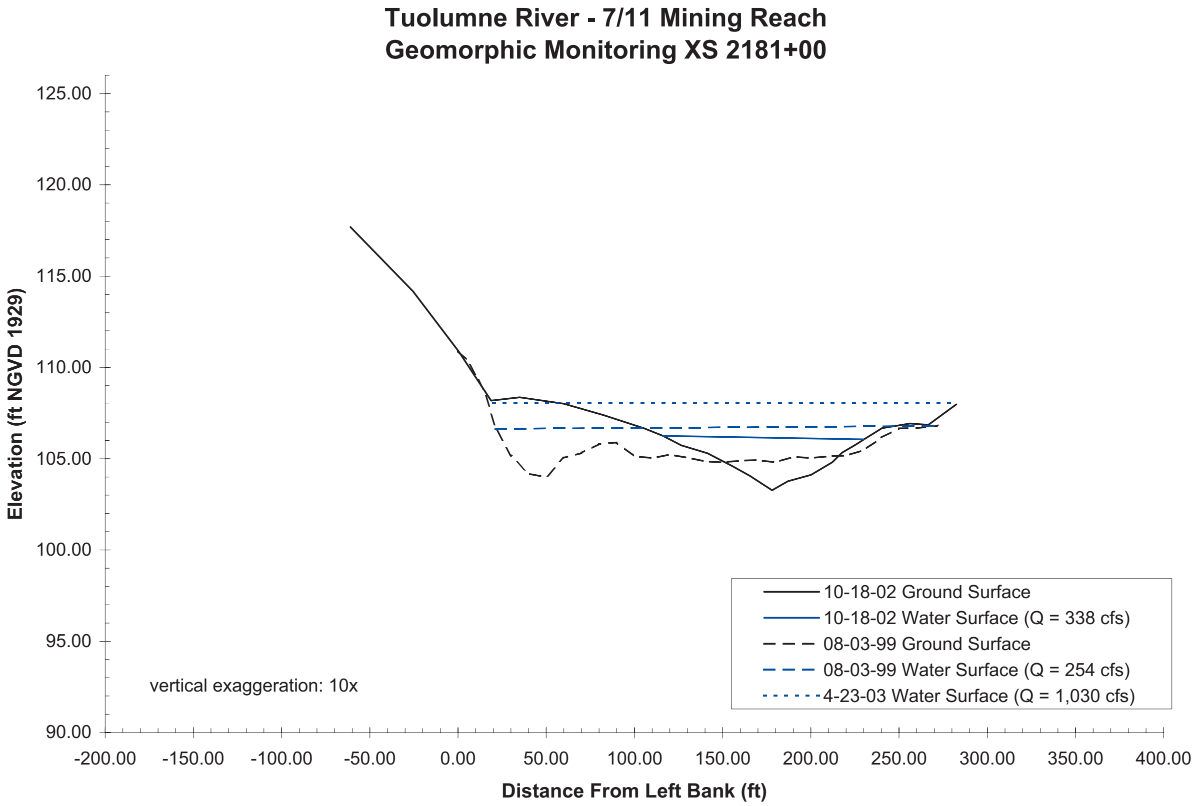


Figure 3-4. 7/11 Reach monitoring cross sections showing pre-project and as-built ground surface and low-flow water surface.



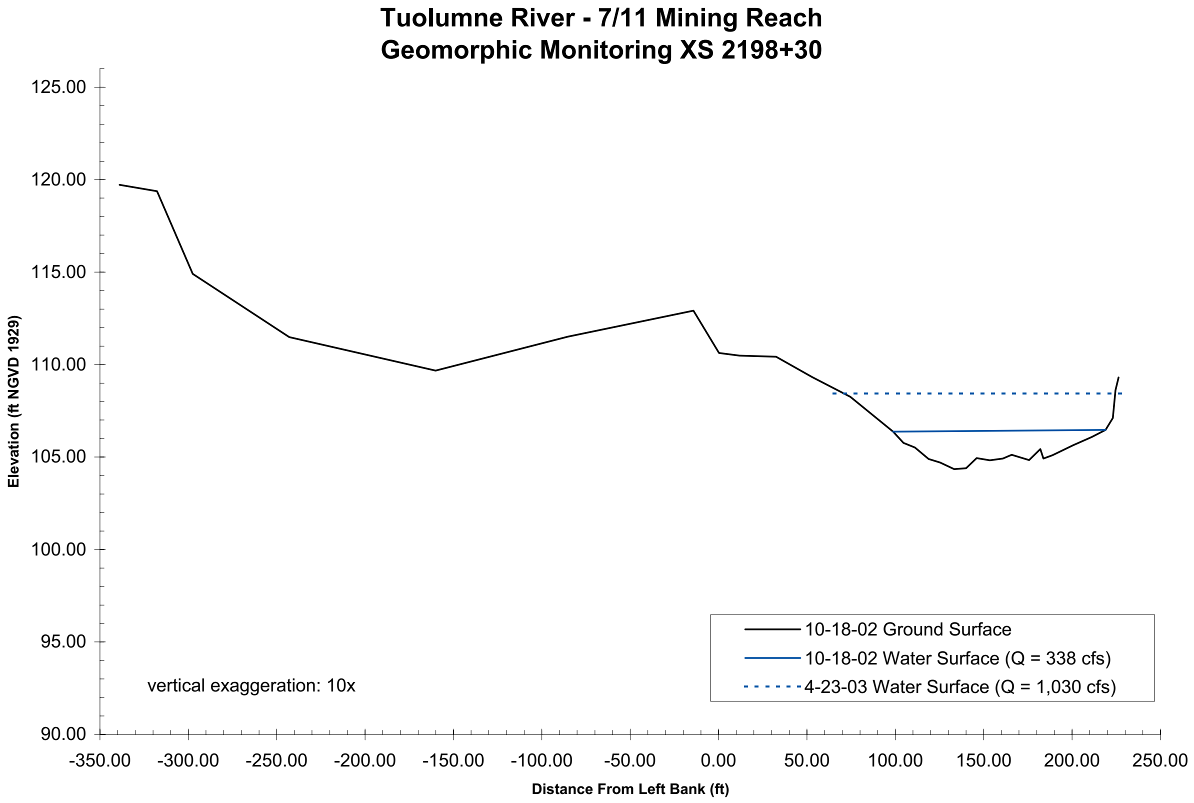
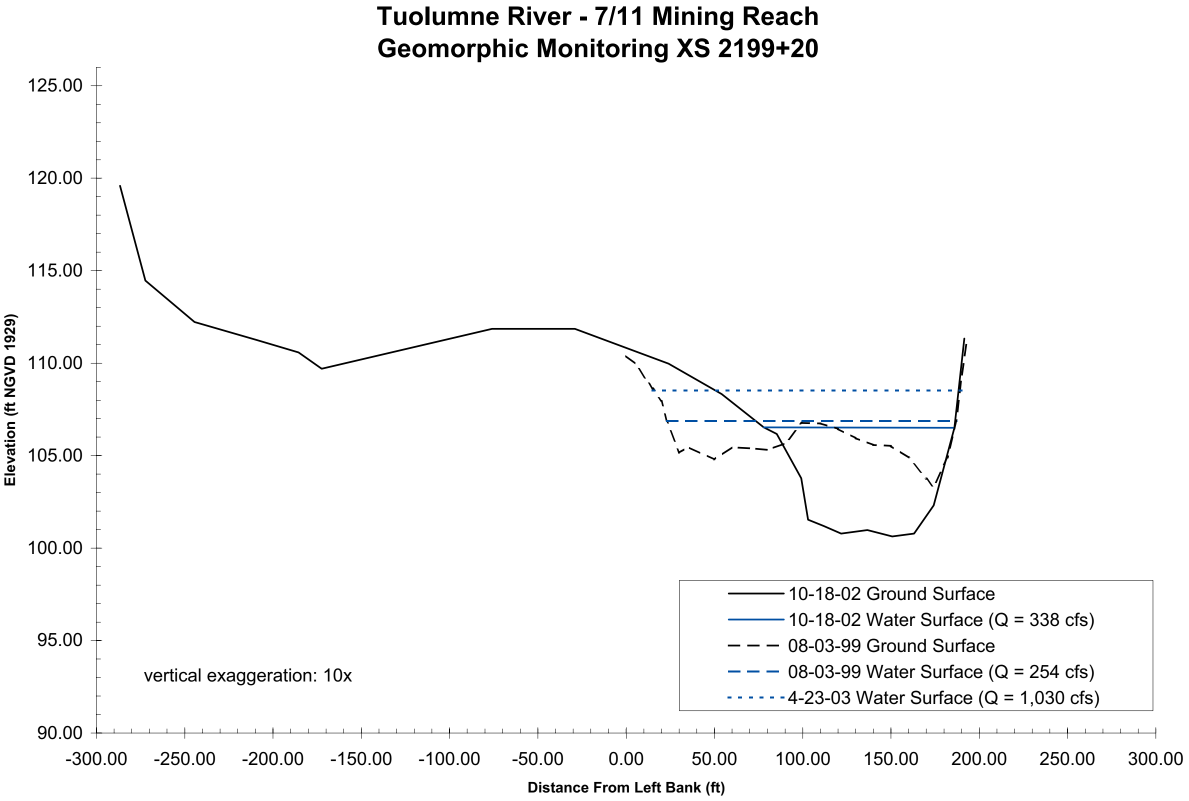
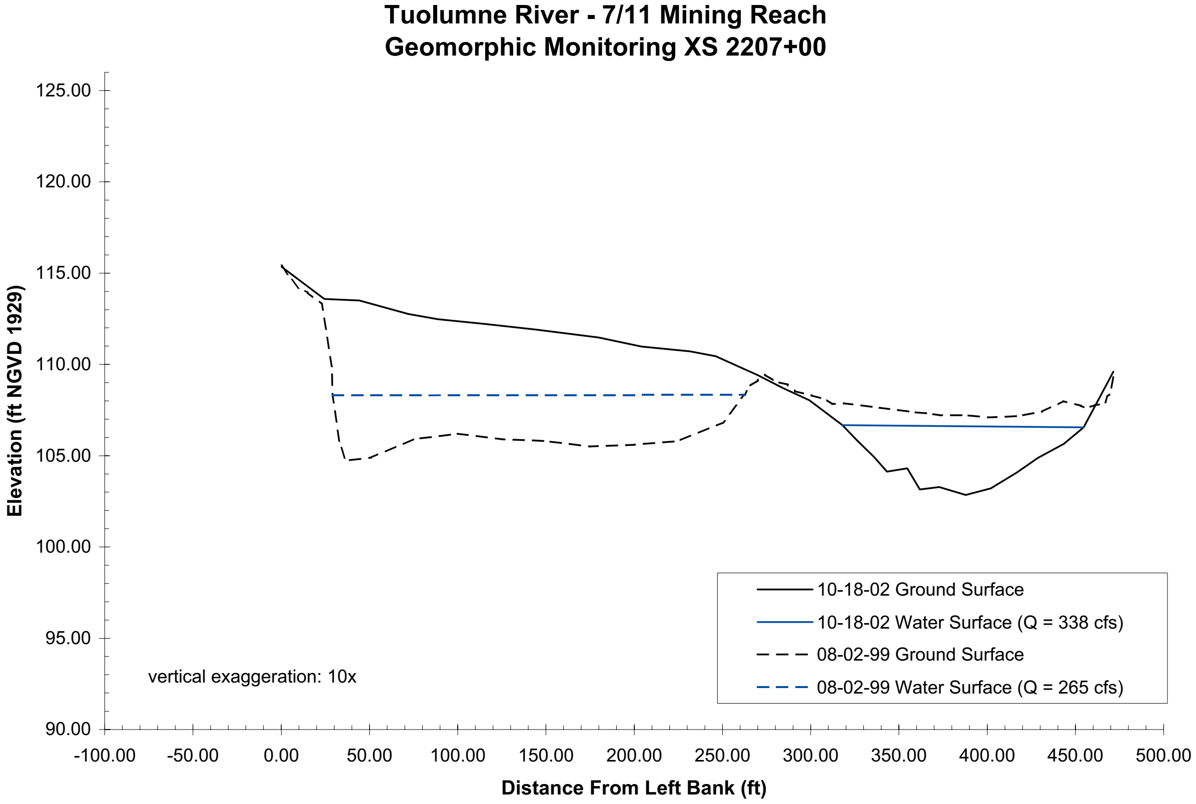


Figure 3-4. 7/11 Reach monitoring cross sections showing pre-project and as-built ground surface and low-flow water surface, continued.

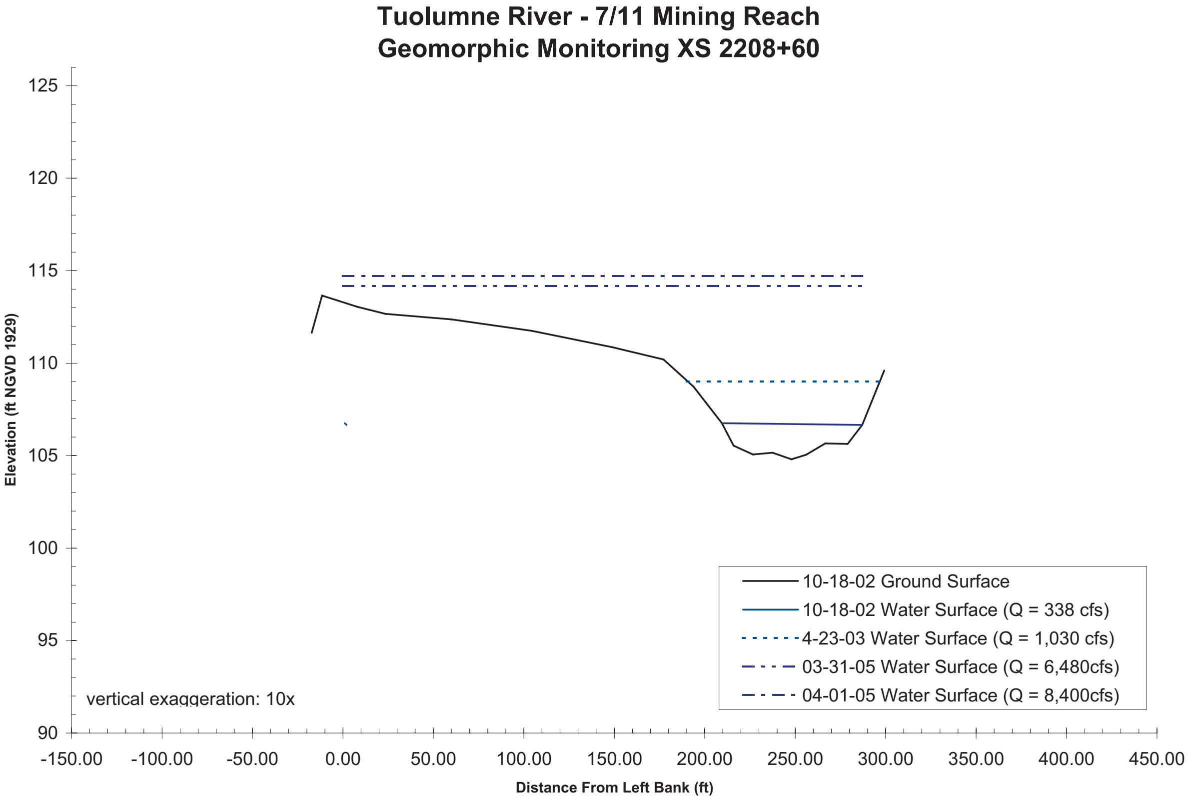


Tuolumne River - 7/11 Mining Reach
Geomorphic Monitoring XS 2199+20



Tuolumne River - 7/11 Mining Reach
Geomorphic Monitoring XS 2207+00

Figure 3-4. 7/11 Reach monitoring cross sections showing pre-project and as-built ground surface and low-flow water surface, continued.



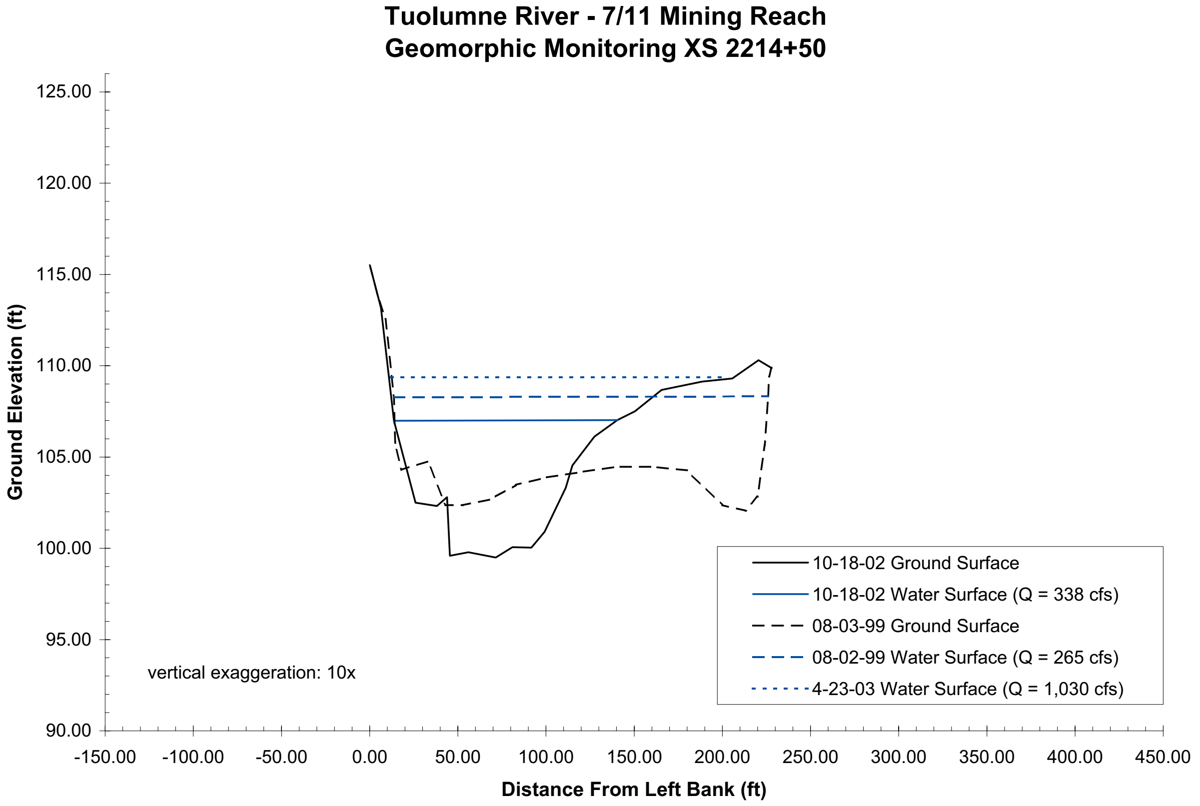


Figure 3-4. 7/11 Reach monitoring cross sections showing pre-project and as-built ground surface and low-flow water surface, continued.

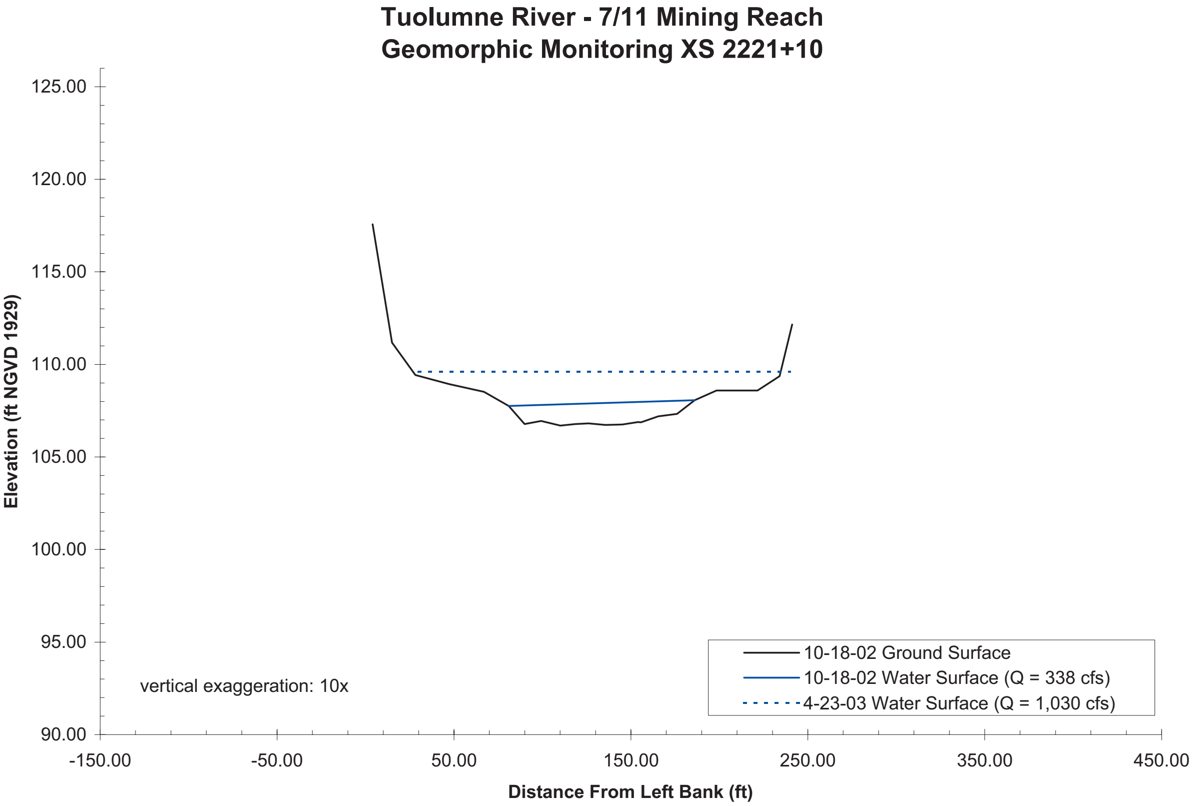


Figure 3-4. 7/11 Reach monitoring cross sections showing pre-project and as-built ground surface and low-flow water surface, continued.

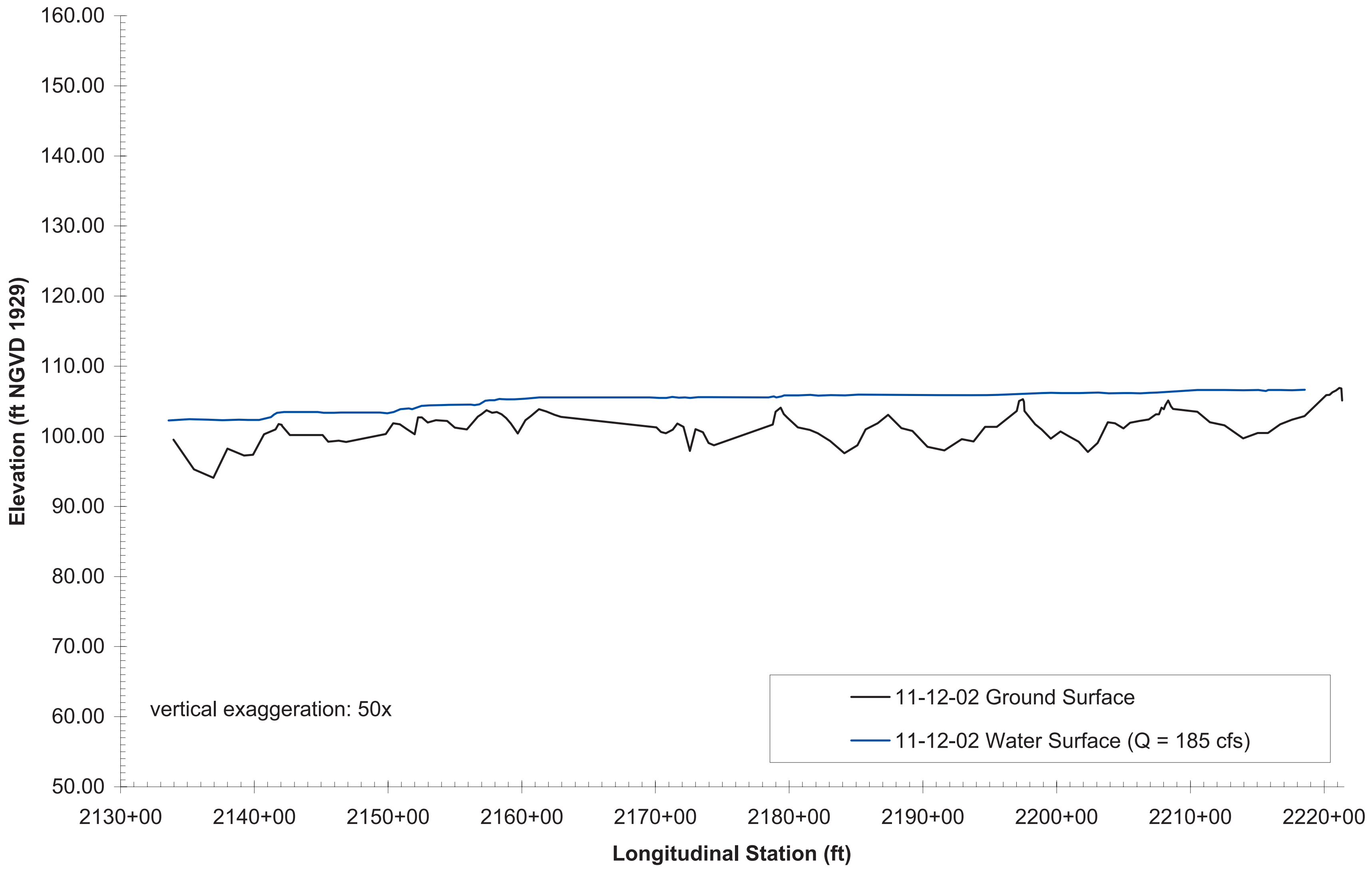


Figure 3-5. 7/11 Reach as-built channel thalweg profile.

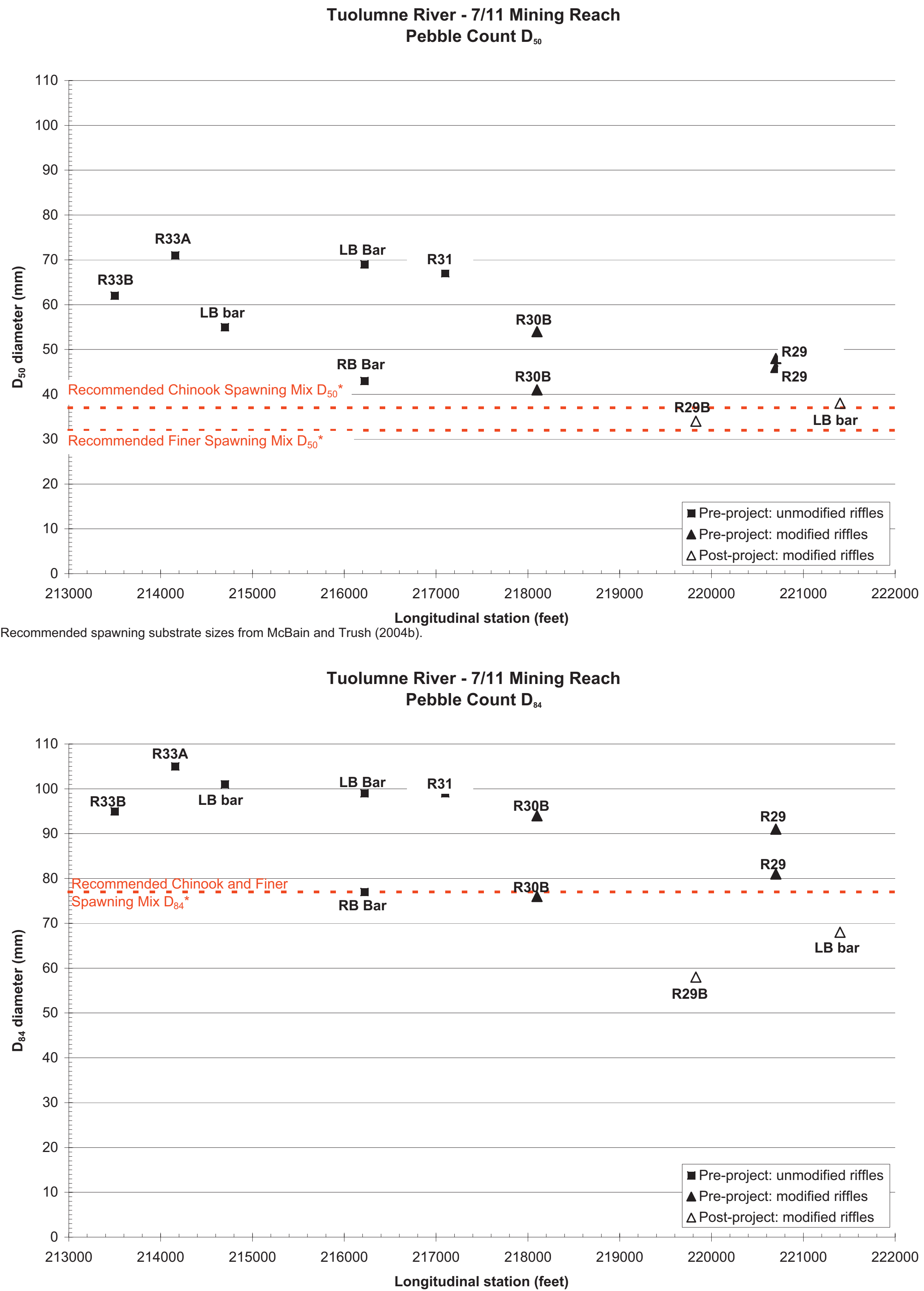
Figure 3-6. View of left bank floodplain from cross section 2247+00 during flows of 5,960 cfs [March 25, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne River below La Grange Dam nr La Grange CA.)

Figure 3-7. View of left bank floodplain between cross sections 2198+30 and 2208+60 during flows of 5,960 cfs [March 25, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne River below La Grange Dam nr La Grange CA.)

Figure 3-8. *View from Roberts Ferry Bridge (looking downstream) during flows of 5,960 cfs [March 25, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne River below La Grange Dam nr La Grange CA.)*

Figure 3-9. *View of left bank floodplain upstream of the 7/11 haul road during flows of 5,960 cfs [March 25, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne River below La Grange Dam nr La Grange CA.)*

Figure 3-10. View of left bank floodplain from downstream project boundary during flows of 5,960 cfs [March 25, 2005]. (Flow is daily average flow at USGS gage no. 1289650 Tuolumne River below La Grange Dam nr La Grange CA.)



*Recommended spawning substrate sizes from McBain and Trush (2004b).

*Recommended spawning substrate sizes from McBain and Trush (2004b).

Figure 3-11. 7/11 Reach pre-project and as-built bed texture – D_{50} and D_{84}.

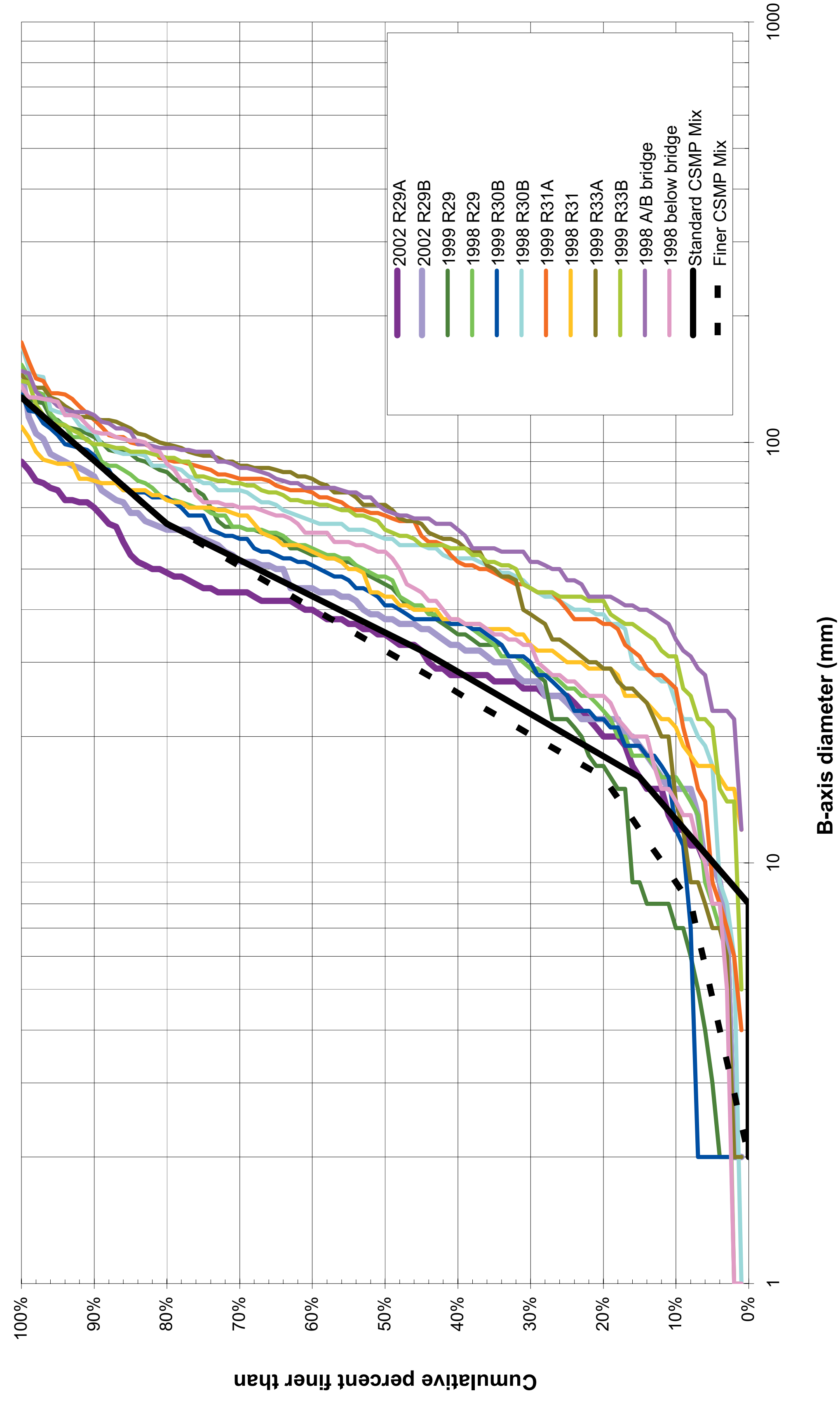


Figure 3-12. 7/11 Reach pre-project and as-built bed texture – cumulative distribution.

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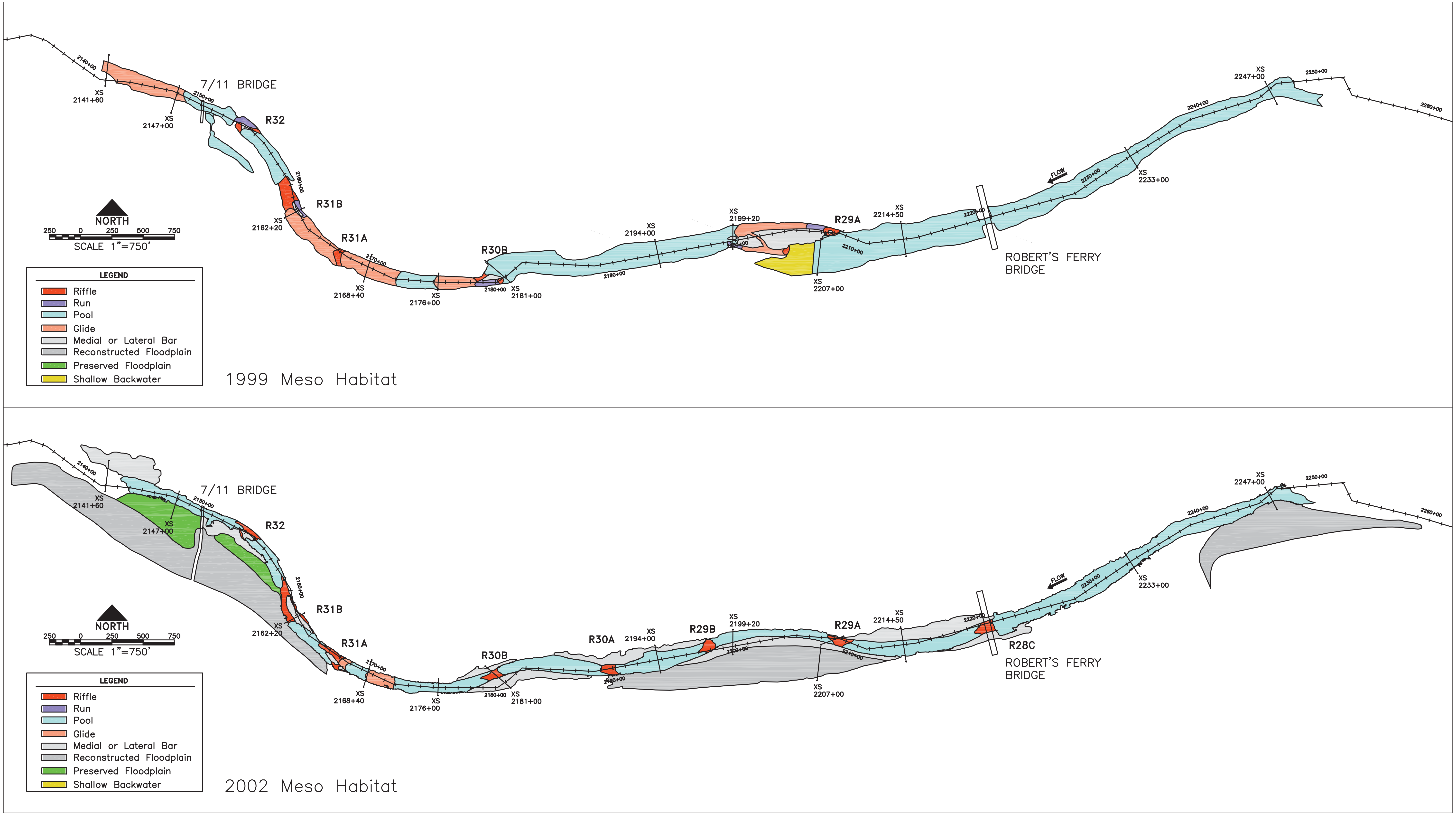

Figure 3-13. 7/11 Reach pre-project meso-habitat mapped at 254–265cfs (pre-project, August 1999) and as-built meso-habitat mapped at 187 cfs (as-built, November 2002).

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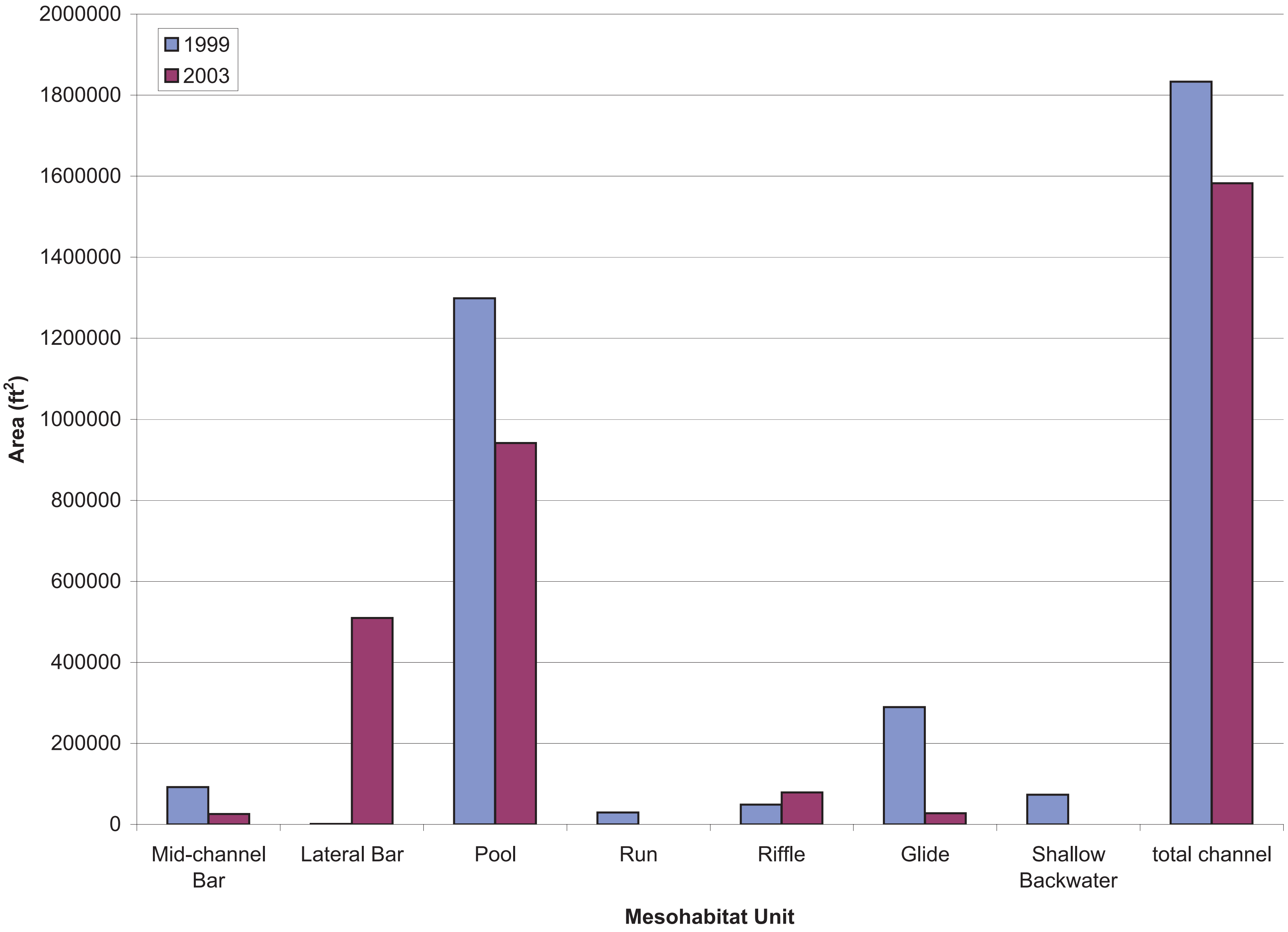

Figure 3-14. Comparison of pre-project and as-built meso-habitat unit areas in the 7/11 Reach.

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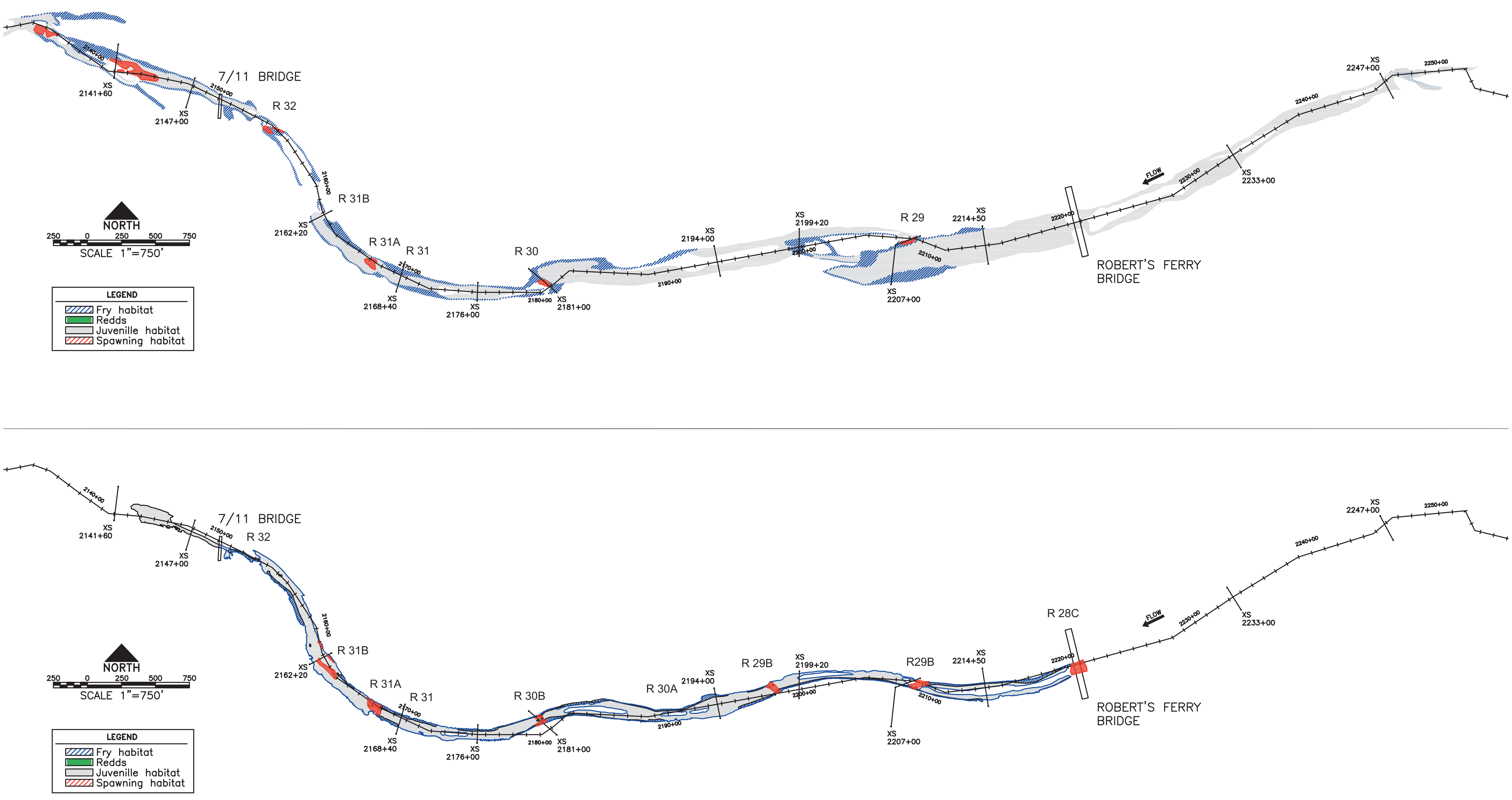

Figure 3-15. 7/11 Reach pre-project and as-built Chinook salmon fry and juvenile rearing and adult spawning habitat mapped at 254–265cfs (pre-project, August 1999) and 187 cfs (post-project, November 2002).

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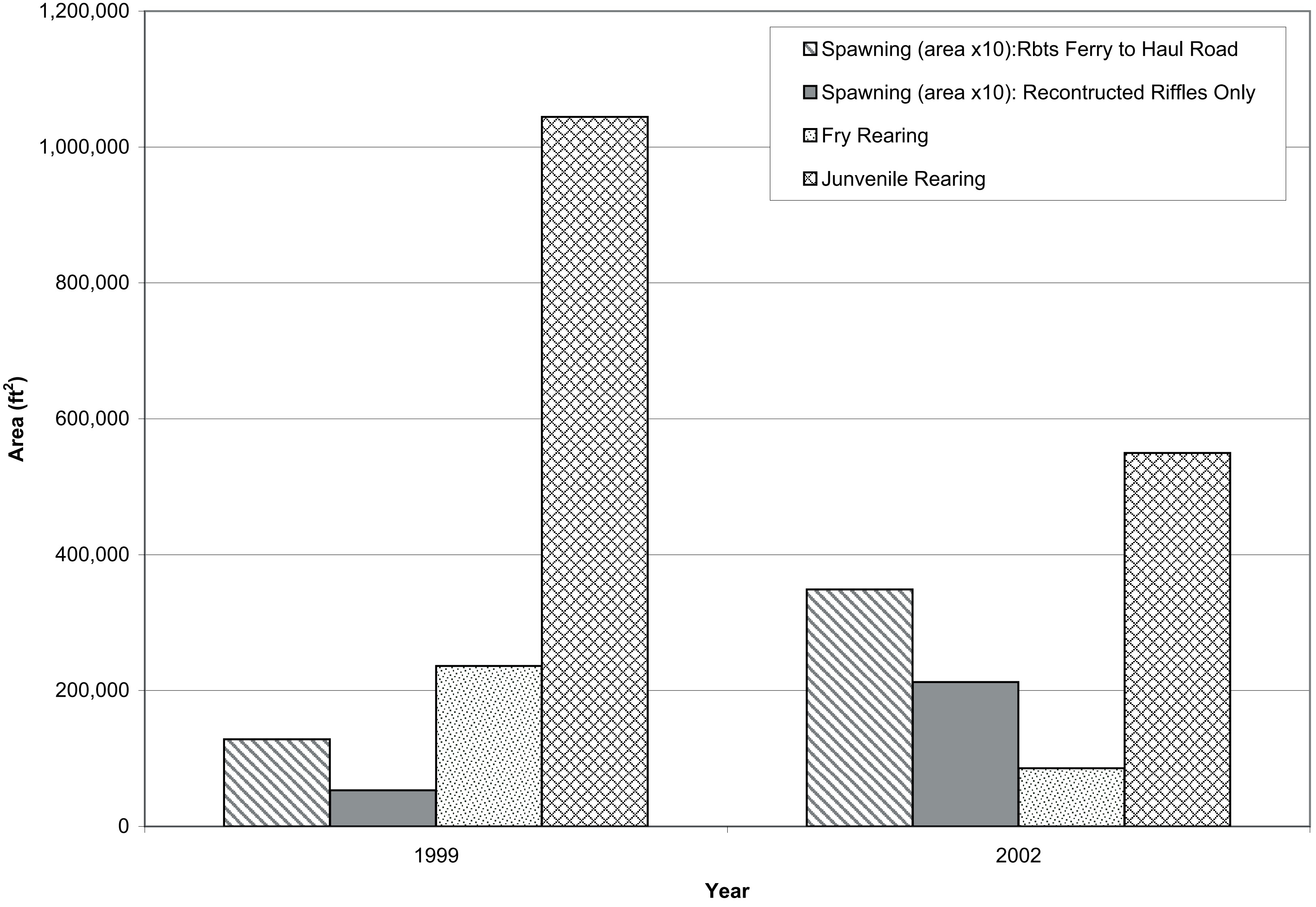


Figure 3-16. Comparison of pre-project and as-built Chinook salmon fry and juvenile rearing and adult spawning habitat area in the 7/11 Reach.

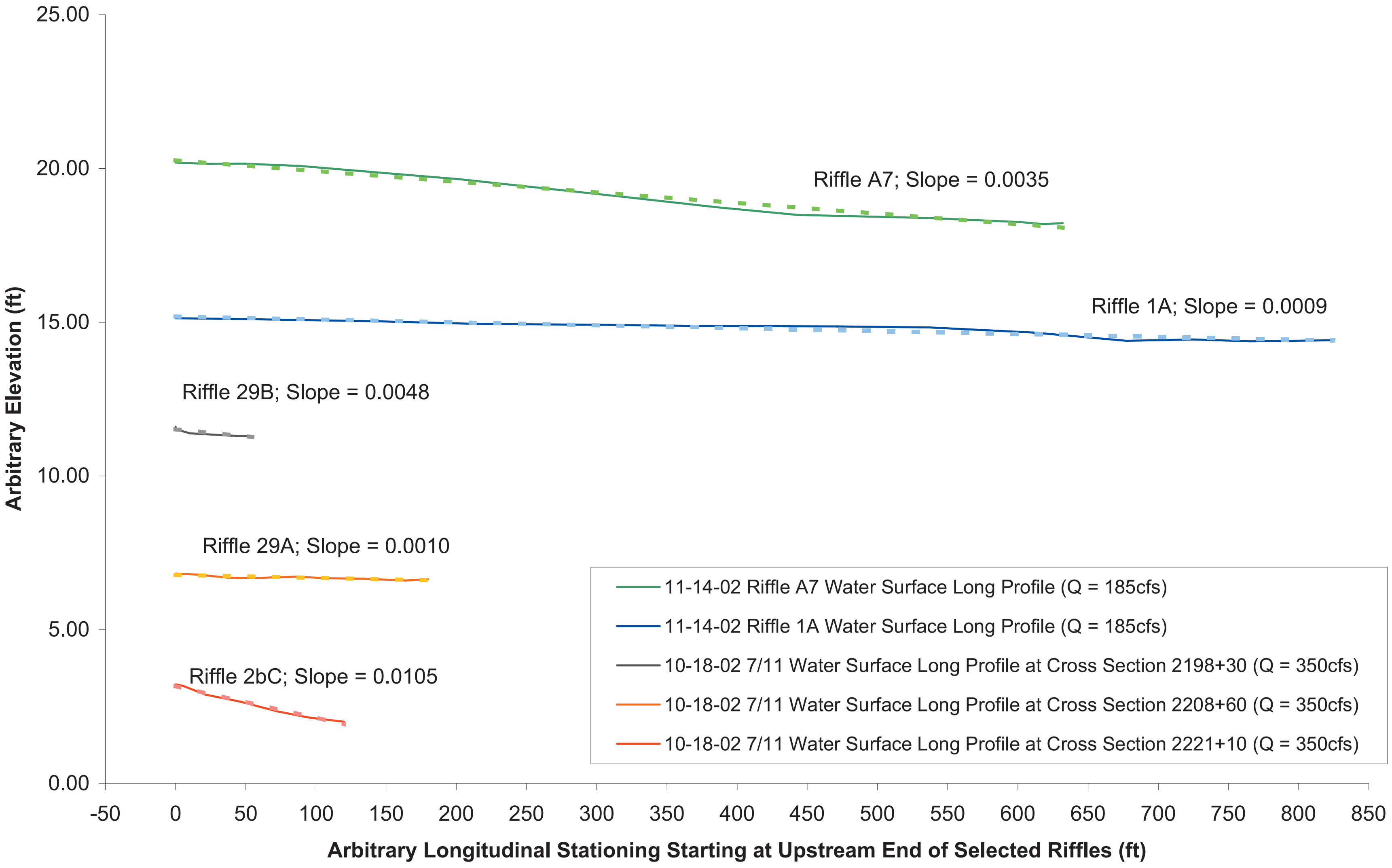


Figure 3-17. Water surface slopes at 7/11 project riffles (Riffles 29A and 29B) and heavily used spawning riffles in the Tuolumne River primary spawning reach (Riffles A7, 1A, and 2bC).

4 DISCUSSION

4.1 Conceptual Models

The Habitat Restoration Plan for the Lower Tuolumne River (McBain & Trush 2000) identifies 10 "Attributes of Alluvial River Integrity." The *Attributes* are: (1) spatially complex channel morphology; (2) variable yet predictable streamflow patterns; (3) frequently mobilized channel bed surface; (4) periodic channel scour and fill; (5) fine and course sediment supply in balance with long-term transport rates; (6) periodic channel migration and/or avulsion; (7) a functional floodplain; (8) infrequent channel resetting floods; (9) self-sustaining, diverse riparian corridor; and (10) naturally fluctuating groundwater table. Based on the *Attributes* and our current understanding of alluvial rivers, one can describe the linkages between **physical inputs** (e.g., sunlight, streamflow, sediment), **physical processes** (e.g., sediment transport, bank erosion, fine sediment deposition), **habitat structure** (e.g., shallow-gradient riffles, well-sorted and clean spawning gravels) and **biological responses** (e.g., healthy incubation, low density-dependent mortality) (Figure 4-1). These *Attributes* and the simple conceptual model shown in Figure 4-1 are the foundation of the conceptual models described below.

In June 2001, the UC Davis Center for the Environment and AFRP sponsored an Adaptive Management Forum to review the science behind the large-scale restoration projects on the Tuolumne River. The TRTAC Monitoring Subcommittee, with assistance and peer review by panel members from the Adaptive Management Forum, developed several interconnected conceptual models depicting our current understanding of (1) the effects of flow regulation and mining on geomorphic processes, habitat structure, and salmonid abundance in the river, (2) the river's Chinook salmon population dynamics, and (3) effects of individual restoration actions on geomorphic processes, habitat structure, and salmonid abundance. These conceptual models are presented in the report *AFRP / CALFED Adaptive Management Forum: Tuolumne River Restoration Summary Report* (Stillwater Sciences 2001b). River-wide and project-specific models relevant to the SRP 9 and 7/11 Reach projects are described below.

Model G-1. Effects of dams and mining on geomorphic inputs and processes, habitat structure, and population response (Figure 4-2). This model illustrates linkages between physical inputs, geomorphic processes, habitat structure, and salmonid abundance and the effects of dams and mining on these linkages. In this model, dams alter seasonal flow patterns in the lower river, reduce peak flow magnitude, reduce fine sediment supply, and eliminate coarse sediment supply. Aggregate mining and gold dredging further reduce coarse sediment supply to the river by removing stored sediment from the channel and floodplain and by trapping coarse sediment that is in transport. These reductions in flow and sediment supply reduce sediment transport, channel migration and avulsion, recruitment of large wood, and floodplain inundation, and result in channel incision, bed armoring, channel narrowing (through riparian vegetation encroachment), and abandonment of pre-dam floodplains. In-channel mining also creates large, lake-like pits in the river channel. These alterations reduce habitat quality for salmonid spawning, incubation, rearing, and outmigration. In addition, reductions in flow magnitude and alteration of seasonal flow patterns potentially affect salmonid run timing and emigration timing, as well as incubation, rearing, and outmigrant survival.

Model S-1. Factors affecting Chinook salmon population abundance in the Tuolumne River (Figure 4-3). This conceptual model depicts the factors affecting each Chinook salmon life history stage, within and outside of the Tuolumne River basin. Within the basin, research and monitoring have identified three primary factors that limit Chinook salmon population abundance: (1) redd superimposition; (2) low survival-to-emergence resulting from low substrate permeability; and (3) low outmigrant survival resulting from spring flow conditions, predation by largemouth bass, and water temperature. Other factors could also affect Chinook salmon population abundance, but these are not considered to be limiting. Of the limiting factors identified, redd superimposition is the only density-dependent mortality factor. The superimposition model developed by Stillwater Sciences from field studies on the Tuolumne River supports the hypothesis that superimposition and delayed fry emergence is a key factor driving the stock-recruitment curves developed from empirical observations in the Tuolumne River (TID/MID 1992b). Numerous factors outside the Tuolumne River watershed also affect the numbers of Chinook salmon returning to the Tuolumne to spawn. Such factors include (but are not limited to) Delta exports and entrainment in the Delta pumps, ocean harvest, ocean conditions, and predation and water quality in the Delta.

Model P-1. Effects of the Special Run-Pools (SRPs) 9 and 10 Projects on geomorphic process, riparian vegetation, and Chinook salmon survival (Figure 4-4). Past studies of Tuolumne River Chinook salmon population dynamics identified predation by largemouth bass as a major factor limiting outmigrant survival (and thus recruitment) in the Tuolumne River, particularly during drier years (TID/MID 1992a). Largemouth bass prefer deep, low velocity, warm-water habitats with abundant cover. In this model, replacing the large, deep SRP pit with a shallower, narrower channel reduces habitat suitability for adult largemouth bass and, thus, reduces adult bass carrying capacity (and adult bass abundance) and predation pressure on outmigrating salmon at the site. During high flows (>1,400 cfs), reconstructed floodplains provide rearing areas and outmigration routes that may reduce juvenile salmon interactions with adult largemouth bass. The reconstructed floodplain also provides a surface for colonization by riparian vegetation. (Note that the project also includes initial planting and maintenance of riparian vegetation.)

Model P-2. Effects of the Gravel Mining Reach Project on geomorphic processes, riparian vegetation, and Chinook salmon survival (Figure 4-5). In this model, reconstructing a channel and floodplain that are scaled to contemporary flow conditions, combined with planting native riparian vegetation on the reconstructed floodplain and maintaining coarse sediment supply, improves in-channel and floodplain geomorphic and riparian processes and improves Chinook salmon spawning and rearing habitat. Constructing an appropriately scaled channel and maintaining coarse sediment supply balances sediment transport capacity with sediment supply, thus providing a channel and floodplain that functions under contemporary, regulated flow conditions. By providing conditions that allow the channel to construct bars and riffles, the project improves salmon spawning, incubation, and rearing habitats. In addition, by reducing floodplain elevation, increasing floodplain width, and creating high flow channels on the floodplain, the project reduces flow velocities during floods and provides refugia for rearing salmon.

4.2 SRP 9 Project Implementation and Effectiveness

The SRP 9 project was monitored for five years following construction, but monitoring after 2003 was limited to opportunistic observations of high flow stage (due to lack of monitoring funds). Pre-project and post-project monitoring through 2003 partially tested hypotheses related to the primary goal of the project – reducing largemouth and smallmouth bass habitat and increasing Chinook salmon rearing habitat. Geomorphic monitoring thresholds (such as high flow events) were not exceeded until 2005. Several geomorphic hypotheses, therefore, have not yet been tested. Also, vegetation hypotheses have not been tested because riparian vegetation has not been monitored since irrigation ended at the site.

4.2.1 Project Design Process and Implementation

The SRP 9 project design underwent several revisions as it proceeded from conceptual design through implementation. The conceptual design process included participation by scientists from a range of disciplines, including biologists, geomorphologists, and riparian ecologists. As the conceptual design proceeded toward final design, revisions were controlled primarily by engineering and logistical constraints, and revisions were not reviewed in detail by the biologists who had contributed to the conceptual design. While not the sole cause of the extent of largemouth bass habitat at the site, some of the design revisions, such as widening the channel for the infiltration gallery, increased post-project largemouth bass habitat at the site relative to the conceptual design. Better communication between engineers and biologists throughout the design process could help avoid some, though certainly not all, changes to project designs that may reduce the project's ability to meet its biological objectives. Recommended revisions to the project design and implementation process for future restoration projects are discussed in Section 5.1.

Based on preliminary monitoring results from SRP 9, project engineers worked with biologists and geomorphologists to improve the SRP 10 design. Accordingly, the SRP 10 design was revised to reduce channel width, increase channel slope, reduce pool depth, and incorporate multiple floodplain surfaces that will be inundated at flows of 2,000 cfs and 4,500 cfs. The largemouth bass, smallmouth bass, and juvenile Chinook salmon habitat models developed for this project were used to test and iteratively refine the design. Model results and design recommendations are reported in McBain & Trush (2005, 2006a, and 2006b). The revised SRP 10 design also does not rely on off-site sources for construction fill. Construction fill will be obtained by excavating the right-bank terrace at the site, and cut-and-fill volume will be balanced within the project area. Obtaining fill material on-site provides more control over project implementation and design by avoiding unforeseen increases in fill cost and last minute design changes driven by fill material cost, as occurred as SRP 9 and the 7/11 Reach projects. It also substantially reduces project costs, eliminates the traffic and air quality impacts of hauling fill from off-site, and doubles the area of constructed floodplain/riparian surfaces.

4.2.2 Geomorphic Processes

Relevant Hypotheses:

H1. The constructed channel conveys 1,500 cfs; flows exceeding 1,500 cfs spill over 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.

Post-project monitoring to date has tested hypothesis H1. The effects of high flows on bed mobility (hypothesis H2), channel morphology (hypothesis H3), and channel migration (hypothesis H4) have not been tested because the 5,000-cfs geomorphic monitoring threshold was not exceeded during the funded monitoring period (2001–2003). The geomorphic monitoring threshold was exceeded for long periods in 2005 and 2006. The geomorphic effects of these high flows have not been monitored.

Monitoring during flows of 1,030 cfs suggests that the channel capacity may be slightly less than 1,500 cfs. At flows of 1,030 cfs, floodplain surfaces were not inundated, but high flow scour channels on the floodplains were inundated to a depth of 1.4 feet. At 2,200 cfs, the left-bank floodplain was inundated to a depth of 0.8–2.7 feet, and the right-bank floodplain was inundated to a depth of 1.6–2.3 feet. Stage was not monitored during the design bankfull discharge (1,500 cfs). To more-cost-effectively capture a broader range of flows (including the 1,500-cfs design flow), we suggest replacing field surveys of flow stage with an automated stage recorder.

4.2.3 Bass Habitat and Abundance

Relevant Hypotheses

H10. Elimination of the pits will reduce habitat suitability for largemouth bass.

H11. Reduction in bass habitat suitability will result in reduced largemouth bass abundance at the project sites and an increase in Chinook salmon outmigrant survival at the project sites.

Largemouth and smallmouth bass have been documented in the Tuolumne River from Old La Grange Bridge (RM 50.5) to Shiloh (RM 3.4), but smallmouth bass are typically most abundant downstream of RM 37 and largemouth bass are most abundant downstream of Hickman Bridge (RM 31.6) (Ford and Brown 2001, Ford and Brown 2002). SRPs 9 and 10 and the monitoring control sites are downstream of Hickman Bridge and are in the river reach where both largemouth and smallmouth bass are expected to be abundant.

Pre- and post-project monitoring documents a pattern of largemouth bass population depletion caused by the 1997 flood and subsequent recovery. During extremely wet years, high flows can flush largemouth bass out of a stream, but typically a sufficient number of adults can find shelter in flooded areas to repopulate the stream during lower flow conditions (Moyle 2002). In January 1997, the Tuolumne River experienced its third largest flood of record, with flows downstream of La Grange peaking at 58,900 cfs. The January 1997 flood was sufficient to drive largemouth bass far downstream or into off-channel refugia (such as floodplain mining pits). After the flood, few adult bass remained in the river, but the presence of age 4+ and 5+ adults in 1998 indicated that adult largemouth bass were able to find refuge and move back into the river during lower flows. Floodplain mining pits may have provided refugia for large numbers of adult bass. The 1997 flood breached dikes that separated several floodplain mining pits from the river, allowing bass to move in and out of the pits after flow receded. The floodplain mining pit in the monitoring reach was partially surveyed in September 1998 (one electrofishing pass was completed along less than 25% of the total bank length in the pit). The number of largemouth bass captured during this brief pass exceeded the number of captured on a single pass at any of the SRP monitoring sites and was 25% of the total number of largemouth bass captured at all SRP sites combined.

During the years following the flood, largemouth bass abundance was controlled by spring and summer flow conditions that were unfavorable for reproduction. Largemouth bass require low water velocities and warm water temperatures to reproduce (Moyle 2002, Swingle and Smith 1950, Harlan and Speaker 1956, Mraz 1964, Clugston 1966, Allan and Romero 1975; all as cited in Stuber et al. 1982). In California populations, Moyle (2002) reports that spawning begins when water temperature reaches 59–61°F (15–16°C) (usually in March or April in California) and continues through June at temperatures up to 75°F (24°C). Other authors report slightly broader temperature ranges for spawning and incubation, with suitable temperature ranging from 55 to 79°F (13 to 26°C) (Carr 1942, Kelley 1968), and 68–70°F (20–21°C) reported as optimal (Clugston 1966, Badezhuizenn 1969). During the first two years following the flood (1997 and 1998), reproductive conditions for largemouth bass were poor, and bass abundance remained low. In 1997, water temperature in the monitoring reach was suitable for spawning for only two weeks in late May, after which temperatures exceeded the maximum spawning threshold (Figure 4-6). In 1998, water temperature was below the preferred spawning range until mid-June, and flow fluctuations through spring and summer could have caused sufficient disturbance to reduce egg viability or destroy the nests (Eipper 1975) (Figure 4-7). In fall 1998, adult abundance remained low and few juvenile bass were captured. In 1999, flow and water temperature were favorable for largemouth bass for the first time since the 1997 flood. Water temperature was within the preferred range for spawning from late May throughout the summer, and river discharge was constant (Figure 4-8). In fall 1999, young-of-the-year bass were abundant at all SRP sites and the Riffle 64 site, indicating high reproductive success for that year. Flow and temperature continued to be suitable for largemouth bass reproduction each spring and summer from 2000 through 2003 (Figures 4-9 through 4-12). By September 2003, the capture of adult largemouth bass (>200 mm) increased 254% relative to 1998 and 189% relative to 1999, indicating at least partial recovery of the population.

Smallmouth bass also appear to be recovering from the effects of the 1997 flood. Smallmouth bass spawn in warm waters, moving into shallow-water, low-velocity areas in late spring. In northern California, most spawning occurs in May and June but can extend into July depending on flow and water temperature (Moyle 2002). Nests are constructed in rubble, gravel, and sand bottoms near submerged cover at a depth of approximately three feet, and spawning begins as water temperatures increase to 55–61°F (13–16°C) (Moyle 2002). In 1998 and 1999, very few smallmouth bass were captured at any of the monitoring locations. Estimated abundance for all sites and size classes combined was 33 bass in 1998 and 57 bass in 1999. In 2003, estimated abundance for all sites and size classes combined was 466 bass. This was the first monitoring year for which strong YOY, 1+, and 2+ cohorts occurred. In 2003, 50% of the smallmouth bass captured were estimated to be YOY (2003 cohort), 44% were estimated to be ages 1+ and 2+ (2001 and 2002 cohorts), 3% were estimated to be age 3+ (2000 cohort). This increase in adult abundance and successful reproduction since 2000 illustrates the positive response of smallmouth bass to low flow years.

<u>*Project Effects on Largemouth Bass Abundance and Habitat*</u>

The SRP 9 project substantially reduced predicted largemouth bass habitat at the site relative to pre-project conditions. Largemouth bass is a warm-water species that prefers low-velocity habitats. Optimal riverine habitat for largemouth bass includes fine-grained (sand or mud) substrates, some aquatic vegetation, and relatively clear water (Trautman 1957, Larimore and Smith 1963, Scott and Crossman 1973, all as cited in Stuber et al. 1982). The SRPs provide extensive low-velocity areas suitable for largemouth bass foraging and reproduction. The SRP 9 project increased flow velocity at the site, and thus reduced largemouth bass habitat area. Compared to pre-project conditions, the project reduced predicted largemouth bass primary habitat at the site by 11–92% (total usable area) and 68–95% (weighted usable area) over the range of flows modeled (i.e., 75–5,000 cfs). For the flow conditions typical of spring and summer 2003, the project reduced predicted largemouth bass primary habitat by 34% (total usable area) and 76% (weighted usable area) compared to pre-project conditions.

Despite reducing habitat area, the SRP 9 project did not reduce piscivore-size largemouth bass abundance at the project site relative to pre- and post-project control sites for the conditions monitored from 1998–2003. For both pre-project and post-project monitoring, density of piscivore-size largemouth bass at SRP 9, while lower than at SRPs 8 and 10, was not statistically different from SRP 7 and was significantly higher than both Charles Road and Riffle 64. Success in reducing bass abundance would have been demonstrated by: (1) post-project bass density at SRP 9 significantly less than density at SRP 7 [minimum measure of success], and/or (2) post-project bass density at SRP 9 not significantly greater than at Charles Rd. and Riffle 64 [higher measure of success]. The period tested (2001–2003) included only dry or below normal years. Since the project increased flow velocity relative to the pre-construction conditions, the project may reduce largemouth bass abundance (relative to control sites) during higher flow years (i.e., years with relatively high late spring and early summer flows). Bass abundance monitoring during years with high spring and early summer flows would be required to test this hypothesis.

Predicted largemouth bass habitat density at SRP 9 (post-project) remained well above predicted density at the channel control sites, and predicted habitat density was consistent with observed bass abundance. Density of piscivore-size largemouth bass at SRP 9 in 2003 (post-project) was 260% of observed density at Charles Rd. and 730% of observed density at Riffle 64. For 2003 summer flows, primary habitat density at SRP 9 was 120% of predicted density at Charles Rd. and 430% of predicted density at Riffle 64 (for total usable area). High flow velocity was more important than depth in limiting largemouth bass habitat area at the channel sites. Flow velocity is controlled by channel slope, confinement, and roughness. The channel control sites were both more confined (i.e., had narrower channels) and steeper than SRP 9. Average low-flow channel width at the control sites was less than 100 feet, and channel gradient was 0.0005 and 0.0006. Channel gradient was 0.00007, an order of magnitude less than the channel control sites. At SRP 9, low-flow channel width in the upstream third of site (i.e., where predicted largemouth bass habitat occurs) was 170 feet, 43% wider than the channel control sites.

Observed bass densities suggest that habitat at SRP 9 pre- and post-project was less favorable for piscivore-size largemouth bass than at SRPs 8 and 10 and similar to SRP 7. Based on similarities in channel morphology, however, pre-project largemouth bass habitat at SRP 9 was expected to be similar to SRPs 8 and 10. Before the project was constructed, channel width and depth at SRP 9 was similar to SRPs 8 and 10.

Bass density at the project and control sites may also be affected by angling pressure. The Tuolumne River is a popular fishing location. The bass fishing season is open for most of the year (January 1–October 31), and there is no limit on the size or number of bass caught (CDFG 2004e). Angling, therefore, could reduce bass abundance in the project area. In the monitoring reach, public access (including a public boat ramp) is provided at Fox Grove County Park, immediately upstream of SRP 9. This is a popular fishing access area, and anglers and bait boxes were often observed at SRP 9 during field surveys. The control sites are also accessible from Fox Grove by boat, but access to SRP 10, Charles Road, and Riffle 64 is difficult during low flows when boats must maneuver over shallow riffles. Due to its close proximity to Fox Grove County Park and easy pedestrian and boat access, fishing pressure is likely more significant at SRP 9 than at the other monitoring sites. If this is the case, bass density at SRP 9 may have been underestimated. While the effects of angling on bass density at the monitoring sites cannot be determined, underestimation of bass density at SRP 9 would not change the conclusion that the project did not reduce bass density to levels similar to the channel control sites or less than SRP 7 over the monitoring period.

Project Effects on Smallmouth Bass Abundance and Habitat

Effects of the SRP 9 project on smallmouth bass are not clear. Monitoring did not identify any statistically significant trends in smallmouth bass density among the project and control sites, but it is clear that SRP 9 supports a relatively high density of piscivore-size smallmouth bass — significantly higher than all other SRP sites and similar to channel control sites. While smallmouth bass distribution and habitat utilization at the site have not been assessed, incidental observations during monitoring surveys suggest that some features of the SRP 9 project may further enhance smallmouth bass habitat. In 2003, most smallmouth bass captures at SRP 9 were along the rock revetment on the left bank. The revetment provides usable or preferred cover in and adjacent to swift water velocities preferred by smallmouth bass. The revetment may also support crayfish, a preferred prey item for adult smallmouth bass (Moyle 2002). Crayfish prefer habitats with cover provided by interstitial spaces (Saiki and Tash 1979) and may be abundant in the revetment.

In past studies on the Tuolumne River, observed smallmouth bass predation rates on juvenile Chinook salmon were 2.5 times observed largemouth bass predation rates (TID/MID 1992a). The study, however, concluded that smallmouth bass were a less important predator than largemouth bass due to their low abundance in the river. Converting deep, low-velocity SRP units to shallower, steeper channels with higher flow velocities could potentially replace largemouth bass habitat with smallmouth bass habitat, in essence exchanging one non-native predator for another.

4.2.4 Predation on Juvenile Chinook Salmon

Relevant Hypothesis

H11. Reduction in bass habitat suitability will result in reduced largemouth bass abundance at the project sites and an increase in Chinook salmon outmigrant survival at the project sites.

The most important goal of the project was to increase Chinook salmon outmigrant survival. Several studies have identified a positive relationship between spring flows and Chinook salmon outmigrant survival from the Tuolumne River, as well as recruitment to the population in subsequent years (e.g., TID/MID 1992b, 2004a). This restoration project was based on studies conducted in the early 1990s that concluded that predation by largemouth and smallmouth bass was a significant source of density-independent mortality for outmigrant salmon (TID/MID 1992a). It is notable that this study was conducted during low flow years, when bass are expected to be most abundant (Brown and Ford 2002) and predator efficiency is expected to be high. The results may be most applicable to dry year conditions.

Despite the continued high abundance of smallmouth and largemouth bass at the SRP 9, the River 2D model provides a new conceptual model and tool 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 post-project channel and floodplain morphology at SRP 9 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. (Pre- and post-project flow velocity profiles are shown in Appendices D and E.)

The FSA requires pulse flows to be released each spring in the Tuolumne River to stimulate outmigration and increase outmigrant survival. The total volume of the pulse flow release specified in the FSA ranges from 12,000 acre-feet to 90,000 acre-feet depending on the water year type. The timing, duration, and magnitude of pulse flows are determined by the Districts in coordination with the Vernalis Adaptive Management Plan managers on a year-by-year basis and are coordinated with pulse flows from other San Joaquin River tributaries. Pulse flows are typically released over a two-week period in April and/or May and generally consist of two steps—a higher pulse held for approximately seven days followed by a lower pulse of the same duration. In many but not all years, peak outmigration of wild juvenile Chinook salmon coincides with the pulse flow release (e.g., CDFG 2004c, 2004d; Stillwater Sciences 2000, 2001a).

The pulse flows benefit Chinook salmon by reducing water temperature and increasing flow velocity. In 2002 and 2003 (i.e., after project construction), spring pulse flows consisted of two steps of approximately 1,300 and 600 cfs each year. In 2002, spring pulse flows reduced water temperature in the project reach from 66°F (19°C) to 55°F (13°C) during the 1,300 cfs pulse and 63°F (17°C) during the 600 cfs pulse. In 2003, pulse flows reduced water temperature in the project reach from 64°F (18°C) to 55°F (13°C) during the 1,300 cfs pulse and 59°F (15°C) during the 600 cfs pulse.

Largemouth bass foraging rates are positively correlated with water temperature up to a maximum, at which point consumption declines. Foraging begins at 41°F (5°C) and increases until water temperatures reach 79–81°F (26–27°C) (Coutant 1975, Zweifel et al. 1999) (Figure 4-13). At temperatures exceeding 81°F (27°C), foraging rapidly declines and adult bass remain quiescent in low velocity, shaded areas (Coutant 1975). For smallmouth bass, maximum prey consumption rate peaks at approximately 72°F (22°C) and declines at higher temperatures (Zweifel et al. 1999). Estimated largemouth bass foraging rates during Chinook salmon outmigration in 2002 and 2003, based on the data presented in Coutant (1975), are shown in Figures 4-14 and 4-15. While spring water temperatures in the Tuolumne River are never low enough to preclude bass foraging, the reduction in temperature during the pulse flows was sufficient to depress expected foraging rates. The reduction in water temperature provided by the pulse flows provides a river-wide benefit to outmigrating salmon and probably is not greatly affected by conversion of the SRP to a narrower channel. Wide-scale elimination of the SRPs could conceivably contribute to further reduction in water temperature, but the potential for such an effect has not been analyzed.

By segregating suitable bass from outmigrant salmon, the SRP 9 project provides an additive benefit to the required spring minimum flows and pulse flows. To illustrate the improvement in outmigration conditions before and after restoration, the timing of the safe-velocity window for 2002 and 2003 is illustrated in Figures 4-14 and 4-15. For the 2002 and 2003 spring pulse flows, the River 2D model predicted that at 600 cfs pulse (represented by the 500 cfs model), largemouth and smallmouth bass are restricted to the right bank floodplain and the left bank along the pool and that at 1,300 cfs (represented by the 1,000 cfs model) largemouth and smallmouth bass are pushed further onto the right bank floodplain. Assuming that the safe velocity corridor begins at flows of 300 cfs, flow velocity provided habitat segregation during outmigration for 57–75% the 61-day outmigration period (defined as April 1 through May 31) in 2002–2004. The pre-project 2,000 cfs threshold was not met or exceeded during the 2002–2004 outmigration periods.

Increased flow velocity in the reconstructed channel may also reduce energetic expenditure for outmigrating salmon. Outmigrating juvenile Chinook salmon seek high velocity portions of the channel and orient facing upstream as the flow carries them down the river. In unmined reaches of the river, velocities are likely sufficient to carry the outmigrants downstream with minimal energy expenditure (i.e., without swimming). Flow velocity in the SRP units (pre-restoration), however, is near zero until flows exceed 1,000 cfs. 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. A review of the literature did not identify a sustained swimming speed for outmigrating juvenile Chinook salmon. Brett et al. (1958) found that juvenile coho salmon (54 mm FL) could sustain a speed of 1 ft/s at a temperature of 68°F (20°C), and larger juveniles (69 mm FL) could sustain a swimming speed of 1.4 ft/s at the same temperature. At lower temperatures, the maximum sustained swimming performance was reduced for both size classes, with peak sustained speeds of 0.7 ft/s and 1.1 ft/s for the smaller and larger juveniles, respectively at 50°F (10°C) (Brett et al. 1958). These results should be comparable to Chinook salmon.

Using flow velocity as an indicator, Chinook salmon in the Tuolumne River could be expected to actively swim through SRP 9 during flows less than 2,000 cfs under pre-project conditions (see velocity profiles provided in Appendix D). Modeled pre-project flow velocity through SRP 9 at this flow was less than the maximum expected swimming speed of juvenile Chinook salmon in the temperature range typically experienced during the outmigration period (Appendix E and Figures 4-14 and 4-15). With the new channel configuration, flow velocity through the majority of SRP 9 exceed the 1.0 ft/s swimming speed threshold at flows of 300 cfs and higher. 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.

The analyses presented herein are based on model results and have not been validated with field observations. In fall 2004, the CBDA provided funds to conduct a pilot predation study at SRP 9. Because spring flows in 2005 and 2006 were well above the 300-cfs threshold, the study assessed predation on juvenile Chinook salmon during high flow conditions. The objectives of the study were to:

- document the predation rate in SRP 9 and compare with predation rates at SRP and riffle control sites; and
- document velocity-driven or temperature-driven spatial distribution of predators and salmon at SRP 9 and an SRP control site, and determine whether the two species are spatially segregated.

The predation assessment was conducted from May 3–24, 2006, at three sites on the Tuolumne River between RM 25.9 and RM 24.8: (1) the project site (restored SRP 9), (2) an SRP control site (SRP 10), and (3) a riffle control site (Charles Rd.). All of the sites were located downstream of the Geer Road bridge and were accessed by boat via the Fox Grove fishing access. Predator capture and marking, as well as seine surveys and temperature monitoring, occurred during a three day period from May 3–5, 2006. Subsequent monitoring (tracking) of marked predators occurred weekly thereafter, concluding on May 24, 2006. Study results are will be provided in a separate report available in July 2006.

4.2.5 Chinook Salmon Rearing Habitat

Relevant Hypothesis

H10. Elimination of the pits will reduce habitat suitability for largemouth bass and will increase habitat suitability for Chinook salmon rearing.

The restoration project increased predicted 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 bankfull, but exceeded 180% for flows from 1,000 to 3,000 cfs. Predicted juvenile Chinook salmon habitat increased 46–121% for flows less than bankfull and 50–392% for flows exceeding bankfull.

The FSA requires minimum flows from October 16 through May 31 ranging from 150 cfs for "median dry" and drier water years to 300 cfs for "intermediate below normal/above normal" and wetter water years. During these flows, fry and juvenile Chinook salmon rearing habitat overlaps considerably with bass habitat. Once water temperatures reach suitable foraging ranges for largemouth and smallmouth bass, predation risk would limit the in-channel rearing habitat value at the site. In 2002 and 2003, suitable bass foraging temperatures at the site (represented by 55°F [13°C]) were reached by February. Successful rearing at the site during these years, therefore, was likely very low.

The greatest benefits of the project for rearing salmon occur during flows $\geq$ 1,500 cfs, when rearing habitat becomes available on the floodplains and in the high flow channels. Recently, Central Valley researchers have reported the benefits of floodplain rearing habitats for Chinook salmon (e.g., Sommer et al. 2000). During the period for which the FSA flow schedule has been in place during the Chinook salmon rearing period (1997–2006), flow was sufficient to inundate the SRP 9 constructed floodplain during January 1–March 31 (early rearing) in nine of ten years and April 1–June 15 (late rearing) in six of ten years. Most benefit is expected during above normal and wetter years, when flow exceeds 1,500 cfs for long periods during the rearing season. For 1997–1999 and 2005–2006 (all above normal and wetter years), flow exceeded 1,500 cfs for 45–90 days during the early rearing period and 19–76 days during the late rearing period. During dry and below normal years (2001–2004), flow exceeded 1,500 cfs for a maximum of only eight days during the early rearing period. Flow did not exceed 1,500 cfs during the late rearing period.

Flow sufficient to inundate the floodplain also is expected to maintain suitable Chinook salmon rearing temperature at the site. Temperatures of 55–65°F (13–18°C) are optimal for rearing Chinook salmon, but positive growth can occur at temperatures of 41–66°F (5–19°C) (Marine 1997, McCullough 1999, both as cited in Moyle 2002). The SNTEMP model developed for the Tuolumne River predicts 5-day average water temperature throughout the river. Meteorological inputs to the model are from 1978 through 1988. Using average meteorological conditions for the 11-year period for which the model was constructed, predicted flow required to maintain temperatures $\leq$65°F (18°C) at the project site in May and June range from 300 cfs to 800 cfs, much lower than the bankfull flow (Figure 4-16). This analysis may over-represent habitat suitability by relying on 5-day average temperature. Juvenile Chinook salmon, however, can withstand brief exposure to temperatures exceeding preferred rearing conditions but cannot survive even brief exposure to temperatures exceeding 75°F (24°C). Mortality in wild populations has been observed at temperatures of 71–73°F (22–23°C) (Baker et al. 1995, McCullough 1999 as cited in Moyle 2002). Also, water on the floodplain would likely be warmer than predicted by the model. The 5-day average temperature should be interpreted with caution but could adequately represent chronic temperature exposure for rearing Chinook salmon at the site.

The importance of this reach for rearing juvenile Chinook salmon varies among years. TID has conducted seine surveys from January through May at several locations throughout the river to monitor juvenile salmon distribution, outmigration timing, and growth since 1986. Peak fry and juvenile densities for 1999 through 2004 for all locations in the river are shown in Figure 4-17. TID/MID (2004a) divides the river into three reaches and has developed a rearing abundance index to compare rearing in each reach. The monitoring sites are located in each reach as follows: upper reach (RM 50.5 to RM 42.4), middle reach (RM 31.6 to RM 17.2), and the lower reach (RM 7.4 to RM 3.4). During four of the six years analyzed (1999–2003), rearing abundance was highest in the upper reach (TID/MID 2004b). In 1999, rearing abundance was highest in the middle reach. In 2001, rearing abundance was highest in the lower reach. These results indicate that the potential importance of the site for rearing, therefore, will vary among years and likely will be most important during wetter years. Actual rearing use cannot be determined because Chinook salmon fry and juvenile rearing at the site is not currently being monitored.

4.2.6 Other Native Fish Species (Fish Community Species Composition)

<u>Relevant Hypothesis</u>

- The project did not include specific objectives for fish community composition or native fish, other than Chinook salmon, at the site. No specific hypothesis was included in the monitoring plan.

Species composition can be an important indicator of ecosystem health, with dominance by native species indicating positive trends in health. Several researchers have shown that, in California rivers, altered flow regimes are linked to invasion success of non-native fish species (Baltz and Moyle 1993, Brown and Moyle 1997, and Marchetti and Moyle, 2001, as cited in Brown and Ford 2002). On the Tuolumne River, Brown and Ford (2002) analyzed twelve years (1986–1997) of spring/summer seining data from throughout the river to identify trends in non-native versus native fish abundance. The surveys documented 28 taxa (including Chinook salmon), ten of which were native and 18 of which were non-native. The combination of longitudinal location in the river and mean April–May flow during the year prior to sampling was a good predictor of relative non-native to native fish abundance. Non-native species occurred in greatest abundance at downstream locations, with abundance increasing and distribution extending further upstream in drier years. This model explained nearly two-thirds of the variance in non-native species abundance. Brown and Ford (2002) conclude that spring spawning success is the primary life history mechanism controlling relative abundance of non-native and native fish. The more abundant native species (Sacramento sucker, Sacramento pikeminnow, and riffle sculpin) are riffle spawners. Under natural flow conditions with which these species evolved, spring flows were high, driven by mountain snowmelt. These species, therefore, spawn successfully in high flow years. Conversely, the most abundant non-native species are bottom-nesting and require low-velocity areas for nest building. High spring flows reduce the availability of suitable nesting sites for these species, and these species do not spawn successfully in high flow years.

The project monitoring reach is located at the transition from native to non-native dominance (Brown and Ford 2002), and is best represented by monitoring locations at Hickman Bridge (RM 31.6) and Charles Road (RM 24.9). Electrofishing data from the SRP 9 monitoring extend the data set analyzed by Brown and Ford to include a range of wet and dry years occurring after the FSA flow schedule was implemented. These data also provide an opportunity to compare the effects of habitat structure on fish community composition, which was not analyzed by Brown and Ford (2002). Patterns observed at the SRP and channel sites follow the same pattern as documented by Brown and Ford (2002), with the dominance of non-native fish increasing in lower flow years. The ratio of introduced to non-native fish increased at all sites in 2003 relative to 1998 and 1999. 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 spring flows experienced from 2000 through 2003. As would be expected based on habitat requirements for these species, the SRPs support 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). Striped bass (Family Percichthyidae), inland silverside (Family Atherinidae), American and threadfin shad (Family Clupeidae), and bigscale logperch (Family Percidae) were also present at the sites. Centrarchids were consistently the most abundant family at the SRPs in all years.

Converting SRP 9 from a mined pit to a channel and floodplain was expected to increase native fish abundance at the site. Native fish abundance and diversity at the site, however, decreased relative to pre-project conditions and relative to SRP control sites. Native species found at the site prior to construction but absent following construction included lamprey, sculpin, hardhead, hitch, Sacramento pikeminnow, and Sacramento splittail. Of these species, lamprey, Sacramento blackfish, Sacramento pikeminnow, and sculpins were present at other SRP units in 2003. Hardhead and hitch were present at the channel control sites but not at the SRP sites. This reduction in native fish could be due to several factors, including: (1) low reproductive success of native fish during low flow years since the project was completed, (2) low cover that was only beginning to establish at the site by 2003, (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 which provided poor habitat for native fish. Native fish abundance at SRP 9 might increase with improved river-wide reproductive success during higher flow years. Due to the low channel gradient at SRP 9 relative to the channel control sites, the non-native:native fish ratio is expected to stabilize at a level lower than unrestored SRP sites but higher than the channel control sites.

4.2.7 Riparian Vegetation

<u>*Relevant hypotheses*</u>

H7. Planted riparian vegetation will become established on the constructed floodplain.
H8. Natural recruitment of native riparian plant species will occur on the constructed floodplain.
H9. Riparian vegetation will not encroach into the constructed channel.

No post-project vegetation monitoring at the 7/11 Reach has been conducted to date. Survival of planted vegetation, therefore, can not be determined.

Natural recruitment of native vegetation on the constructed floodplain has not been monitored. Throughout the Tuolumne River corridor, the area of frequently inundated floodplains has been reduced by a combination of flow regulation and levee construction. Several projects currently being designed and implemented in this reach will construct floodplains that are inundated at flows exceeding 5,000 cfs, approximately the 3-year flood. Floodplain elevation at SRP 9 was lowered to reduce the volume of fill needed to construct the project. The constructed floodplain is designed to be inundated at flows exceeding 1,500 cfs (slightly less than the 1.3-year flood). This site provides an opportunity to test riparian plant recruitment on frequently inundated surfaces. Monitoring should include measures of plant establishment and recruitment, species composition (including invasion by non-native species), and plant health. Factors that are thought to control native plant establishment and recruitment at the site should also be monitored, including flow timing, magnitude and elevation; groundwater elevation and drawdown rates; and seed availability at the site. These data would be useful for future restoration project design and for identifying flow measures that support native riparian ecosystems on the river.

4.3 7/11 Project Implementation and Effectiveness

The 7/11 Reach project was monitored for four years following construction, but monitoring after 2002 was limited to opportunistic observations of high flow stage and one bed mobility experiment. Pre-project and post-project monitoring through 2006 partially tested hypotheses related to Chinook salmon habitat, bed mobility thresholds, and floodplain inundation. The 5,000-cfs geomorphic monitoring threshold was not exceeded until 2005, and follow-up surveys have not been conducted due to lack of monitoring funds. Basic geomorphic hypotheses, therefore, have not been tested. Riparian vegetation also has not been monitored since irrigation ended. Riparian vegetation hypotheses, therefore, have not been tested.

4.3.1 Project Design Process and Implementation

From channel cross section surveys and review of the as-built aerial photographs, the project construction seems to adhere to the modified final design. Because as-built floodplain topography was not surveyed, floodplain construction relative to design has not been evaluated. If funds become available, analysis of floodplain topography generated from the 2005 LIDAR surveys could assess as-built floodplain elevation.

During final design and construction, the project design downstream of the 7/11 haul road was modified to reduce construction cost. Design modifications included: (1) replacing the preferred bridge span with a fill and culverts for the portion of the haul road that crosses the floodplain, and (2) narrowing floodplain width by approximately 50 feet (10%) and lowering floodplain elevation downstream of the 7/11 haul road bridge. The effects of these modifications on project performance were expected to be minor and included:

- The 7/11 haul road will require maintenance to prevent the accumulated debris from blocking the culverts. If kept clear of debris, the culverts can provide flood conveyance, but there is substantial risk that they will be partially or wholly blocked by debris that accumulates during a flood. The hydraulic model developed for the project predicted that flows up to 15,000 cfs can be conveyed through the bridge span (i.e., without requiring conveyance through the culverts) if the culverts get plugged. Conveying all flow through the bridge spawn, however, may pose increased risk of damage to the bridge and potential scour and deposition at the upstream side of the culverts.
- Reduced floodway width downstream of the 7/11 haul road could slightly increase flow depth and velocity during high flows in this portion of the project.
- The reduced floodway width downstream of the 7/11 haul road bridge reduced the area of new riparian vegetation by approximately three acres.

Some effects of the design modifications and project implementation were observed during high flows in spring 2005. Because high flow stage was not surveyed or analyzed for the project reach, these field observations are preliminary only. Observed effects included:

- The floodplain upstream of the 7/11 haul road bridge was not inundated until flow was between 6,500 cfs and 8,400 cfs. The floodplain was designed to be inundated when flow exceeds 5,000 cfs.
- Water does not begin to flow through the culverts in the 7/11 haul road (i.e., the fill-and-culvert berm) until flow exceeds 8,400 cfs. At lower flows, the haul road blocks flow from reaching the downstream constructed floodplain. Even at 8,400 cfs, flow depth in the culverts was only 0.2 feet, and only minimal flow reached the downstream floodplain. With upstream flow blocked, the downstream floodplain functions as a backwater channel, with flow backing up onto the constructed surface from the scour channel at the downstream end until flow exceeds at least 8,400 cfs.

4.3.2 Geomorphic Processes

<u>*Relevant hypotheses*</u>

H1. The constructed channel conveys 5,000 cfs; flows exceeding 5,000 cfs spill over 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.

Most geomorphic hypotheses for the 7/11 Reach have not been tested because the 5,000-cfs geomorphic monitoring threshold was not exceeded during the funded monitoring period (1998–2002). The monitoring threshold was exceeded for long periods in 2005 and 2006, but monitoring was limited to opportunistic surveys due to lack of monitoring funds.

Channel conveyance (hypothesis H1) and bed mobility thresholds were partially tested in 2002 and 2005. The channel was designed to convey a 5,000-cfs bankfull discharge through most of the project reach. Downstream of the 7/11 haul road, the modifications to the floodplain design reduced expected bankfull flow to 4,500 cfs. Flow stage was marked during flows of 5,690 cfs, slightly above the bankfull discharge. Upstream of the 7/11 haul road, this flow slightly exceeded channel conveyance, and floodplains were shallowly inundated. Downstream of the 7/11 haul road, bankfull conveyance exceeds 8,410 cfs because the 7/11 haul road and the riparian berm left in place to preserve existing vegetation downstream of the 7/11 haul road bridge confine flow to the channel.

The project design attempted to achieve bed mobilization at the 5,000-cfs bankfull discharge (hypothesis H2). During project design, flow depth required to mobilize the river bed in the project reach was estimated to be 5.8 feet assuming a D_{84} of 74 mm and a 0.0015 water surface slope during flows of 5,400 cfs (based on surveys in the Ruddy Reach) (McBain & Trush 2004a). To achieve bed mobilization at the bankfull discharge, the design bankfull depth was six feet. Marked rock experiments in 2005 tested bed mobilization during a flow of 8,410 cfs, the post-NDPP 11-year flood. The as-built D_{84} (as represented by two as-built pebble counts) was finer than the D_{84} assumed for design calculations (68 mm on constructed bars and 58 mm at constructed riffles). Even with the finer bed texture, bed mobilization was achieved at only one of the two sites where marked rock experiments were conducted. The bed surface was fully mobilized at the constructed bar at the upstream end of the reach (cross section 2214+50), where the channel is confined by adjacent terraces. Further downstream at cross section 2198+30, where setback dikes and constructed floodplains provide less channel confinement, the constructed bar surface was only partially mobilized.

The effects of the 2005 and 2006 flows on the stability of the constructed bankfull channel (hypothesis H3) and channel migration (hypothesis H4) have not been tested. The 2005 high flows were significant. Peak flow was an 11-year flood (8,410 cfs), and the 5,000-cfs geomorphic monitoring threshold was exceeded on 27 days. Flow in 2006 was even higher. Daily average flow peaked at 8,850 cfs (to 14-year annual maximum flood), and the 5,000-cfs geomorphic monitoring threshold was exceeded on 86 days (as of June 25). The instantaneous peak was likely higher, but instantaneous peak flow data are not yet available. Data are available to partially test effects of the 2005 high flows on channel morphology (hypothesis H3) and channel migration. Available data include high flow stage markers placed in 2005 during flows of 5,690 cfs, 6,500 cfs, and 8,400 cfs, and aerial photographs, floodplain topography, and channel bathymetry (provided by the Coarse Sediment Transfusion Project). No data are available to test the effects of the 2006 flows. These flows provide an opportunity to test many aspects of the restoration design. If geomorphic monitoring specified in the Monitoring Plan is not be conducted before winter of WY 2007, learning opportunities may be lost due to removal or degradation of high flow stage markers placed in 2005, high water marks from 2006, and other field evidence of the effects of these high flows on the channel. Moreover, if flows are higher in WY 2007, it will not be possible to isolate the effects of the WY2005–2006 from higher flows in WY 2007.

4.3.3 Chinook Salmon Spawning Habitat

Relevant hypothesis

H5. The extent and quality of Chinook salmon spawning habitat is increased.

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 (TID/MID 1992c), pre-project spawning habitat area could support 64 spawning pairs, and post-project habitat could support 174 spawning pairs, an increase of 172% relative to pre-project conditions. For the 2002–2005 post-project monitoring period, CDFG redd counts did not detect a significant change in Chinook salmon spawning at riffles in the project reach relative to control riffles. These drift boat counts, however, are not appropriate for assessing spawning use at the scale of individual riffles. Changes in the riffle naming system among years also complicate the analysis. More detailed redd counts at project and control riffles would provide a better means of assessing the effects of the project on spawning use in the project reach.

Monitoring also should include other habitat factors known to affect selection of the spawning sites and egg and alevin survival-to-emergence from redds. The habitat mapping used to quantify changes in spawning habitat area defined suitable habitat based on flow depth, flow velocity, and surface substrate texture. Other factors, such as substrate permeability, hydraulic downwelling and upwelling, and intragravel dissolved oxygen, also affect salmon selection of spawning sites and egg and alevin survival-to-emergence. Many researchers believe that salmon select these sites based on downwelling caused by bed morphology and woody debris, which provides oxygen-rich water to the incubating eggs and alevin in the redds (Bjornn and Reiser 1991, Healey 1991). These areas also typically offer nearby cover in the form of deep water, large woody debris, or overhanging vegetation (Bjornn and Reiser 1991). Subsurface substrate texture also affects site selection and incubation success. Substrates preferred by Chinook salmon range from 0.5 inches to four inches in diameter and contain less than 25% fines less than 2 mm in diameter (Platts et al. 1979; Bell 1986, as cited in Bjornn and Reiser 1991). Accumulation of fine sediment in subsurface substrate reduces substrate permeability and can reduce survival-to-emergence from redds. These factors were not included in the Monitoring Plan.

4.3.4 Chinook Salmon Rearing Habitat

Relevant hypothesis:

H6. The extent and quality of Chinook salmon rearing habitat is increased.

Compared to 1999 pre-project mapping, post-project habitat mapped in 2002 was reduced by 150,700 ft^2 (64%) for fry and 494,500 ft^2 (47%) for juveniles. A portion of this reduction is likely attributable to the difference in flows during pre- and post-project mapping. Project monitoring compared pre- and post-project Chinook salmon fry and juvenile rearing habitat during conditions typical of minimum flows required by the FSA. Pre-project habitat, mapped at 254–265 cfs, represents minimum spring flows during “intermediate below normal/above normal” and wetter water years. Post-project habitat, mapped at 185 cfs, represents minimum spring flows during “median below normal” and drier water years.

Following emergence, Chinook salmon fry occupy low velocity, shallow areas near stream margins, including backwater eddies and areas associated with bank cover or large woody debris, where they aggregate in schools of 20 to 40 (Lister and Genoe 1970, Everest and Chapman 1972, McCain 1992). Fry also use pool margins and pool tails associated with bedrock obstructions, rootwads, and overhanging banks. Both pre- and post-project, suitable fry habitat occurred in a narrow band along the channel margins. For most of the reach, the project increased the length of channel margin suitable for fry rearing relative to pre-project conditions but reduced the width of the suitable habitat band. Fry habitat area is expected to increase at higher flows relative to pre-project conditions as lateral bars and floodplains are inundated. The project replaced steep banks and dikes throughout the project reach with lateral bars and floodplains. These steep banks and dikes that confined the channel would not have provided suitable fry habitat during high flows. Conversion of these steep banks to gently sloping bars and floodplains maintains low-velocity zones along the channel margins during flows up to and exceeding the bankfull discharge.

As fry increase in size and become juveniles, they shift from using channel margins to using pools, where they feed on invertebrate drift near the surface (Lister and Genoe 1970, Everest and Chapman 1972, Hillman et al. 1987, McCain 1992). Juvenile chinook salmon appear to prefer pools with cover provided by banks, overhanging vegetation, larger substrates, or large woody debris (Steward and Bjornn unpublished data, as cited in Bjornn and Reiser 1991). Maximum summer rearing densities occur in the heads of pools, where juvenile chinook form schools (Reedy 1995). During higher flows, juveniles have been observed to move to deeper areas in pools and may also move laterally toward channel margins in search of velocity refuge (Steward and Bjornn 1987, Shirvell 1994). Shirvell (1994) suggests that preferred habitat locations vary according to activity. For feeding, juvenile Chinook and other salmonids are likely to select positions with optimal velocity conditions, whereas for predator avoidance, optimal light conditions are more likely to be important (Shirvell 1994). While the project reduced suitable low-flow rearing habitat area, it likely increased 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 the steep banks and confined floodway with gently sloping banks and a broader, vegetated floodplain. During flows exceeding 5000 cfs, constructed floodplains are expected to provide an additional 33 acres of rearing habitat.

The Monitoring Plan did not include direct observations of the Chinook salmon juvenile and fry use of different habitats in the project reach. TID has conducted winter and spring seine surveys at several locations throughout the river since 1986. Adding sites within the 7/11 Reach would be a cost-effective way of building on long-term, river-wide data to conduct site-specific monitoring. Sites already included in the river-wide surveys provide control sites needed to isolate project-related effects from other factors affecting fry and juvenile density and conditions in the river.

4.3.5 Riparian Vegetation

Relevant hypotheses:

H7. Planted riparian vegetation will become established on the constructed floodplain.
H8. Natural recruitment of native riparian plant species will occur on the constructed floodplain.
H9. Riparian vegetation will not encroach into the constructed channel.

Post-irrigation success of planted vegetation and natural recruitment of native vegetation on the constructed floodplain has not been monitored. The 7/11 Project provides an opportunity to evaluate riparian plant survival and recruitment on constructed floodplains with different inundation characteristics. Monitoring should include measures of plant establishment and recruitment, species composition (including invasion by non-native species), and plant health. Factors that are thought to control native plant establishment and recruitment at the site should also be monitored, including flow timing, magnitude and elevation; groundwater elevation and drawdown rates; and seed availability at the site. These data would be useful for future restoration project design and for identifying flow measures that support native riparian ecosystems on the river.

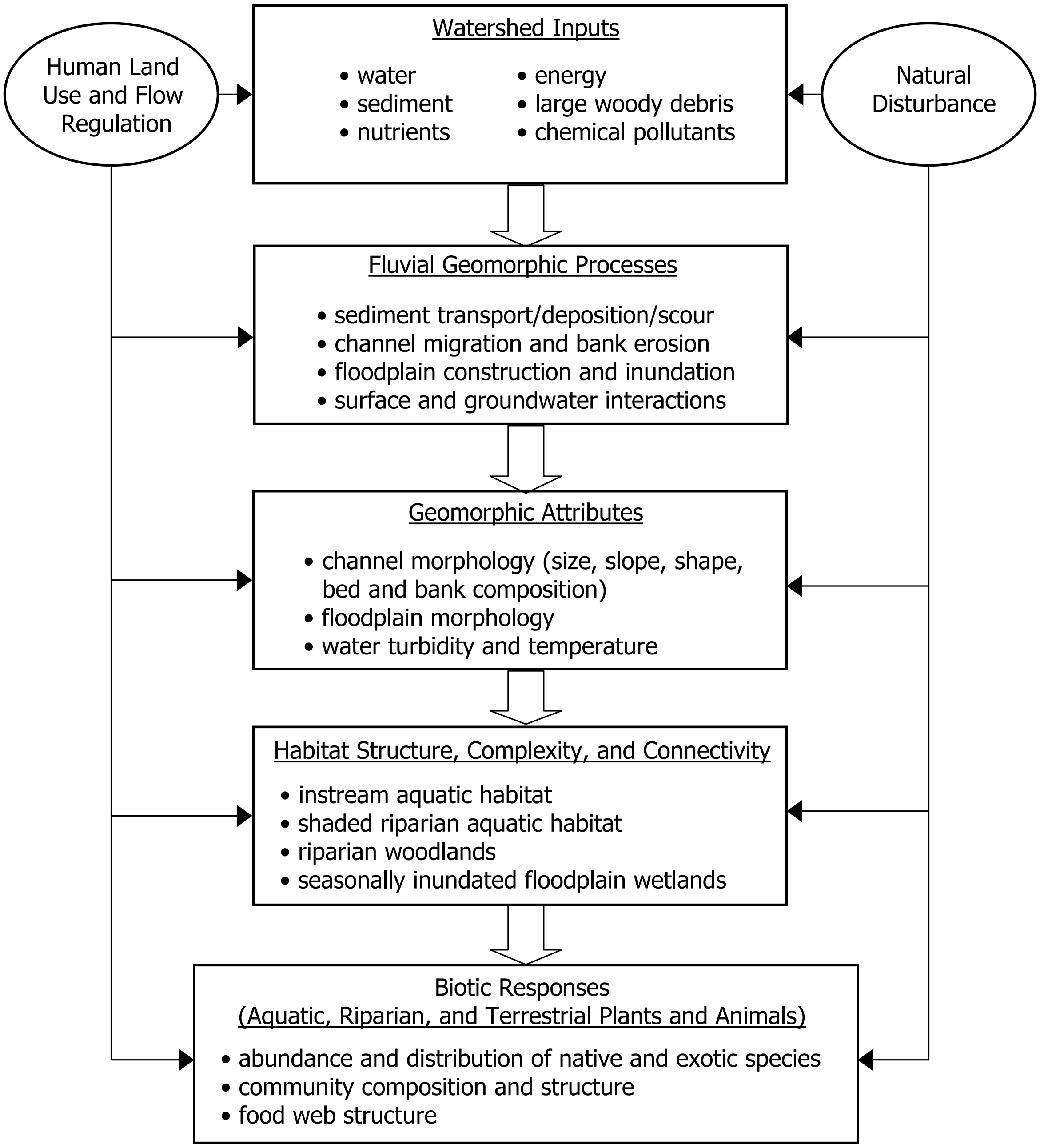


Figure 4.1. A simplified conceptual model of the physical and ecological linkages in alluvial river–floodplain systems. SOURCE: Stillwater Sciences.

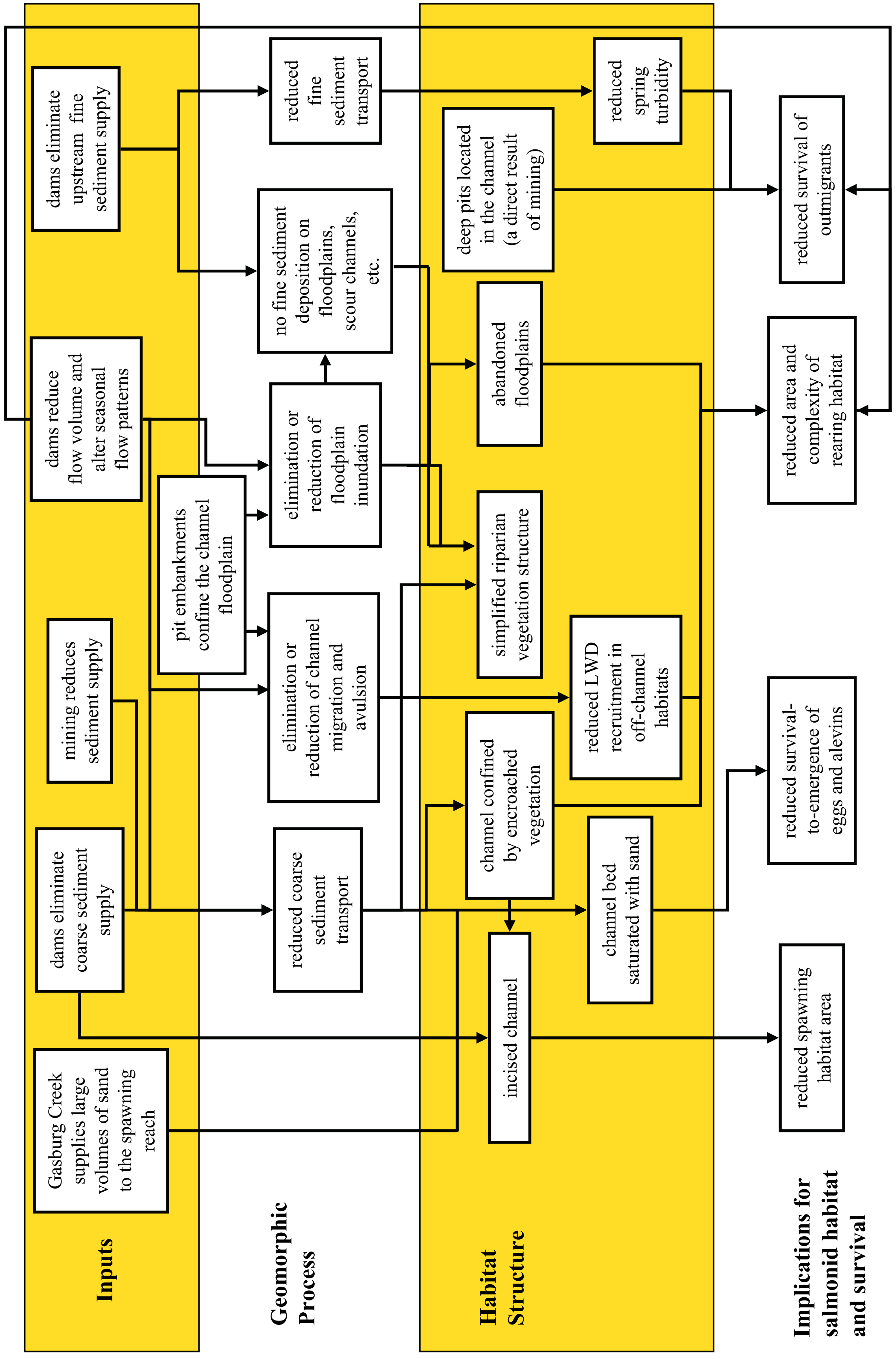
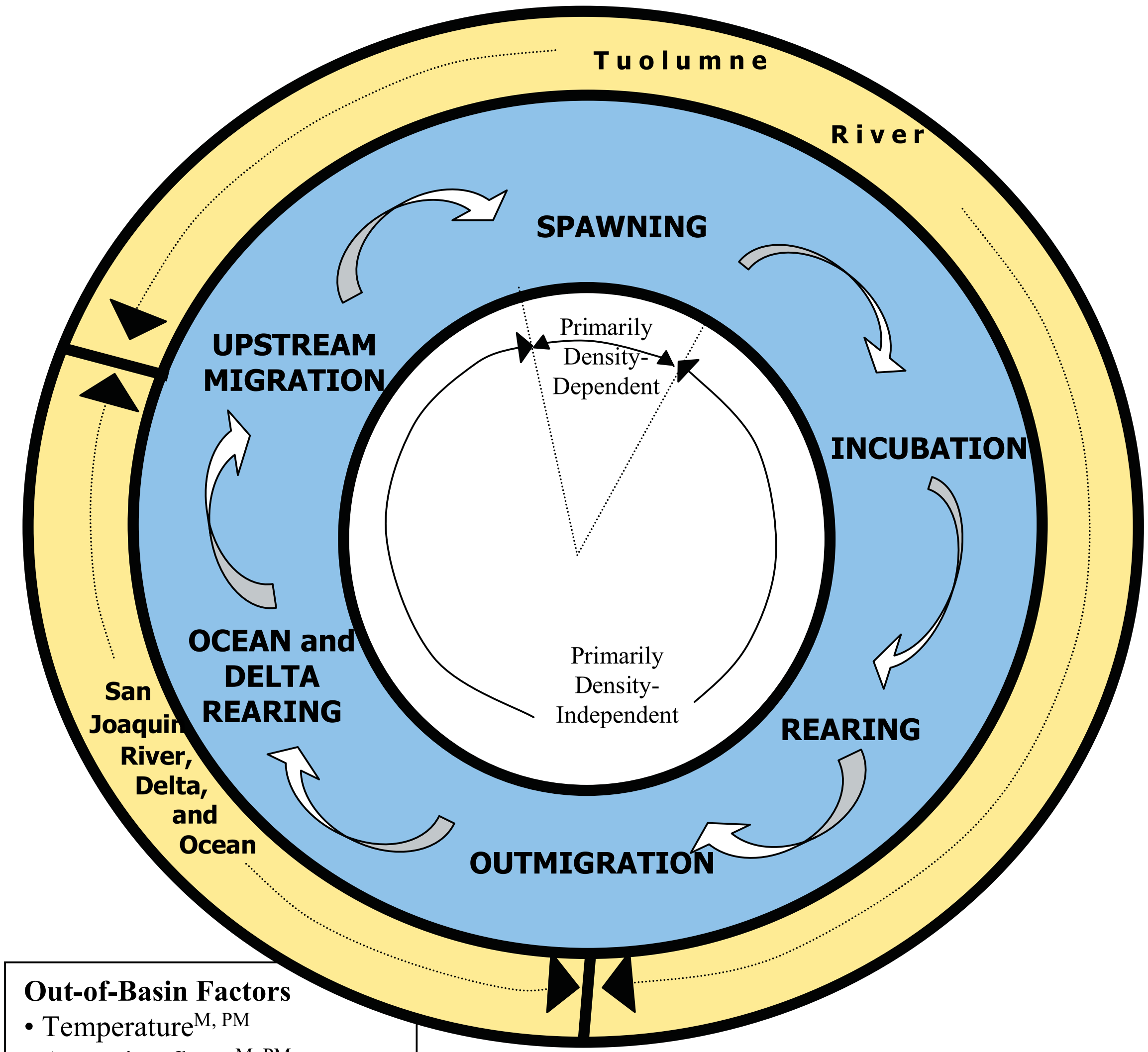


Figure 4-2. Conceptual model of the effects of dams and mining on geomorphic inputs and processes, habitat structure, and population response



Key In-Basin Factors

Affecting Adult Migration
- Flow
- Temperature
- Dissolved oxygen

submodel

Affecting Spawning and Incubation Survival
- Redd superimposition$^{*,\ PM}$ [S-2]
- Habitat area$^{M,\ PM}$ [S-2, S-3]
- Substrate permeability $^{*,\ PM}$ [S-3]
- Water temperature$^{M,\ PM}$ [S-3]

Affecting In-river Rearing Survival
- Water temperature$^{M,\ PM}$
- Stranding$^{M,\ PM}$
- Food supply^{PM}
- Flow variability $^{M,\ PM}$
- Habitat [G-1]

Affecting Outmigration Survival
- Spring flow $^{*,\ M,\ PM}$ [S-4]
- Temperature$^{*,\ M,\ PM}$ [S-4]
- Predation $^{*,\ M,\ PM}$ [S-4]

* Indicates factors that are considered to be limiting.
M Indicates factors that are currently being monitored.
PM Indicates factors for which past monitoring data are available.

Out-of-Basin Factors
- Temperature$^{M,\ PM}$
- Attraction flows$^{M,\ PM}$
- Water quality $^{M,\ PM}$
- Dissolved oxygen$^{M,\ PM}$
- Harvest$^{*,\ M,\ PM}$
- Ocean conditions$^{M,\ PM}$
- Delta export mortality $^{*,\ M,\ PM}$

Model S-1. Overarching model of factors affecting chinook salmon population abundance in the Tuolumne River.
[Relevant submodel numbers are indicated in brackets.]

Figure 4-3. Conceptual model of the factors affecting Chinook salmon population abundance in the Tuolumne River

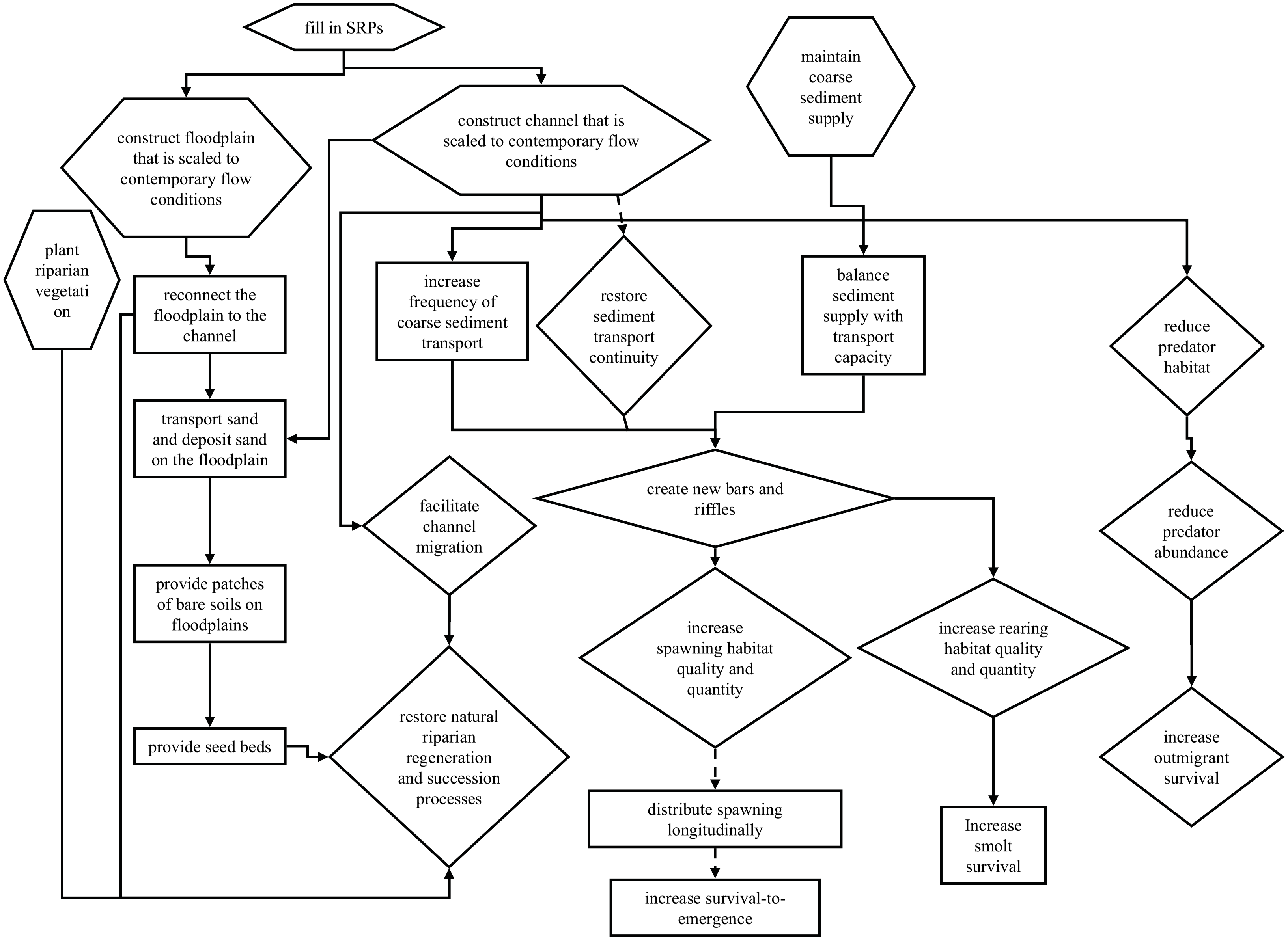


Figure 4-4. Conceptual model of the effects of reconstruction of Special Run Pools (SRPs) on geomorphic processes, riparian vegetation, and Chinook salmon survival.

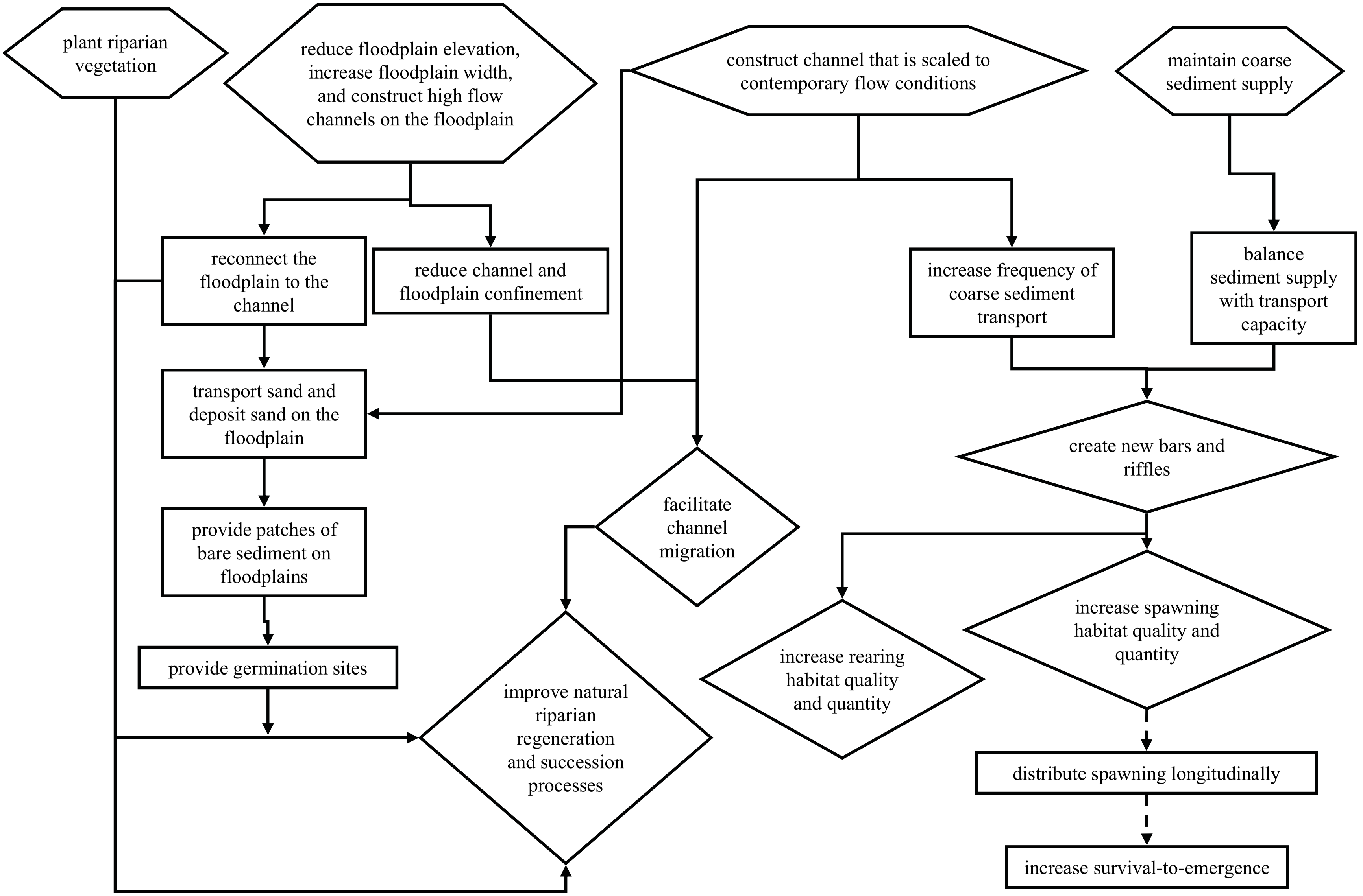


Figure 4-5. Conceptual model of the effects of the Gravel Mining Reach Project on geomorphic processes, riparian vegetation, and Chinook salmon survival

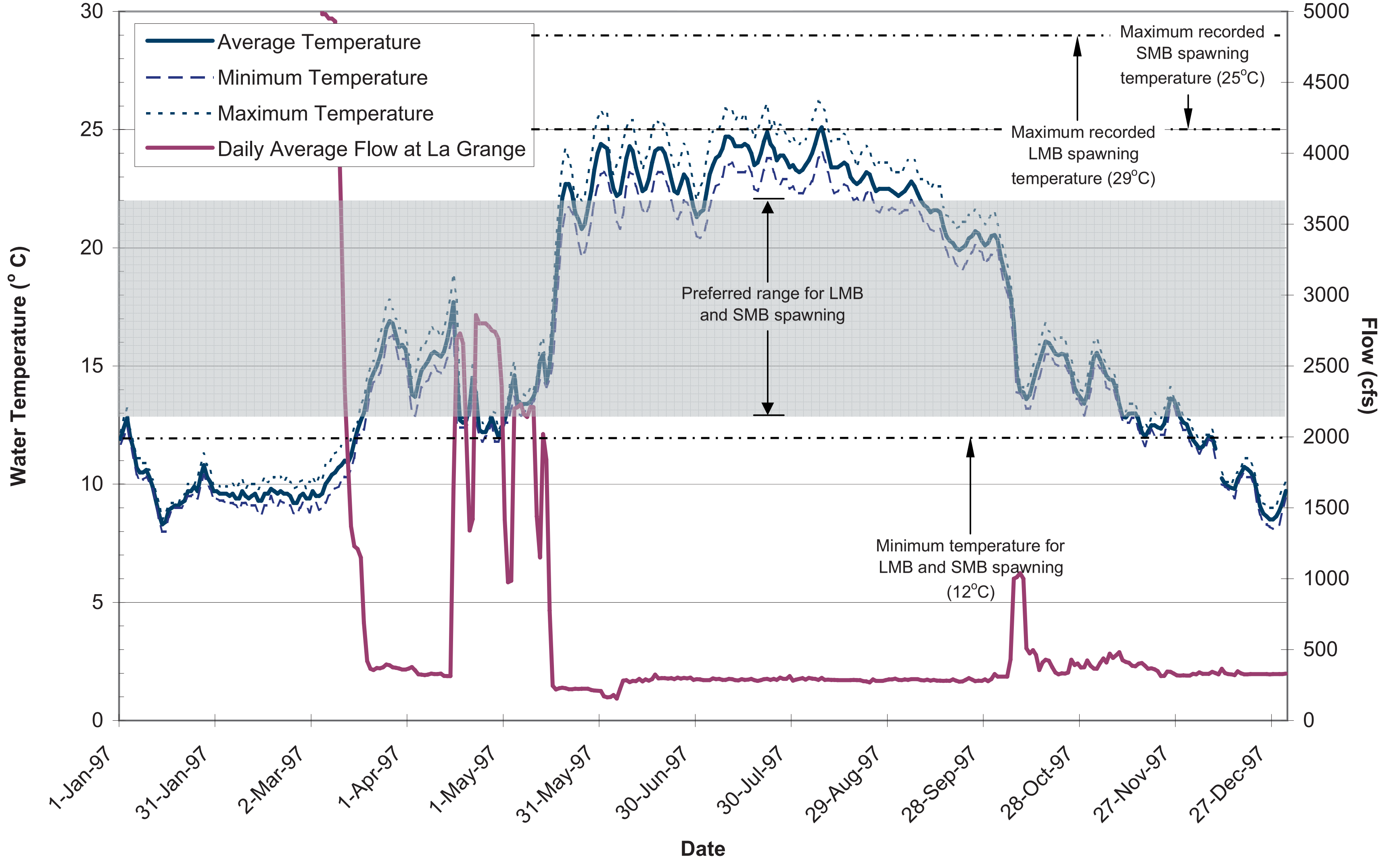


Figure 4-6. 1997 flow and temperature conditions in the project reach, with bass spawning temperatures. (Sources: USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.; TID/MID thermographs at RM 23.6 and 3.4.)

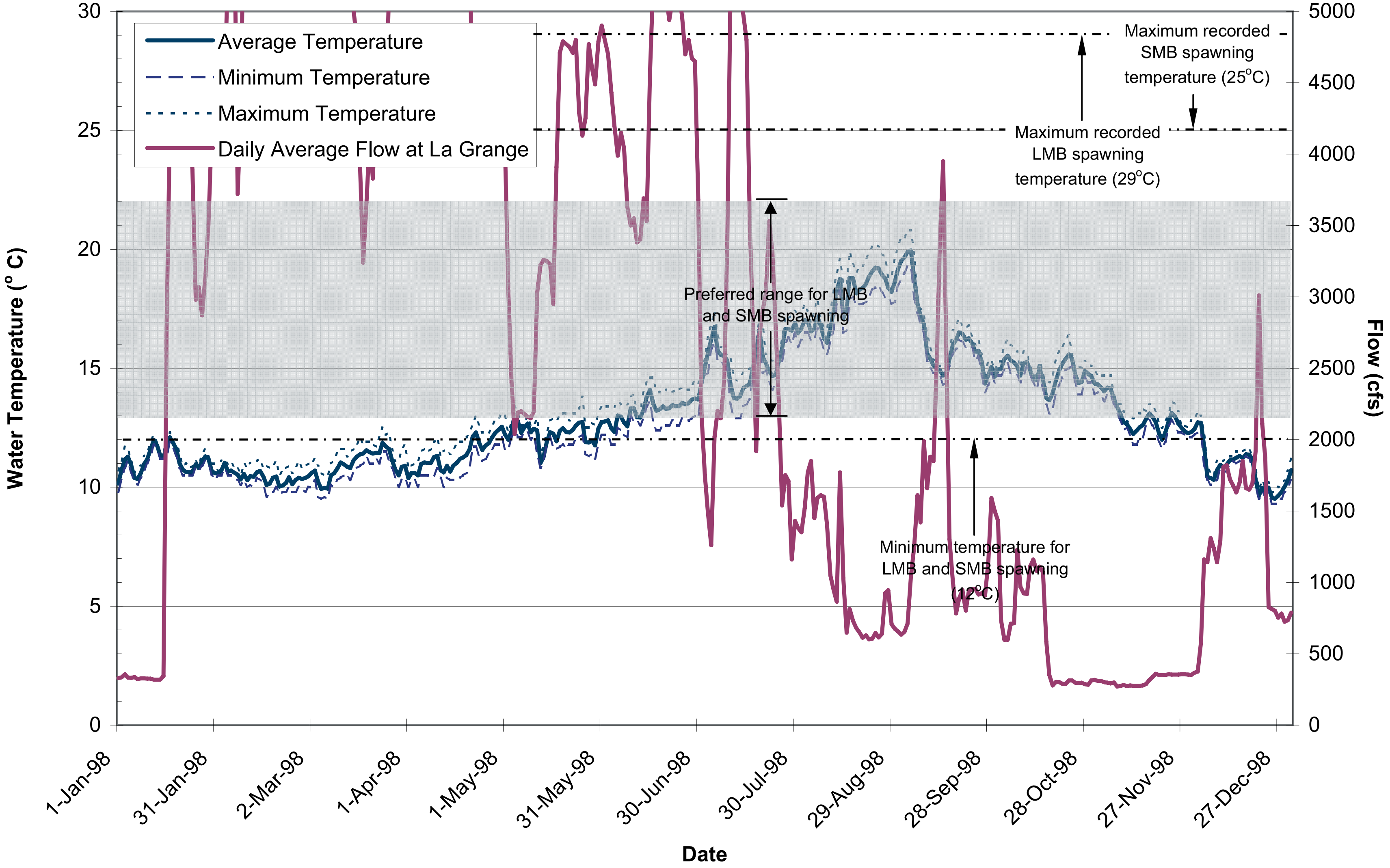


Figure 4-7. 1998 flow and temperature conditions in the project reach, with bass spawning temperatures. (Sources: USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.; TID/MID thermographs at RM 23.6 and 3.4.)

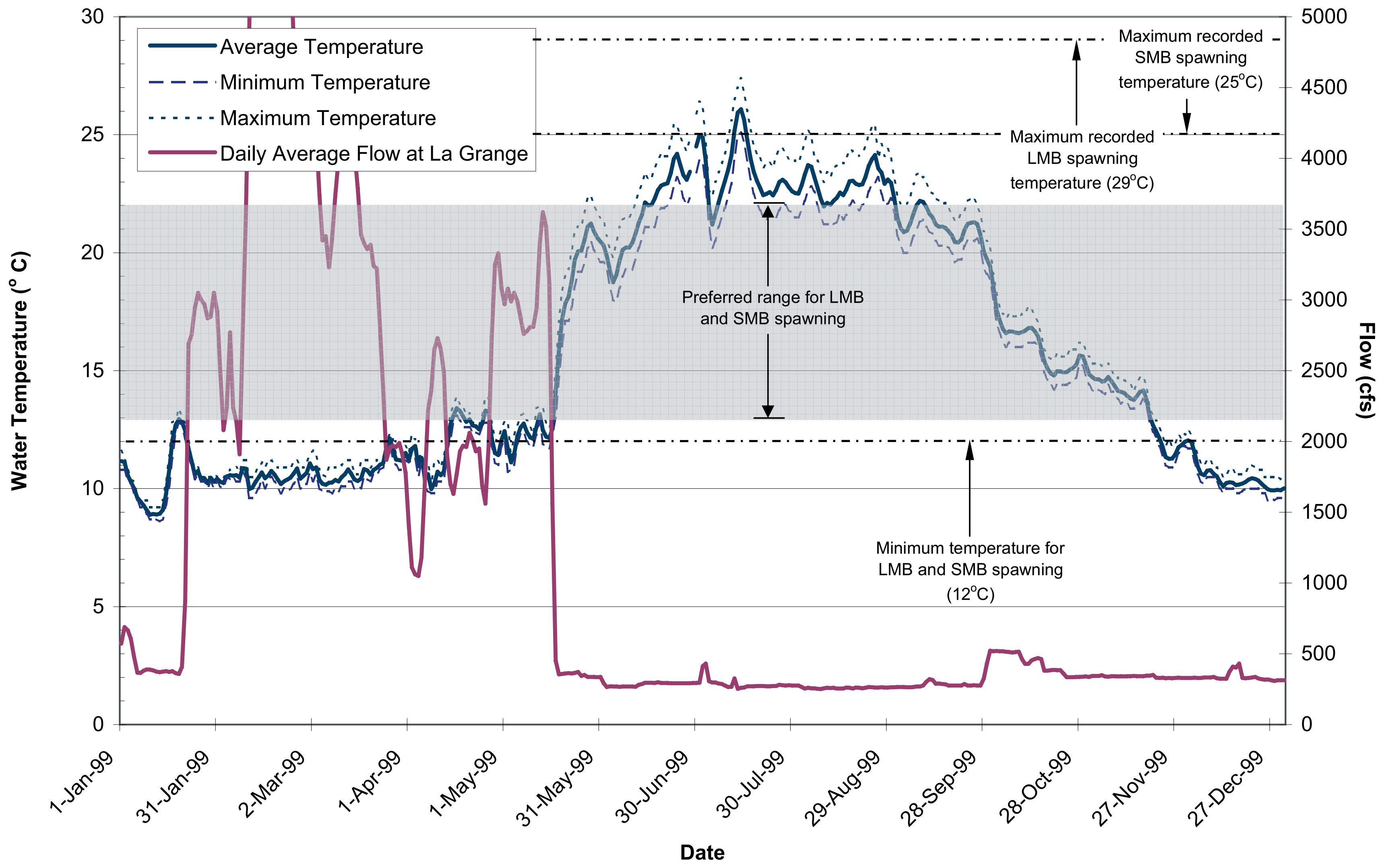


Figure 4-8. 1999 flow and temperature conditions in the project reach, with bass spawning temperatures. (Sources: USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.; TID/MID thermographs at RM 23.6 and 3.4.)

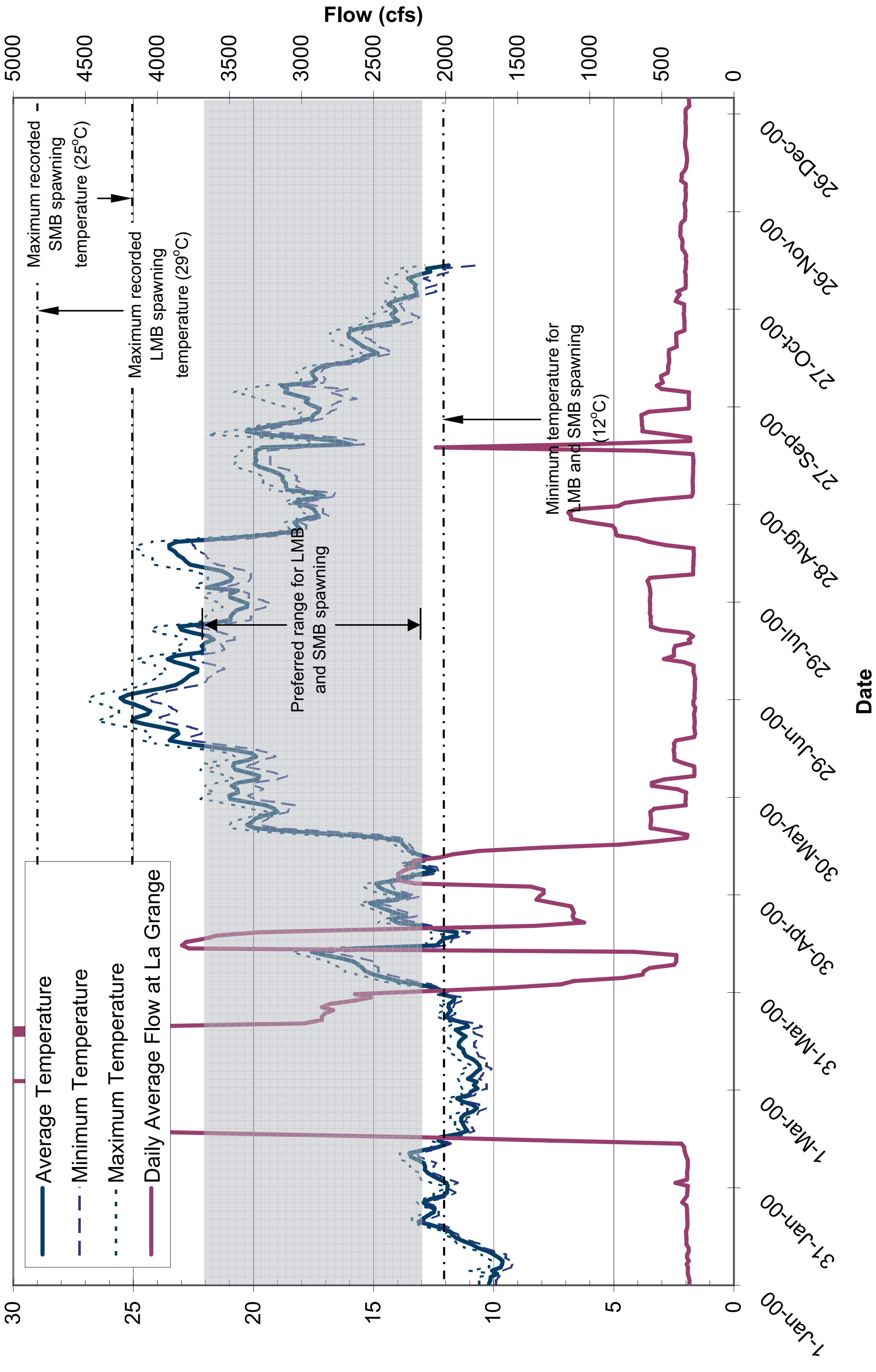


Figure 4-9. 2000 flow and temperature conditions in the project reach, with bass spawning temperatures. (Sources: USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.; TID/MID thermographs at RM 23.6 and 3.4.)

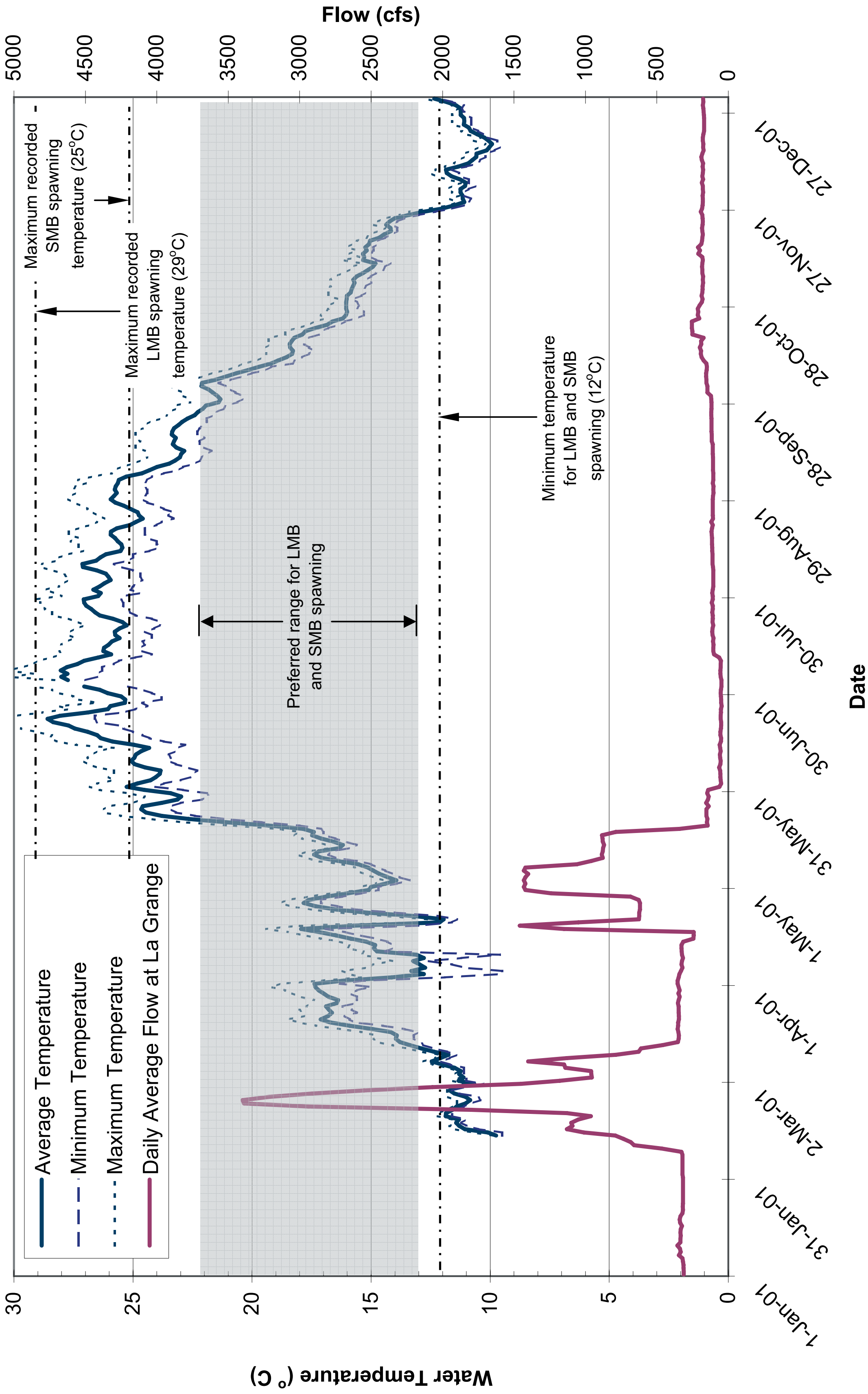


Figure 4-10. *2001 flow and temperature conditions in the project reach, with bass spawning temperatures. (Sources: USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.; TID/MID thermographs at RM 23.6 and 3.4.)*

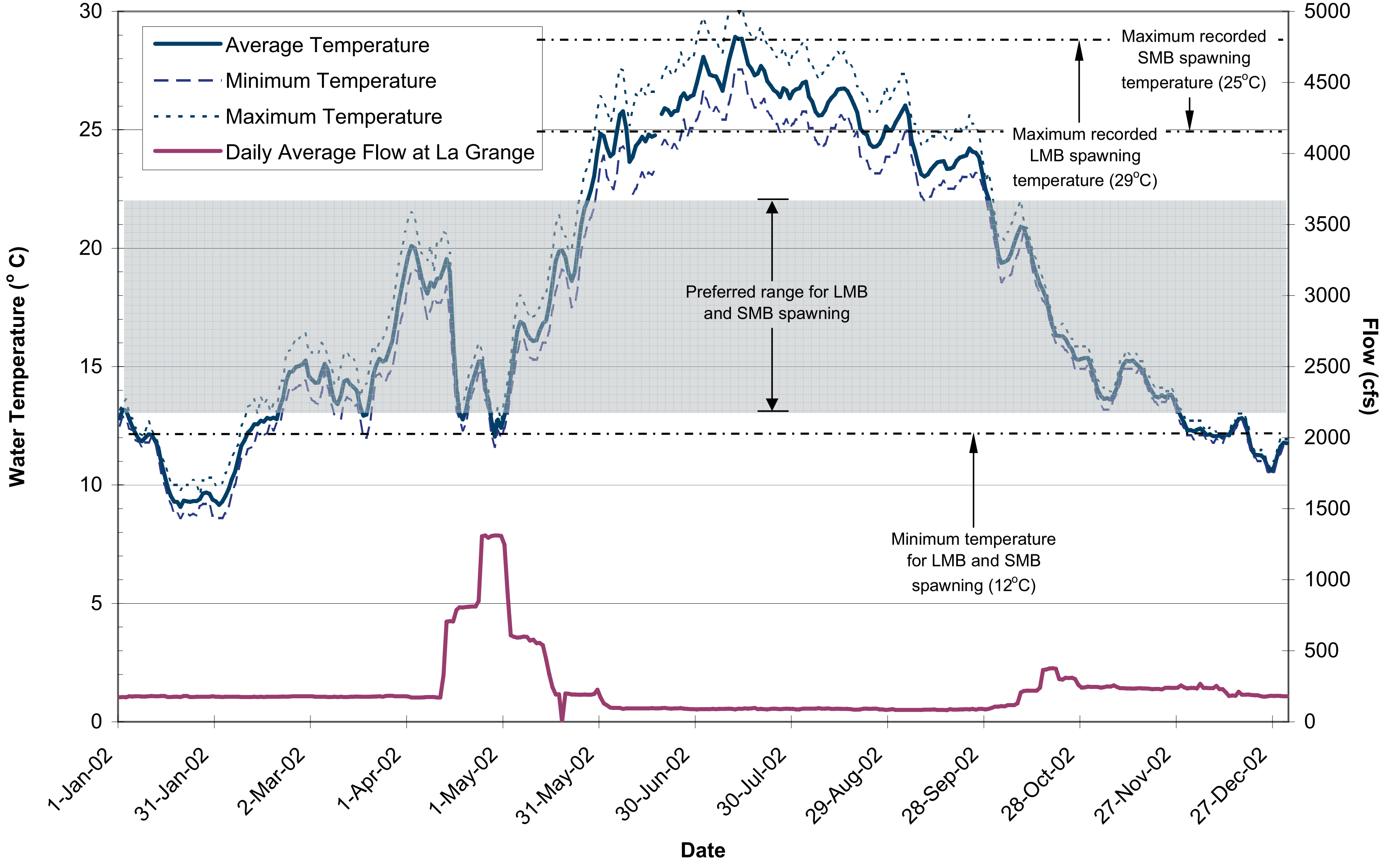


Figure 4-11. 2002 flow and temperature conditions in the project reach, with bass spawning temperatures. (Sources: USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.; TID/MID thermographs at RM 23.6 and 3.4.)

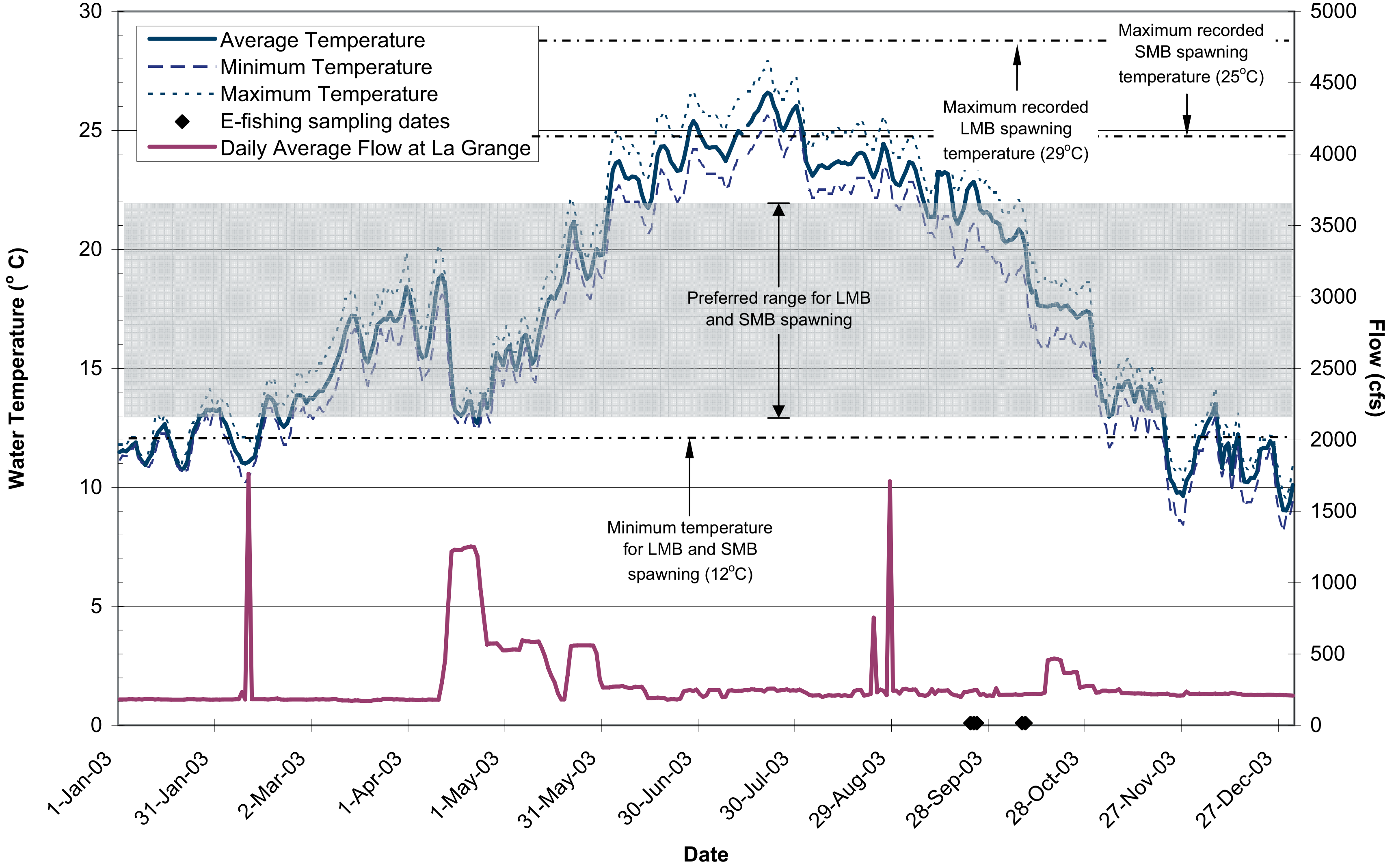


Figure 4-12. *2003 flow and temperature conditions in the project reach, with bass spawning temperatures. (Sources: USGS gage no. 1289650 Tuolumne R bl La Grange Dam nr La Grange CA.; TID/MID thermographs at RM 23.6 and 3.4.)*

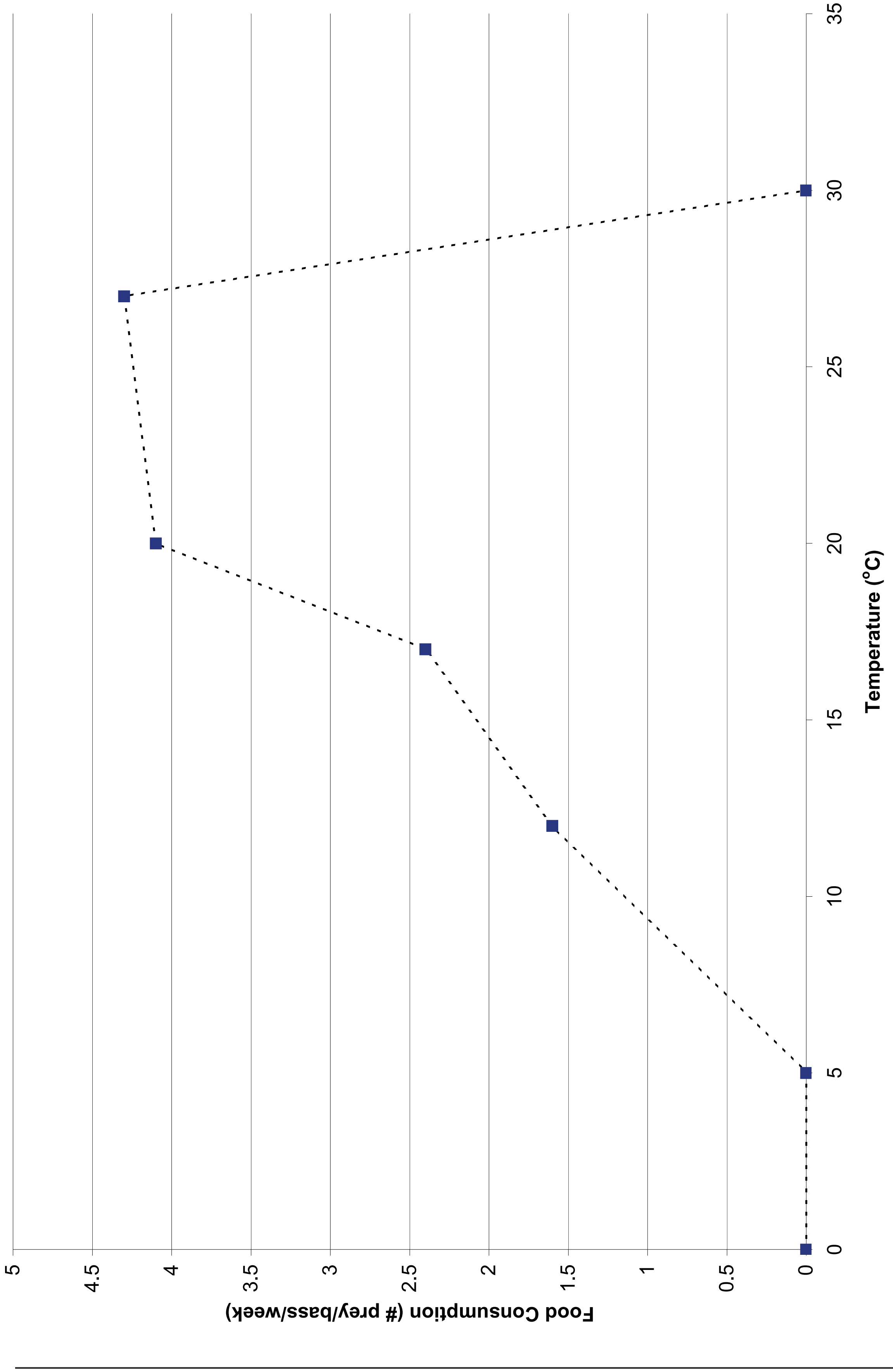


Figure 4-13. Relationship between water temperature and largemouth bass foraging rates, modified from Coutant 1975.

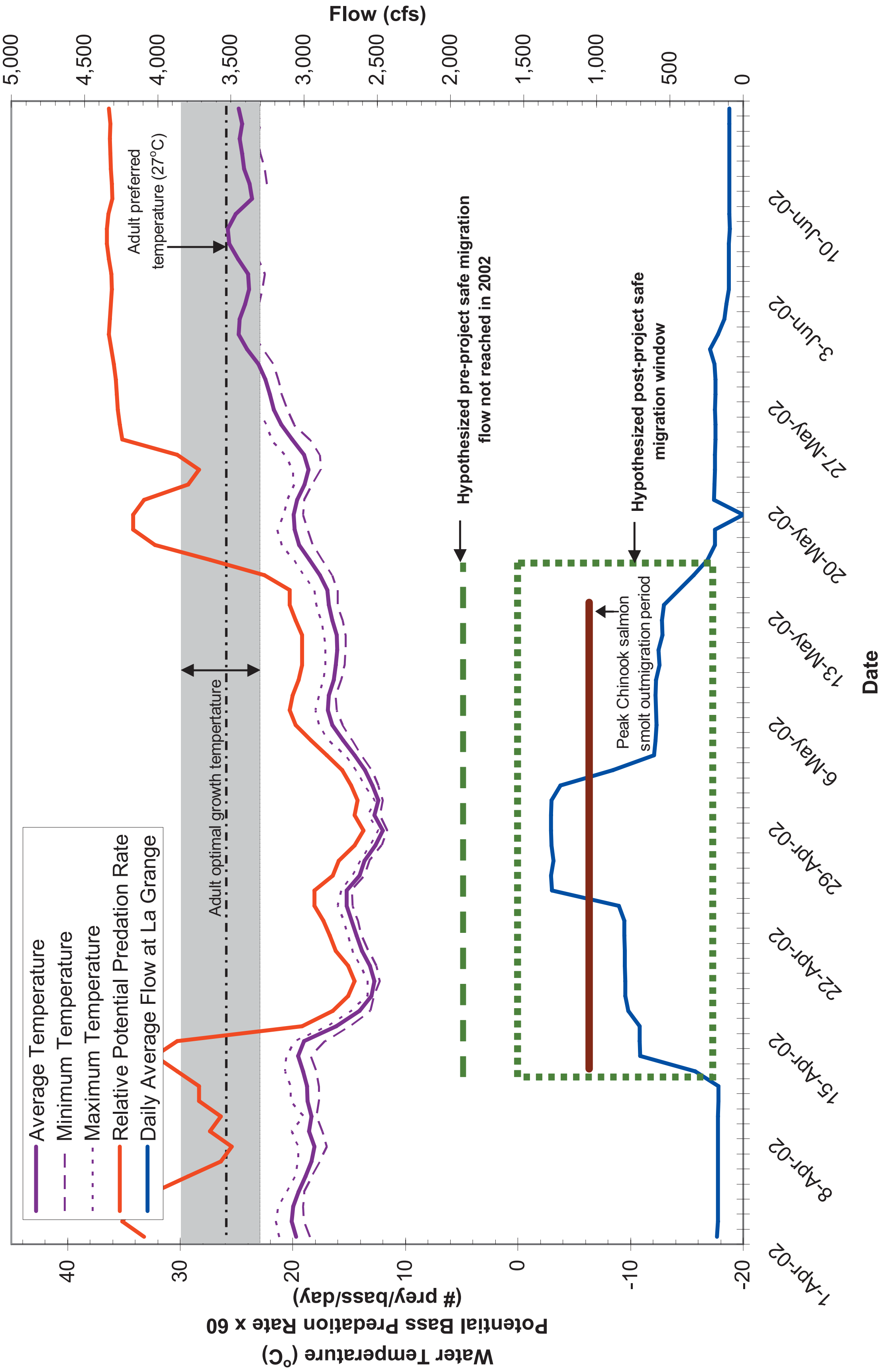


Figure 4-14. Flow, temperature, and predicted relative bass predation rates during peak Chinook salmon outmigration in 2002.

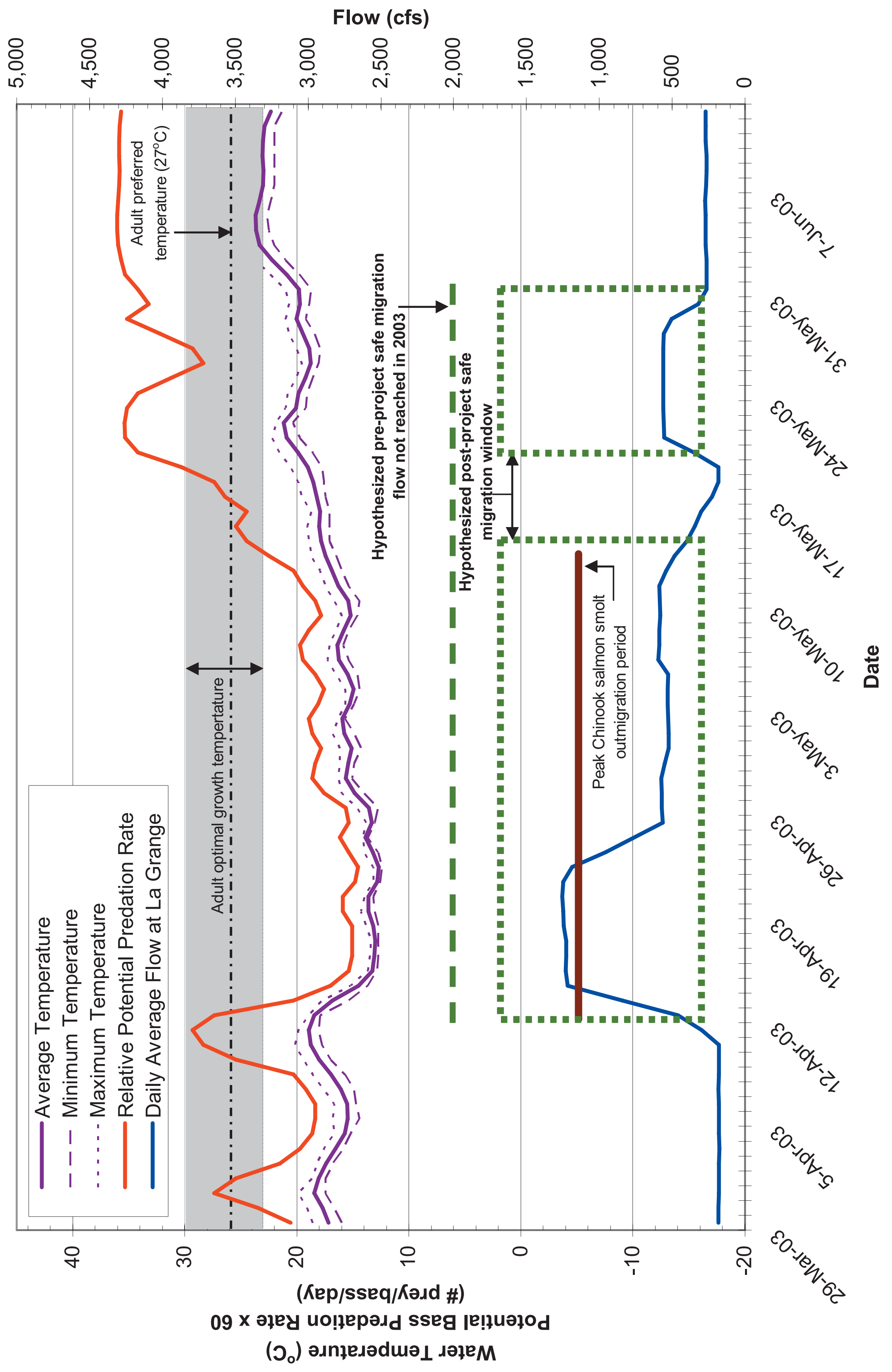


Figure 4-15. Flow, temperature, and predicted relative bass predation rates during peak Chinook salmon outmigration in 2003.

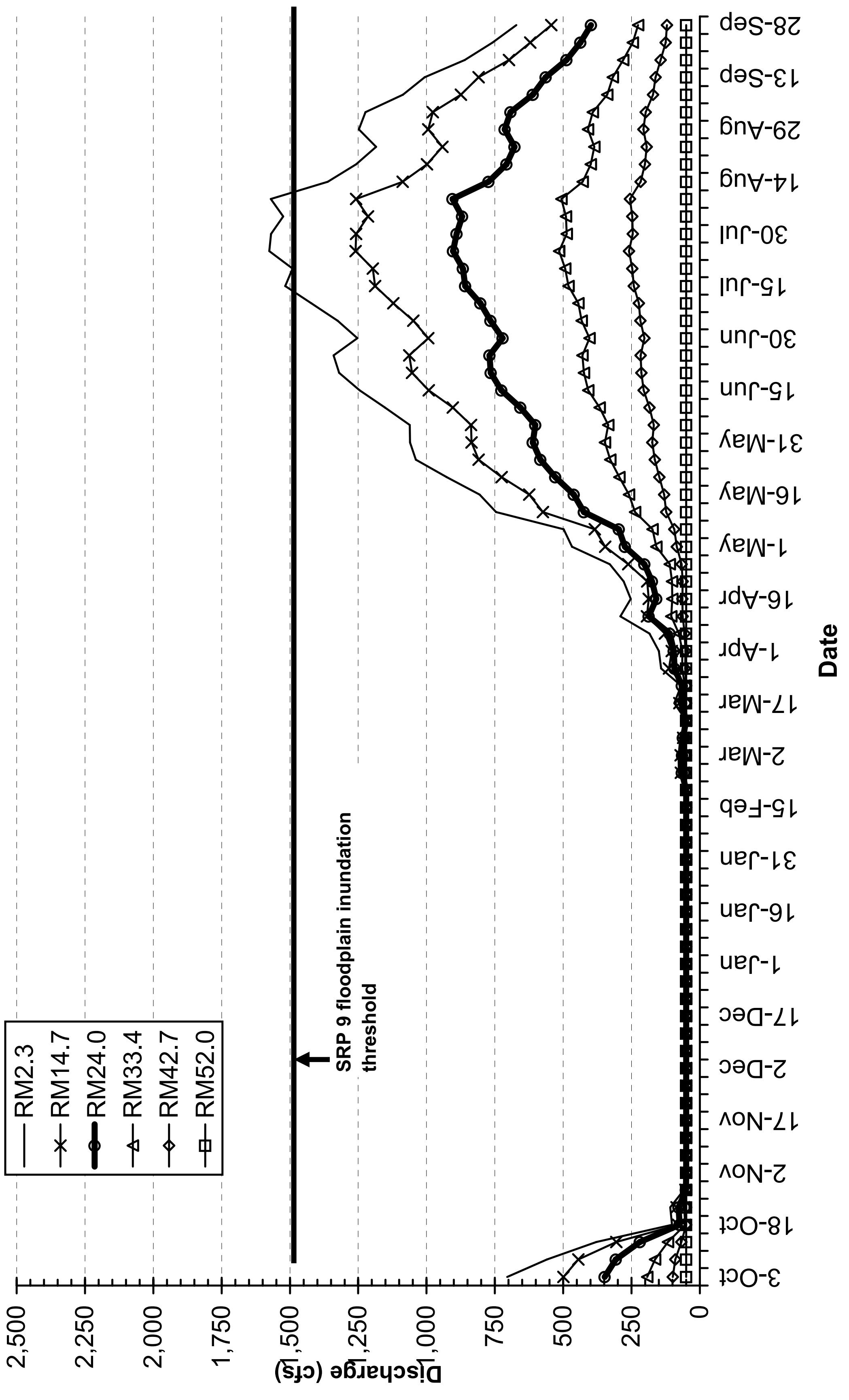
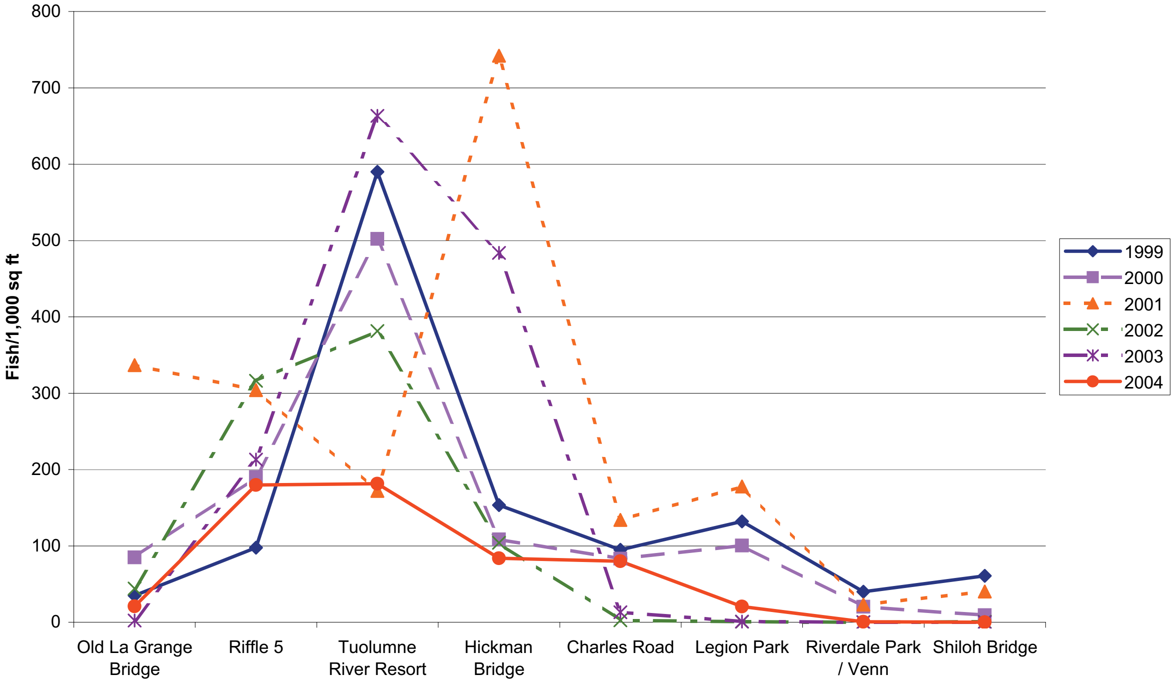


Figure 4-16. SNTEMP assessment of flow needed to maintain water temperature <65 F from La Grange Dam (RM 52) to Shilo Bridge (RM 2.3) for mean 1978-88 meteorological conditions.



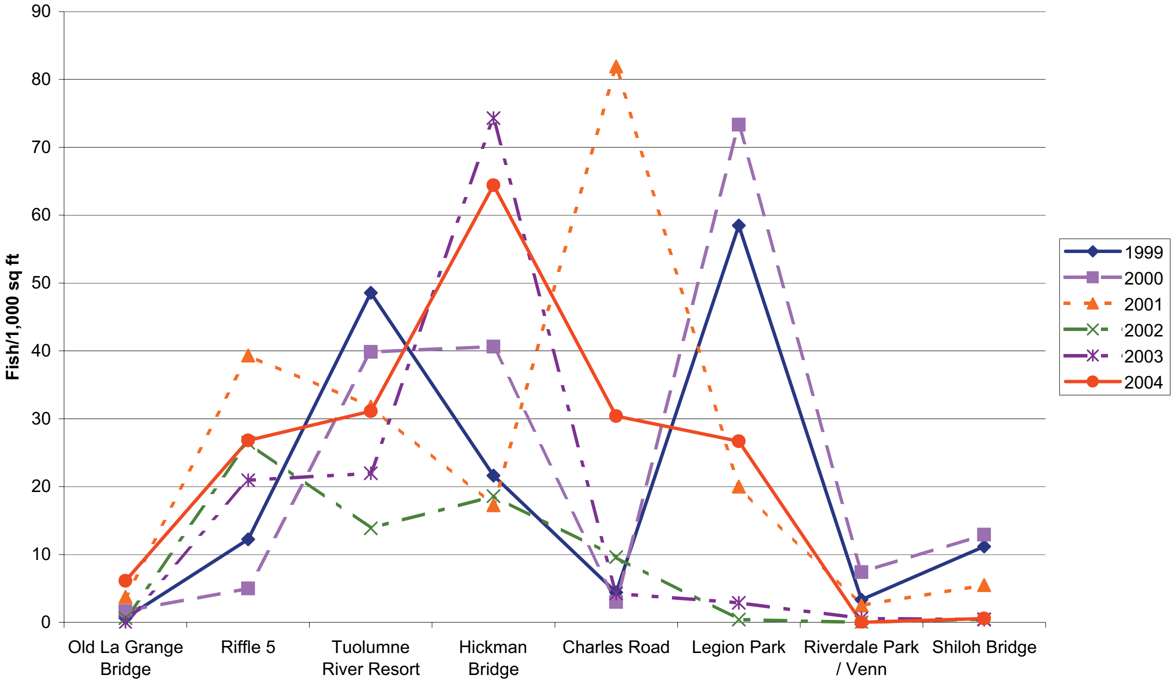


Figure 4-17. (A) Peak fry rearing distribution in the Tuolumne River 1999-2004 (B) Peak juvenile rearing distribution in the Tuolumne River 1999-2004. (Source-TID)

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5 RECOMMENDATIONS

5.1 Restoration Project Design Process

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.

5.2 River-wide and Population-level Monitoring

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 Adaptive Management Forum, in their review of Tuolumne River restoration projects, emphasized the need for integration of monitoring across spatial scales (i.e., from site-specific to river-wide) (AMF 2001). In combination with project-specific monitoring, river-wide and population-level monitoring is essential for identifying the individual and cumulative effects of current and planned restoration actions on ecosystem health and target species recovery.

In the past, river-wide monitoring was funded by the Districts and CCSF (through the FSA) and CDFG. As of 2005, FSA river-wide monitoring funds were fully expended and are no longer available. To continue gathering data needed to evaluate these restoration projects and other restoration actions, we recommend continuation of the following river-wide monitoring:

- 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.

5.3 Improvements to SRP 9 Implementation

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 3 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 (Figure 5-1).

5.4 Improvements to SRP 9 Monitoring

Based on results from pre- and post-project monitoring, we recommend continued monitoring to test hypotheses presented in Section 2. 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.

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 Rd. 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 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.

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.

5.5 Improvements to 7/11 Reach Implementation

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 to:

- 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.
- 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.

5.6 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.

Table 37. SRP 9 Monitoring Recommendations.
(Modifications to existing monitoring are indicated by an asterisk next to the hypothesis number.)*

Hypothesis	Metric	Method	Timing
H1*	• Floodplain inundation and depth at flows $\geq$1,500 cfs.	• Survey high flow markers placed in 2005. • Replace level surveys during high flows with automated and semi-automated recording gages. Establish and maintain one continuously recording stage gage at the site and a minimum of three crest gages, with each gage placed on a monitored channel/floodplain cross section.[1]	• Survey high flow stage markers as soon as possible. • Download the recording gage a minimum of once/month from November through March and every other month from April through October. Maintain crest gages after each flow event exceeding 1,500 cfs. • If automated recorders or crest gages are not installed, water surface elevation should be recorded in conjunction with predation studies to be conducted during pulse flows in spring 2005. Ideally, water surface elevation should be recorded for each step in the pulse flow event exceeding 1,000 cfs. The bankfull threshold should also be documented during the ramping up or down of the pulse flow.
H2	• Flow magnitude that mobilizes 80% of D_{84} tracer rocks at monitoring cross sections.	• Conduct tracer rock experiments at the riffle at the upstream end of SRP 9.	• Install tracer rocks immediately and monitor after at least one high flow event exceeding 5,000 cfs.
H3, H9, H4	• Net, reach-averaged aggradation and incision. Net bed elevation change $\geq$2 feet would be considered an indicator of instability. • Change in bankfull cross section width at monitoring cross sections. Change in cross section or bank erosion $\geq$5 horizontal feet without corresponding deposition on the opposite bank would be considered an indicator of possible instability. • Establishment of woody vegetation in the active channel. Establishment of willows or alders in the active channel $\geq$3 years old	• Continue periodic surveys of monitoring cross sections and longitudinal profile. For woody vegetation within the active channel, record vegetation species, location on cross section, and age.	• Resurvey channel cross sections and profile immediately to assess the effects of the 2005 and 2006 high flows. • Resurvey cross sections and profile after each high flow event exceeding 5,000 cfs.

Hypothesis	Metric	Method	Timing
	below the 1,500 cfs water surface elevation would be considered an indicator of vegetation encroachment.		
H5*	Chinook salmon do not typically spawn this far downstream. Eliminate this measure from the monitoring program.		
H6*	• Juvenile Chinook salmon size and density relative to upstream and downstream control sites.	• Add seining locations at SRP 9 (post-project) and an SRP control site to the long-term river-wide seining surveys.	• Biweekly surveys conducted from January through May each year. Floodplain surveys should be conducted during flows exceeding 1,200 cfs.
H7*	• Survival, percent cover, canopy height, and vigor of planted riparian vegetation through post-project year 5.	• Use plots or band transects to monitor survival, percent cover, canopy height, and vigor of planted riparian vegetation through post-project year 5 (i.e., 2006). • Add groundwater elevation and rate of change as monitoring parameters. Install and monitor five groundwater wells on reconstructed floodplains within the project reach. • Using portable probes, monitor soil moisture.	• Survey vegetation as soon as possible to establish 2005 condition relative to as-built planting. • Monitor groundwater wells weekly during April through October. • Monitor soil moisture weekly during April through October.
H8*	• Density of naturally recruited native woody riparian vegetation on constructed floodplains.	• Conduct annual plot-based monitoring of natural riparian vegetation recruitment and establishment on the reconstructed floodplains for three years. • Add groundwater elevation and rate of change as monitoring parameters. Install and monitor five groundwater wells on reconstructed floodplains within the project reach.	• Conduct vegetation surveys annually in late summer or early fall (after seed dispersal has ceased but leaf drop has not begun). • Continuously monitor at least one groundwater well (using a datalogger) April through June. Adjust the period of continuous groundwater monitoring based on observed seed release, as needed.
H10, H11, H12	• Linear density of piscivorous-size largemouth bass relative to channel and SRP control sites.	• Multiple-pass depletion surveys at project and control sites.	• Conduct surveys in September to maintain consistency with previous years of monitoring in one year during which water temperate at the site remains above 60^{o}F (15.5^{o}C) through July 15.
H13*	Measures to test these hypotheses will be considered in the report for the pilot predation study conducted in 2006. This reported will be available in July 2006.		
H14*			

[1] These data will be used to back-calculate Manning's roughness coefficient and test the hydraulic model developed for the site. The results will be applied to improve the hydraulic model developed for the SP 10 design.

Table 38. 7/11 Reach Monitoring Recommendations.
(Modifications to existing monitoring are indicated by an asterisk next to the hypothesis number.)*

Hypothesis	Metric	Method	Timing
H1*	• Floodplain inundation and depth at flows ≥5,000 cfs.	• Survey high flow markers placed in 2005. • Replace level surveys conducted during high flows with automated and semi-automated recording gages. • Establish and maintain one continuously recording stage gage at or near Roberts Ferry Bridge and a minimum of three crest gages, with each gage placed on a monitored channel/floodplain cross section.	• Survey high flow stage markers as soon as possible. • Download the recording gage a minimum of once/month from November through March and every other month from April through October. • Maintain crest gages after each flow event exceeding 4,500 cfs.[1]
H2	• Flow magnitude that mobilizes 80% of D_{84} tracer rocks on monitoring transects.	• Continue to deploy and monitor tracer rocks, but increase the number of cross sections monitored to include locations upstream and downstream of Riffle 30B (i.e., within and downstream of the channel reconstruction reach.	• Check and replace rocks after each flow exceeding 4,500 cfs. Implement a minimum of tracer rock deployments at each site.
H3, H4, H9	• Net, reach-averaged aggradation and incision. Net bed elevation change ≥ 2 feet would be considered an indicator of instability. • Change in bankfull cross section width at monitoring cross sections. Change in cross section or bank erosion ≥ 5 horizontal feet without corresponding deposition on the opposite bank would be considered an indicator of possible instability. • Establishment of woody vegetation in the active channel. Establishment of willows or alders in the active channel ≥3 years old below the 5,000 cfs water surface elevation would be considered an indicator of vegetation encroachment.	• Continue periodic surveys of monitoring cross sections and longitudinal profile. For woody vegetation within the active channel, record vegetation species, location on cross section, and age. • Analyze 2005 aerial photographs, channel bathymetry, and floodplain topography surveys to isolate the effects of the 2005 flows from the 2006 flows.	• Resurvey channel cross sections and profile immediately to assess the effects of the 2005 and 2006 high flows. • Resurvey cross sections and profile after each of two high flow events exceeding 4,500 cfs.

Hypothesis	Metric	Method	Timing
H4	• Bank erosion/channel migration rates throughout the reach.	• Analyze 2005 aerial photographs, channel bathymetry, and floodplain topography surveys to isolate the effects of the 2005 flows from the 2006 flows. • In addition to channel surveys above, continue aerial photograph interpretation. Aerial photographs should be true color, stereo pairs, and at suitable resolution for printing and interpretation at a scale of 1:6,000 or larger.	• Based on review of 2005 photographs and field surveys, determine the need for additional photographs to capture the effects of the 2006 high flows. • Obtain additional photographs following one flow exceeding 9,000 cfs or if noticeable changes in channel location occur.
H5*	• Chinook salmon spawning density and distribution at project riffles relative to control riffles.	• Supplement habitat mapping with detailed redd counts and habitat characterization in the channel reconstruction reach (Roberts Ferry Bridge to Riffle 30B), downstream riffles within the project reach, and upstream control riffles. • At least one time during spawning flows, quantify habitat characteristics at each monitoring riffles.	• Biweekly from approximately November 1 through December 31 each year.
H6*	• Rearing fry and juvenile density relative to upstream and downstream monitoring sites and control sites in pre-project future project reaches in the Gravel Mining Reach.	• Supplement habitat mapping with seine surveys.	• Biweekly surveys conducted from January through May each year.
H7*	• Survival, percent cover, canopy height, and vigor of planted riparian vegetation through post-project year 5.	• Use plots or band transects to monitor survival, percent cover, canopy height, and vigor of planted riparian vegetation through post-project year 5 (i.e., 2008). • Add groundwater elevation and rate of change as monitoring parameters. Install and monitor five groundwater wells on reconstructed floodplains within the project reach.	• Survey vegetation as soon as possible to establish 2005 condition relative to as-built planting. Resurvey in project year 5 (2008). • Monitor groundwater wells weekly during April through October. • Monitor soil moisture weekly during April through October.
H8*	• Density of naturally recruited native woody riparian vegetation on constructed floodplains.	• Conduct annual plot-based monitoring of natural riparian vegetation recruitment and establishment on the reconstructed floodplains for three years. Add groundwater elevation and rate of change as monitoring parameters. • Install and monitor five groundwater wells on	• Conduct vegetation surveys annually in late summer or early fall (after seed dispersal has ceased but leaf drop has not begun). • Continuously monitor at least one groundwater well (using a datalogger) April through June. Adjust the period of continuous groundwater monitoring based on observed seed

Hypothesis	Metric	Method	Timing
		reconstructed floodplains within the project reach. • Using portable probes, monitor soil moisture.	release, as needed.
H10*	• Riparian nesting bird species composition, abundance and associations with vegetation structure.	• Conduct repeat point count bird surveys and associated riparian vegetation relevée surveys during the breeding season (May and June) on at least one restored floodplain location in the project site and at least two control sites (i.e., one "natural" riparian forest and one unrestored site) for three years.	• Monthly surveys at each site for a period of three years.

[1] These data will be used to back-calculate Manning's roughness coefficient and test the hydraulic model developed for the site. The results will be applied to improve the hydraulic model developed for the design of subsequent phases.

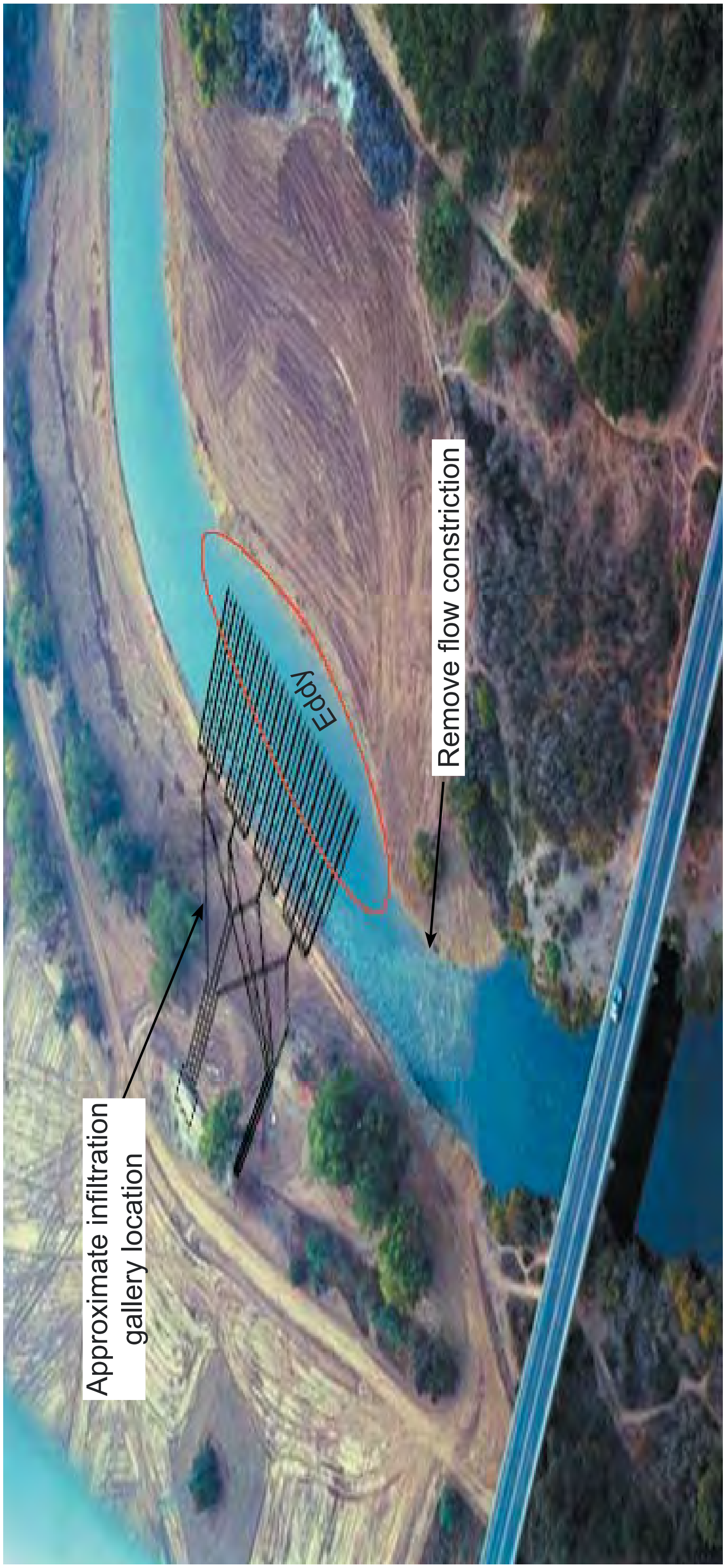

Figure 5-1. Proposed retroactive modifications to SRP 9 to reduce largemouth bass habitat.

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Appendix A.

Abundance and Density of Largemouth and Smallmouth Bass at Project and Reference Sites in 1998, 1999, 2003.

Table A-1. 1998 estimates of abundance and density of largemouth bass (all size clases combined) at project and control sites

							CARLE-STRUB ESTIMATOR				PROFILE-LIKELIHOOD (SEBER) ESTIMATOR			
Location	Sample date	Bank length (ft)	Site area (sq ft)	Pass No.	No. Captured	Mean fork length (mm)	Probability of Capture	Population abundance (95% C.I.)	Fish per unit bank length (no./ft)	Fish per unit site area (no./ft^2)	Probability of Capture	Population abundance (95% C.I.)	Fish per unit bank length (no./10^{3}ft)	Fish per unit site area (no./10^{6}ft^2)
Project Sites														
SRP 9	09/21/98	1,830	284,653	1	7	336	0.4857	19	0.0104	6.67E-05	0.4474	20	3.2	6.69
				2	8	242		(14-25)				(14-46)		
				3	2	257								
SRP 10	09/23/98	2,498	429,703	1	12	281	0.4110	37	0.0148	8.61E-05	0.3947	38	4.6	8.54
				2	14	220		(27-51)				(27-89)		
				3	4	230								
Reference Sites														
SRP 7	09/25/98	3,847	418,518	1	9	237	0.3385	30	0.0078	7.17E-05	0.2651	36	2.9	8.29
				2	7	195		(18-44)				(17-INF)		
				3	6	255								
SRP 8	09/24/98	3,172	575,161	1	23	302	0.5211	41	0.0129	7.13E-05	0.5211	41	3.5	6.52
				2	6	254		(34-50)				(34-52)		
				3	8	213								
Charles Rd	09/26/98	2,950	147,684	1	0		NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]
				2	1	140								
				3	1	115								
South Pit														
South Pit	09/26/98	5,224	NA	1	26	296	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]
				2	NA									
				3	NA									
All Sites Combined:														
		19,521	*1,855,719.00*	*1*	*77*	*292*	*0.5038*	*152*			*0.4981*	*153*		
				2	*36*	*223*		*(137-173)*				*(137-175)*		
				3	*21*	*228*								

[1] NE = Not Estimable

Table A-2. 1998 estimates of abundance and density of largemouth bass 180 - 380 mm FL at project and control sites

						CARLE-STRUB ESTIMATOR				PROFILE-LIKELIHOOD (SEBER) ESTIMATOR			
Location	Sample date	Bank length (ft)	Site area (sq ft)	Pass No.	No. Captured	Probability of Capture	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)
Project Sites													
SRP 9	09/21/98	1,830	284,653	1	3	0.80	4 (3-4)	2.2	1.4	0.80	4 (3-4)	2.2	1.4
				2	1								
				3	0								
SRP 10	09/23/98	2,498	429,703	1	5	0.45	15 (10-21)	6.0	3.5	0.41	16 (9-inf)	6.4	3.7
				2	6								
				3	2								
Reference Sites													
SRP 7	09/25/98	3,847	418,518	1	4	0.40	12 (6-16)	3.1	2.9	0.32	14 (6-inf)	3.6	3.3
				2	3								
				3	3								
SRP 8	09/24/98	3,172	575,161	1	12	0.67	18 (15-19)	5.7	3.1	0.67	18 (16-20)	5.7	3.1
				2	3								
				3	3								
Charles Rd	09/26/98	2,950	147,684	1	0	NE	0	0.0	0.0	NE	0	0.0	0.0
				2	0								
				3	0								
All Sites Combined:													
		14,297	*1,855,717.44*	*1*	*24*								
				2	*13*								
				3	*8*								

Table A-3. 1998 estimates of abundance and density of smallmouth bass (all size clases combined) at project and control sites

							CARLE-STRUB ESTIMATOR				PROFILE-LIKELIHOOD (SEBER) ESTIMATOR			
Location	Sample date	Bank length (ft)	Site area (ft2)	Pass No.	No. Captured	Mean fork length (mm)	Probability of Capture	Population abundance (95% C.I.)	Fish per unit bank length (no./10^{3}ft)	Fish per unit site area (no./10^{6}ft^2)	Probability of Capture	Population abundance (95% C.I.)	Fish per unit bank length (no./10^{3}ft)	Fish per unit site area (no./10^{6}ft^2)
Project Sites														
SRP 9	09/21/98	1,830	284,653	1	4	153.75	0.6000	9	4.92E-03	3.16E-05	0.6000	9	1.4	3.01
				2	4	193.25		(7-10)				(7-12)		
				3	1	120.00								
SRP 10	09/23/98	2,498	429,703	1	0		NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]
				2	1	138.00								
				3	0									
Control Sites														
SRP 7	09/25/98	3,847	418,518	1	2	132.50	0.5455	6	1.56E-03	1.43E-05	0.5455	5	0.4	1.15
				2	3	199.33		(4-7)				(4-13)		
				3	1	150.00								
SRP 8	09/24/98	3,172	575,161	1	0		NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]
				2	0									
				3	0									
Charles Rd	09/26/98	2,950	147,684	1	12	152.82	0.7500	15	5.08E-03	1.02E-04	0.7500	15	1.4	8.47
				2	1	160.00		(14-16)				(14-16)		
				3	2	128.50								
All Sites Combined:		5,224												
		14,297	*1,855,719.00*	*1*	*18*	*150.77*	*0.5741*	*33*			*0.5741*	*33*		
				2	*9*	*185.44*		*(28-38)*				*(27-40)*		
				3	*4*	*131.75*								

[1] NE = Not Estimable

Table A-4. 1998 estimates of abundance and density of smallmouth bass 180 - 380 mm FL at project and control sites

						CARLE-STRUB ESTIMATOR				PROFILE-LIKELIHOOD (SEBER) ESTIMATOR			
Location	Sample date	Bank length (ft)	Site area (sq ft)	Pass No.	No. Captured	Probability of Capture[1]	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture[1]	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)
Project Sites													
SRP 9	09/21/98	1,830	284,653	1	1	0.67	2	1.1	0.7	0.67	2	1.1	0.7
				2	1		(1-2)				(1-2)		
				3	0								
SRP 10	09/23/98	2,498	429,703	1	0	NE	0	0.0	0.0	NE	0	0.0	0.0
				2	0								
				3	0								
Control Sites													
SRP 7	09/25/98	3,847	418,518	1	0	0.50	1	0.3	0.2	0.50	1	0.3	0.2
				2	1		(0-1)				(0-1)		
				3	0								
SRP 8	09/24/98	3,172	575,161	1	0	NE	0	0.0	0.0	NE	0	0.0	0.0
				2	0								
				3	0								
Charles Rd	09/26/98	2,950	147,684	1	2	1.00	2	0.7	1.4	1.00	2	0.7	1.4
				2	0		(2-2)				(2-2)		
				3	0								
All Sites Combined:													
		14,297	*1,855,717*	*1*	*3*								
				2	*2*								
				3	*0*								

[1] NE = Not Estimable

Table A-5. 1999 estimates of abundance and density of largemouth bass (all size clases combined) at project and control sites

							Carle-Strub Estimator				Profile-likelihood Estimator			
Site	**Bank Length (ft)**	**Area (ft^2)**	**Date**	**Pass**	**Count**	**Mean Length (mm)**	**Population (95% C.I.)**	**Fish per unit length (ft)**	**Fish per unit area (ft^2)**	**Probability of Capture**	**Population (95% C.I.)**	**Fish per unit length (ft)**	**Fish per unit area (ft^2)**	**Probability of Capture**
Project Sites														
SRP 9	1,830	284,653	09/13/99	1	61	125.9	165	0.09016	5.80E-04	0.3800	167	0.0913	5.87E-04	0.3700
				2	40	122.4	(135-214)				(137-231)			
				3	25	100.4								
SRP 10	2,498	429,703	09/14/99	1	52	194.8	179	0.07166	4.17E-04	0.2800	189	0.0757	4.40E-04	0.2600
				2	30	123.7	(129-248)				(132-536)			
				3	31	109.5								
Control Sites														
U/S Riffle	2,682	157,863	09/17/99	1	26	128.9	124	0.04623	7.85E-04	0.2400	145	0.0541	9.19E-04	0.2000
				2	28	130.3	(75-206)				(82-inf)			
				3	17	121.8								
SRP 7	3,847	418,518	09/16/99	1	210	122.4	767	0.19938	1.83E-03	0.2800	777	0.2020	1.86E-03	0.2800
				2	164	118.0	(637-955)				(644-1,015)			
				3	109	110.5								
SRP 8	3,172	575,161	09/15/99	1	263	105.7	1,007	0.31745	1.75E-03	0.2600	1,020	0.3216	1.77E-03	0.2500
				2	183	89.7	(837-1,243)				(843-1,373)			
				3	150	88.4								
Charles Road	2,950	147,684	09/18/99	1	15	135.3	24	0.00814	1.63E-04	0.6100	24	0.0081	1.63E-04	0.6100
				2	4	96.8	(20-28)				(20-28)			
				3	4	178.3								
South Pit[1]	5,224		09/19/99	1	14	210.1	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]
				2	9	227.7								
				3										
All Sites Combined														
	17,876	*1,299,225*		*1*	*641*	*124.2*		0.00E+00	*0.00E+00*			*0.0000*	*0.00E+00*	
				2	*458*	*110.2*								
				3	*336*	*101.2*								

[1] Only two passes were made on a portion of the bank in the South Pond. No population estimate can be obtained from these passes.

[2] NE = not estimable

Table A-6. 1999 estimates of abundance and density of largemouth bass 180 - 380 mm FL at project and control sites

						Carle-Strub Estimator				Profile-likelihood Estimator			
Site	Bank Length (ft)	Area (ft^2)	Date	Pass	Count	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture[1]	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture[1]
Project Sites													
SRP 9	1,830	284,653	09/13/99	1 2 3	4 3 0	7 (6-7)	3.8	2.5	0.70	7 (6-8)	3.8	2.5	0.70
SRP 10	2,498	429,703	09/14/99	1 2 3	17 4 2	23 (21-24)	9.2	5.4	0.74	23 (21-24)	9.2	5.4	0.74
Control Sites													
R64	2,682	157,863	09/17/99	1 2 3	2 0 0	2 (2-2)	0.7	1.3	1.00	2 (2-2)	0.7	1.3	1.00
SRP 7	3,847	418,518	09/16/99	1 2 3	10 4 3	18 (14-21)	4.7	4.3	0.57	18 (14-25)	4.7	4.3	0.57
SRP 8	3,172	575,161	09/15/99	1 2 3	10 10 7	40 (23-60)	12.6	7.0	0.30	50 (24-inf)	15.8	8.7	0.23
Charles Road	2,950	147,684	09/18/99	1 2 3	3 0 0	3 (3-3)	1.0	2.0	1.00	3 (3-3)	1.0	2.0	1.00
All Sites Combined													
	12,652	*1,299,225*		*1* *2* *3*	*46* *21* *12*								

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[1] NE = not estimable

Table A-7. 1999 estimates of abundance and density of smallmouth bass (all size clases combined) at project and control sites

							Carle-Strub Estimator				Profile-likelihood Estimator			
Site	Bank Length (ft)	Area (ft^2)	Date	Pass	Count	Mean Length (mm)	Population (95% C.I.)	Fish per unit length (ft)	Fish per unit area (ft^2)	Probability of Capture	Population (95% C.I.)	Fish per unit length (ft)	Fish per unit area (ft^2)	Probability of Capture
Project Sites														
SRP 9	1,830	284,653	09/13/99	1	10	204.60	13	0.0071	4.57E-05	0.7600	13	0.0071	4.57E-05	0.7600
				2	2	243.00	(12-13)				(12-13)			
				3	1	260.00								
SRP 10	2,498	429,703	09/14/99	1	19	195.00	20	0.0080	4.65E-05	0.9500	20	0.0080	4.65E-05	0.9500
				2	1	222.00	(20-20)				(20-20)			
				3	0									
Control Sites														
U/S Riffle	2,682	157,863	09/17/99	1	0		NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]
				2	1	257.70								
				3	0									
SRP 7	3,847	418,518	09/16/99	1	1	305.00	1	0.0003	2.39E-06	1.0000	1	0.0003	2.39E-06	1.0000
				2	0		(1-1)				(1-1)			
				3	0									
SRP 8	3,172	575,161	09/15/99	1	0		NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]
				2	0									
				3	0									
Charles Road	2,950	147,684	09/18/99	1	11	209.60	23	0.0078	1.56E-04	0.5300	23	0.0078	1.56E-04	0.5300
				2	7	123.90	(18-29)				(18-33)			
				3	3	241.00								
South Pit[1]	5,224		09/19/99	1	0		NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]	NE[2]
				2	0									
				3										
All Sites Combined														
	17,876	*2,013,580*		*1*	*41*	*203.94*		0.0000	0.00E+00			0.0000	0.00E+00	
				2	*11*	*166.64*								
				3	*4*	*245.75*								

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[1] Only two passes were made on a portion of the bank in the South Pond. No population estimate can be obtained from these passes.

[2] NE = not estimable

Table A-8. 1999 estimates of abundance and density of smallmouth bass 180 - 380 mm FL at project and control sites

						Carle-Strub Estimator				Profile-likelihood Estimator			
Site	Bank Length (ft)	Area (ft^2)	Date	Pass	Count	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture[1]	Population (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture[1]
Project Sites													
SRP 9	1,830	284,653	09/13/99	1	5	7	3.8	2.5	0.70	7	3.8	2.5	0.70
				2	1	(6-7)				(6-8)			
				3	1								
SRP 10	2,498	429,703	09/14/99	1	8	9	3.6	2.1	0.90	9	3.6	2.1	0.90
				2	1	(9-9)				(9-9)			
				3	0								
Control Sites													
R64	2,682	157,863	09/17/99	1	0	1	0.4	0.6	0.50	1	0.4	0.6	0.50
				2	1	(0-1)				(0-1)			
				3	0								
SRP 7	3,847	418,518	09/16/99	1	1	1	0.3	0.2	1.00	1	0.3	0.2	1.00
				2	0	(1-1)				(1-1)			
				3	0								
SRP 8	3,172	575,161	09/15/99	1	0	0	0.0	0.0	NE	0	0.0	0.0	NE
				2	0								
				3	0								
Charles Road	2,950	147,684	09/18/99	1	9	13	4.4	8.8	0.65	13	4.4	8.8	0.65
				2	1	(11-15)				(11-16)			
				3	3								
All Sites Combined													
	12,652	*2,013,580*		*1*	*23*								
				2	*4*								
				3	*4*								

---

[1] NE = not estimable

Table A-9. 2003 estimates of abundance and density of largemouth bass (all size clases combined) at project and control sites

							Carle-Strub Estimator				Profile-likelihood Estimator			
Site	Bank Length (ft)	Area (ft^2)	Date	Pass	Count	Mean Length (mm)	Population (95% C.I.)	Fish per unit length (1000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture	Population (95% C.I.)	Fish per unit length (1000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture
Project Sites														
SRP 9	1,727	98,473	10/08/03	1	39	165.23	60	34.74	60.93	0.6200	60	34.74	60.93	0.6200
				2	10	167.30	(54-65)				(54-66)			
				3	8	164.88								
SRP 10	2,498	429,703	10/09/03	1	77	236.12	149	59.65	34.68	0.4800	149	59.65	34.68	0.4800
				2	24	256.67	(132-173)				(132-174)			
				3	27	242.56								
Control Sites														
Riffle 64	2,682	157,863	09/24/03	1	9	141.78	14	5.22	8.87	0.7000	14	5.22	8.87	0.7000
				2	4	149.75	(12-15)				(12-15)			
				3	1	61.00								
SRP 7	3,847	418,518	09/22/03	1	46	190.33	205	53.29	48.98	0.2400	225	58.49	53.76	0.2100
				2	41	171.32	(138-325)				(144-1,089)			
				3	29	114.07								
SRP 8	3,172	575,161	09/23/03	1	79	222.13	257	81.02	44.68	0.2900	265	83.54	46.07	0.2800
				2	42	152.79	(197-380)				(199-473)			
				3	45	169.49								
Charles Road	2,950	147,684	10/08/03	1	10	203.50	40	13.56	27.08	0.3400	45	15.25	30.47	0.2900
				2	14	246.86	(25-58)				(27-inf)			
				3	5	85.60								
All Sites Combined														
	16,877	*1,827,401*		*1*	*260*	*208.6*								
				2	*135*	*187.6*								
				3	*115*	*167.8*								

Table A-10. 2003 estimates of abundance and density of largemouth bass 180 - 380 mm FL at project and control sites

						Carle-Strub Estimator				Profile-likelihood Estimator			
Site	Bank Length (ft)	Area (ft^2)	Date	Pass	Count	Abundance (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture	Abundance (95% C.I.)	Fish per unit length (1,000 ft)	Fish per unit area (10^5 ft^2)	Probability of Capture
Project Sites													
SRP 9	1,727	98,473	10/08/03	1	15	24	13.9	24.4	0.61	24	13.9	24.4	0.61
				2	4	(20-28)				(20-29)			
				3	4								
SRP 10	2,498	429,703	10/09/03	1	44	93	37.2	21.6	0.44	94	37.6	21.9	0.43
				2	15	(77-117)				(78-123)			
				3	18								
Control Sites													
Riffle 64	2,682	157,863	09/24/03	1	3	5	1.9	3.2	0.71	5	1.9	3.2	0.71
				2	2	(4-5)				(4-6)			
				3	0								
SRP 7	3,847	418,518	09/22/03	1	21	48	12.5	11.5	0.46	49	12.7	11.7	0.45
				2	13	(38-59)				(38-78)			
				3	7								
SRP 8	3,172	575,161	09/23/03	1	47	95	29.9	16.5	0.45	96	30.3	16.7	0.44
				2	14	(80-115)				(81-123)			
				3	19								
Charles Road	2,950	147,684	10/08/03	1	5	16	5.4	10.8	0.54	17	5.8	11.5	0.48
				2	10	(12-20)				(12-34)			
				3	0								

Table A-11. 2003 estimates of abundance and density of smallmouth bass (all size clases combined) at project and control sites

							Carle-Strub Estimator				Profile-likelihood Estimator			
Site	**Bank Length (ft)**	**Area (ft^2)**	**Date**	**Pass**	**Count**	**Mean Length (mm)**	**Population (95% C.I.)**	**Fish per unit length (1000 ft)**	**Fish per unit area (10^5 ft2)**	**Probability of Capture**	**Population (95% C.I.)**	**Fish per unit length (1000 ft)**	**Fish per unit area (10^5 ft2)**	**Probability of Capture**
Project Sites														
SRP 9	1,727	98,473	10/08/03	1	32	142.56	191	110.60	193.96	0.1900	254	147.08	257.94	0.1300
				2	32	138.09	(107-298)				(113-inf)			
				3	25	132.04								
SRP 10	2,498	429,703	10/09/03	1	8	178.13	14	5.60	3.26	0.5200	14	5.60	3.26	0.5200
				2	1	254.00	(10-17)				(10-22)			
				3	4	176.50								
Control Sites														
Riffle 64	2,682	157,863	09/24/03	1	32	132.41	71	26.47	44.98	0.4500	72	26.84	45.61	0.4400
				2	17	175.00	(58-90)				(58-102)			
				3	11	202.00								
SRP 7	3,847	418,518	09/22/03	1	11	93.14	102	26.51	24.37	0.2500	122	31.71	29.15	0.2000
				2	44	92.18	(61-162)				(63-inf)			
				3	4	122.50								
SRP 8	3,172	575,161	09/23/03	1	1	182.00	2	0.63	0.35	0.5000	2	0.63	0.35	0.5000
				2	0	n/a	(1-2)				(1-2)			
				3	1	200.00								
Charles Road	2,950	147,684	10/08/03	1	23	204.96	86	29.15	58.23	0.3000	94	31.86	63.65	0.2700
				2	21	137.38	(58-130)				(61-527)			
				3	13	133.85								
All Sites Combined														
	16,877	*1,827,401*		*1*	*107*	*150.88*								
				2	*115*	*126.86*								
				3	*58*	*149.29*								

Table A-3. 1998 estimates of abundance and density of smallmouth bass (all size clases combined) at project and control sites

							CARLE-STRUB ESTIMATOR				PROFILE-LIKELIHOOD (SEBER) ESTIMATOR			
Location	Sample date	Bank length (ft)	Site area (ft2)	Pass No.	No. Captured	Mean fork length (mm)	Probability of Capture	Population abundance (95% C.I.)	Fish per unit bank length (no./10^{3}ft)	Fish per unit site area (no./10^{6}ft^2)	Probability of Capture	Population abundance (95% C.I.)	Fish per unit bank length (no./10^{3}ft)	Fish per unit site area (no./10^{6}ft^2)
Project Sites														
SRP 9	09/21/98	1,830	284,653	1	4	153.75	0.6000	9	4.92E-03	3.16E-05	0.6000	9	1.4	3.01
				2	4	193.25		(7-10)				(7-12)		
				3	1	120.00								
SRP 10	09/23/98	2,498	429,703	1	0		NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]
				2	1	138.00								
				3	0									
Control Sites														
SRP 7	09/25/98	3,847	418,518	1	2	132.50	0.5455	6	1.56E-03	1.43E-05	0.5455	5	0.4	1.15
				2	3	199.33		(4-7)				(4-13)		
				3	1	150.00								
SRP 8	09/24/98	3,172	575,161	1	0		NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]	NE[1]
				2	0									
				3	0									
Charles Rd	09/26/98	2,950	147,684	1	12	152.82	0.7500	15	5.08E-03	1.02E-04	0.7500	15	1.4	8.47
				2	1	160.00		(14-16)				(14-16)		
				3	2	128.50								
All Sites Combined:		5,224												
		14,297	*1,855,719.00*	*1*	*18*	*150.77*	*0.5741*	*33*			*0.5741*	*33*		
				2	*9*	*185.44*		*(28-38)*				*(27-40)*		
				3	*4*	*131.75*								

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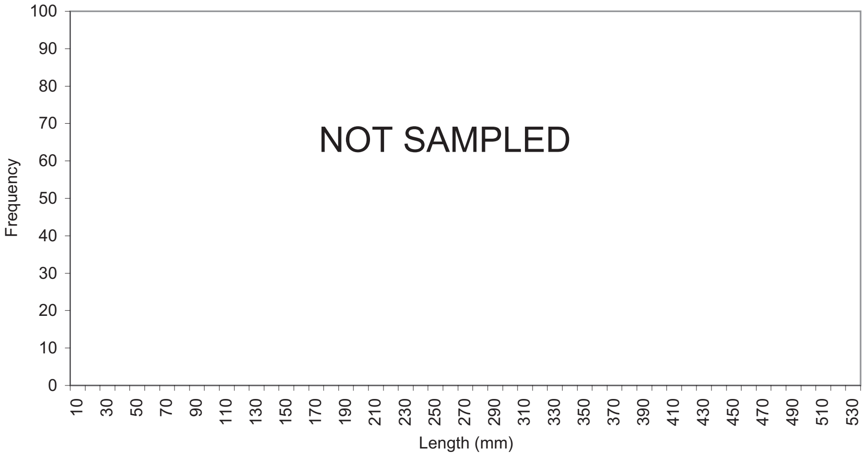
[1] NE = Not Estimable

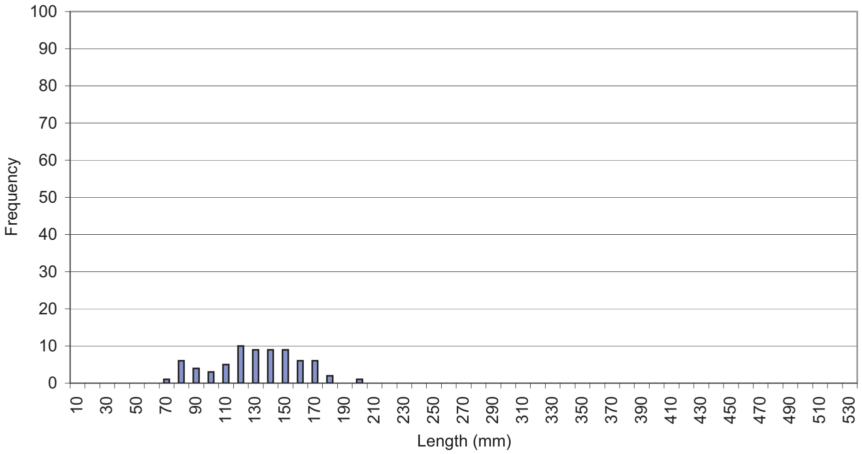
Appendix B

Length Frequencies of Largemouth and Smallmouth Bass Captured at Project and Reference Sites in 1998, 1999, and 2003.

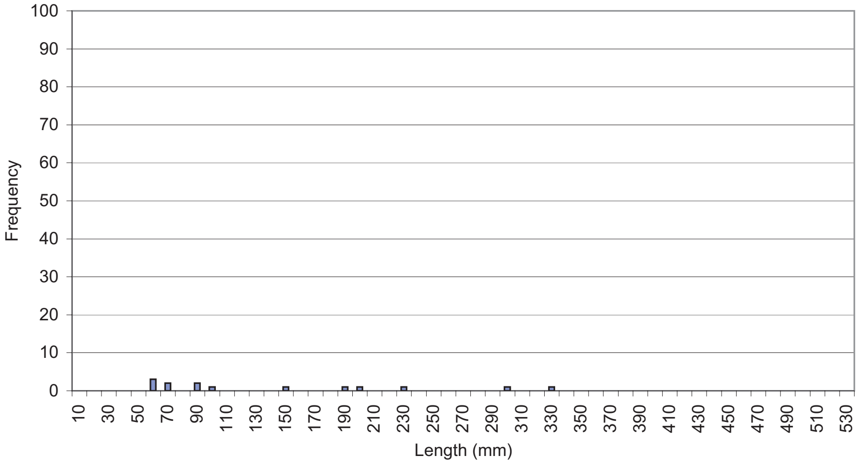
1998 R64 Largemouth Bass



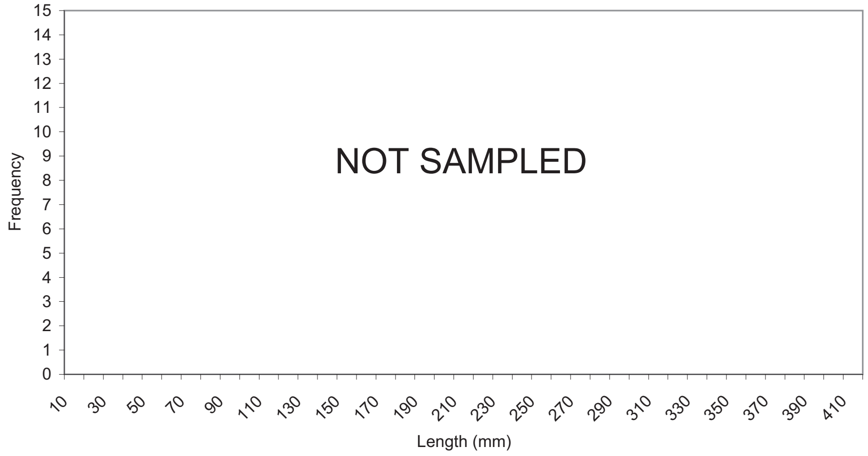
1999 R64 Largemouth Bass



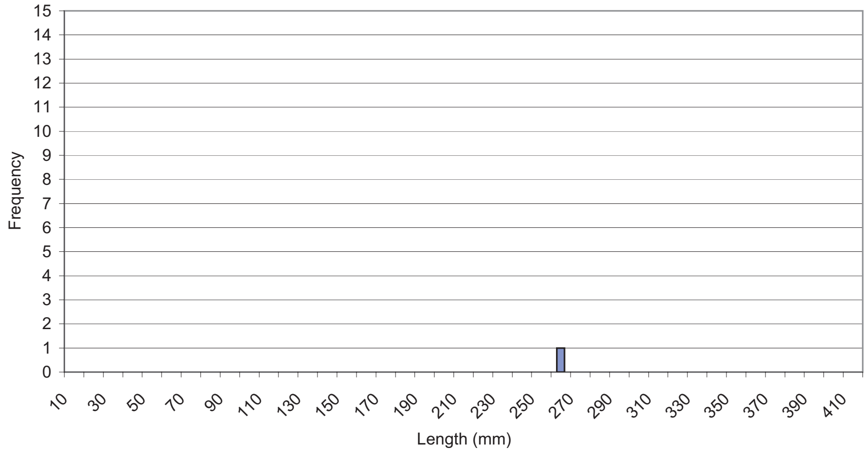
2003 R64 Largemouth Bass



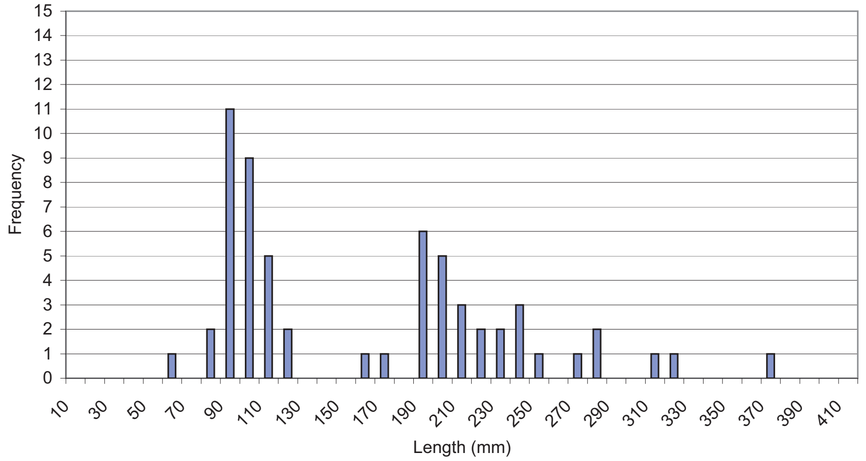
1998 R64 Smallmouth Bass



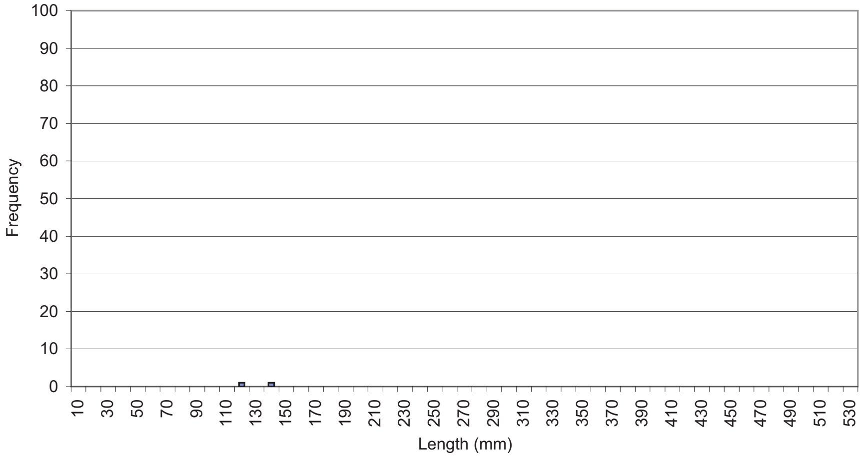
1999 R64 Smallmouth Bass



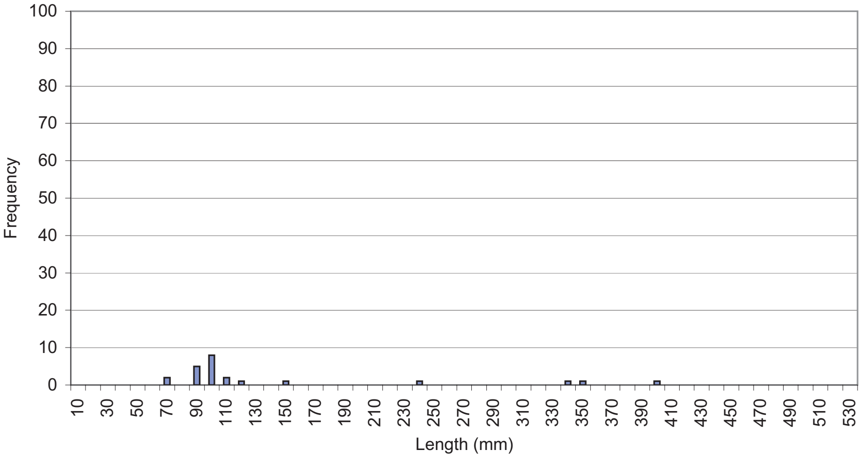
2003 R64 Smallmouth Bass



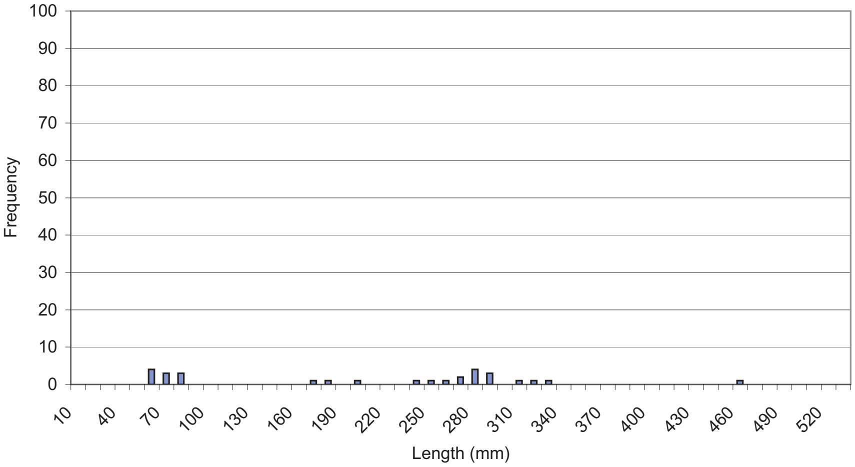
1998 Charles Road Largemouth Bass



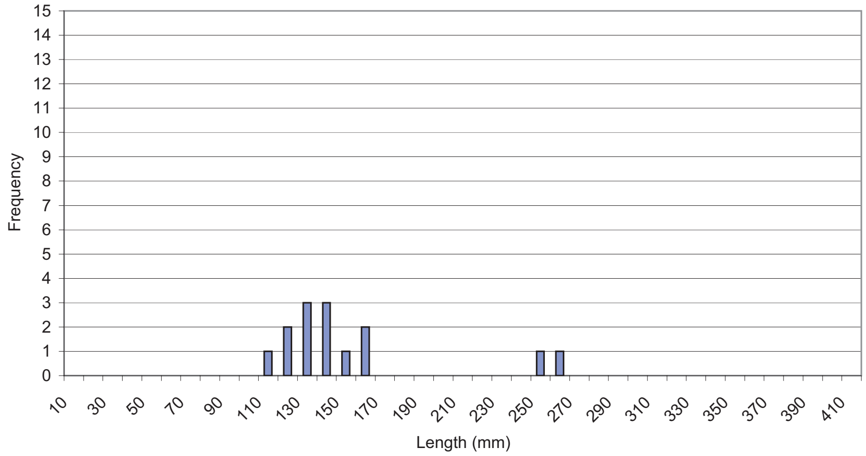
1999 Charles Road Largemouth Bass



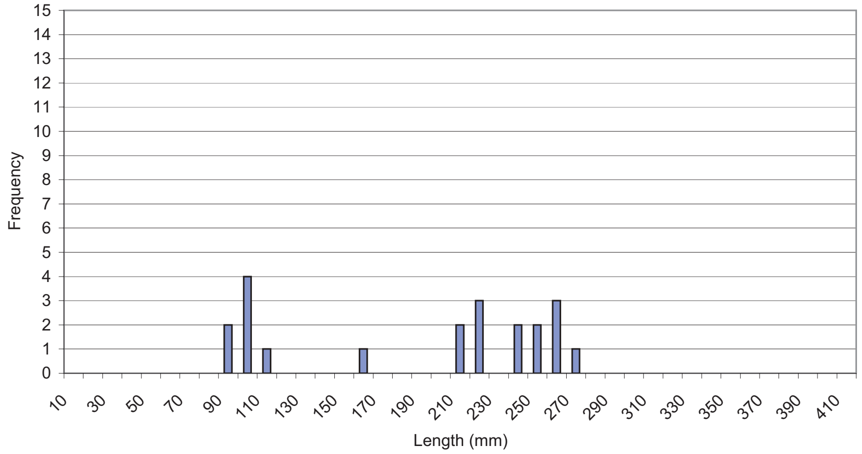
2003 Charles Road Largemouth Bass



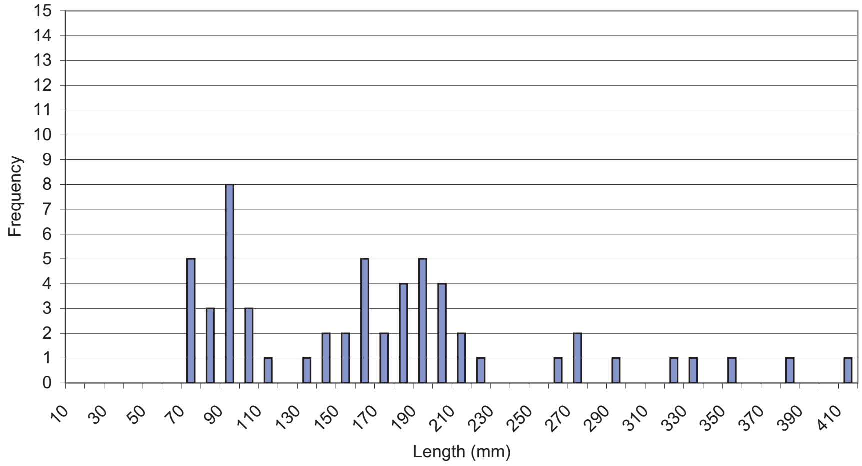
1998 Charles Road Smallmouth Bass



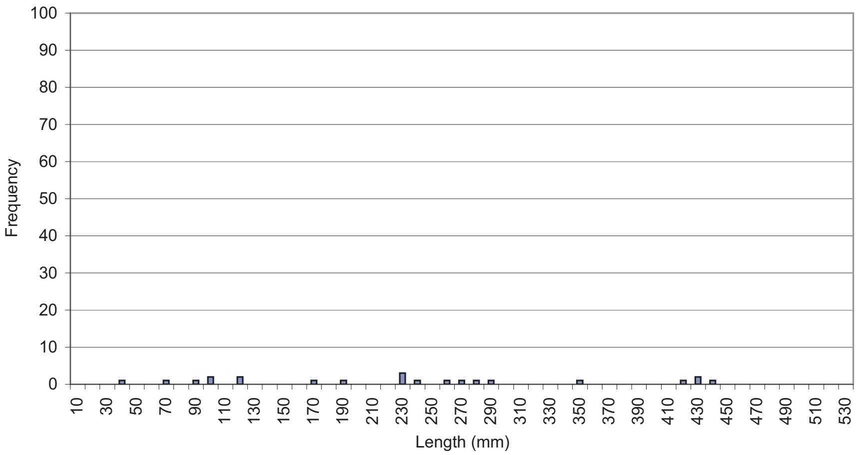
1999 Charles Road Smallmouth Bass



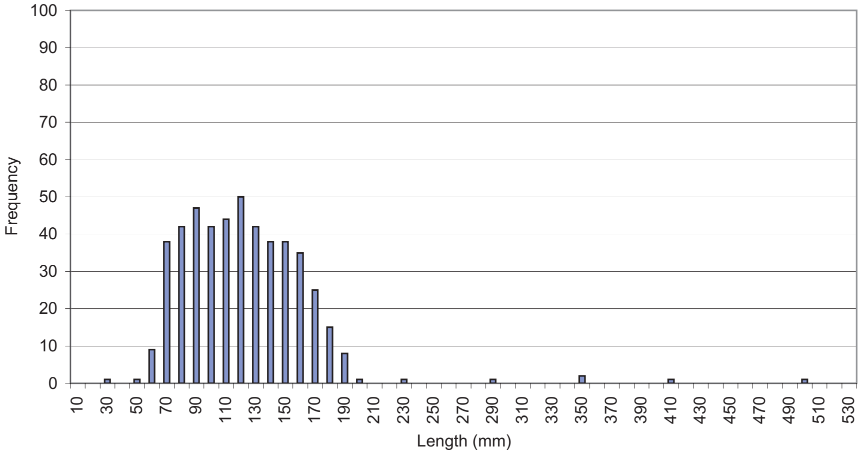
2003 Charles Road Smallmouth Bass



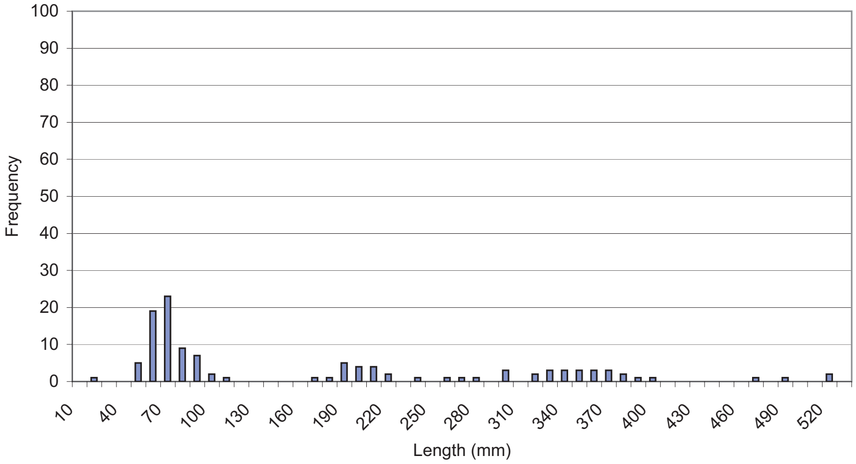
1998 SRP 7 Largemouth Bass



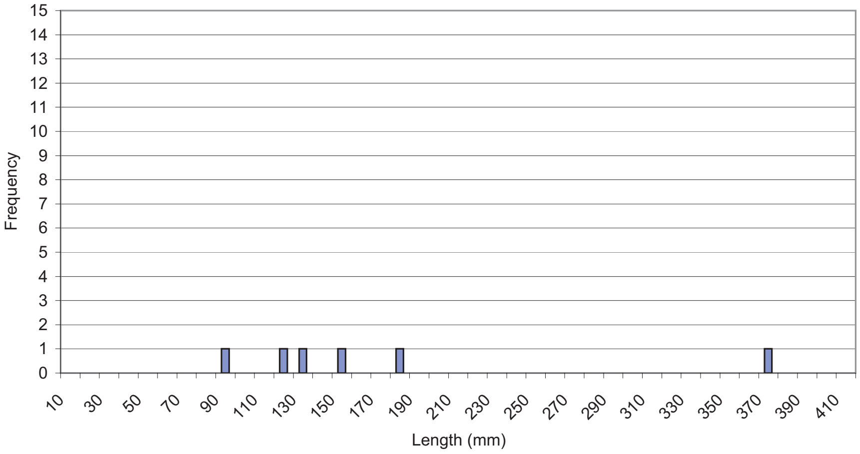
1999 SRP 7 Largemouth Bass



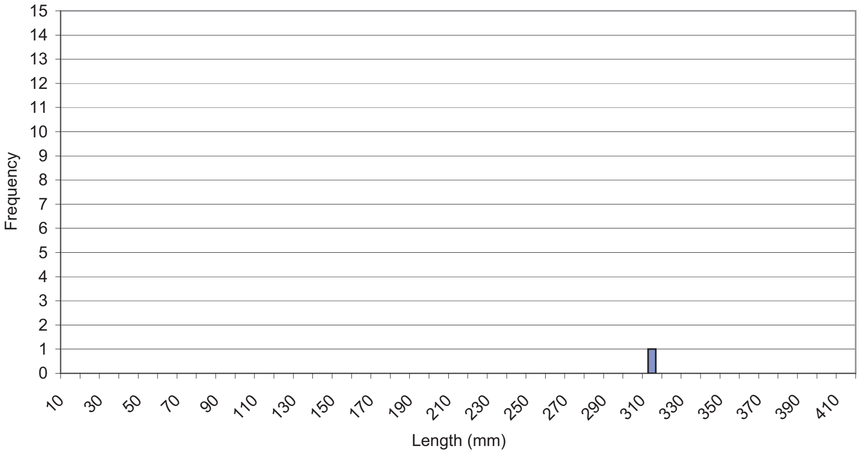
2003 SRP 7 Largemouth Bass



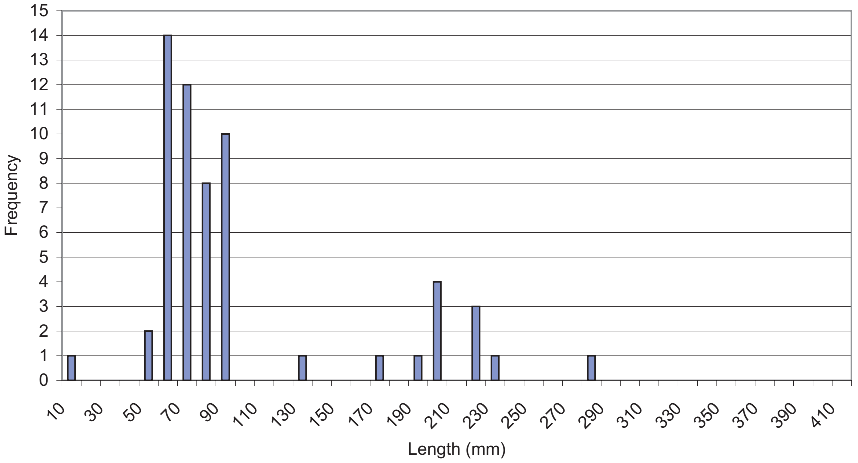
1998 SRP 7 Smallmouth Bass



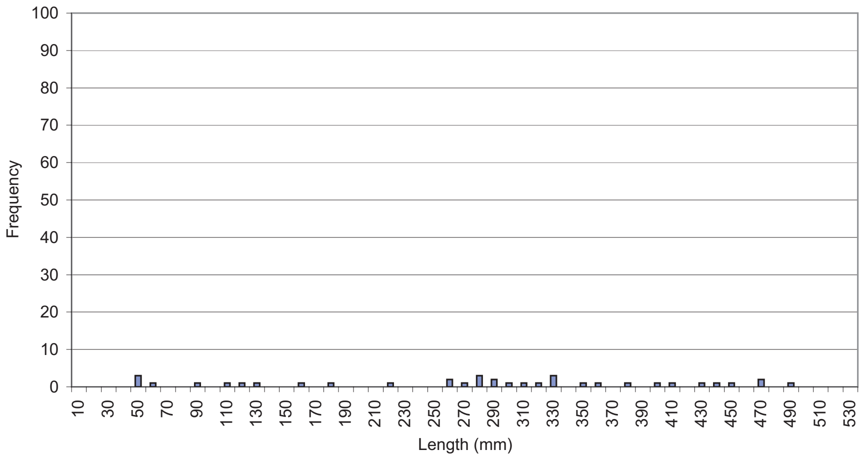
1999 SRP 7 Smallmouth Bass



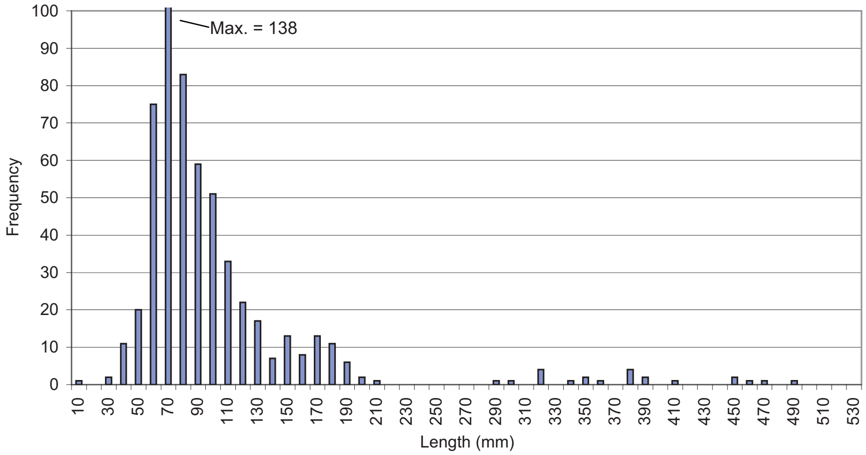
2003 SRP 7 Smallmouth Bass



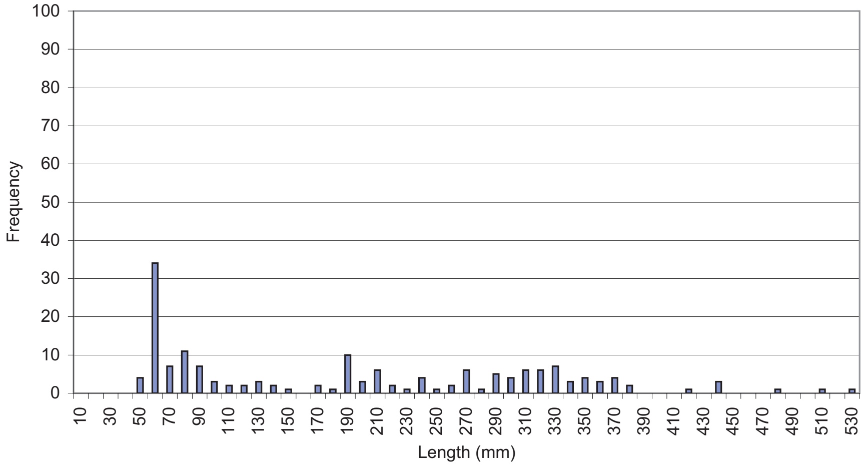
1998 SRP 8 Largemouth Bass



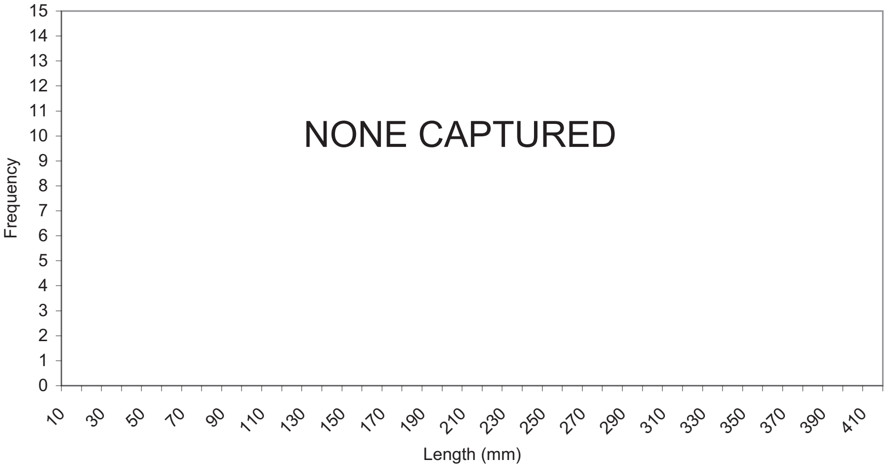
1999 SRP 8 Largemouth Bass


Max. = 138

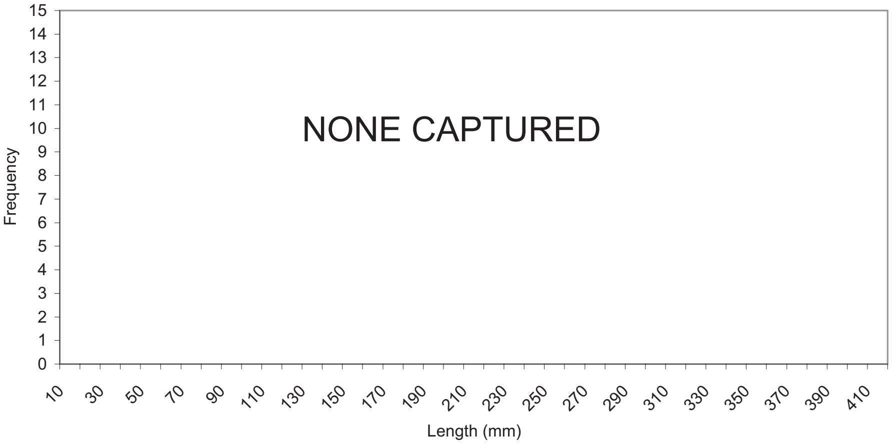
2003 SRP 8 Largemouth Bass



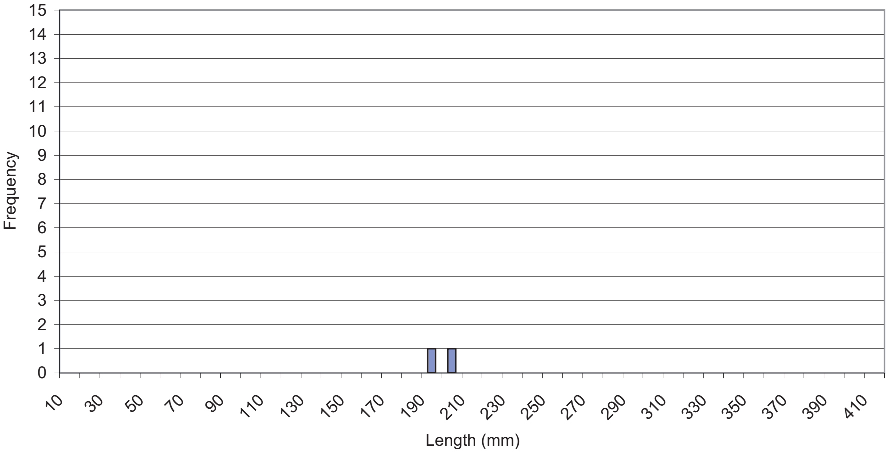
1998 SRP 8 Smallmouth Bass



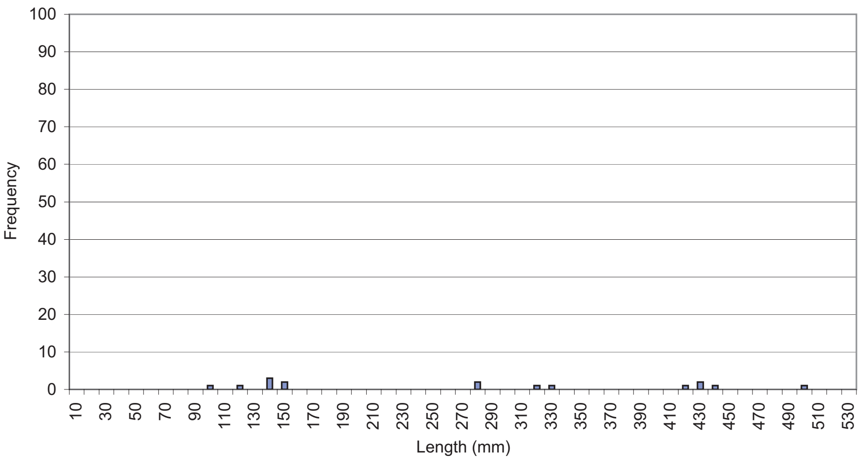
1999 SRP 8 Smallmouth Bass



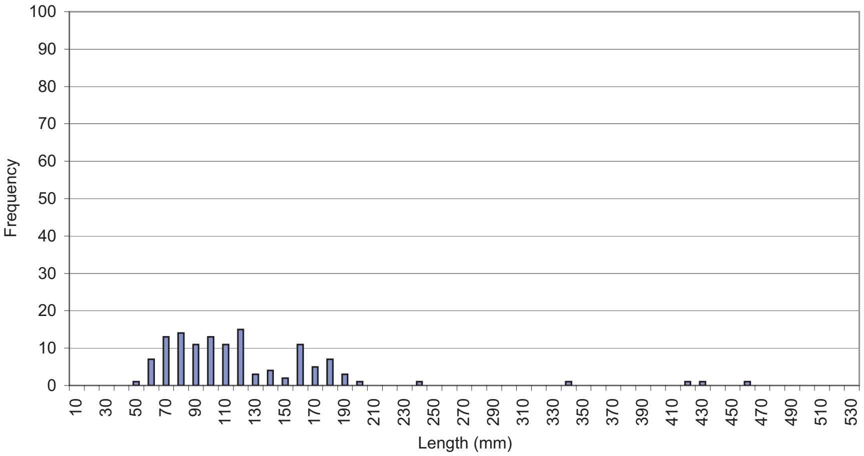
2003 SRP 8 Smallmouth Bass



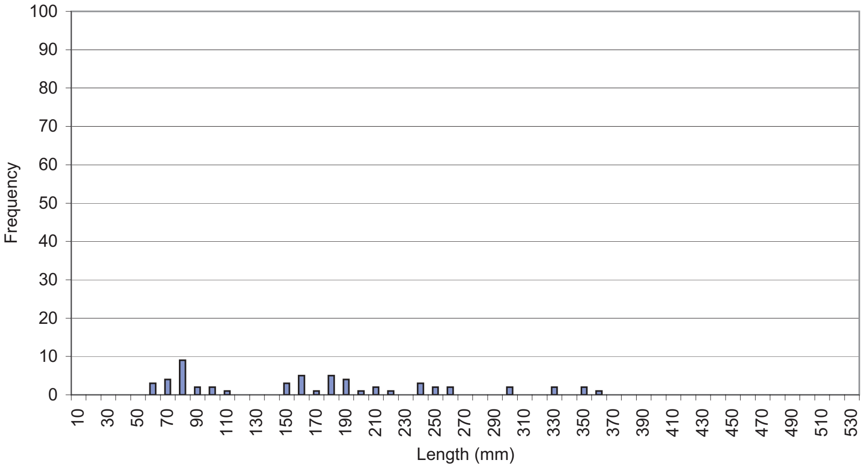
1998 SRP 9 Largemouth Bass



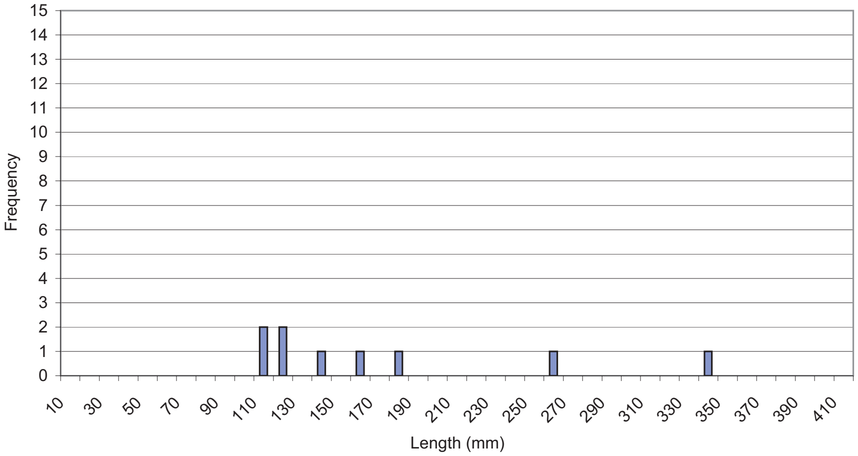
1999 SRP 9 Largemouth Bass



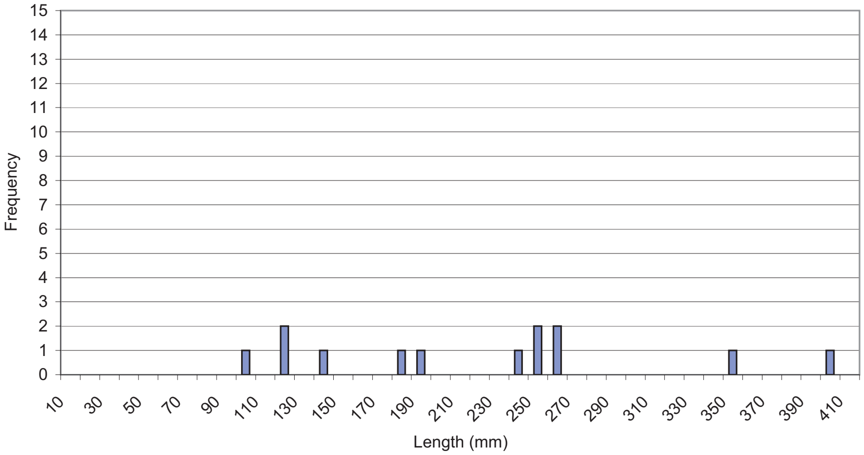
2003 SRP 9 Largemouth Bass



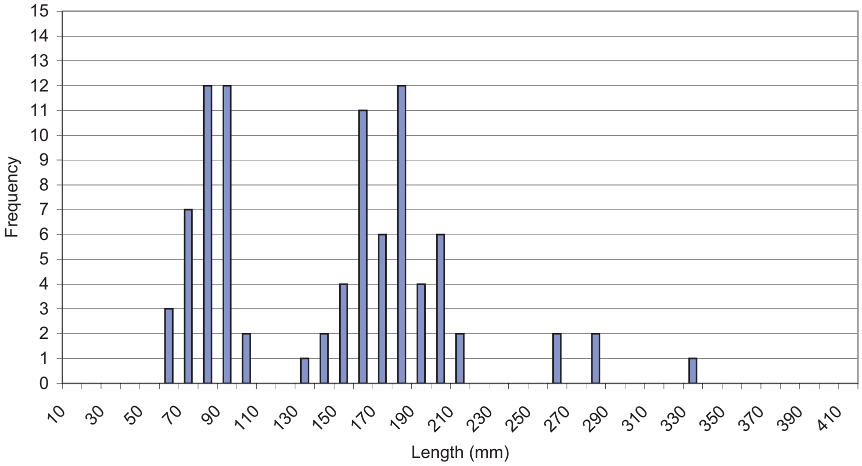
1998 SRP 9 Smallmouth Bass

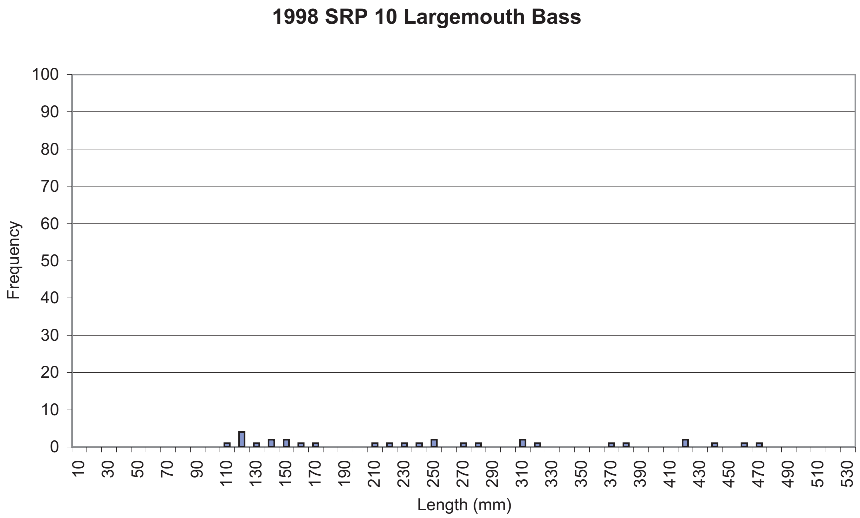


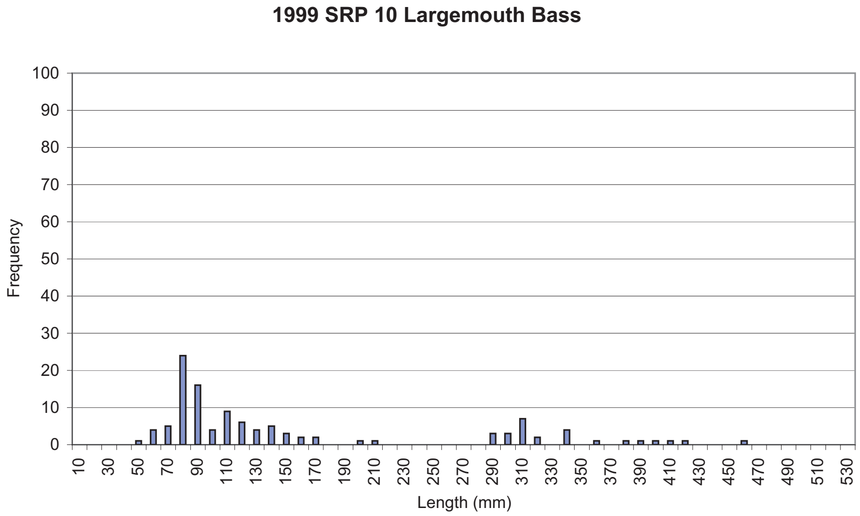
1999 SRP 9 Smallmouth Bass

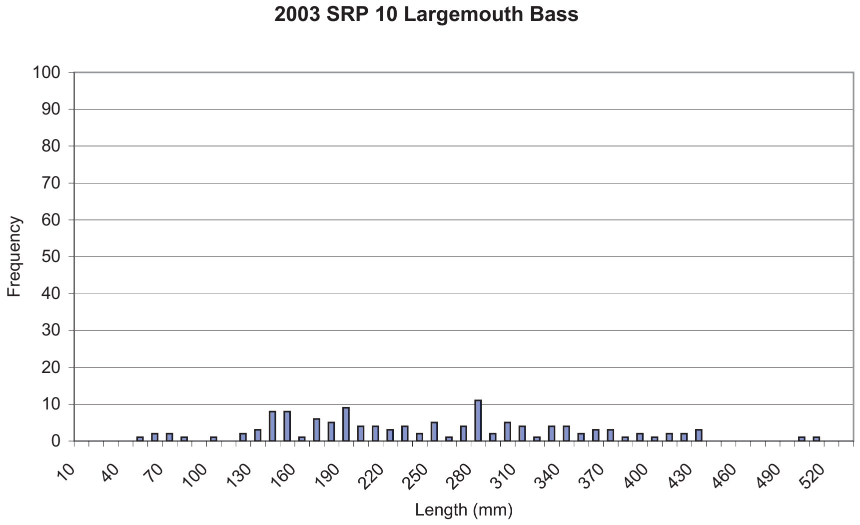


2003 SRP 9 Smallmouth Bass

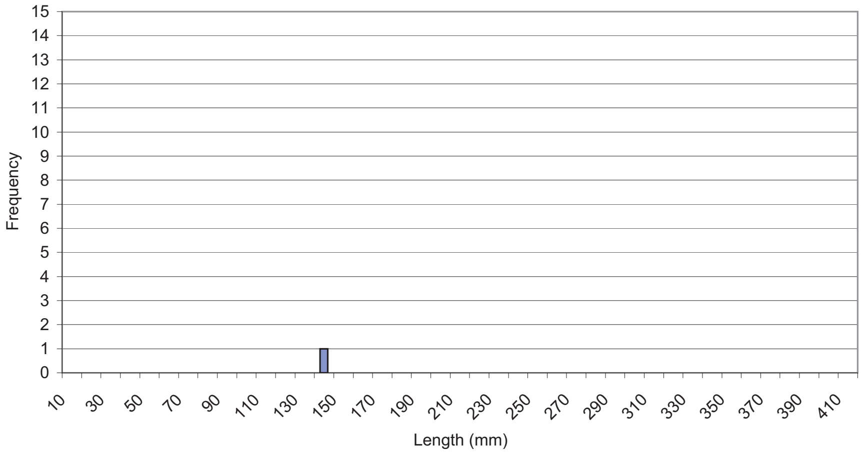



1998 SRP 10 Largemouth Bass
Frequency
Length (mm)
0
10
20
30
40
50
60
70
80
90
100
10 30 50 70 90 110 130 150 170 190 210 230 250 270 290 310 330 350 370 390 410 430 450 470 490 510 530

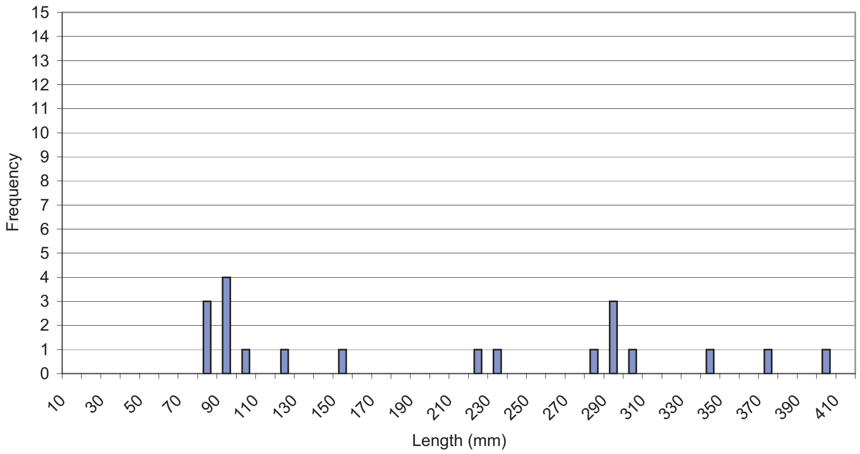

1999 SRP 10 Largemouth Bass
Frequency
Length (mm)
0
10
20
30
40
50
60
70
80
90
100
10 30 50 70 90 110 130 150 170 190 210 230 250 270 290 310 330 350 370 390 410 430 450 470 490 510 530


2003 SRP 10 Largemouth Bass
Frequency
Length (mm)
0
10
20
30
40
50
60
70
80
90
100
10 40 70 100 130 160 190 220 250 280 310 340 370 400 430 460 490 520

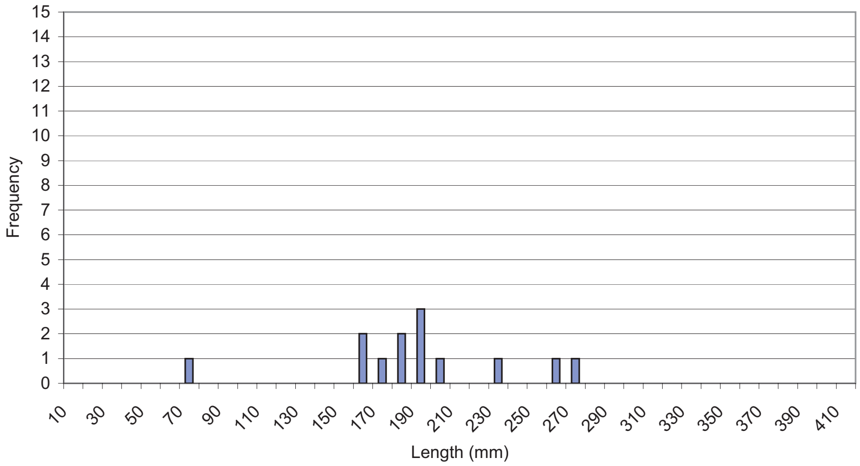
1998 SRP 10 Smallmouth Bass



1999 SRP 10 Smallmouth Bass



2003 SRP 10 Smallmouth Bass



Appendix C

Abundance and Density of All Fish Species Captured at Project and Reference Sites in 1998, 1999, 2003.

Table C-1. 1998 abundance and density estimates for all non-bass fish species captured at the channel restoration and reference sites

Species	Native or Introduced	Location	No. Captured/Pass			Total No. Captured	CARLE-STRUB ESTIMATOR[1]						PROFILE-LIKELIHOOD (SEBER) ESTIMATOR[1]					
							Probability of Capture	Population Abundance			Population Density		Probability of Capture	Population Abundance			Population Density	
			1	2	3			estimate	lower 95% CI	upper 95% CI	Fish per unit bank length (no./10^3ft)	Fish per unit site area (no./10^6ft^2)		estimate	lower 95% CI	upper 95% CI	Fish per unit bank length (no./10^3ft)	Fish per unit site area (no./10^6ft^2)
Family Atherinidae																		
inland silverside	I	South Pit	3	0	0	3	1.00	3	3	3	0.5	NA	1.00	3	3	3	0.5	NA
Family Catostomidae																		
Sacramento sucker	N	Charles Road	62	31	10	103	0.59	110	101	120	10.5	62.1	0.58	111	102	122	10.5	62.7
		South Pit	1	0	0	1	1.00	1	1	1	0.2	NA^2	1.00	1	1	1	0.2	NA^2
		SRP 10	0	3	9	12	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 7	6	6	0	12	0.67	12	10	13	1.0	2.8	0.67	12	10	14	1.0	2.8
		SRP 8	5	3	3	11	0.42	13	8	17	1.1	2.1	0.38	14	8		1.2	2.2
		SRP 9	8	3	3	14	0.54	15	11	19	2.4	5.0	0.54	15	11	22	2.4	5.0
Family Centrarchidae																		
black crappie	I	SRP 10	0	6	3	9	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 7	3	2	0	5	0.71	5	4	5	0.4	1.2	0.71	5	4	6	0.4	1.2
		SRP 8	7	5	2	14	0.54	15	11	19	1.3	2.4	0.54	15	11	25	1.3	2.4
bluegill	I	Charles Road	2	2	2	6	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		South Pit	1	0	0	1	1.00	1	1	1	0.2	NA^2	1.00	1	1	1	0.2	NA^2
		SRP 10	138	75	45	258	0.44	311	280	349	37.3	69.9	0.44	312	281	355	37.4	70.2
		SRP 7	139	72	44	255	0.45	304	275	341	24.5	70.0	0.45	305	275	345	24.6	70.3
		SRP 8	224	118	139	481	0.25	843	674	1107	71.9	134.1	0.24	860	688	1227	73.4	136.8
		SRP 9	63	37	17	117	0.48	135	119	156	21.7	45.1	0.48	136	119	162	21.9	45.5
green sunfish	I	SRP 10	1	2	11	14	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 7	2	0	1	3	0.60	3	2	3	0.2	0.7	0.60	3	2	5	0.2	0.7
		SRP 8	2	2	4	8	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 9	2	2	6	10	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
hybrid sunfish	I	SRP 9	1	1	0	2	0.67	2	1	2	0.3	0.7	0.67	2	1	2	0.3	0.7
redear sunfish	I	Charles Road	0	1	0	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		South Pit	2	0	0	2	1.00	2	2	2	0.3	NA	1.00	2	2	2	0.3	NA
		SRP 10	18	4	7	29	0.52	32	26	40	3.8	7.2	0.49	33	26	47	4.0	7.4
		SRP 7	17	12	16	45	0.19	96	45	144	7.7	22.1	0.08	203	50	Infinite	16.4	46.8
		SRP 8	9	5	8	22	0.27	35	18	50	3.0	5.6	0.16	54	19	Infinite	4.6	8.6
		SRP 9	20	12	6	38	0.49	43	35	53	6.9	14.4	0.48	44	35	61	7.1	14.7
warmouth	I	SRP 8	0	1	0	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table C-1. 1998 abundance and density estimates for all non-bass fish species captured at the channel restoration and reference sites

Species	Native or Introduced	Location	No. Captured/Pass			Total No. Captured	CARLE-STRUB ESTIMATOR[1]						PROFILE-LIKELIHOOD (SEBER) ESTIMATOR[1]					
							Probability of Capture	Population Abundance			Population Density		Probability of Capture	Population Abundance			Population Density	
			1	2	3			estimate	lower 95% CI	upper 95% CI	Fish per unit bank length (no./10^3ft)	Fish per unit site area (no./10^6ft^2)		estimate	lower 95% CI	upper 95% CI	Fish per unit bank length (no./10^3ft)	Fish per unit site area (no./10^6ft^2)
Family Clupeidae																		
threadfin shad	I	SRP 8	0	1	0	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Family Cottidae																		
sculpin	N	Charles Roac	0	0	1	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 10	0	1	5	6	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 7	25	12	15	52	32	75	51	113	6.1	17.3	0.29	81	53	426	6.5	18.7
		SRP 8	4	15	14	33	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 9	0	3	0	3	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Family Cyprinidae																		
carp	I	Charles Roac	2	5	1	8	0.44	9	5	11	0.9	5.1	0.38	10	5	Infinite	1.0	5.6
		SRP 10	6	7	2	15	0.47	17	12	23	2.0	3.8	0.43	18	12	81	2.2	4.0
		SRP 7	14	5	7	26	0.43	31	22	43	2.5	7.1	0.39	33	23	89	2.7	7.6
		SRP 8	5	4	4	13	0.35	17	9	23	1.5	2.7	0.25	22	9	Infinite	1.9	3.5
		SRP 9	3	4	0	7	0.64	7	5	7	1.1	2.3	0.64	7	5	8	1.1	2.3
goldfish	I	SRP 10	0	0	1	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 7	4	4	1	9	0.60	9	7	10	0.7	2.1	0.60	9	7	12	0.7	2.1
		SRP 8	5	4	2	11	0.50	12	8	15	1.0	1.9	0.50	12	8	27	1.0	1.9
		SRP 9	0	0	1	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
hardhead	N	SRP 7	5	2	0	7	0.78	7	6	7	0.6	1.6	0.78	7	6	7	0.6	1.6
		SRP 8	0	1	0	1												
		SRP 9	6	4	2	12	0.52	13	9	17	2.1	4.3	0.52	13	9	23	2.1	4.3
mirror carp	I	SRP 8	0	1	0	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Sacramento pikeminn	N	Charles Roac	0	1	0	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		South Pit	1	0	0	1	1.00	1	1	1	0.2	NA[2]	1.00	1	1	1	0.2	NA[2]
		SRP 10	12	1	1	14	0.82	14	13	14	1.7	3.1	0.82	14	13	14	1.7	3.1
		SRP 8	1	1	0	2	0.67	2	1	2	0.2	0.3	0.67	2	1	2	0.2	0.3
		SRP 9	3	3	0	6	0.67	6	5	6	1.0	2.0	0.67	6	5	8	1.0	2.0

Table C-1. 1998 abundance and density estimates for all non-bass fish species captured at the channel restoration and reference sites

Species	Native or Introduced	Location	No. Captured/Pass			Total No. Captured	CARLE-STRUB ESTIMATOR[1]						PROFILE-LIKELIHOOD (SEBER) ESTIMATOR[1]					
							Probability of Capture	Population Abundance			Population Density		Probability of Capture	Population Abundance			Population Density	
			1	2	3			estimate	lower 95% CI	upper 95% CI	Fish per unit bank length (no./10^3ft)	Fish per unit site area (no./10^6ft^2)		estimate	lower 95% CI	upper 95% CI	Fish per unit bank length (no./10^3ft)	Fish per unit site area (no./10^6ft^2)
Family Ictaluridae																		
brown bullhead	I	Charles Roac	0	0	1	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 7	0	1	0	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 8	1	2	0	3	0.60	3	2	3	0.3	0.5	0.60	3	2	5	0.3	0.5
channel catfish	I	Charles Roac	2	0	2	4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		SRP 10	1	0	0	1	1.00	1	1	1	0.1	0.2	1.00	1	1	1	0.1	0.2
		SRP 7	0	0	1	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
white catfish	I	Charles Roac	5	0	0	5	1.00	5	5	5	0.5	2.8	1.00	5	5	5	0.5	2.8
		SRP 10	23	4	8	35	0.55	38	32	46	4.6	8.5	0.55	38	32	48	4.6	8.5
		SRP 7	15	6	3	24	0.62	25	21	29	2.0	5.8	0.62	25	21	29	2.0	5.8
		SRP 8	8	4	4	16	0.47	18	13	23	1.5	2.9	0.43	19	13	51	1.6	3.0
		SRP 9	12	11	4	27	0.44	32	23	44	5.1	10.7	0.42	33	24	73	5.3	11.0
Family Percichthyidae																		
striped bass	I	Charles Roac	1	0	0	1	1.00	1	1	1	0.1	0.6	1.00	1	1	1	0.1	0.6
		South Pit	1	0	0	1	1.00	1	1	1	0.2	NA[2]	1.00	1	1	1	0.2	NA[2]
		SRP 8	0	0	1	1	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Family Percidae																		
bigscale logperch	I	SRP 10	1	0	0	1	1.00	1	1	1	0.1	0.2	1.00	1	1	1	0.1	0.2
Family Salmonidae																		
chinook salmon	N	Charles Roac	2	0	0	2	1.00	2	2	2	0.2	1.1	1.00	2	2	2	0.2	1.1
		SRP 10	1	0	0	1	1.00	1	1	1	0.1	0.2	1.00	1	1	1	0.1	0.2
		SRP 9	1	1	0	2	0.67	2	1	2	0.3	0.7	0.67	2	1	2	0.3	0.7

[1] NE indicates populations that are not estimable because the number of fish captured in the first pass (n_1) was less than or equal to the number of fish captured in the third pass (n_3).

[2] Only a small portion of the bank of the South Pit was sampled. Densities, therefore, were not extrapolated to the whole pit for this site.

Table C-2. 1999 abundance and density estimates for all fish species captured at the project and reference sites

						Carle-Strub Estimator						Profile Likelihood Estimator					
			Number Captured				Population Abundance			Population Density			Population Abundance			Population Density	
Species	Native or Introduced	Location	Pass 1	Pass 2	Pass 3	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./10^3 ft)	Fish per Unit Site Area (No./10^5 ft^2)	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./10^3 ft)	Fish per Unit Site Area (No./10^5 ft^2)
Family Petromyzontidae																	
Lamprey (unidentified species)	N	Charles Road	0	1	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	1	0	7	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-9	3	0	2	0.56	5	3	6	2.7	1.8	0.56	5	3	13	2.7	1.8
		Upstream Riffle	5	2	1	0.67	8	6	9	3.0	5.1	0.67	8	6	9	3.0	5.1
Lamprey ammocoetes (unidentified species)	N	SRP-7	1	11	0	0.38	15	8	21	3.9	3.6	0.27	19	8	Inf	4.9	4.5
		SRP-8	1	2	2	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Family Clupeidae																	
American shad	I	Charles Road	3	5	5	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-10	0	1	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	2	0	0	1.00	2	2	2	0.5	0.5	1.00	2	2	2	0.5	0.5
		SRP-9	1	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Threadfin shad	I	SRP-10	2	0	0	1.00	2	2	2	0.8	0.5	1.00	2	2	2	0.8	0.5
		SRP-8	3	10	1	0.40	17	10	23	5.4	3.0	0.32	20	10	Inf	6.3	3.5
		Upstream Riffle	0	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Family Salmonidae																	
Chinook salmon	N	Upstream Riffle	0	1	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Family Cyprinidae																	
Carp	I	Charles Road	11	18	7	0.27	57	33	84	19.3	38.6	0.21	71	36	Inf	24.1	48.1
		SRP-10	26	9	8	0.54	47	40	56	18.8	10.9	0.52	48	40	64	19.2	11.2
		SRP-7	10	5	6	0.38	27	17	39	7.0	6.5	0.34	29	17	Inf	7.5	6.9
		SRP-8	14	11	4	0.48	33	26	42	10.4	5.7	0.46	34	26	55	10.7	5.9
		SRP-9	5	5	5	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		Upstream Riffle	8	5	5	0.38	23	14	33	8.6	14.6	0.32	26	14	Inf	9.7	16.5
Goldfish	I	SRP-10	0	2	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	20	9	10	0.39	50	36	71	13.0	11.9	0.36	52	36	111	13.5	12.4
		SRP-8	94	50	47	0.33	272	222	355	85.8	47.3	0.32	276	223	394	87.0	48.0
		SRP-9	49	51	26	0.27	203	147	292	110.9	71.3	0.26	214	151	484	116.9	75.2
Sacramento blackfish	N	SRP-10	4	6	6	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	2	2	1	0.56	5	3	6	1.3	1.2	0.56	5	3	13	1.3	1.2
		SRP-8	22	9	6	0.55	40	34	48	12.6	7.0	0.55	40	33	50	12.6	7.0
Hardhead	N	Charles Road	0	1	2	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	43	28	26	0.28	155	107	232	40.3	37.0	0.25	166	110	490	43.2	39.7
		SRP-9	2	0	0	1.00	2	2	2	1.1	0.7	1.00	2	2	2	1.1	0.7
		Upstream Riffle	10	7	9	0.25	44	21	64	16.4	27.9	0.14	73	24	Inf	27.2	46.2
Hitch	N	Charles Road	2	0	1	0.60	3	2	3	1.0	2.0	0.60	3	2	5	1.0	2.0
		SRP-10	0	2	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	12	1	0	0.93	13	13	13	3.4	3.1	0.93	13	13	13	3.4	3.1
		SRP-8	8	4	3	0.54	16	12	21	5.0	2.8	0.48	17	12	36	5.4	3.0
		SRP-9	7	1	1	0.75	9	8	9	4.9	3.2	0.75	9	8	9	4.9	3.2
		Upstream Riffle	0	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE

Table C-2. 1999 abundance and density estimates for all fish species captured at the project and reference sites

						Carle-Strub Estimator						Profile Likelihood Estimator					
			Number Captured				Population Abundance			Population Density			Population Abundance			Population Density	
Species	Native or Introduced	Location	Pass 1	Pass 2	Pass 3	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./10^3 ft)	Fish per Unit Site Area (No./10^5 ft^2)	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./10^3 ft)	Fish per Unit Site Area (No./10^5 ft^2)
Sacramento pikeminnow	N	Charles Road	1	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	128	34	17	0.68	185	178	191	48.1	44.2	0.68	185	178	192	48.1	44.2
		SRP-8	46	34	13	0.45	111	95	136	35.0	19.3	0.44	112	95	144	35.3	19.5
		SRP-9	17	8	4	0.57	31	26	36	16.9	10.9	0.57	31	26	38	16.9	10.9
		Upstream Riffle	31	20	17	0.32	99	71	149	36.9	62.7	0.30	104	72	285	38.8	65.9
Sacramento splittail	N	SRP-9	0	1	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Family Catostomidae																	
Sacramento sucker	N	Charles Road	99	80	31	0.41	264	232	309	89.5	178.8	0.40	266	232	326	90.2	180.1
		SRP-10	41	22	23	0.31	126	93	180	50.4	29.3	0.29	132	94	286	52.8	30.7
		SRP-7	298	161	134	0.35	813	728	924	211.3	194.3	0.35	816	721	936	212.1	195.0
		SRP-8	25	44	34	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-9	22	21	17	0.21	115	63	182	62.8	40.4	0.15	154	69	Inf	84.2	54.1
		Upstream Riffle	289	190	171	0.25	1129	935	1420	421.0	715.2	0.24	1145	947	1510	426.9	725.3
Family Ictaluridae																	
Channel catfish	I	Charles Road	11	8	5	0.42	29	21	39	9.8	19.6	0.38	31	21	90	10.5	21.0
		SRP-10	3	0	0	1.00	3	3	3	1.2	0.7	1.00	3	3	3	1.2	0.7
		SRP-7	2	2	4	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-8	1	1	0	0.67	2	1	2	0.6	0.3	0.67	2	1	2	0.6	0.3
		Upstream Riffle	5	4	1	0.63	10	8	11	3.7	6.3	0.63	10	8	12	3.7	6.3
White catfish	I	Charles Road	5	4	4	0.35	17	9	23	5.8	11.5	0.25	22	9	Inf	7.5	14.9
		SRP-10	2	3	0	0.63	5	4	5	2.0	1.2	0.63	5	4	6	2.0	1.2
		SRP-7	15	6	9	0.36	40	27	56	10.4	9.6	0.32	43	27	388	11.2	10.3
		SRP-8	14	11	5	0.43	36	27	49	11.3	6.3	0.42	37	27	77	11.7	6.4
		SRP-9	11	10	8	0.28	45	25	68	24.6	15.8	0.21	57	26	Inf	31.1	20.0
		Upstream Riffle	9	4	2	0.65	15	13	17	5.6	9.5	0.65	15	13	17	5.6	9.5
Brown bullhead	I	SRP-7	0	3	2	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Black bullhead	I	Upstream Riffle	0	2	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Family Atherinidae																	
Inland silverside	I	Charles Road	2	0	1	0.60	3	2	3	1.0	2.0	0.60	3	2	5	1.0	2.0
		SRP-10	7	6	6	0.28	29	14	42	11.6	6.7	0.18	42	15	Inf	16.8	9.8
		SRP-7	0	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-8	9	8	4	0.43	25	17	35	7.9	4.3	0.38	27	17	187	8.5	4.7
		SRP-9	0	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Family Percichthyidae																	
Striped bass	I	SRP-10	2	0	0	1.00	2	2	2	0.8	0.5	1.00	2	2	2	0.8	0.5
Family Centrarchidae																	
White crappie	I	SRP-10	2	2	0	0.67	4	3	4	1.6	0.9	0.67	4	3	4	1.6	0.9
		SRP-8	1	0	0	1.00	1	1	1	0.3	0.2	1.00	1	1	1	0.3	0.2
Green sunfish	I	Charles Road	3	0	1	0.67	4	3	4	1.4	2.7	0.67	4	3	4	1.4	2.7
		SRP-10	2	5	2	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	1	1	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-8	0	2	2					NE	NE					NE	NE

Table C-2. 1999 abundance and density estimates for all fish species captured at the project and reference sites

						Carle-Strub Estimator						Profile Likelihood Estimator					
			Number Captured				Population Abundance			Population Density			Population Abundance			Population Density	
Species	Native or Introduced	Location	Pass 1	Pass 2	Pass 3	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./10^3 ft)	Fish per Unit Site Area (No./10^5 ft^2)	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./10^3 ft)	Fish per Unit Site Area (No./10^5 ft^2)
Bluegill	I	Charles Road	3	5	1	0.47	10	6	13	3.4	6.8	0.47	10	6	40	3.4	6.8
		SRP-10	38	41	44	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	23	16	12	0.34	71	50	102	18.5	17.0	0.31	75	51	247	19.5	17.9
		SRP-8	49	16	39	0.20	215	127	375	67.8	37.4	0.15	264	140	Inf	83.2	45.9
		SRP-9	9	20	20	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		Upstream Riffle	0	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Redear sunfish	I	Charles Road	2	1	0	0.75	3	2	3	1.0	2.0	0.75	3	2	3	1.0	2.0
		SRP-10	3	3	2	0.44	9	5	11	3.6	2.1	0.38	10	5	Inf	4.0	2.3
		SRP-7	3	3	2	0.44	9	5	11	2.3	2.2	0.38	10	5	Inf	2.6	2.4
		SRP-8	3	5	3	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		Upstream Riffle	0	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Largemouth bass	I	Charles Road	15	4	4	0.61	24	20	27	8.1	16.3	0.61	24	20	29	8.1	16.3
		SRP-10	52	30	31	0.28	179	130	278	71.7	41.7	0.26	189	134	451	75.7	44.0
		SRP-10 South Pit	14	9	.	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	210	164	109	0.28	767	642	946	199.4	183.3	0.28	777	647	1000	202.0	185.7
		SRP-8	263	183	150	0.26	1007	827	1288	317.5	175.1	0.25	1020	847	1349	321.6	177.3
		SRP-9	61	40	25	0.38	165	135	206	90.2	58.0	0.37	167	138	240	91.3	58.7
		Upstream Riffle	26	28	17	0.24	124	76	195	46.2	78.5	0.20	145	79	Inf	54.1	91.9
Smallmouth bass	I	Charles Road	11	7	3	0.53	23	18	29	7.8	15.6	0.53	23	18	38	7.8	15.6
		SRP-10	19	1	0	0.95	20	20	20	8.0	4.7	0.95	20	20	20	8.0	4.7
		SRP-7	1	0	0	1.00	1	1	1	0.3	0.2	1.00	1	1	1	0.3	0.2
		SRP-9	10	2	1	0.76	13	12	13	7.1	4.6	0.76	13	12	14	7.1	4.6
		Upstream Riffle	0	1	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Sunfish (unidentified species)	I	SRP-10	23	0	2	0.86	25	24	25	10.0	5.8	0.86	25	24	25	10.0	5.8
		SRP-7	0	1	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-8	5	21	2	0.29	43	24	64	13.6	7.5	0.22	53	25	Inf	16.7	9.2
		SRP-9	13	12	0	0.63	26	22	29	14.2	9.1	0.63	26	22	29	14.2	9.1
Family Percidae																	
Bigscale logperch	I	SRP-10	4	3	2	0.47	10	6	13	4.0	2.3	0.47	10	6	40	4.0	2.3
		SRP-8	7	1	6	0.33	19	10	26	6.0	3.3	0.23	25	10	Inf	7.9	4.3
Family Cottidae																	
Prickly sculpin	N	Charles Road	0	1	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-10	0	1	4	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	17	22	26	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-8	17	14	30	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-9	1	0	1	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		Upstream Riffle	3	5	5	.	.	.	.	NE	NE	.	.	.	.	NE	NE
Riffle sculpin	N	Upstream Riffle	10	4	5	0.45	22	15	29	8.2	13.9	0.42	23	15	63	8.6	14.6
Sculpin (unidentified species)	N	Charles Road	0	2	0	.	.	.	.	NE	NE	.	.	.	.	NE	NE
		SRP-7	1	0	0	1.00	1	1	1	0.3	0.2	1.00	1	1	1	0.3	0.2
		Upstream Riffle	21	1	14	0.35	49	34	73	18.3	31.0	0.30	54	34	502	20.1	34.2

Table C-3. 2003 abundance and density estimates for all fish species captured at the project and reference sites

						Carle-Strub Estimator						Profile Likelihood Estimator					
			Number Captured				Population Abundance			Population Density			Population Abundance			Population Density	
Species	Native or Introduced	Location	Pass 1	Pass 2	Pass 3	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./1000 ft)	Fish per Unit Site Area (No./10^5 ft^2)	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./1000 ft)	Fish per Unit Site Area (No./10^5 ft^2)
Family Petromyzontidae																	
Unspecified Ammocoete	N	CR	1	1	0	0.67	2	1	2	1	1	0.67	2	1	2	1	1
		R64	2	0	1	0.60	3	2	3	1	2	0.60	3	2	5	1	2
		SRP10	0	0	1	0.33	1	0	1	0	0	0.33	1	0	1	0	0
		SRP7	0	1	0	0.50	1	0	1	0	0	0.50	1	0	1	0	0
Family Clupeidae																	
American Shad	I	SRP10	0	0	2	0.33	2	0	2	1	0	0.00	undefined	NE	NE	NE	NE
Family Cyprinidae																	
Carp	I	CR	8	10	5	0.33	32	18	46	11	22	0.26	38	20	infinite	13	26
		R64	7	1	2	0.67	10	8	11	4	6	0.67	10	8	12	4	6
		SRP10	1	1	2	0.44	4	2	4	2	1	0.19	8	1	infinite	3	2
		SRP7	27	18	29	0.12	231	86	333	60	55	0.00	undefined	NE	NE	NE	NE
		SRP8	10	1	5	0.48	18	13	25	6	3	0.48	18	13	34	6	3
		SRP9	2	6	2	0.34	13	6	17	8	13	0.20	20	6	infinite	12	20
Goldfish	I	SRP8	0	3	0	0.50	3	1	3	1	1	0.50	3	1	5	1	1
Sacramento Blackfish	N	SRP10	0	1	0	0.50	1	0	1	0	0	0.50	1	0	1	0	0
Hardhead	N	R64	22	0	2	0.86	24	23	24	9	15	0.86	24	23	24	9	15
Hitch	N	CR	0	1	0	0.50	1	0	1	0	1	0.50	1	0	1	0	1
Sacramento Pikeminnow	N	CR	1	1	1	0.50	3	1	3	1	2	0.50	3	1	5	1	2
		R64	4	5	1	0.59	10	8	12	4	6	0.50	11	7	32	4	7
		SRP10	2	0	0	1.00	2	2	2	1	0	1.00	2	2	2	1	0
		SRP7	0	1	1	0.40	2	0	2	1	0	0.40	2	0	2	1	0
		SRP8	0	0	2	0.33	2	0	2	1	0	0.00	undefined	NE	NE	NE	NE
Family Catostomidae																	
Sacramento Sucker	N	CR	45	26	33	0.21	201	125	367	68	136	0.18	233	131	infinite	79	158
		R64	33	42	20	0.24	169	110	272	63	107	0.21	190	115	3491	71	120
		SRP10	1	0	2	0.43	3	1	3	1	1	0.23	5	1	infinite	2	1
		SRP7	2	5	4	0.23	19	7	23	5	5	0.00	undefined	NE	NE	NE	NE
		SRP8	0	0	1	0.33	1	0	1	0	0	0.33	1	0	1	0	0
		SRP9	5	8	5	0.26	29	13	39	17	29	0.12	57	14	infinite	33	58

Table C-3. 2003 abundance and density estimates for all fish species captured at the project and reference sites

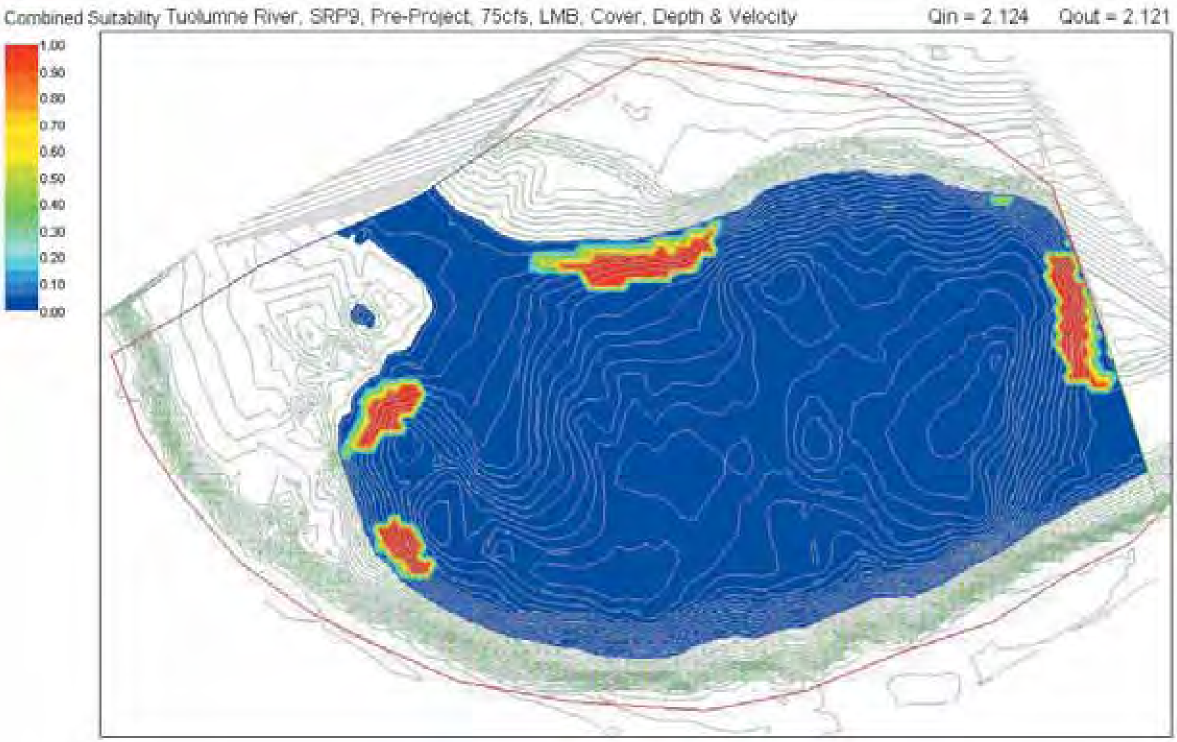
Species	Native or Introduced	Location	Number Captured			Carle-Strub Estimator						Profile Likelihood Estimator					
							Population Abundance			Population Density			Population Abundance			Population Density	
			Pass 1	Pass 2	Pass 3	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./1000 ft)	Fish per Unit Site Area (No./10^5 ft^2)	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./1000 ft)	Fish per Unit Site Area (No./10^5 ft^2)
Family Ictaluridae																	
Channel Catfish	I	CR	30	32	28	0.14	245	112	365	83	166	0.06	560	131	infinite	190	379
		R64	1	2	2	0.36	6	2	7	2	4	0.14	13	2	infinite	5	8
		SRP10	9	3	1	0.72	13	11	14	5	3	0.72	13	11	14	5	3
		SRP7	1	0	4	0.23	8	2	9	2	2	0.00	undefined	NE	NE	NE	NE
		SRP8	5	3	1	0.64	9	7	10	3	2	0.64	9	7	12	3	2
		SRP9	12	6	5	0.45	27	19	37	16	27	0.45	27	19	49	16	27
Black Bullhead	I	SRP8	0	1	0	0.50	1	0	1	0	0	0.50	1	0	1	0	0
White Catfish	I	CR	30	22	12	0.39	82	64	110	28	56	0.38	84	66	144	28	57
		R64	9	19	8	0.21	70	34	98	26	44	0.10	133	38	infinite	50	84
		SRP10	1	2	1	0.50	4	2	4	2	1	0.50	4	2	8	2	1
		SRP7	11	6	6	0.39	29	19	42	8	7	0.35	31	20	206	8	7
		SRP8	0	1	0	0.50	1	0	1	0	0	0.50	1	0	1	0	0
		SRP9	8	26	10	0.15	114	45	155	66	116	0.00	undefined	NE	NE	NE	NE
Brown Bullhead	I	CR	2	0	1	0.60	3	2	3	1	2	0.60	3	2	5	1	2
		R64	1	0	0	1.00	1	1	1	0	1	1.00	1	1	1	0	1
		SRP10	1	0	0	1.00	1	1	1	0	0	1.00	1	1	1	0	0
		SRP7	1	6	3	0.23	17	5	21	4	4	0.00	undefined	NE	NE	NE	NE
		SRP8	0	1	1	0.40	2	0	2	1	0	0.40	2	0	2	1	0
Family Atherinidae																	
Inland Silverside	I	SRP10	6	2	1	0.69	9	8	10	4	2	0.69	9	7	10	4	2
		SRP7	0	2	0	0.50	2	1	2	1	0	0.50	2	1	2	1	0
		SRP8	4	1	6	0.23	19	7	23	6	3	0.00	undefined	NE	NE	NE	NE
Family Percichthyidae																	
Striped Bass	I	CR	2	0	0	1.00	2	2	2	1	1	1.00	2	2	2	1	1
		R64	0	1	0	0.50	1	0	1	0	1	0.50	1	0	1	0	1
Family Centrarchidae																	
Bluegill	I	CR	92	109	63	0.18	590	387	968	200	400	0.16	648	409	2821	220	439
		R64	72	8	2	0.87	82	81	82	31	52	0.87	82	81	82	31	52
		SRP10	681	305	200	0.48	1380	1323	1441	552	321	0.48	1380	1330	1447	552	321
		SRP7	145	156	107	0.15	1046	683	1676	272	250	0.14	1152	734	4227	299	275
		SRP8	335	225	234	0.18	1744	1346	2417	550	303	0.18	1793	1386	2656	565	312
		SRP9	90	0	68	0.22	296	199	444	171	301	0.20	321	207	1771	186	326
Redear Sunfish	I	CR	1	8	1	0.34	13	6	17	4	9	0.20	20	6	infinite	7	14
		R64	5	1	0	0.86	6	6	6	2	4	0.86	6	6	6	2	4
		SRP10	27	8	9	0.52	49	41	61	20	11	0.52	49	42	65	20	11
		SRP7	20	33	12	0.24	113	69	177	29	27	0.20	134	72	infinite	35	32
		SRP8	27	7	23	0.21	113	61	168	36	20	0.14	161	66	infinite	51	28
		SRP9	3	32	1	0.23	65	34	94	38	66	0.14	101	36	infinite	58	103

Table C-3. 2003 abundance and density estimates for all fish species captured at the project and reference sites

						Carle-Strub Estimator						Profile Likelihood Estimator					
			Number Captured				Population Abundance			Population Density			Population Abundance			Population Density	
Species	Native or Introduced	Location	Pass 1	Pass 2	Pass 3	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./1000 ft)	Fish per Unit Site Area (No./10^5 ft^2)	Probability of Capture	Estimate	Lower 95% C.I.	Upper 95% C.I.	Fish per Unit Bank Length (No./1000 ft)	Fish per Unit Site Area (No./10^5 ft^2)
Pumpkinseed	I	R64	2	0	0	1.00	2	2	2	1	1	1.00	2	2	2	1	1
		SRP8	5	0	0	1.00	5	5	5	2	1	1.00	5	5	5	2	1
Green Sunfish	I	CR	4	0	6	0.23	17	6	21	6	12	0.00	undefined	NE	NE	NE	NE
		R64	1	0	0	1.00	1	1	1	0	1	1.00	1	1	1	0	1
		SRP10	24	12	6	0.54	46	38	55	18	11	0.54	46	39	56	18	11
		SRP7	2	3	4	0.26	14	5	18	4	3	0.00	undefined	NE	NE	NE	NE
		SRP8	8	3	0	0.79	11	10	11	3	2	0.79	11	10	11	3	2
		SRP9	30	111	23	0.13	488	241	833	283	496	0.07	787	277	infinite	456	799
Warmouth	I	CR	0	2	0	0.50	2	1	2	1	1	0.50	2	1	2	1	1
		SRP10	4	1	0	0.83	5	5	5	2	1	0.83	5	4	5	2	1
		SRP8	0	6	3	0.21	16	4	19	5	3	0.00	undefined	NE	NE	NE	NE
White Crappie	I	SRP8	4	1	1	0.67	6	5	6	2	1	0.67	6	5	8	2	1
Black Crappie	I	SRP10	1	1	0	0.67	2	1	2	1	0	0.67	2	1	2	1	0
		SRP8	0	0	3	0.25	4	0	4	1	1	0.00	undefined	NE	NE	NE	NE
Largemouth Bass	I	CR	10	14	5	0.34	40	25	58	14	27	0.29	45	27	infinite	15	30
		R64	9	4	1	0.70	14	12	15	5	9	0.70	14	12	15	5	9
		SRP10	77	24	27	0.48	149	132	173	60	35	0.48	149	132	174	60	35
		SRP7	46	41	29	0.24	205	138	325	53	49	0.21	225	144	1089	58	54
		SRP8	79	42	45	0.29	257	197	380	81	45	0.28	265	199	473	84	46
		SRP9	39	10	8	0.62	60	54	65	35	61	0.62	60	54	66	35	61
Smallmouth Bass	I	CR	23	21	13	0.30	86	58	130	29	58	0.27	94	61	527	32	64
		R64	32	17	11	0.45	71	58	90	26	45	0.44	72	58	102	27	46
		SRP10	8	1	4	0.52	14	10	17	6	3	0.52	14	10	22	6	3
		SRP7	11	44	4	0.25	102	61	162	27	24	0.20	122	63	infinite	32	29
		SRP8	1	0	1	0.50	2	1	2	1	0	0.50	2	1	2	1	0
		SRP9	32	32	25	0.19	191	107	298	111	194	0.13	254	113	infinite	147	258
Family Percidae																	
Bigscale Logperch	I	SRP7	0	1	0	0.50	1	0	1	0	0	0.50	1	0	1	0	0
		SRP8	1	0	1	0.50	2	1	2	1	0	0.50	2	1	2	1	0
		SRP9	2	0	0	1.00	2	2	2	1	2	1.00	2	2	2	1	2
Family Cottidae																	
Unspecified Sculpin	N	CR	0	2	0	0.50	2	1	2	1	1	0.50	2	1	2	1	1
		R64	3	1	3	0.41	8	4	10	3	5	0.27	11	4	infinite	4	7
		SRP10	1	0	0	1.00	1	1	1	0	0	1.00	1	1	1	0	0
		SRP7	0	2	0	0.50	2	1	2	1	0	0.50	2	1	2	1	0
		SRP8	0	0	1	0.33	1	0	1	0	0	0.33	1	0	1	0	0

Appendix D

Predicted Largemouth Bass, Smallmouth Bass, and Chinook Salmon Habitat at SRP 9 Pre-project..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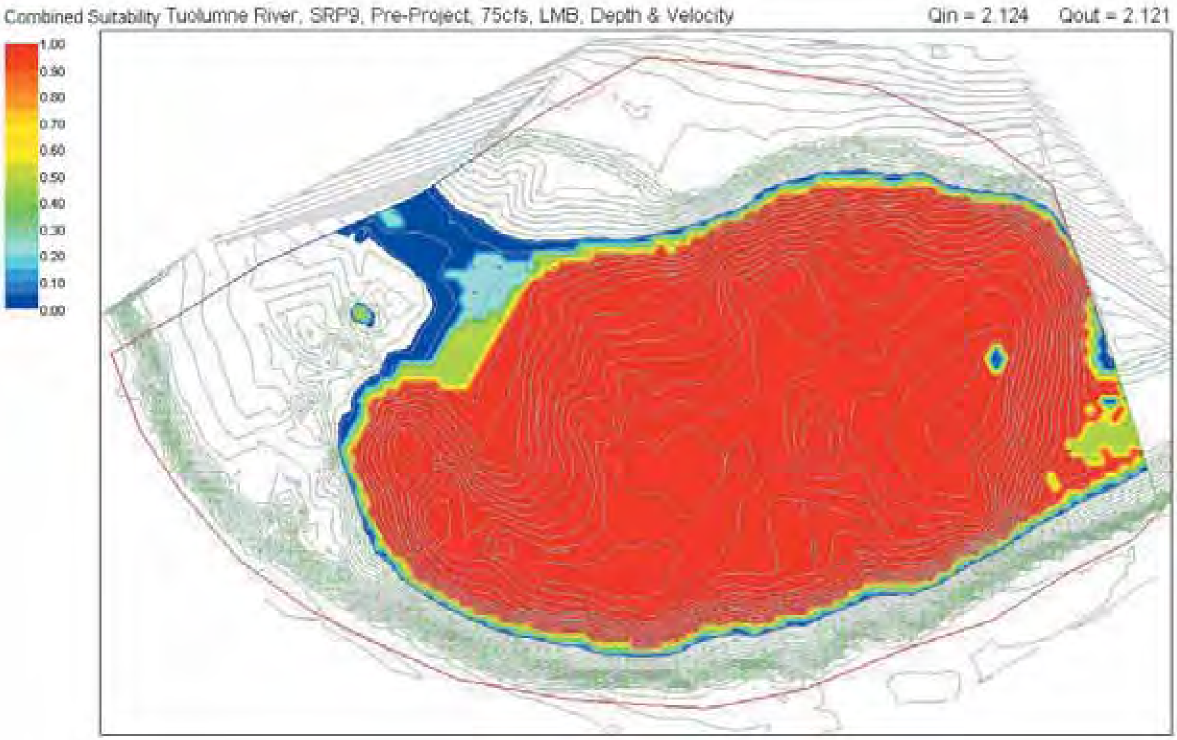
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00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0.80
0.70
0.60
0.50
0.40
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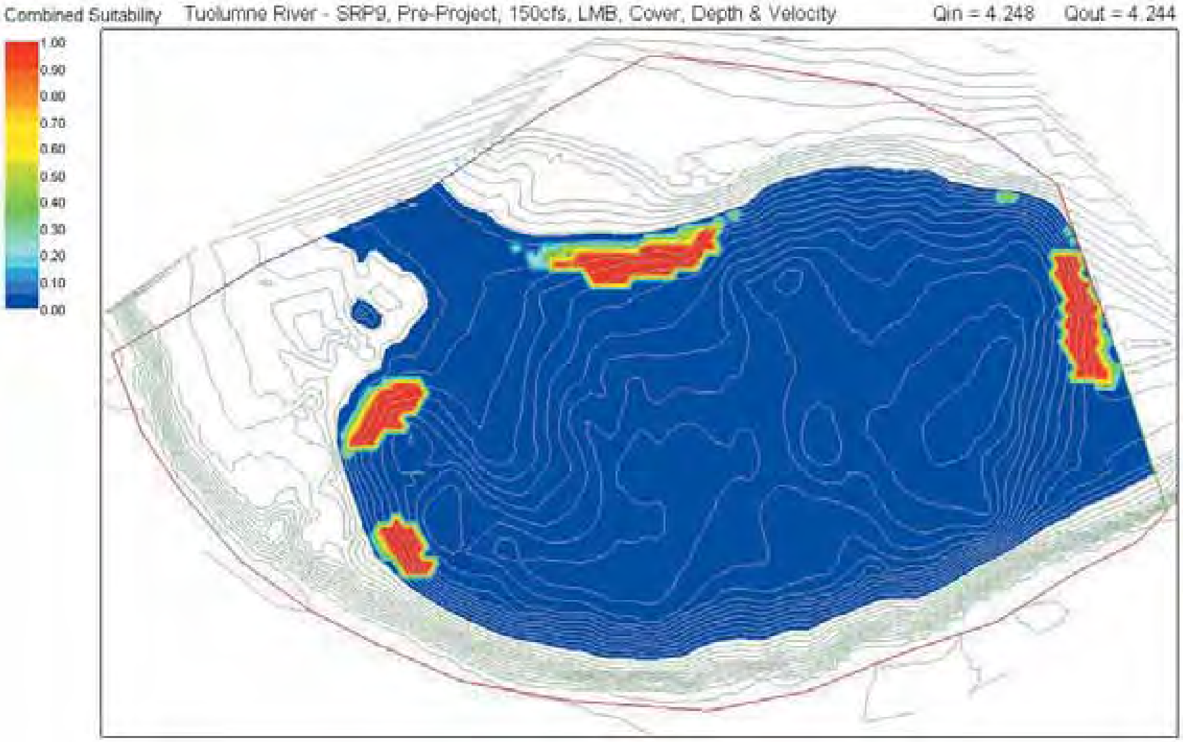
0.10
0.00


Combined Suitability
Tuolumne River - SRP9, Pre-Project, 150cfs, LMB, Cover, Depth & Velocity
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Qout = 4.244
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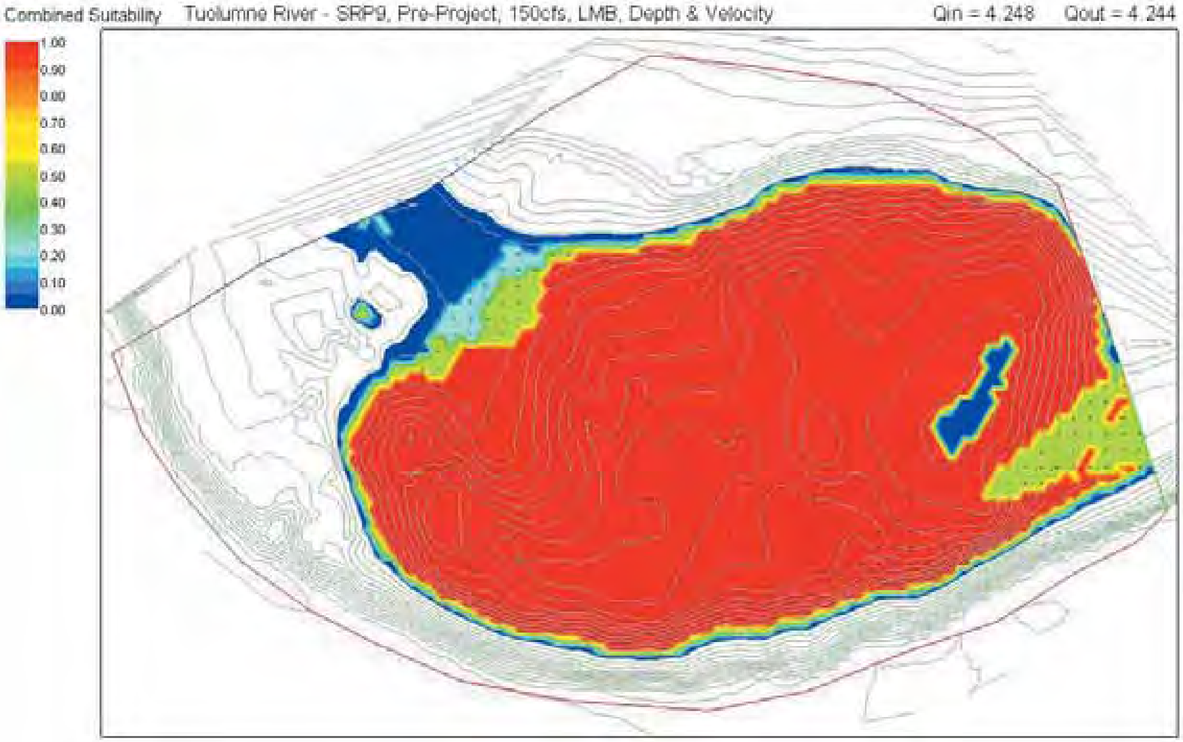
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - SRP9, Pre-Project, 150cfs, LMB, Depth & Velocity
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Qout = 4.244
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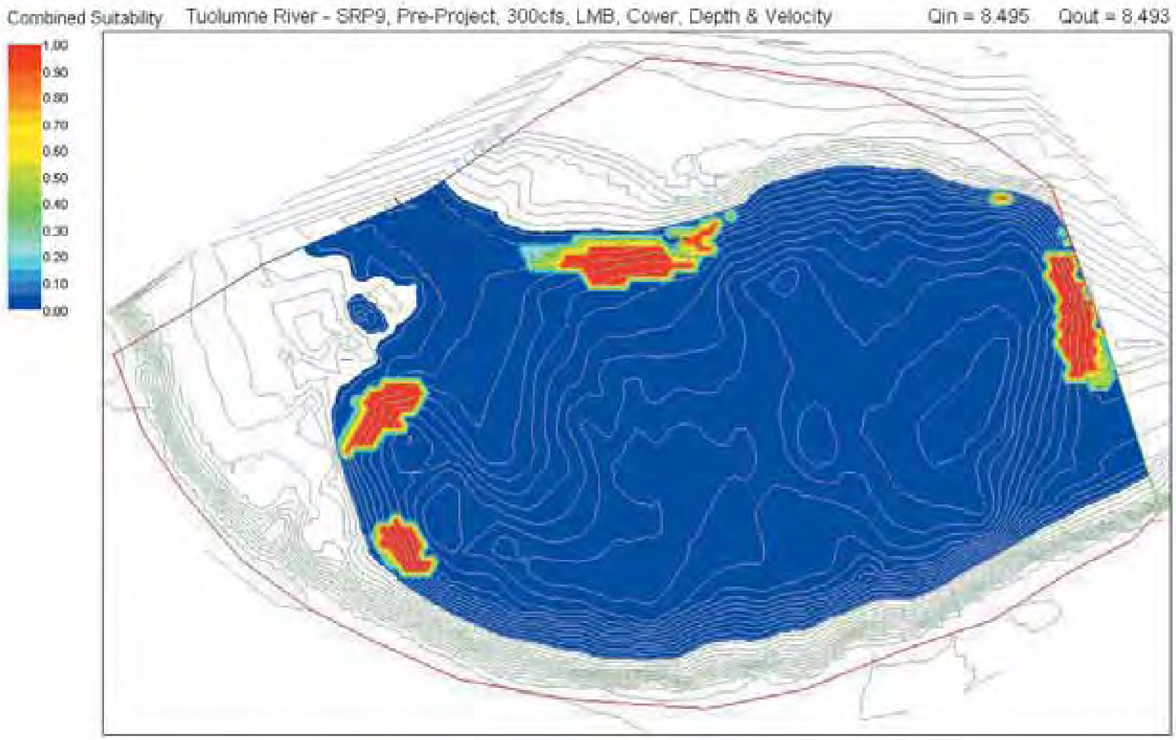
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - SRP9, Pre-Project, 300cfs, LMB, Cover, Depth & Velocity
Qin = 8.495
Qout = 8.493
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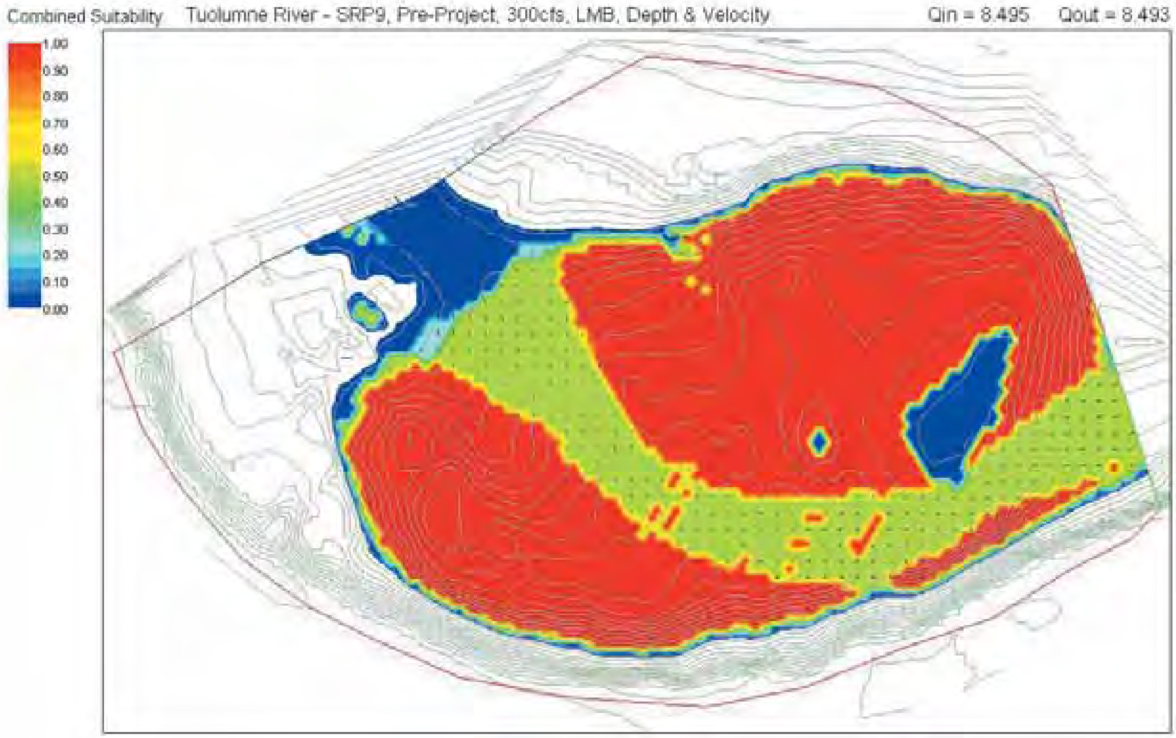
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - SRP9, Pre-Project, 300cfs, LMB, Depth & Velocity
Qin = 8.495
Qout = 8.493
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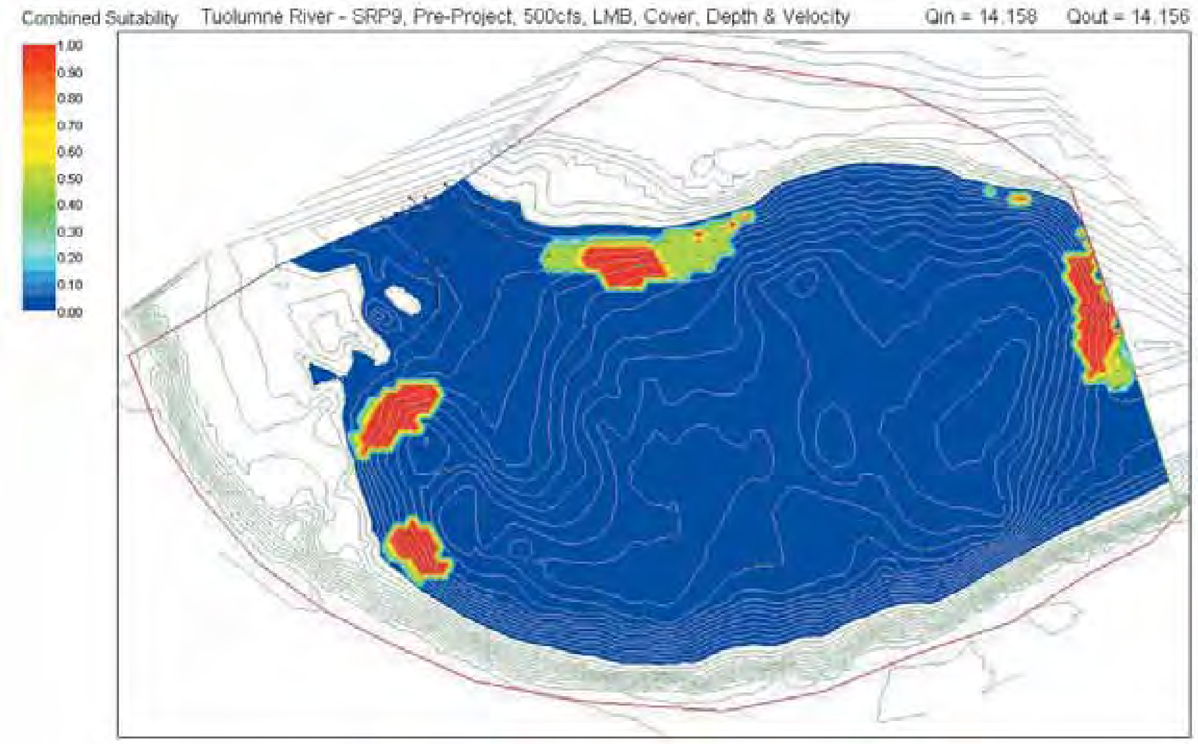
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00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Tuolumne River - SRP9, Pre-Project, 500cfs, LMB, Cover, Depth & Velocity
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Qout = 14.156
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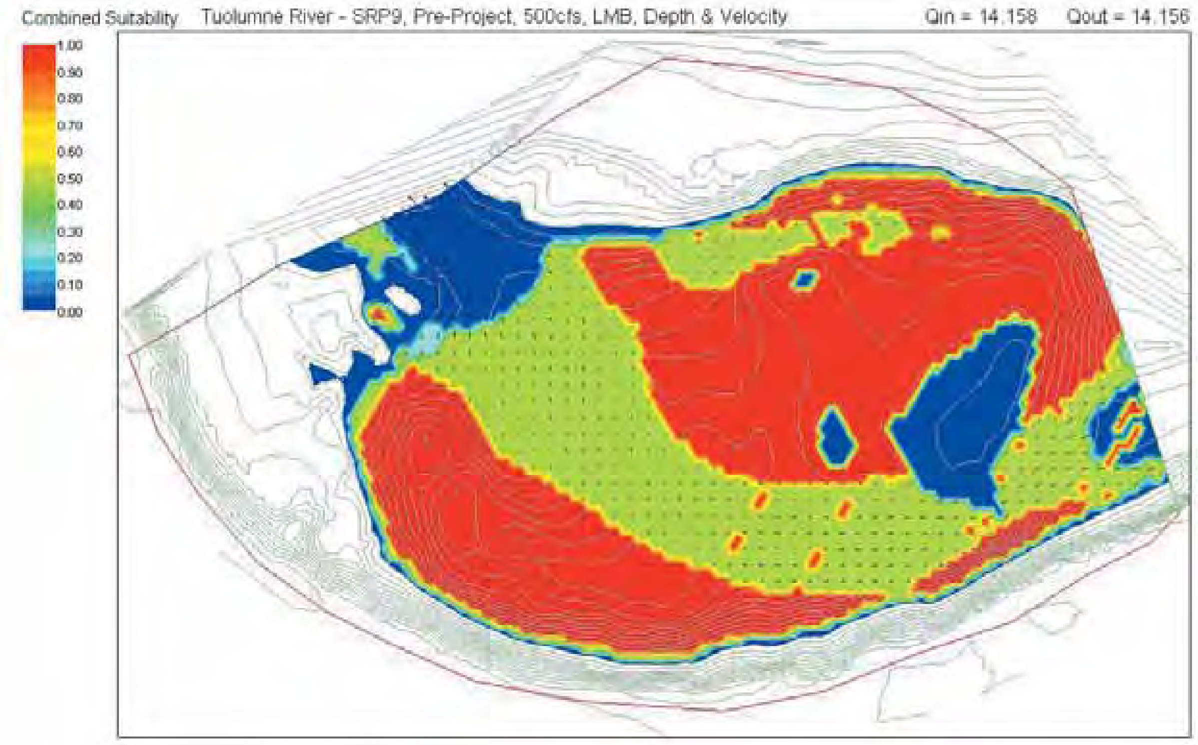
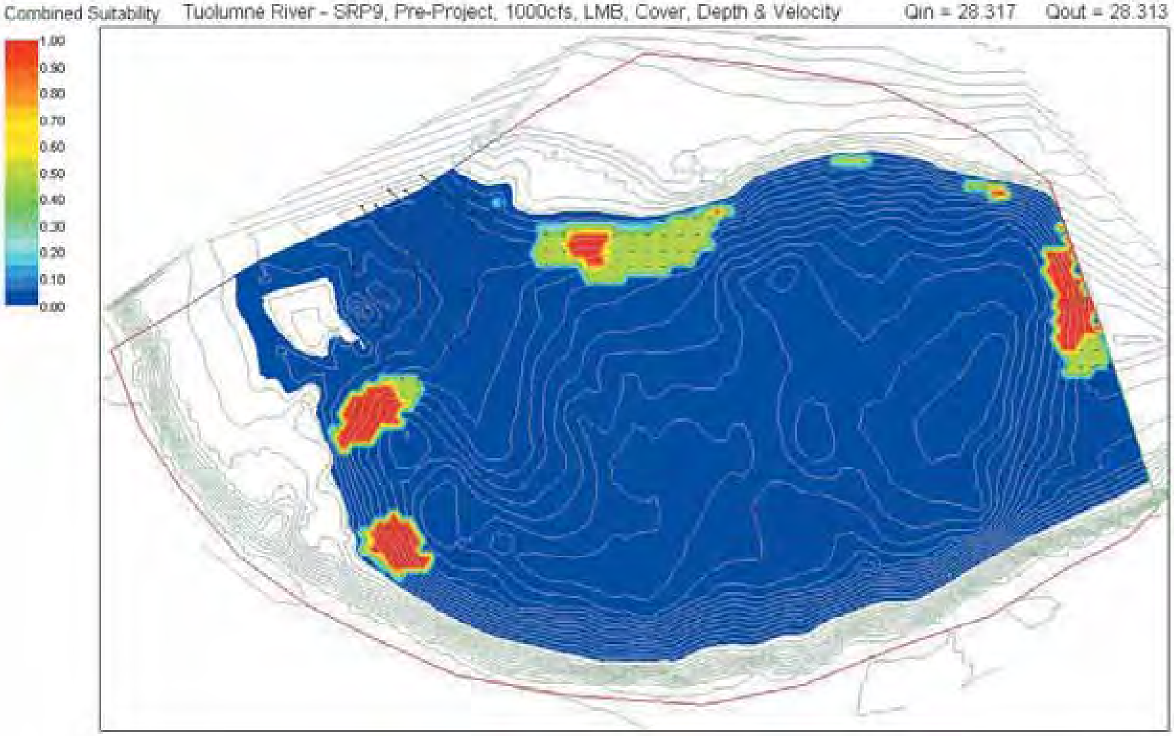
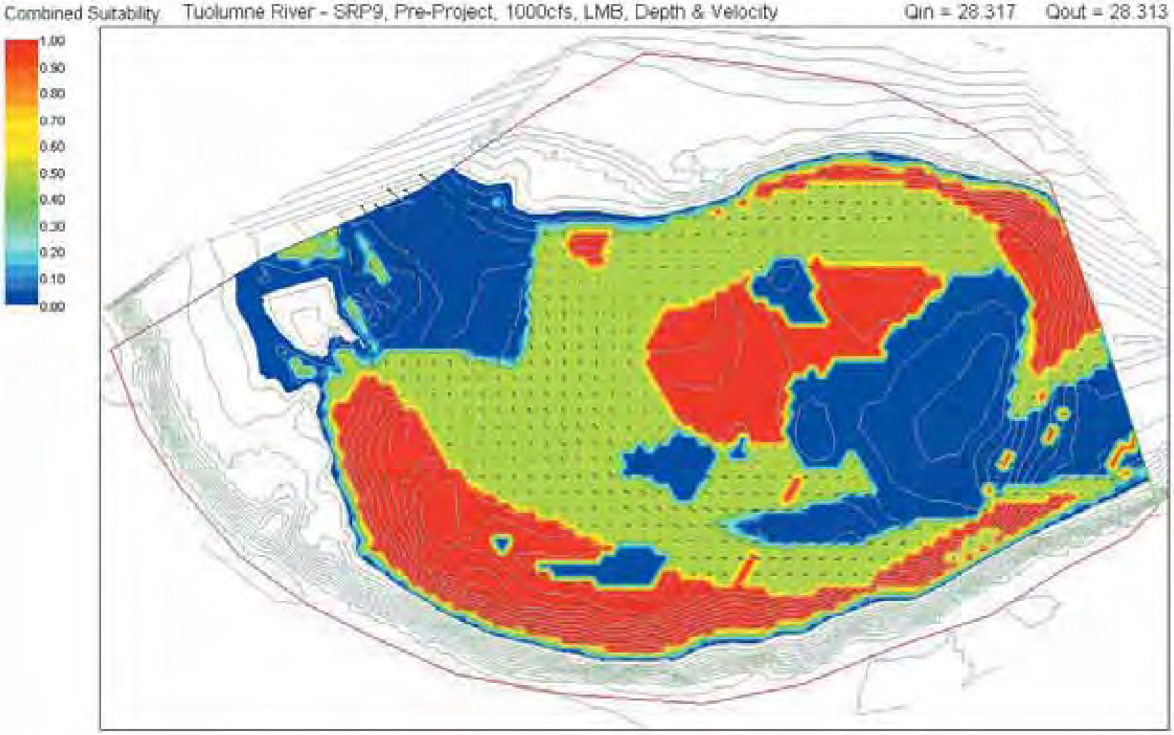
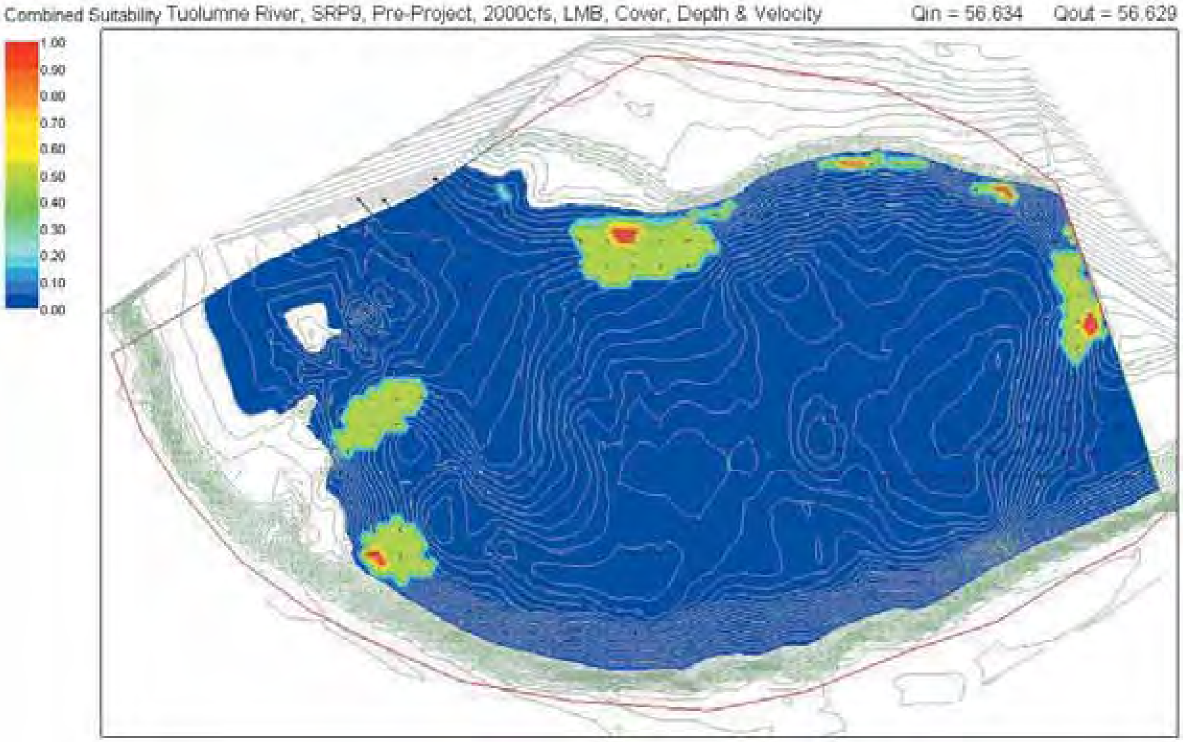
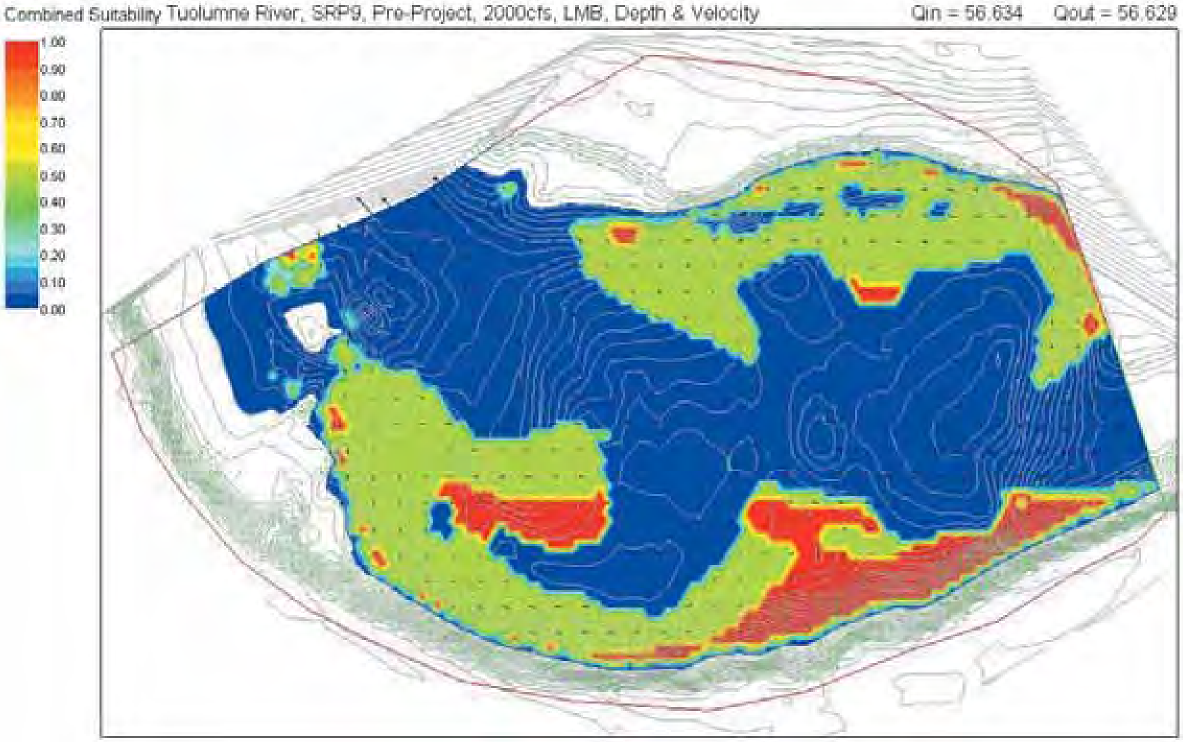
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

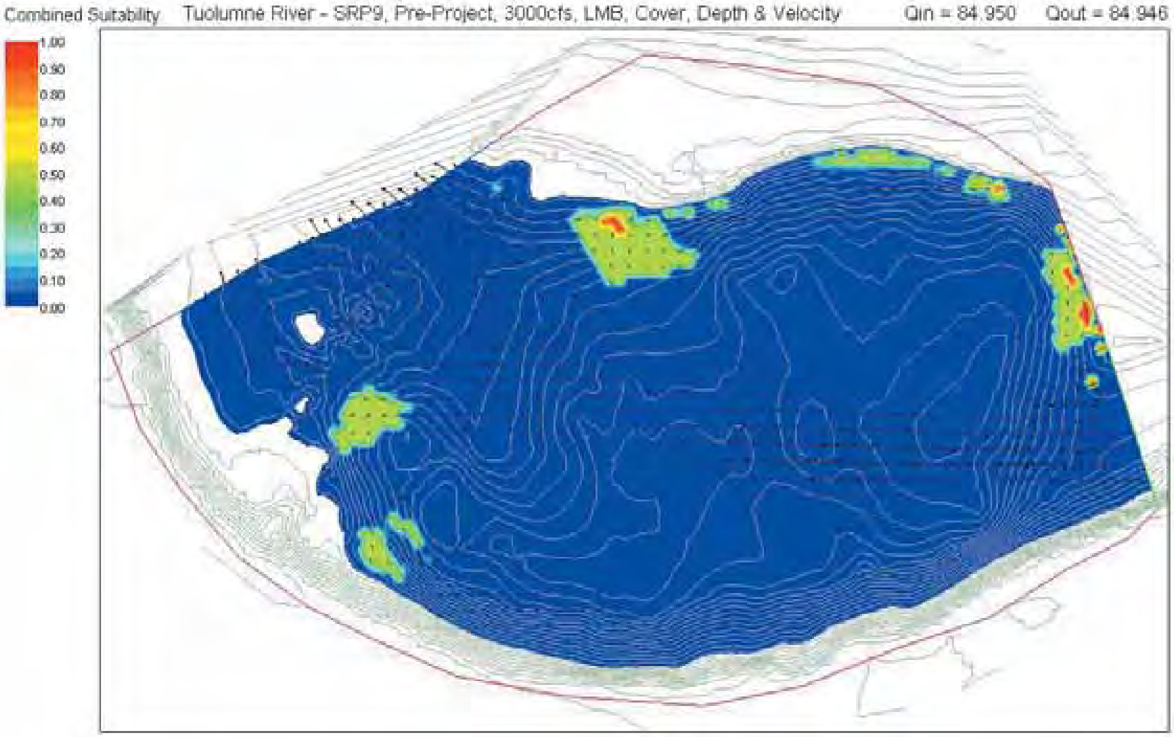

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 500cfs, LMB, Depth & Velocity
Qin = 14.158
Qout = 14.156
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

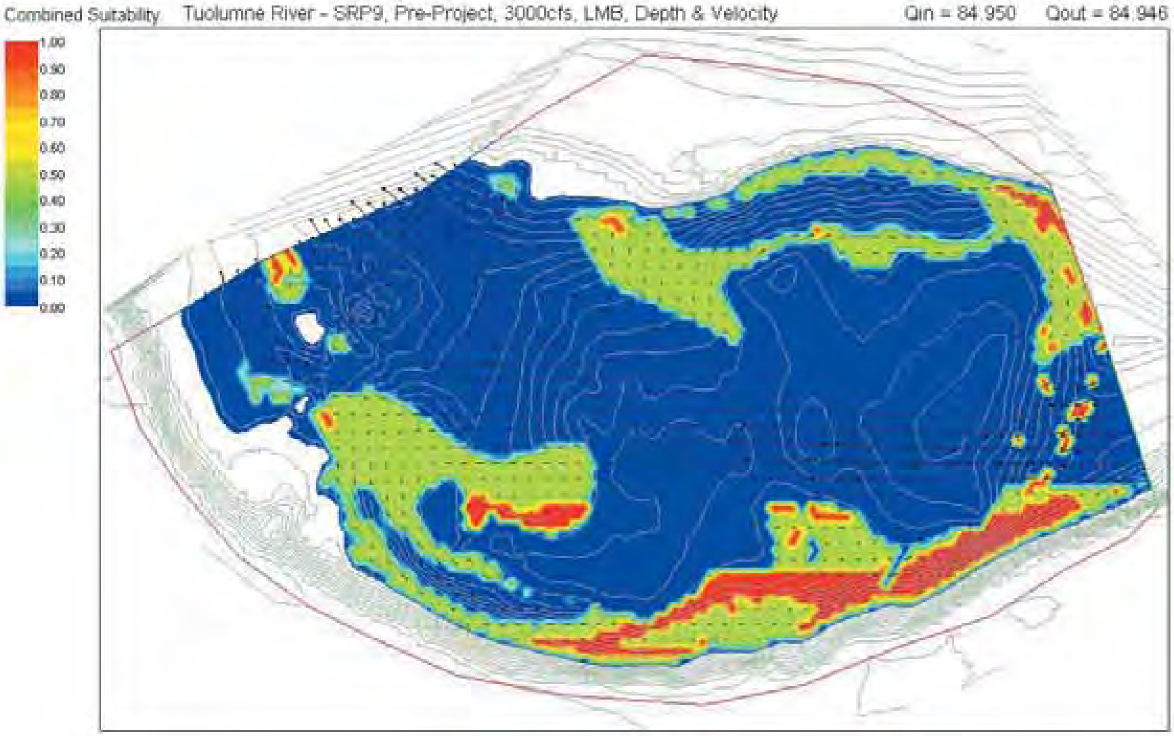

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 1000cfs, LMB, Cover, Depth & Velocity
Qin = 28.317
Qout = 28.313
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

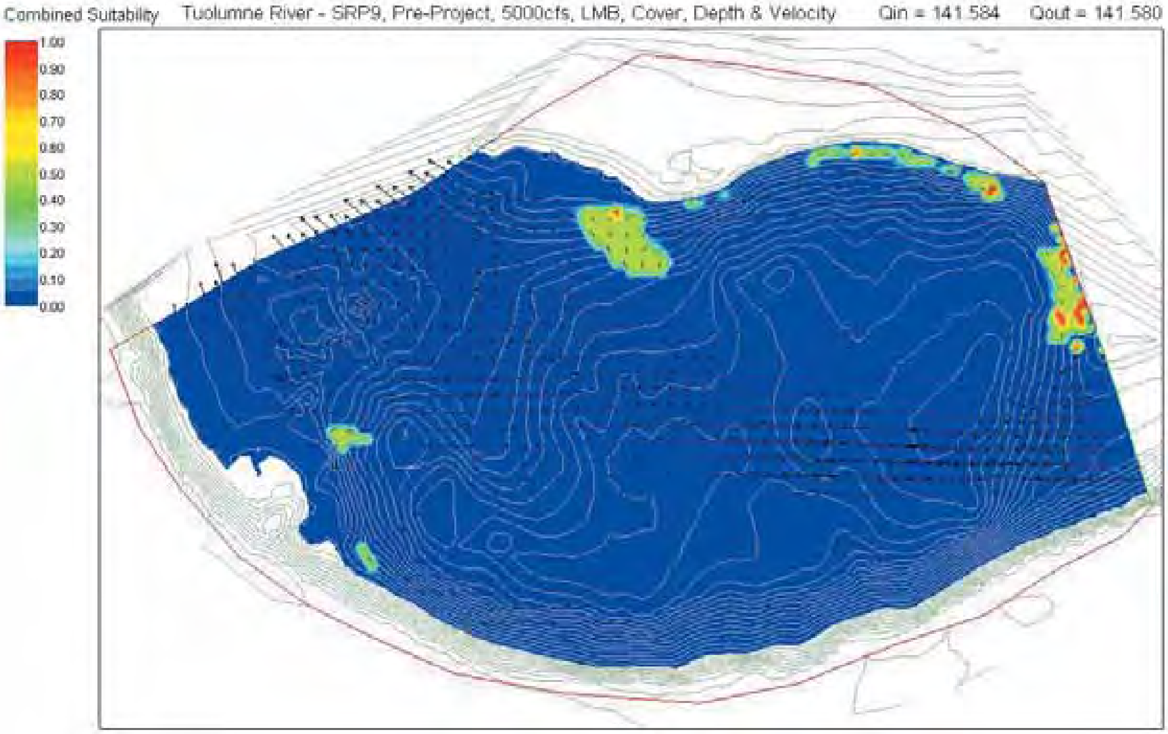

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 1000cfs, LMB, Depth & Velocity
Qin = 28.317
Qout = 28.313
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

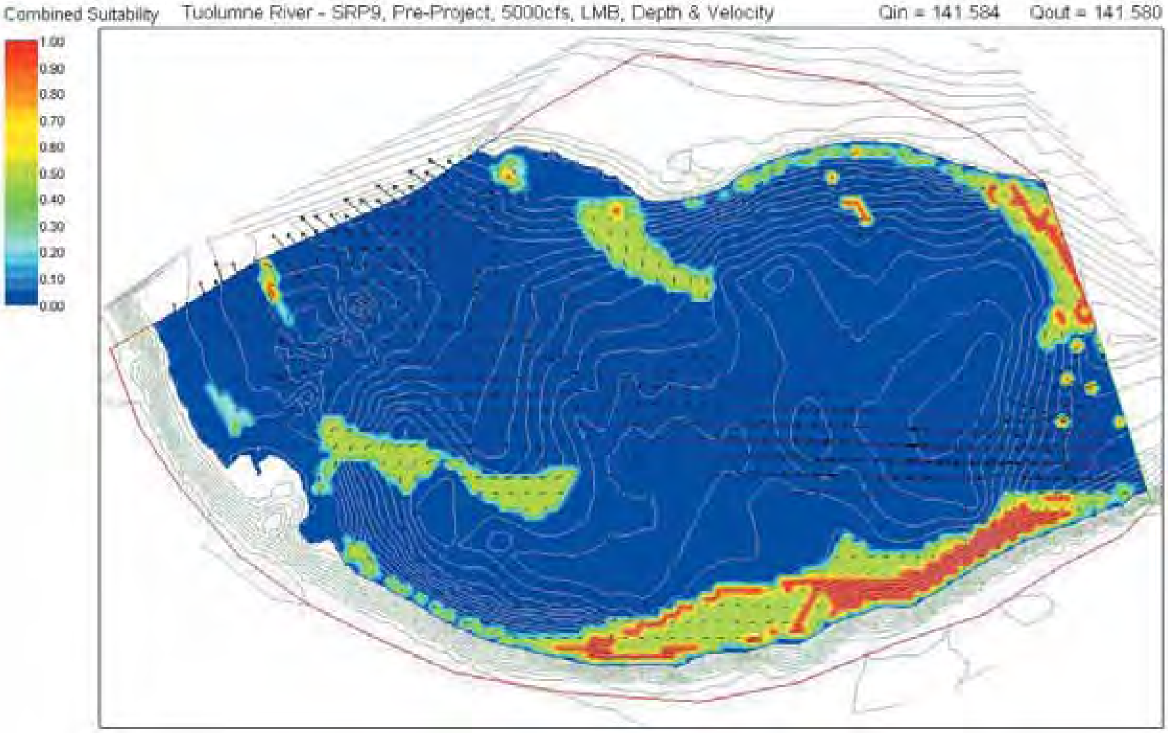

Combined Suitability Tuolumne River, SRP9, Pre-Project, 2000cfs, LMB, Cover, Depth & Velocity
Qin = 56.634
Qout = 56.629
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

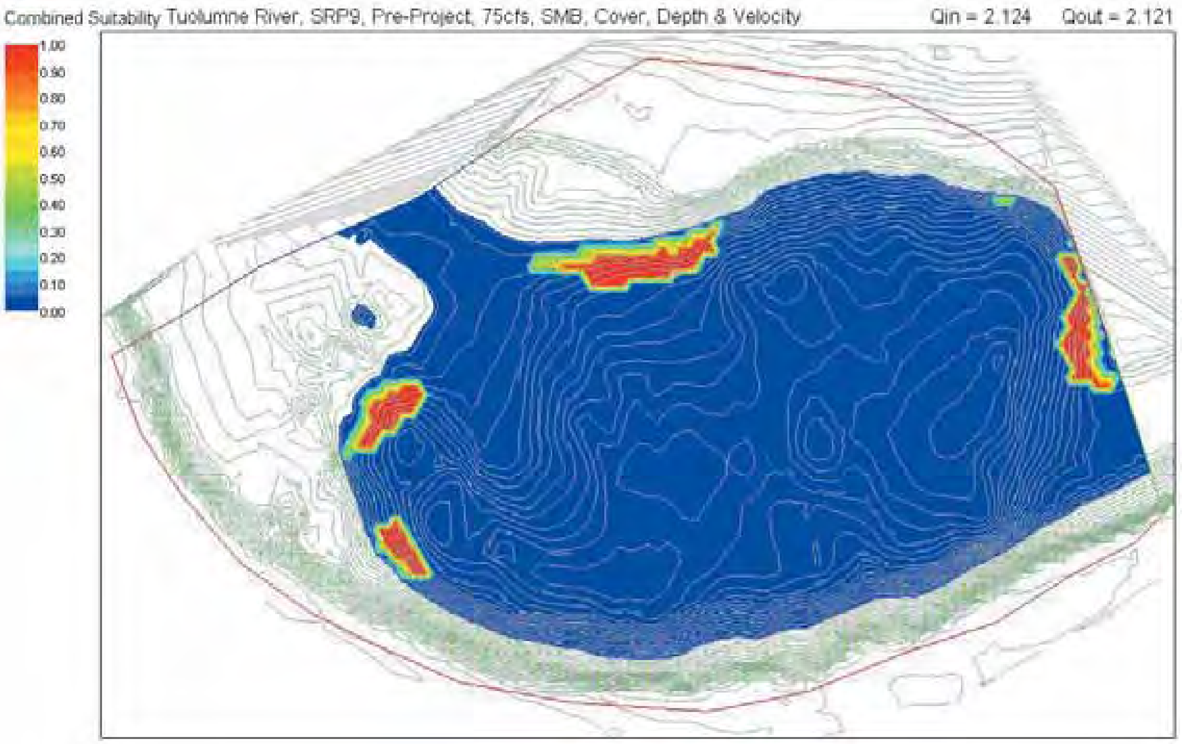

Combined Suitability Tuolumne River, SRP9, Pre-Project, 2000cfs, LMB, Depth & Velocity
Qin = 56.634
Qout = 56.629
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - SRP9, Pre-Project, 3000cfs, LMB, Cover, Depth & Velocity
Qin = 84.950
Qout = 84.946
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

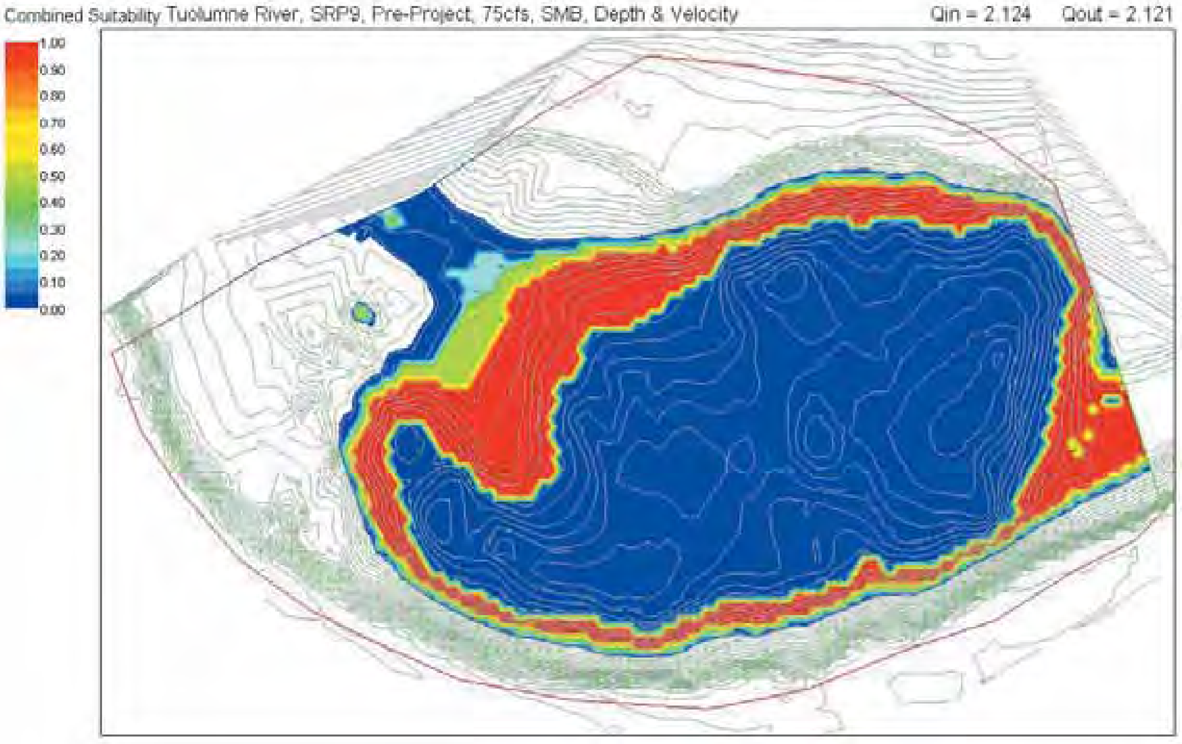

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 3000cfs, LMB, Depth & Velocity
Qin = 84.950
Qout = 84.946
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - SRP9, Pre-Project, 5000cfs, LMB, Cover, Depth & Velocity
Qin = 141.584
Qout = 141.580
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

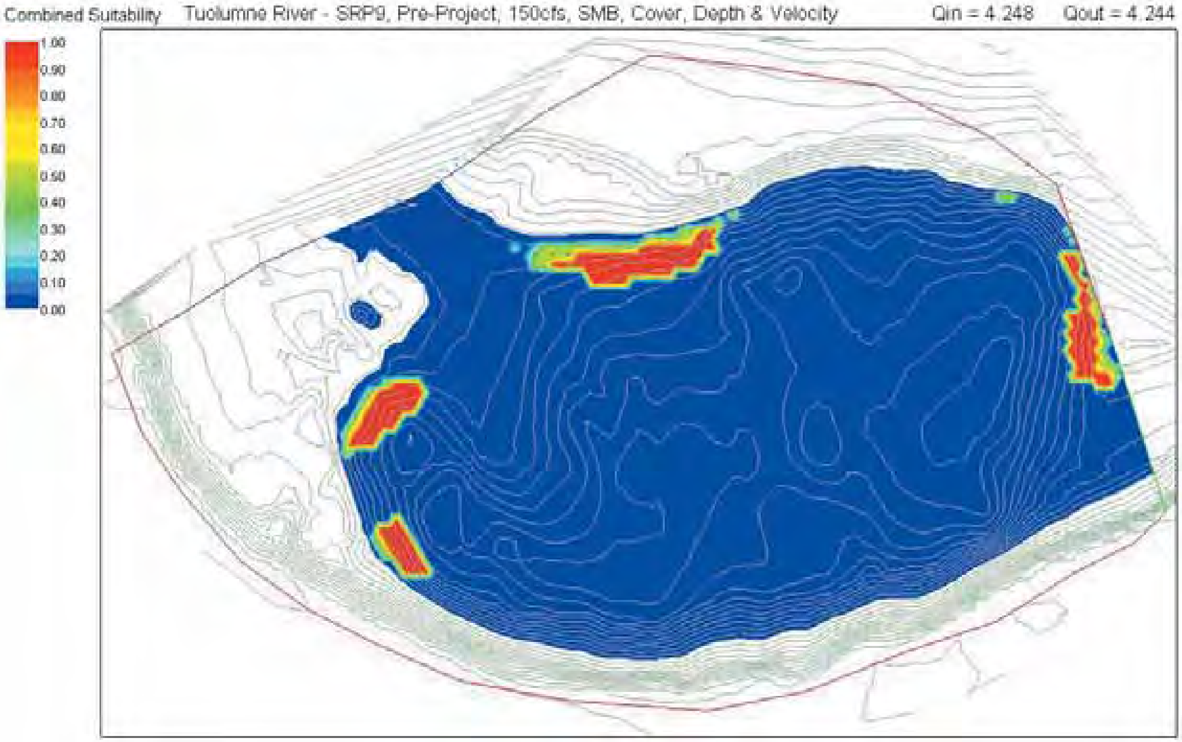

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 5000cfs, LMB, Depth & Velocity
Qin = 141.584
Qout = 141.580
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

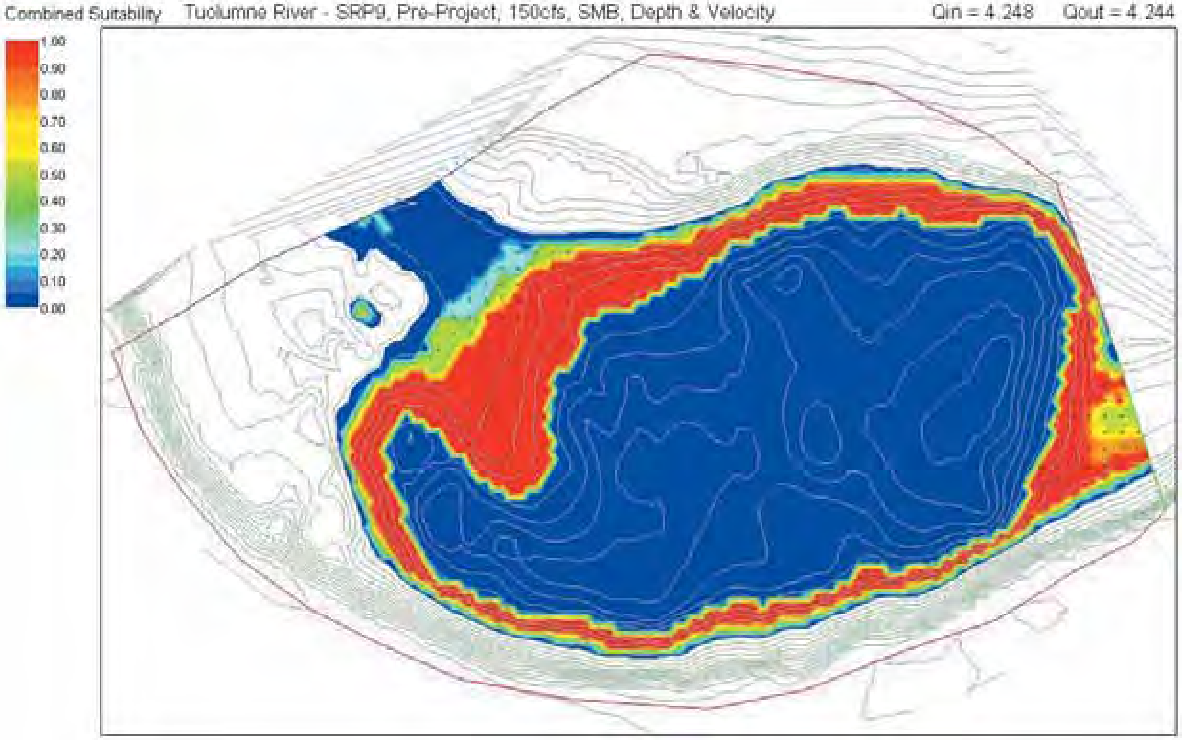


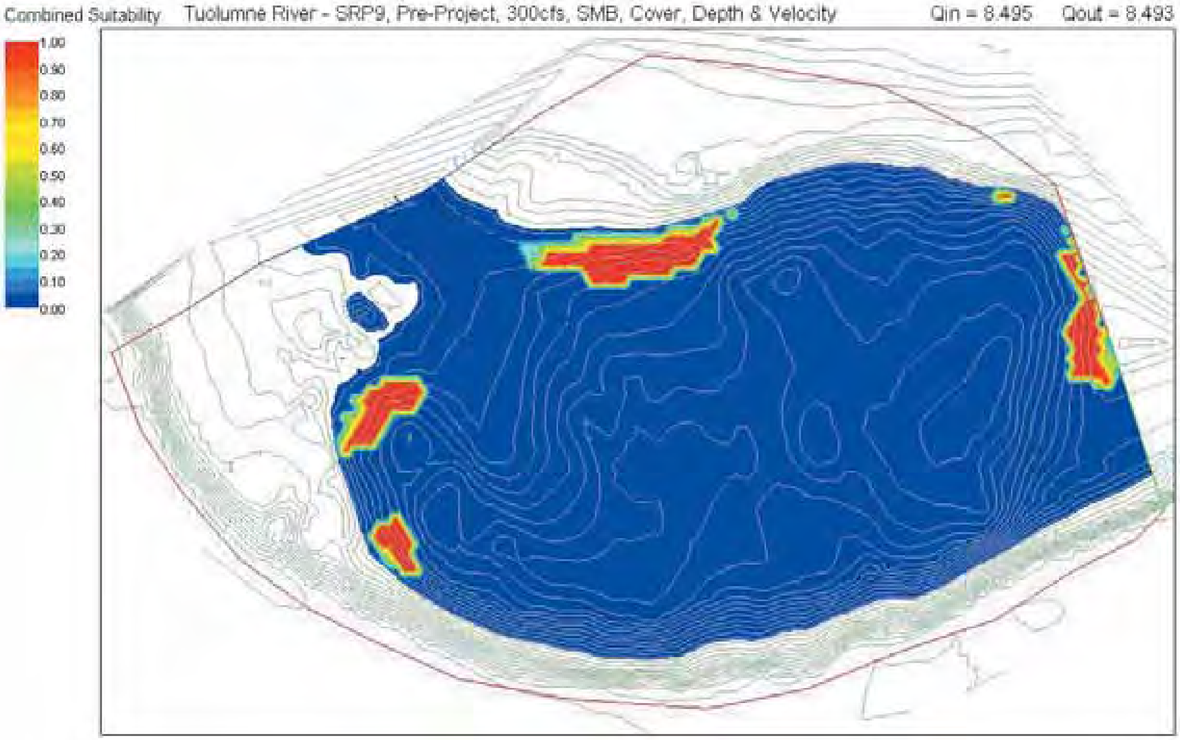
Combined Suitability Tuolumne River, SRP9, Pre-Project, 75cfs, SMB, Cover, Depth & Velocity Qin = 2.124 Qout = 2.121

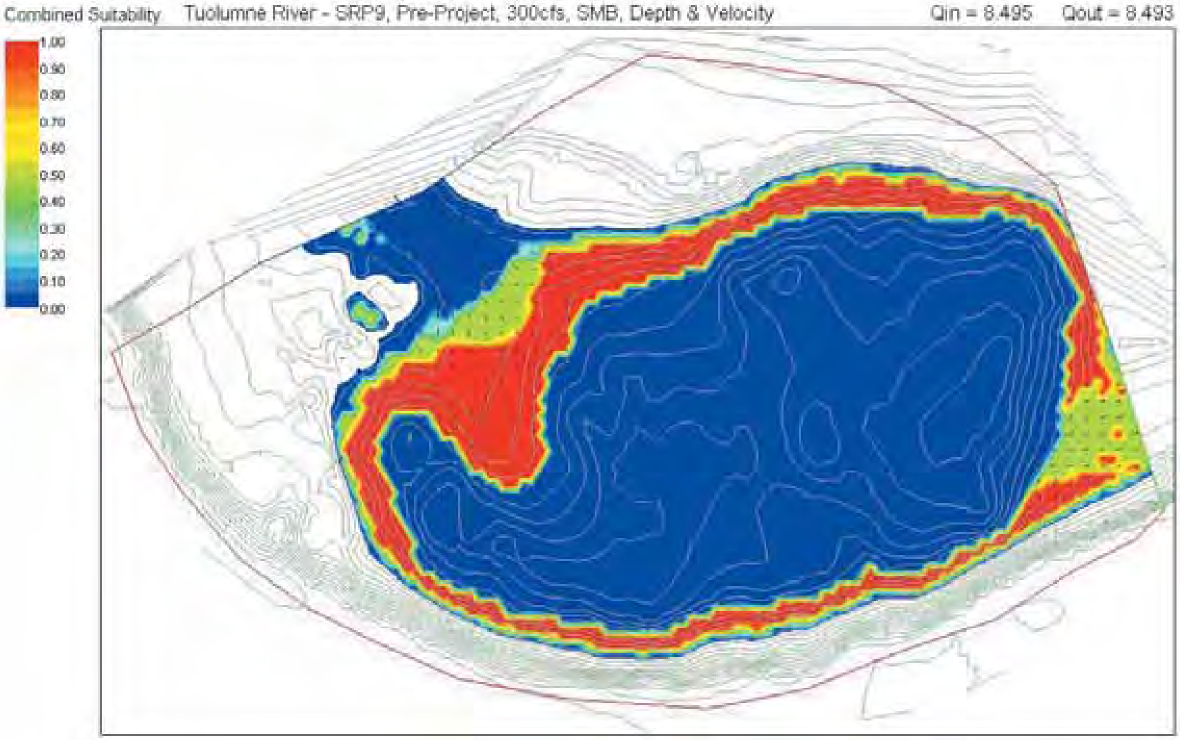


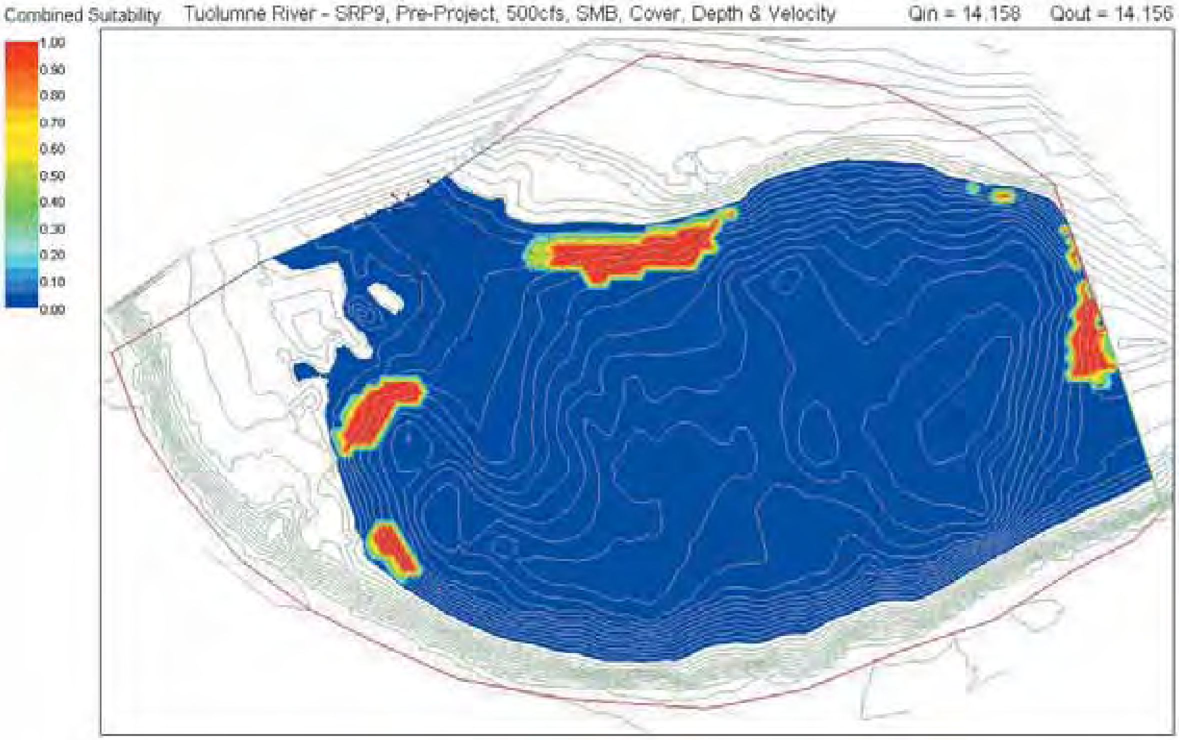
Combined Suitability Tuolumne River, SRP9, Pre-Project, 75cfs, SMB, Depth & Velocity Qin = 2.124 Qout = 2.121

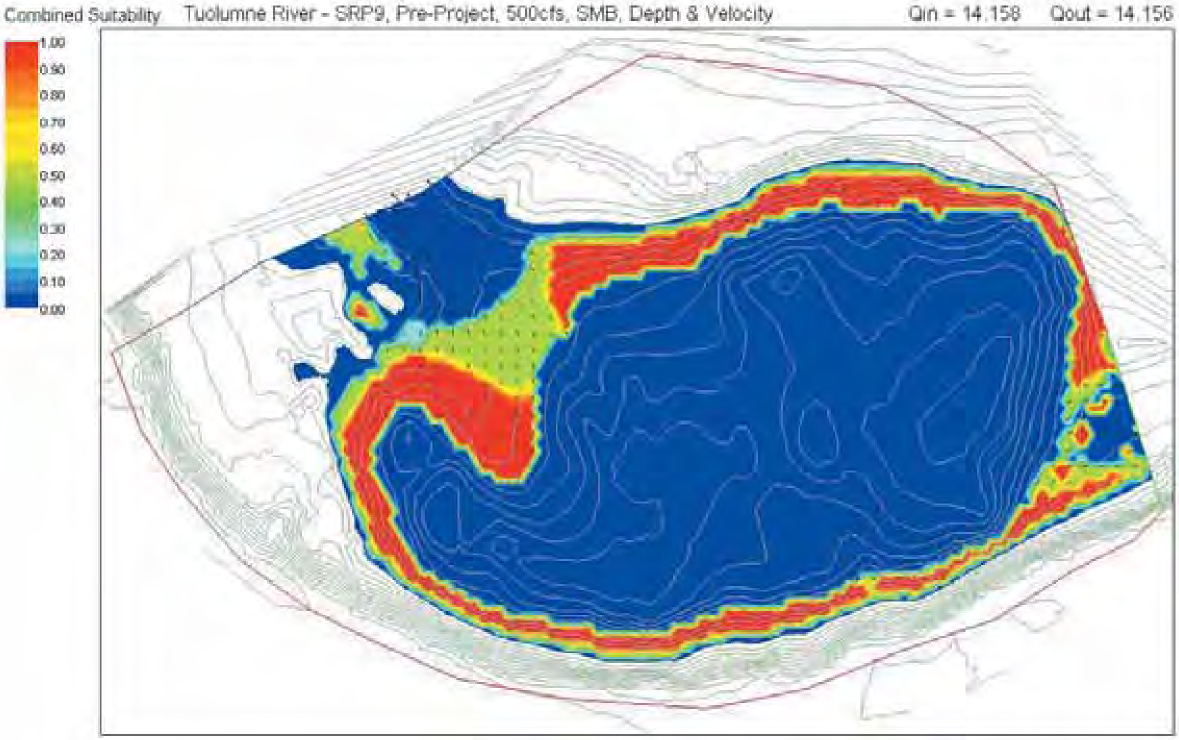

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 150cfs, SMB, Cover, Depth & Velocity
Qin = 4.248
Qout = 4.244
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

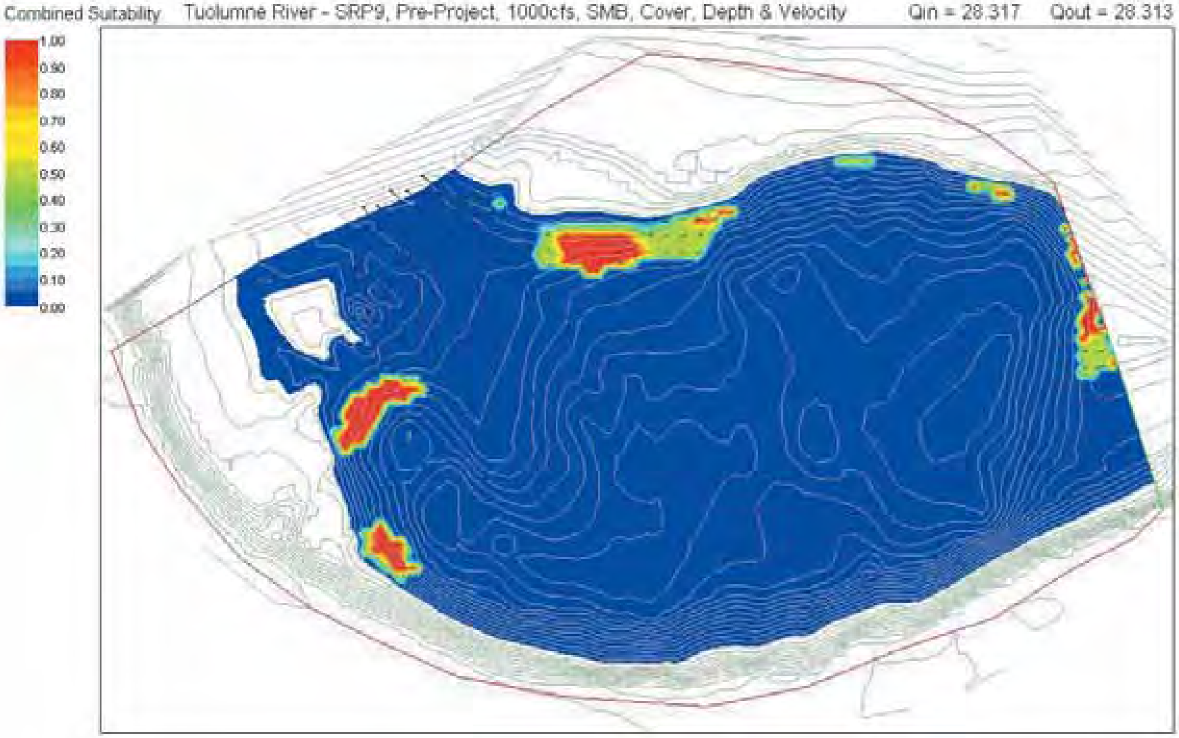

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 150cfs, SMB, Depth & Velocity
Qin = 4.248
Qout = 4.244
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

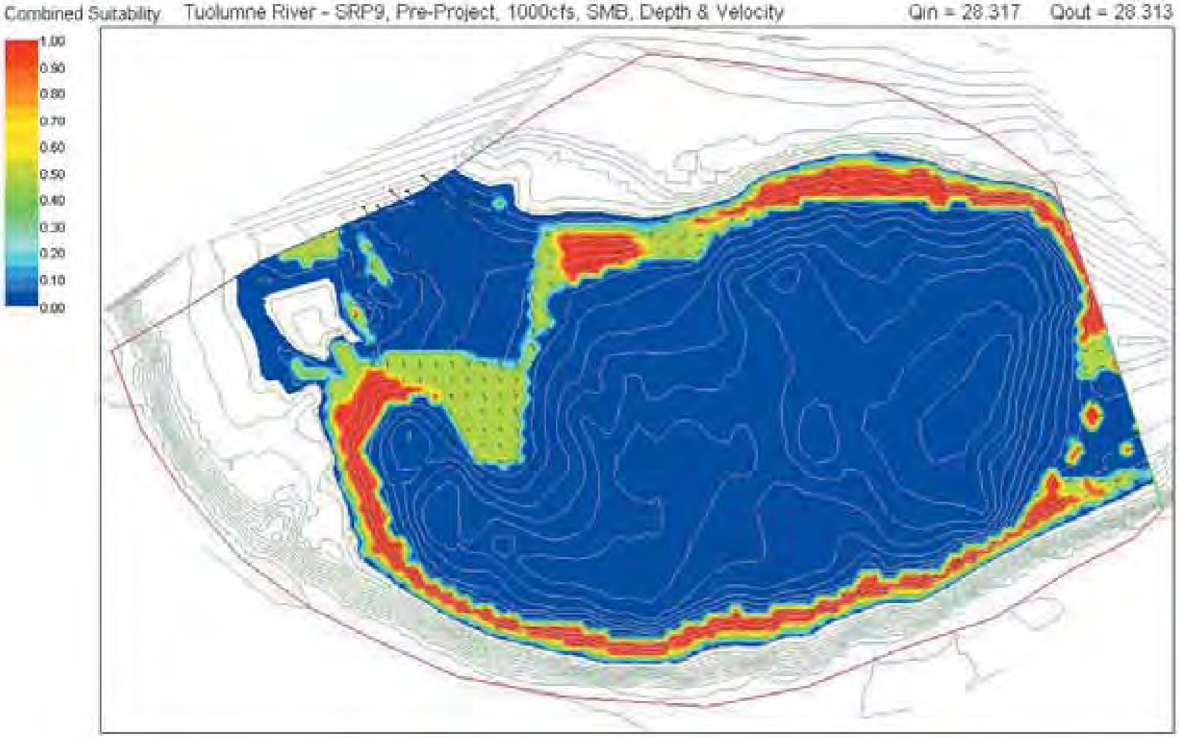

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 300cfs, SMB, Cover, Depth & Velocity
Qin = 8.495
Qout = 8.493
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

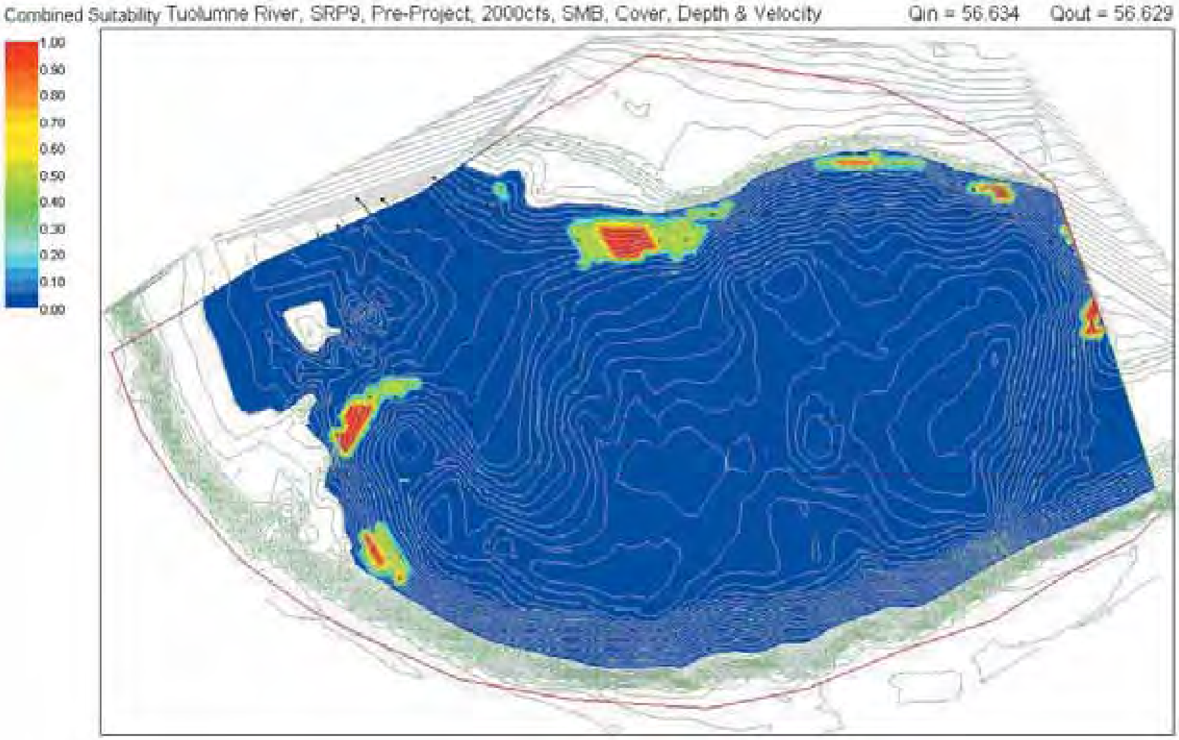

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 300cfs, SMB, Depth & Velocity
Qin = 8.495
Qout = 8.493
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

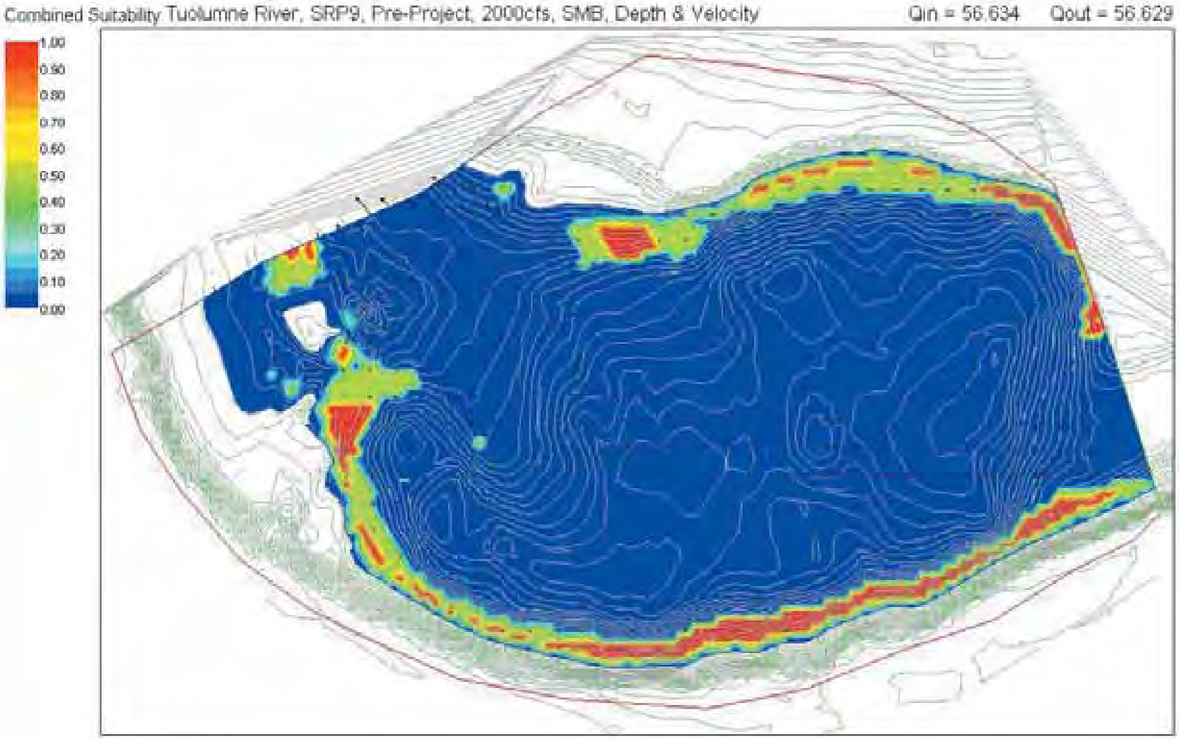

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 500cfs, SMB, Cover, Depth & Velocity
Qin = 14.158
Qout = 14.156
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

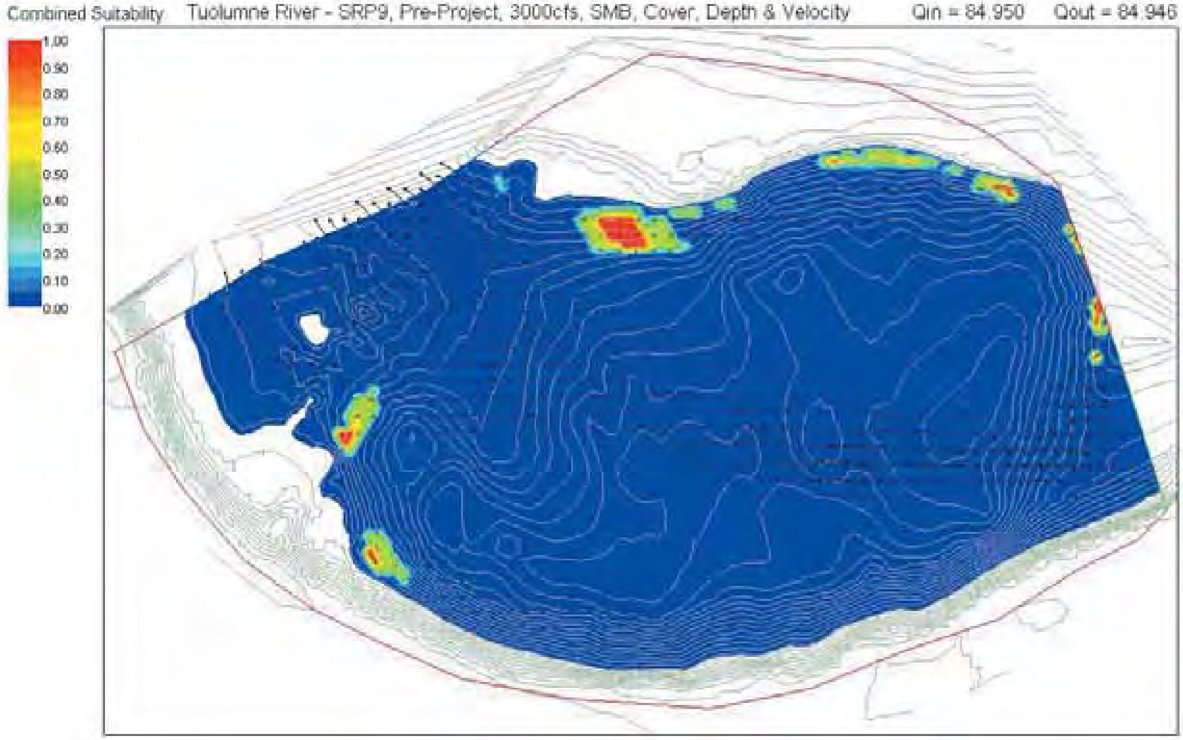

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 500cfs, SMB, Depth & Velocity
Qin = 14.158
Qout = 14.156
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

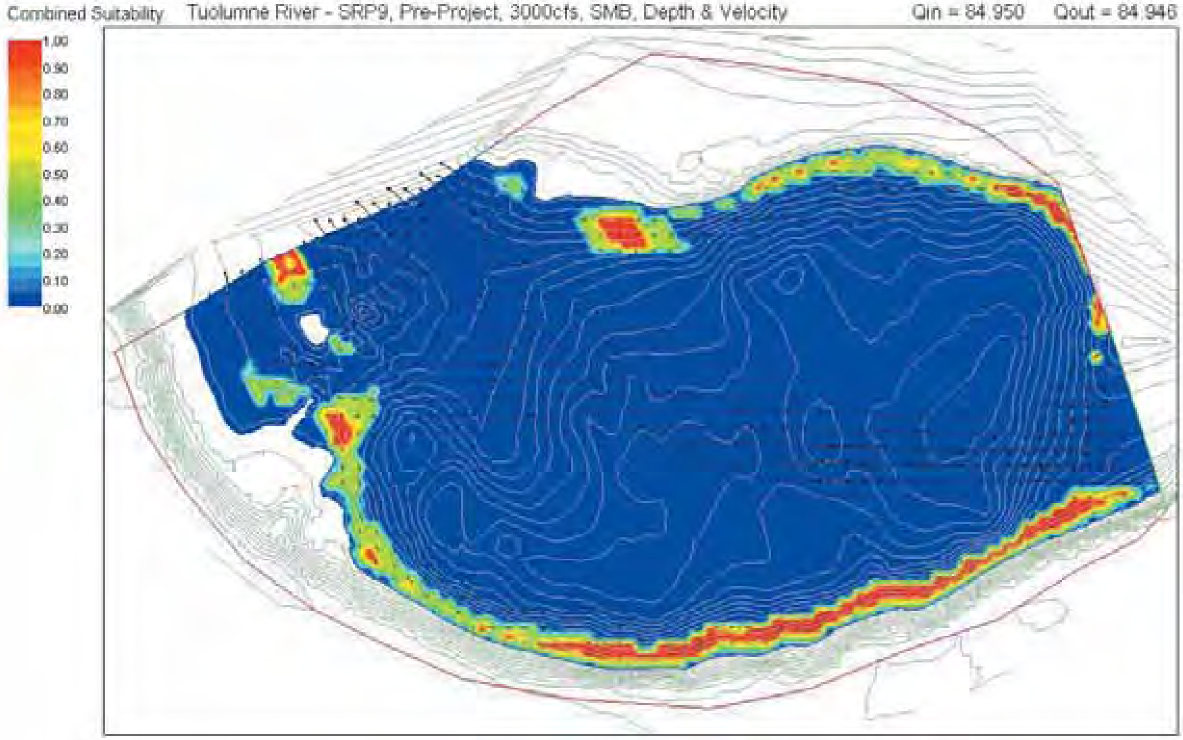

Combined Suitability Tuolumne River - SRP9, Pre-Project, 1000cfs, SMB, Cover, Depth & Velocity Qin = 28.317 Qout = 28.313

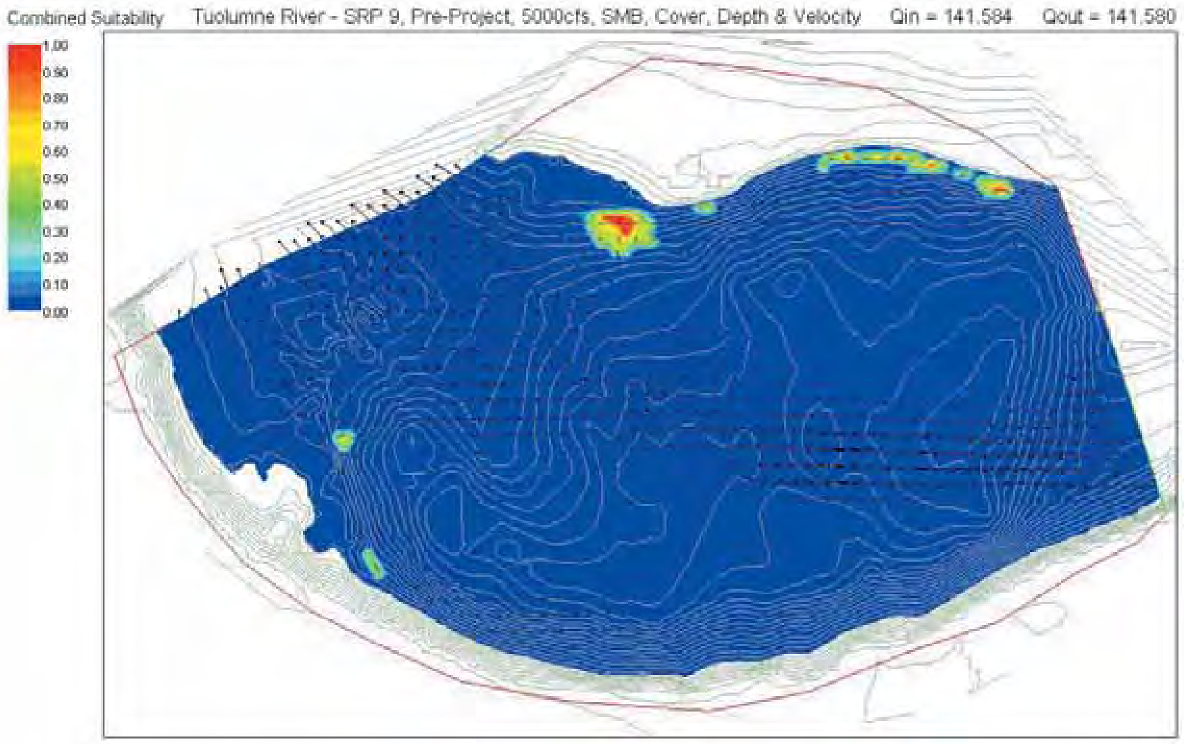

Combined Suitability Tuolumne River - SRP9, Pre-Project, 1000cfs, SMB, Depth & Velocity Qin = 28.317 Qout = 28.313

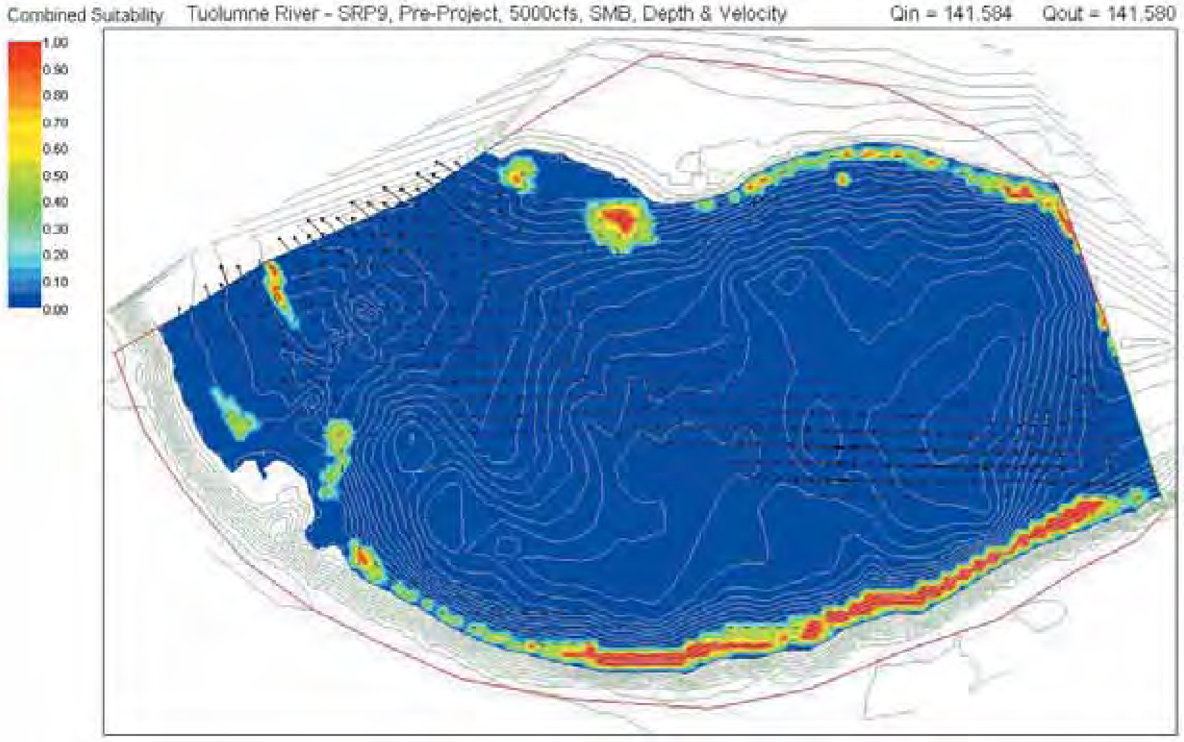

Combined Suitability Tuolumne River, SRP9, Pre-Project, 2000cfs, SMB, Cover, Depth & Velocity
Qin = 56.634
Qout = 56.629
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

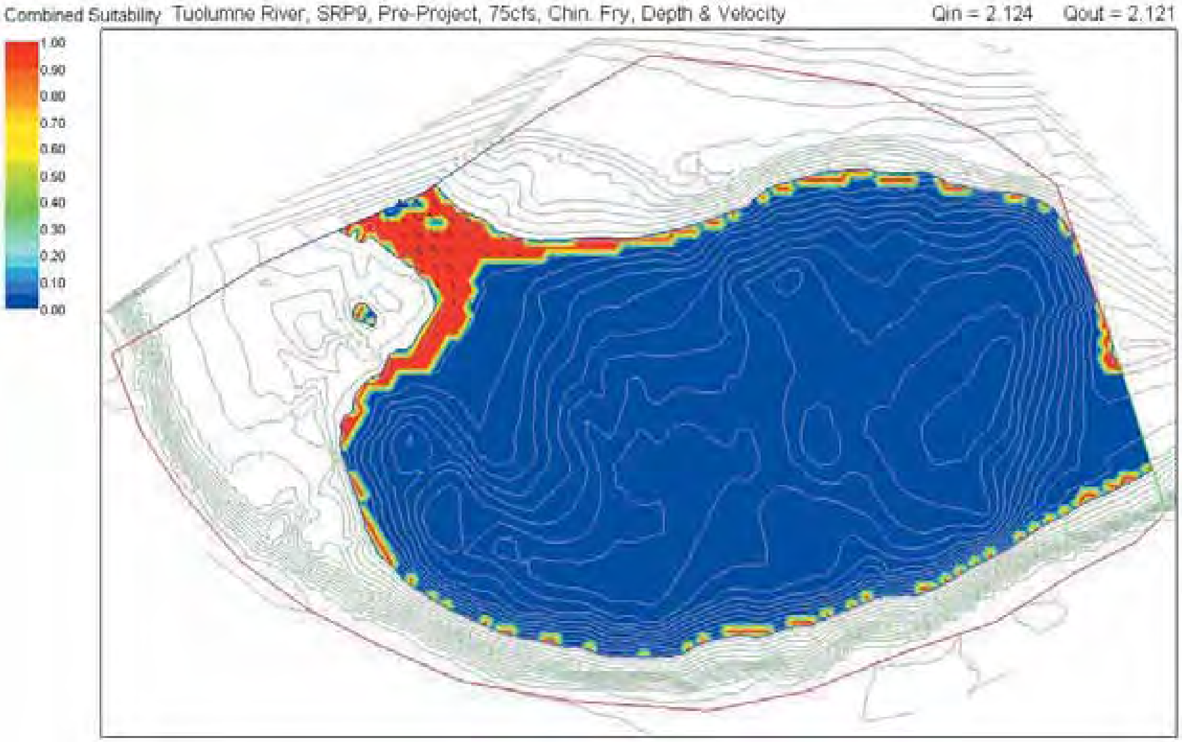

Combined Suitability Tuolumne River, SRP9, Pre-Project, 2000cfs, SMB, Depth & Velocity
Qin = 56.634
Qout = 56.629
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

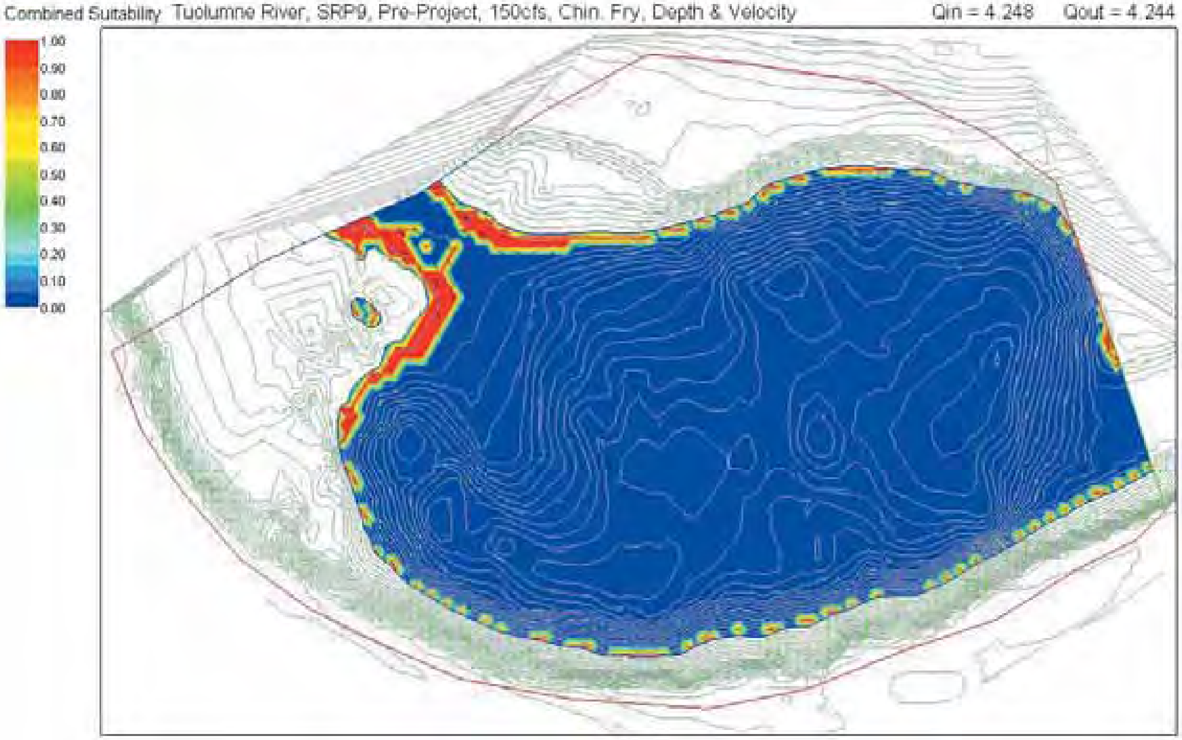

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 3000cfs, SMB, Cover, Depth & Velocity
Qin = 84.950
Qout = 84.946
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

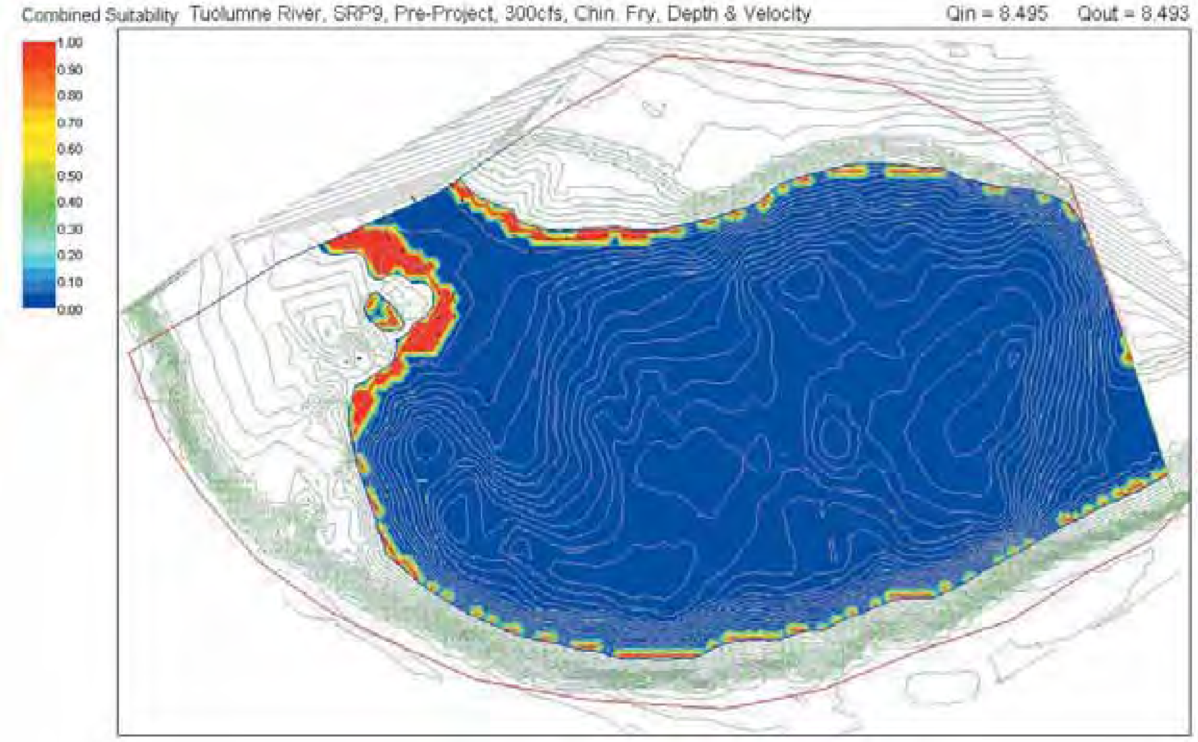

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 3000cfs, SMB, Depth & Velocity
Qin = 84.950
Qout = 84.946
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

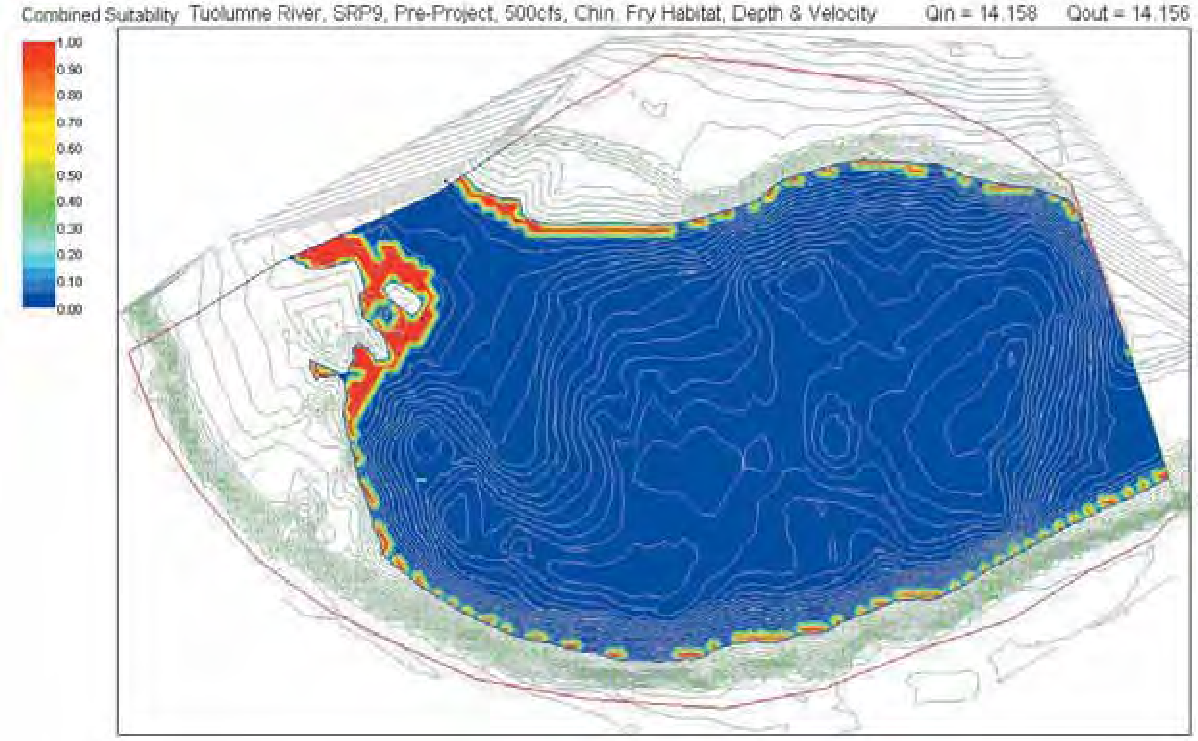

Combined Suitability
Tuolumne River - SRP 9, Pre-Project, 5000cfs, SMB, Cover, Depth & Velocity
Qin = 141.584
Qout = 141.580
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

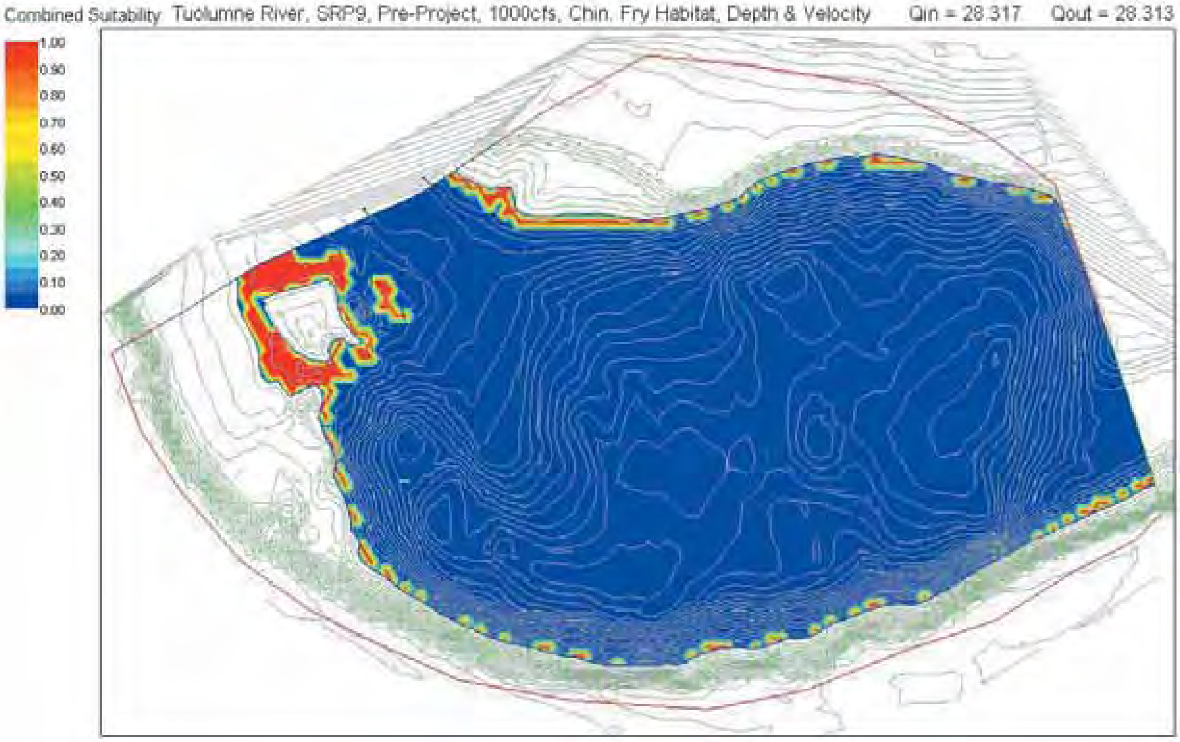

Combined Suitability
Tuolumne River - SRP9, Pre-Project, 5000cfs, SMB, Depth & Velocity
Qin = 141.584
Qout = 141.580
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

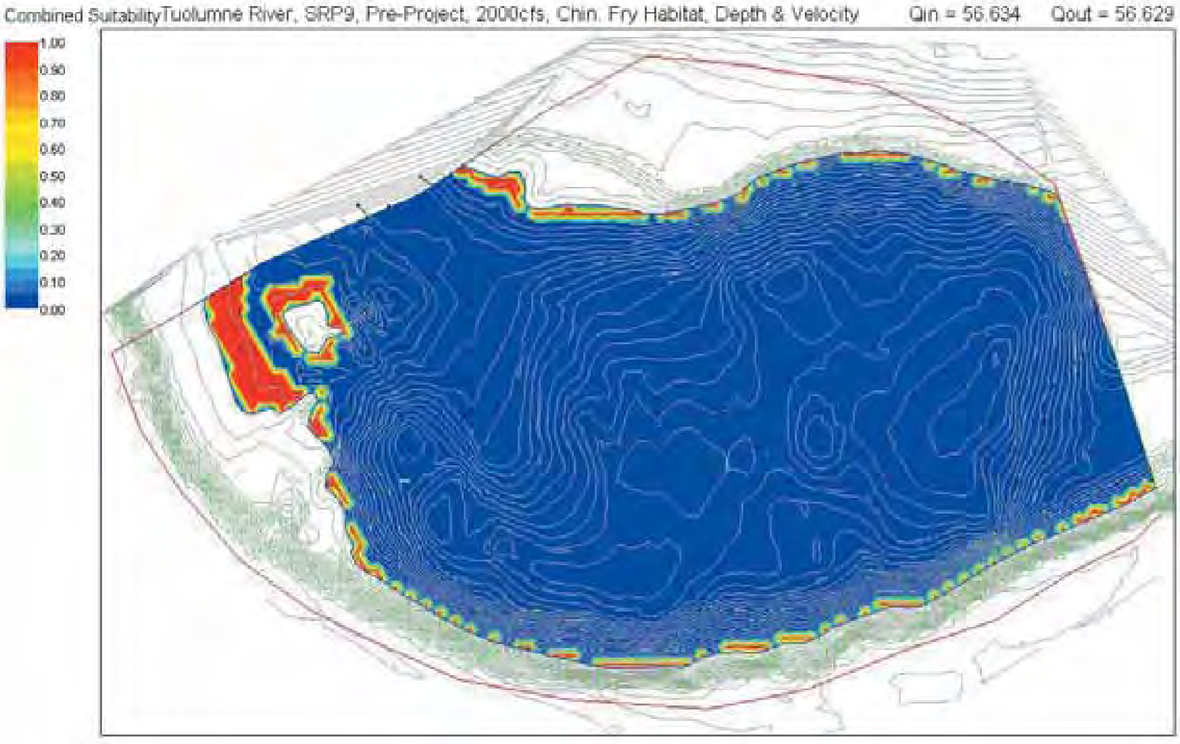

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 75cfs, Chin. Fry, Depth & Velocity
Qin = 2.124
Qout = 2.121
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

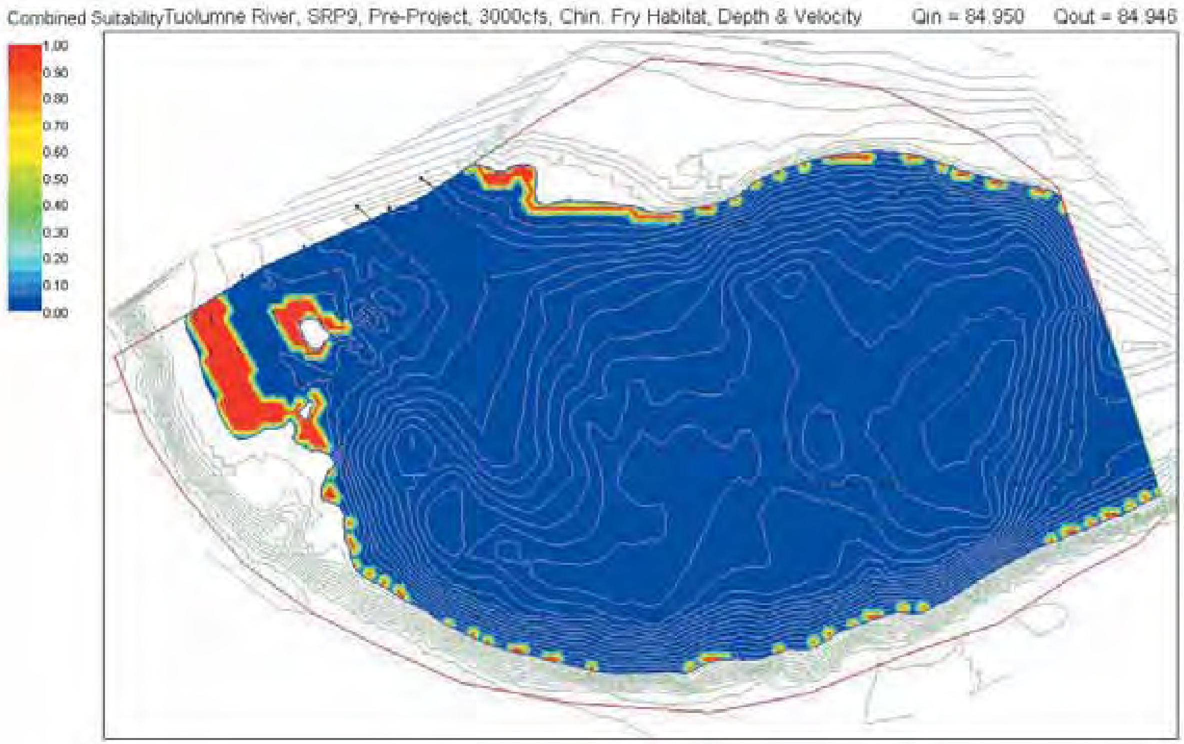

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 150cfs, Chin. Fry, Depth & Velocity
Qin = 4.248
Qout = 4.244
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

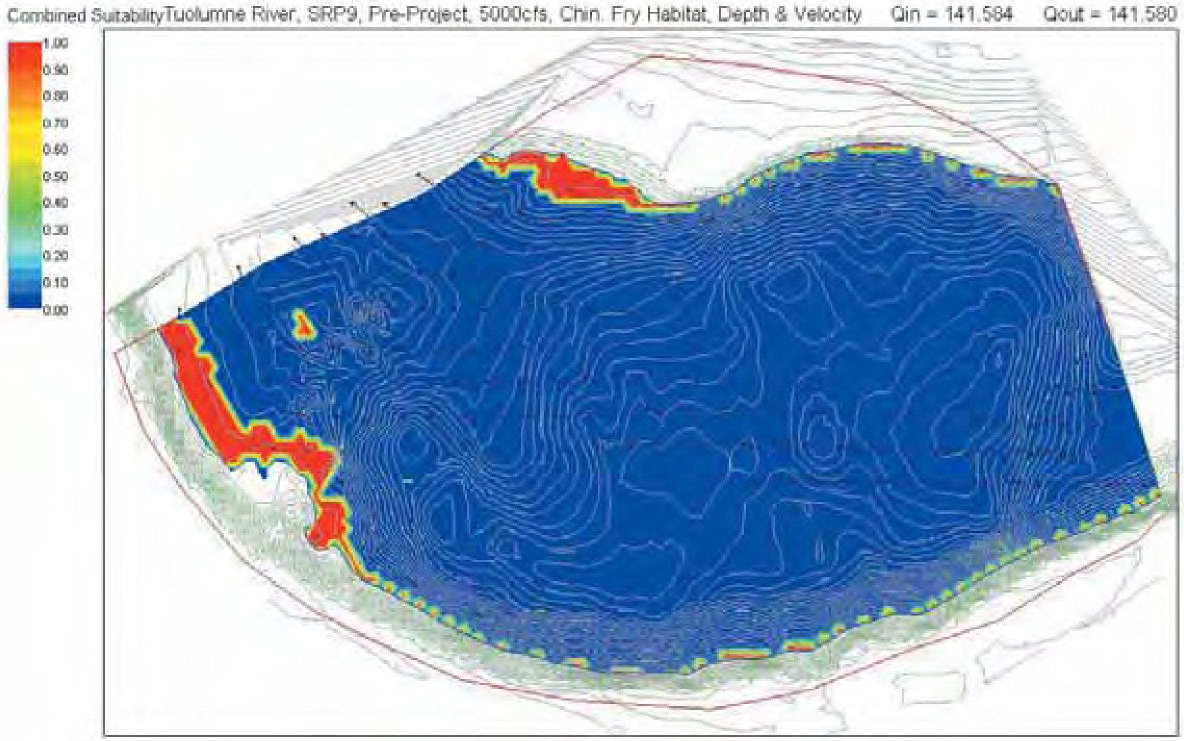

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 300cfs, Chin. Fry, Depth & Velocity
Qin = 8.495
Qout = 8.493
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

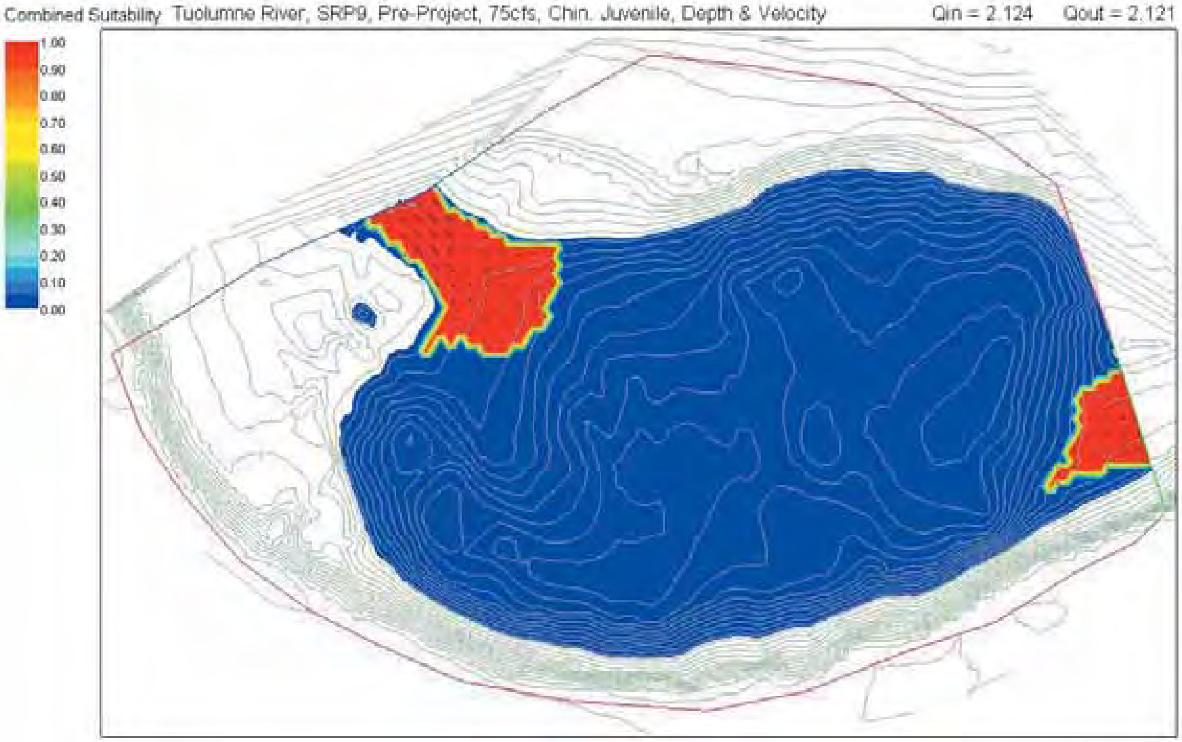

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 500cfs, Chin. Fry Habitat, Depth & Velocity
Qin = 14.158
Qout = 14.156
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

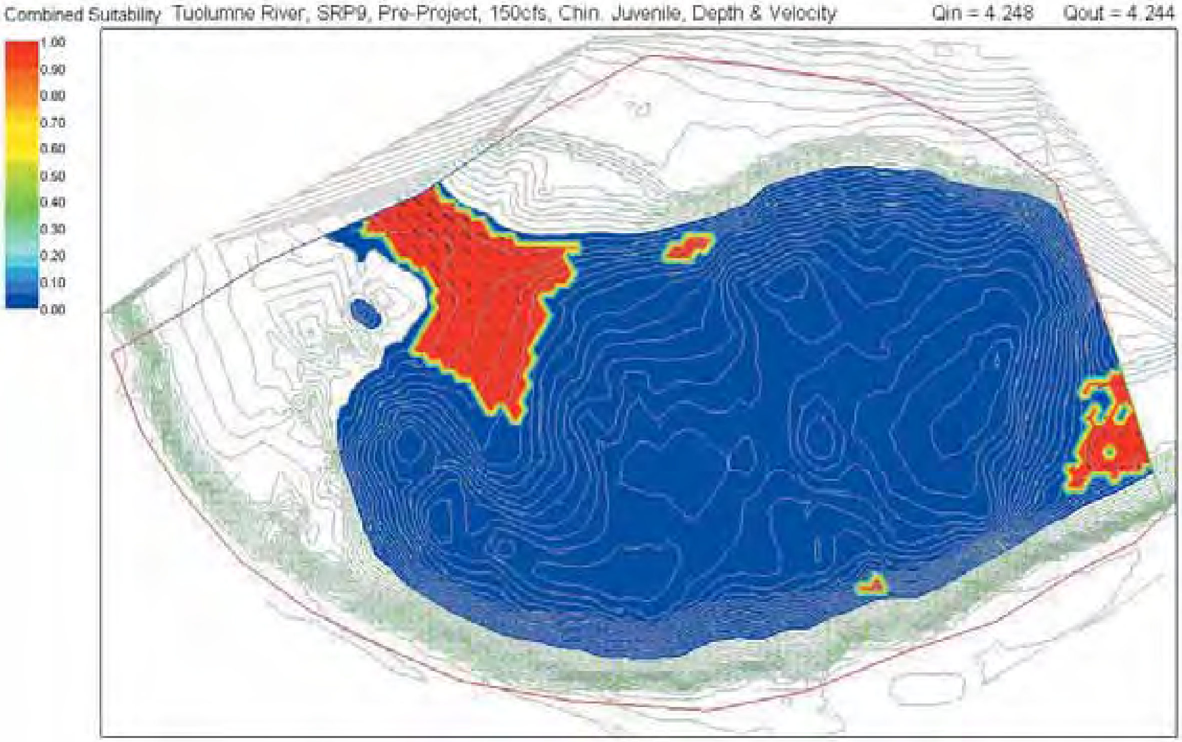

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 1000cfs, Chin. Fry Habitat, Depth & Velocity
Qin = 28.317
Qout = 28.313
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

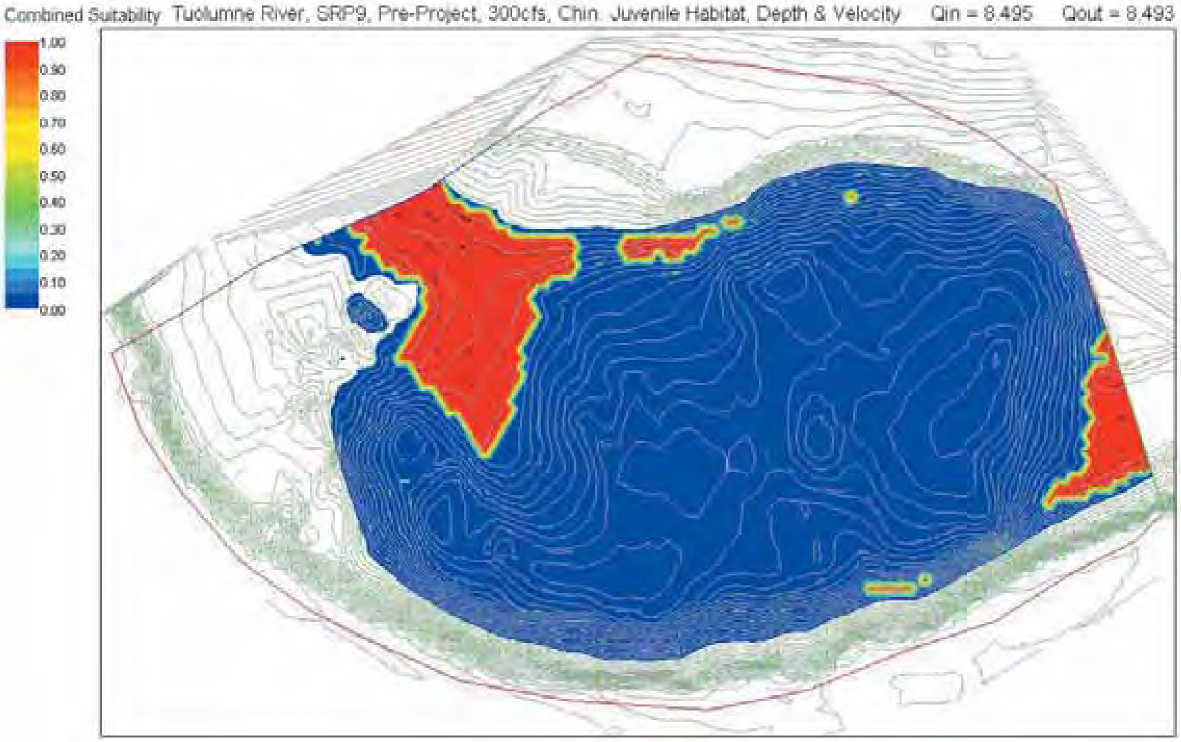

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 2000cfs, Chin. Fry Habitat, Depth & Velocity
Qin = 56.634
Qout = 56.629
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

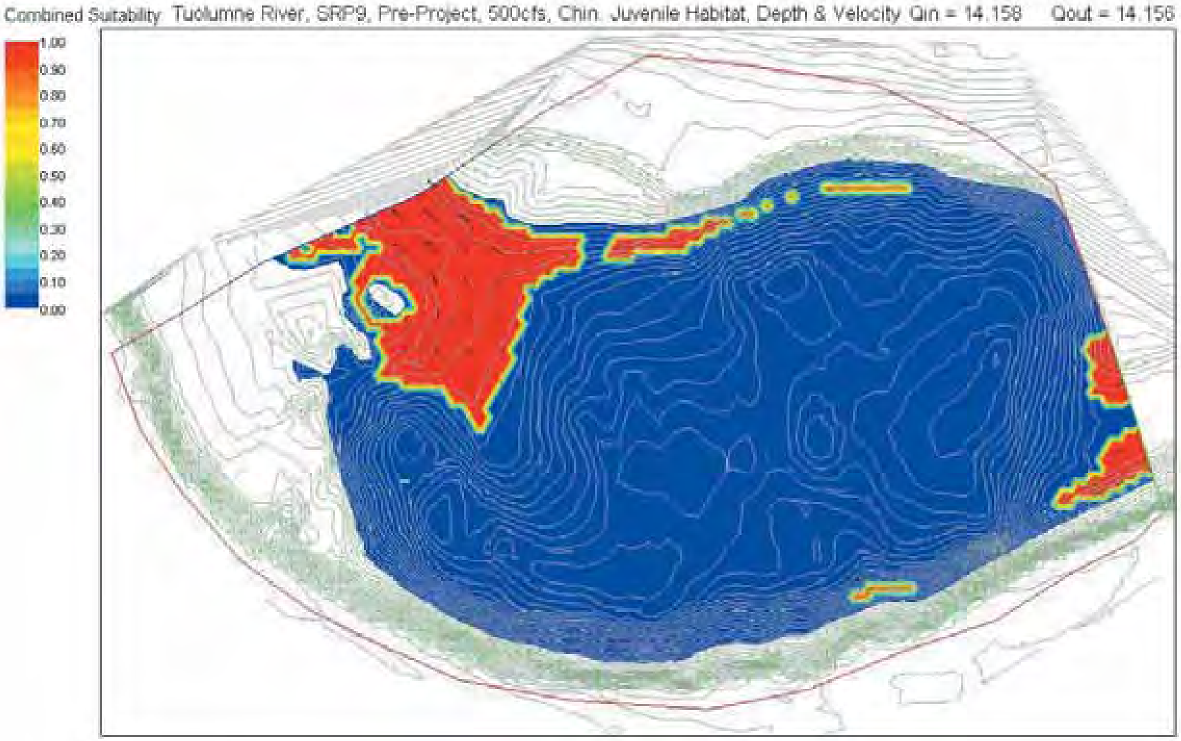

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 3000cfs, Chin. Fry Habitat, Depth & Velocity
Qin = 84.950
Qout = 84.946
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

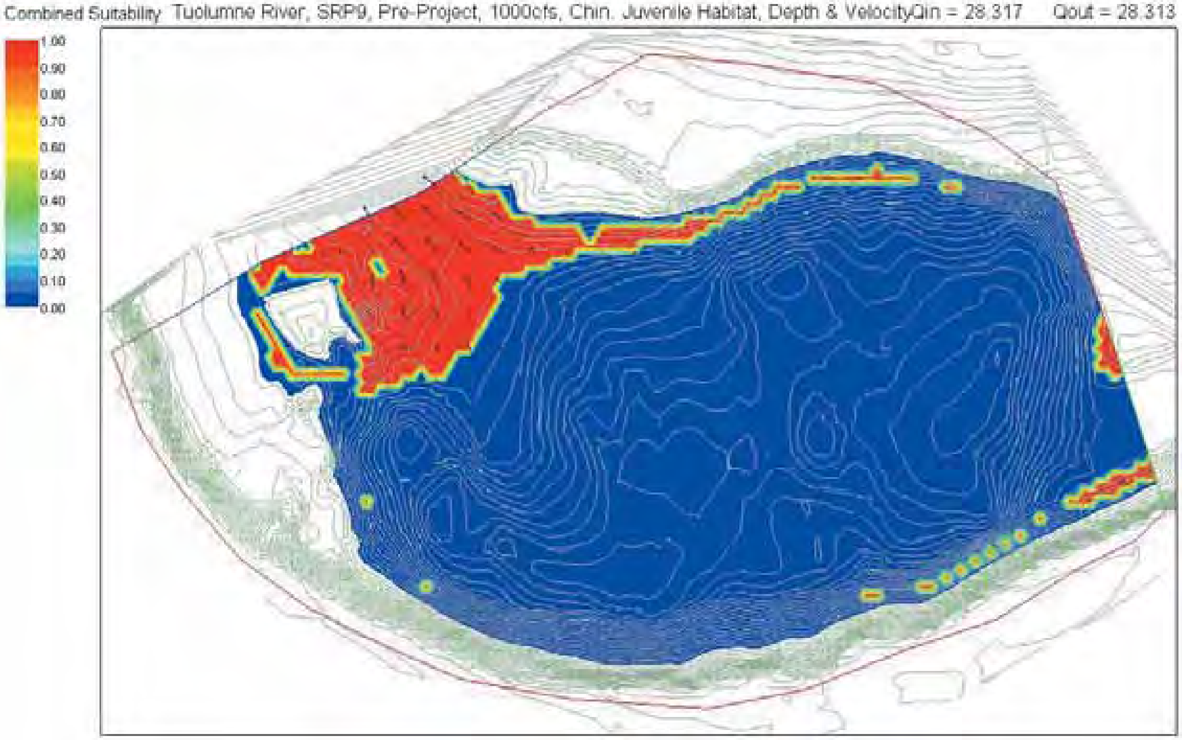

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 5000cfs, Chin. Fry Habitat, Depth & Velocity
Qin = 141.584
Qout = 141.580
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

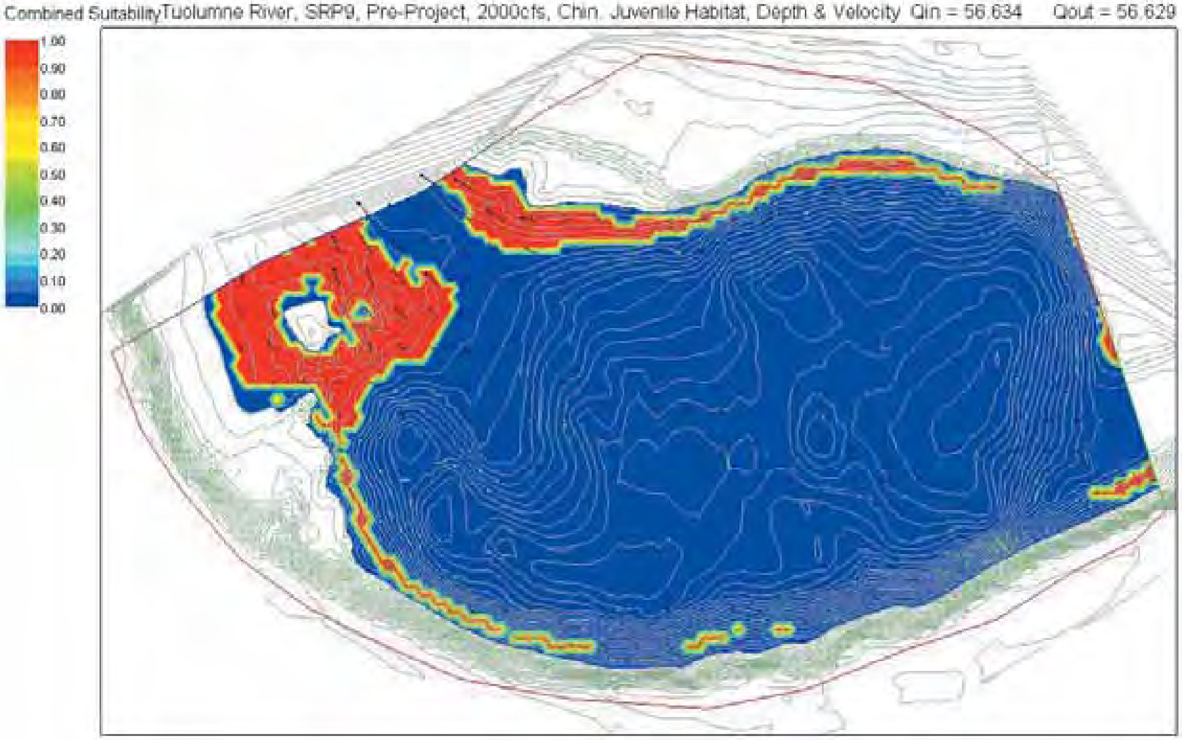

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 75cfs, Chin. Juvenile, Depth & Velocity
Qin = 2.124
Qout = 2.121
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

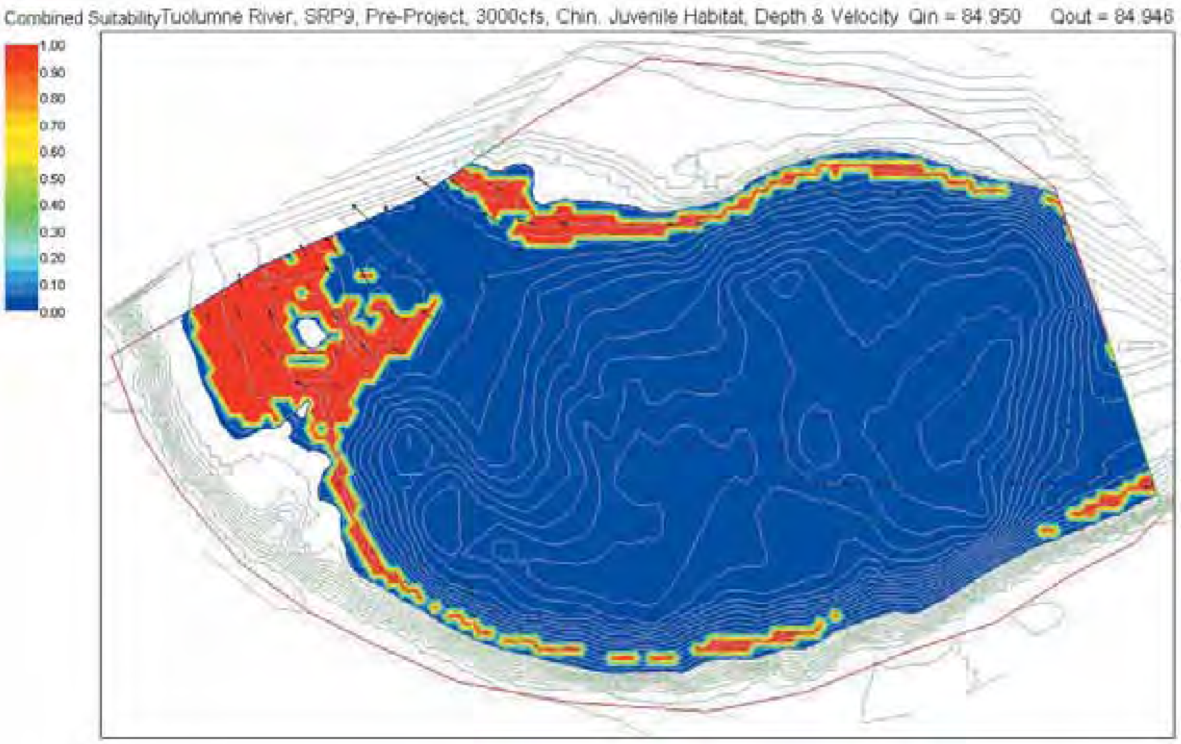

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 150cfs, Chin. Juvenile, Depth & Velocity
Qin = 4.248
Qout = 4.244
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

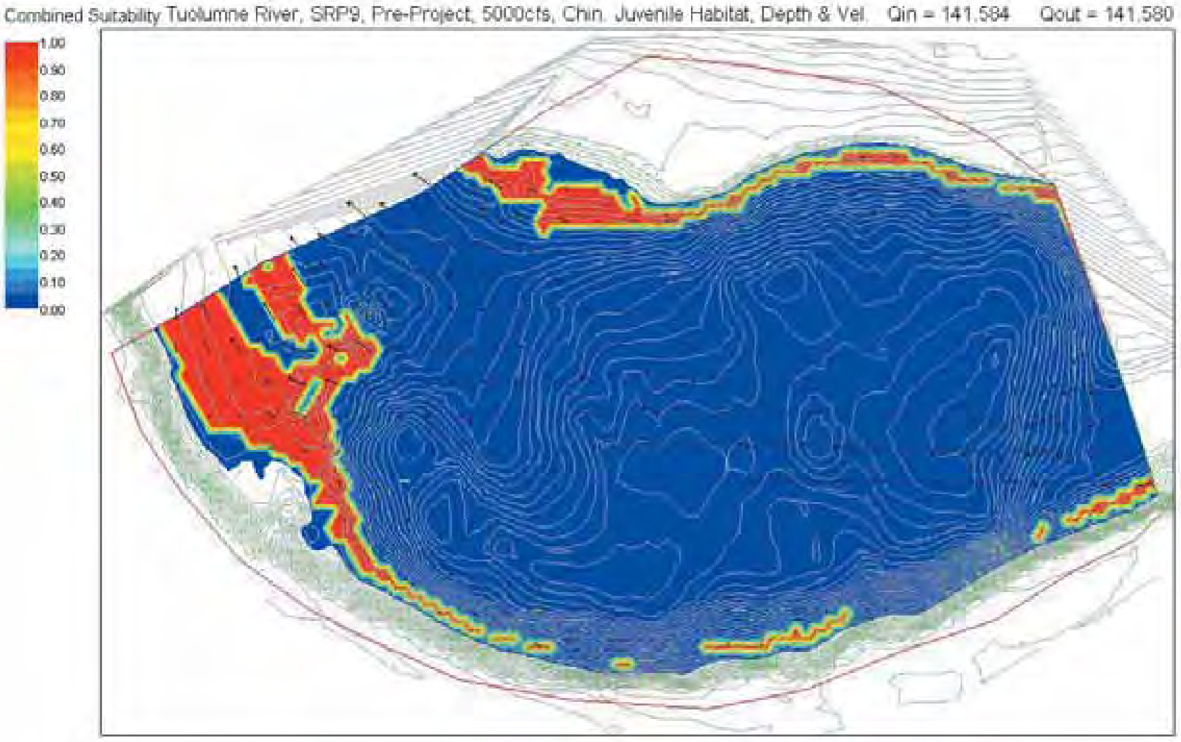

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 300cfs, Chin. Juvenile Habitat, Depth & Velocity
Qin = 8.495
Qout = 8.493
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

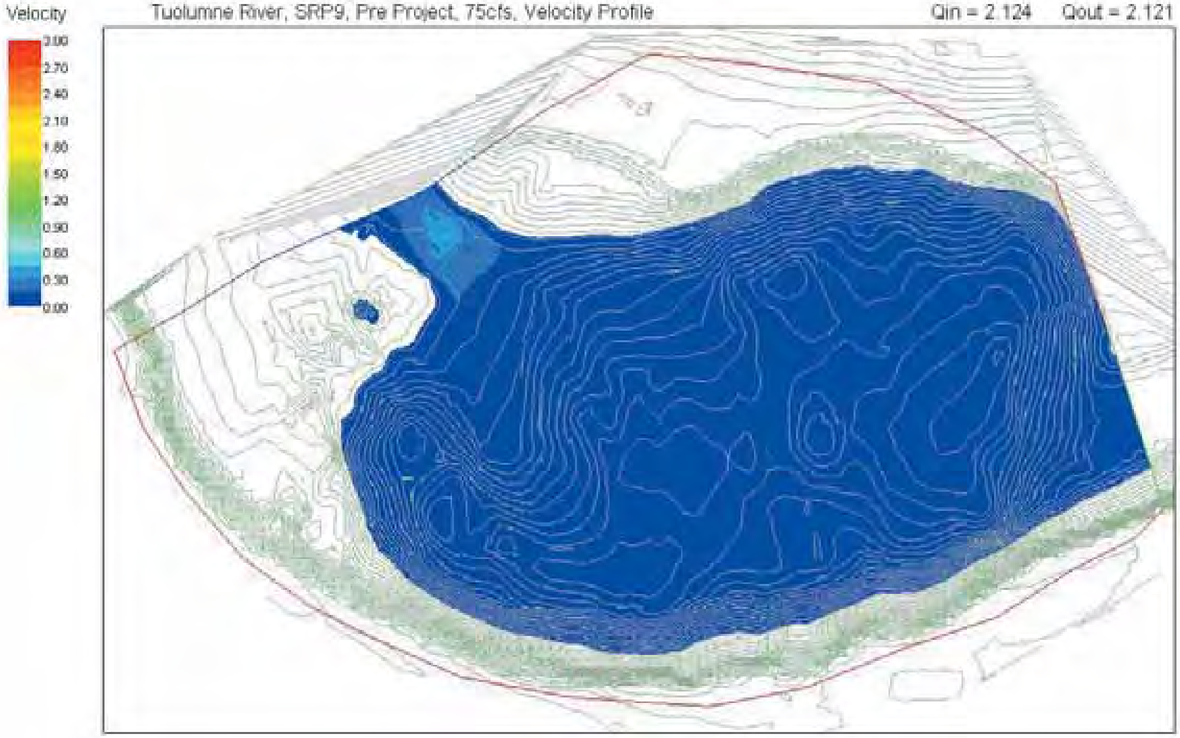

Combined Suitability
Tuolumne River, SRP9, Pre-Project, 500cfs, Chin. Juvenile Habitat, Depth & Velocity
Qin = 14.158
Qout = 14.156
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

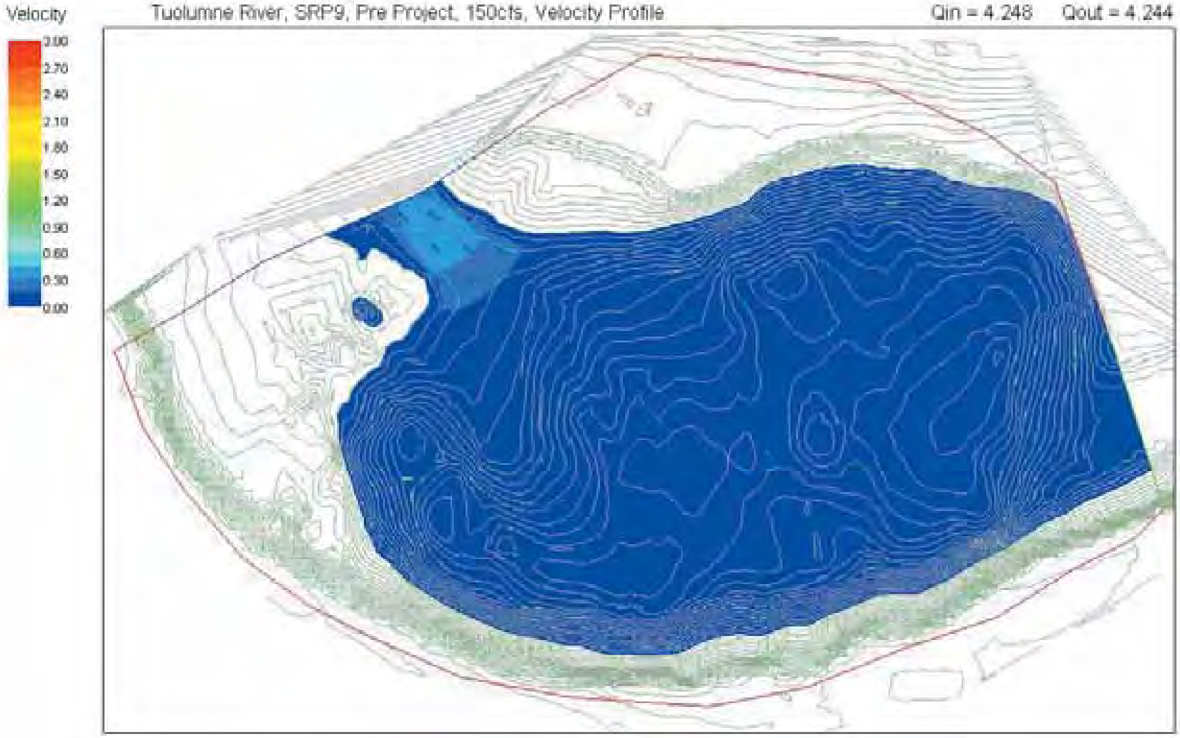

Combined Suitability Tuolumne River, SRP9, Pre-Project, 1000cfs, Chin. Juvenile Habitat, Depth & Velocity Qin = 28.317 Qout = 28.313
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

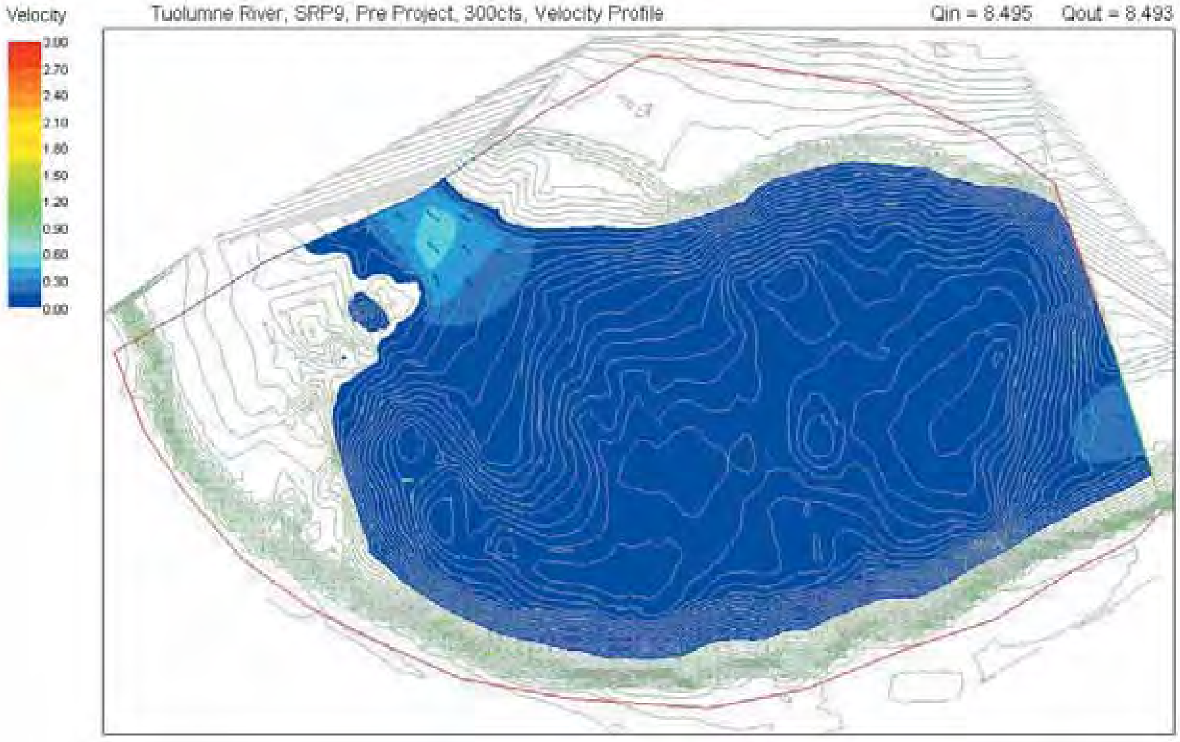

Combined Suitability Tuolumne River, SRP9, Pre-Project, 2000cfs, Chin. Juvenile Habitat, Depth & Velocity Qin = 56.634 Qout = 56.629
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

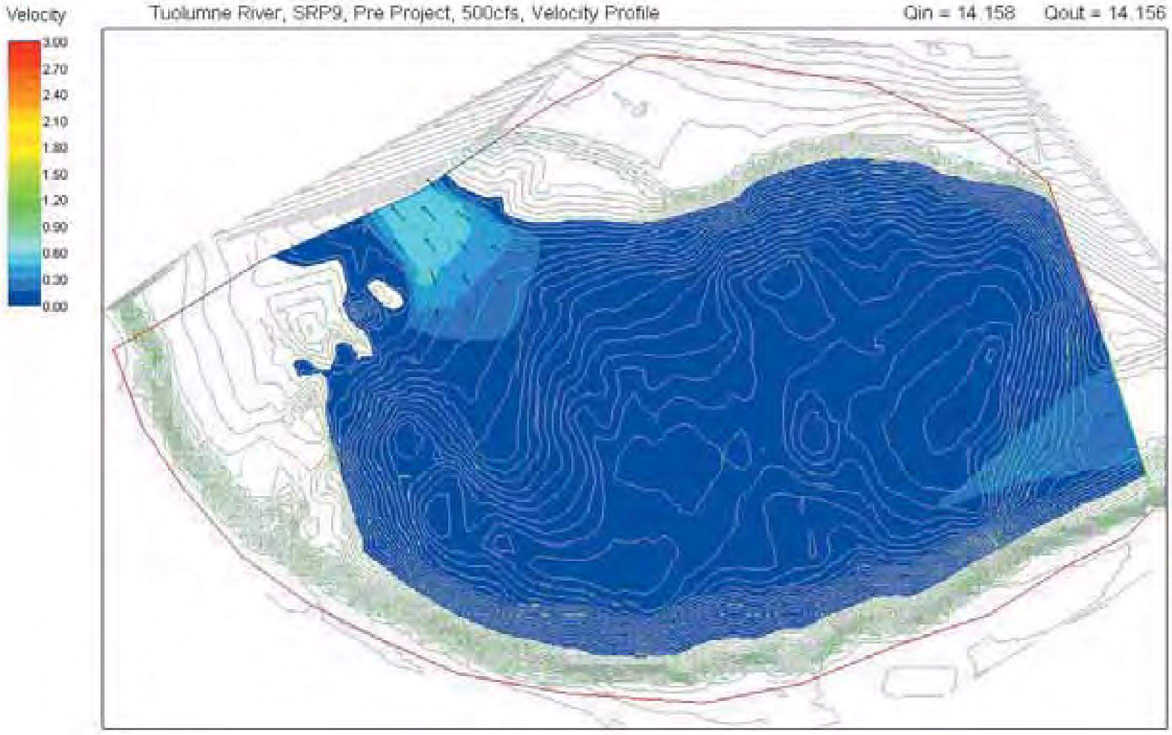

Combined Suitability Tuolumne River, SRP9, Pre-Project, 3000cfs, Chin. Juvenile Habitat, Depth & Velocity Qin = 84.950 Qout = 84.946
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

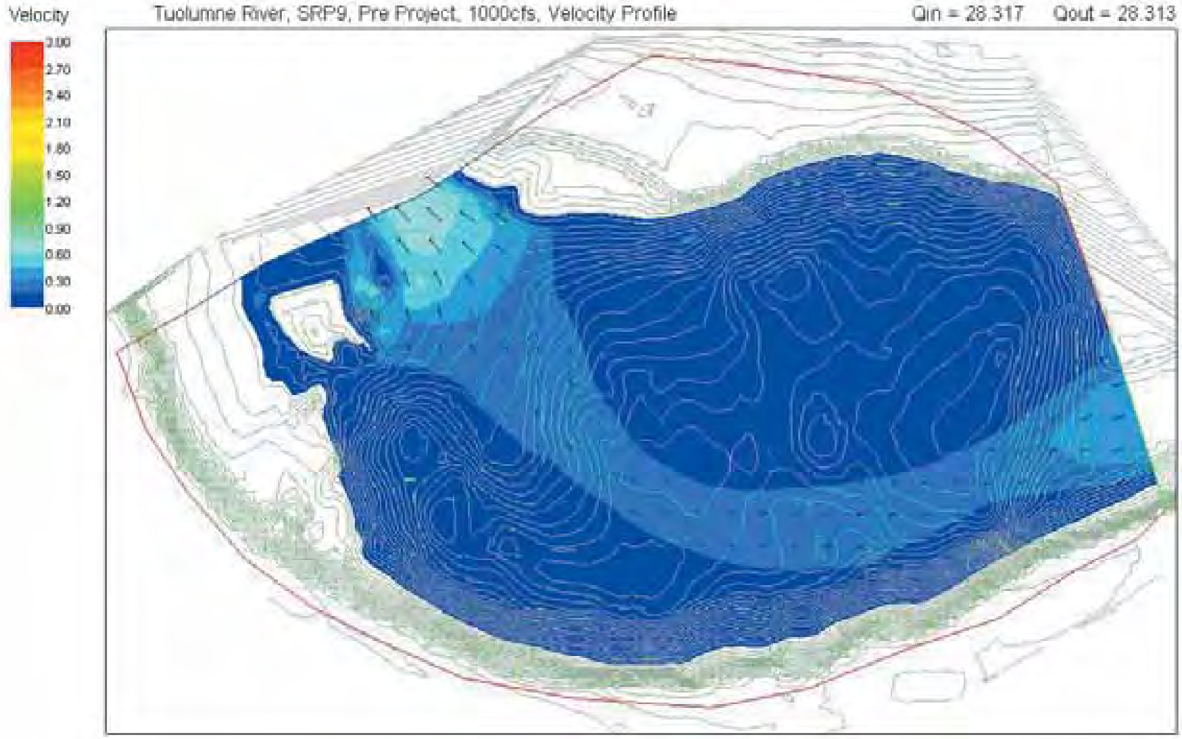

Combined Suitability Tuolumne River, SRP9, Pre-Project, 5000cfs, Chin. Juvenile Habitat, Depth & Vel. Qin = 141.584 Qout = 141.580
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

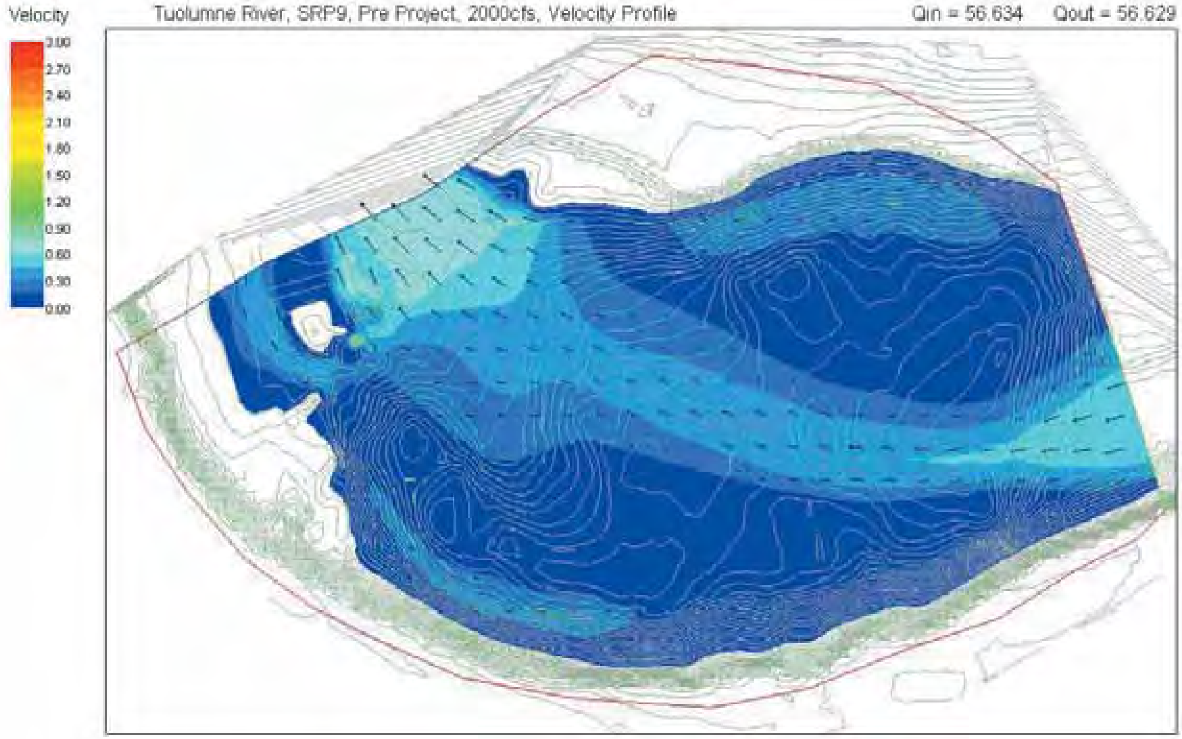

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 75cfs, Velocity Profile
Qin = 2.124
Qout = 2.121

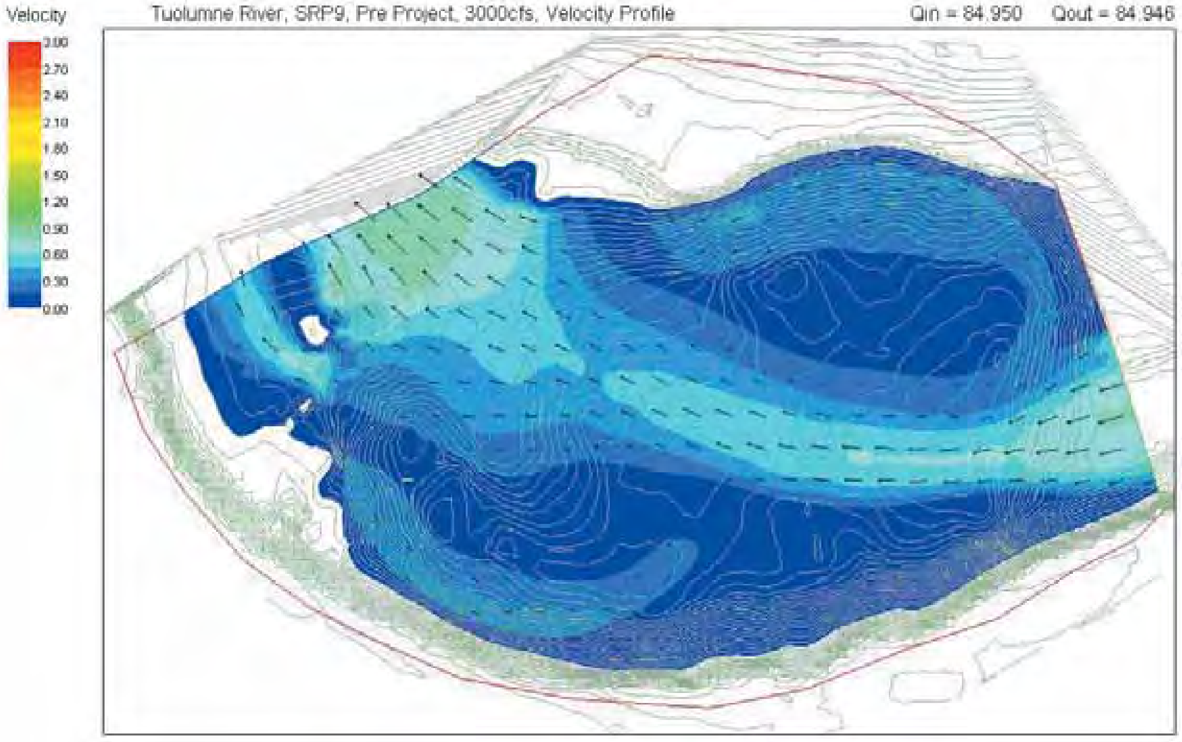

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 150cfs, Velocity Profile
Qin = 4.248
Qout = 4.244

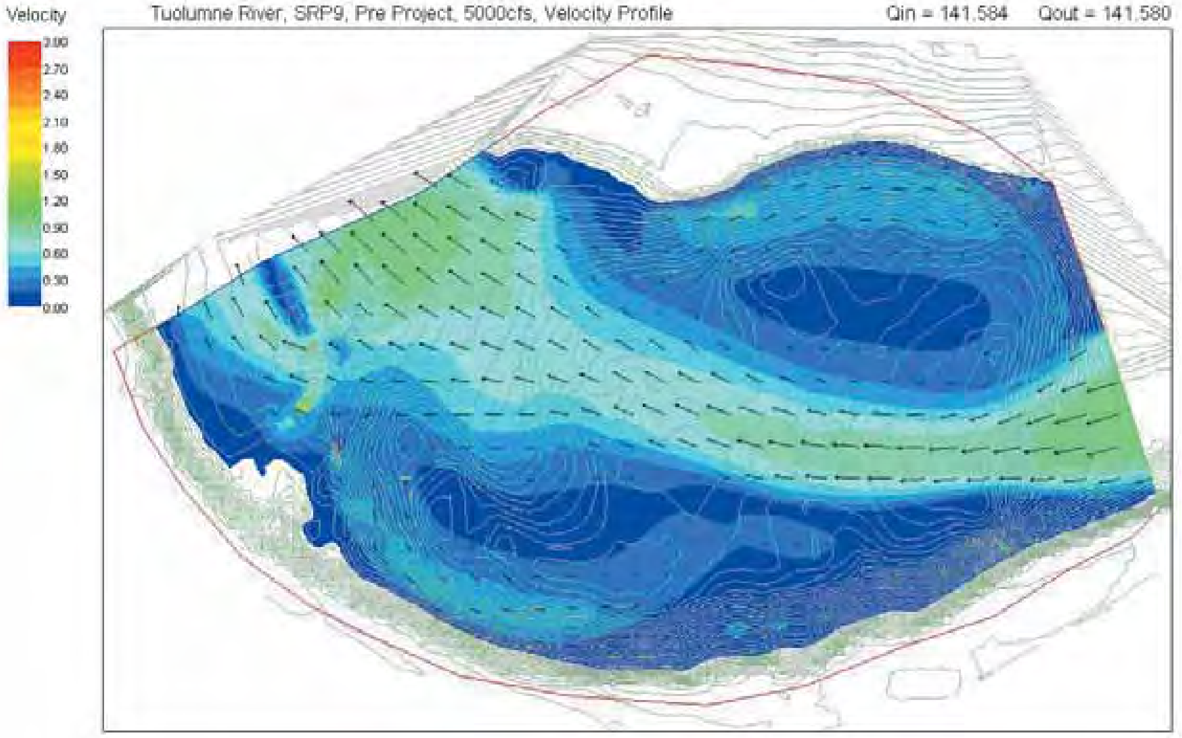

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 300cfs, Velocity Profile
Qin = 8.495
Qout = 8.493


Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 500cfs, Velocity Profile
Qin = 14.158
Qout = 14.156


Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 1000cfs, Velocity Profile
Qin = 28.317
Qout = 28.313

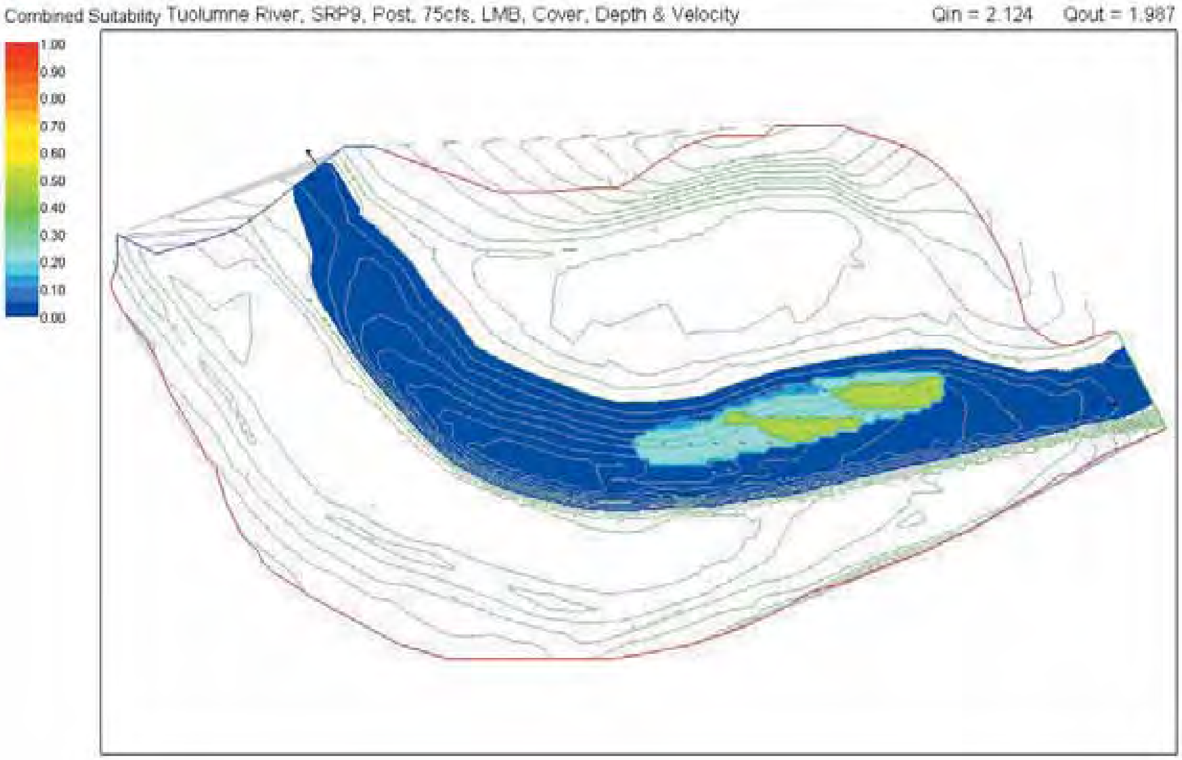

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 2000cfs, Velocity Profile
Qin = 56.634
Qout = 56.629

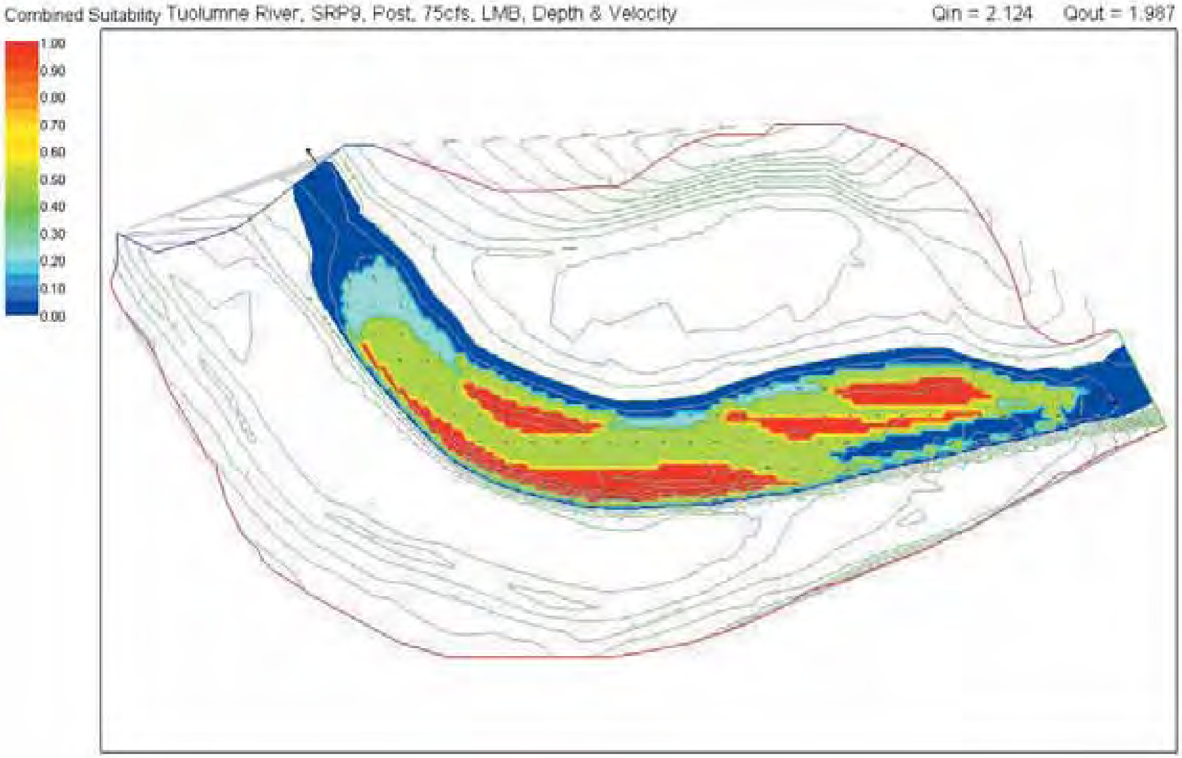

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 3000cfs, Velocity Profile
Qin = 84.950
Qout = 84.946


Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Pre Project, 5000cfs, Velocity Profile
Qin = 141.584
Qout = 141.580

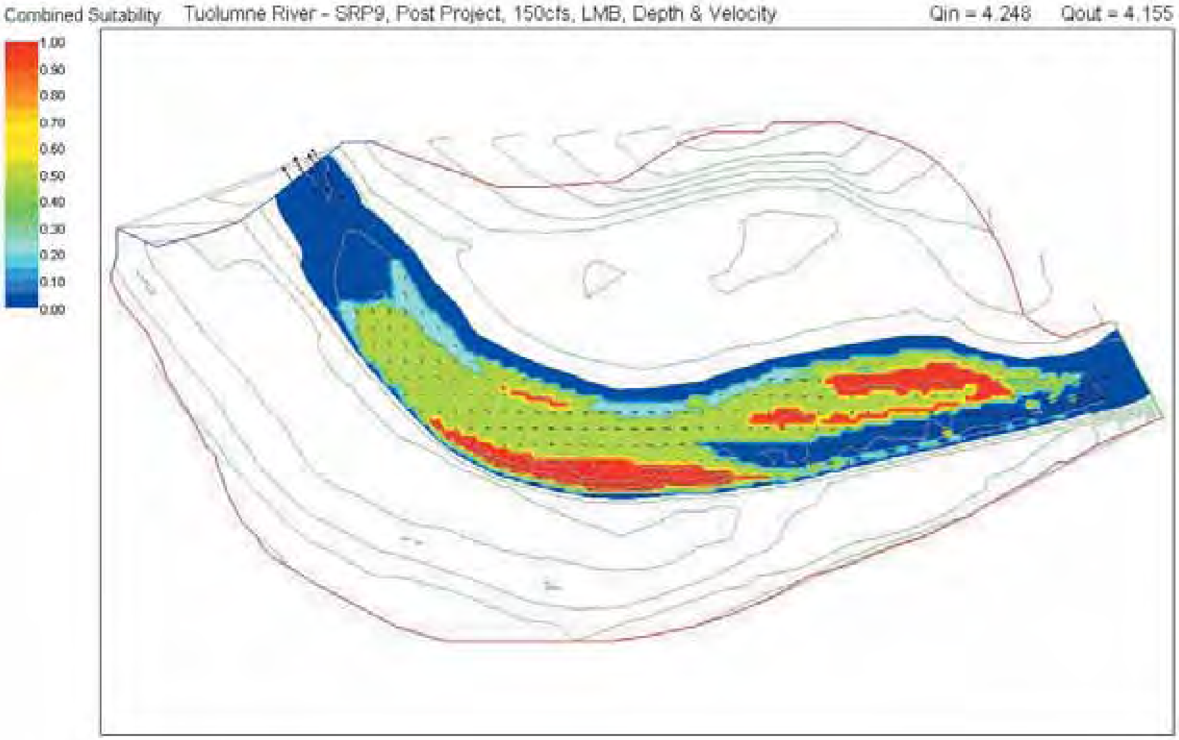
Appendix E

Predicted Largemouth Bass, Smallmouth Bass, and Chinook Salmon Habitat at SRP 9 Post-project.

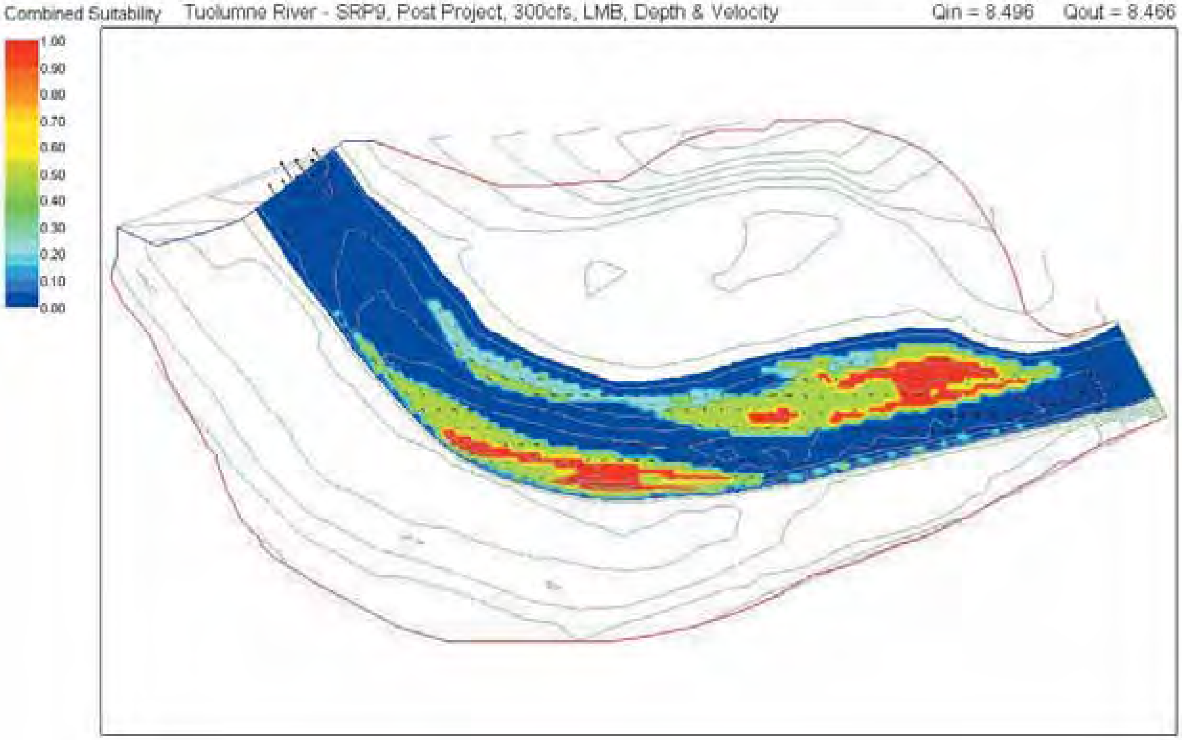

Combined Suitability Tuolumne River, SRP9, Post, 75cfs, LMB, Cover, Depth & Velocity
Qin = 2.124
Qout = 1.987
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

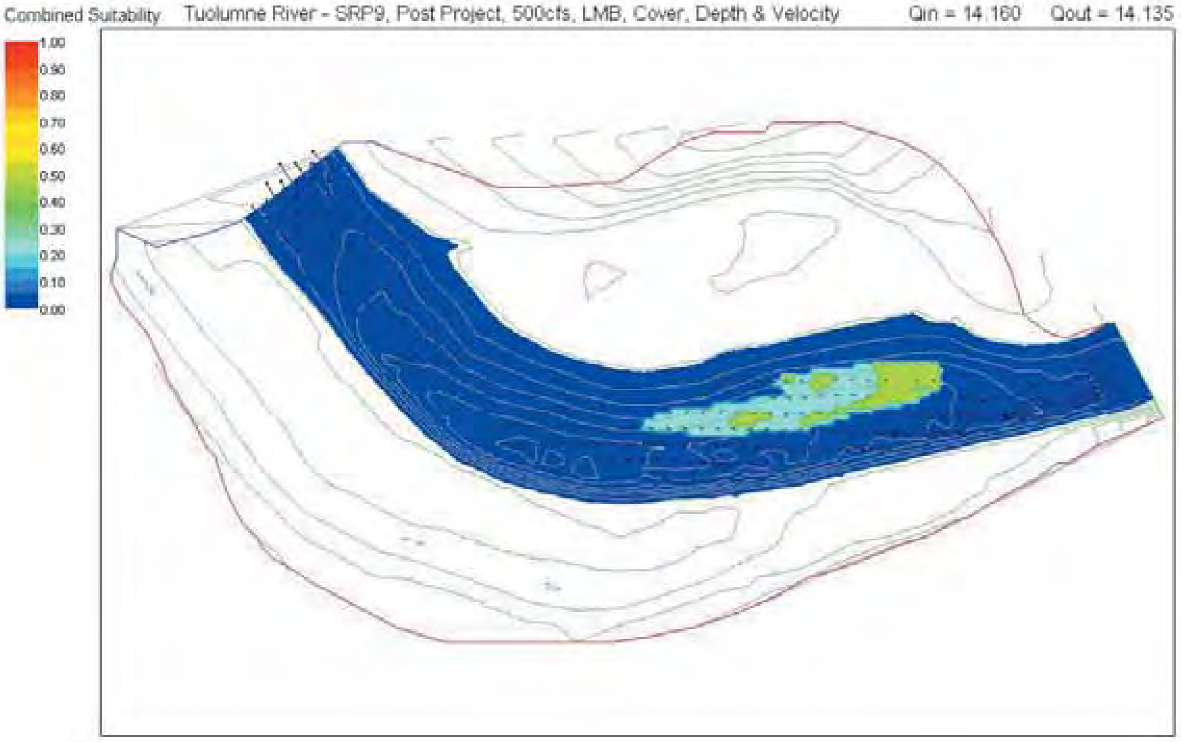

Combined Suitability Tuolumne River, SRP9, Post, 75cfs, LMB, Depth & Velocity
Qin = 2.124
Qout = 1.987
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

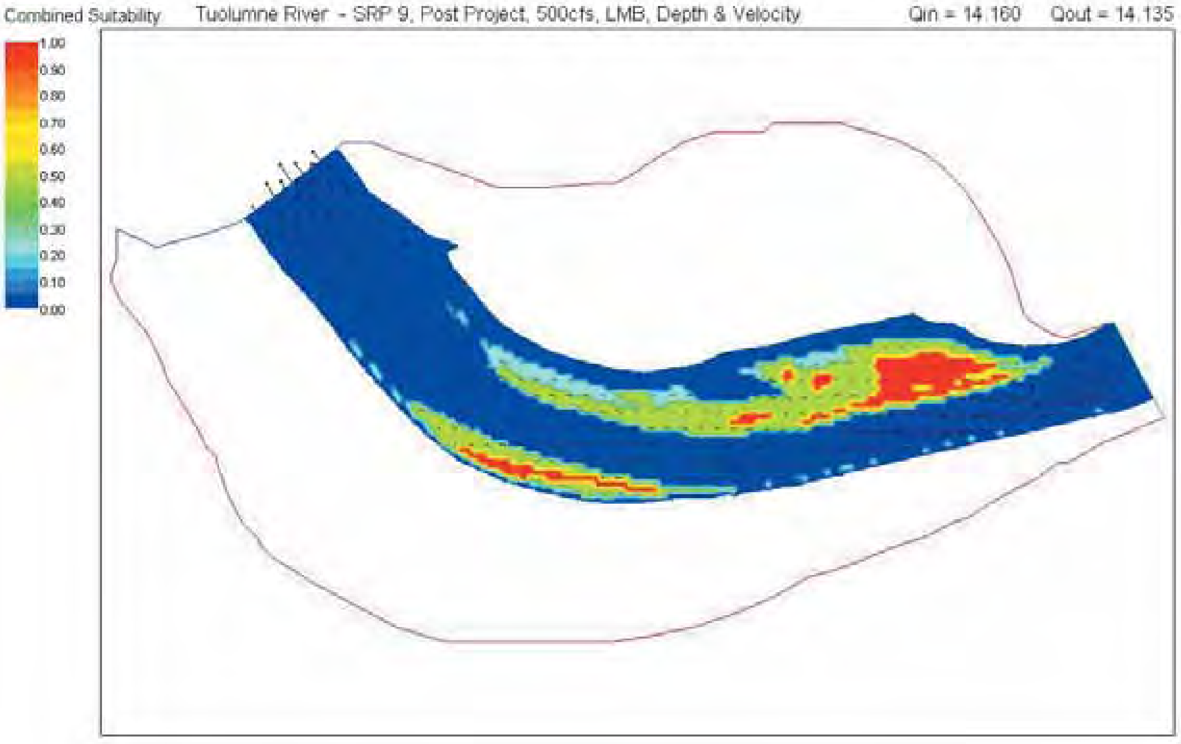

Combined Suitability
Tuolumne River - SRP9, Post Project, 150cfs, LMB, Cover, Depth & Velocity
Qin = 4.248
Qout = 4.155
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

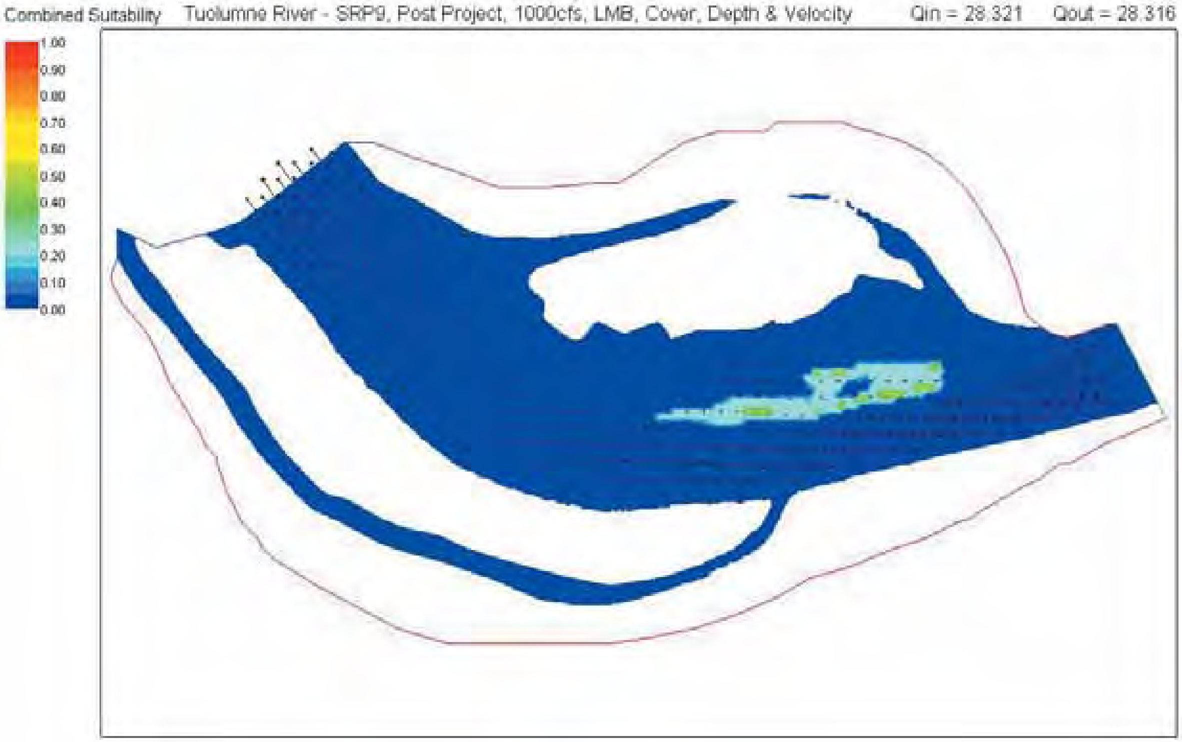

Combined Suitability
Tuolumne River - SRP9, Post Project, 150cfs, LMB, Depth & Velocity
Qin = 4.248
Qout = 4.155
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

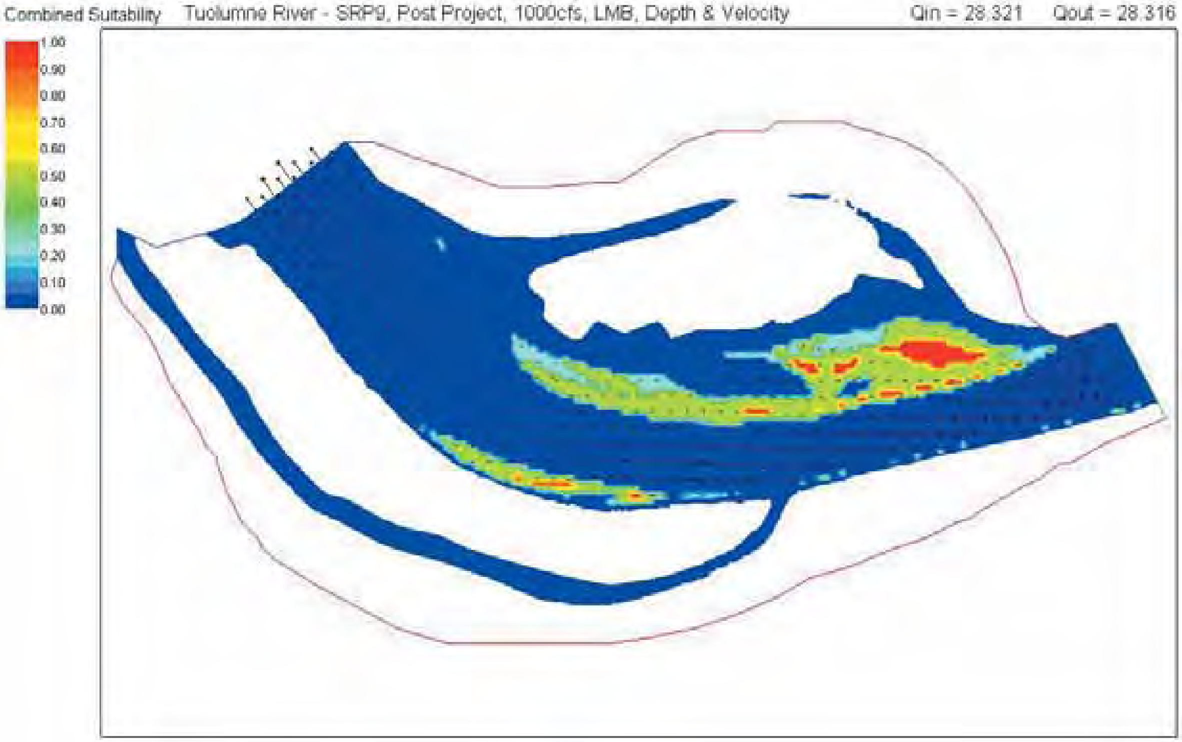

Combined Suitability
Tuolumne River - SRP9, Post Project, 300cfs, LMB, Cover, Depth & Velocity
Qin = 8.496
Qout = 8.466
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

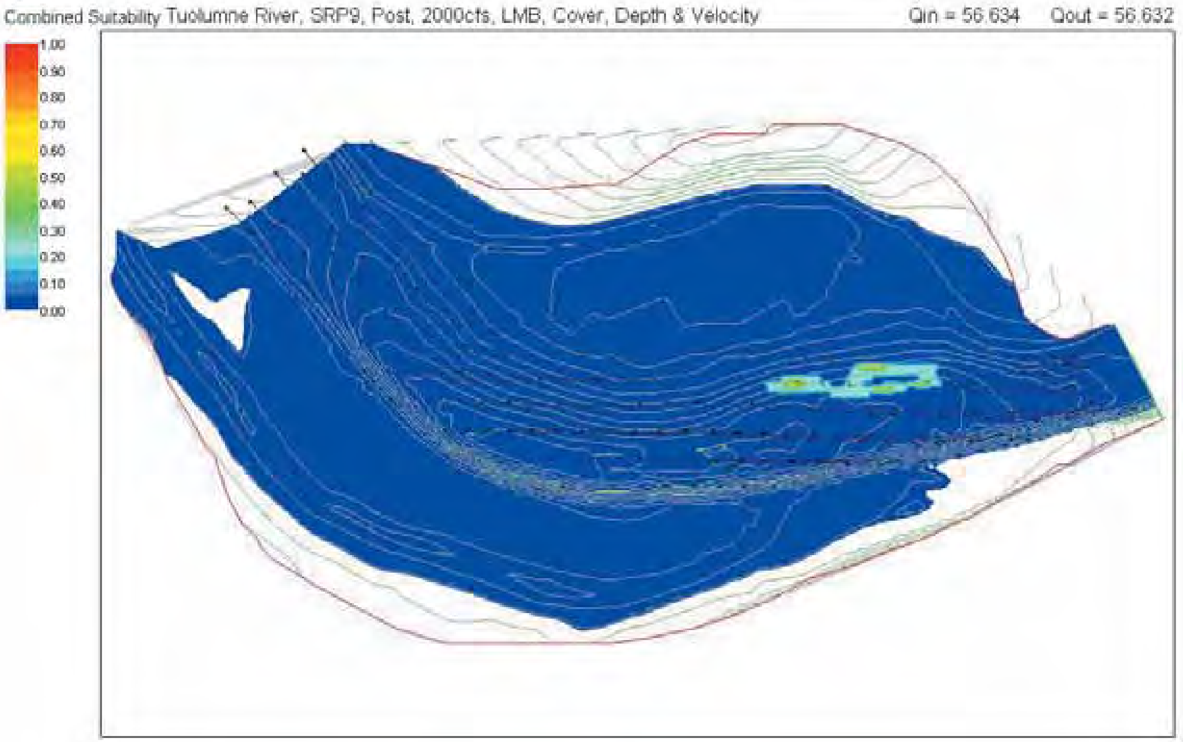

Combined Suitability
Tuolumne River - SRP9, Post Project, 300cfs, LMB, Depth & Velocity
Qin = 8.496
Qout = 8.466
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

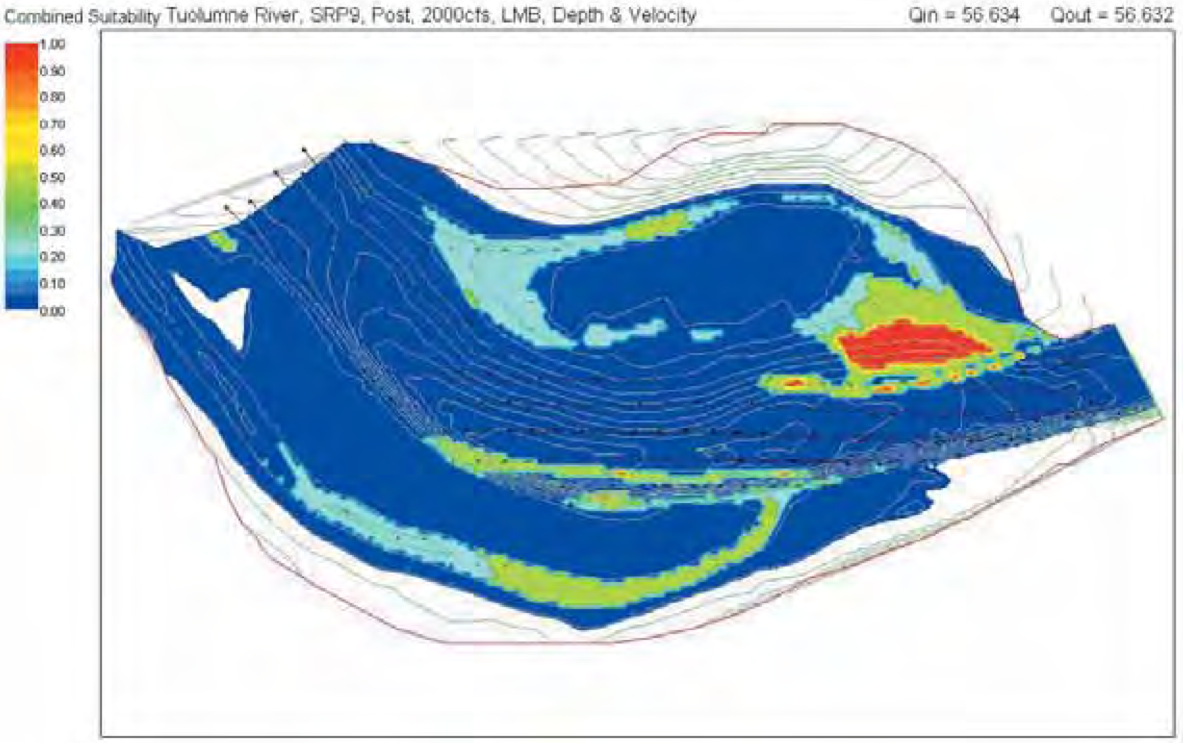

Combined Suitability
Tuolumne River - SRP9, Post Project, 500cfs, LMB, Cover, Depth & Velocity
Qin = 14.160
Qout = 14.135
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

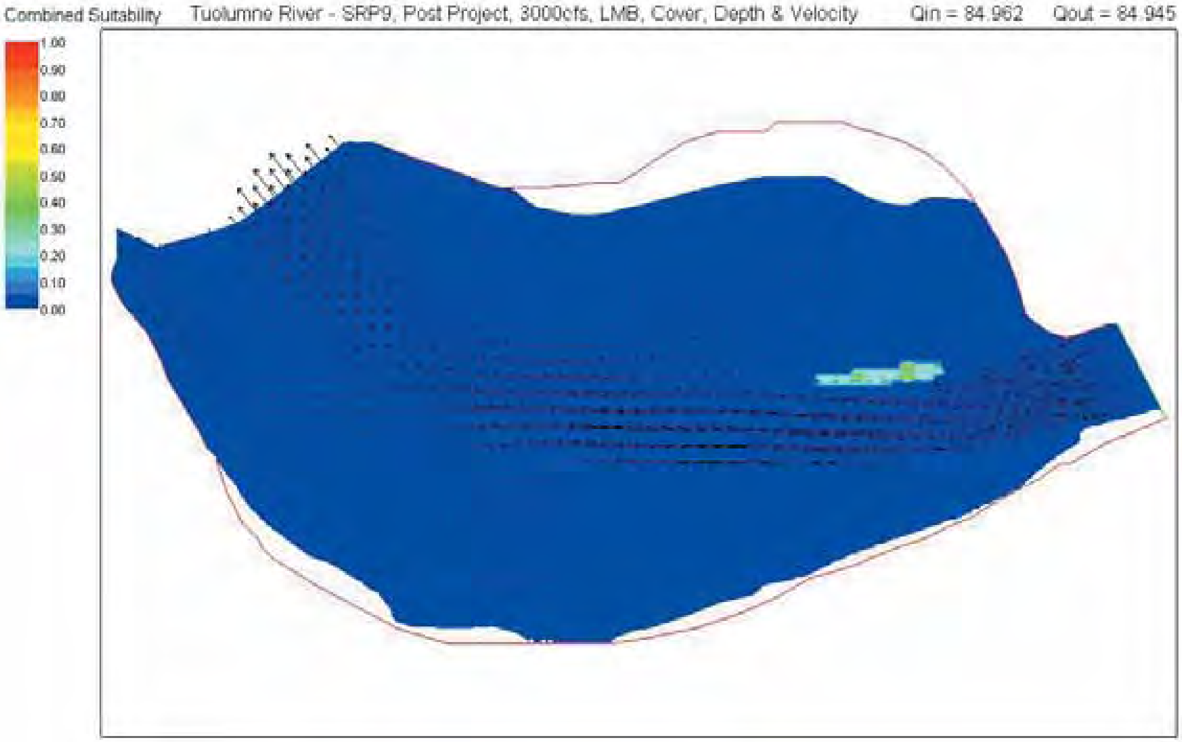

Combined Suitability
Tuolumne River - SRP 9, Post Project, 500cfs, LMB, Depth & Velocity
Qin = 14.160
Qout = 14.135
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

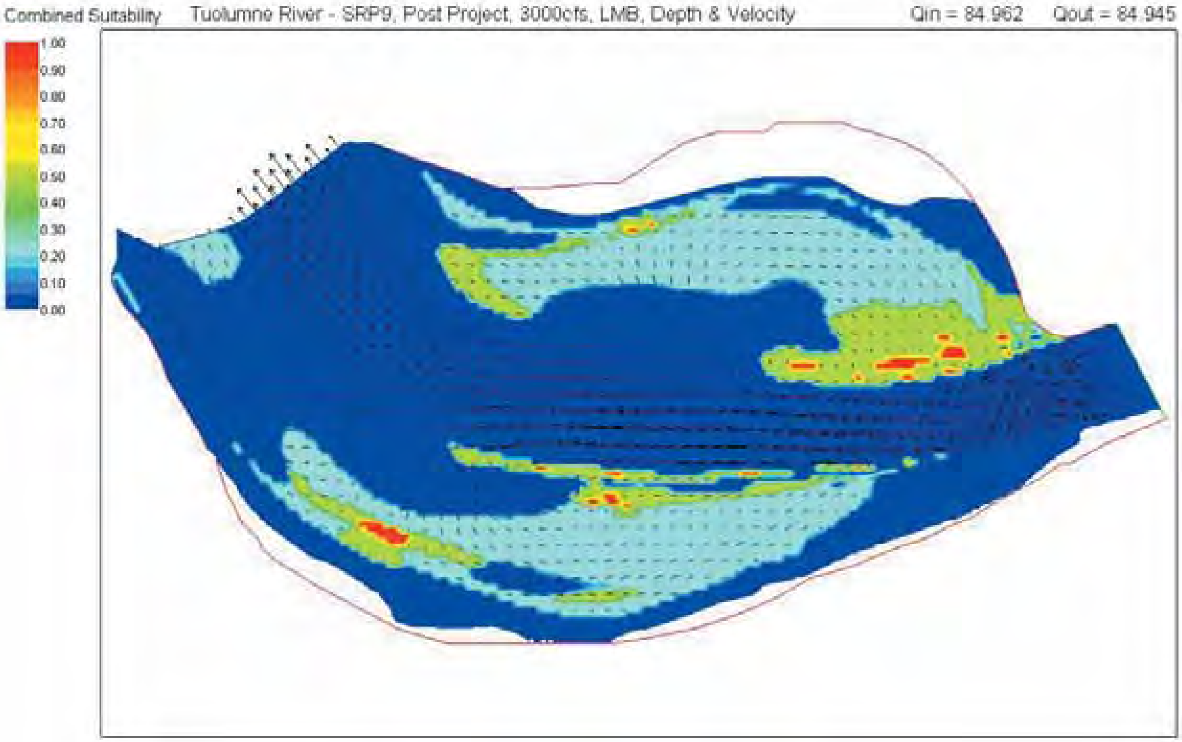

Combined Suitability
Tuolumne River - SRP9, Post Project, 1000cfs, LMB, Cover, Depth & Velocity
Qin = 28.321
Qout = 28.316
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

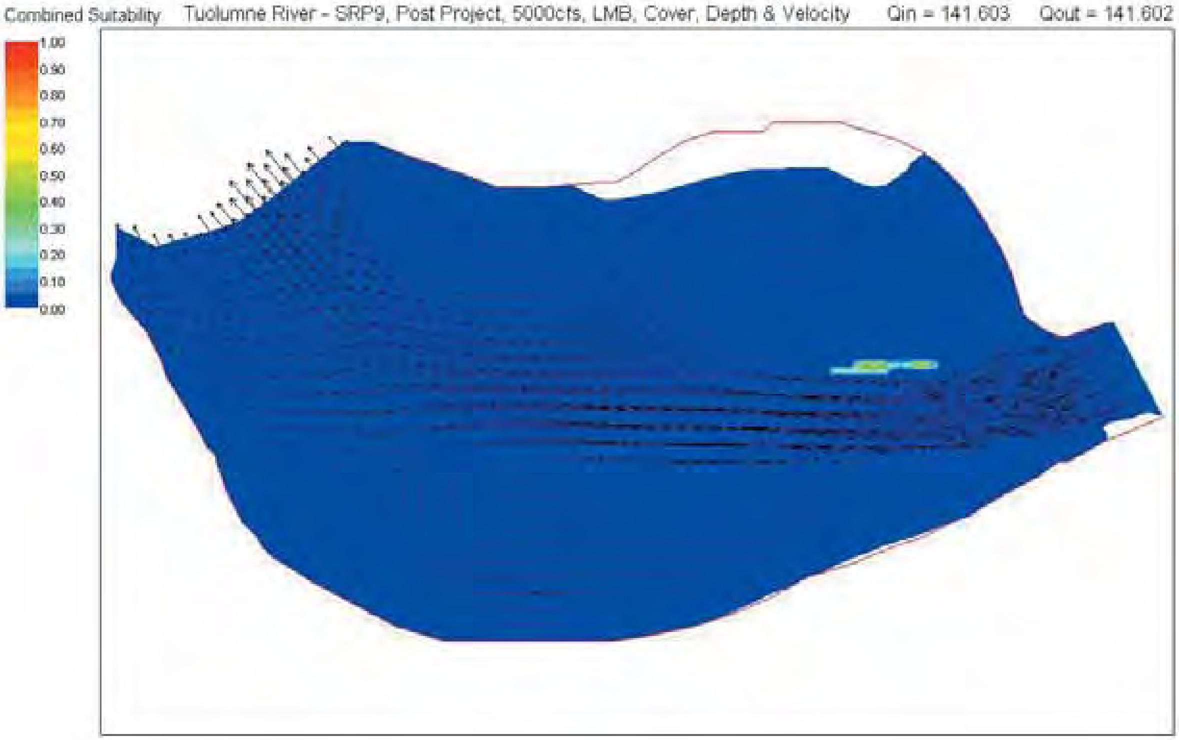

Combined Suitability
Tuolumne River - SRP9, Post Project, 1000cfs, LMB, Depth & Velocity
Qin = 28.321
Qout = 28.316
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

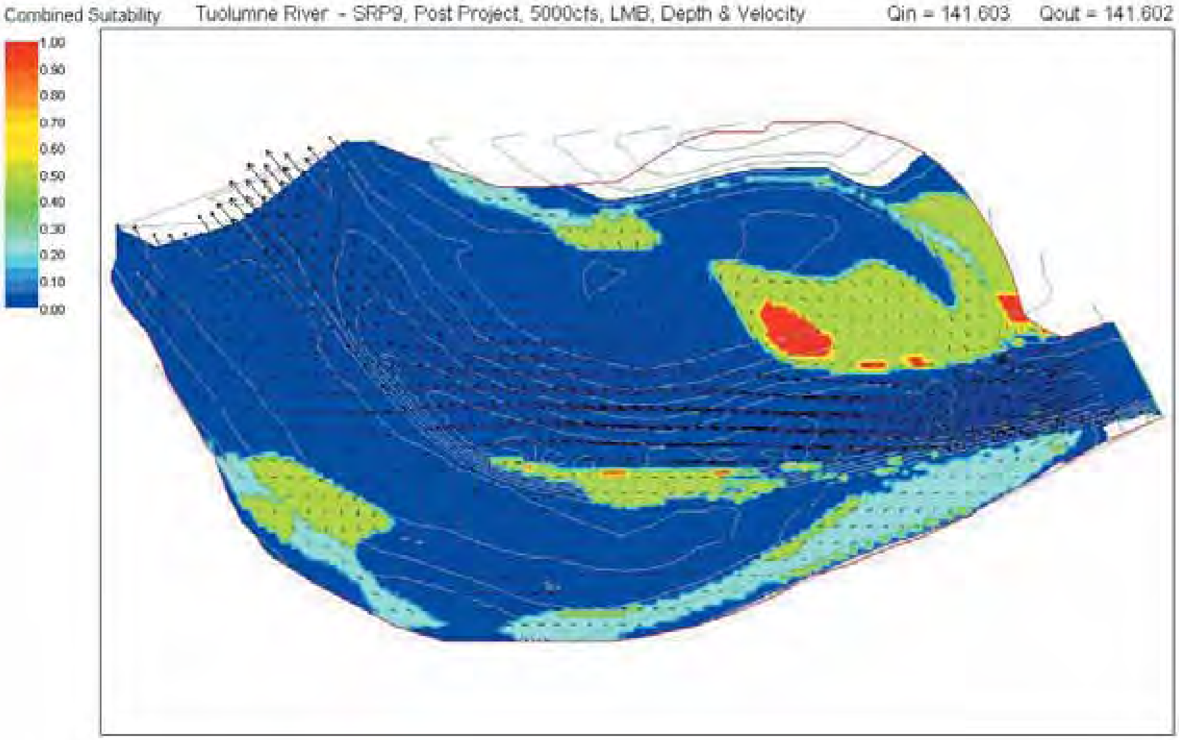

Combined Suitability Tuolumne River, SRP9, Post, 2000cfs, LMB, Cover, Depth & Velocity
Qin = 56.634
Qout = 56.632
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

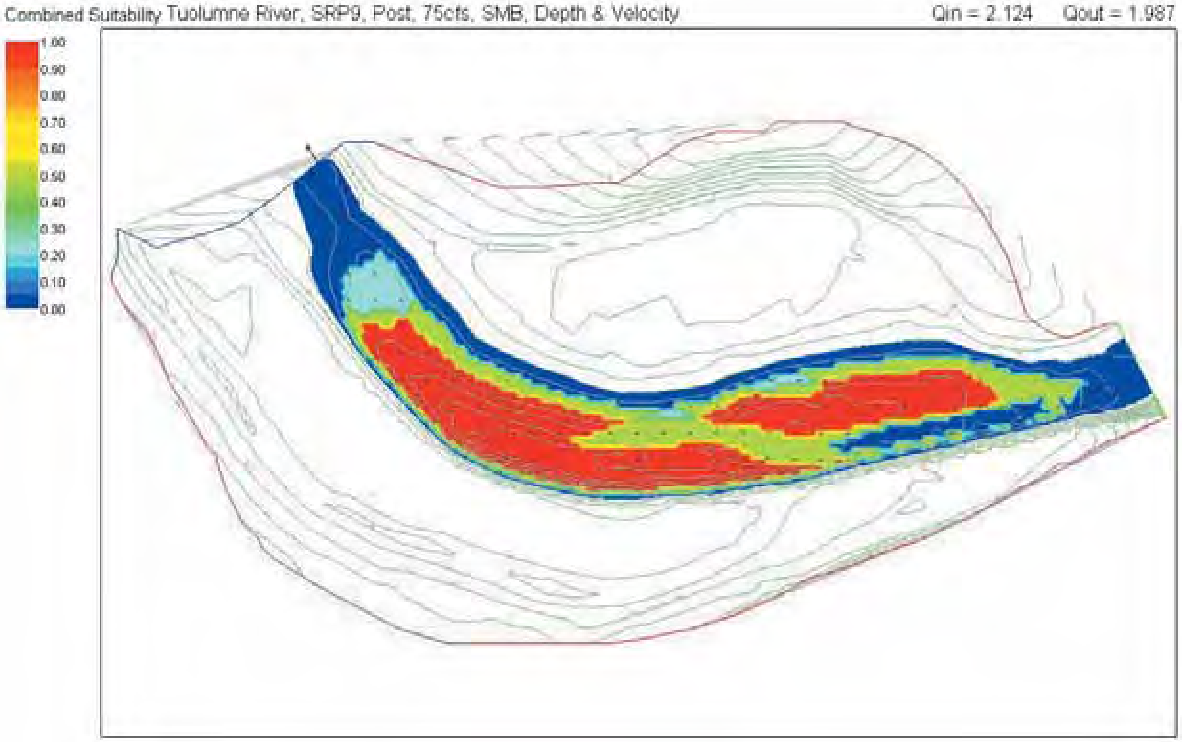

Combined Suitability Tuolumne River, SRP9, Post, 2000cfs, LMB, Depth & Velocity
Qin = 56.634
Qout = 56.632
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

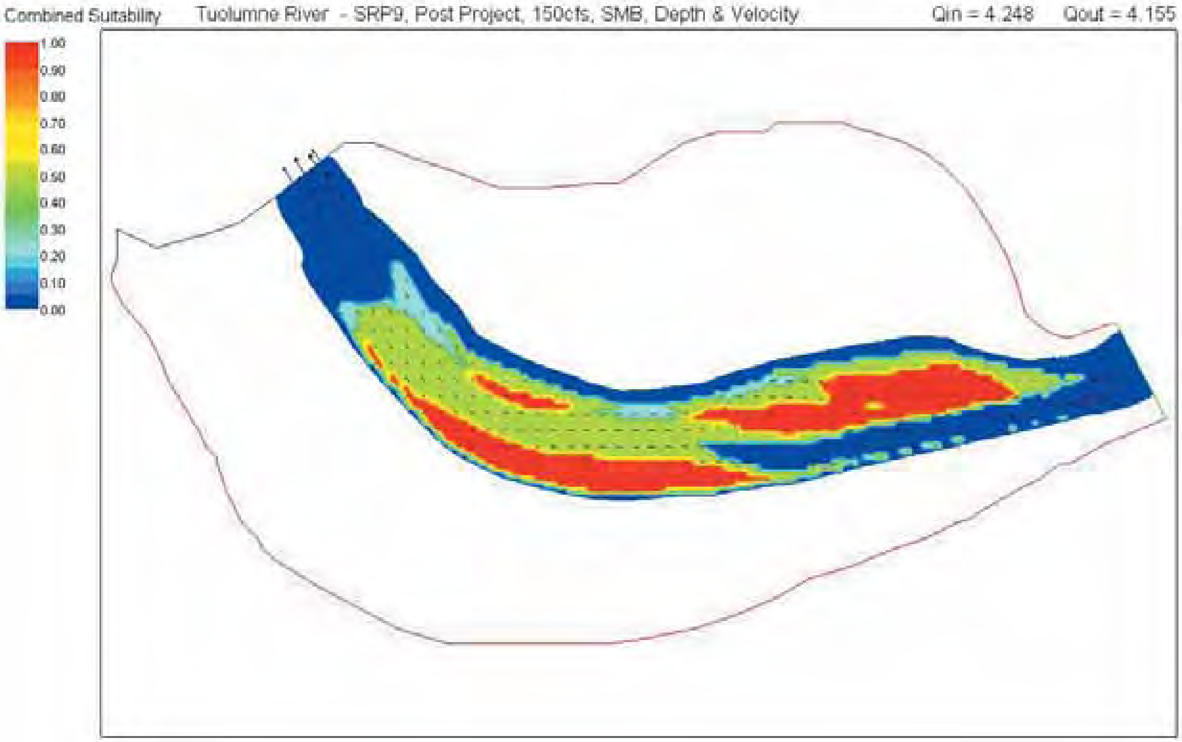

Combined Suitability
Tuolumne River - SRP9, Post Project, 3000cfs, LMB, Cover, Depth & Velocity
Qin = 84.962
Qout = 84.945
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

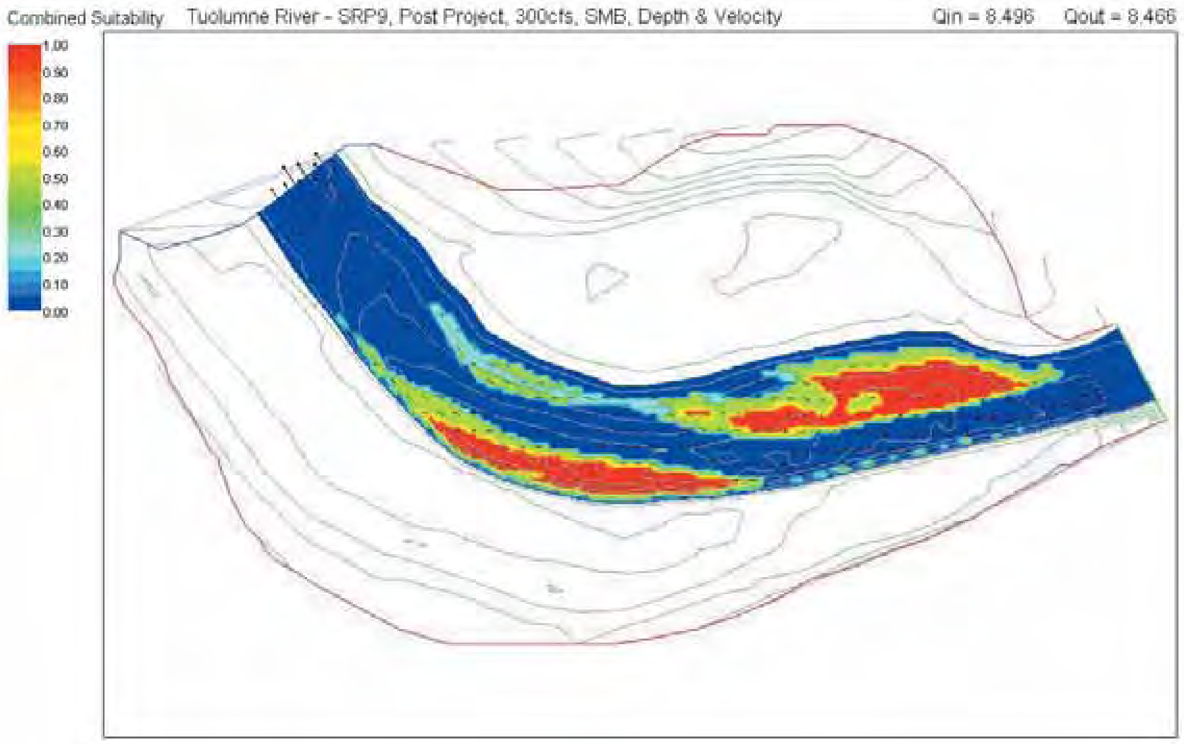

Combined Suitability
Tuolumne River - SRP9, Post Project, 3000cfs, LMB, Depth & Velocity
Qin = 84.962
Qout = 84.945
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

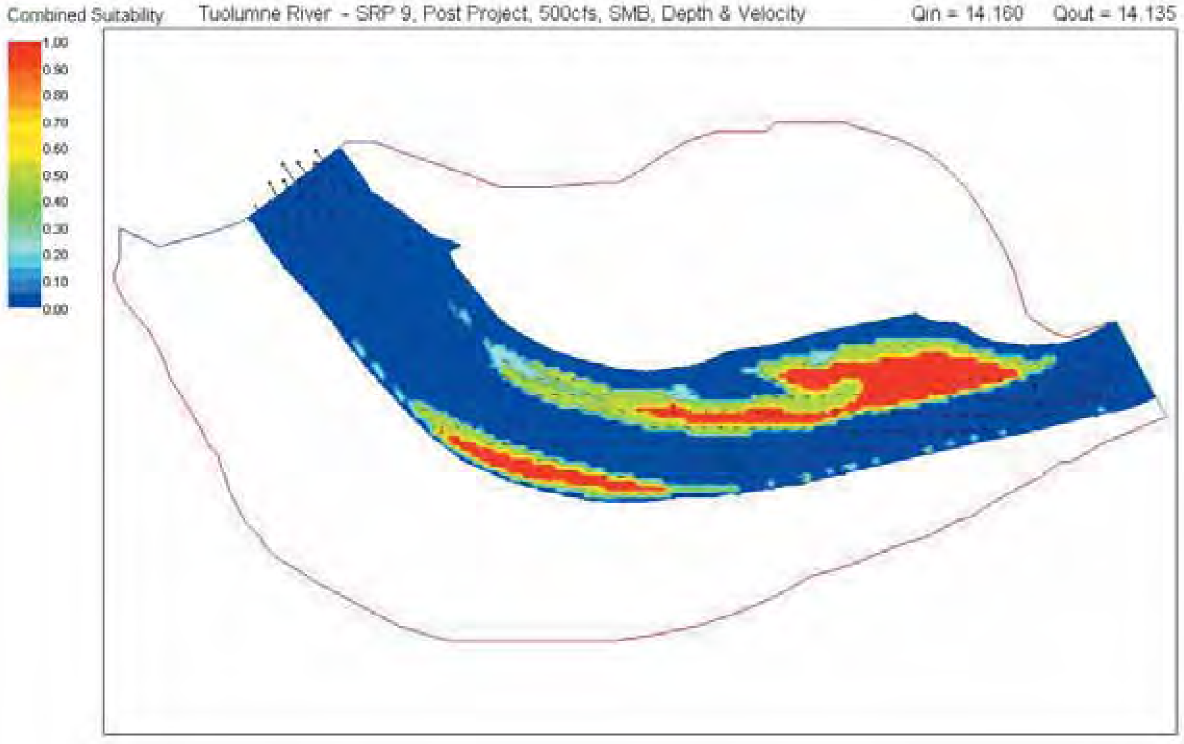

Combined Suitability
Tuolumne River - SRP9, Post Project, 5000cfs, LMB, Cover, Depth & Velocity
Qin = 141.603
Qout = 141.602
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

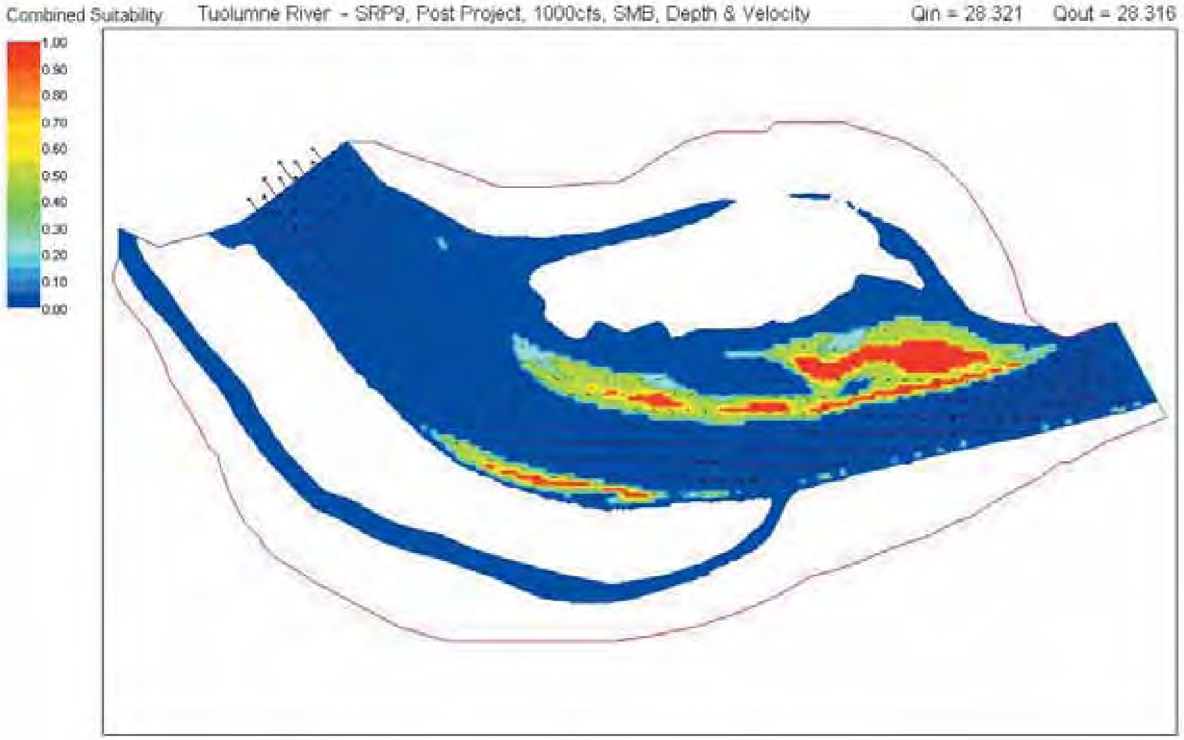

Combined Suitability
Tuolumne River - SRP9, Post Project, 5000cfs, LMB, Depth & Velocity
Qin = 141.603
Qout = 141.602
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

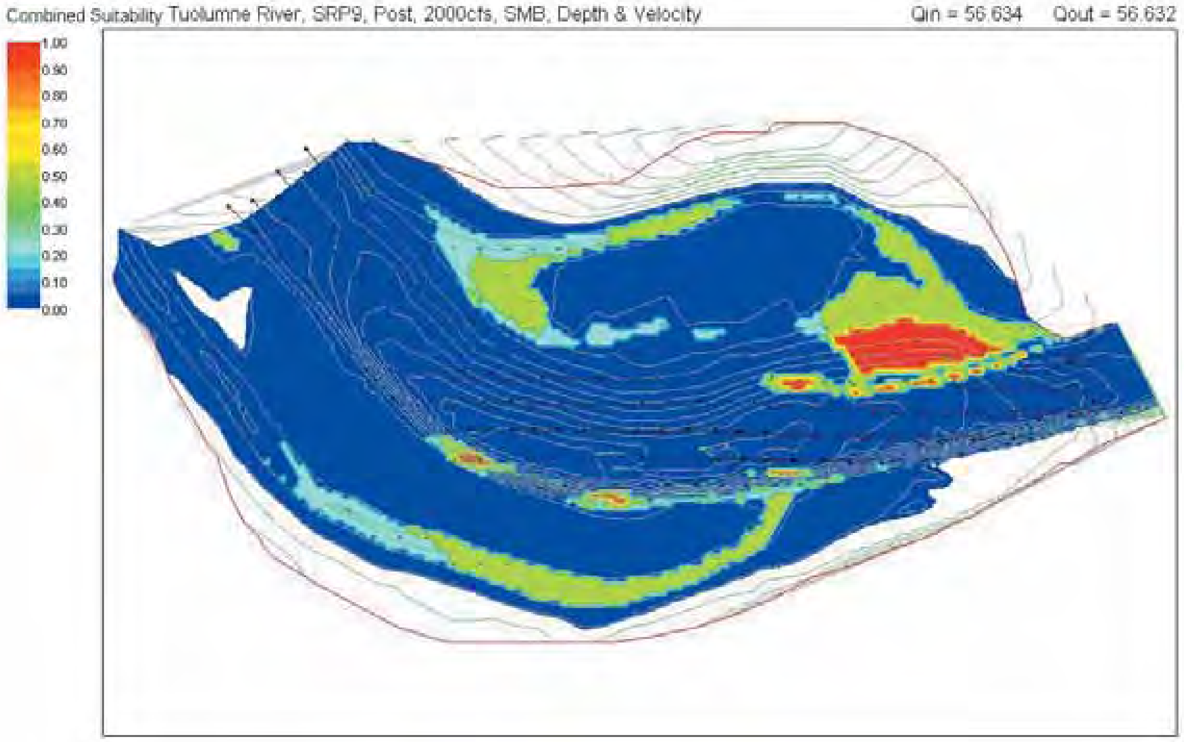

Combined Suitability Tuolumne River, SRP9, Post, 75cfs, SMB, Depth & Velocity
Qin = 2.124
Qout = 1.987
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

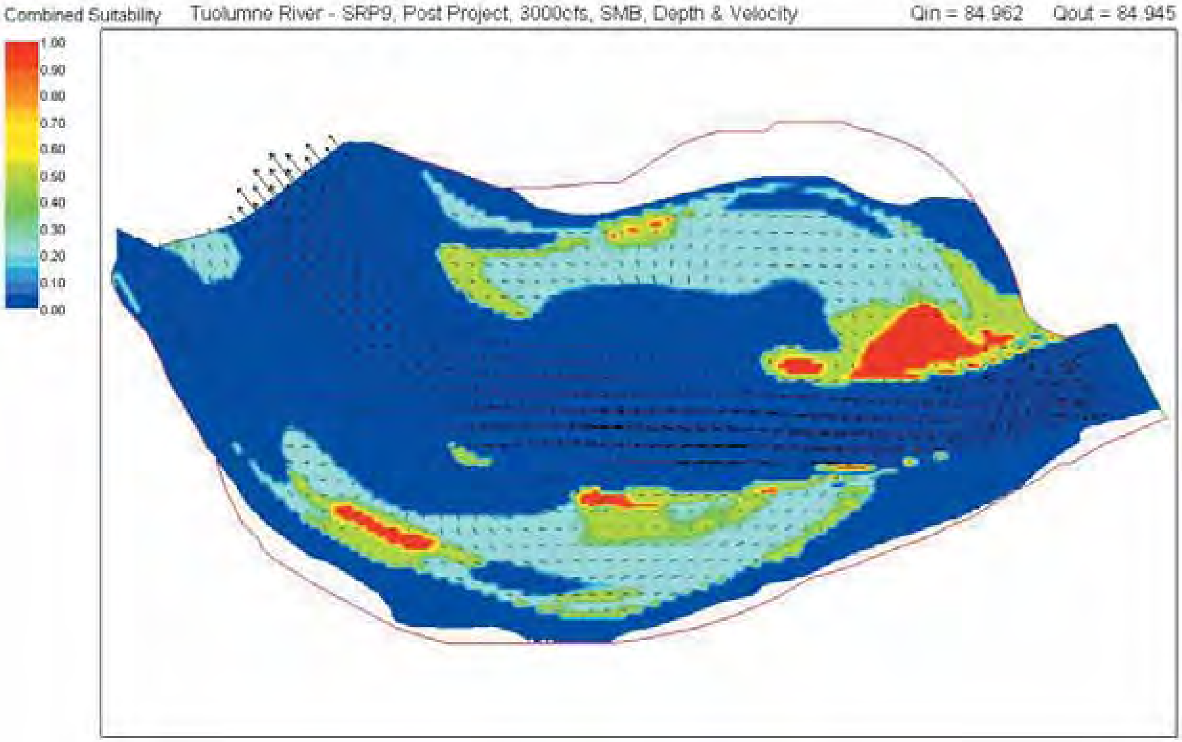

Combined Suitability
Tuolumne River - SRP9, Post Project, 150cfs, SMB, Depth & Velocity
Qin = 4.248
Qout = 4.155
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

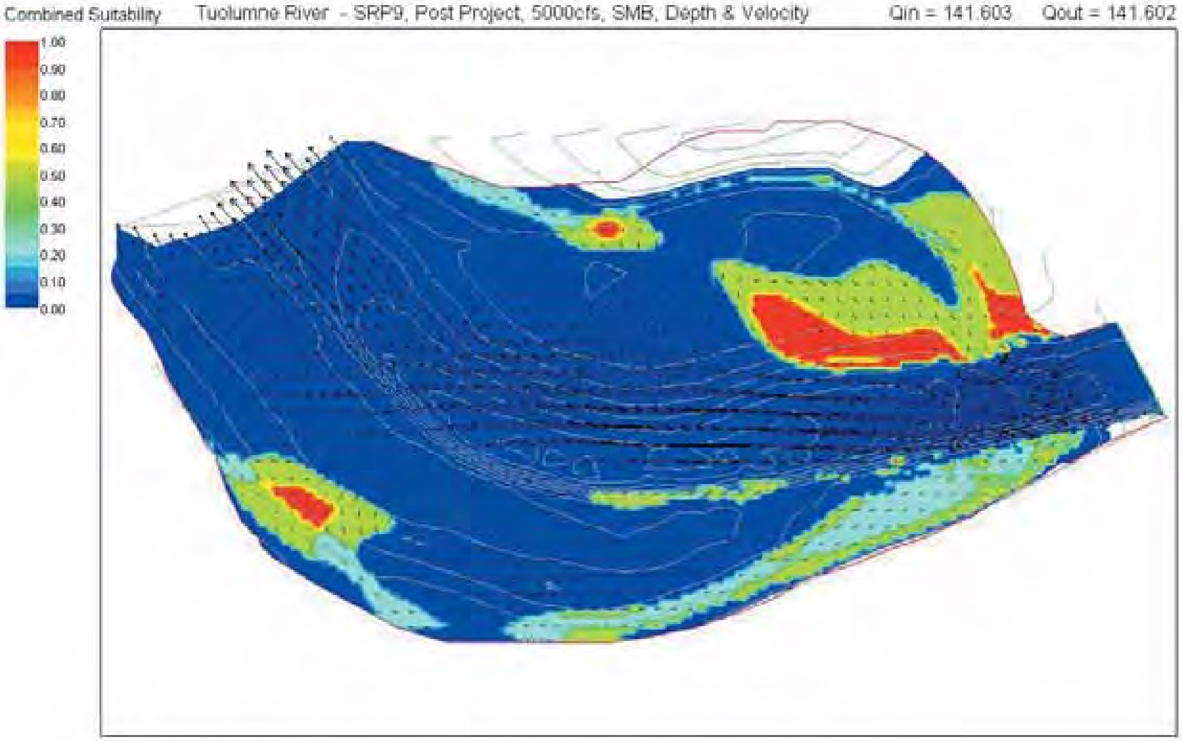

Combined Suitability
Tuolumne River - SRP9, Post Project, 300cfs, SMB, Depth & Velocity
Qin = 8.496
Qout = 8.466
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - SRP 9, Post Project, 500cfs, SMB, Depth & Velocity
Qin = 14.160
Qout = 14.135
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

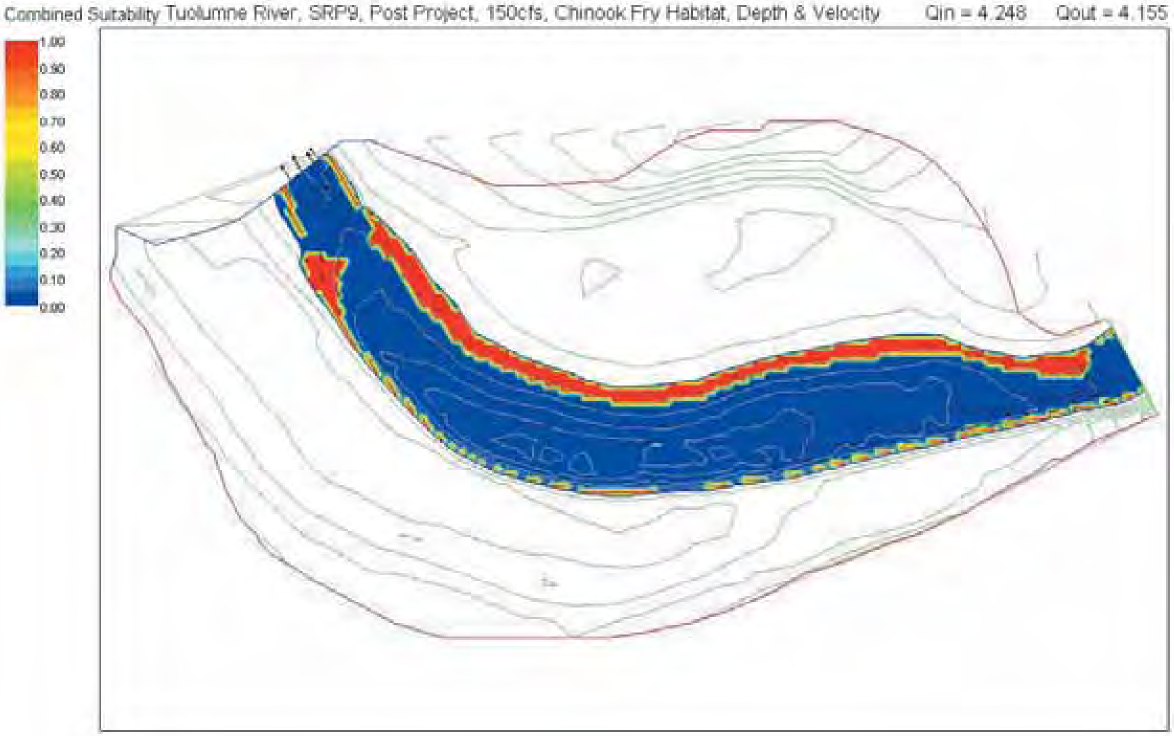

Combined Suitability
Tuolumne River - SRP9, Post Project, 1000cfs, SMB, Depth & Velocity
Qin = 28.321
Qout = 28.316
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

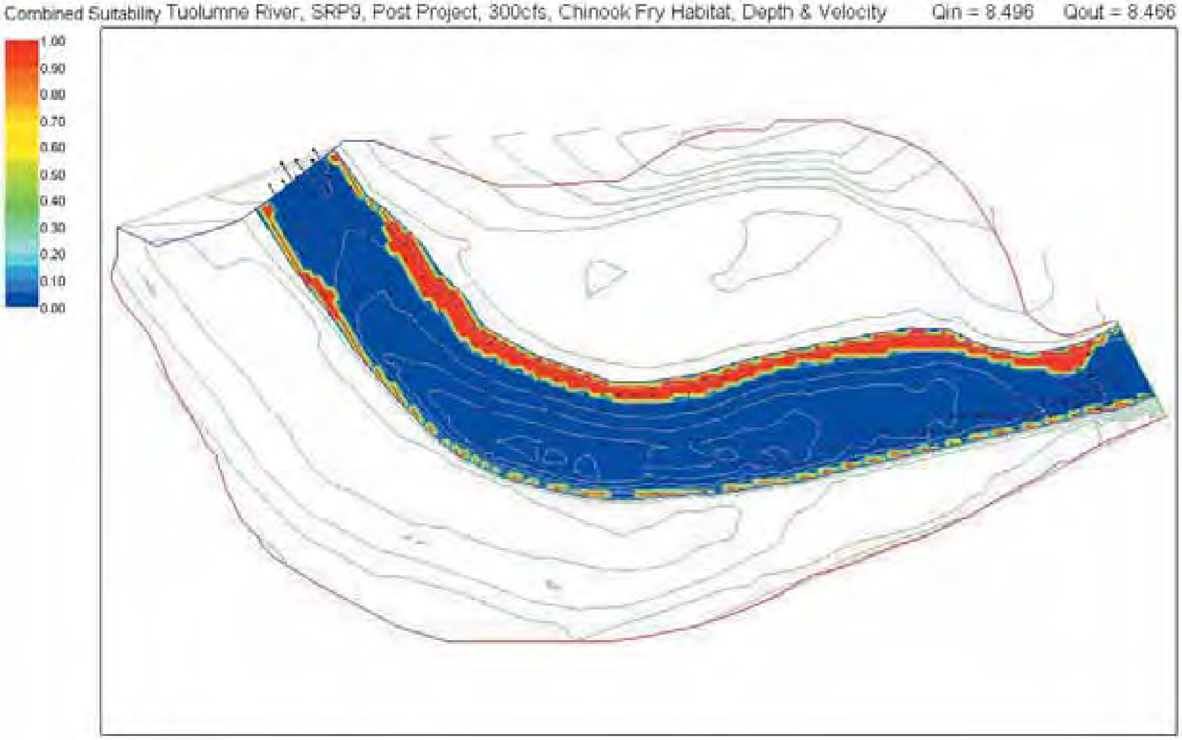

Combined Suitability
Tuolumne River, SRP9, Post, 2000cfs, SMB, Depth & Velocity
Qin = 56.634
Qout = 56.632
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - SRP9, Post Project, 3000cfs, SMB, Depth & Velocity
Qin = 84.962
Qout = 84.945
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

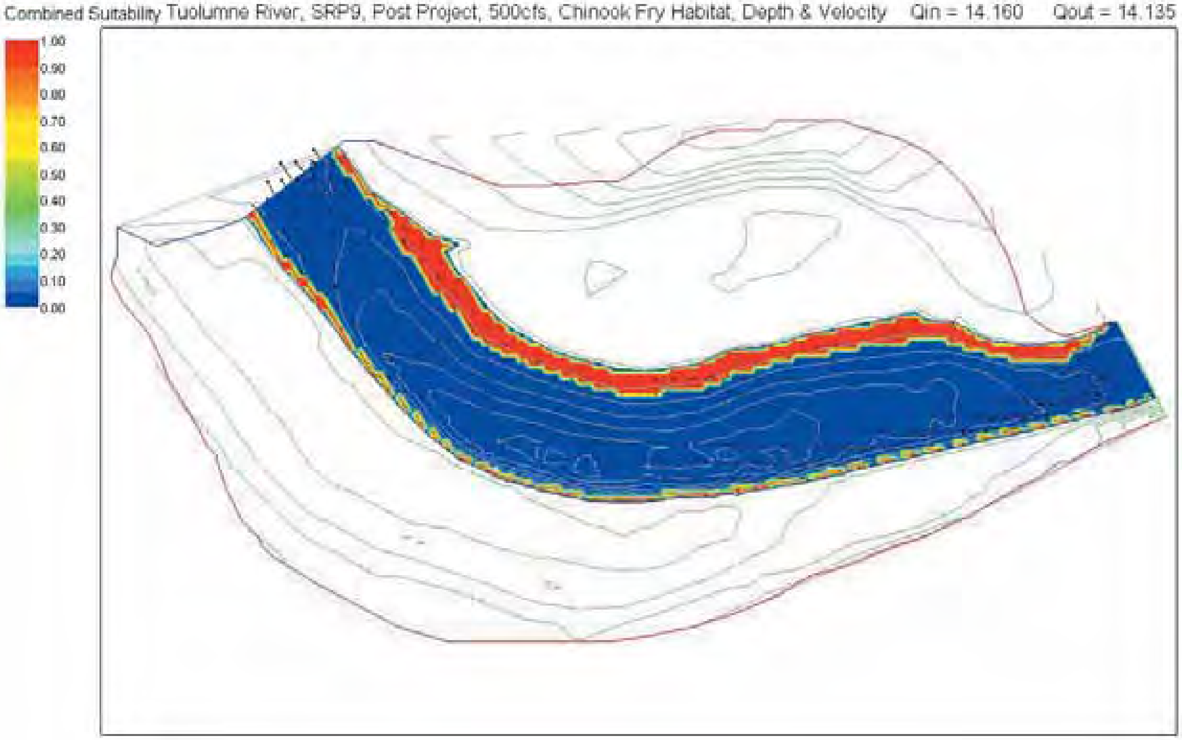

Combined Suitability
Tuolumne River - SRP9, Post Project, 5000cfs, SMB, Depth & Velocity
Qin = 141.603
Qout = 141.602
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability Tuolumne River, SRP9, Post Project, 75cfs, Chinook Fry Habitat, Depth & Velocity Qin = 2.124 Qout = 1.987

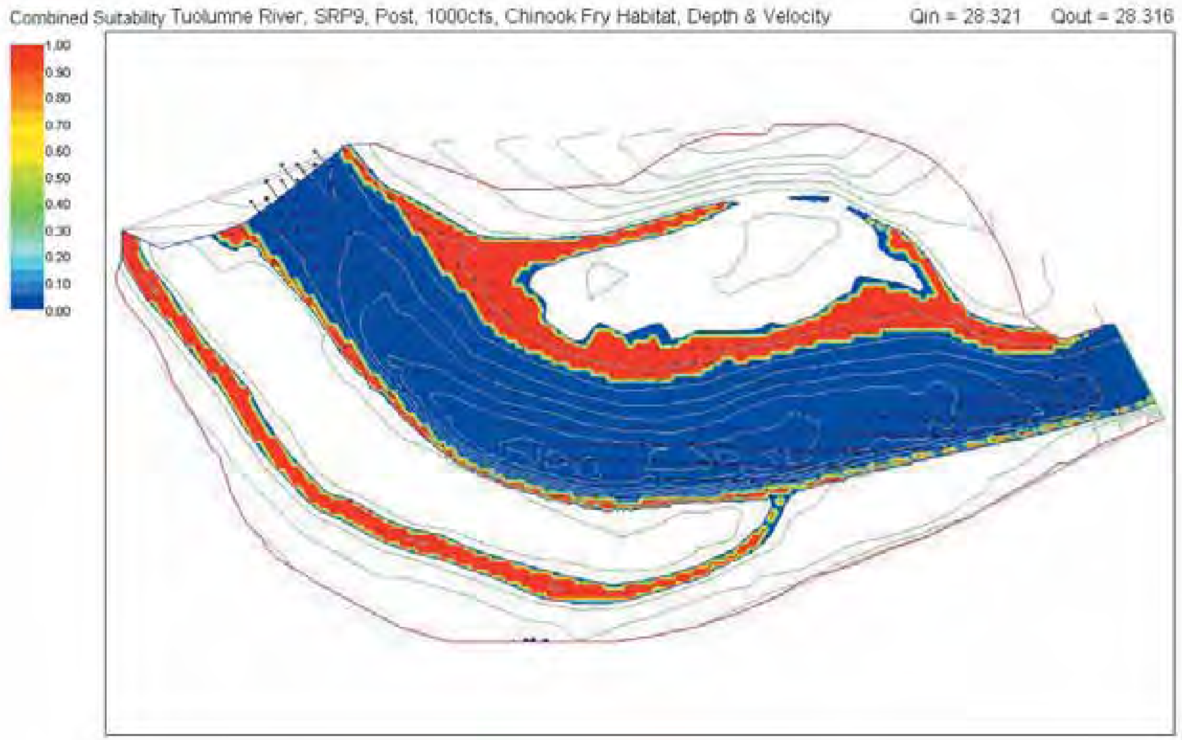

Combined Suitability Tuolumne River, SRP9, Post Project, 150cfs, Chinook Fry Habitat, Depth & Velocity Qin = 4.248 Qout = 4.155

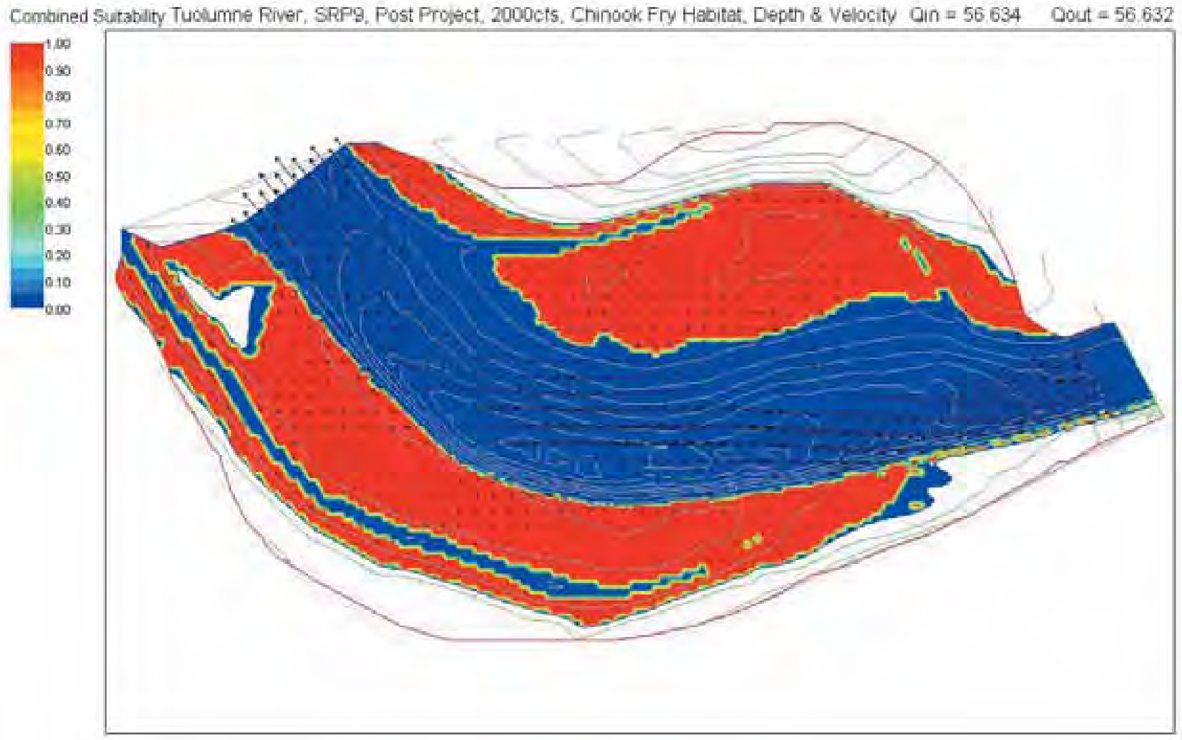


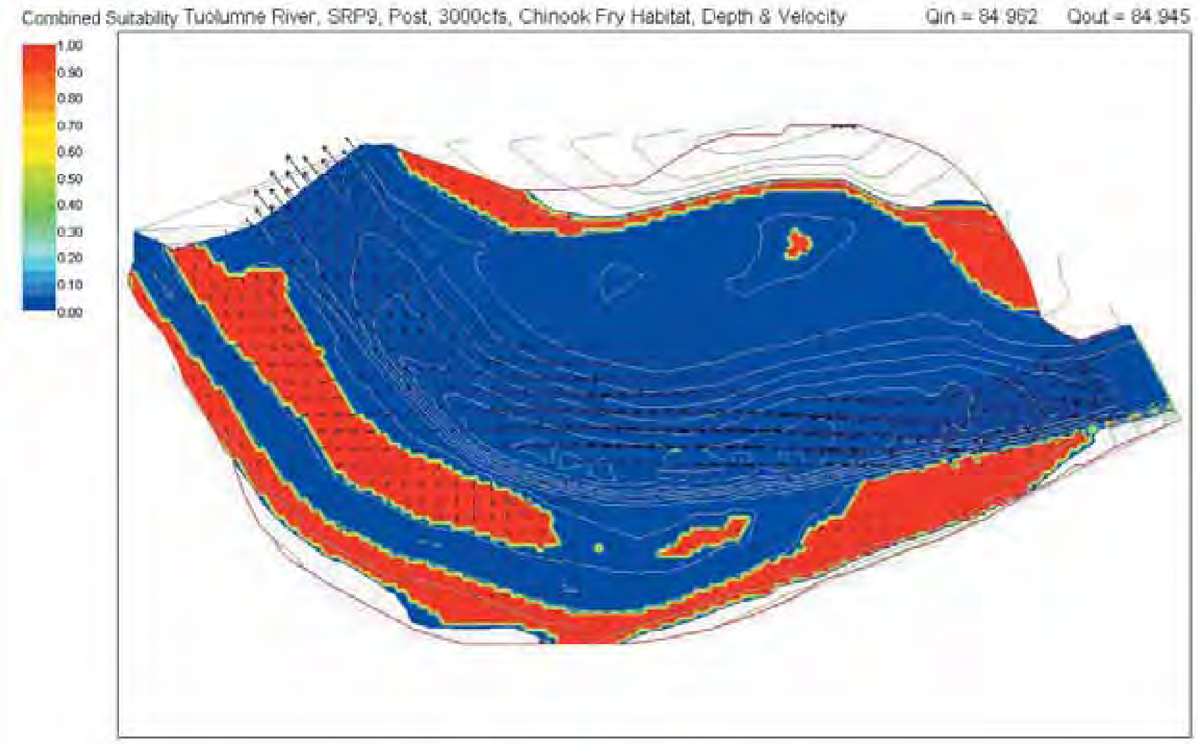
Combined Suitability Tuolumne River, SRP9, Post Project, 300cfs, Chinook Fry Habitat, Depth & Velocity Qin = 8.496 Qout = 8.466

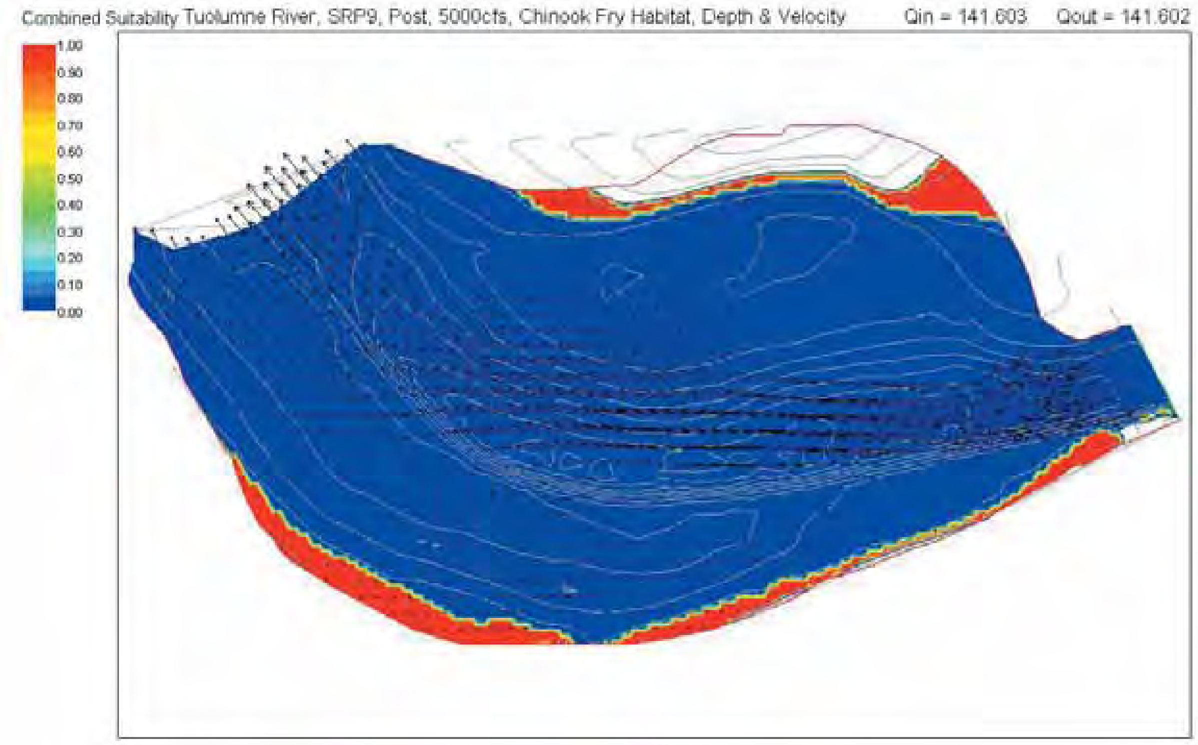


Combined Suitability Tuolumne River, SRP9, Post Project, 500cfs, Chinook Fry Habitat, Depth & Velocity Qin = 14.160 Qout = 14.135


Combined Suitability Tuolumne River, SRP9, Post, 1000cfs, Chinook Fry Habitat, Depth & Velocity
Qin = 28.321
Qout = 28.316
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability Tuolumne River, SRP9, Post Project, 2000cfs, Chinook Fry Habitat, Depth & Velocity
Qin = 56.634
Qout = 56.632
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

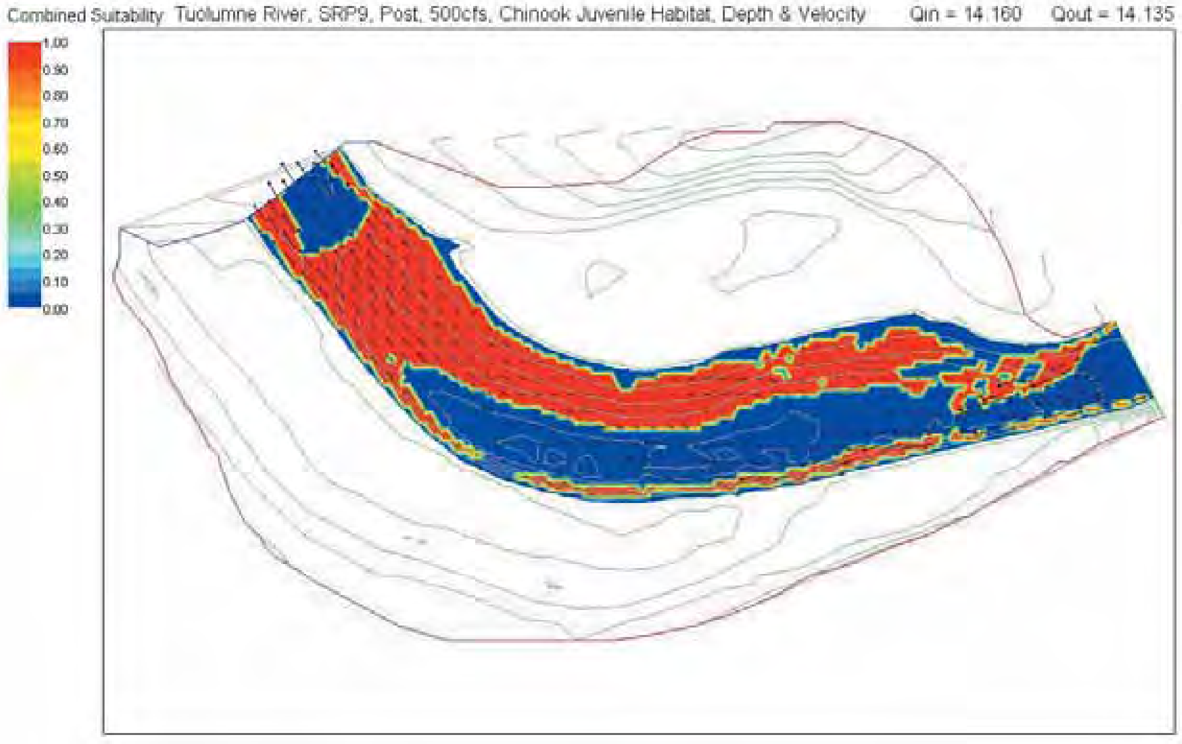

Combined Suitability Tuolumne River, SRP9, Post, 3000cfs, Chinook Fry Habitat, Depth & Velocity
Qin = 84.962
Qout = 84.945
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

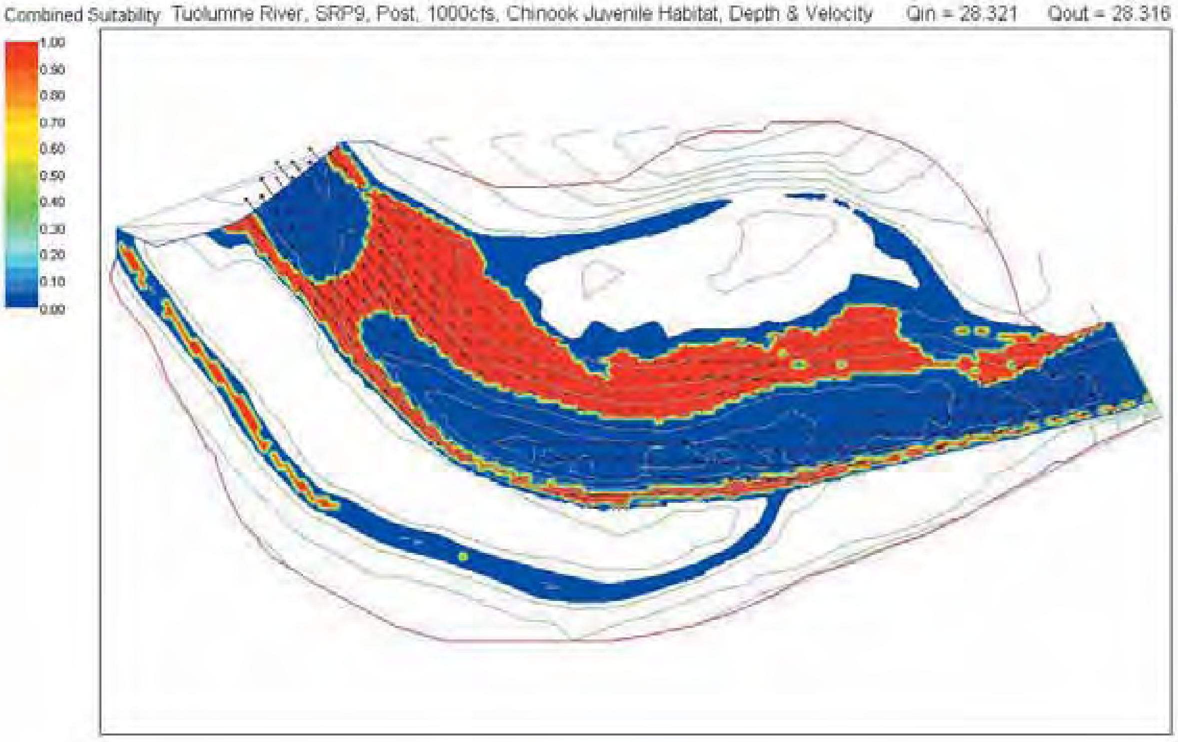

Combined Suitability Tuolumne River, SRP9, Post, 5000cfs, Chinook Fry Habitat, Depth & Velocity
Qin = 141.603
Qout = 141.602
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

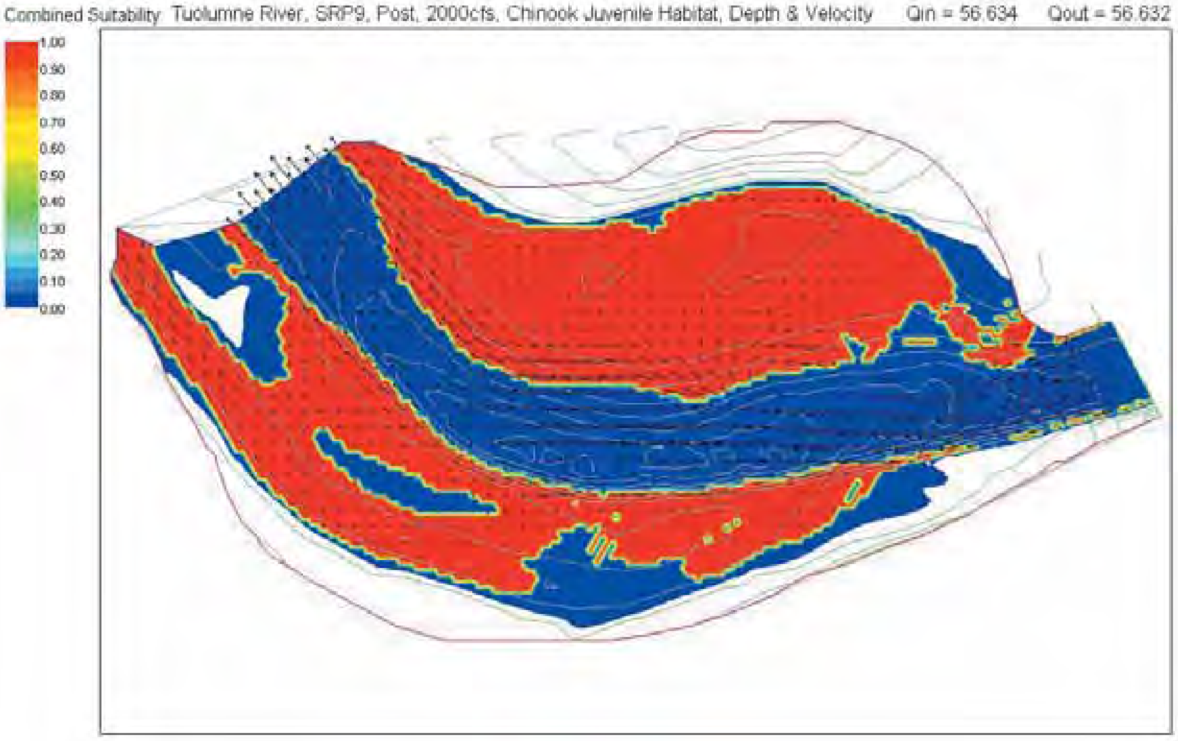
Combined Suitability Tuolumne River, SRP9, Post, 75cfs, Chinook Juvenile Habitat, Depth & Velocity Qin = 2.124 Qout = 1.987

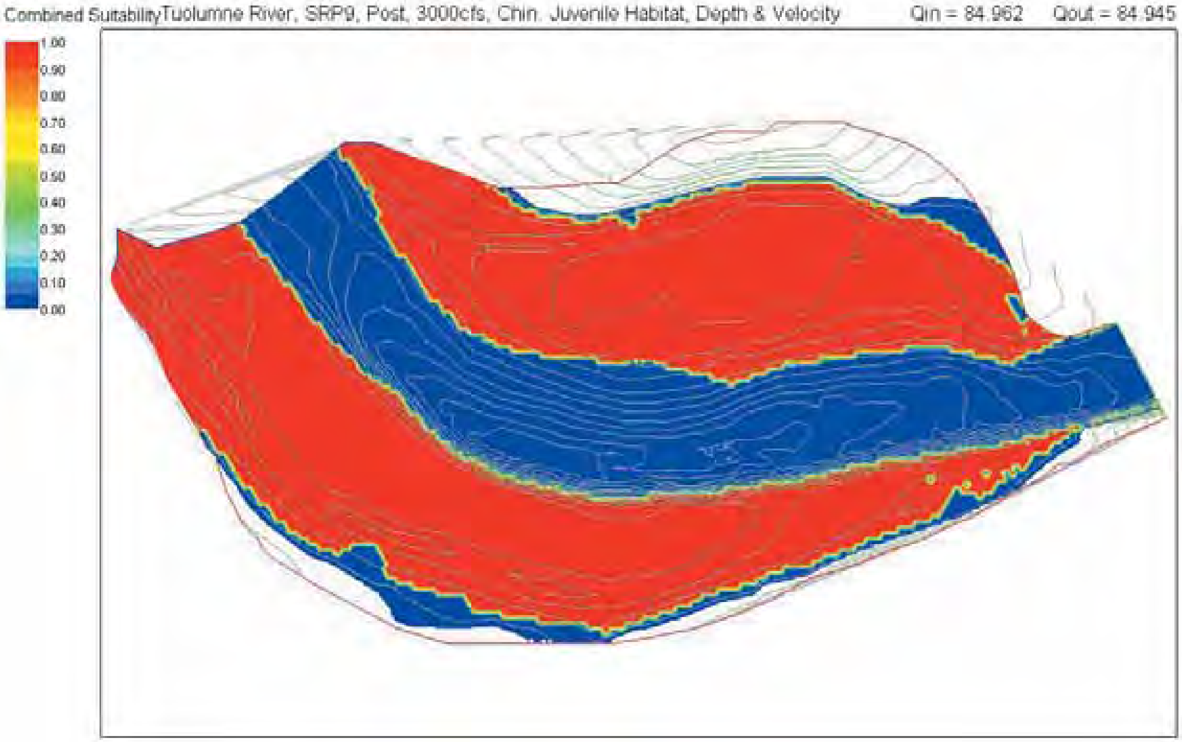
Combined Suitability Tuolumne River, SRP9, Post, 150cfs, Chinook Juvenile Habitat, Depth & Velocity Qin = 4.248 Qout = 4.155

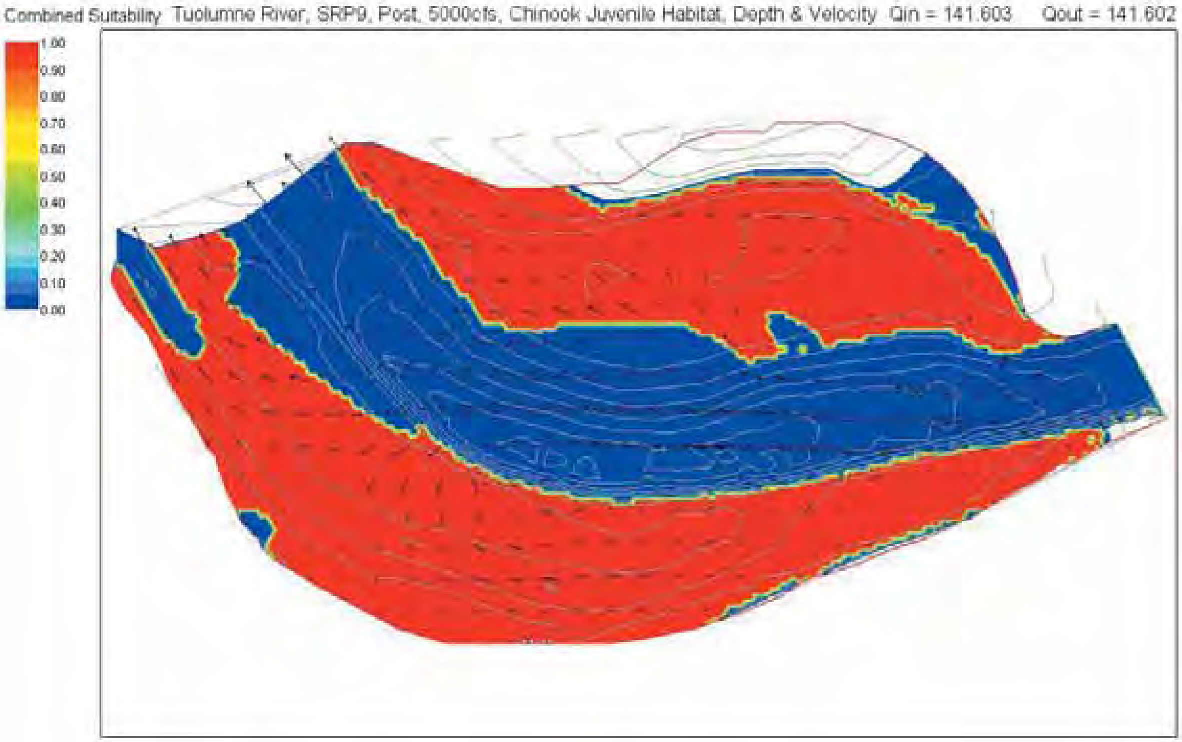

Combined Suitability Tuolumne River, SRP9, Post, 300cfs, Chinook Juvenile Habitat, Depth & Velocity
Qin = 8.496 Qout = 8.466
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

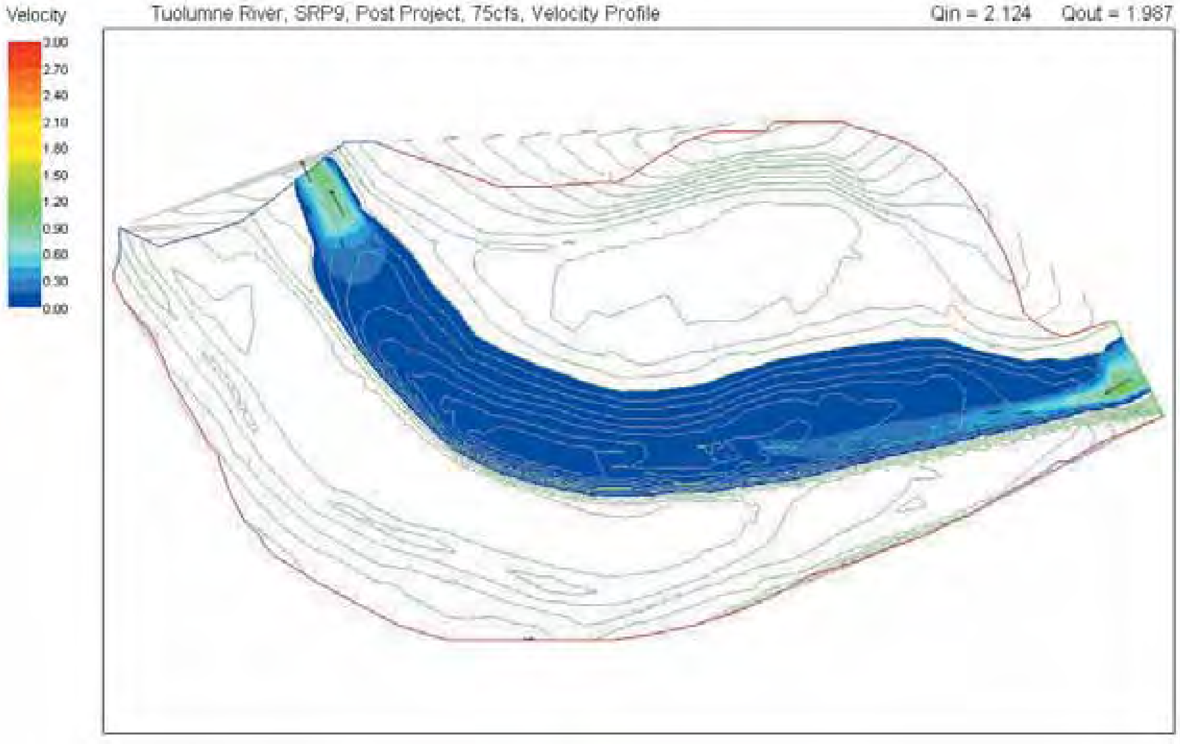

Combined Suitability Tuolumne River, SRP9, Post, 500cfs, Chinook Juvenile Habitat, Depth & Velocity
Qin = 14.160 Qout = 14.135
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

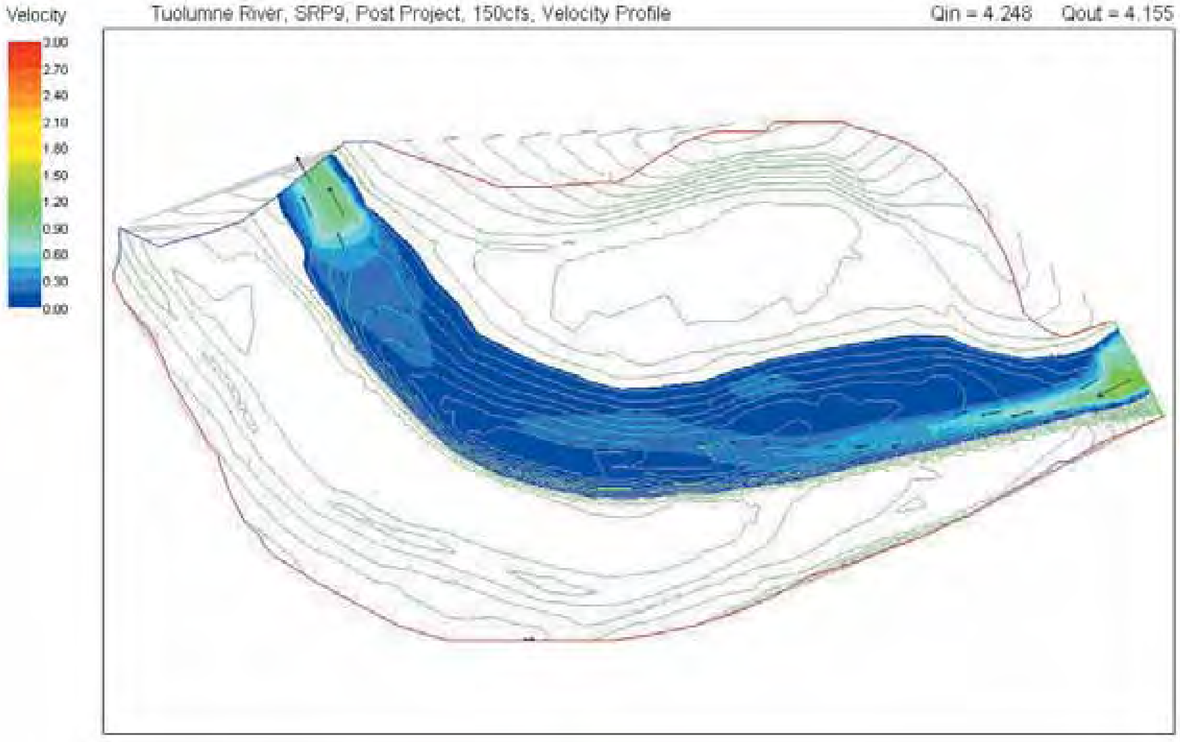

Combined Suitability Tuolumne River, SRP9, Post, 1000cfs, Chinook Juvenile Habitat, Depth & Velocity
Qin = 28.321
Qout = 28.316
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

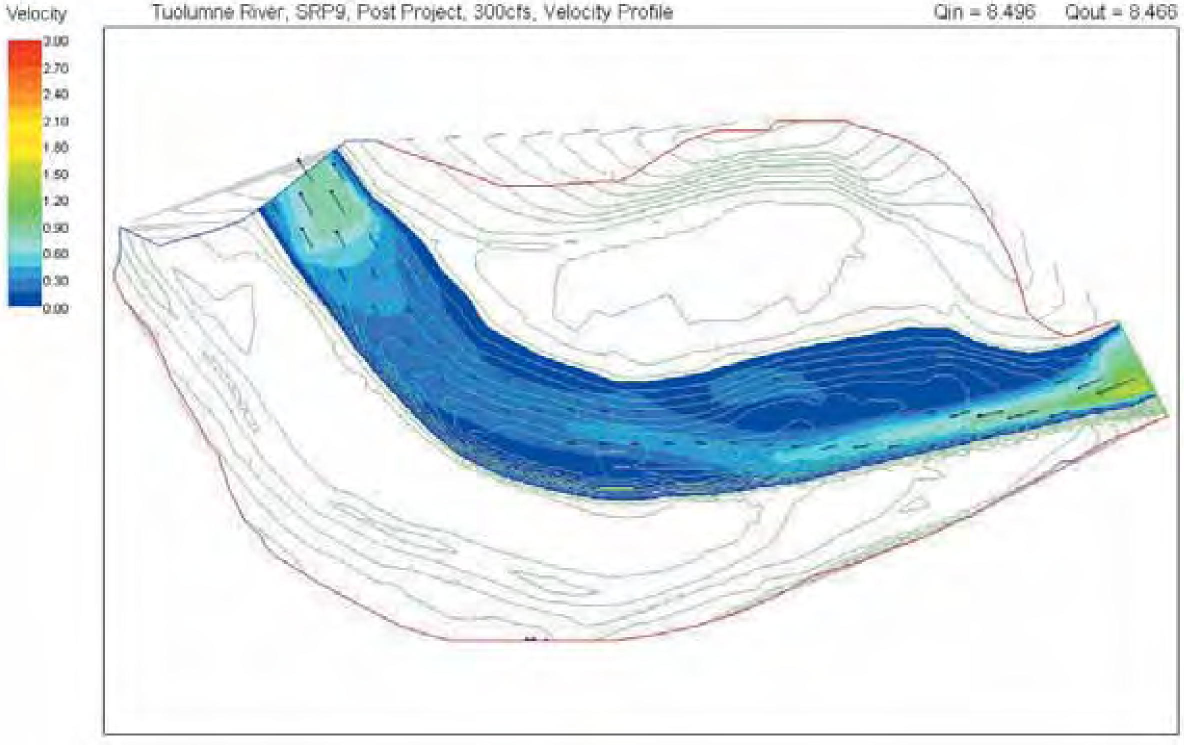

Combined Suitability Tuolumne River, SRP9, Post, 2000cfs, Chinook Juvenile Habitat, Depth & Velocity
Qin = 56.634
Qout = 56.632
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

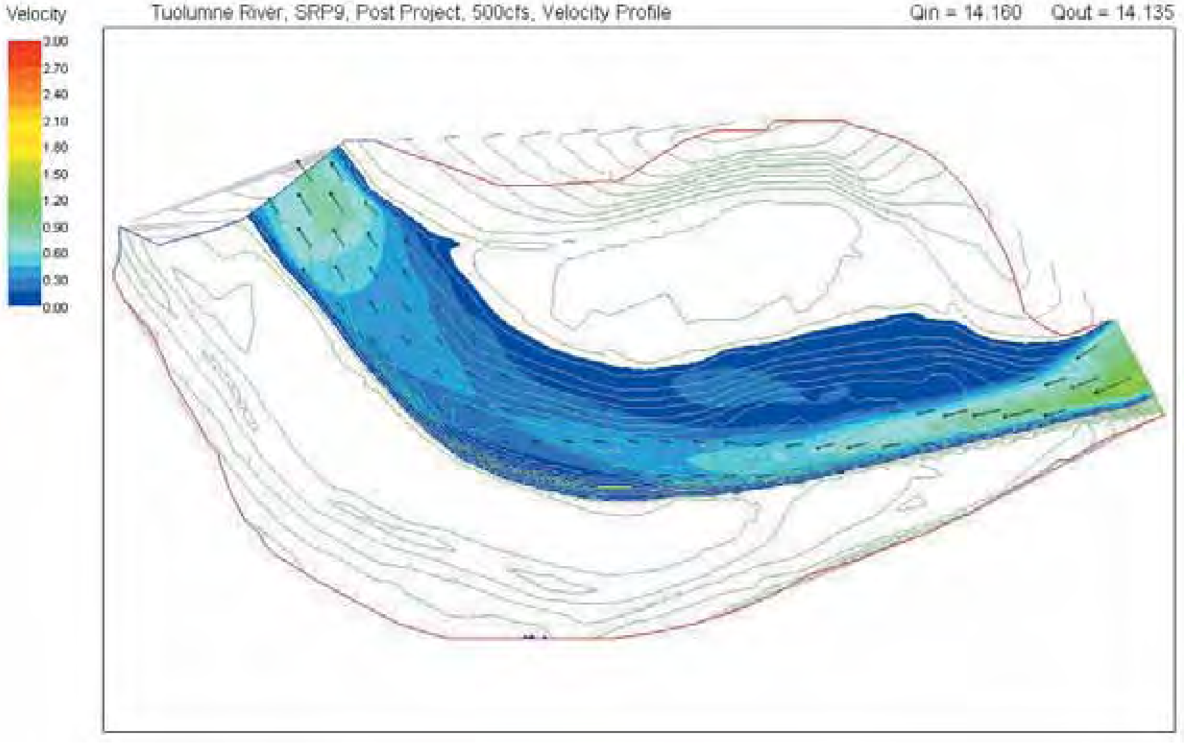

Combined Suitability
Tuolumne River, SRP9, Post, 3000cfs, Chin. Juvenile Habitat, Depth & Velocity
Qin = 84.962
Qout = 84.945
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

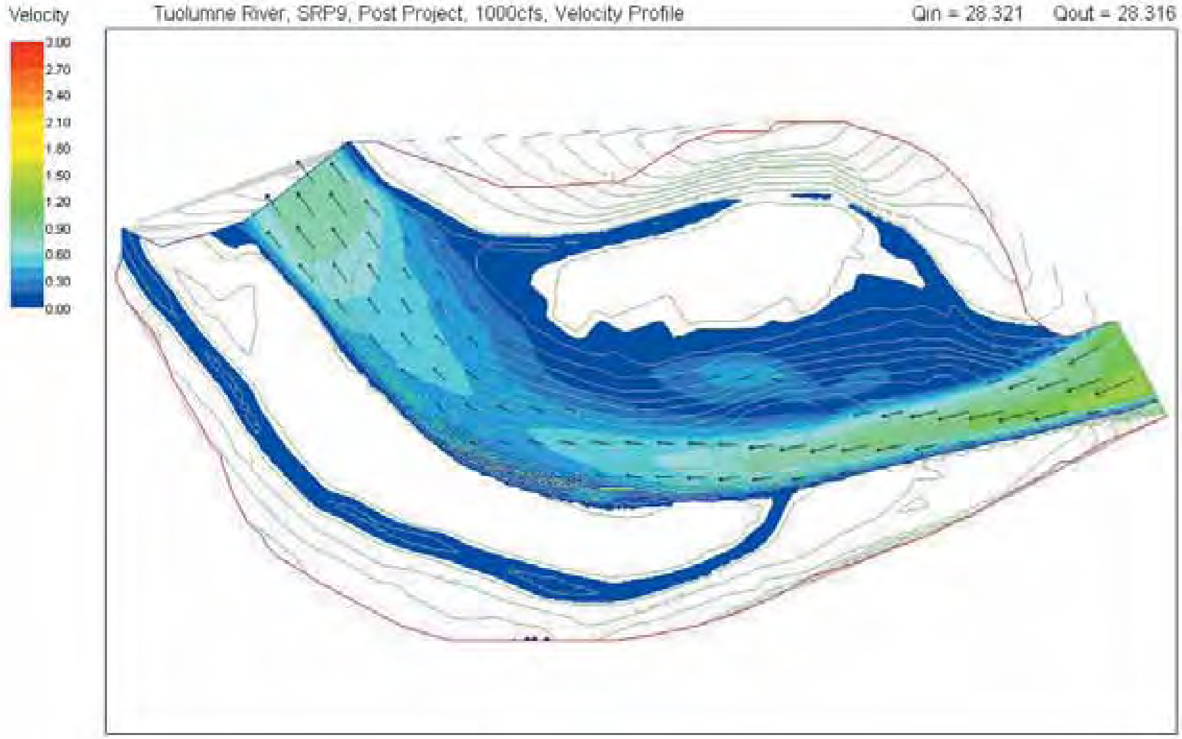

Combined Suitability
Tuolumne River, SRP9, Post, 5000cfs, Chinook Juvenile Habitat, Depth & Velocity
Qin = 141.603
Qout = 141.602
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

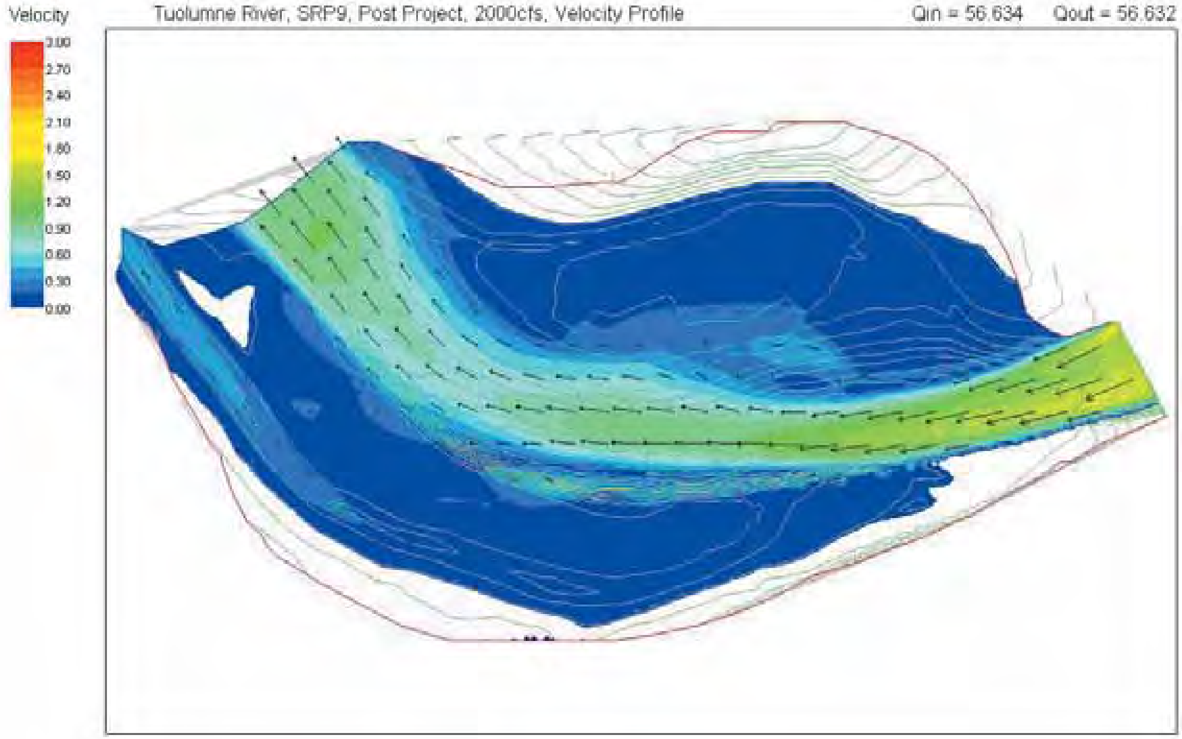

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 75cfs, Velocity Profile
Qin = 2.124
Qout = 1.987

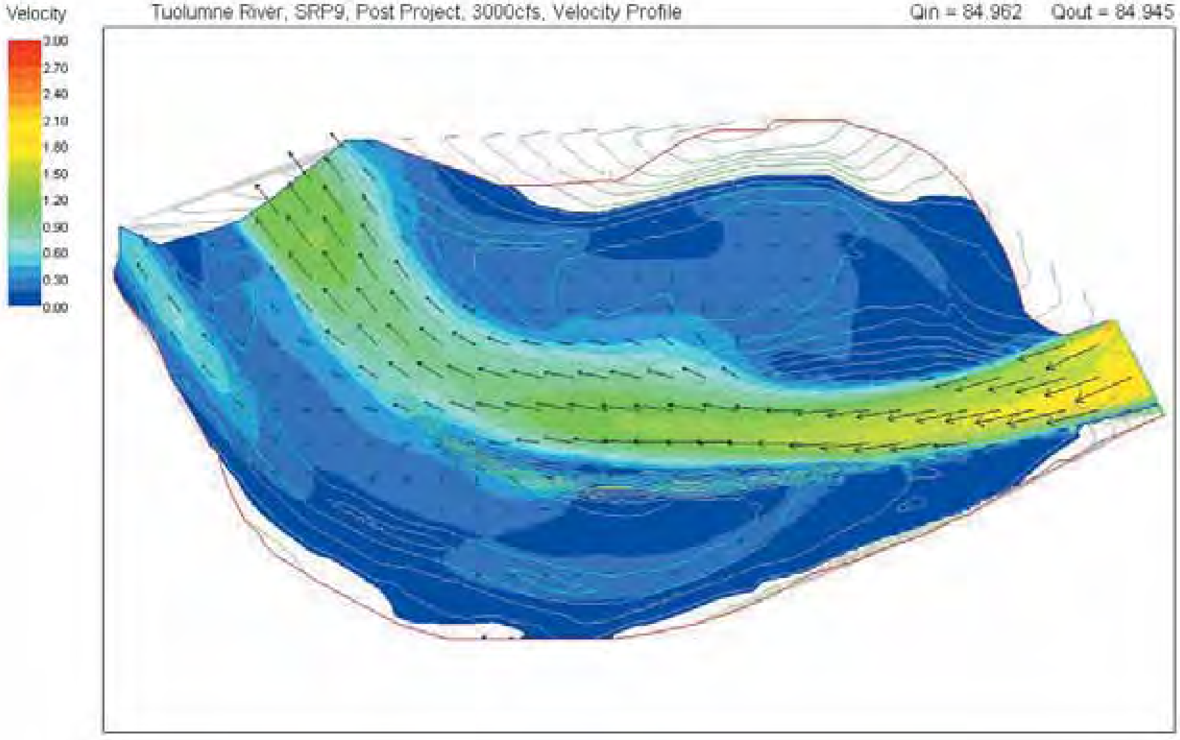

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 150cfs, Velocity Profile
Qin = 4.248
Qout = 4.155

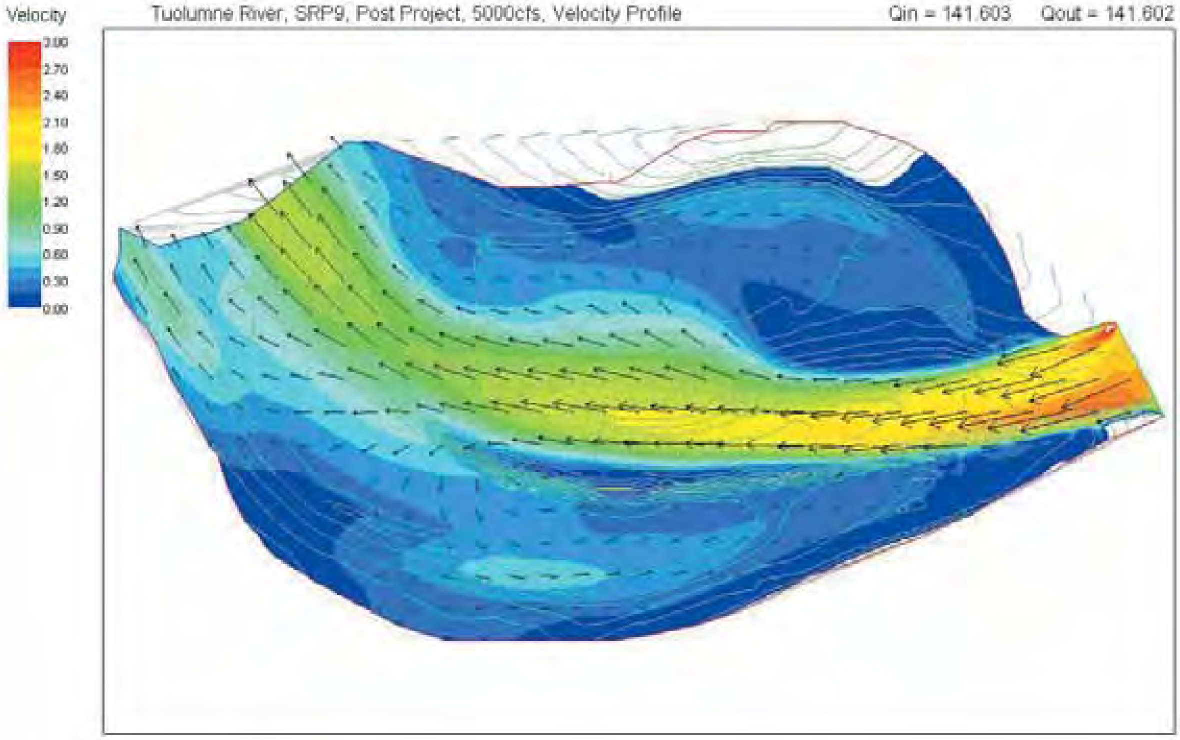

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 300cfs, Velocity Profile
Qin = 8.496 Qout = 8.466


Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 500cfs, Velocity Profile
Qin = 14.160 Qout = 14.135


Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 1000cfs, Velocity Profile
Qin = 28.321
Qout = 28.316


Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 2000cfs, Velocity Profile
Qin = 56.634
Qout = 56.632

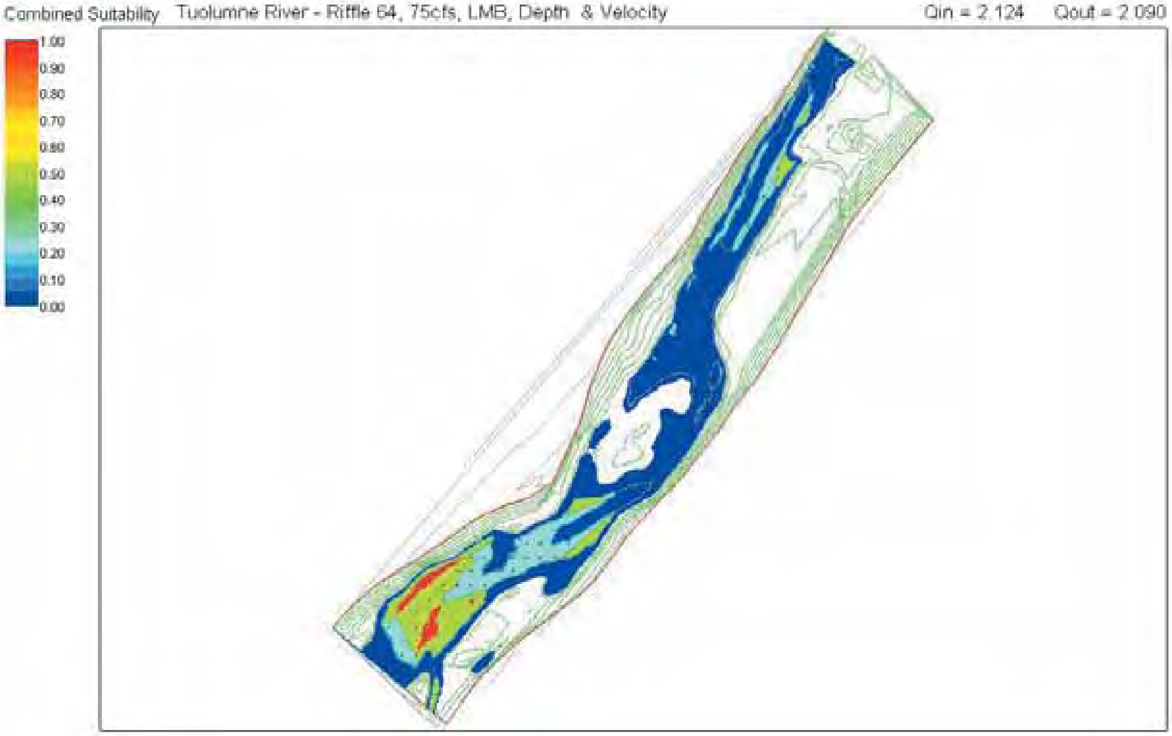

Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 3000cfs, Velocity Profile
Qin = 84.962
Qout = 84.945


Velocity
3.00
2.70
2.40
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
Tuolumne River, SRP9, Post Project, 5000cfs, Velocity Profile
Qin = 141.603
Qout = 141.602

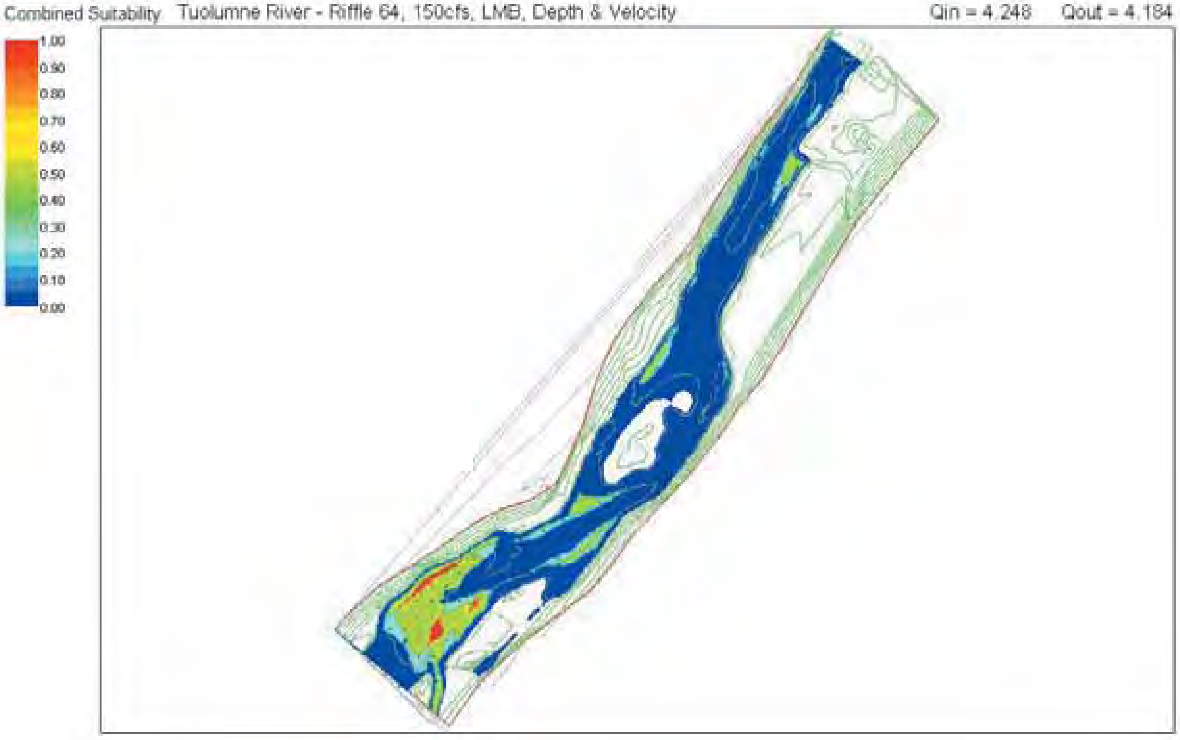
Appendix F

Predicted Largemouth Bass, Smallmouth Bass, and Chinook Salmon Habitat at Riffle 64.

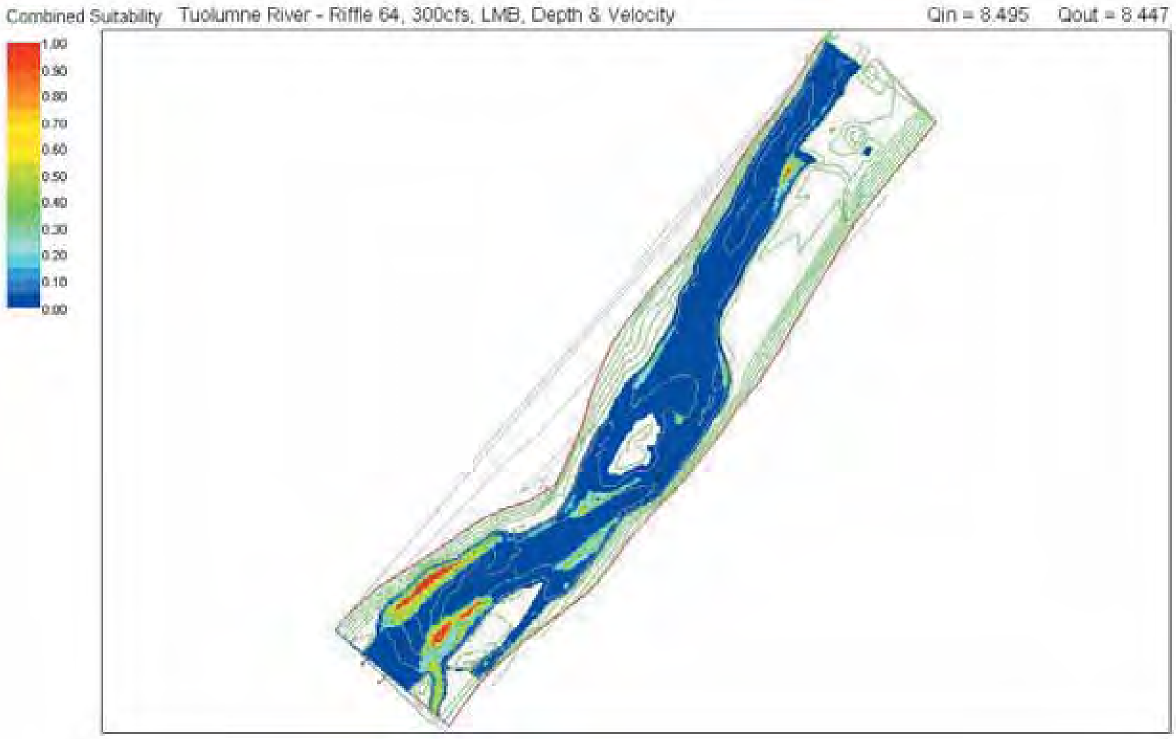

Combined Suitability
Tuolumne River - Riffle 64, 75cfs, LMB, Cover, Depth & Velocity
Qin = 2.124
Qout = 2.090
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, 75cfs, LMB, Depth & Velocity
Qin = 2.124
Qout = 2.090
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

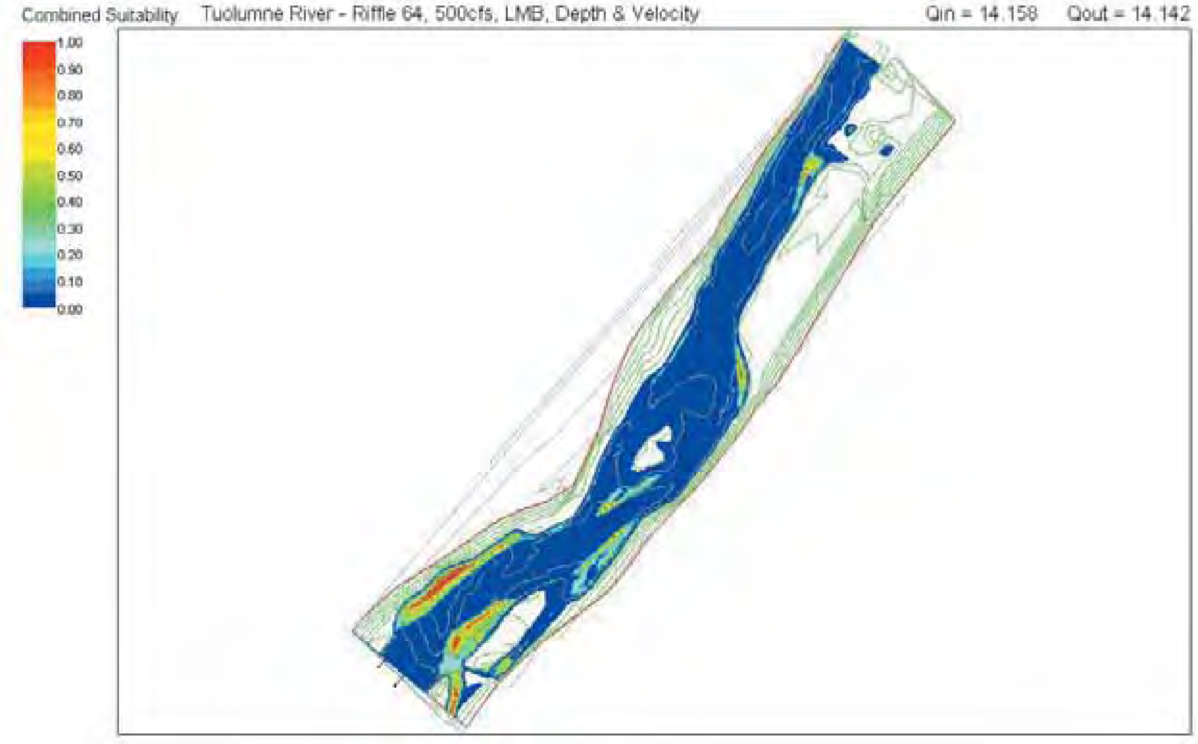

Combined Suitability
Tuolumne River - Riffle 64, 150cfs, LMB, Cover, Depth & Velocity
Qin = 4.248
Qout = 4.184
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

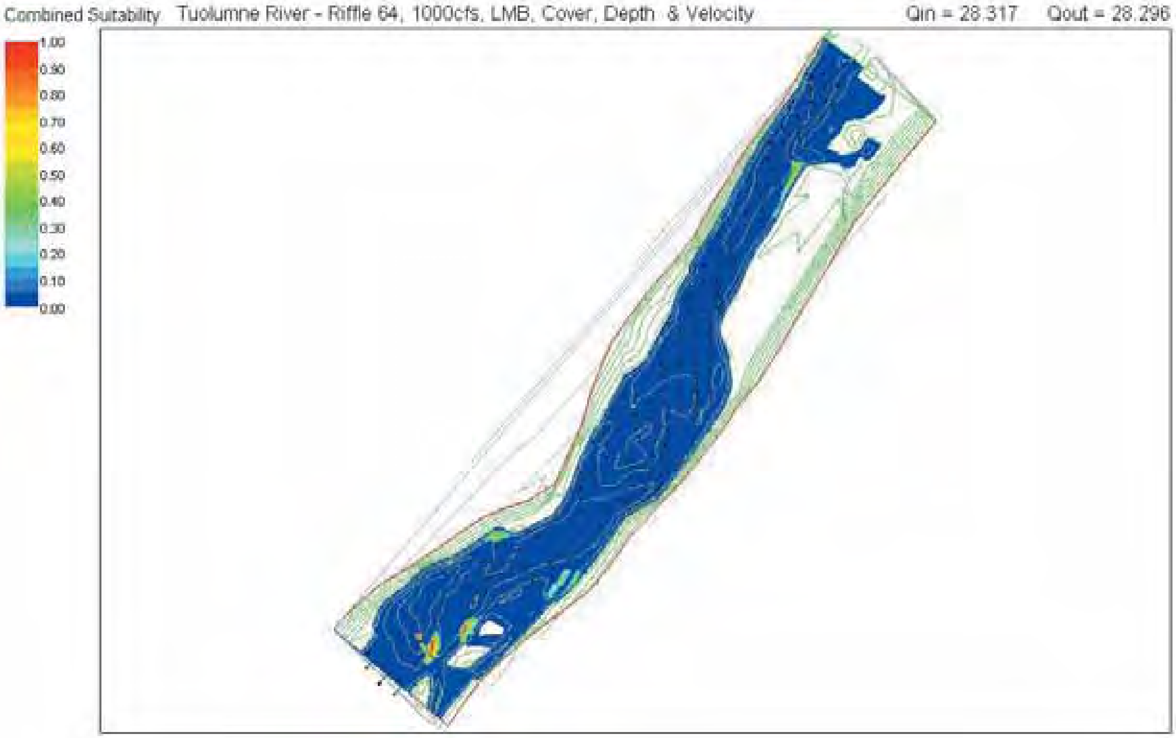

Combined Suitability
Tuolumne River - Riffle 64, 150cfs, LMB, Depth & Velocity
Qin = 4.248
Qout = 4.184
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

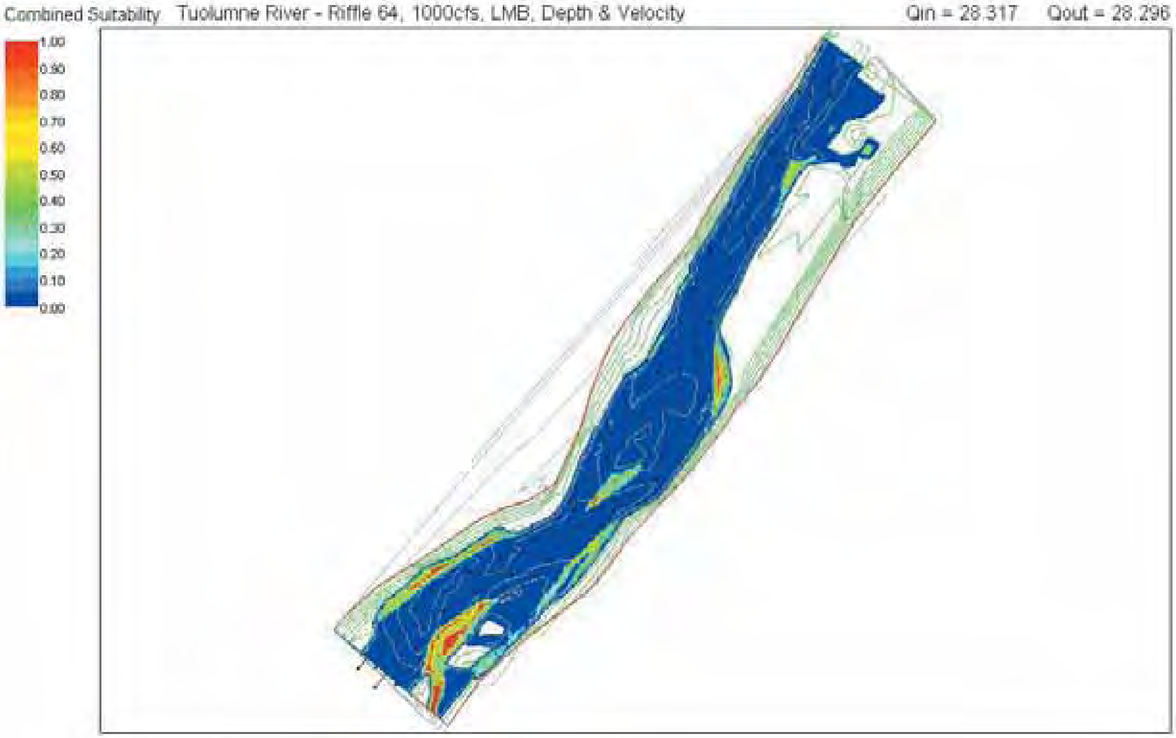

Combined Suitability
Tuolumne River - Riffle 64, 300cfs, LMB, Cover, Depth & Velocity
Qin = 8.495
Qout = 8.447
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

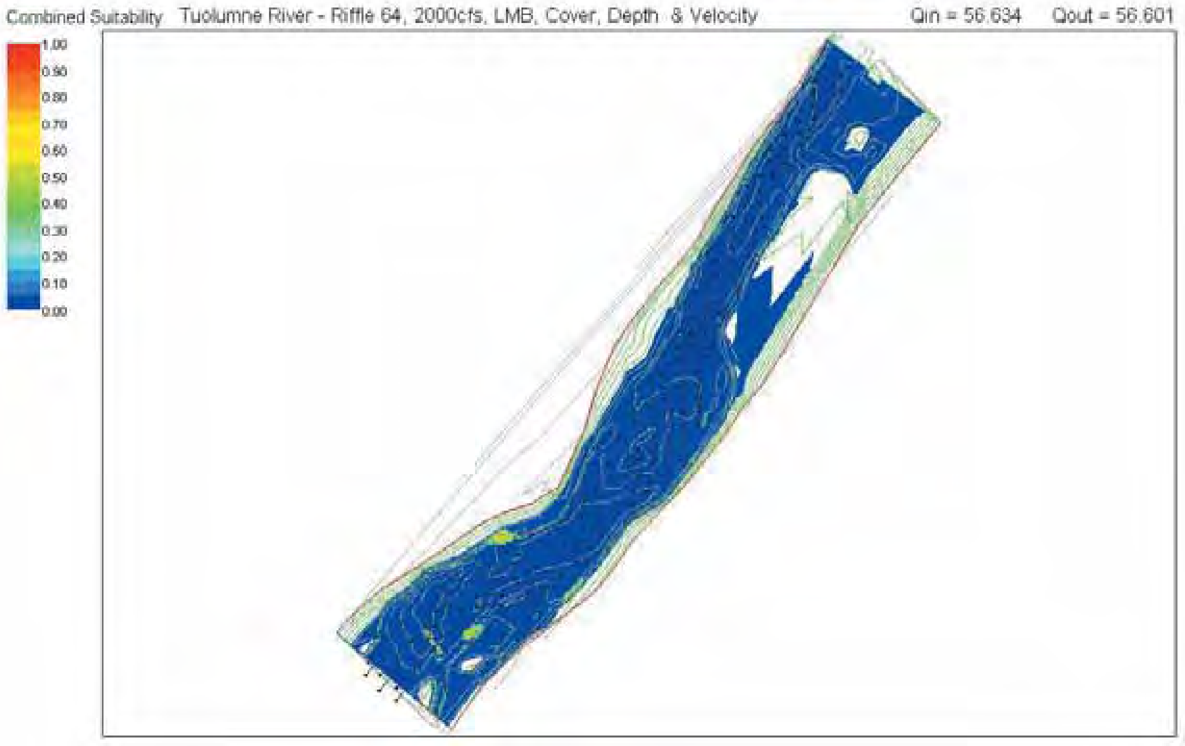

Combined Suitability
Tuolumne River - Riffle 64, 300cfs, LMB, Depth & Velocity
Qin = 8.495
Qout = 8.447
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

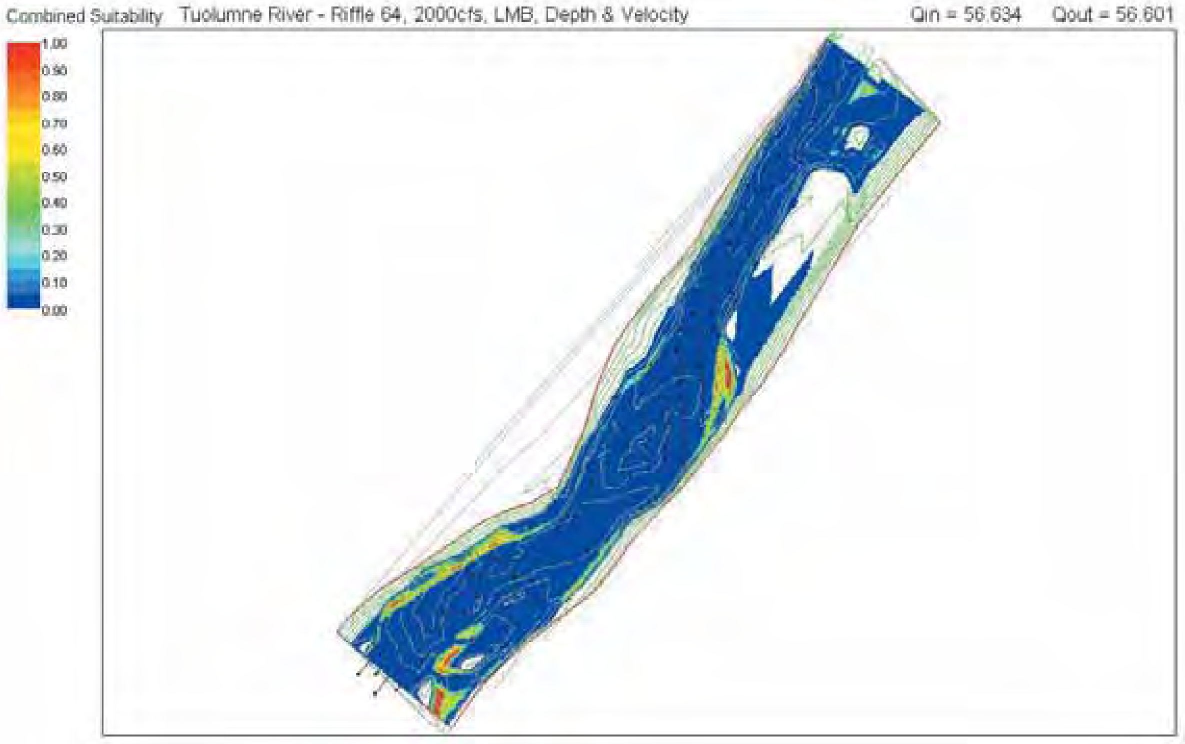

Combined Suitability
Tuolumne River - Riffle 64, 500cfs, LMB, Cover, Depth & Velocity
Qin = 14.158
Qout = 14.142
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

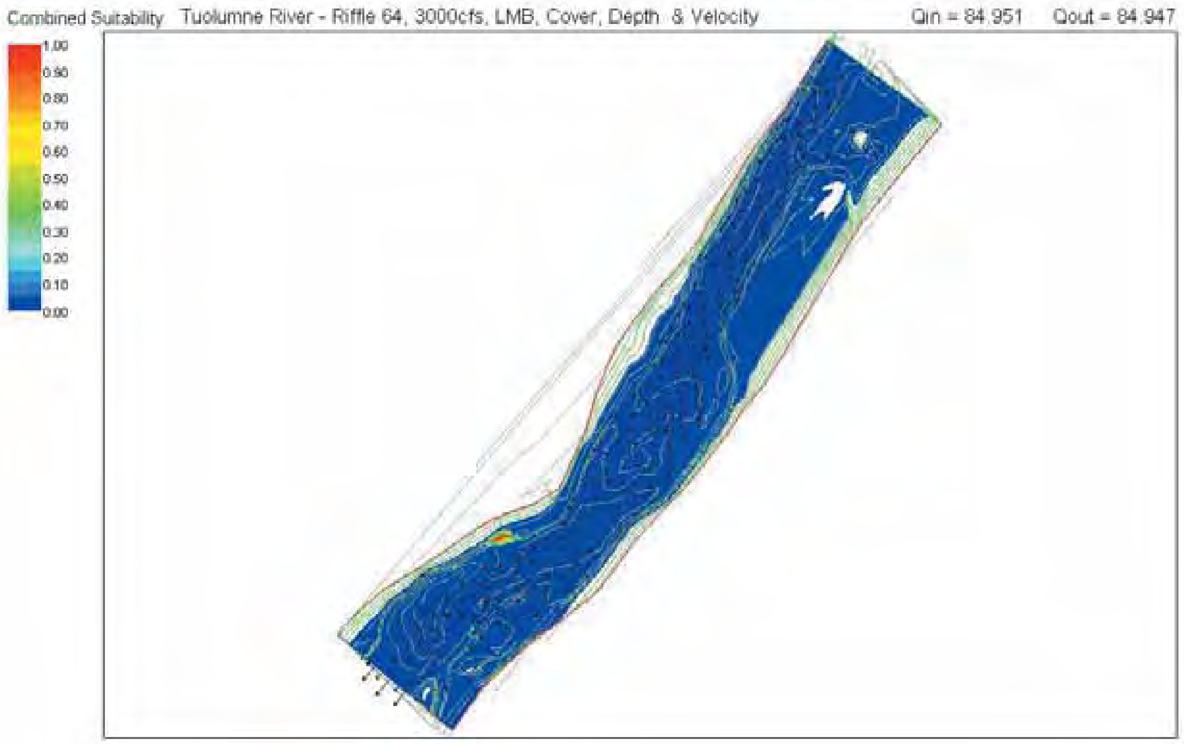

Combined Suitability
Tuolumne River - Riffle 64, 500cfs, LMB, Depth & Velocity
Qin = 14.158
Qout = 14.142
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

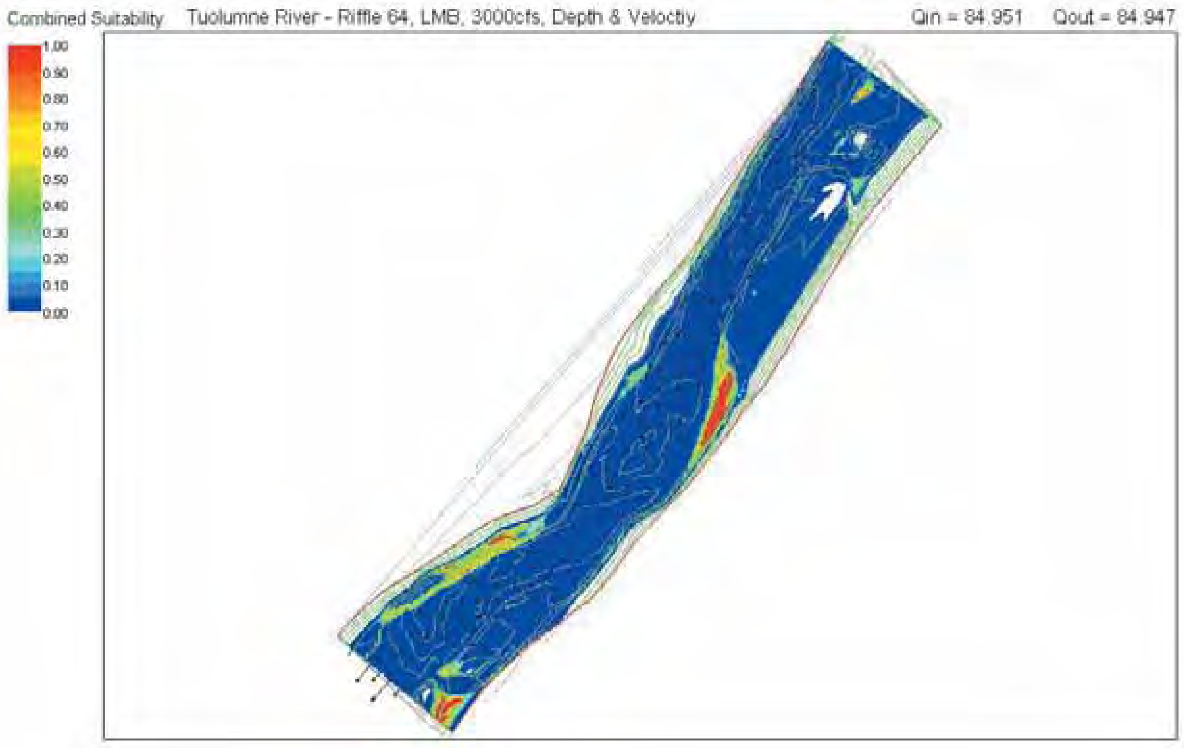

Combined Suitability
Tuolumne River - Riffle 64, 1000cfs, LMB, Cover, Depth & Velocity
Qin = 28.317
Qout = 28.296
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

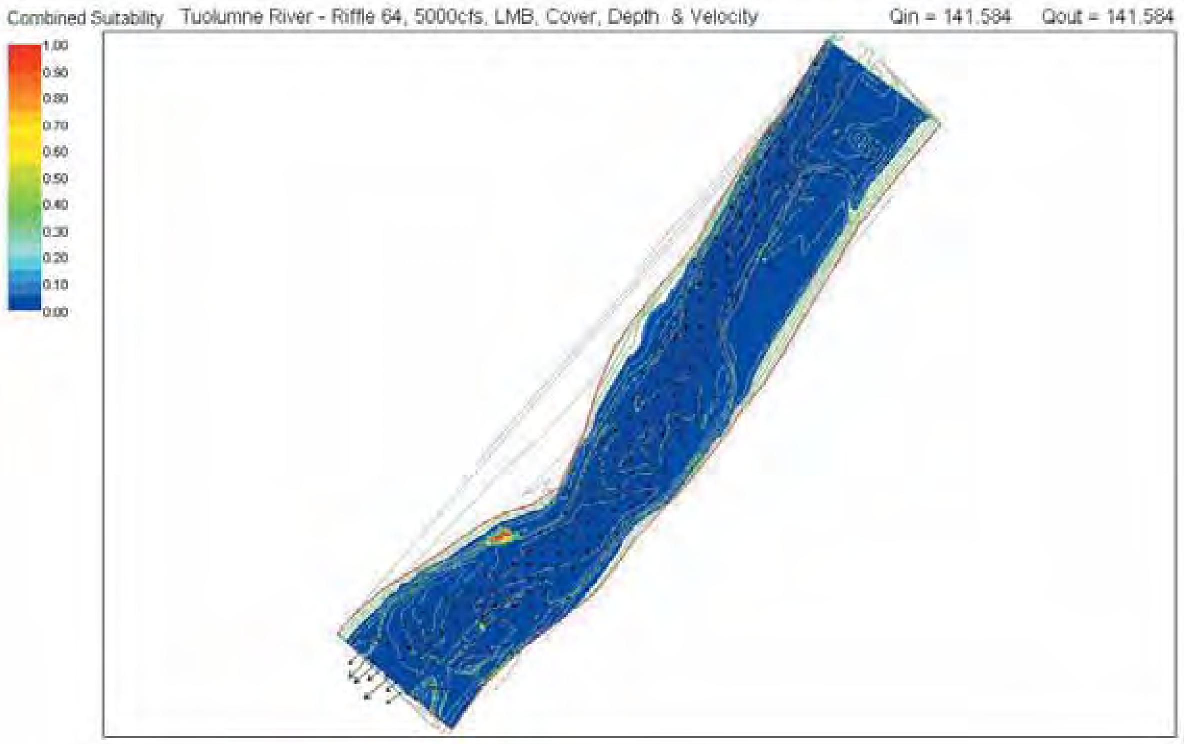

Combined Suitability
Tuolumne River - Riffle 64, 1000cfs, LMB, Depth & Velocity
Qin = 28.317
Qout = 28.296
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

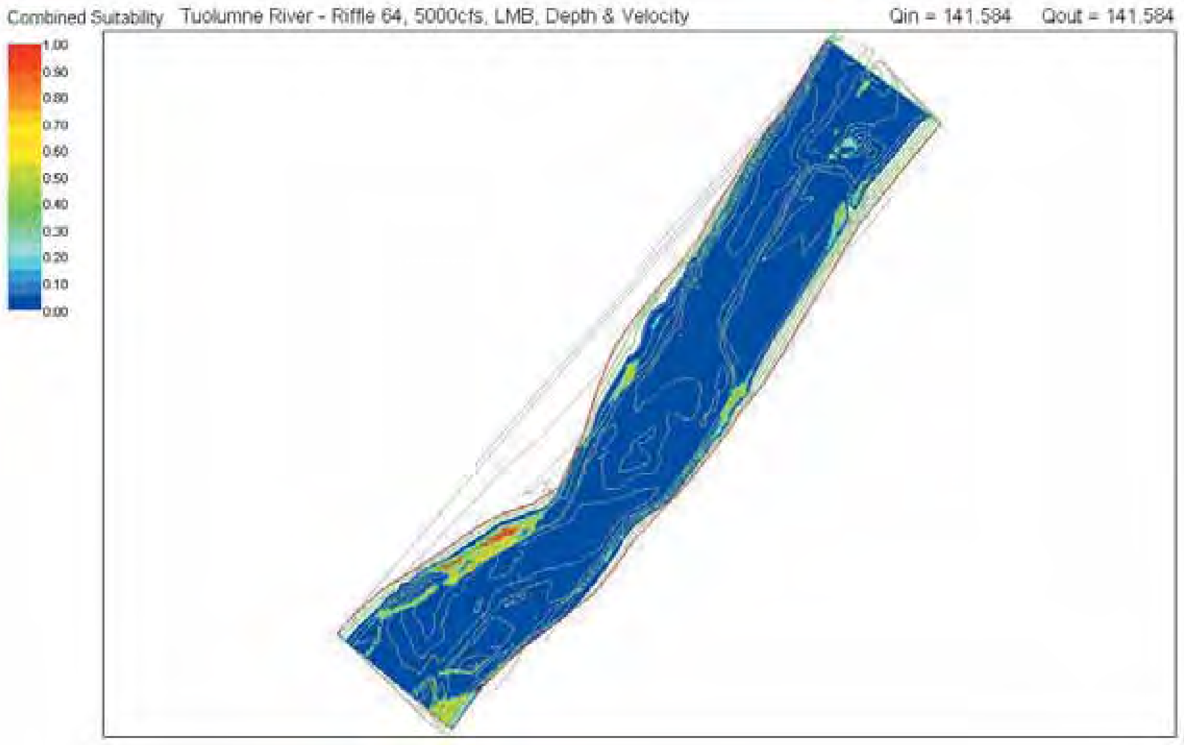

Combined Suitability
Tuolumne River - Riffle 64, 2000cfs, LMB, Cover, Depth & Velocity
Qin = 56.634
Qout = 56.601
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, 2000cfs, LMB, Depth & Velocity
Qin = 56.634
Qout = 56.601
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

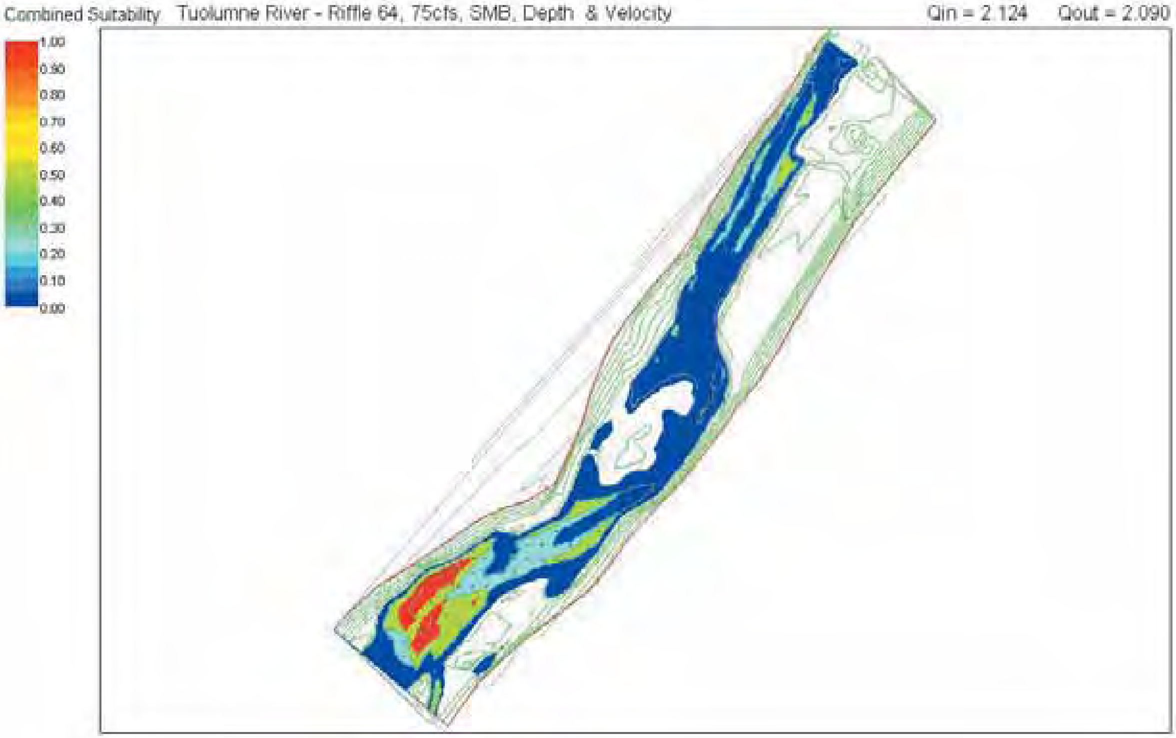

Combined Suitability
Tuolumne River - Riffle 64, 3000cfs, LMB, Cover, Depth & Velocity
Qin = 84.951
Qout = 84.947
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, LMB, 3000cfs, Depth & Velocity
Qin = 84.951
Qout = 84.947
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

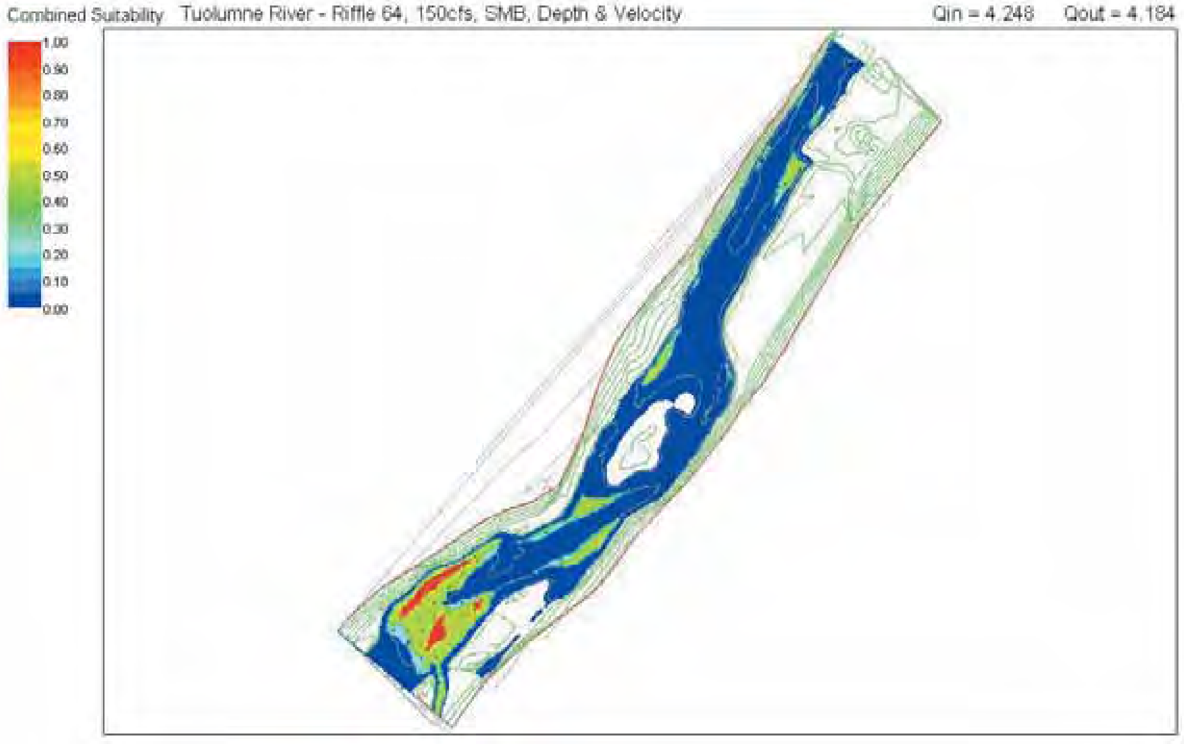

Combined Suitability
Tuolumne River - Riffle 64, 5000cfs, LMB, Cover, Depth & Velocity
Qin = 141.584
Qout = 141.584
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, 5000cfs, LMB, Depth & Velocity
Qin = 141.584
Qout = 141.584
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

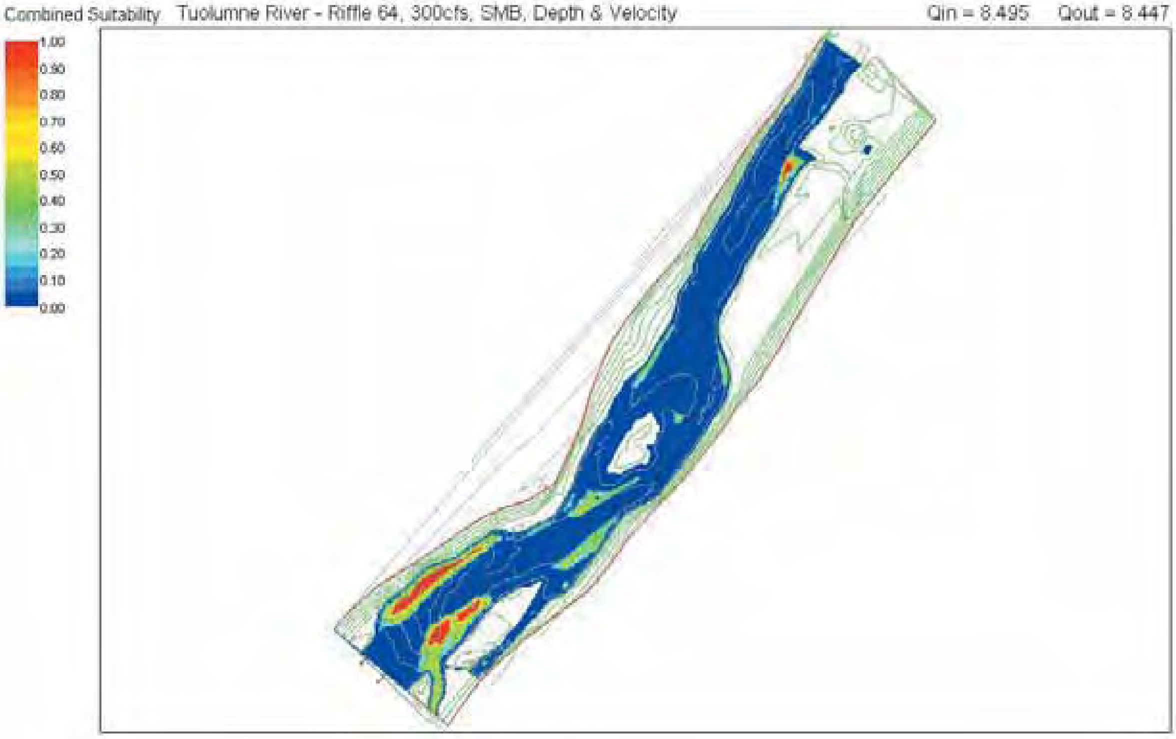

Combined Suitability
Tuolumne River - Riffle 64, 75cfs, SMB, Cover, Depth & Velocity
Qin = 2.124
Qout = 2.090
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

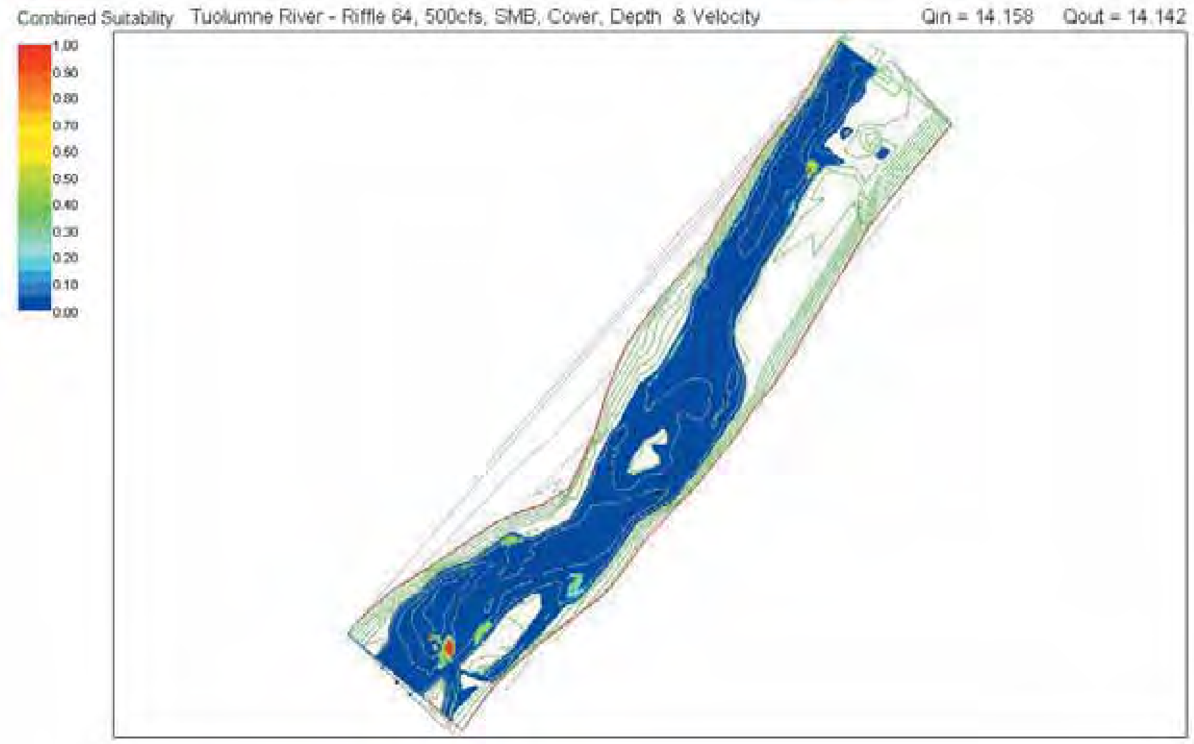

Combined Suitability
Tuolumne River - Riffle 64, 75cfs, SMB, Depth & Velocity
Qin = 2.124
Qout = 2.090
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

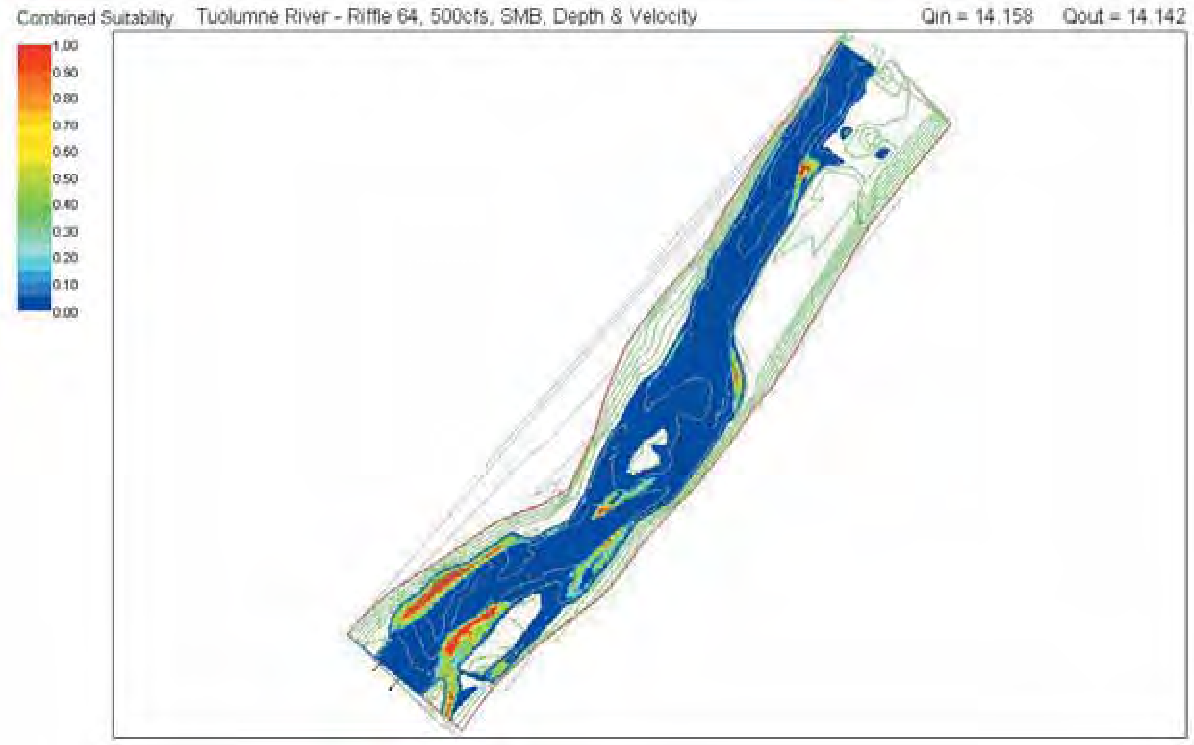

Combined Suitability
Tuolumne River - Riffle 64, 150cfs, SMB, Cover, Depth & Velocity
Qin = 4.248
Qout = 4.184
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

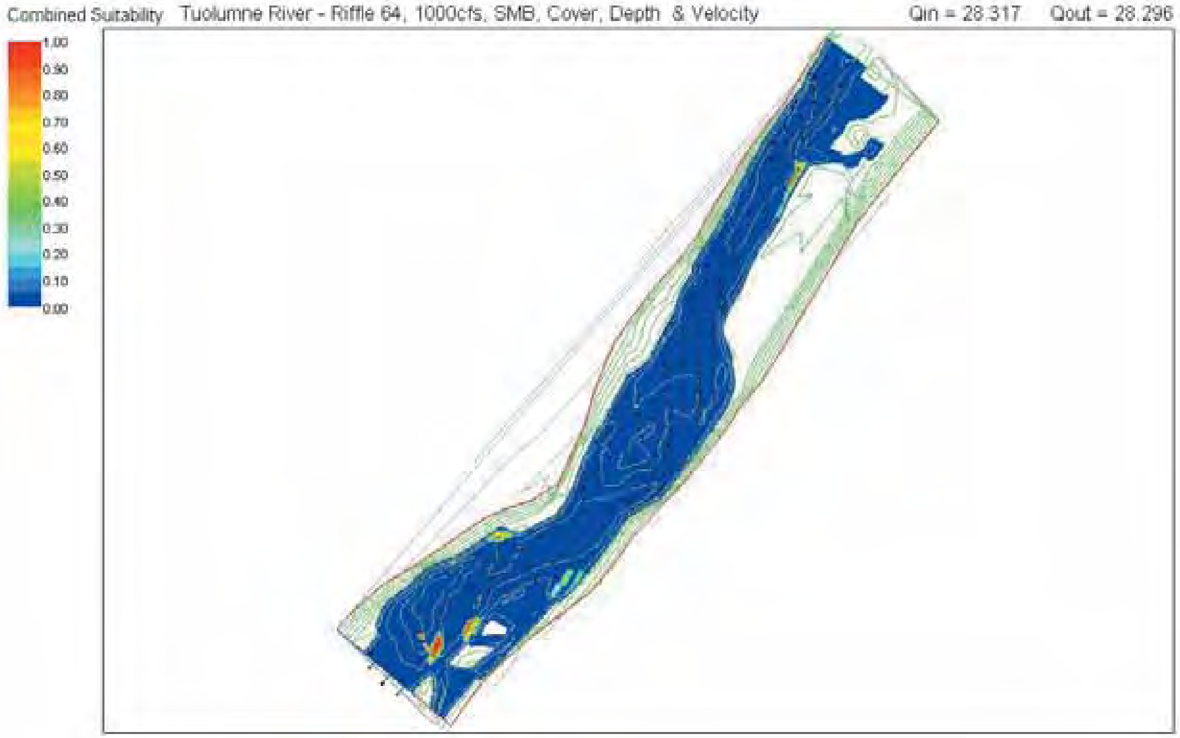

Combined Suitability
Tuolumne River - Riffle 64, 150cfs, SMB, Depth & Velocity
Qin = 4.248
Qout = 4.184
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

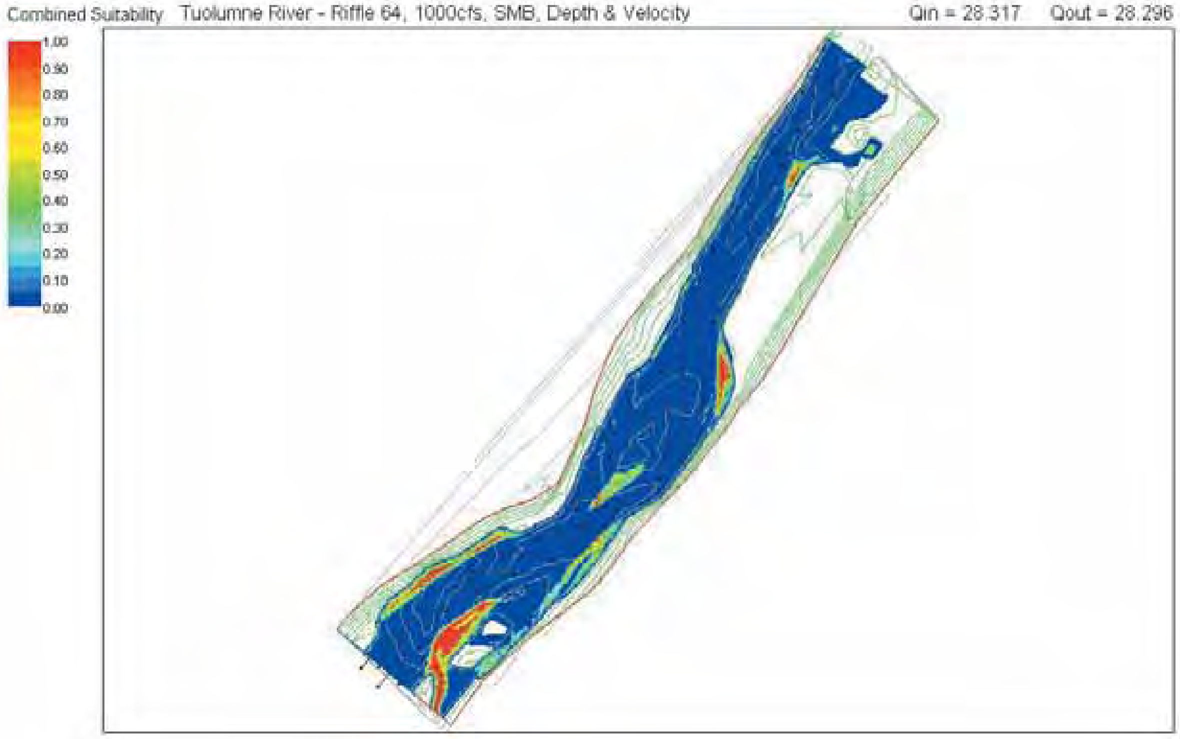

Combined Suitability
Tuolumne River - Riffle 64, 300cfs, SMB, Cover, Depth & Velocity
Qin = 8.495
Qout = 8.447
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

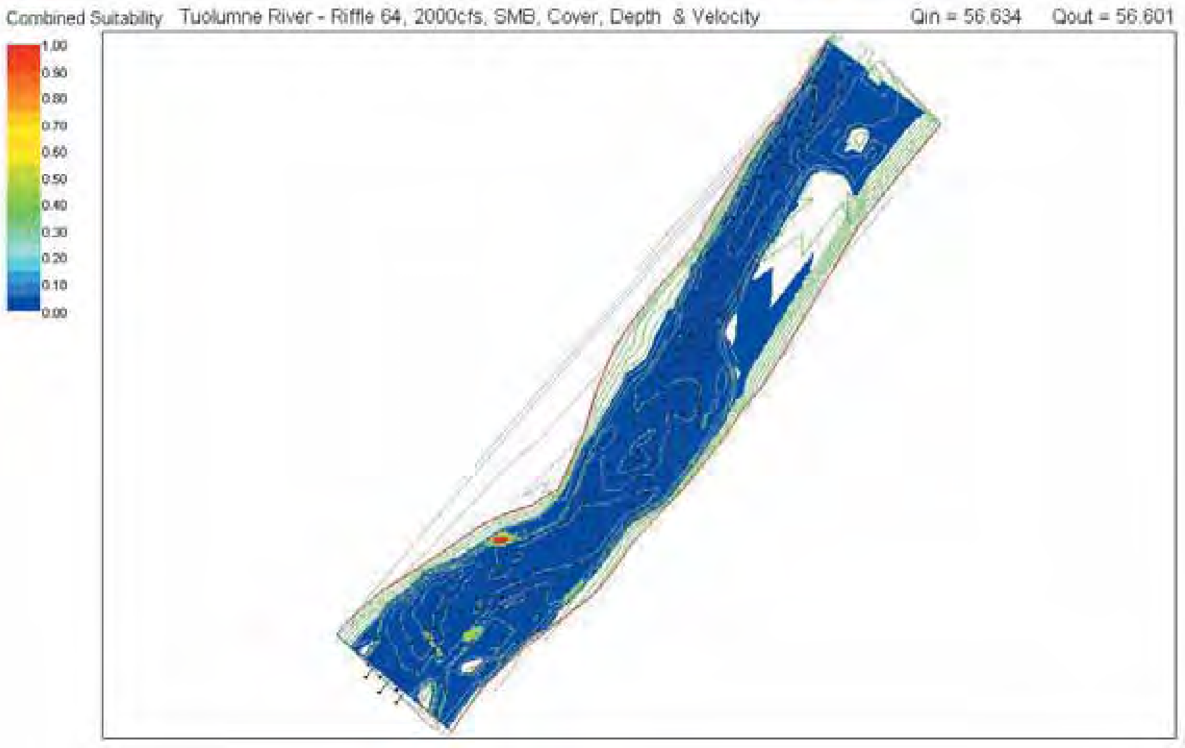

Combined Suitability
Tuolumne River - Riffle 64, 300cfs, SMB, Depth & Velocity
Qin = 8.495
Qout = 8.447
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

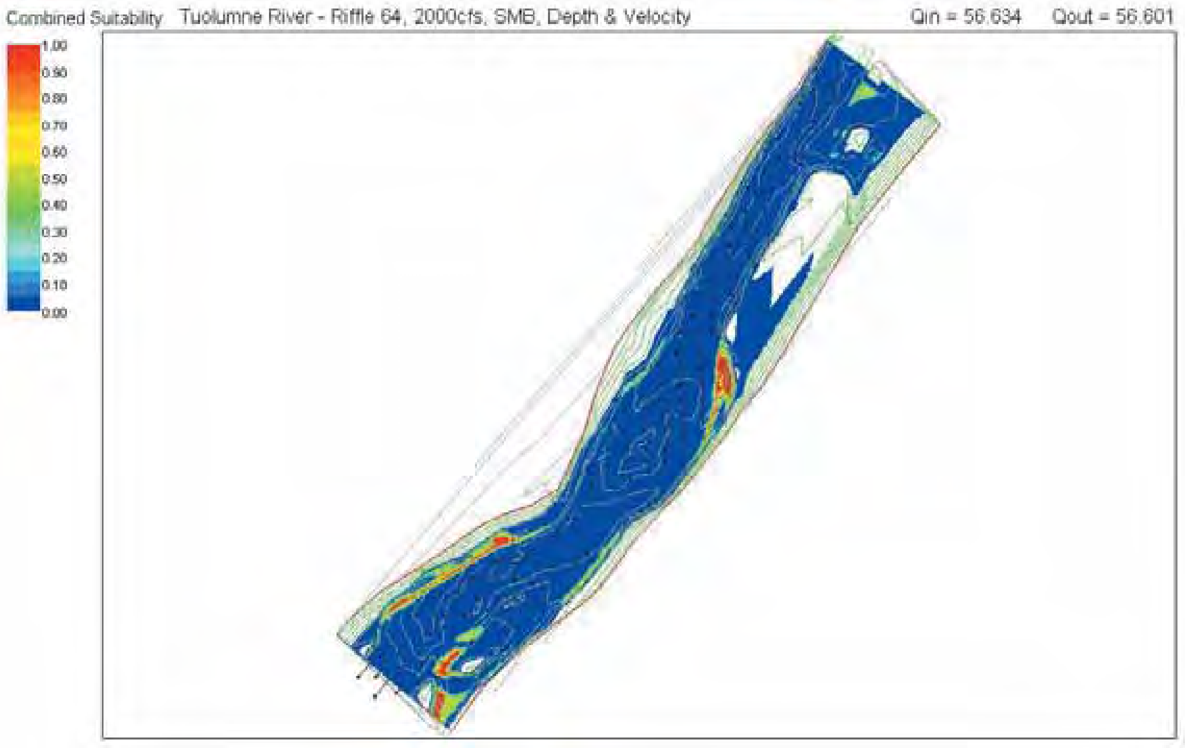

Combined Suitability
Tuolumne River - Riffle 64, 500cfs, SMB, Cover, Depth & Velocity
Qin = 14.158
Qout = 14.142
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

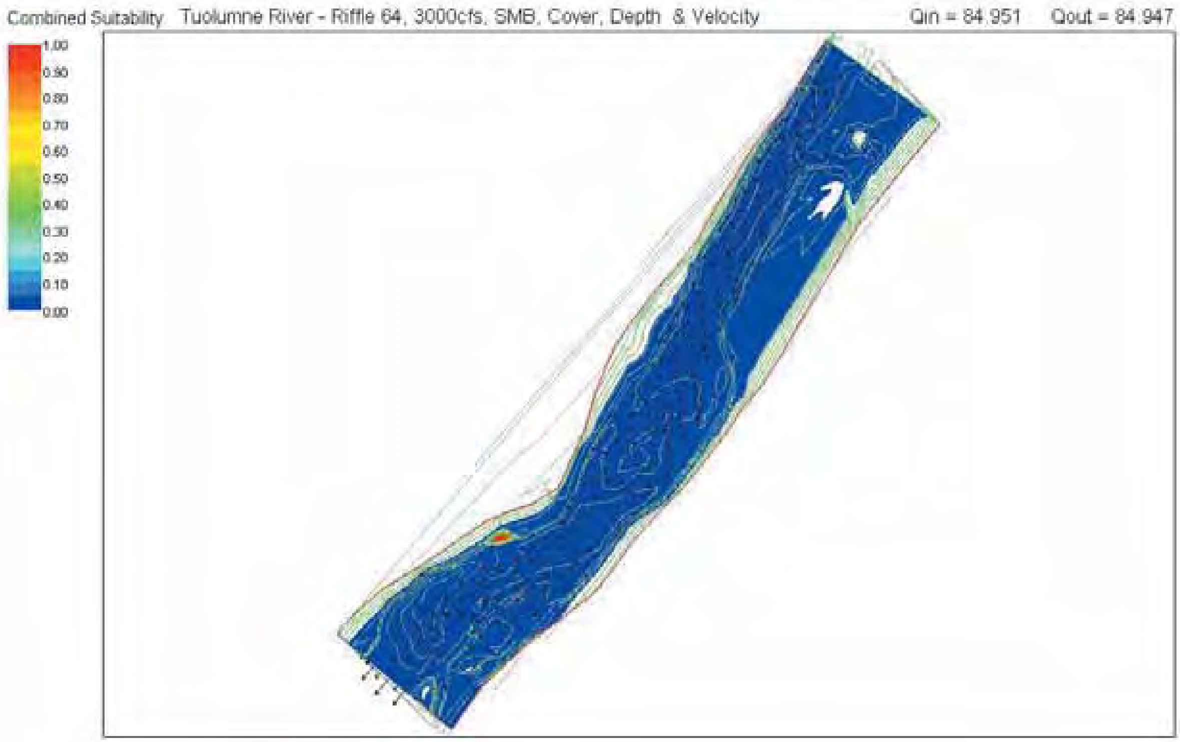

Combined Suitability
Tuolumne River - Riffle 64, 500cfs, SMB, Depth & Velocity
Qin = 14.158
Qout = 14.142
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

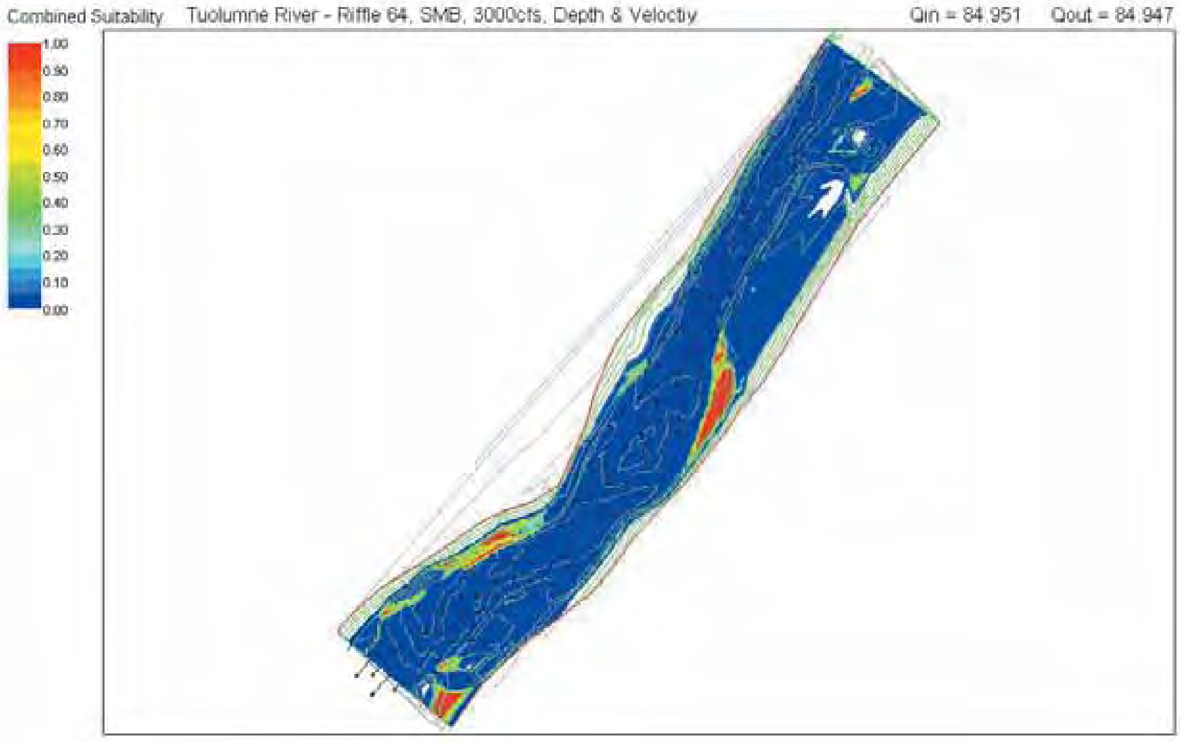

Combined Suitability
Tuolumne River - Riffle 64, 1000cfs, SMB, Cover, Depth & Velocity
Qin = 28.317
Qout = 28.296
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, 1000cfs, SMB, Depth & Velocity
Qin = 28.317
Qout = 28.296
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, 2000cfs, SMB, Cover, Depth & Velocity
Qin = 56.634
Qout = 56.601
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, 2000cfs, SMB, Depth & Velocity
Qin = 56.634
Qout = 56.601
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Riffle 64, 3000cfs, SMB, Cover, Depth & Velocity
Qin = 84.951
Qout = 84.947
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00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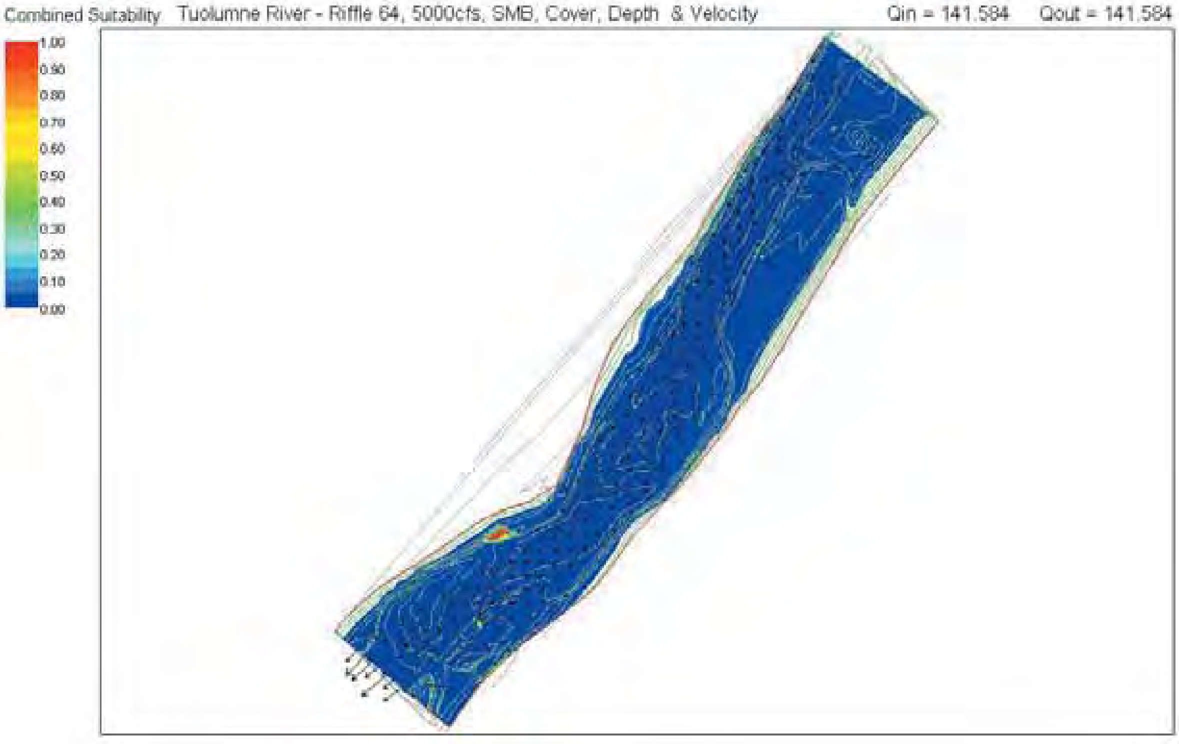
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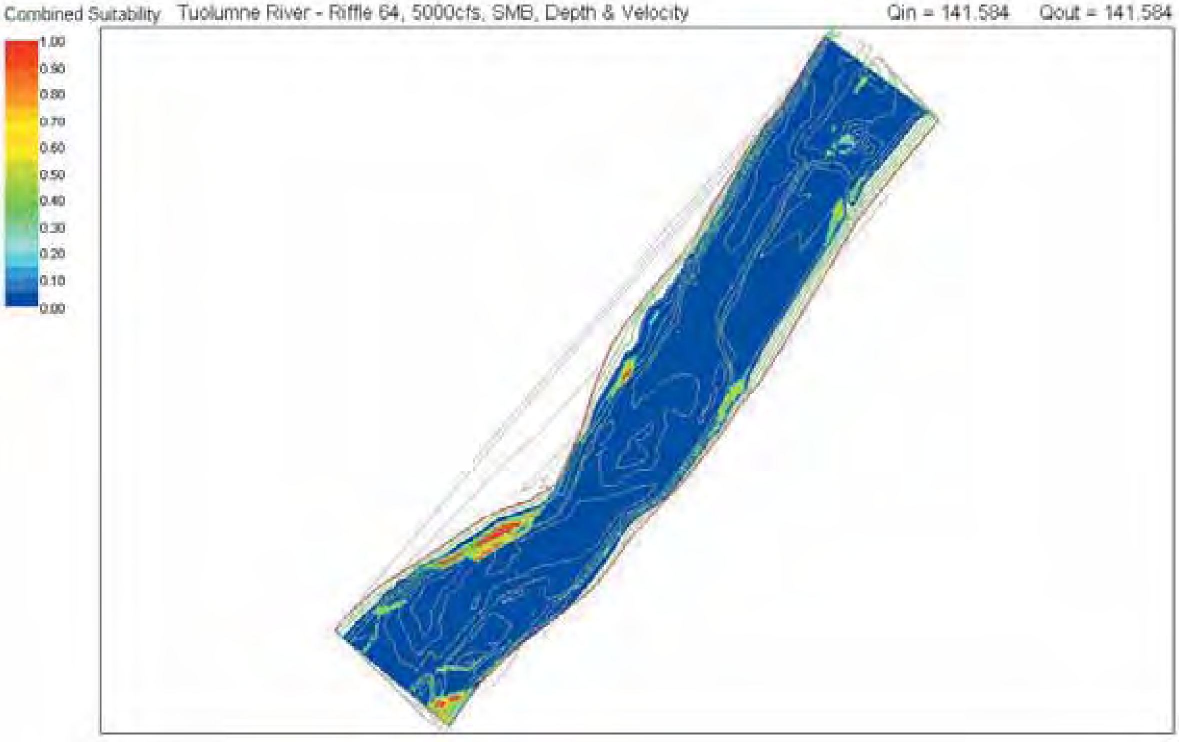
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0.80
0.70
0.60
0.50
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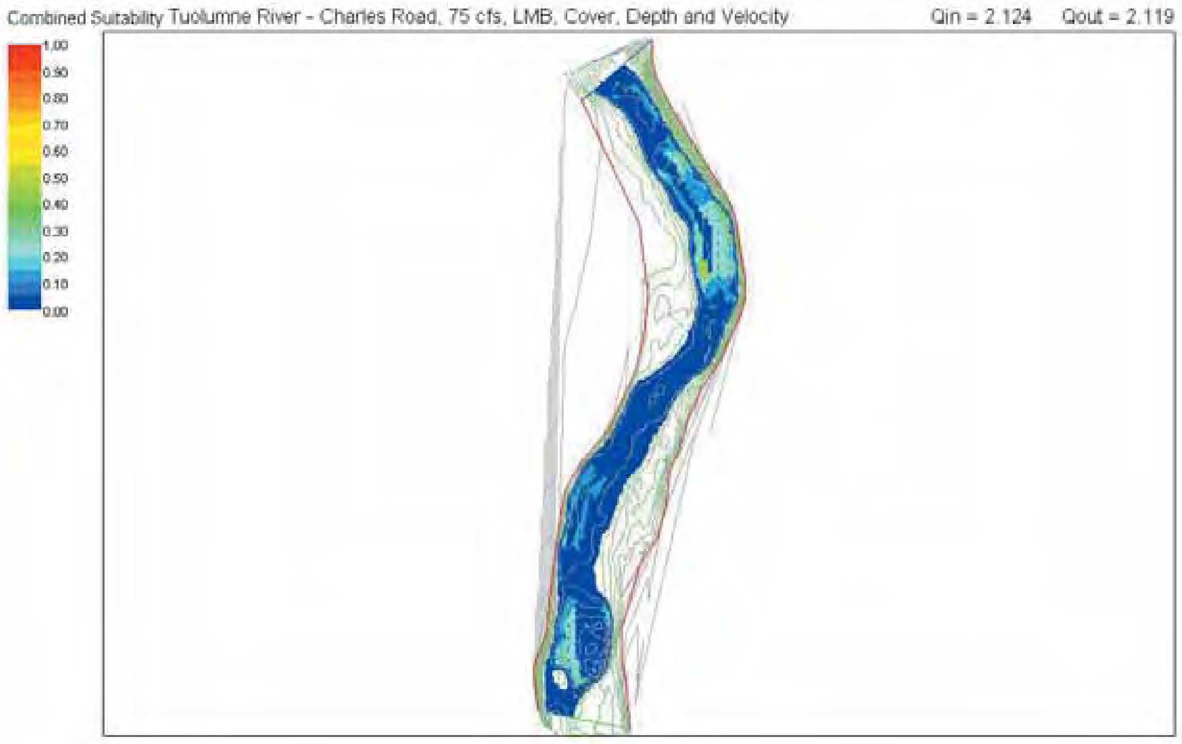
0.20
0.10
0.00

Appendix G

Predicted Largemouth Bass, Smallmouth Bass, and Chinook Salmon Habitat at Charles Road.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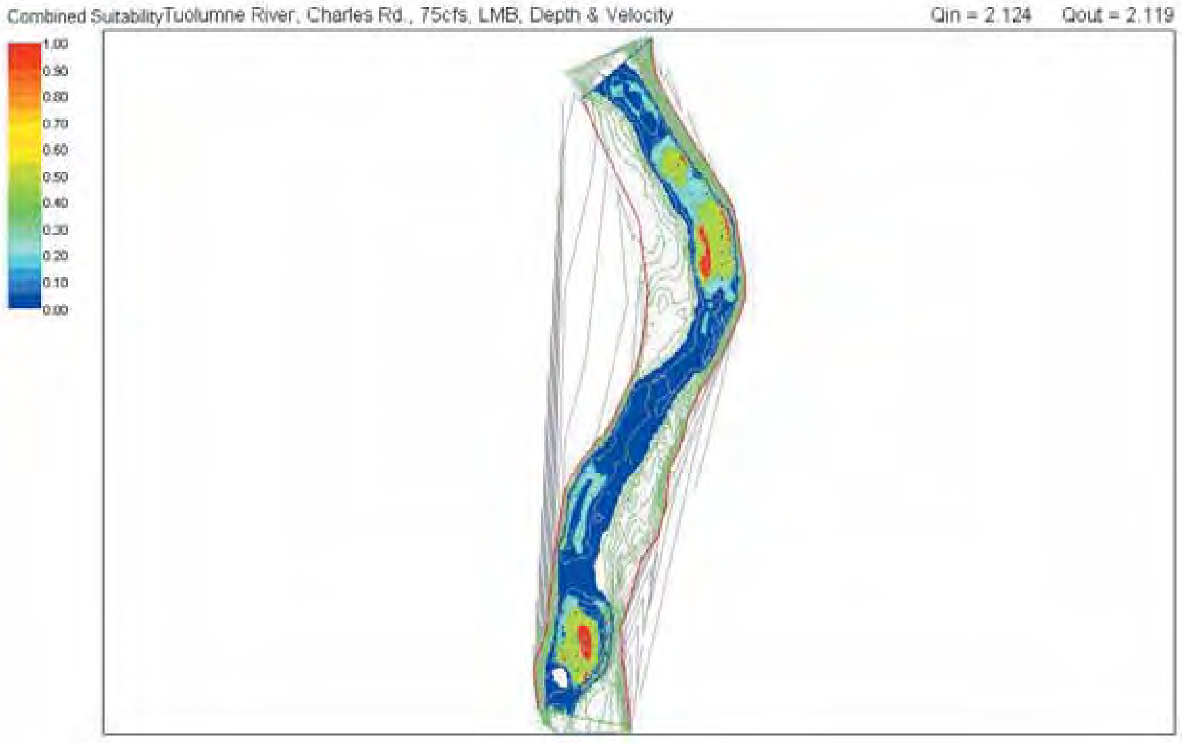
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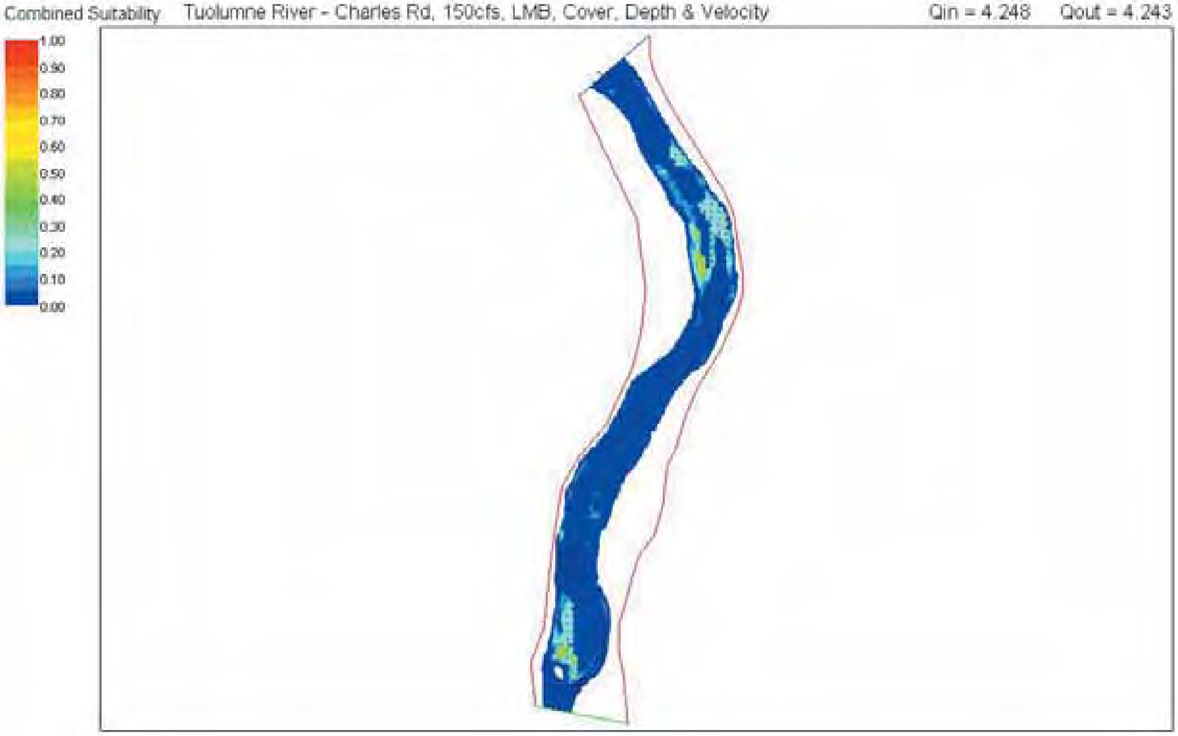
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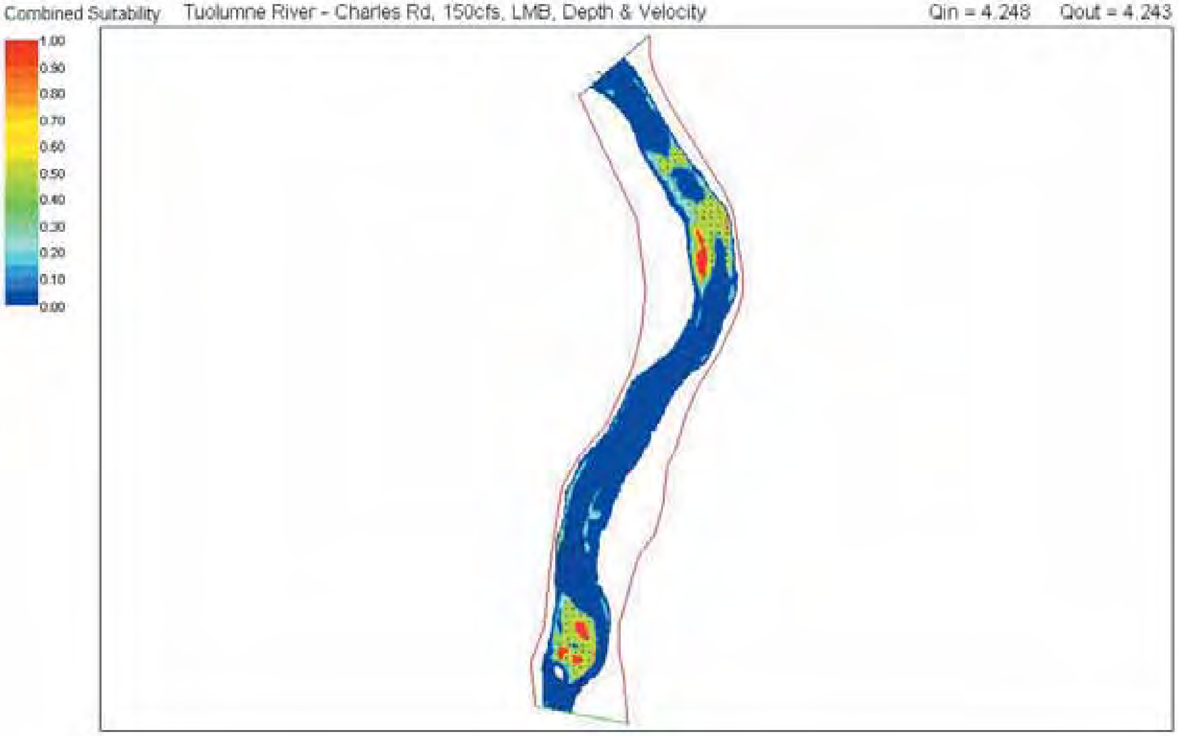
0.00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0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Charles Rd, 300cfs, LMB, Cover, Depth & Velocity
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0.70
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0.40
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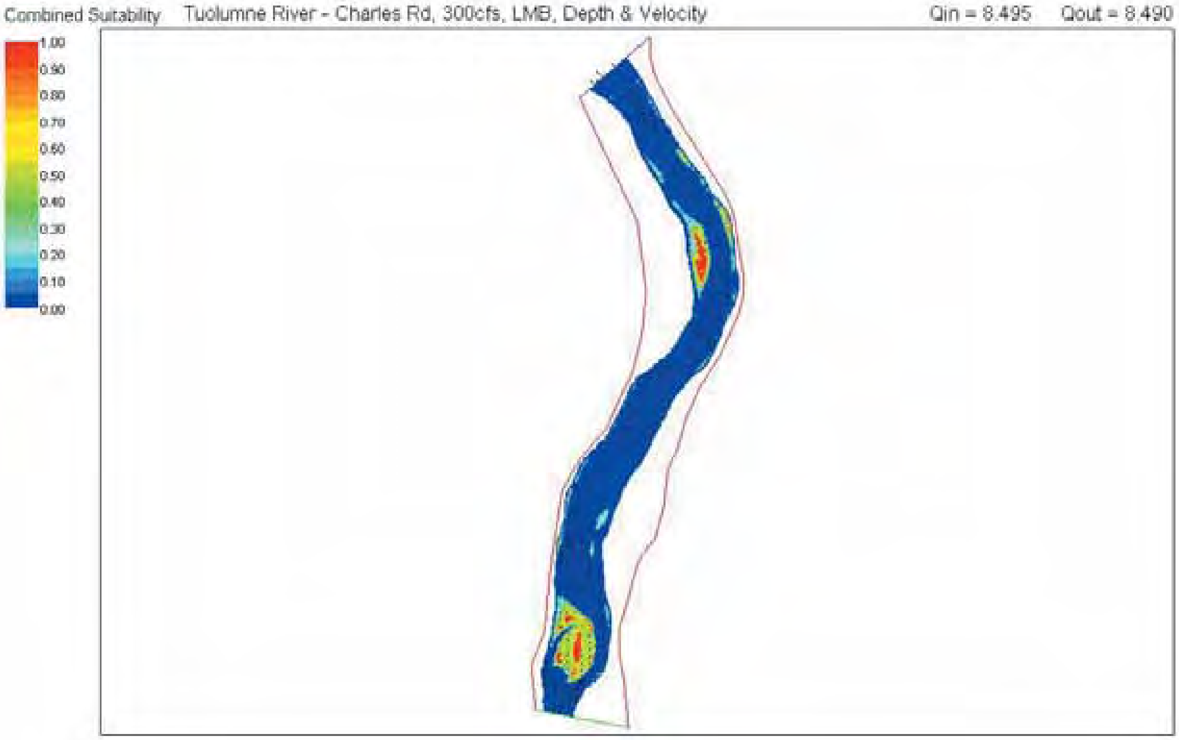
0.20
0.10
0.00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0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Charles Rd, 500cfs, LMB, Cover, Depth & Velocity
Qin = 14.158
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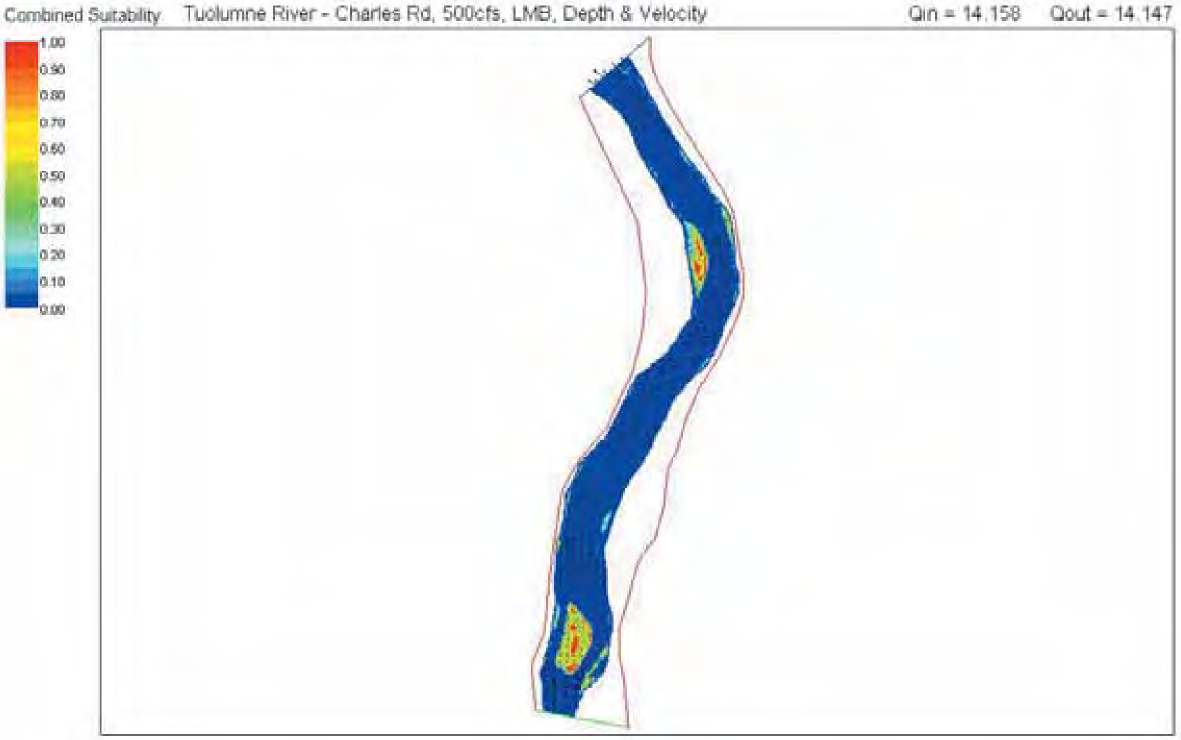
0.00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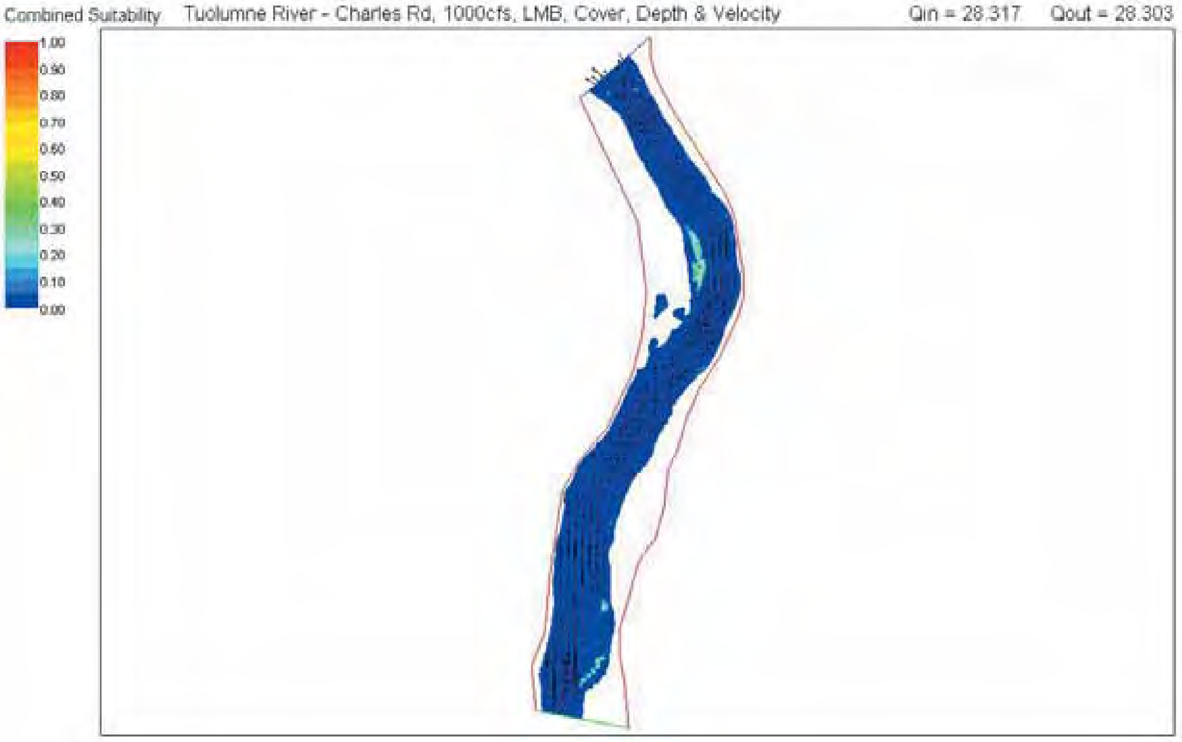
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0.70
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0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Charles Rd, 1000cfs, LMB, Depth & Velocity
Qin = 28.317
Qout = 28.303
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0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability Tuolumne River, Charles Rd., 2000cfs, LMB, Cover, Depth & Velocity
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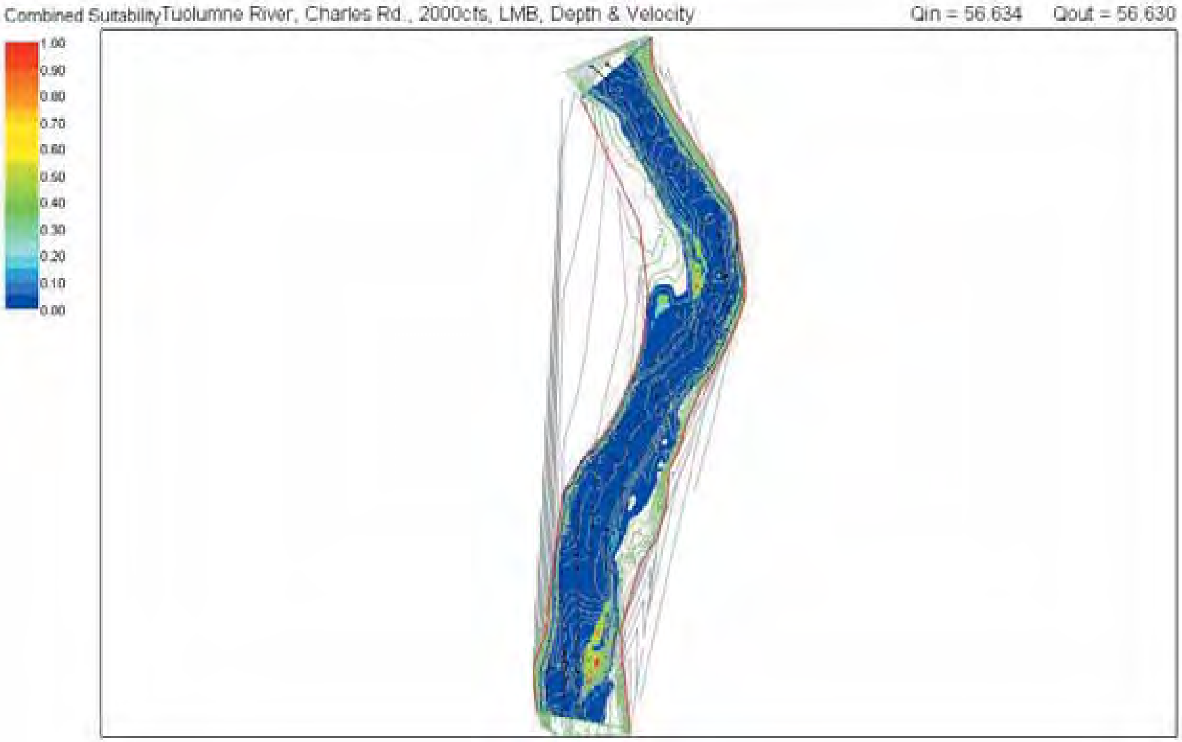
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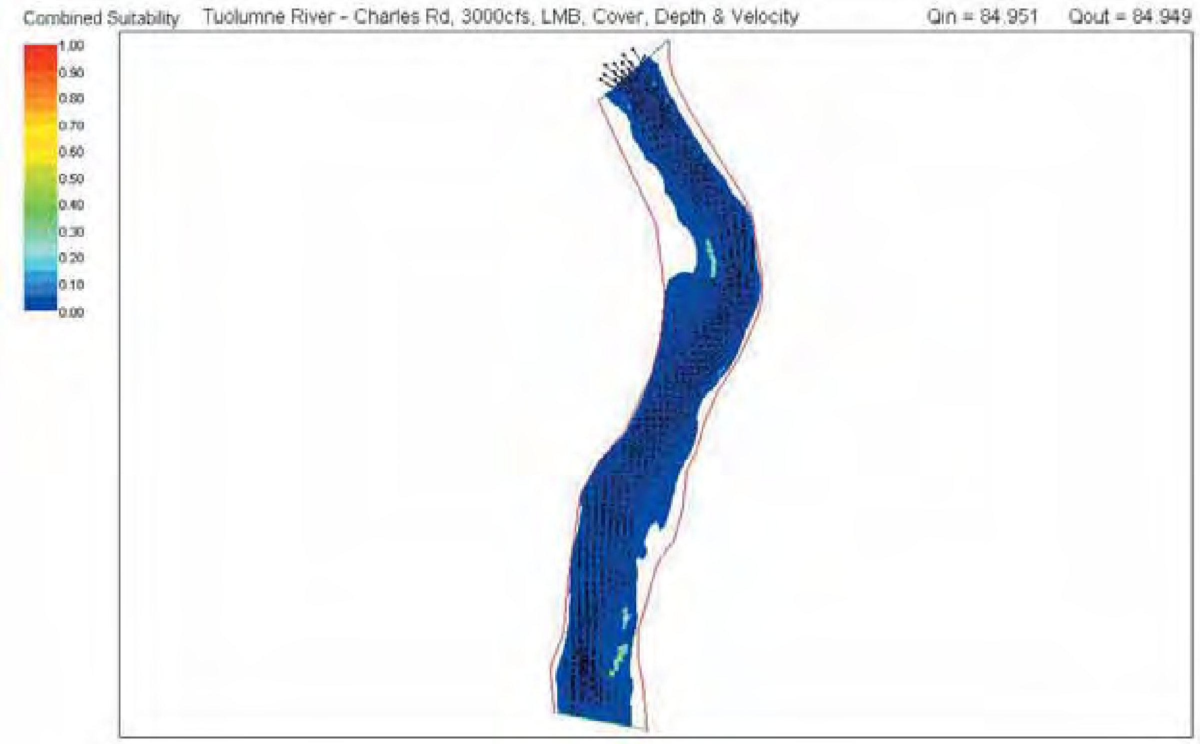
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0.40
0.30
0.20
0.10
0.00


Combined Suitability
Tuolumne River - Charles Rd, 3000cfs, LMB, Depth & Velocity
Qin = 84.951
Qout = 84.949
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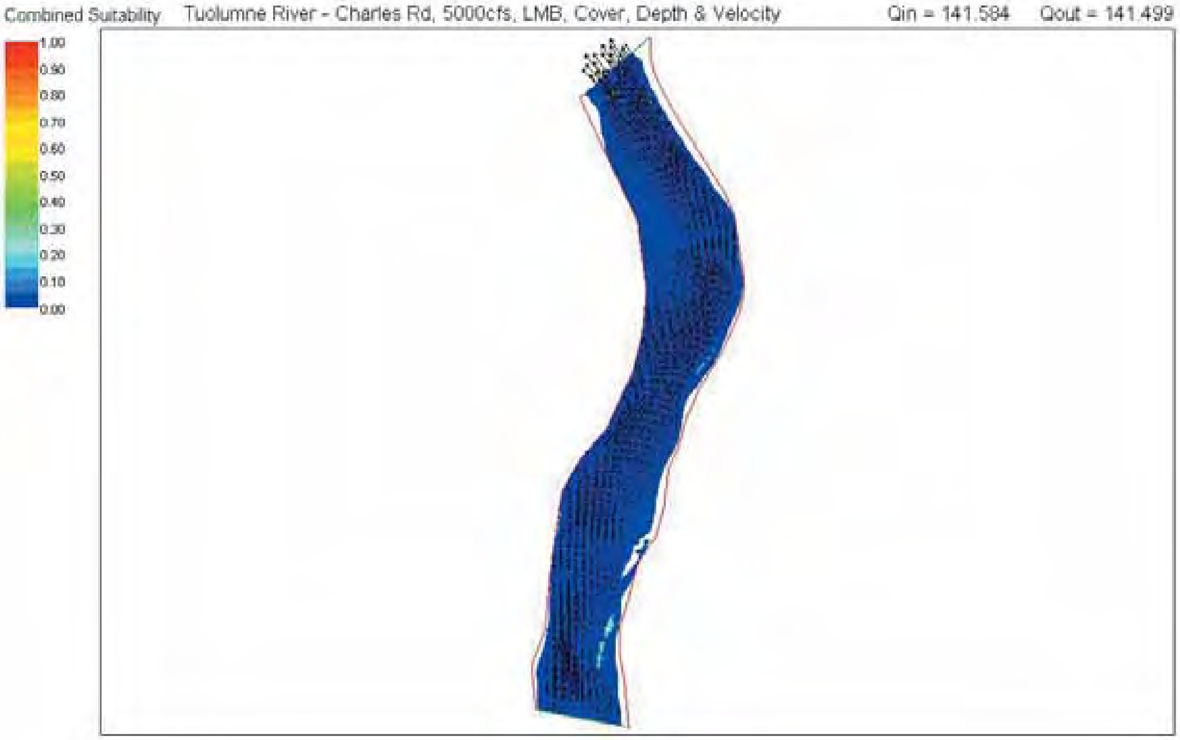
Combined Suitability
Tuolumne River - Charles Rd, 5000cfs, LMB, Cover, Depth & Velocity
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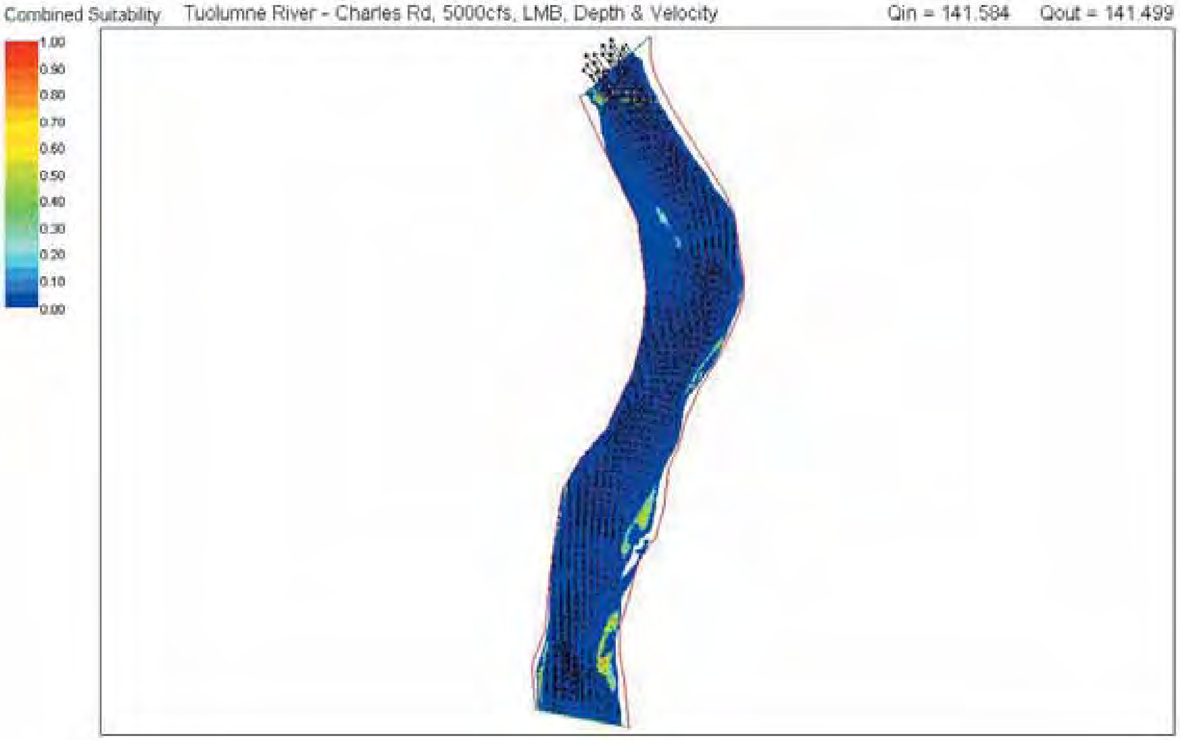
0.00


Combined Suitability
Tuolumne River - Charles Rd, 5000cfs, LMB, Depth & Velocity
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Qout = 141.499
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

Appendix H

Draft Monitoring Plan

TUOLUMNE RIVER SPECIAL RUN POOLS 9 & 10 AND GRAVEL MINING REACH RESTORATION PROJECTS

---DRAFT MONITORING PLAN---

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and

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Prepared for:
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Turlock, CA 95381

March 1998

TABLE OF CONTENTS

1. PURPOSE AND NEEDS

This monitoring plan describes methods to evaluate the SRP 9, SRP 10, and Gravel Mining Reach restoration projects on the Tuolumne River. The plan recommends monitoring objectives and proposes field techniques, data management and analysis protocols, budget and funding needs, and an example timeline for implementing the monitoring plan. The plan is a culmination of ideas and efforts originally formulated by the Monitoring Subcommittee of the Tuolumne River Technical Advisory Committee (TRTAC) and is provided to accompany the CEQA/NEPA documents and permit applications for the restoration projects. Several important issues were considered when selecting the proposed monitoring protocols, including: (1) how to interpret the effectiveness of specific restoration actions, (2) appropriate target species and life stages capable of elucidating expected population responses, (3) integrating project-specific monitoring proposals into existing river-wide programs or other requirements with similar objectives or methods, (4) specific requirements of environmental permits and mitigation monitoring, and (5) funding source requirements.

The monitoring plan is designed to evaluate two important aspects of the restoration projects: first, to test whether stated project objectives have been met, and to guide future restoration design (project performance), and second, to evaluate success of the mitigation measures (mitigation success). Project performance monitoring is organized into three sections: fluvial geomorphic processes, fisheries resources and riparian resources. Where possible, the restoration objectives and associated hypotheses for each section were stated with enough specificity that they could be related to the proposed monitoring objectives. Because some of the hypothesized benefits of the restoration projects are predicated on assumptions of salmonid limiting factors (e.g., bass predation), we propose testing specific hypotheses in the monitoring phase of these projects. Using a hypothesis-based approach for some aspects of the monitoring program, we will generate information that will guide future project design and selection (adaptive management).

The monitoring plan attempts to meet CEQA/NEPA requirements, and integrate with the FERC Settlement Agreement (FSA), the CVPIA- AFRP and CAMP programs, and the CALFED program. Monitoring data will be collected and analyzed according to standardized techniques and stored in a common database, under the purview of either TID, USFWS-AFRP or CAMP, or CALFED'S CMARP program. The data will be reviewed by technical personnel and published annually in reports submitted to resource and funding agencies, and will emphasize data interpretation and adaptive recommendations. Because some of the monitoring approaches are considered experimental, modification of technique or approach may occur after the first year of monitoring, especially for some of the proposed fisheries techniques.

The restoration projects are scheduled for implementation over several years, beginning in summer/fall of 1998 and continuing through 2002 (assuming all funding needs are provided). The monitoring plan assumes project implementation will follow the proposed schedule, but can be adapted to changes in the implementation schedule. Because the reconstructed channel morphology may respond to high discharge events by adjusting channel dimensions, several geomorphic monitoring protocols are triggered by exceedence of discharge thresholds. Field experience in 1987-1992 on the Tuolumne River showed that geomorphic monitoring during drought years (or years without significant flow events) is unnecessary, as no useful data are collected. Therefore, geomorphic monitoring is designed to evaluate up to three peak flow events, preferably within three different discharge ranges, as a way to guarantee that meaningful data will be collected. The threshold discharge corresponds to the design bankfull discharge, initially assumed at 5,000 cfs. This discharge may occur in any given year, so to illustrate a potential monitoring schedule, we assigned an example annual peak discharge to each future year, and then linked monitoring responses to these threshold events. For example, in 2003 the hypothesized peak discharge of 10,400 cfs follows two dry years and triggers numerous geomorphic monitoring elements, but these elements will have been monitored in previous years if peak discharge exceeds the threshold. The third example threshold event occurs in 2005, so budget outlays and scheduling timelines for geomorphic monitoring are projected through 2005, but would be prolonged beyond 2005 in the absence of threshold-exceeding flows. Revegetated riparian zones will be monitored for 5 years following each construction phase. There is no guarantee, however, that desired flow events will occur as hypothesized in this monitoring plan. No artificial flow releases will be made to create conditions for such monitoring. Table 1 shows the project implementation schedule and the proposed monitoring components for each year.

Annual funding requirements were estimated by determining the monitoring required after each example water year, and then estimating time and expenses to conduct that monitoring. The budget allocates funding based on the assumption that all monitoring components would be implemented, but not necessarily in the example year. While wet years require more funds than dry years due to additional monitoring tasks, the average annual cost estimated through 2007 is approximately $102,000 per year. Budget estimates are based on prevailing labor rates, and time estimates based on our monitoring experience on similar projects, and assume no inflation. Costs for each monitoring component were estimated independent of other activities, but would be reduced by coordinating monitoring activities (for example, monitoring geomorphic and riparian cross sections together, etc). [References to budget edited out]

2. SRP 9 AND 10

Aggregate mining at the SRP 9 and 10 sites has left in-channel pits disproportionately larger than the natural channel scale, eliminated a functional floodplain, and created preferred habitat for non-native predatory fish (largemouth and smallmouth bass). The SRP 9 site is 400 feet wide and up to 19 feet deep, and SRP 10 is up to 36 feet deep. The combined length of these reaches is less than one mile, but because of the severity of the channel and floodplain alterations and their strategic location below the primary chinook salmon spawning grounds, the SRP 9 and 10 sites severely impair channel geomorphic and riparian processes and limit chinook salmonid production by increasing smolt mortality (EA 1992). The goal of restoring this reach is to create a functionally scaled channel morphology in (or near) equilibrium with the contemporary hydrologic and geomorphic processes, which will improve chinook salmon survival by reducing predator habitat, abundance and predation rate. Specifically, the SRP 9 and 10 project objectives are to:

- Reduce non-native predator species abundance and habitat.
- Restore and increase salmonid habitat.
- Rebuild a natural channel geometry scaled to current channel forming flows and sediment supply.
- Restore and increase native riparian plant communities, establishing each species within the predicted hydrological niche of the contemporary hydrologic regime.

Because of the distinct biological objectives of the SRP projects, project monitoring prioritizes quantifying biological responses to hypothesized limiting factors. Thus geomorphic and riparian monitoring are less intensive in the SRP sites than in the Gravel Mining Reach.

2.1. FLUVIAL GEOMORPHIC PROCESSES

Restoring the SRP 9 and 10 reaches will require large volumes of fill to meet specific project objectives of *creating a functionally scaled channel geometry*. Design and construction phases of the project must meet as-built performance criteria. Following final construction evaluation, the monitoring plan assumes responsibility for fluvial geomorphic monitoring of two objectives:

- document hydraulic design performance (project performance)
- document channel adjustment after construction

The monitoring timeline is built upon threshold flow events triggering specific monitoring actions. Channel morphology will be monitored prior to construction and then again immediately after construction to document as-built conditions. Subsequent monitoring will occur after each of three threshold high flow events. Three target discharge ranges are proposed: 4,000 to 7,000 cfs, 7,000 to 10,000 cfs, and 10,000 to 15,000 cfs; geomorphic monitoring will attempt to evaluate a flow event in each of these classes, for a maximum of three monitoring sequences. Flows exceeding 9,000 cfs are contingent upon Army Corp of Engineers issuing a variance in discharge limits, currently set at 9,000 cfs at Ninth Street, Modesto. More detailed descriptions of the proposes monitoring schedule are provided in the following sections.

2.1.1. Project performance

2.1.1.1. Topography

In the project design phase, a topographic map (digital terrain model) of the restoration site will be surveyed prior to construction. Cross section endpoints will be installed at fixed locations for future channel morphology monitoring. A digital terrain model depicting the design channel will then be used to develop construction specifications and to construct the project. Immediately after construction, a digital terrain topographic map will be re-surveyed to evaluate project compliance (compares as-built topography to design topography for contractual sign-off). The "as-built" topographic model will then help compare future channel adjustments revealed by monitoring cross sections (see Section 2.1.2). Bed surface particle size distribution will be documented at 1 or 2 selected reconstructed riffles immediately after construction as a baseline for comparing particle size adjustment from future high flow events.

Schedule: Topographic maps will be surveyed immediately after construction (tentatively winter 1999-2000 for SRP 9 and winter 2001-02 for SRP 10).

2.1.1.2. Hydraulics

Computations of floodway conveyance and geomorphic surface design (floodplains and terraces) depend on hydraulic roughness values. Manning's *n* is typically the roughness variable of choice, and is a function of particle size, bedforms (bars), sinuosity, vegetation, and other channel obstructions. When channel restoration projects are constructed, the initial Manning's *n* is smaller (0.025 to 0.030) than it is after vegetation matures (0.035 and higher). These roughness values are typically estimated by back-calculation from other sites or from professional experience. By monitoring water surface elevations during discreet high flow events immediately after construction, we can back-calculate roughness values using HEC-RAS to compare observed versus design values, which can then be used to improve future designs. Additionally, we can evaluate floodplain and terrace inundation during discreet high flow events to determine if floodplains were inundated by discharges exceeding the design bankfull discharge. This monitoring will occur on SRP 9 only, and information will be used to aid in determining floodplain elevations in the final design phase of SRP 10. Because the period in which riparian vegetation will begin to significantly increase Manning's *n* will exceed five years, the change in roughness as vegetation matures will not be included in this monitoring plan.

Schedule: Water surface elevations will be monitored during the <u>first</u> high flow after SRP 9 construction that equals or exceeds the design bankfull discharge. O*ne flow event monitored.*

2.1.1.3. Bed mobility at design bankfull discharge

A fundamental characteristic of properly functioning alluvial rivers is the initiation of bed surface mobility and bedload transport of the larger particle clasts at streamflows approaching bankfull discharge. Based on the anticipated future high flow regime, one objective of the project is to mobilize the bed surface particles by flows approaching and exceeding the design bankfull discharge. Evaluation of this objective will be monitored by placing painted tracer rocks on two riffle cross sections in the restored SRP 9 reach, or immediately downstream. Bed mobility in the SRP 10 reach will be inferred from SRP 9 monitoring results. The tracer rocks representing the D_{84} and D_{50} particle sizes will be placed on cross sections and monitored until a discharge large enough to initiate movement is observed. This discharge will then be compared to the design bankfull discharge to evaluate whether the design bankfull discharge would achieve the objective of mobilizing the bed surface. Water surface elevation and slopes will be measured to estimate the hydraulic variables of the discharge that mobilizes the bed surface particles.

Schedule: Tracer rocks will be installed immediately after SRP 9 construction, and monitored after each high flow event until mobilization is observed. Some periodic maintenance will be required (i.e., repainting tracer rocks that fade, periodically checking for movement) if the mobilization flow does not occur in a reasonable time. O*ne flow event monitored.*

2.1.2. Channel adjustment

2.1.2.1. Channel migration/planform adjustment

Small-scale planform adjustments such as lateral movement will be documented by surveying cross sections at locations susceptible to lateral movement (apex of meanders). Large-scale planform adjustments will be documented by a combination of cross section evaluations and low-altitude aerial photographs (1”=500’ or better contact print). Cross sections established during the pre-and post-construction topographic surveys will be relocated and surveyed with engineers levels and tapes to document channel adjustment. This objective will be monitored in both SRP 9 and SRP 10 restored reaches.

Schedule: Cross sections will be surveyed immediately after each of three high flow events that exceeds a threshold that causes channel adjustment (initially assumed at 5,000 cfs). Low-altitude aerial photos will be obtained once after a flow exceeding 10,000 cfs (and assumes flight costs are covered by other programs). Monitoring channel migration after each threshold high flow event is needed to evaluate any potential threat to human structures that requires maintenance. The magnitude of the threshold event will be estimated during the design phase. *Up to three flow events monitored.*

2.1.2.2. Channel degradation/aggradation

Vertical adjustment of the channel bed (bed aggradation/degradation) and floodplain (fine sediment deposition) will be documented at specific locations by surveying cross sections on bend of apex (pools) and at meander crossovers (riffles). A thalweg profile surveyed with an engineers level or total station will document changing bed elevation and pool/riffle sequencing (e.g., determine if pools are filling or readjusting longitudinally).

Schedule: Cross sections will be surveyed immediately after <u>each</u> of three high flow events that exceeds a threshold that causes channel adjustment (initially assumed at 5,000 cfs). *Up to three flow events monitored.*

2.2. FISHERIES RESOURCES

The SRP 9 and 10 sites currently provide habitat to predatory fish species, including non-native largemouth and smallmouth bass, striped bass, and the native Sacramento squawfish. A pilot predation study in the lower Tuolumne River (EA 1992, Appendix 22) identified twelve potential chinook salmon predator species, and subsequent studies at other SRP's estimated largemouth bass abundance in SRP's ranged from 133 to 181 fish per site (and projected to more than 10,000 largemouth bass river-wide) and predation rates as high as 3.6 to 5.3 salmon per predator per day for smallmouth bass during pulse flows. In sum, conditions are potentially unfavorable to emigrating juvenile chinook salmon. In addition, salmonid spawning and rearing habitat is lacking. The SRP restoration projects are predicated in part on the hypothesis that these large pits contribute to an increase in juvenile salmon mortality and a consequent reduction in total salmon production. The principal biological objectives of the SRP 9 and 10 projects are to *reduce salmon mortality by reducing predator habitat and abundance, and provide improved salmonid spawning and rearing habitat conditions.*

Recommended biological monitoring protocols for the SRP sites include:

- field experiments comparing survival of juvenile chinook salmon passing through the project reaches before and after restoration.
- evaluation of bass species abundance before and after restoration, by electrofishing techniques and standardized statistical methods.
- comparison of habitat availability by habitat mapping before and after restoration, for various life history stages of predator species and chinook salmon.

An initial investigation of each monitoring approach is recommended during the first year to determine the relative utility of each monitoring effort and its ability to detect hypothesized responses. Findings from this initial effort can then focus resource expenditure in the following years (adaptive management approach).

2.2.1. Juvenile salmonid survival estimates

Non-native bass species prey on emigrating chinook juveniles and smolts. A direct measure of project efficacy would be to quantify salmonid survival through the project reaches before and after project implementation. Our study plan emphasizes replicated field tests of marked-recapture survival estimates, based on releases of test groups of natural chinook smolts above the restoration site, and recapture below the test site using fyke nets or rotary screw traps (RST) to generate an index of smolt survival. The survival index is based on the proportion of released fish recaptured, adjusted by the estimated trap efficiency. This recommendation follows an evaluation of various sampling methods and gear types, and recognition that these efforts can be partially incorporated into other monitoring programs currently employed on the Tuolumne River.

Test fish will be collected at an upstream site currently used in river-wide monitoring programs, and marked using PanJet dye inoculation, fin clips or other methods. The marking systems will be coordinated with other Tuolumne River programs. The number of distinct experiments will depend on the availability of test fish and personnel for marking fish, but may include 2 to 3 test runs each season. The availability of fish may limit this work. The number of fish per test may need to be modified (increased or decreased) in subsequent years depending on results of the first year's results. Tests should target peak periods of smolt movement, and use only migrating fish captured in upstream screw traps or fyke nets, since these fish show a propensity to move downstream. Tests should also target pulse flows and non-pulse flow periods to test hypotheses about the utility of pulse flows.

Smolt survival studies (and similar production estimates) using marked recapture methodologies and rotary screw trapping have been implemented annually on the Tuolumne by CDFG, and contain considerable uncertainty in their estimates of survival and river-wide production. In addition, they often depend on hatchery-produced juvenile chinook for release groups large enough to satisfy statistical requirements. Other problems such as differences in diel movement of smolts, trap avoidance, and comparisons of behavioral differences between hatchery and naturally produced smolts have not been resolved. Pending the outcome of the initial year of study, we recommend considering other methods to obtain survival estimates.

Schedule: Survival estimates will be conducted for four years, beginning in 1998 before SRP 9 construction, and continuing for two years after completion of SRP 10 (through 2002).

2.2.2. Bass abundance

Bass population densities are expected to decline as a result of project implementation, and changes in fish abundance can potentially be detected using a variety of monitoring methods . The monitoring plan includes a statistical comparison of predator abundance before and after project implementation, estimated by electrofishing, to document changes that result from restoration. Predator populations will be sampled in the SRP 9 and 10 treatment sites, in an undisturbed control site at SRP 7 or SRP 8, and in one or two sites similar to post-restoration conditions. Reference sites will be useful to isolate specific project-related responses from annual local variability in population abundance, and may also help determine if population responses in treatment reaches are redirected to other sites (e.g., increased abundance in other SRP's as a result of project-site displacement). The SRP treatment and reference sites will be electrofished at night to estimate abundance of adult largemouth, smallmouth and striped basses, and Sacramento squawfish. Field methods will employ gillnets and blocking nets when needed, and use multiple-pass depletion removal or marked-recapture methods for estimating fish abundance. The electrofishing equipment best suited to sampling in the large SRP units is a boat shocker (e.g., Smith-Root). Snorkeling may also be used.

Our initial approach to surveying predator abundance during the first year of monitoring, will be to conduct a multiple marked-recapture experiment over a several week period (at fewer sites) and then if feasible, conduct a multiple pass depletion removal test on the last marked-recapture run to obtain two separate abundance estimates. This pilot study approach would help determine which method has the most merit for reliable estimates of predator density or abundance and would allow a determination of subsequent effort required to accurately estimate abundance. Fish species and counts other than those specified above will be recorded for presence or absence, but abundance estimates will not be attempted for those species.

Reference sites selected that resemble anticipated post-project conditions will be monitored by electrofishing and/or snorkeling according to the above schedule. As there are no riffles in the vicinity upstream of the project site, these references sites will be located below SRP 10 in the vicinity of riffle 73A, 73B or 74 (RM 25.0). Some modifications to field techniques may be required at these reference sites and in post-construction SRP 9 and 10 reaches, dictated primarily by water depths and velocities.

Schedule: Electrofishing will take place during spring/summer 1998 to establish pre-project abundance and suitable techniques, and then again in May/Junespring/summer of the following 3 years (1999, 2000, and 2001) to evaluate post-restoration conditions and to track short-term trends in bass abundance. Pre- and post-restoration sampling in SRP 10 will perform the dual function of providing two years of reference conditions for comparison to SRP 9 and also to establish baseline conditions for SRP 10, scheduled for restoration in 1999. SRP 10 and accompanying reference sites will be monitored through 2002. At least one year of monitoring should accompany a high-flow event to provide insight into predator persistence in relation to high flows in reconstructed habitat. We also recommend continued sampling of SRP 7 or 8 reference sites and SRP's 9 and 10 project sites to track long-term trends in abundance, particularly if other channel reconstruction projects are anticipated (e.g., SRP 5 and 6) but recognize that funding is not presently allocated for this monitoring.

2.2.3. Bass and Salmonid habitat availability

Methods to quantify habitat availability generally rely on data collected from cross-section transects and IFIM models, which can be labor intensive and provide data of limited use. Our study plan will quantify habitat availability and changes in pre-and post-restoration conditions by field mapping habitat area onto aerial photographs. Maps showing physical habitat boundaries of greater resolution for fish species such as pools, riffles, runs, SRP's and backwater areas will be produced from aerial photos, and will provide the physical backdrop for delineating habitat boundaries for impacted fish species such as chinook salmon and bass. Identifying habitat boundaries will be based on specified criteria for species habitat preferences, and will focus on predator species spawning and rearing habitat in addition to salmonid habitat preferences. These criteria will include variables such as depth and velocity preferences for each species, determined according to site-specific information when available, or otherwise will refer to published literature values of habitat preferences. A full set of criteria will be defined for each species of interest prior to field mapping. High resolution aerial photographs available from project construction (1"=2,000 ft or better) will provide field templates for mapping habitat boundaries. These maps offer the flexibility of later incorporating habitat boundaries for other fish species, amphibians, migratory birds, etc. Data will be digitized for comparing habitat areas before and after construction, and presented in planform color format. Where possible, we recommend quantifying habitat boundaries in reference to a common denominator such as alternate bar sequences, which are repeatable geomorphic features that can be treated statistically and compared to other river reaches.

Verification of habitat use by various life stages of fish species will provide important information for evaluating the success of project objectives. We will employ direct observation or seining during field mapping to establish the presence of juvenile salmonids and bass. These activities will be done systematically to allow testing hypotheses about habitat preferences. Additionally, seining efforts similar to those conducted by the Districts will be used in the SRP 9 and 10 reaches to assess habitat use by rearing salmonids during subsequent seasons. CDFG seasonal spawning surveys will also incorporate newly created spawning habitat within the project boundaries. Two field days will be provided for CDFG personnel for field calibration of redd counts to spawner surveys.

Schedule: Pre-construction habitat maps will be prepared in summer 1998 for SRP 9 and summer 1999 for SRP 10, and post construction maps will be prepared in 1999 for SRP 9 and in 2000 for SRP 10. Spawning and seining surveys will begin during the appropriate season following construction, and continue indefinitely for spawning surveys, and for four years post-construction for seining.

2.3. RIPARIAN RESOURCES

A major component of the SRP 9 and SRP 10 projects is riparian revegetation. Native riparian vegetation consists of different plant assemblages called plant series (Sawyer 1995). Currently these sites have fragmented native vegetation and many exotic plant species created by a legacy of land alteration. Project construction will disturb some riparian vegetation and will be mitigated through extensive revegetation. The revegetation objective is to *establish different plant series on reconstructed surfaces with inundation patterns characteristic of that plant series, provide continuity between remnant riparian stands, and increase natural regeneration.*

2.3.1. Project performance

Riparian monitoring will evaluate project performance using plot-based descriptions of species composition, survival, and cover to evaluate recruitment, survival and growth. Potential performance standards for plantings are: 90 % plant survival in year 0, 70% plant survival to year 2, and 60% survival to year 3, a 10% increase in cover and growth annually for surviving plants, and no more than ten planted hardwoods dead in a 3 meter radius. Plantings will be irrigated in the first and second growing season after revegetation. Trends in survival will be documented and used to evaluate project success in establishing self sustaining vegetation series. Quantitative performance standards will be correlated to revegetation techniques such as design, planting, and irrigation methods, fertilizer, root stock quality, and environmental causes.

Plot descriptions will sample plant series on each restored geomorphic surface, including the active channel, floodplain and terrace. Three permanent plots will be established within each restored series type, with each plot located along cross sections established for geomorphic monitoring. Data collected within plots will include dominant species, plant vigor, and plant size in the tree, shrub, and herb strata. Plant vigor will be assessed using visual decline indicators (for example, yellowing or burnt leaves, leaf abscission, stunted growth, irregular plant morphology or stem death). Plant size assessment will be based on root collar or breast height diameter and height. Plant density, and survivorship will also be calculated. Changes in plant size, vigor or species composition will be used to evaluate revegetation success. It will be necessary to protect young trees from beavers, and this may include temporary depredation permits from CDFG.

Schedule: Monitoring will begin immediately after construction (year-0) to evaluate planting success and document as-built conditions, and again at year-2 at the end of irrigation (contractual signed off pending results). Additional monitoring will occur in years 3 and 5, or potentially after a high flow event that exceeds the channel geomorphic design flow (assumed to be 5,000 cfs) and inundates reconstructed floodplains, for a maximum 4 monitoring seasons for the first 5 years after construction. The final riparian vegetation monitoring will occur in 2004 for SRP 9 and 2006 for SRP 10.

2.4. THREATENED AND ENDANGERED SPECIES

Surveys are recommended to identify the occurrence of threatened, endangered, and special status species at the restoration and source material sites. At the restoration sites, surveys are recommended for the following species: Delta button-celery, California hibiscus, Merced monardella, Hartweg's golden sunburst, and Sanford's arrowhead, valley elderberry longhorn beetle, California red-legged frog, foothill yellow-legged frog, western pond turtle, giant garter snake (habitat survey), Clark's/western grebe, double-crested cormorant (nesting), great blue heron (nesting), great egret (nesting), snowy egret (nesting), osprey (nesting), white-tailed kite (nesting), Swainson's hawk (nesting), golden eagle (nesting), Forster's tern (nesting), western burrowing owl, and tricolored blackbird. If access roads are constructed through grasslands, surveys are recommended for the California tiger salamander and western spadefoot.

If surveys document the occurrence of any of these species or their protected habitats at the restoration or source material sites, the U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG) should be consulted and avoidance measures should be undertaken. If these species or their protected habitats cannot be avoided, the U.S. Fish and Wildlife Service and the California Department of Fish and Game should be consulted to identify appropriate mitigation measures.

2.5. CULTURAL RESOURCES

In the vicinity of the Gravel Mining Reach project area, prehistoric and historical archaeological sites, as well as other cultural resources are evident. A majority of the project was once part of the historic dredger mining operations along the Tuolumne River which now supply the waste gravels mined by the aggregate companies. The historic landscape of this former mining area has been thoroughly altered and is no longer identifiable as a cultural resource. However, it is possible that buried features may be located during construction activities. A second resource area is located adjacent to, but outside the current project, based on surface indications. The prehistoric and historic Roberts Ferry included two historic bridges, several buildings and structures, a prehistoric activity area, an Indian burial ground, and more. Only bridge footings for the 1887 Roberts Ferry bridge are located within the current Tuolumne River channel and project area. However, there is potential for discovering subsurface archaeological deposits and human burials remains during the proposed restoration. Thus, based on the possibility of encountering buried or unidentified resources, monitoring provisions are outlined below.

2.5.1. Subsurface archaeological deposits and human burials remains

With a project like the Gravel Mining Reach Restoration, involving substantial excavation and ground disturbance, it is always possible that previously undiscovered resources may be uncovered. Generally, federal agencies prepare plans for the treatment of such resources discovered in their Memoranda of Agreement which conclude the Section 106 process. In this case, such a plan remains undeveloped. Provisions for a Gravel Mining Reach Monitoring Plan are proposed until a federal plan can be implemented; the procedures for treatment are laid out at 36CFR Part 800, the Advisory Council on Historic Preservation (ACHP) regulations for Section 106 (see §800.11).

The 1887 Roberts Ferry bridge footings will be protected during the project by creating a buffer of no less than 50 meters (165 feet) surrounding the resource. Such a buffer can be identified with orange fencing or a similar mechanism which prevents encroachment by construction equipment.

Undiscovered resources may be a simple artifacts, located out of context or without association, or they may be intact archaeological deposits. In the case of the former, simple documentation may be sufficient to resume project activities. Treatment in the latter may prove more complex. As treatment must be assessed by a qualified professional, there are several measures outlined to meet this goal.

1. The USFWS will retain a professional archaeologist who meets the Secretary of Interior Professional Qualification Standards for Archeology for the duration of the project.

2. Prior to project construction, the USFWS will insure that either an Inadvertent Discoveries Plan has been developed among the lead federal agency, the California SHPO, and the ACHP, or that if such an agreement does not exist, that such a plan will be developed which meets both the requirements of the State of California and the intent of Section 106 of the National Historic Preservation Act (36CFR 800.11). This document will discuss the documentation, evaluation, and treatment of resources discovered inadvertently during the life of the project. The plan must address the possibility of encountering human remains.

3. The USFWS will insure that all contractors and equipment operators are instructed and required to watch for potential archaeological artifacts and sites, along with human remains. Evidence includes skeletal remains, chipped stone, shaped stone (bowls, pestles), shell and bone artifacts, metal and glass artifacts, concentrations of fire-affected rock and/or charcoal, trash pits, foundations, pits, rock alignments, and other cultural materials. In addition, the USFWS will insure that construction inspectors are instructed about the potential for finding artifacts and archaeological deposits, and are supplied with a list of contact individuals with numbers to telephone in the event of discovery.

4. The USFWS will insure that in the event prehistoric or historic resources are located within the project, all work will stop within a circumference of 10 meters (33 feet) of the find until a qualified professional (meeting the terms of 1, supra) has assessed the find and developed treatment, if appropriate.

5. In the event that human remains other than dissociated teeth or bones are encountered during Project activities, all work will stop (4, supra) and the responsible field supervisor will issue immediate notification of the find to the USFWS, the retained archaeologist, and, as required by law, to the Stanislaus County Coroner/Sheriff. In addition, if the remains are determined to be Native American, the USFWS will notify the Native American Heritage Commission, the landowner, and any appropriate Project personnel

(California Health and Safety Code §7050.5(b) and (c); California Public Resources Code §5097.94-99).

Schedule: Coordination between lead federal agency and retained archaeologist will occur prior to construction in 1998 to insure an Inadvertent Discoveries Plan is agreed upon and duly executed. Instruction of responsible construction managers and contractors will occur prior to ground disturbance and mobilization in 1998. Archaeologist will remain on call through 2005.

3. GRAVEL MINING REACH

Off-channel mining for aggregate on the Tuolumne River began in the 1950's, and is presently concentrated into a six mile river reach (RM 40.3 to 34.3) referred to as the Gravel Mining Reach. Agricultural encroachment and aggregate mining in this reach have reduced the floodway capacity, and the reach represents a potential bottleneck to river ecosystem and chinook salmon recovery. Mining activity has changed the natural channel morphology and physical processes, reduced floodway capacity by narrowing the channel with dikes and berms that are subject to frequent and costly failures from minor flood events, and eliminated extensive areas of floodplain and terrace riparian habitat. In addition, mining has created extensive lentic aquatic habitat in off-channel ponded pits, which are occasionally "captured" by the main channel when dikes fail (as in the January 1997 flooding). These ponds harbor non-native predator species, particularly bass, and subject juvenile chinook salmon to high in-river mortality. The project proposes to restore a riparian floodway by rebuilding and setting back dikes to increase floodway width to 500 ft minimum, and safely convey discharge of at least 15,000 cfs (minimum). Increased width and flood capacity should significantly reduce risks of dike failure, thus protecting human resources (structures and mining operations). Restoration will also reduce mortality to chinook salmon by reducing exposure to predation in captured off-channel pits. The project also proposes to restore native riparian communities on rebuilt floodplains and terraces. In addition, a principle objective of restoring this reach is to improve chinook spawning and rearing habitats. Specifically, the objectives of the Gravel Mining Reach project as stated in the conceptual design are:

- Improve salmonid spawning and rearing habitats by restoring an alternate bar (pool-riffle) morphology, and filling in-channel mining pits
- Reduce the potential for future production losses to juvenile salmon by preventing future connection between the Tuolumne River mainstem and off-channel mining pits
- Restore native riparian communities on appropriate geomorphic surfaces (i.e., active channel, floodplains, terraces) within the restored floodway
- Restore habitats for special status species (e.g., egrets, ospreys, herons)
- Restore a floodway width that will safely convey floods of at least 15,000 cfs
- Establish migratory corridor within the restored floodway to improve and maintain riparian and salmonid habitat
- Remove floodway "bottleneck" created by inadequate dikes (i.e., prevent dike failure above a certain discharge threshold)

- Protect aggregate extraction operations, bridges, and other human structures from future flood damage

Due to the large scale of the Gravel Mining Reach project, implementation of channel and riparian restoration will occur in four phases beginning in 1998, and follow the proposed completion dates outlined below:

Phase I (7/11) to be completed by May 1999
Phase II (MJ Ruddy) to be completed by May 2000
Phase III (Warner/Deardorff) to be completed by May 2001
Phase IV (Reed) to be completed by May 2002

The project objectives emphasize restoring the floodway and riparian zones and isolating the off-channel pits, and requires that monitoring prioritize geomorphologic and riparian components. The monitoring period will extend through 2007. Most monitoring will occur immediately after threshold hydrologic events (e.g., whenever floods exceed 5,000 cfs).

3.1. FLUVIAL GEOMPORPHIC PROCESSES

Fluvial geomorphic objectives of the project are to *create a functional floodway that safely conveys flows of at least 15,000 cfs, create functional floodplains that begin to inundate at design bankfull discharges, establish a channel migratory corridor, restore the alternate bar (pool-riffle) morphology, and restore bedload continuity*. Specific monitoring objectives related to geomorphic processes are:

- document channel adjustment after construction
- document success of hydraulic design variables
- document channel dynamics as a function of discharge (e.g., bedload mobility and routing).

As with the SRP 9 and 10 projects, the monitoring schedule is built upon threshold flow events triggering specific monitoring actions. The threshold flow is initially assumed at 5,000 cfs. Channel morphology will be monitored prior to construction, and then again immediately after construction, to document as-built conditions. Subsequent monitoring will occur after a maximum of three threshold high flow events. We propose three target discharge ranges: 4,000 to 7,000 cfs, 7,000 to 10,000 cfs, and 10,000 to 15,000 cfs, and suggest that geomorphic monitoring evaluate a flow event in each of these classes if possible, for a maximum of three monitoring sequences. Flows exceeding 9,000 cfs are contingent upon Army Corp of Engineers issuing a variance in discharge limits, currently set at 9,000 cfs at Ninth Street, Modesto. More detailed descriptions of the proposes monitoring schedule is provided in the following sections.

3.1.1. Project performance

3.1.1.1. Topography

As with the SRP 9 and SRP 10 designs, the project design phase in the Gravel Mining Reach will develop a topographic map (digital terrain model) of the site immediately prior to construction. Cross sections will be established at locations appropriate for future channel morphology monitoring. A digital terrain model depicting the design channel will then be developed and used to construct the project. Immediately after each phase of construction is completed, another topographic map will be surveyed to document as-built conditions (compares as-built topography to design topography for contractual sign-off). The as-built topography will then serve as the basis for comparing subsequent channel adjustment (see Section 3.1.2). Bed surface particle size distribution will be documented at two selected riffles immediately after each construction phase for later comparison of particle size adjustment resulting from high flow events.

Schedule: Topographic maps will be surveyed immediately after completing each construction phase (Winter 1998 for Phase I, Winter 1999 for Phase II, Winter 2000 for Phase III, and Winter 2001 for Phase IV).

3.1.1.2. Hydraulics

Because floodway conveyance is a primary objective of the Gravel Mining Reach project, hydraulic floodway computations and geomorphic surface design (floodplains and terraces) are of primary importance. During a 5,400 cfs flow in 1996, hydraulic variables at the M.J. Ruddy Restoration Project (Delta Pumps) channel restoration project showed that as-built Manning's *n* values were consistently between 0.028 and 0.029 based on HEC-RAS water surface profile modeling. By monitoring water surface elevations during discreet high flow events immediately after construction, we can re-evaluate roughness values using HEC-RAS, improving our estimates for later phases of construction. Because the period in which riparian vegetation will begin to significantly increase Manning's *n* will be in excess of five years, the change in roughness as vegetation matures will not be included in this monitoring plan.

Floodplains and terraces will be constructed at elevations inundated at designed discharges. Their proper inundation discharge is dependent on channel geometry, energy, slope, and Manning's *n* values. As part of the water surface elevation monitoring, elevations will be marked on the monitoring cross sections to evaluate floodplain and terrace inundation at the appropriate discharges, and hydraulic explanations can be provided for sites where inundation objectives are not met.

Schedule: Water surface elevations will be monitored during the first high flow after construction that equals or exceeds the design bankfull discharge. *One flow event monitored*

3.1.1.3. Bed mobility at design bankfull discharge

A fundamental characteristic of properly functioning alluvial rivers is the initiation of bed surface mobility and bedload transport of the larger particle clasts at streamflows approaching bankfull discharge. Bedload movement through the system thus depends on flows near or exceeding the design bankfull discharge to at least transport bedload through a riffle-pool-riffle sequence. Bed mobility will be monitored by placing painted tracer rocks on two riffle cross sections on each phase of the Gravel Mining Reach project. The tracer gravels, representing the D_{84} and D_{50} particle sizes, will be monitored for mobility threshold and travel distance (i.e., are the particles moving, and if so, are they moving through pools and onto the next downstream riffle). For each construction phase the marked rock experiments will be in place until a discharge just large enough to initiate movement is observed. This discharge will then be compared to the design bankfull discharge, to evaluate bed surface mobility objectives. Once the tracer rocks are mobilized, their deposition location will be mapped to document travel distance, and left to monitor future movement through pools and riffles.

Surface pebble counts and subsurface bulk samples will be collected on each monitoring riffle to document particle size distributions and to track adjustments over time. Water surface elevation and slopes will be measured at monitoring riffles to estimate the hydraulic variables of the discharge that mobilizes the bed.

Schedule: Tracer rocks will be installed immediately after construction of each phase, and monitored after each high flow event until mobility is observed. Once mobility has occurred, marked rocks will continue to be monitored to observe future movement through 2005 to evaluate the extent of coarse bedload routing through pool-riffle sequences. Some periodic maintenance will be required over time (i.e., repainting tracer rocks that fade, periodically checking for movement). *Up to three flow events monitored.*

3.1.2. <u>Channel adjustment</u>

3.1.2.1. Channel migration/planform adjustment

The primary hydraulic objective of the Gravel Mining Reach project is to improve floodway conveyance and reduce risk and damage resulting from channel migration and berm failure. However, channel migration provides important geomorphic, biological, and riparian benefits to the system. Hence, monitoring channel migration and planform evolution are crucial components of monitoring. Small-scale planform adjustment will be documented by level surveys of cross sections placed at locations susceptible to lateral movement (apex of meanders). Large-scale planform adjustments will be documented by a combination of cross section evaluation and low-altitude aerial photographs (1”=500’ or better contact print). Cross sections established during the pre-and post-construction topographic surveys will be re-surveyed with engineers levels and tapes to provide precise documentation of channel adjustment. Cross section monitoring will be conducted during all construction phases.

Schedule: Monitoring will occur immediately after each high flow event that exceeds a threshold that begins to cause channel adjustment (initial target > 5,000 cfs). Monitoring channel migration after each threshold high flow event will be needed to evaluate whether project maintenance is required to further protect human structures adjacent to the floodway. *Up to three flow events monitored.*

3.1.2.2. Channel degradation/aggradation

Vertical adjustment for both inner channel (bed aggradation/degradation) and floodplain (fine sediment deposition) will be documented at specific locations by surveying cross sections at apex of meanders (pools) and at meander crossovers (riffles). A thalweg profile surveyed through all phases with an engineers level or total station will document changes to the bed elevation and pool/riffle sequencing (e.g., are pools filling, riffles steepening, or readjusting longitudinally).

Schedule: Monitoring will occur immediately after the each of three high flow event that exceeds a threshold that begins to cause channel adjustment (initial target > 5,000 cfs). *Up to three flow events monitored.*

3.2. FISHERIES RESOURCES

The six mile long Gravel Mining Reach contains large off-channel and instream gravel extraction pits that negatively impact chinook salmon by stranding juveniles in ponds and harboring predator species, notably bass. Additionally, chinook spawning and rearing habitat is either absent or severely degraded. Restoring these reaches will reverse past trends of habitat degradation. Specific objectives of the Gravel Mining Reach restoration project related to fisheries resources include: *(1) improving salmonid spawning and rearing habitats by restoring an alternate-bar morphology, (2) restoring spawning habitat within the meandering channel, and filling in-channel mining pits, (3) improving juvenile salmonid survival by preventing future connection between the Tuolumne River and off-channel mining pits (that contain introduced predator species).*

In general, biological monitoring protocols will focus on:

- quantifying changes in habitat availability
- documenting habitat use by rearing juveniles and spawning adults
- document potential improvements in juvenile survival in the Gravel Mining Reach by evaluating on-going river-wide survival monitoring

3.2.1. Salmonid and Bass habitat availability

The fisheries study plan will quantifying habitat availability and changes in pre-and post-restoration conditions by field mapping habitat areas onto aerial photographs. Maps showing physical habitat boundaries of pools, riffles, runs, SRPs and backwater areas will be produced from aerial photos, and will provide the physical backdrop for delineation of habitat boundaries for fish species of interest, such as chinook salmon and bass. Identifying habitat boundaries will be based on specified criteria for species habitat preferences, and will focus on predator species spawning and rearing habitat in addition to salmonid habitat preferences. These criteria will include variable such as depth and velocity preferences for each species, determined according to site-specific information when available, or otherwise will refer to published literature values of habitat preferences. A full set of criteria will be defined for each species of interest prior to field mapping. High resolution aerial photographs available from the project construction activities (1”=2,000 ft or better) will provide field templates for mapping habitat boundaries. These maps offer the flexibility of later incorporating habitat boundaries for other fish species, amphibians, migratory birds, etc. Data will be digitized for comparing habitat areas before and after construction, and presented in planform color format. Additional layers incorporating information about particle sizes of sorted bed surface materials can also be added (qualitative facies maps) to quantify changes in physical habitat complexity. Where possible, we recommend quantifying physical habitat boundaries in reference to a common denominator such as alternate bar sequences, which are repeatable geomorphic features that can be treated statistically and compared to other river reaches. Once construction is completed, the habitat maps will be available for monitoring long-term changes (succession) of habitat quantity, quality and use.

Field mapping can also address the added benefits incurred by preventing reconnection of off-channel pits/ponds that remain outside the reconstructed setback levees. These ponded pits will be mapped onto the aerial photos and digitized to quantify the post-construction surface area of isolated ponds altered by project construction.

Verification of habitat use by various life stages of fish species will provide important information for evaluating the success of project objectives. We will employ direct observation or seining during field mapping to establish the presence of juvenile salmonids and bass. Additionally, seining similar to that currently conducted by the Districts will be used for four years after each construction phase to assess habitat use by rearing salmonids in each project reach. CDFG will also extend seasonal spawning surveys to newly created spawning habitat within the project boundaries. Two field days will be provided for CDFG personnel for field calibration of redd counts to spawner surveys.

Schedule: Pre-construction habitat maps will be prepared for all project phases before initiation of phase I construction in 1998. Each project reach will then be re-mapped after construction is finished to document changes in habitat area. Monitoring habitat use will include four years of seining, and annually for spawning.

3.3. RIPARIAN RESOURCES

Similar to the SRP 9 and 10 projects, a major component of the Gravel Mining Reach project is riparian revegetation. Native riparian vegetation consists of different plant assemblages called plant series (Sawyer 1995). Currently the riparian vegetation is restricted to levees and relic stands, and is imbedded with exotic plants. Construction will disturb some riparian vegetation and off-channel wetlands, but will be mitigated by extensive revegetation. The revegetation objectives in the Gravel Mining Reach are to *establish different plant series on reconstructed surfaces with inundation patterns characteristic of that plant series, provide continuity between remnant riparian stands, and increase natural regeneration.*

A major addition to revegetation methods in the Gravel Mining Reach project is use of bioengineered bank protection in Phases I, II and III. Bioengineering uses plant materials together with inert materials during construction to protect and stabilize riverbanks. In the Gravel Mining Reach bioengineering will take two forms: joint plantings and brush mattressing. Joint plantings consist of soil rammed into the spaces between rip-rap, and planted with willow or cottonwood cuttings. Brush mattressing consists of willow cuttings woven into a large “mattresses”, and anchored to the riverbank through trenches and backfill and large “pins” made of live willow stakes. Bioengineered banks become stronger over time and provide excellent habitat value. The Gravel Mining Reach includes monitoring to evaluate the integrity of bioengineered structures during the first five years after construction.

3.3.1. Project performance

Riparian monitoring will evaluate project performance using plot-based descriptions of species composition, survival, and cover to evaluate recruitment, survival and growth. Potential performance standards for plantings are: 90 % plant survival in year 0, 70% plant survival to year 2, and 60% survival to year 3, a 10% increase in cover and growth annually for surviving plants, and no more than ten planted hardwoods dead in a 3 meter radius. Plantings will be irrigated in the first and second growing season after revegetation. Trends in survival will be documented and used to evaluate project success in establishing self sustaining vegetation series. Quantitative performance standards will be correlated to revegetation techniques such as design, planting, and irrigation methods, fertilizer, root stock quality, and environmental causes.

Plot descriptions will sample plant series on each restored geomorphic surface, including the active channel, floodplain and terrace. Three permanent plots will be established within each restored series type, with each plot located along cross sections established for geomorphic monitoring. Data collected within plots will include dominant species, plant vigor, and plant size in the tree, shrub, and herb strata. Plant vigor will be assessed using visual decline indicators (for example, yellowing or burnt leaves, leaf abscission, stunted growth, irregular plant morphology or stem death). Plant size assessment will be based on root collar or breast height diameter and height. Plant density, and survivorship will also be calculated. Changes in plant size, vigor or species composition will be used to evaluate revegetation success. It will be necessary to protect young trees from beavers, and this may include temporary depredation permits from CDFG.

3.3.2. Bioengineering response

Each bioengineered structure will be visually inspected to evaluate structural responses to floods. Photo-monitoring points will be established immediately after construction and re-photographed during subsequent monitoring. When possible, photos will be taken at the same time of year and during a similar discharge. Photos will be overlaid and used for photogrammetric analysis to document the extent of plant growth between monitoring and the extent of erosion. Failure nodes will be documented to determine the cause of failure. Bioengineering will be assumed effective if the structure is growing well in all areas and visual inspection indicates there is no erosion.

Schedule: Project performance monitoring will begin immediately after construction (year-0) to evaluate planting success and document as-built conditions, and again at year-2 at the end of irrigation (contractual signed off pending results). Additional monitoring will occur in years 3 and 5, or potentially after a high flow event that exceeds the channel geomorphic design flow (assumed to be 5,000 cfs) and inundates reconstructed floodplains. The final riparian vegetation monitoring will occur in 2004 for Phase I, 2005 for Phase II, 2006 for Phase III, and 2007 for Phase IV, for a maximum 4 monitoring seasons for the first 5 years after construction. Bioengineering will be monitored after each of three high flow events that exceeds the design flow (that may cause bank erosion) for 5 years after construction, or once at years 3 and 5 if no high flow events occur.

3.4. THREATENED AND ENDANGERED SPECIES

Surveys are recommended to identify the occurrence of threatened, endangered, and special status species at the restoration and source material sites. At the restoration sites, surveys are recommended for the following species: Delta button-celery, California hibiscus, Merced monardella, Hartweg's golden sunburst, and Sanford's arrowhead, valley elderberry longhorn beetle, California red-legged frog, foothill yellow-legged frog, western pond turtle, giant garter snake (habitat survey), Clark's/western grebe, double-crested cormorant (nesting), great blue heron (nesting), great egret (nesting), snowy egret (nesting), osprey (nesting), white-tailed kite (nesting), Swainson's hawk (nesting), golden eagle (nesting), Forster's tern (nesting), western burrowing owl, and tricolored blackbird. If access roads are constructed through grasslands, surveys are recommended for the California tiger salamander and western spadefoot.

If surveys document the occurrence of any of these species or their protected habitats at the restoration or source material sites, the U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG) should be consulted and avoidance measures should be undertaken. If these species or their protected habitats cannot be avoided, the U.S. Fish and Wildlife Service and the California Department of Fish and Game should be consulted to identify appropriate mitigation measures.

3.5. AIR QUALITY

Construction activities associated with the proposed project could result in the generation of fugitive dust (PM_{10}) emissions and equipment exhaust emissions (ROG and NO_x). Projected emissions of NO_x and PM_{10} could exceed the San Joaquin Valley Unified Air Pollution Control District's (SJVUAPCD) thresholds of 10 tons/year for NO_x and 15 tons/year for PM_{10}. However, implementation of the following mitigation measures, which include the use of fugitive dust and equipment exhaust measures recommended by the SJVUAPD, the modification of the construction schedule to a four-year schedule, and the use of pollution offsets, would reduce this impact to a less-than-significant level is recommended. As discussed in the EA/IS, long-term operational noise impacts would not be significant, because no change in operational activity would occur with project implementation.

3.5.1. Short-term construction fugitive dust emissions

For the purpose of reducing construction emissions of fugitive dust (PM_{10}), the proponent shall implement the following measures during project construction in accordance with SJVUAPCD Regulation VIII and recommended fugitive dust control measures (SJVUAPCD; January 12, 1998):

1. Gravel strips, paved access aprons, wheel washers, or other measures designed to limit mud and dirt deposits on public roads shall be installed where vehicles enter and exit unpaved roads onto paved public roads.

2. The accumulation of mud or dirt on public paved roads, including shoulders, located adjacent to the project sites shall be removed at least once every twenty-four hours when operations are occurring. The use of dry rotary brushes and blower devices for the removal of deposited mud/dirt shall be prohibited.

3. All clearing, grading, earth moving, and excavation activities shall cease during periods of high winds.

4. All soils and fill materials transported to the project site shall either be of sufficient moisture content to limit visible dust emissions, provide at least six inches of freeboard space from the top of the transport container sides, or securely covered to prevent an excessive amount of dust being generated.

5. All soils and fill materials stored at the project site shall either be sufficiently watered or securely covered to prevent an excessive amount of dust being generated.

6. Areas disturbed by clearing, earth moving, or excavation activities shall be minimized at all times. All disturbed areas shall be stabilized using water or chemical dust stabilizers or seeded and watered until vegetation is established.

7. On-site vehicle speeds shall be limited to 15 MPH.

8. Water or petroleum-based palliatives shall be used as a dust control measure for the use of any unpaved roadways constructed or modified as part of this project which exceed one half mile in length.

Implementation of the above mitigation measures, as provided in District Regulation VIII, would reduce short-term construction-related PM_{10} generation to a less-than-significant level, assuming a 50% control efficiency (SCAQMD, 1993).

Schedule: During project construction.

3.5.2. Short-term construction equipment exhaust emissions

For the purpose of reducing construction emissions of NO_x, the proponent shall implement the following mitigation measure, in accordance with the recommendations of the District:

1. All on-site equipment driven by internal combustion engines shall be properly maintained and well tuned according to manufacturers' specifications. Maintenance records demonstrating this shall be kept on-site by the proponent and shall be made available to the County upon request.

2. Limit on-site idle time of heavy equipment to 10 minutes.

3. Encourage employees to rideshare or carpool to job site to reduce the amount of vehicle traffic to and from the project area.

Implementation of the above mitigation measures would reduce NO_x emissions by approximately 5%, which would reduce projected emissions to below the SJVUAPCD's threshold of 10 tons/year for that pollutant.

Schedule: During project construction.

3.6. NOISE

As discussed in the EA/IS, onsite construction equipment use associated with the proposed project could result in the exposure of sensitive receptors to noise levels in excess of adopted policies and standards of the County's Noise Element. Therefore, short-term construction equipment noise impacts are considered potentially significant. Implementation of mitigation measures provided in the Monitoring Plan would achieve compliance with the adopted policies and standards, and would therefore reduce this impact to a less-than-significant level. As explained in the EA/IS, no significant impacts related to offsite construction traffic and long-term operational noise would occur with project implementation.

3.6.1. Short-term construction generated noise impacts

TID shall implement the following measures to achieve compliance with the adopted standards and policies of the Noise element:

1. All construction and related activities within the project sites normally shall be limited to the hours of one-half hour before sunrise, Monday through Saturday, with no excavation to be permitted on Sundays or holidays (Thanksgiving, Christmas, New Years, Fourth of July, Memorial Day, and Labor Day). Should the County determine that additional hour restrictions are needed to minimize construction-related impacts, additional hours and/or seasonal limitations may be added following review of the matter with TID.

2. Construction equipment shall comply with noise level performance standards of the industry and be kept in proper working order to reduce noise impacts.

3. Where possible, noise-generating construction equipment shall be shielded from residential areas by noise-attenuating buffers such as truck trailers or noise barriers with an effective height of seven feet.

4. Stationary noise sources, such as pumps, compressors and generators, shall be located at a reasonable distance from residential areas.

5. Noise associated with the project shall not exceed the performance standards of the County's Noise Element.

Schedule: During project construction.

3.7. CULTURAL RESOURCES

The area of SRP 9 and 10 appears to be within the recent flood plain of the Tuolumne River, thus decreasing the potential for buried archaeological sites. Historic agricultural activities were observed, but no remains greater than 50 years of age were noted during the field investigation. Nonetheless, there is a potential for discovering subsurface archaeological deposits, human burials, and historic structural remains during the proposed restoration. Based on the possibility of encountering buried or unidentified resources, monitoring provisions are outlined below.

3.7.1. Subsurface archaeological deposits and human burials remains

With project restoration in SRP 9 and 10, where the mining activities have probably already removed cultural resources, buried resources are not anticipated. However, it is always possible that previously undiscovered resources may be uncovered.

Undiscovered resources may be a simple artifacts, located out of context or without association, or they may be intact archaeological deposits. In the case of the former, simple documentation may be sufficient to resume project activities. Treatment in the latter may prove more complex. As treatment must be assessed by a qualified professional, there are several measures outlined to meet this goal.

1. The USFWS will retain a professional archaeologist who meets the Secretary of Interior Professional Qualification Standards for Archeology for the duration of the project.

2. Prior to project construction, the USFWS will insure that either an Inadvertent Discoveries Plan has been developed among the lead federal agency, the California SHPO, and the ACHP, or that if such an agreement does not exist, that such a plan will be developed which meets both the requirements of the State of California and the intent of Section 106 of the National Historic Preservation Act (36CFR 800.11). This document will discuss the documentation, evaluation, and treatment of resources discovered inadvertently during the life of the project. The plan must address the possibility of encountering human remains.

3. The USFWS will insure that all contractors and equipment operators are instructed and required to watch for potential archaeological artifacts and sites, along with human remains. Evidence includes skeletal remains, chipped stone, shaped stone (bowls, pestles), shell and bone artifacts, metal and glass artifacts, concentrations of fire-affected rock and/or charcoal, trash pits, foundations, pits, rock alignments, and other cultural materials. In addition, the USFWS will insure that construction inspectors are instructed about the potential for finding artifacts and archaeological deposits, and are supplied with a list of contact individuals with numbers to telephone in the event of discovery.

4. The USFWS will insure that in the event prehistoric or historic resources are located within the project, all work will stop within a circumference of 10 meters (33 feet) of the find until a qualified professional (meeting the terms of 1, supra) has assessed the find and developed treatment, if appropriate.

5. In the event that human remains other than dissociated teeth or bones are encountered during Project activities, all work will stop (4, supra) and the responsible field supervisor will issue immediate notification of the find to the USFWS, the retained archaeologist, and, as required by law, to the Stanislaus County Coroner/Sheriff. In addition, if the remains are determined to be Native American, the USFWS will notify the Native American Heritage Commission, the landowner, and any appropriate Project personnel (California Health and Safety Code §7050.5(b) and (c); California Public Resources Code §5097.94-99).

Schedule: Coordination between lead federal agency and retained archaeologist will occur prior to construction in 1998 to insure an Inadvertent Discoveries Plan is agreed upon and duly executed. Instruction of responsible construction managers and contractors will occur prior to ground disturbance and mobilization in 1998. Archaeologist will remain on call through 2003.

4. LA GRANGE RESERVOIR SOURCE MATERIAL SITE

4.1. FISHERIES RESOURCES

Excavation of material from La Grange Reservoir may increase turbidity downstream of La Grange Dam during the period of excavation and may increase sedimentation in the channel bed. This increase in turbidity and sedimentation may have short-term, adverse impacts to aquatic organisms downstream. The transport of fine sediment over La Grange Dam and delivery to the channel downstream can be minimized by construction a berm to isolate turbid water in the excavation area. Such a berm was successful in minimizing turbidity downstream of the reservoir in October 1997, when the Districts excavated sand from the reservoir. Also, increases in turbidity could be coordinated with the chinook salmon outmigration period (in spring) when turbidity would be high under natural conditions during high flows associated with snowmelt in the Sierra Nevada. Such increases in turbidity may reduce bass predation efficiency and improve juvenile salmon survival. Construction of a berm to minimize turbidity or coordination would prevent adverse impacts downstream of La Grange Dam. Coordination with the spring outmigration period may produce beneficial impacts downstream of La Grange Dam. No impacts to fish resources are anticipated upstream of La Grange Dam.

4.2. VEGETATION/RIPARIAN RESOURCES

No text added.

4.3. WILDLIFE

No text added.

4.4. THREATENED AND ENDANGERED SPECIES

Surveys are recommended to identify the occurrence of threatened, endangered, and special status species at the restoration and source material sites. At the La Grange Reservoir source material site, surveys are recommended for Hoover’s calycadenia, beaked clarkia, and Hartweg’s golden sunburst, California tiger salamander (habitat), western spadefoot (habitat), western pond turtle, giant garter snake (habitat survey), great blue heron (nesting), great egret (nesting), osprey (nesting), white-tailed kite (nesting), golden eagle (nesting), and Swainson’s hawk (nesting).

If surveys document the occurrence of any of these species or their protected habitats at the restoration or source material sites, the U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG) should be consulted and avoidance measures should be undertaken. If these species or their protected habitats cannot be avoided, the U.S. Fish and Wildlife Service and the California Department of Fish and Game should be consulted to identify appropriate mitigation measures.

5. REFERENCES

EA (EA Engineering, Science, and Technology). 1992. Don Pedro Project Fisheries Studies Report. Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Vol. II. EA, Lafayette, California.

EA (EA Engineering, Science, and Technology). 1992. Lower Tuolumne River Predation Study Report, Appendix 22 *of* Don Pedro Project Fisheries Studies Report. Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299. Vol. II. EA, Lafayette, California.

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