U.S. Fish & Wildlife Service

Arcata Fisheries Technical Series Report TR 2015-28

Integrated Habitat Assessment of the Upper Trinity River, 2009

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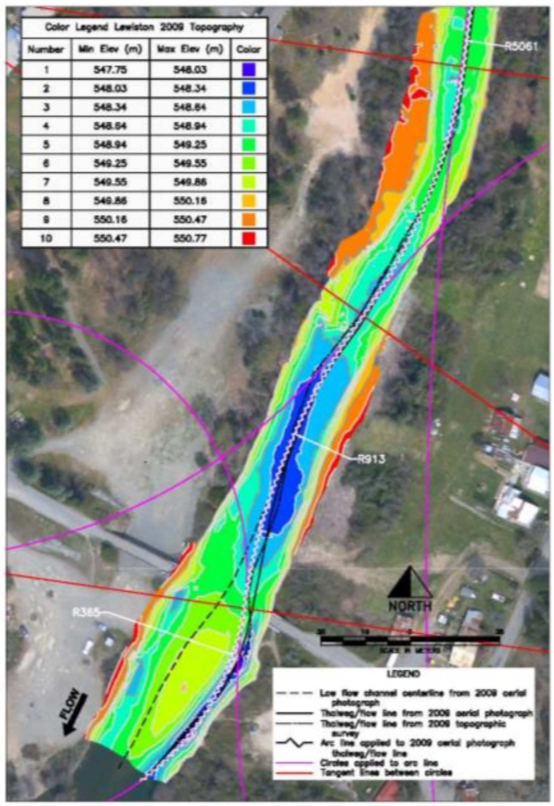

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December 2015

This study was conducted as part of the Trinity River Restoration Program, with financial support provided by the Bureau of Reclamation and the Arcata Fish and Wildlife Office, U. S. Fish and Wildlife Service.

The Arcata Fish and Wildlife Office Fisheries Program reports its study findings through two publication series. The **Arcata Fisheries Data Series** was established to provide timely dissemination of data to local managers and for inclusion in agency databases. The **Arcata Fisheries Technical Reports** publishes scientific findings from single and multi-year studies that have undergone more extensive peer review and statistical testing. Additionally, some study results are published in a variety of professional fisheries journals.

Key words: River Restoration, Salmon, Riverine Habitat, Geomorphology, Botany

The correct citation for this report is:

Alvarez, J., J. Bair, D.H. Goodman, G. Hales, A. Hilton, S. McBain, A. Martin, and J. Polos. 2015. Integrated Habitat Assessment of the Upper Trinity River, 2009. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2015-28, Arcata, California.

Acknowledgments

We would like to thank Jeremy Alameda, Larry Alameda, Jr., Ryan Bahten, Kyle De Juilio, Will Gray, Dwight Hostler, Rocky Jones, Brian Jordan, Sunny Loya, Daniel Menten, Fred Meyer, Brian Powell, David Ruiz, Matt Smith-Caggiano, Bill Trush and the rest of the field staff who collected data associated with this project. We appreciate the analytical support of Ken Newman and Nicholas A. Som, as well as, the sampling design support of Darcy Pickard. We also appreciate the support of the TRRP-Weaverville staff for providing suggestions during the development of this project and technical editing support of Mark Magneson and Peter Martin.

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Acronyms, Abbreviations, and Symbols

AEAM	Adaptive Environmental Assessment and Management
AICc	Akaike Information Criterion corrected for small sample sizes
C	cover criteria (for defining salmonid habitats)
cfs	cubic feet per second
cms	cubic meters per second
D_{84}	measure that exceeds the particle diameter of 84 percent of sampled particles
d.f.	degrees of freedom
DV	depth/velocity criteria (for defining salmonid habitats)
F	The F statistic
FL	fork length (fish length measured from the tip of the snout to the fork of the tail)
ft	feet
GRTS	generalized random tessellation stratified sampling design
GIS	geographic information system
GPS	Global Positioning System
GzLM	generalized linear model
HVT	Hoopa Valley Tribe
HSC	habitat suitability criteria
IAP	Integrated Assessment Plan
IHAP	Integrated Habitat Assessment Project
in	inches
km	kilometers
m	meters
m^2	square meters
m^3	cubic meters
mi	miles
mm	millimeters
n	number of samples or items
p	significance
Q1	first quartile
Q3	third quartile
r^2	coefficient of determination
rkm	river kilometer (measured upstream from mouth of river)
rm	river mile (measured upstream from mouth of river)
ROC	radius of curvature
ROD	Record of Decision
s	seconds
SE	standard error
sq. ft	square feet
TRBFWTF	Trinity River Basin Fish and Wildlife Task Force
TRD	Trinity River Division of the Central Valley Project
TRFE	Trinity River Flow Evaluation Final Report
TRRP	Trinity River Restoration Program

U	Mann-Whitney test statistic *U*
USDOI	United States Department of the Interior
USFWS	United States Fish and Wildlife Service
WY	water year (October through September)
yd^3	cubic yards
yr	years
α	significance threshold value
χ^2	chi-square statistic
ρ	Spearman's correlation coefficient

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Executive Summary

Within 10 years of construction of the Trinity River Division of the Central Valley Project, severe declines in salmon and steelhead populations of the Trinity River were observed and attributed to the degradation of instream habitat. The habitat degradation was influenced by decreased stream flows, with an average of 88% of the annual inflow diverted to the Sacramento River, and watershed management practices that led to increased erosion.

Information from the Trinity River Flow Evaluation Study (TRFE), as well as evaluation of restoration activities implemented in the 1980s and 1990s, led to recommendations on channel rehabilitation actions and flow regimes intended to restore the fishery resources of the Trinity River. These recommendations were evaluated in the Trinity River Mainstem Fishery Restoration EIS/EIR and subsequently adopted for implementation in the Trinity River Mainstem Fishery Restoration Record of Decision (ROD).

The primary goal of the Trinity River Restoration Program (TRRP) is to restore and sustain natural production of anadromous fish populations downstream of Lewiston Dam to pre-dam levels to facilitate dependent tribal, commercial, and sport fisheries' full participation in the benefits of restoration via enhanced harvest opportunities. Actions necessary to achieve this goal are: (1) mechanical rehabilitation of the channel, (2) flow management to restore fluvial processes that create and maintain suitable salmonid habitat and to meet water temperature objectives for juvenile and adult salmonids, (3) coarse and fine sediment management, and (4) watershed

restoration.

The restoration strategy integrates riverine processes and instream flow-dependent fish habitat needs. The primary hypothesis of the TRFE is that the mechanical manipulation of the channel, in combination with coarse sediment augmentation and release of geofluvial flows, will dramatically increase riverine habitat quantity, quality, and diversity; and design and implementation of these projects will be conducted under an adaptive management framework.

This assessment evaluated the salmonid habitat and riparian responses to mechanical channel rehabilitation and physical processes. These results will contribute to adaptive management through the evaluation of progress toward achieving TRRP goals and objectives. This is done by providing short-term feedback to improve management actions, specifically channel rehabilitation, coarse sediment augmentation, and annual flow management, as well as provide information for long-term trend monitoring.

The TRRP has been implementing the channel rehabilitation components of the ROD since 2005, and approximately half of the proposed 44 channel rehabilitation projects in the ROD were completed by the end of 2011. This monitoring effort focuses on the 64 km (40 mi) of the Trinity River located between Lewiston Dam and the confluence with the North Fork Trinity River (restoration reach), the reach where habitat degradation due to reduced flow was most pronounced and where channel rehabilitation activities are implemented.

Evaluation of project performance is critical to inform the remaining channel rehabilitation designs. The objective of the report is to address these overarching questions by completing the following tasks:

1. Assess pre-construction/post-construction salmonid habitat at recently constructed sites;
2. Assess salmonid fry and pre-smolt habitat conditions for the restoration reach;
3. Evaluate and refine habitat assessment techniques;
4. Assess site-specific design performance of constructed features; and
5. Document whether TRFE geomorphic and riparian objectives were met in WY2009, a Dry Water year under ROD criteria, as a result of ROD releases and tributary high-flows, including assessment of riparian encroachment risk at channel rehabilitation sites.

1.1. Integration of assessments

The integrated habitat assessment is an attempt to bring together individual assessments of geomorphology, channel complexity, habitat availability, and riparian habitat structural evolution to develop a more thorough understanding of how management actions induce changes in channel morphology and riparian vegetation establishment and structure, and how these changes relate to changes in aquatic and riparian habitats. Integration is a vital part of facilitating the data collection, analysis, and interpretation for the multiple disciplines that are assessing how the programmatic objectives are being achieved.

Individual assessments were designed to answer specific questions on these physical and biological components of the Trinity River ecosystem. Where possible, individual assessments were also tailored to integrate to evaluate how TRRP management actions interact with the current river ecosystem to achieve programmatic goals of increasing fish habitats. For this initial effort, integration analyses focused on the relationships between physical characteristics/parameters and rearing salmonid habitat availability.

1.2. Overarching sampling design strategy

The overarching strategy had two primary components. The first was a site-specific strategy with multi-disciplinary assessments at channel rehabilitation sites. The second component was a restoration reach wide assessment of salmonid rearing habitat, using a generalized random-tessellation stratified sampling design.

1.3. Geomorphic and topographic evaluation

Monitoring assessed whether or not Dry water year process-based (bed mobility and scour) TRFE geomorphic management targets were met. Monitoring also looked at feature-specific performance, such as side channel entrances, alcove self-maintenance, berm removal via notching, and channel migration.

Channel migration, alluvial features, and propagation of change upstream and downstream of rehabilitation sites were monitored at five sites (Valdor Gulch, Conor Creek, Hocker Flat, Bucktail-Dark Gulch, and Lewiston Cableway). In most instances, only minor changes in topography were observed, indicating features are being maintained, but the mainstem channel and associated alluvial features have not been substantially altered. For example, at Conner Creek, only one of five monitored cross section (247+40) showed some lateral movement. The conclusion to date is that instantaneous floods up to 233 cms (8,230 cfs) are causing very little channel migration at Conner Creek, despite attempts to encourage it through the implementation of the rehabilitation design. Many sites have yet to experience multiple Wet or Extremely Wet WY types. Change in channel migration may be more apparent after sites have experienced greater magnitude flow releases.

1.4. Riparian and large wood assessments

Riparian monitoring examined whether or not process-based TRFE riparian targets were met by annual flow releases. Riparian related flow objectives were to inhibit riparian vegetation initiation along the low water margin, increase the species and age diversity of riparian vegetation, and encourage establishment and growth of woody riparian vegetation on floodplains. This included the inundation of gravel bars to prevent riparian seed germination, mortality of seedlings 2 years old or younger via channelbed scour, and riparian recruitment on floodplains above 2,000 cfs.

Riparian scour targets (ROD flows, in combination with tributary accretion, are capable of inhibiting hardwood seedling establishment along the 13-cms [450-cfs] water surface) were met at all sites except Hoadley Gulch, where it is too early to tell. Floodplain recruitment targets (bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains the areal extent, species richness, and age diversity of riparian vegetation on floodplains) were met only at Indian Creek and not at Pear Tree, Valdor Gulch, Hocker Flat, Lewiston Cableway, and Sven Olbertson; it is too early to tell if the floodplain recruitment targets were met at Bucktail-Dark Gulch or Hoadley Gulch.

Riparian monitoring also assessed changes in aerial extent, species richness, age diversity and vertical structure of floodplain vegetation after rehabilitation at ten sites. At six sites, it was too soon after rehabilitation to be able to detect changes in riparian vegetation parameters, oftentimes because there has not been sufficient time between construction and monitoring to allow for plant growth. Change was observed at four sites: Hocker Flat, Lower Indian Creek, Bucktail-Dark Gulch, and Sven Olbertson. At Hocker Flat, natural seedling regeneration has not contributed to the increase in complexity, and there has been no establishment of natural seedlings on constructed floodplains. Monitoring should be continued as seedlings have time to sprout and grow in upcoming years.

Substrates with a higher percent composition of finer textured particles—like the Lower Indian Creek and Sven Olbertson rehabilitation sites—were better for seed germination due to a higher capillary fringe (and therefore less opportunity for desiccation) and fewer air pockets (which are fatal to roots). It is possible that the lack of fine sediment in the constructed floodplains may inhibit future seedling regeneration, as was observed at Hoadley Gulch.

At six of the sites, large wood storage decreased. With the exception of Valdor Gulch, these sites were closest to Lewiston Dam (Bucktail-Dark Gulch and upstream) where input of large wood is low. Slight increases in large wood storage were observed at Conner Creek, Hocker Flat, and Indian Creek. Wood was not placed during construction at Hocker Flat; thus all large wood mapped at the site originated from natural recruitment.

While riparian scour targets have been met at downstream sites (i.e., Valdor Gulch and Pear Tree), ROD flows were unable to scour root sprouts (i.e., roots remnant from construction). Root sprouts in the Canyon Creek suite were unaffected by ROD flows. At Valdor Gulch, post-construction regrowth has allowed willows to regenerate similar to pre-construction conditions. This was due to incomplete root removal during rehabilitation. A sediment berm has formed and the low water channel has begun to simplify. At Conner Creek, because of root regrowth, the floodplain could lose some function, and the area may become an extension of the existing riparian berm. At Hocker Flat, re-encroachment, assisted by remnant roots, has already begun; re-encroachment of the low water channel margin is anticipated in five to ten years unless corrective actions are taken.

1.5. Fish Habitat

1.5.1. Estimation of Chinook salmon and coho salmon rearing habitat at specific rehabilitation sites on the Trinity River

The objectives of this assessment were to (1) estimate changes in Chinook and coho salmon rearing habitat at winter base flow from construction at channel rehabilitation sites, (2) evaluate the effect of selected channel rehabilitation sites on flow-habitat relationships, and (3) estimate the quantity and quality of Chinook and coho salmon rearing habitat at multiple flows at selected channel rehabilitation sites before construction. We assessed these objectives at six channel rehabilitation sites which were either recently rehabilitated or expected to be rehabilitated in the near future (objective 3 only). The effect of channel rehabilitation actions were evaluated at Bucktail-Dark Gulch, Hoadley Gulch, Lewiston Cableway, and Sven Olbertson. Conditions before rehabilitation actions were documented at Lowden and Lower Reading Creek to inform the design processes and initiate before-after studies. Finally, the results of previous assessments were reviewed to add context to current results.

After channel rehabilitation, habitat area increased at winter base flow in all cases. The improvements from rehabilitation varied by site and ranged from 6 to 67%, with the largest increases at Bucktail-Dark Gulch and Sven Olbertson. Side channel creation accounted for 82 to 100% of improvements in habitat amounts. After construction, Sven Olbertson had the most habitat area per unit channel length of TRRP channel rehabilitation sites evaluated to date.

Channel rehabilitation altered flow-habitat relationships. At Bucktail and Lewiston Cableway habitat was improved at all measured flows and the shape of the flow-habitat relationship was largely unchanged. A similar result was observed in total habitat area at Upper Dark Gulch with increases at all streamflows and little change to the shape of the flow-habitat relationship. However at the same site, high quality rearing habitats increased at lower streamflows, but decreased relative to pre-construction conditions above approximately 40 cms (1,413 cfs). The reduction of high quality habitats at higher flows is likely from vegetation removal during construction.

When comparing flow-habitat relationships across channel rehabilitation sites the shape of the curves and amounts available varied by site. Lewiston Cableway had the most habitat area at all streamflows and habitat area increased with streamflow. This site has a side channel through most of the site and a low elevation, vegetated, and sloping floodplain. In contrast, Hocker Flat (the first site constructed by the

TRRP), per prior assessment, typically had the lowest habitat area across streamflows and habitat area generally decreased with flow. Hocker Flat is a single thread channel and vegetation was removed during construction with little growth 3 years after construction. Future assessments are planned for these sites after riparian establishment and sediment initiating peak flow releases from Lewiston Dam.

1.5.2. Estimation of Chinook salmon and coho salmon rearing habitat area within the primary restoration reach of the Trinity River

Chinook and coho salmon rearing habitat area was estimated within the restoration reach of the Trinity River. The objectives of this assessment included (1) estimation of rearing habitat area in 2009, (2) an assessment of correlation between habitat area variables, (3) an evaluation of site specific predictors of habitat area and (4) establishment of a revisit design to evaluate the status and trend of rearing habitat amounts with implementation of restoration actions. Rearing habitat area was measured at 32 400-m sites and then extrapolated to estimate habitat area for the restoration reach. This assessment represents conditions at summer baseflow or 12.7 cms (450 cfs).

Restoration reach estimates were 343,201 (CI = 279,633 to 406,769) and 436,613 (CI = 374,909 to 498,318) m^2 for fry and presmolt habitat area, respectively. High quality habitats represented 25% and 26% of the total habitat area. Standard error of estimates ranged from 7 to 9% for total habitat area and high quality respectively. These estimates will provide a foundation for future evaluations of changes in rearing habitat with restoration actions. Fry and presmolt habitat area were highly correlated and may lead to improved survey efficiency in future assessments. Several site-specific variables were significantly correlated to rearing habitat area including bank length, side channel length, and distance from dam. Additionally, sample units with post-ROD channel rehabilitation actions had higher habitat values than other sites and supported the benefits of channel rehabilitation efforts. Three sites had higher habitat values compared to the rest of the samples. These sites shared several characteristics such as proximity to Lewiston Dam, a history of channel rehabilitation, and characteristics related to high channel complexity such as side channels, alcoves and other channel features.

1.5.3. Diel and longitudinal effects on rearing Chinook salmon and coho salmon habitat use

Several assumptions used for the rearing habitat assessment were evaluated: (1) mapped categories are related to counts of Chinook and coho salmon, (2) higher quality habitats hold higher fish densities, and (3) the fish use of mapped habitat categories is similar between day-time and night-time. These assumptions were tested at the Lowden Meadows channel rehabilitation site. Factors in the analysis included rearing habitat category, day-time vs. night-time sampling and the interaction between the two factors.

In all cases, there was a higher probability of observing fish and higher expected fish counts with higher habitat quality. These results support the use of habitat categories for fish habitat assessments. Diurnal differences were observed in all cases and the effects varied by species and life stage. For Chinook salmon there was a higher probability of observing fish during night-time surveys, however higher night-time counts were predicted for fry and not presmolt. In contrast, the probability of observing coho salmon was higher during the day in high quality habitats.

This study was compared to a previous evaluation of fish use at Lewiston Cableway and Hoadley Gulch. Significant differences were detected between the two studies. In general, more fish were observed at Lewiston Cableway and Hoadley Gulch than at Lowden Meadows and is likely related to the distance of habitats from spawning areas. Despite observed differences between sites, results from Lewiston Cableway, Hoadley Gulch and Lowden are concordant with higher fish densities associated with higher quality habitats.

1.5.4. Redefining Chinook salmon spawning habitat in the Trinity River

Increases in spawning habitat area and quality are expected from TRRP actions and will contribute to realization of restoration goals. Spawning habitat assessment techniques are under development for the Trinity River. Since initiation of the TRRP, a previous study attempted to quantify spawning habitat area. However, the previous study results did not validate with known redd locations at acceptable levels. Therefore, work was needed to develop an approach to evaluate changes in spawning habitat area and quality from TRRP actions. This study assessed the following objectives, (1) modify the spawning habitat mapping technique from the previous study and evaluate its performance, (2) assess variables used to define habitat and (3) evaluate if habitat use has changed from implementation of restoration actions.

Spawning habitat mapping was modified from a previous application with changes to mapping criteria and applied as a validation study. The spawning habitat mapping showed an improvement in prediction success, from 36% in the previous study to 57% with the modified approach. Despite improvements, prediction success was below the target of 70%. However, 80% of redds were within a 3-m buffer of mapped habitat. Although a high proportion of redds were encompassed within the buffered areas, this analysis likely leads to over-prediction errors.

In a companion study, several variables were assessed for predicting spawning habitat including depth, velocity, distance to cover, substrate and geomorphic features. The best model of spawning habitat included all variables and resulted in an misclassification error rate of 13%. Although this model needs additional validation, it has the promise to provide a tool to lead to improvements in spawning habitat assessment. For example this equation could link 2-D hydrodynamic model predictions to spawning habitat. In addition, it provides information on the primary factors describing spawning habitat which could be incorporated into rehabilitation site design processes.

Observations of depth, velocity and substrate at Chinook salmon redds were compared to similar observations made in the 1980's during development of the TRFE and before initiation of TRRP restoration efforts. The depth and velocity measured at redds in this study were similar between the two studies. However, the dominant substrate observed at redds in the TRFE were small cobbles and larger than the medium to large gravels at redds in this study. Substrate at redds in this study were within the particle size distributions added by the TRRP as part of the coarse sediment augmentation program which may have changed availability between the two studies.

1.5.5. Precision of salmonid rearing habitat mapping surveys

Two of the assumptions inherent to the habitat mapping technique applied to study restoration effects are: (1) measurements are repeatable and the level of measurement error inherent to the assessment technique is less than the anticipated response (i.e., restoration effects). To evaluate repeatability and precision of the salmonid rearing habitat mapping techniques the following objectives were evaluated: (1) assess the level of difference observed between repeat estimates of habitat categories, (2) evaluate the level of measurement error in rearing habitat mapping relative to anticipated changes from restoration, and (3) compare results of this assessment to precision estimates from other aquatic habitat assessment techniques. Rearing habitat was mapped twice at seven randomly selected 400-m segments and then compared.

Differences between initial and repeat surveys were compared for 11 habitat variables and differences varied by life stage and habitat category. A significant difference was detected in high quality presmolt habitat area. However, mean pairwise difference between initial and repeat surveys was between 14 and 16%. No other significant differences were detected in other variables. Differences in total habitat area ranged from 6 to 8%. Differences in other habitat variables ranged from 1 to 22% rearing habitat area. In all cases the error between initial and repeat habitat mapping estimates were lower than the interim TRRP target of a 400% increase.

These results provide support for the use of rearing habitat mapping to evaluate restoration effects on the Trinity River. The differences observed in the current study were compared to the results of similar studies conducted on two other stream habitat assessment techniques. Precision of the habitat mapping technique presented in this report were in most cases better than variables measured in other techniques.

1.5.6. Comparison of habitat mapping and two dimensional hydrodynamic model predictions of salmonid rearing habitat availability

Habitat mapping has been the primary technique applied to evaluate the effects of Trinity River restoration efforts on salmonid rearing habitat. However, two-dimensional hydrodynamic models (model hereafter) have been used for similar purposes. Models have many additional applications that may be useful to the TRRP including the ability to predict the effects of restoration site design alternatives on habitat availability, evaluate the effects of geomorphic processes and evaluate effects of various flow schedules on habitat availability. The objective of this study was to evaluate the compatibility of the habitat mapping and modeling techniques implemented by the TRRP for site design purposes. Two-dimensional hydrodynamic models and flow-habitat mapping surveys were applied and compared at the Reading Creek and Lowden Meadows channel rehabilitation sites.

At Reading Creek, mapping estimated a higher quantity of habitat area at all measured streamflows with differences ranging from 16% to 107% depending on life stage and habitat variable. The shapes of flow-habitat relationships were generally similar between the two techniques at Reading Creek. In contrast, model predictions of habitat area at Lowden Meadows were generally higher than mapping estimates. Differences in habitat area estimates between techniques ranged from 17% to 108%. The difference in streamflow to habitat relationships generally increased with streamflow. Discrepancies in the locations of model and mapped habitat areas were identified at both sites. Although some zones of overlap occurred, in general the size and shape of habitat areas were dissimilar. The patterns in differences between modeled and mapped habitat make comparisons of habitat estimates seemingly incompatible at this point.

While the trends in the flow-habitat relationships were similar for the mapped and modeled data, the differences throughout the relationships were not consistent and the magnitudes of difference were substantial in some cases. This comparison should be considered in light of the modeled data which used pre-existing data sets with no model calibration data within the range of flows evaluated in this comparison. It is possible that the resolution of input data was not sufficient to produce accurate predictions and higher resolution model input data may result in improved concordance between methodologies. Future assessments should focus on collecting independent validation datasets to better understand the level of error of each technique, and particularly for model data that is predicted and not measured.

1.6. Integration

Seven sites of varying lengths were selected where habitat mapping and physical process monitoring were conducted in 2009. Where data were available, exploratory integrative analyses were conducted for data from the following sites: Hocker Flat, Lower Indian Creek, Lowden Meadows, Bucktail-Dark Gulch, Lewiston Cableway, Hoadley Gulch, and Sven Olbertson. These sites were selected based on a combination of the following factors: (1) Reasonable distribution of sites over the restoration reach, (2) Pre- and post-construction fish habitat assessments at most sites, and (3) Pre- and post-construction topographic information at most sites.

Physical variables tested against fish habitat were: radius of curvature, topographic diversity, shear stress diversity, length of wetted edge, and area of exposed active alluvial deposit.

1.6.1. Radius of curvature

A total of 52 pre-construction and 55 post-construction habitat and radius of curvature (ROC) data pairs were generated. It was expected that as channel changes occur and the channel exhibits a more sinuous nature (greater ROC) the amount of rearing habitat will increase. We identified a weak but significant relationship between ROC and habitat density for the post-construction conditions. A general, non-linear trend of decreasing habitat density with increasing ROC was observed but there was substantial variability in the data, especially at the lower range of ROC. Pre-construction data were widely scattered with no obvious relationship between fry habitat density and ROC. Future investigations into this relationship should consider other factors such as adjacent conditions that may influence this relationship and account for some of the unexplained variability that was observed in the post-construction dataset.

1.6.2. Topographic diversity

It was anticipated that changes in channel form, resulting from restoration actions will increase instream topographic diversity and lead to increases in habitat. Diverse topography is expected to be a desirable trait and provides a range of depth and flow combinations to meet the physical habitat needs of aquatic species. Two categories of channelbed diversity were derived: (1) the standard deviations of depth for a specific flow and (2) ratio of the channelbed surface area to the water surface area. Channelbed diversity based on standard deviations of depth did not exhibit any relationship to rearing habitat area for the low flow conditions, but did exhibit a weak direct relationship at higher streamflows. The channelbed surface area to water surface area ratio metric of diversity did not exhibit any relationship to rearing habitat for the pre-construction data and an inverse relationship to the post-construction data. Some of the possible reasons for this include: (1) limited extent of the area surveyed, (2) data from only one flow level, and (3) range of ratios close to 1.0 and any error surface area computation may have a big effect on the ratio.

The 2009 analysis was limited to the Lewiston Cableway rehabilitation site and quantifying channel complexity in 50 m (164 ft.) long sections may not stratify channel complexity into units that define habitat (i.e. meso-habitat pools or riffles). Future efforts will sample 11 sites (2-D GRTS sites) which will allow assessment of how rearing habitat is maintained across flows, at different scales, and how the topographic diversity influences a suite of species and life stages.

1.6.3. Shear stress diversity

It was hypothesized that sections of the river that had more variable shear stress would have greater habitat by providing a greater range of velocities. There were no apparent relationships between shear stress diversity and rearing habitat in the data used for this evaluation. There may be a similar weakness with the shear stress diversity evaluation as discussed in the topographic diversity section with the limited area sampled. While the shear stress diversity metric used for this analysis used all shear stresses values acting on a portion of river, only low shear stress values with slow velocities and/or shallow depths could represent areas for rearing habitat. New concepts such as evaluating the range of shear stresses that occur inside and outside the identified habitats will be considered among others when moving forward with the future integration analyses.

1.6.4. Length of wetted edge

Restoration actions were expected to increase the sinuosity and complexity of edge features, leading to more available habitat. All relationships evaluated (pre- and post-construction and fry and presmolt) indicated that there was a positive relationship between habitat density and wetted edge density. This relationship was also observed in the restoration reach rearing habitat assessment where the highest habitat densities were in sections of river which complex edge features or multiple channels.

1.6.5. Area of active alluvial deposit

The amount of rearing habitat was expected to increase with increases of alluvial bars due to the more diverse suite of depth and velocity combinations associated with these features. While some of the data suggest that was a direct relationship, these analyses were limited with a small dataset at one channel rehabilitation site. Future investigations into these relationships should expand the number of bars sampled and the longitudinal distribution along the restoration reach of the river.

1.6.6. Integration insights

While this initial attempt to conduct integrative analyses relating fry and presmolt Chinook salmon habitat to physical parameters did not result in many significant results, the data did support some of the hypothesized relationships and warrants further investigation. Comparing various types of physical data with rearing habitat areas is a complex task and a variety of exploratory analyses were attempted. This was an exploratory exercise with a limited number of sites and replicates
Future analyses should consider multivariate analyses rather than the univariate comparisons that were used in this initial analysis. Some of the challenges that arose during the integration analyses should be resolved with the implementation of a GRTS sampling design in 2010. Also, eleven of the GRTS sites will have a full suite of physical data associated with them as they will have validated and calibrated two dimensional models. This will allow comparisons across a suite of sites and streamflows.

1.7. Discussion and management recommendations

The following list summarizes 19 key discussion and management recommendations.

1.7.1. Geomorphology

1. A Dry water year is not expected to result in an abundance of geomorphic change on the Trinity River. Given this reality, it is recommended that geomorphic monitoring be continued in future years.

1.7.2. Fish habitat

2. Change in habitat area from construction activities varied by channel rehabilitation site. The improved understanding of differences in habitat response from this monitoring should be incorporated into the design process to maximize the benefit of future channel rehabilitation sites.

3. The TRRP should develop realistic habitat targets necessary to meet fishery resource goals so that estimates of existing habitat can be put into context with habitat requirements.

4. The relationship between channel rehabilitation sites and rearing habitat areas identified the highest values associated with post-ROD sites. Continued monitoring is needed to ensure habitat area continues to increase and meet long-term restoration goals.

5. Brown trout use of rearing habitat areas was documented and in some cases outnumbered native salmonids. The brown trout population should be evaluated for their population size, dynamics and feeding strategies in relation to impacts on restoration of the Trinity River native salmonid populations.

6. Results of the two dimensional hydrodynamic model and rearing habitat mapping differed to varying degrees, and differences were not consistent among variables or sites. It is recommended that future comparisons increase the resolution of model input data, quantify error associated with model predictions and ensure model calibration data and mapping data are collected at similar flows.

1.7.3. Channel rehabilitation-related activities

7. As a result of evaluating channel migration, it is recommended to consider constructing in-channel bars and/or other features at Valdor Gulch to initiate more substantial topographic change.

8. Remnant root sprouts should be removed at Pear Tree, Valdor Gulch, Connor Creek, and Hocker Flat. If not removed, berm formation is likely to contribute to these sites reverting to a pre-construction condition. Future root regrowth should be inhibited through implementation measures taken in future construction.

9. To promote riparian regeneration at channel rehabilitation sites, substrate needs a minimum of 15% of the overall composition smaller than 2 mm (0.08 in).

10. The installation of large wood at channel rehabilitation sites is one of the primary restoration techniques used by the TRRP to create this habitat feature. However,

the longevity of the benefits of large wood installations is uncertain and should be evaluated through time.

11. It is recommended that site designers develop quantitative predictions on the magnitude of change and time frame anticipated from channel rehabilitation actions.
12. The effect of channel rehabilitation was evaluated at locations designed to alter streamflow to habitat relationships. The effects of channel rehabilitation also varied and did not consistently improve the shape of the streamflow to habitat relationship to between 8.5 and 42.5 cms (300 and 1,500 cfs). Site designers should evaluate the responses observed based on treatment type and incorporate this information into future designs.
13. The highest rearing habitat densities occurred at sites where side channels were created or enhanced. Side channels with the highest habitat densities are those which have a more sinuous channel form, large wood installed, and varied side slopes constructed to provide habitat at multiple flows. The location or placement of side channel entrances is critical to their long term success. Monitoring of naturally occurring and constructed side channels and their entrance conditions is recommended to elucidate what conditions can contribute to long term persistence of these features.
14. It is recommended that a focused investigation on side channel entrance conditions be conducted.
15. Preliminary data indicate berm notches, in combination with high-flow releases (192.8 cms, 6,810 cfs) were not able to generate additional berm removal at Vitzthum Gulch to date. If the notches continue to fill in, the revisiting of this site should be considered and a new site rehabilitation design developed.
16. The two constructed alcoves monitored (Pear Tree and Valdor Gulch) were observed to be depositional and thus not fully functional or self-maintaining at present. Future rehabilitation designs will likely benefit from refined alcove design criteria to better ensure appropriate scour and self-maintenance (Hoopa Valley Tribe et al. 2011).
17. The highest rearing habitat densities occurred at sample sites in proximity to Lewiston Dam. In planning future restoration actions, the TRRP should consider emphasizing increases in rearing habitat area in downstream reaches to improve habitat conditions throughout the restoration reach.

1.7.4. Integration analysis

18. Integration analyses evaluated the correlation between variables indicative of physical processes and Chinook salmon and coho salmon rearing habitat area. Results from the length of wetted edge and rearing habitat comparison demonstrated similar results as were seen in the site specific and systemic analyses. The sections of river with the highest densities of habitat occurred where bank length density was highest. Higher bank length densities are an anticipated response to physical processes which form and maintain complex channel morphologies. Where appropriate, it is recommended that the TRRP continue to consider design features such as multiple channels that have high bank length densities in the channel design process.

19. Although some integration analysis relationships were more apparent than others, it is important to consider this analysis reflects just one year of sampling at a limited number of sites. It is recommended to continue cross-discipline analysis using lessons learned from the 2009 effort.

CHAPTER 1. INTERDISCIPLINARY SALMONID HABITAT ASSESSMENT OF THE UPPER TRINITY RIVER

1.1. Introduction

Within 10 years of construction of the Trinity River Division (TRD) of the Central Valley Project, severe declines in salmon and steelhead populations were observed and attributed to the degradation of instream habitat (Hubbel 1973). The habitat degradation, in turn, was attributed to decreased streamflows (an average of 88 percent of the annual inflow was diverted to the Sacramento River) and to watershed management practices that led to increased erosion (TRBFWTF 1977).

In 1981, the Secretary of the Interior directed the U.S. Fish and Wildlife Service to conduct a flow study to evaluate the flow needs for anadromous salmonids in the mainstem Trinity River and to recommend actions necessary to restore the fish populations impacted by the construction and operation of the TRD. Additionally, in 1984, the Trinity River Basin Fish and Wildlife Management Act, P.L. 98–541, established a restoration program to implement actions necessary to rehabilitate the degraded instream habitats, including watershed restoration activities to reduce fine sediment input into the mainstem (USFWS and HVT 1999). Mechanical channel rehabilitation was one of the primary actions implemented and evaluated under this program. Information from the flow study as well as evaluation of restoration activities implemented by the restoration program led to recommendations on channel rehabilitation actions and flow regimes contained in the Trinity River Flow Evaluation Final Report (TRFE; USFWS and HVT 1999). These recommendations were evaluated in the Trinity River Mainstem Fishery Restoration EIS/EIR (USFWS et al. 2000) and subsequently adopted for implementation in the Trinity River Mainstem Fishery Restoration Record of Decision (ROD; USDOI 2000).

The primary goal of the Trinity River Restoration Program (TRRP) is to restore and sustain natural production of anadromous fish populations downstream of Lewiston Dam to pre-dam levels to facilitate dependent tribal, commercial, and sport fisheries' full participation in the benefits of restoration via enhanced harvest opportunities (TRRP and ESSA Technologies Ltd. 2009, Bureau of Reclamation 2009). Actions necessary to restore and maintain the freshwater habitats for anadromous salmonids to achieve this goal are (USDOI 2000):

1. Mechanical rehabilitation of the channel,
2. Flow management to restore fluvial processes that create and maintain suitable salmonid habitat and to meet water temperature objectives for juvenile and adult salmonids,
3. Coarse and fine sediment management, and
4. Watershed restoration.

In signing the Trinity River Mainstem Fishery Restoration ROD, the Secretary of the Interior adopted a restoration strategy to meet the primary goal of TRRP. That strategy is presented in the TRFE (USFWS and HVT 1999):

> If naturally produced salmonid populations are to be restored and maintained, the habitat on which they depend must be rehabilitated. The most practical strategy to achieve fish habitat rehabilitation is a management approach that integrates riverine processes and instream flow dependent needs. This management approach physically reshapes selected channel sections, regulates sediment input, and prescribes reservoir releases to (1) allow fluvial processes to reshape and maintain a new dynamic equilibrium condition and (2) provide favorable water temperatures. This strategy does not strive to recreate the pre-TRD mainstem channel morphology. Several sediment and flow constraints imposed by the TRD cannot be overcome or completely mitigated. The new alluvial channel will be smaller in scale, but it will exhibit almost all the dynamic characteristics of the 10 alluvial attributes necessary to restore and maintain fisheries resources.

Before the ROD was signed in 2000, bank rehabilitation projects were implemented at nine pilot sites between 1991 and 1993. The geomorphology, riparian vegetation, fish use, and fish habitat were all monitored at these sites after implementation, and information gained from that monitoring guided the restoration strategy and management actions contained in the TRFE and ROD (Krakker 1991, Hampton 1992, Glase 1994, Gallagher, 1995, USFWS 1997, Gallagher 1999a, 1999b, 1999c, Bair J. H. 2001, 2003, Chamberlain 2003). Monitoring of these pilot sites ceased in 2001, in anticipation of implementation of the ROD. The TRFE identified an additional 44 potential channel rehabilitation projects and 3 potential side-channel rehabilitation projects between Lewiston Dam and the North Fork Trinity River.

The primary hypothesis of the TRFE is that the mechanical manipulation of the channel, in combination with coarse sediment augmentation and release of intermittent high flows, will dramatically increase riverine habitat quantity, quality, and diversity. The TRFE recommended that these projects be designed and implemented under an adaptive management framework. The components of the Adaptive Environmental Assessment and Management (AEAM) process (in the context of the channel rehabilitation effort) include:

1. Determine project goals and objectives.
2. Hypothesize and predict: Assess channel rehabilitation site opportunities and predict geomorphic response and the resulting habitat response of sites for different rehabilitation alternatives.
3. Design: Develop channel rehabilitation designs (and assessments) based on predictions.
4. Implement: Implement channel rehabilitation designs and assessments.
5. Monitor: Monitor channel and habitat response, as well as fish and wildlife use and population response.
6. Assess: How did the habitat and/or the channel respond compared to predictions? How can we improve our designs to better achieve desired habitat/channel responses? What were cause-and-effect relationships between

habitat/channel response and channel design, flow management, sediment management, and large wood management?

7. Adapt: Alter management actions such as restoration designs, annual flow releases, coarse sediment augmentation, and large wood management.

The goal of this assessment was to evaluate the effectiveness of TRRP restoration actions; that is, to determine the changes in salmonid habitat resulting from both mechanical channel rehabilitation and restoration of fluvial processes necessary to create and maintain riverine habitats. This assessment evaluated the salmonid habitat response and the riparian response to mechanical channel rehabilitation and physical processes. Results will contribute to the TRRP's adaptive management through the evaluation of progress toward achieving TRRP goals and objectives. They will provide short-term feedback to improve management actions, specifically channel rehabilitation, coarse sediment augmentation, and annual flow management, and they will also provide information for long-term trend monitoring.

The TRRP has been implementing the channel rehabilitation components of the ROD since 2005; nearly half of the proposed 44 channel rehabilitation projects in the ROD are expected to be completed by the end of 2011. Evaluation of project performance is critical to inform the remaining channel rehabilitation designs. Accordingly, there are several overarching questions that this assessment addressed (Figure 1–1). The objective of the report is to address these overarching questions by completing the following tasks:

1. Assess pre-construction/post-construction salmonid habitat at recently constructed sites, and selected sites scheduled for construction in 2009 and 2010;
2. Assess systemic fry/juvenile salmonid habitat for the primary restoration reach from Lewiston Dam to the North Fork Trinity River confluence;
3. Evaluate and refine habitat assessment techniques;
4. Assess site-specific design performance of constructed features; and
5. Document whether TRFE geomorphic and riparian objectives are being met as a result of ROD releases and/or tributary high-flows, including assessment of riparian encroachment risk at channel rehabilitation sites.

1.2. Study Area and Drainage Description

The Trinity River is located in northwestern California within Humboldt and Trinity counties. The watershed has a drainage area of 7,679 km^2 (2,965 sq. mi), approximately one-quarter of which is upstream of Lewiston Dam (USFWS 1989; Bureau of Reclamation 2009). The river's headwaters are in the Salmon-Trinity Mountains of northern California, from which it flows 274 km (170 mi) to its confluence with the Klamath River at Weitchpec, California. This monitoring effort focuses on sites located within the 64-km (40-mi) stretch of the Trinity River located between Lewiston Dam and the confluence of the North Fork Trinity River (Figure 1–2). This is the reach where habitat degradation due to reduced flow was most

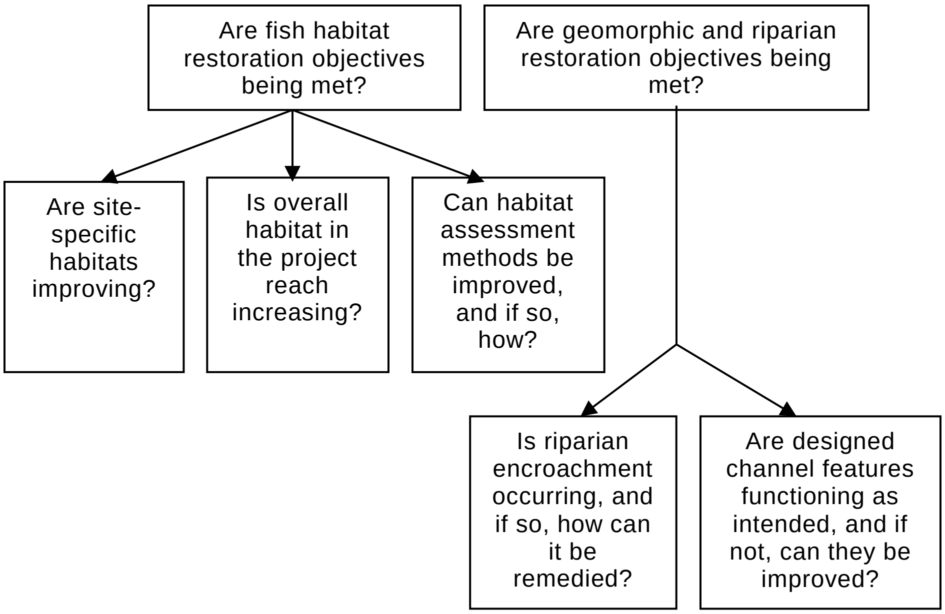

Figure 1–1. Overarching discipline-specific questions pursued in this report.

pronounced (USFWS and HVT 1999). Site-specific descriptions of channel rehabilitation sites can be found in Appendix A.

1.3. Integration of Assessments

The Integrated Habitat Assessment Project (IHAP) is an effort to bring together individual assessments in geomorphology, channel complexity, habitat availability, riparian habitat, and structural evolution as envisioned in the Integrated Assessment Plan (IAP; TRRP and ESSA Technologies Ltd. 2009). The goal of the integration is to promote a more thorough understanding of how management actions induce changes in channel morphology and riparian vegetation structure, and how changes relate to increases (or decreases) in aquatic and riparian habitats. Integration facilitates data collection, analysis, and interpretation for the multiple disciplines that are assessing how the programmatic goal is (or is not) being achieved. Integrating fundamental program components of geomorphology and channel complexity (IAP Chapter 3.1) with assessments of habitat availability (IAP Chapter 3.2) and riparian vegetation (IAP Chapter 3.5) will better inform the TRRP of the effectiveness of channel rehabilitation actions, coarse sediment augmentation, and ROD flow releases (Figure 1–3).

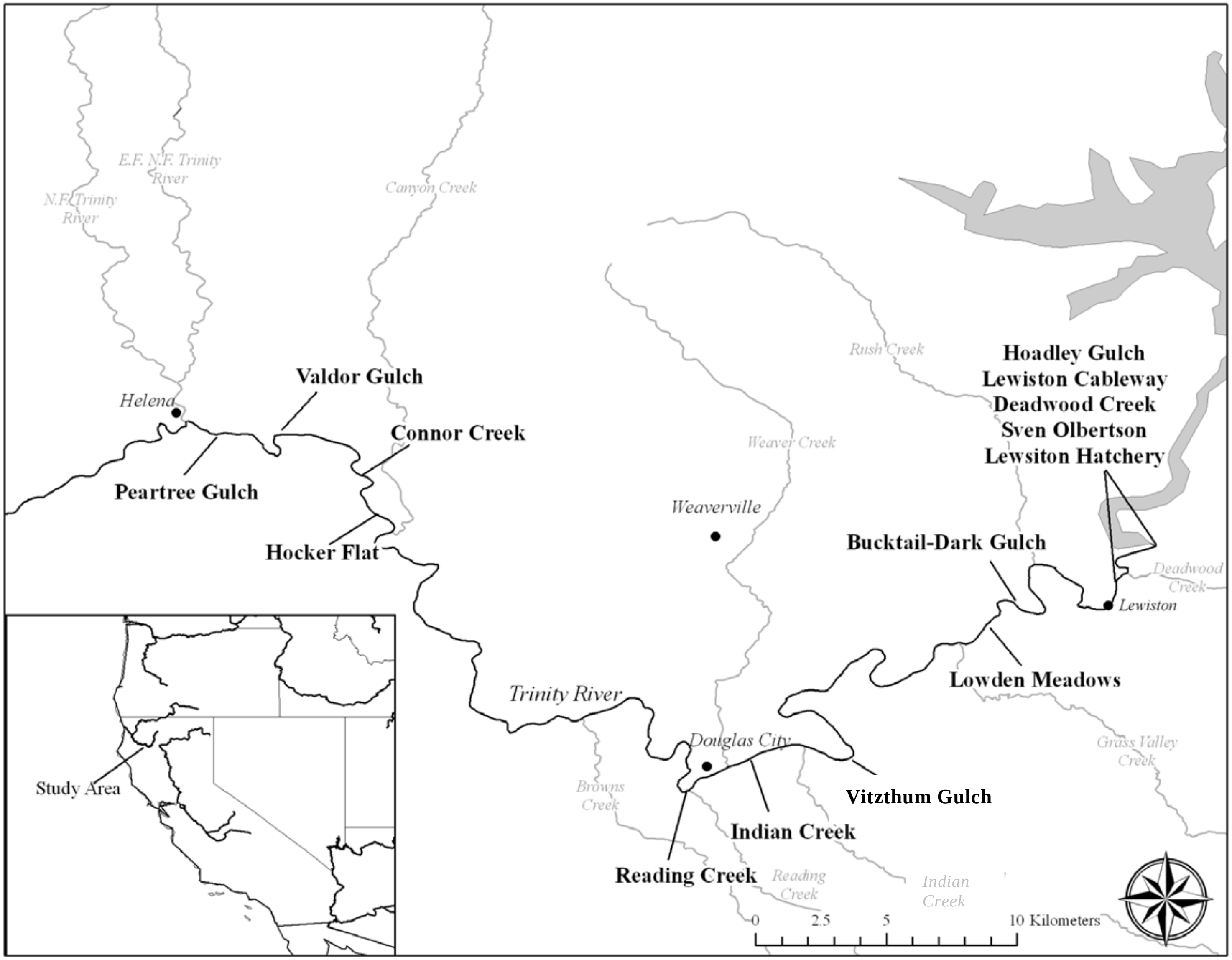

Figure 1–2. Location of bank rehabilitation assessment sites, 2009. Integration analyses were conducted at Sven Olbertson, Lewiston Cableway, Hoadley Gulch, Bucktail–Dark Gulch, Lowden Meadows, Indian Creek, and Hocker Flat.

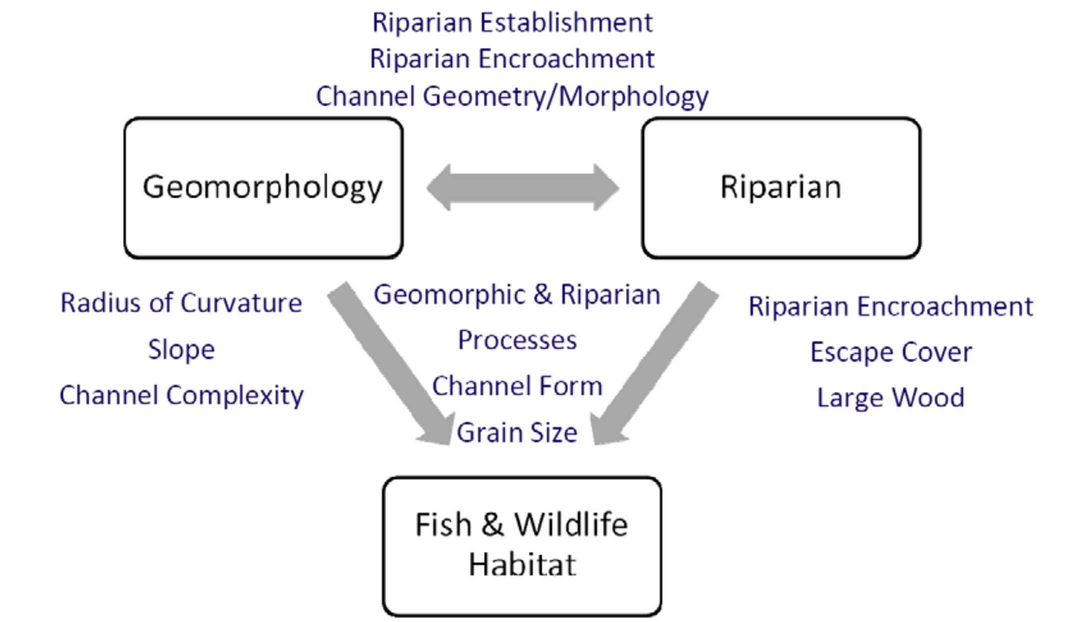

Figure 1–3. Conceptual linkages among physical processes and riparian vegetation, and the effects of these processes on biological habitats.

At the very basic level, assessments of the various disciplines are to be integrated so that the results of geomorphology and riparian assessments can be related to changes in salmonid habitat availability. In some cases, this required collocation of monitoring sites for the various disciplines. At a finer level, managers need to assess fluvial processes and riparian colonization, and to understand how these processes are affected by high-flow releases, tributary floods, coarse sediment augmentation, fine sediment reduction efforts, and channel rehabilitation actions. Such an understanding will allow them to evaluate the effectiveness of management actions and to modify those actions as necessary.

Individual assessments were designed to answer specific questions on these physical and biological components of the Trinity River ecosystem. However, individual assessments were also tailored, where possible, to fit together (i.e., to be integrated) in a broader sense to allow us to evaluate how TRRP management actions interact with the current river ecosystem to achieve programmatic goals and objectives. Assessments conducted in isolation that focus on one aspect of the ecosystem without considering other ecosystem processes or responses are limited in their ability to explain how management actions are or are not achieving programmatic goals and objectives.

To date, the physical and biological components have not been integrated in a structured way. This project initiates the integration process to help us evaluate the relative effects of key variables and to set the stage for the refinement of future integration assessments.

Seven sample sites of varying lengths were selected where fish habitat mapping and physical process monitoring were collocated in 2009. Integration analyses of this report focused on the relationships between components of Objective #1 and Objective #2 in Figure 1–4. These sites were used for exploratory, focused integrative assessments: Hocker Flat, Lower Indian Creek, Lowden Meadows, Bucktail–Dark Gulch, Lewiston Cableway, Hoadley Gulch, and Sven Olbertson. These sites were selected based on a combination of the following factors:

1. Reasonable distribution of sites over the primary management reach (Lewiston Dam to the North Fork Trinity River confluence),
2. Pre- and post-construction fish habitat assessments and flow versus fish habitat curves at most sites, and
3. Pre- and post-construction topographic information.

1.4. Investigation Strategies and Priority Questions

This investigation strategy is a hypothesis-based approach based on the assessments described in the IAP. To apply the IAP assessments, this effort (1) clearly illustrated the priority questions being posed for future evaluation and (2) focused monitoring efforts to best address those priority questions. The overarching questions posed in Figure 1–1 are further specified by discipline in the following sections.

1.5. Fish Habitat

Eight high-priority fish-habitat questions, listed below, were assessed at channel rehabilitation and/or systemic sites (Table 1-1). These questions were addressed through site-specific, restoration-reach (systemic), or integration analyses. Priority questions F-1 through F-4 are fundamental to assessing the outcomes of core TRRP management actions, including the degree to which overarching TRRP objectives have been met. Priority questions F-5 through F-7 aim to refine current habitat mapping methodologies, as described in Goodman et al. (2010), to help ensure that implemented monitoring methods meet the information needs of the TRRP. Priority question F-8 explores how the integration of physical and fish habitat variables relate to the availability of fish habitat and has the potential to better inform designs for future channel rehabilitation sites and other management actions.

F-1) What was the change in Chinook salmon and coho salmon rearing habitat at winter base flow resulting from construction of bank rehabilitation sites (pre- and post-construction assessment)?

F-2) How do selected bank rehabilitation treatments alter the flow-habitat relationships and habitat availability at these locations?

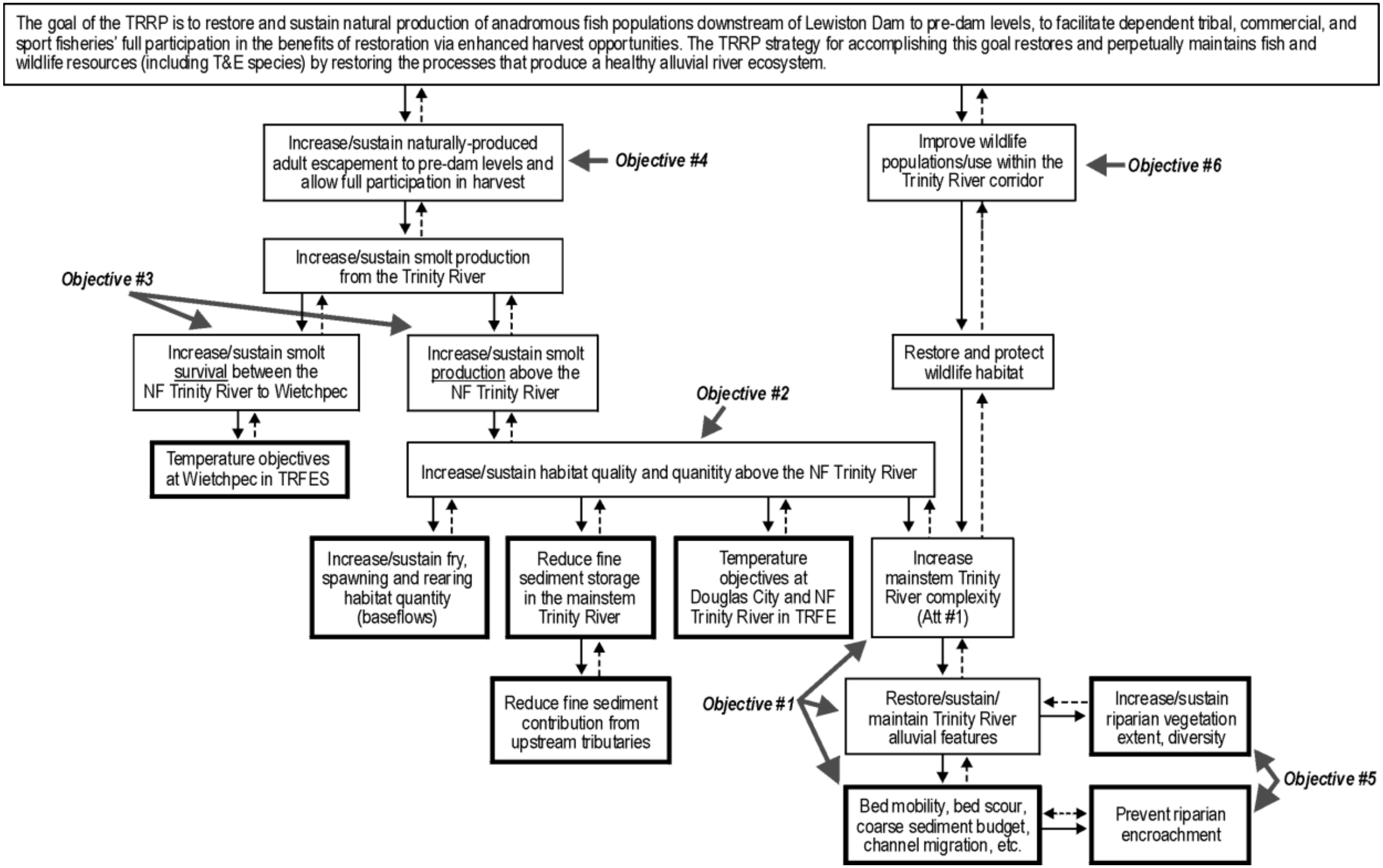

Figure 1–4. Conceptual linkages between IAP objectives and Trinity River Restoration Program Goals (TRRP and ESSA 2009).

Table 1–1. IHAP Fish Habitat Priority Questions Targeted by WY 2009 Monitoring Sites

Priority Question	Sven Olbertson	Lewiston Cableway	Hoadley Gulch	Bucktail-Dark Gulch	Lowden	Lower Reading	Systemic	Additional Spawning Invest. Sites
F-1	X	X	X	X				
F-2		X		X	X	X		
F-3					X	X		
F-4							X	
F-5					X	X		
F-6					X			
F-7			X	X				X
F-8		X		X			X	

F-3) What was the quantity and quality of Chinook salmon and coho Salmon rearing habitat at winter base flow at selected rehabilitation sites before construction in 2009?

F-4) How much Chinook salmon and coho salmon rearing habitat is present from Lewiston Dam to the North Fork Trinity River during a 13-cms (450-cfs) Lewiston dam release?

F-5) How do the results from the rearing-habitat mapping and development of flow-habitat relationships compare to the simulations from a two-dimensional hydraulic habitat model, and are these data sources complementary?

F-6) What is the abundance of Chinook salmon and coho salmon fry and presmolt within rearing-habitat categories during daytime and nighttime hours?

F-7) How can we refine the spawning habitat assessment methodology?

F-8) How do geomorphic variables such as side channel length, distance from Lewiston Dam, radius of thalweg curvature, and channel slope relate to habitat availability?

1.6. Geomorphology and Topography

The restoration strategy adopted by the TRFE and ROD is to (1) reverse the undesirable evolution of in-channel morphology (riparian berms) that has reduced fish habitat quantity and quality downstream of Lewiston Dam by mechanically rescaling and reshaping the channel to improve habitat, and then (2) maintain this “scaled-down” alluvial channel morphology with high-flow releases and coarse-sediment management. The restoration strategy also envisioned synergistic interactions between channel rehabilitation sites, such that effects at one site would physically propagate downstream to other reaches. The channel mobility, scour, and migration regimen at channel rehabilitation sites is a critical process in creating and maintaining a dynamic and complex channel morphology. It prevents the establishment of dense, continuous bands of riparian hardwood on alluvial features, which can lead to the creation of riparian berms, channel simplification, and ultimately loss of instream habitat. IAP objectives include key quantitative targets for fluvial geomorphic management. Specific fluvial geomorphic management objectives are identified by water year class, which is a strategy originally recommended by the TRFE (USFWS and HVT 1999).

Eight priority geomorphic questions are evaluated in WY 2009 monitoring. Data was collected at sites to address the priority question; however, not all questions were addressed at every site (Tables 1–2, 1–3). For WY 2009 the fluvial geomorphic related priority questions were:

G-1) Are process-based TRFE geomorphic management targets being met by annual releases (bed mobility/scour, riparian scour along low-flow edge)?

G-2) Does the combination of bank rehabilitation, high-flow releases, and natural floods increase and maintain the number, areal extent, and complexity of alluvial features?

G-3) Can we encourage channel migration by only removing vegetation and berms on opposite banks in advance of high-flow-releases and natural floods (i.e., without putting anything within the active channel to force thalweg adjustment)?

Table 1–2. Summary of Trinity River Fluvial Geomorphic Objectives

TRFE (Table 8.8)		**IAP Independent of Water Year Type**
Dry Water Year Type	**Wet Water Year Type**	
Peak Threshold: Mobilize sediment on bar flank features to depth equivalent to D_{84}.* Duration monitoring: (1) Transport coarse sediment through the mainstem at rates equal to tributary input downstream of Rush Creek, and (2) transport fine sediment through the mainstem at a rate greater than tributary input as measured at the Limekiln Gulch gaging station.	Peak Threshold: (1) Mobilize > 1.0 D_{84} deep* on alternate bar flanks, cleansing gravels and transporting all sizes of sediments, and (2) initiate channel migration at bank rehabilitation sites. Duration monitoring: (1) Transport coarse sediment through the mainstem at rates equal to tributary input downstream of Rush Creek, and (2) transport fine sediment through the mainstem at a rate greater than tributary input as measured at the Limekiln Gulch gaging station.	Create and maintain spatially complex channel morphology. Increase physical habitat diversity and availability. Increase coarse sediment transport and channel dynamics. Reduce fine sediment storage in the mainstem Trinity River.

* D_{84} = Measure that exceeds the particle diameter of 84 percent of sampled particles.

Table 1–3. IHAP Fluvial Geomorphic Priority Questions Targeted by WY 2009 Monitoring Sites

Priority Question	Lewiston Hatchery	Sven Olbertson	Lewiston Cableway	Hoadley Gulch	Bucktail-Dark Gulch	Vitzthum Gulch	Indian Creek	Hocker	Connor Creek	Valdor Gulch	Pear Tree
G-1			X	X	X		X	X		X	
G-2		X	X	X	X	X	X	X		X	
G-3			X		X			X	X	X	
G-4			X		X					X	
G-5										X	X
G-6		X		X			X			X	
G-7						X					
G-8	X										

G-4) Are design meander wavelengths and radii of curvature maintained with high-flow releases, natural floods, and sediment regime, and do these effects exert themselves upstream and downstream of the constructed area or enhance local channel migration of the mainstem Trinity River?

G-5) Are alcoves maintaining themselves with high-flow releases and natural floods?

G-6) Are side channels maintaining themselves with high-flow releases and natural floods?

G-7) Does berm punching destabilize the berm enough that subsequent high flows “finish the job”?

G-8) How much of the augmented coarse sediment placed in the Lewiston Hatchery reach is being transported to downstream reaches, and how will the results of that transport inform future coarse sediment augmentation efforts?

1.7. Riparian Vegetation and Large Wood

Considerable discussion has occurred as to what constitutes good versus bad riparian vegetation, since fish often occupy flooded riparian vegetation. Under the criteria used here, riparian vegetation is defined as “undesirable” if it is: (1) dense in distribution, (2) growing in continuous bands within the 300cfs to 2000cfs inundation zone, (3) more than 3 years old, and (4) especially if observed to be initiating the riparian berm-building process. IAP riparian objectives include key

Table 1–4. Summary of Trinity River Riparian Objectives

TRFE (Table 8.8)		IAP Independent of Water Year Type
Dry Water Year Type	**Wet Water Year Type**	
Inundate gravel bars to prevent riparian seedling initiation.	Encourage establishment and growth of riparian vegetation on floodplains. Discourage or prevent riparian vegetation initiation along the low water margin. Increase the species and age diversity of riparian vegetation. Scour up to 2-yr-old woody riparian vegetation growing along the low water margin.	Establish and maintain riparian vegetation that supports fish and wildlife. Promote diverse native riparian vegetation on different geomorphic surfaces that contributes to complex channel morphology and high quality aquatic and terrestrial habitat. Prevent riparian vegetation from exceeding thresholds, leading to encroachment that simplifies channel morphology and degrades aquatic habitat quality.

quantitative targets, by water year type, for riparian vegetation management as part of the strategy originally recommended by the TRFE (USFWS and HVT 1999). As with the fluvial geomorphic assessments, riparian management targets which vary for Dry and Wet water years were evaluated for sites monitored downstream of Canyon Creek (Table 1–4).

While the TRFE identifies specific management targets related to flow and sediment rehabilitation, the broader programmatic riparian vegetation objectives were only recently defined in the IAP. The monitoring strategies identified in the IAP were applied in this study.

Five priority riparian questions are evaluated in WY 2009 monitoring. Data was collected at sites to address the priority question; however not all questions were addressed at every site (Table 1–5).

For WY 2009 the riparian related priority questions were:

R-1) Are process-based TRFE riparian targets being met by annual flow releases (riparian scour along low-flow edge, riparian recruitment on floodplains)?

R-2) Does bank rehabilitation site implementation, in combination with high-flow releases and natural floods, increase and maintain areal extent, species richness, age diversity and vertical structure of riparian vegetation on floodplains?

R–3) What is the effect of fine sediment supply (or lack thereof) in riparian seedling initiation/establishment along the low-flow channel margins?

Table 1–5. IHAP Riparian Vegetation Priority Questions Addressed at Each Monitoring Site

Priority Question	Sven Olbertson	Deadwood Creek	Lewiston Cableway	Hoadley Gulch	Bucktail–Dark Gulch	Vitzthum Gulch	Indian Creek	Upper Reading	Hocker	Connor Creek	Valdor Gulch	Pear Tree
R–1	X	X	X	X	X		X		X		X	X
R–2	X	X	X	X	X	X	X	X	X	X	X	
R–3	X			X	X		X					
R–4	X	X	X	X	X		X		X	X	X	X
R–5						X						

R–4) How is large wood storage changing at constructed sites over time?

R–5) Does berm punching destabilize the berm enough such that subsequent ROD releases and natural floods continue to remove the remnant berm vegetation?

1.8. Hydrologic Context

Water year 2009 was classified as a Dry WY under the ROD water year classification system (USDOI 2000). Following the standard ROD hydrographs, WY 2009 baseflow releases from Lewiston Dam were lowered from 13 to 8.5 cms (450 to 300 cfs) in October 2008, remaining there until the spring release. Fall and winter flows remained below 28 cms (1,000 cfs) at all monitoring sites until late February, when winter storms caused two tributary-generated peak flow events. The largest of these occurred on March 2, 2009, and was 113 cms (3,990 cfs) at the farthest downstream monitoring sites below Canyon Creek (Table 1–6, Figure 1–5). Following the winter peak-flow events, tributary accretion kept mainstem Trinity River flows[1] above winter baseflow levels until the 127-cms (4,500-cfs) spring 2009 release which began May 1 and lasted for five days. Gradually the flow receded to summer baseflows in mid-July 2009. As in the case of the winter peak flows, tributary accretion from a coincidental rainstorm during the ROD release caused flows to be much higher at the farthest downstream monitoring sites, peaking at 233 cms (8,230 cfs) on May 5, 2009, which was similar to the magnitude of a Wet WY release. Discharge at each monitoring site was estimated from the closest upstream USGS gaging stations in the mainstem and tributaries.

[1] The portion of the Trinity River closest to Lewiston Dam was unaffected by tributary accretions.

Table 1–6. Peak Flow and Spring ROD Release Thresholds for Monitored Sites

Site	Winter peak flow (March 2, 2009)	Spring ROD release (May 1–5, 2009)
Lewiston Hatchery Sven Olbertson Lewiston Cableway Hoadley Gulch Bucktail–Dark Gulch	8.5 cms (300 cfs) (winter baseflow release)	122 cms (4,300 cfs) for 5 days (DRY water year release, instantaneous peak flow recorded at Lewiston during the release = 131 cms, or 4,630 cfs)
Vitzthum Gulch Lower Indian Creek	35 cms (1,230 cfs)	153 cms (5,420 cfs) for < 1 day (DRY water year release at Lewiston + tributary accretion, recorded at Limekiln Gulch)
Hocker Flat Connor Creek Valdor Gulch Pear Tree Gulch	113 cms (3,990 cfs)	233 cms (8,230 cfs) for < 1 day (DRY water year release at Lewiston + tributary accretion, recorded at mainstem Trinity River above North Fork Trinity River)

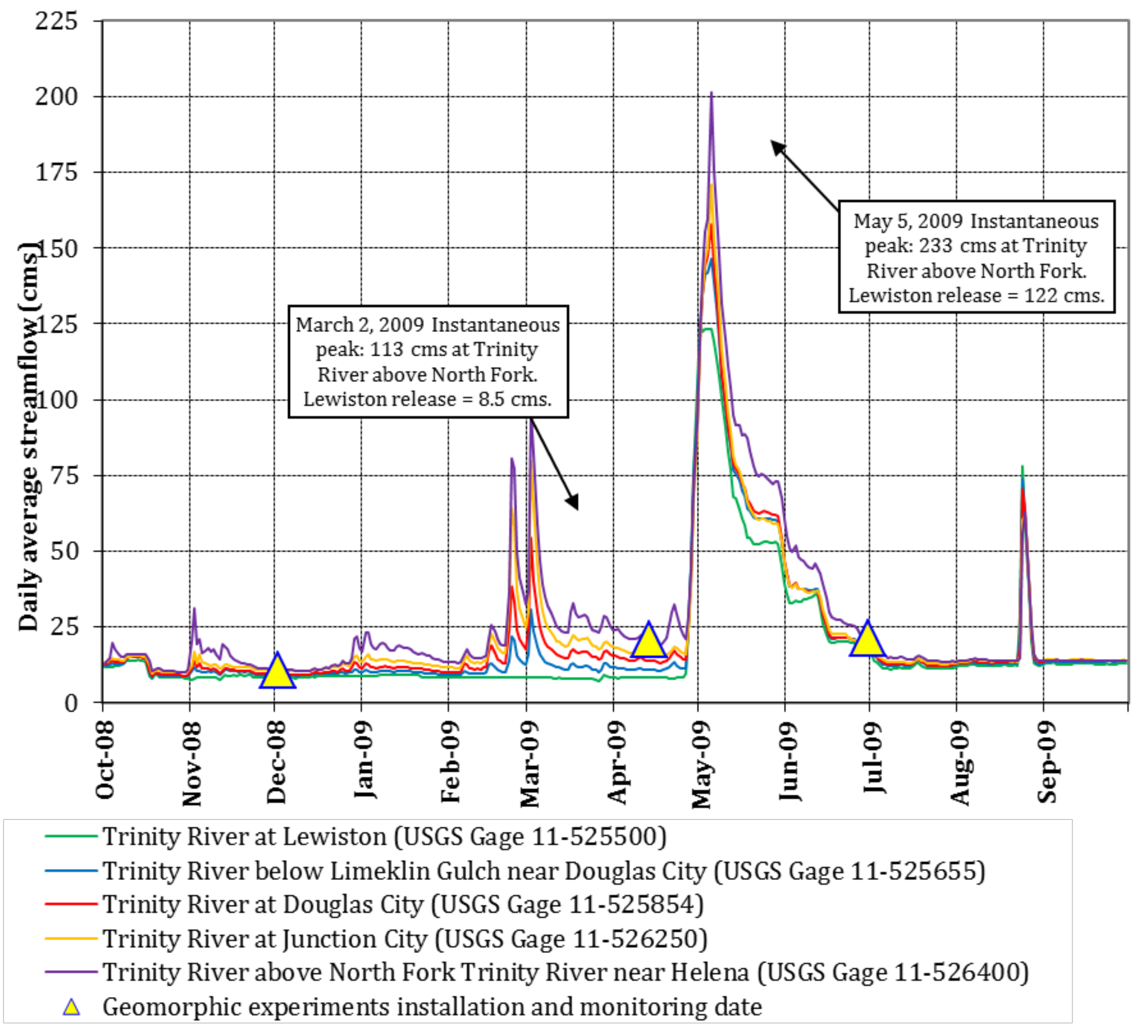

Figure 1–5. WY 2009 daily average streamflow for all major Trinity River gages between Lewiston Dam and the North Fork Trinity River confluence.

1.9. Sampling Strategy

The overarching strategy has two primary components. First, a site-specific strategy with assessments at specific rehabilitation sites (rehabilitation site assessments), including sites that have been previously constructed and sites that will be constructed before the end of 2010. Assessments at these sites were often multi-disciplinary. Second, a systemic strategy of assessment of fish habitat (systemic assessment), using a modified generalized random-tessellation stratified (GRTS) sampling design. Geomorphic and riparian assessments were not conducted as part of the systemic strategy.

1.9.1. Bank Rehabilitation Site Assessments

Fifteen channel rehabilitation sites were assessed in 2009 (Table 1–7, Appendix A). Three different types of assessments (fish habitat, geomorphic, and riparian) were performed at different rehabilitation sites (Table 1–8). At some sites, investigations overlapped and integration analyses were conducted. These 15 sites constitute most, but not all, of the channel rehabilitation sites constructed to date. An additional 32 randomly selected GRTS sites were assessed under the fish habitat restoration reach assessment. Some but not all of the randomly selected sites overlapped with channel rehabilitation sites.

Table 1–7. Bank Rehabilitation Sites Monitored on the Trinity River, California, in 2009

Site	Date of Construction	Location (rkm)*	Total Length (rkm)
Pear Tree Gulch	2005	116.51–118.46	1.95
Valdor Gulch	2005	120.14–122.62	2.12
Connor Creek	2005	123.45–124.73	1.28
Hocker Flat	2004	125.63–127.63	2.01
Lower Reading Creek	2010	148.38–149.19	0.81
Upper Reading Creek	2010	149.19–150.49	2.05
Lower and Middle Indian Creek; Vitzthum Gulch	2007	151.16–156.27	5.11
Lowden Meadows	2010	168.02–169.46	1.44
Bucktail–Dark Gulch	2008	169.74–172.33	2.59
Hoadley Gulch	2008	176.71–177.19	0.48
Lewiston Cableway	2008	177.32–177.77	0.45
Deadwood Creek	2008	177.77–178.57	0.80
Sven Olbertson	2008	178.94–179.84	0.90
Lewiston Hatchery	2008	179.84–180.50	0.66

*Boundary represents environmental study limit stationing for a given rehabilitation site.

Table 1–8. Site-Specific Monitoring Matrix, Including a Summary of Assessments That Occurred at Each Monitored Rehabilitation Site

Assessment categories are grouped by discipline. Integration analyses that occurred at specific sites are detailed in the Integration section.

Rehabilitation Site	Fish Habitat				Geomorphic, Riparian and Large Wood					Integration
	Fish habitat survey	Validation diving	Spawning investigation	2-D fish habitat	Topographic monitoring	Geomorphic monitoring	Riparian band transects	Riparian mapping	Large wood inventory	
Pear Tree					X			X	X	
Valdor					X	X	X	X	X	
Connor					X			X	X	
Hocker					X	X	X	X	X	X
Upper/Lower Reading	X			X			X			
Lower/Middle Indian					X	X	X	X	X	X
Vitzthum Gulch					X					
Lowden	X	X		X						X
Bucktail–Dark Gulch	X		X		X	X	X	X	X	X
Hoadley Gulch	X		X					X	X	X
Lewiston Cableway	X				X	X	X	X	X	X
Deadwood								X	X	
Sven Olbertson	X				X	X	X	X	X	X
Lewiston Hatchery					X					
Systemic	X									

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CHAPTER 2. GEOMORPHIC AND TOPOGRAPHIC EVALUATION OF TRINITY RIVER RESTORATION CHANNEL REHABILITATION PROJECTS

2.1. Introduction

A primary component of the restoration strategy being implemented by the Trinity River Restoration Program is the management of flows to restore fluvial processes that create and maintain salmonid habitats (USFWS and HVT 1999, USDOI 2000). The IAP identifies key fluvial geomorphic management objectives, identified by water year class, with specific quantitative targets (Table 2–1; TRRP and ESSA Technologies Ltd. 2009).

The primary purpose of this effort was to document whether TRFE geomorphic objectives are being met as a result of ROD releases and/or tributary high flows at channel rehabilitation sites. Eight priority geomorphic questions were evaluated in WY 2009 monitoring. Data were collected at channel rehabilitation sites to address the priority questions; however, not all questions were addressed at every site (Table 2–2). For WY 2009 the fluvial geomorphic related priority questions were:

G–1) Are process-based TRFE geomorphic management targets being met by annual releases (bed mobility/scour, riparian scour along low-flow edge)?

Table 2–1. Summary of Trinity River Fluvial Geomorphic Objectives

TRFE (Table 8.8)		IAP Independent of Water Year Type
Dry Water Year Type	**Wet Water Year Type**	
Peak Threshold: Mobilize sediment on bar flank features to depth equivalent to D_{84}. Duration monitoring: (1) Transport coarse sediment through the mainstem at rates equal to tributary input downstream of Rush Creek, and (2) transport fine sediment through the mainstem at a rate greater than tributary input as measured at the Limekiln Gulch gaging station.	Peak Threshold: (1) Mobilize > 1.0 D84 deep on alternate bar flanks, cleansing gravels and transporting all sizes of sediments, and (2) initiate channel migration at bank rehabilitation sites. Duration monitoring: (1) Transport coarse sediment through the mainstem at rates equal to tributary input downstream of Rush Creek, and (2) transport fine sediment through the mainstem at a rate greater than tributary input as measured at the Limekiln Gulch gaging station.	Create and maintain spatially complex channel morphology. Increase physical habitat diversity and availability. Increase coarse sediment transport and channel dynamics. Reduce fine sediment storage in the mainstem Trinity River.

G–2) Does the combination of bank rehabilitation, high-flow releases, and natural floods increase and maintain the number, areal extent, and complexity of alluvial features?

G–3) Can we encourage channel migration by only removing vegetation and berms on opposite banks in advance of high-flow releases and natural floods (i.e., without putting anything within the active channel to force thalweg adjustment)?

G–4) Are design meander wavelengths and radii of curvature maintained with high-flow releases, natural floods, and sediment regime, and do these effects exert themselves upstream and downstream of the constructed area or enhance local channel migration of the mainstem Trinity River?

G–5) Are alcoves maintaining themselves with high-flow releases and natural floods?

G–6) Are side channels maintaining themselves with high-flow releases and natural floods?

G–7) Does berm punching destabilize the berm enough that subsequent high flows “finish the job”?

G–8) How much of the augmented coarse sediment placed in the Lewiston Hatchery reach is being transported to downstream reaches, and how will the results of that transport inform future coarse sediment augmentation efforts?

Table 2–2. IHAP Fluvial Geomorphic Priority Questions Targeted by WY 2009 Monitoring Sites

Priority Question	Lewiston Hatchery	Sven Olbertson	Lewiston Cableway	Hoadley Gulch	Bucktail–Dark Gulch	Vitzthum Gulch	Indian Creek	Hocker	Connor Creek	Valdor Gulch	Pear Tree
G–1			X	X	X		X	X		X	
G–2		X	X	X	X	X	X	X		X	
G–3			X		X			X	X	X	
G–4			X		X					X	
G–5										X	X
G–6		X		X			X			X	
G–7						X					
G–8	X										

Although WY 2009 was classified as a Dry water year, tributary accretion from a coincidental rainstorm caused a significant flow increase downstream. (Dry WY flows released at Lewiston were approximately 4,300 cfs but the total flows reached approximately 8,200 cfs downstream of Canyon Creek, similar to a Wet WY release. See additional discussion in the Hydrologic Context section.) Given this coincidental opportunity, both Dry and Wet WY management targets were evaluated for sites monitored downstream of Canyon Creek (Table 2–3).

2.2. Methods

Water Year 2009 geomorphic monitoring measured changes resulting from the 2009 spring release. Monitoring at Valdor Gulch and Hocker Flat also included measuring geomorphic changes resulting from the winter 2009 flows. Although TRFE hydrograph-related management targets are identified for individual hydrograph components (ascending limb, peak, descending limb baseflows, etc.), WY 2009 experiments were structured to monitor the results of the entire annual hydrograph. Specific geomorphic monitoring activities included documenting pre-winter and/or pre-spring release topographic conditions and channel morphology at site cross sections, and then documenting resulting topographic changes. This included monitoring for planform changes in site topography such as berm notches and coarse sediment placement, monitoring changes in longitudinal profiles at selected sites to document any channel migration, and monitoring the performance of constructed alcoves and side channels. Bed mobility and bed scour experiments were installed at selected sites and monitored following the spring release. At some sites, bed mobility and bed scour monitoring included winter high flows. Table 2–4 summarizes geomorphic monitoring activity by site.

2.2.1. Geomorphology and Topography

For geomorphic monitoring, sites were selected that possessed as many of the following features as possible: (1) multiple design elements (e.g., alcoves, side

Table 2–3. Trinity River above North Fork Hydrology

Lewiston Release	Estimated Peak Flow at Pear Tree, Connor Creek, Valdor Gulch, and Hocker Flat	Water Year Type Used for Site Evaluation
8.5 cms (300 cfs) (Winter baseflow release)	113 cms (3,990 cfs) (Instantaneous peak flow March 2, 2009)	Dry
122 cms (4,300 cfs) (Dry WY release for five days, May 1–5, 2009)	233 cms (8,230 cfs) (Instantaneous peak flow May 5, 2009)	Wet

Table 2–4. Summary of WY 2009 Geomorphic Monitoring Activities at Rehabilitation Sites

Site	Fall 2008 (pre-winter flood):	Spring 2009 (post-winter flood, pre-spring release):	Summer 2009 (post-spring release):
Lewiston Hatchery		PM	PM
Sven Olbertson		LP	LP
Lewiston Cableway	PM	PM, XS, BM	PM, XS, BM
Hoadley Gulch		LP, XS, BM, PM	LP, XS, BM, PM
Bucktail–Dark Gulch		XS, BM	XS, BM
Vitzthum Gulch		PM	PM
Lower Indian Creek		LP, XS	LP, XS
Hocker Flat	XS, BM, BS	BM	XS, BM, BS
Connor Creek		XS	XS
Valdor Gulch	XS, BM, BS, PM	LP, BM	XS, LP, BM, BS, PM
Pear Tree Gulch		LP	LP

Legend: XS = cross section survey, LP = longitudinal profile survey, PM = planform topographic mapping, BM = bed mobility monitoring, BS = bed scour and redeposition monitoring.

channels, feather edges, berm notches, floodplains) to inform future bank rehabilitation site designs, (2) alluvial features suitable to assess the risk of riparian encroachment, and (3) availability of fish habitat data. Six sites (Pear Tree, Valdor Gulch, Connor Creek, Hocker Flat, Lower Indian Creek, and Vitzthum Gulch) were chosen with different design elements (point bars, side channels, alcoves, bars constructed to encourage channel migration) to evaluate how those elements evolve and are maintained by ROD releases and tributary floods. Monitoring was completed between October 2008 and September 2009.

WY 2009 geomorphic monitoring measured changes resulting from the spring 2009 ROD release. Monitoring at Valdor Gulch and Hocker Flat also included measuring geomorphic changes resulting from the winter 2009 flows (derived from tributary flows rather than ROD releases). Specific geomorphic monitoring activities and their related IAP/TRFE objectives included:

- Documenting pre-winter and/or pre-spring release topographic conditions and channel morphology at site cross sections (two dimensions), and then documenting topographic changes following the spring 2009 ROD release. Results of this monitoring effort will be used in evaluating channel response to ROD releases and TRFE floodplain inundation, deposition, and scour objectives, and also will be used to inform bed mobility, bed scour, and riparian vegetation monitoring results.

- Documenting pre- and post-spring 2009 release site topography at selected sites to evaluate planform changes in site topography (three dimensions), such as berm notches and coarse sediment placements.
- Surveying pre- and post-spring 2009 release longitudinal profiles at selected sites to document any channel migration, and the performance of constructed alcoves and side channels.
- Installing bed mobility and bed scour experiments at selected sites and monitoring these experiments following the spring release. At Hocker Flat and Valdor Gulch, bed mobility and bed scour were also monitored after winter high flows. Results of this monitoring effort will be used in evaluating TRFE bed mobility and bed scour objectives.

Priority questions were identified to assess whether designed channel features are functioning as intended. Methods were selected and experiments were installed to evaluate the priority questions in anticipation of measurable geomorphic changes occurring at the bank rehabilitation sites; however, because WY 2009 was a Dry year, the corresponding ROD release (averaging 122 cms [4,300 cfs] for five days) was in many cases insufficient to cause the geomorphic changes targeted by the priority questions (e.g., channel migration, bank erosion). This lack of change is particularly evident at the sites upstream of Lower Indian Creek, where flows were below expected thresholds for mobilizing the bed and maintaining alluvial features—processes that are generally associated with Normal or Above Normal WYs (USFWS and HVT 1999). Conversely, at sites downstream of Hocker Flat, tributary accretion from Canyon Creek resulting from a coincidental rainstorm produced flows nearly double the magnitude of the ROD release (instantaneous peak flow = 233 cms [8,230 cfs]). Because flows during the ROD release peaked significantly higher at these downstream sites, monitoring was able to observe and measure geomorphic changes.

2.2.2. Topographic Surveys

Topographic surveying was conducted at all monitoring sites. Surveys included planform mapping, longitudinal channel profiles, and cross-section surveys. Cross-section surveys were performed using an auto-level. These surveys were used to document streambed topography and water-surface elevations along permanently monumented monitoring cross sections at the rehabilitation sites. All cross-section surveys followed established field protocols (Harrelson and Rawlins 1994). Cross sections were surveyed in fall 2008 and again in summer 2009. These surveys documented topographic changes resulting from the winter and spring flows (Appendix B).

The data from the cross-section surveys were plotted and graphically compared to previous surveys to note changes. In these comparisons, most cross sections showed localized topographic variation caused by differences in survey rod placement along the cross section between surveys and the resulting graphical interpolation (i.e., survey point spacing on cross sections may be as much as several feet, and the exact point spacing may differ between surveys, resulting in apparent variations along the cross section). In addition to different survey points being occupied between surveys, topographic variation can also result from particle size, particularly where the substrate includes large particles (e.g., cobbles, boulders). Survey rod placement can be on top of rocks or can be in void spaces between rocks. Replicate surveys almost always show some topographic variation resulting from this effect. Cross-section surveys are evaluated individually, taking particle size, point distribution, and field observations into consideration when determining whether results are "survey noise" or whether they show real topographic change.

Planform topographic mapping was performed using a total station, which can both map the site topography and also survey longitudinal profiles. Total station surveys were conducted using standard surveying protocols and were referenced to known coordinates.

Similar to the procedure for cross sections, longitudinal profile surveys were compared to previous longitudinal profile surveys to note changes in alignment (migration) and gradient (scour or fill). In addition, site planform mapping was conducted at several sites. These surveys allowed for significantly greater topographic coverage than the cross-section surveys, and as had been done for the cross-section and longitudinal profiles, repeat surveys were compared to document site changes.

Results of topographic survey comparisons are shown as isopach maps, which illustrate the topographic difference between surveys as color-coded isopachs (contours of equal thickness). Isopach maps were prepared for the following sites: Valdor Gulch, Vitzthum Gulch, Bucktail–Dark Gulch, Lewiston Cableway, and Lewiston Hatchery. As a part of interpreting the survey results and creating isopach maps for each site, sensitivity analyses were performed to best estimate the representative topographic changes between surveys. By doing this, it was determined that, for all but one of these sites, topographic changes smaller than 0.08 m (3 in) would be considered "survey noise" (as a result of equipment accuracy and a mixed substrate including gravel, cobble, and boulder bed particle sizes) and would not be included as a part of the estimated topographic change. The one exception to this was Vitzthum Gulch, where survey noise was considered to be ±0.03 m (1 in) due to the sandy substrate at that site. The resulting topographic changes shown on the isopach maps therefore show contours for bed elevation gains and losses at 0.15-m (6-in) intervals starting where changes exceed 0.08 m (3 in). The isopach color intensity increases with increased topographic change, from orange to red where the bed lowered and from light green to dark green where the bed aggraded. Note that this coloring represents net topographic change between surveys and is not the same as measuring scour or fill. For example, if the isopach map shows net degradation, then scour did occur but the maximum scour depth is not portrayed (because the map shows scour plus any redeposition that occurred); actual scour and redeposition were recorded using scour chains. (See the Bed Mobility, Scour, and Redeposition section).

2.2.3. Substrate Characterization

The substrate (i.e., the surface sediments) was characterized at all cross sections where bed mobility was monitored. At each of these cross sections, individual sedimentary units, or facies, were determined by visually delineating distinct textural populations around areas having little to no spatial variation in bed material size (Lisle and Madej 1992). Within each facies, a modified Wolman-style pebble count of 100 grains was conducted to document the bed surface particle size distribution, and statistical particle sizes (D_{84} and D_{50}) were computed for the bed mobility experiments (Leopold 1970, Bunte and Abt 2001).

An exception to this method was used at the Lewiston Cableway, Hoadley Gulch, and Bucktail–Dark Gulch sites. One or more coarse-sediment recruitment piles were constructed at each of these sites using materials derived from sieving specific size fractions out of dredge tailings. All constructed coarse-sediment augmentation piles monitored in WY 2009 had a similar particle size distribution resulting from using the same material source. The coarse sediment mixture used in construction consisted of clean sorted cobbles and gravel with diameters ranging from 2.5 to 12.7 cm (1 to 5 in). The variation between the exposed ground surfaces on constructed coarse sediment recruitment piles was not assessed. One modified Wolman pebble count was conducted on the constructed coarse sediment recruitment pile at the Lewiston Cableway site along cross section 2012+10. The resulting particle size distribution from this cross section was used for bed mobility experiments at the Lewiston Cableway, Hoadley Gulch, and Bucktail–Dark Gulch sites. Bed mobility experiments spanned newly constructed coarse-sediment recruitment piles.

2.2.4. Bed Mobility, Scour, and Redeposition

Bed mobility and bed scour experiments were installed prior to winter and/or spring peak flow events. Bed mobility was measured using sets of individually labeled, brightly marked tracer rock groups installed along the cross sections. Each group contained two sizes of rocks, representing D_{50} and D_{84} size classes determined by the substrate characterization. Groups were set at 4-foot intervals spanning the monitoring feature of interest (commonly over a constructed surface or across a point bar and extending into the low-water channel). Following the peak flows, the cross sections were revisited to determine which tracer rocks moved. Rocks were defined as “mobilized” if travel distances exceeded 0.6 m (2 ft). Any shorter movement was considered a hydraulic adjustment to a more stable position (McBain & Trush and HVT 1997). Efforts to relocate marked rocks included looking downstream of the cross section as well as excavating the bed at each marked rock placement station to see if the rocks remained stationary but were buried by sediments deposited from upstream.

Marked rock sets were installed at five sites: Lewiston Cableway, Hoadley Gulch, Bucktail–Dark Gulch, Hocker Flat, and Valdor Gulch. Monitoring at the Lewiston Cableway, Hoadley Gulch, and Bucktail–Dark Gulch sites was conducted for the spring release. Monitoring at Hocker Flat and Valdor Gulch included both winter flood and spring release monitoring; marked rock sets were installed on selected cross sections in December 2008 (pre-winter flood monitoring), monitored in April following the March 2009 winter peak flow, reset for the May 2009 spring release, and then monitored again following the spring release.

Scour chains were installed at two sites: Hocker Flat and Valdor Gulch. Similar to the marked rock monitoring at these sites, bed scour was monitored for both winter flood and spring release flows. Scour chains were installed on the same cross sections as the marked rocks in December 2008 (pre-winter flood monitoring) and were monitored once following the spring release in June 2009. Scour chains were not monitored following the winter flood because scour was assumed to be negligible.

Bed scour and redeposition were measured using scour chains. Each scour chain consists of a brass chain with approximately 15-mm (0.6-in) links, a duckbill earth anchor affixed on one end, and a stainless steel washer affixed to the other. The chain is driven vertically into the channel substrate to a minimum depth of approximately 0.6 m (2 ft), and a length of chain is left lying flat on the bed surface. Installation procedures follow those described by Lisle and Eads (1991). To measure scour and redeposition, the chain location is reoccupied, its elevation surveyed, and the bed surface is carefully excavated by hand until the chain is found. Differences in pre- and post-high-flow chain length on the bed surface and changes in surveyed bed surface elevations document scour and redeposition depths.

2.3. Results (and Site-Specific Discussion)

WY 2009 was classified as a Dry water year and corresponded to specific geomorphic monitoring objectives defined by the TRFE. These objectives, however, are based on the release hydrograph at Lewiston Dam. Tributary accretion caused flows to be higher at downstream monitoring sites downstream of Lewiston. Tributary accretion generated a winter peak event on March 2, 2009, and also magnified the spring ROD release, causing flows at downstream monitoring sites to exceed the Dry WY release magnitude. For example, flows at the Vitzthum Gulch and Lower Indian Creek sites were closer in magnitude to a Normal WY release (170 cms or 6,000 cfs) (Figure 1–5). As such, geomorphic monitoring results at these two sites are evaluated with respect to TRFE Normal WY objectives rather than Dry WY objectives. For the monitoring sites downstream of Canyon Creek (Hocker Flat, Connor Creek, Valdor Gulch, and Peartree Gulch), winter peak flows and the spring ROD release were further magnified by tributary accretion. The March 2, 2009, winter peak event was approximately 113 cms (3,990 cfs; similar to a Dry WY release magnitude) and the spring ROD release was amplified to an instantaneous peak flow of 233 cms (8,230 cfs; similar to a Wet WY release magnitude of 241 cms or 8,500 cfs) (Figure 1–5.) These flows provided a fortunate opportunity to evaluate both Dry and Wet WY management targets at these bank rehabilitation sites.

2.3.1. Pear Tree Gulch

The Pear Tree Gulch site was constructed in winter 2006 and included a high-flow scour channel with a downstream alcove. Monitoring consisted of two thalweg profile surveys[2] of the scour channel and alcove, conducted before the WY 2009 high flows in fall 2008 (Figure A–2). Monitoring occurred in response to the spring release peak flow (233 cms [8,230 cfs]), measured at the mainstem Trinity River above the North Fork Trinity River gage (Table 2–3).

2.3.1.1. Longitudinal Profile

The longitudinal profile showed little change to the high-flow scour channel except near the scour channel entrance (upstream of Station 9+25) and in the downstream alcove (below Station 1+50; Figure 2–1). Debris lines in the high-water channel provided evidence that the scour channel flowed in WY 2009 and that the minor topographic changes that were quantified occurred as sand deposition. The alcove was not connected to the mainstem during summer and winter baseflows.

2.3.1.2. Pear Tree Geomorphic Discussion

One geomorphic priority question was asked for Pear Tree Gulch. Priority Question G–5 asked if alcoves are maintaining themselves with high-flow releases and natural floods. There are two primary mechanisms by which the alcove at Pear Tree Gulch functions: (1) low-flow backwater or (2) high-flow overtopping. These are partly controlled by the location of the mainstem hydraulic control. The longitudinal profile (Figure 2–1) was surveyed only to evaluate whether the alcove backwatered or overtopped and shows deposition at the upstream and downstream alcove entrances. This result suggests the alcove is not maintaining itself (i.e., flows were depositional). However, the result represents only a single ROD release hydrograph, and additional monitoring will be needed to help determine whether a depositional trend persists (filling and not maintaining) or if the alcove is periodically scoured to maintain its morphology.

2.3.2. Valdor Gulch

Geomorphic monitoring included topographic surveys, bed mobility monitoring, and bed scour and redeposition monitoring. Monitoring included the following four cross sections (from upstream to downstream): 166+75, 151+80, 147+25, and 141+20 (Figures A–4, A–5) to assess both the winter peak flow and spring release peak flow. Peak flows were 113 and 233 cms (3,990 and 8,230 cfs; Table 2–3). Due to the magnitude of flows experienced during these two flood events, results of winter flood geomorphic monitoring were compared to Dry WY TRFE objectives and results of the spring ROD release geomorphic monitoring are compared to Wet WY TRFE objectives.

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[2] The first thalweg profile survey was conducted before the ROD release; the second thalweg survey was conducted after the ROD release in the same location.

2.3.2.1. Longitudinal Profile

A high-flow scour channel is located at the downstream end of the site, and an alcove was constructed at the downstream end of the scour channel. To assess the performance of the alcove, a longitudinal topographic profile was surveyed before and after the spring release). Field observations and the profile (Figure 2–2) both show that the alcove near its confluence with the mainstem Trinity River aggraded approximately 0.15 m (6 in), resulting in its isolation from the mainstem during low flows.

The side channel located at the upstream end of the site (Figure 2–3), between cross sections 163+40 and 172+40, existed prior to site construction. The side channel entrance was modified during construction and the medial bar was graded. Topographic changes following the spring release included some aggradation at the side channel entrance and up to approximately 0.23 m (9 in) of scour at three locations (approximately longitudinal profile stations 1+30, 5+90, and 8+40).

Topographic survey results were evaluated and are summarized on an isopach map (Figure 2–4). The isopachs show that the most changes occurred in the 0.08–0.23 m (0.3–9 in) range and appear in relatively equal proportion; however, the distribution suggests more aggradation occurred in the upstream half of the mapped reach and more scour occurred in the downstream half. Notable changes that can be seen include deposition along the margins of the alternating bar sequence between station 148+00 and 158+00 and corresponding scouring along the opposite banks. In the context of radius of curvature, sinuosity, and alternate bar formation/maintenance, this change suggests the WY 2009 spring release was sufficient to maintain existing features with the overall magnitude of topographic changes being less than 0.23 m (9 in).

2.3.2.2. Cross Section Topography

Overall, WY 2009 topographic change at each cross section appears minimal across constructed surfaces. Some local topographic variation can be seen on the plotted cross sections, but the variation is small and discontinuous. The most significant topographic changes seen on the cross section plots include the following:

- Cross section 141+20: In WY 2009, the thalweg shifted 4.6 m (15 ft) toward the right bank and aggraded approximately 0.3 m (1 ft). From WY 2007 to WY 2008, the thalweg had shifted 9.1 m (30 ft) toward the right bank and aggraded approximately 0.15 m (6 in).
- Cross section 166+75: The location and elevation of the thalweg has not changed since WY 2007. The remainder of the low-flow channel shows uniform aggradation from approximately 0.15 to 0.23 m (6–9 in).

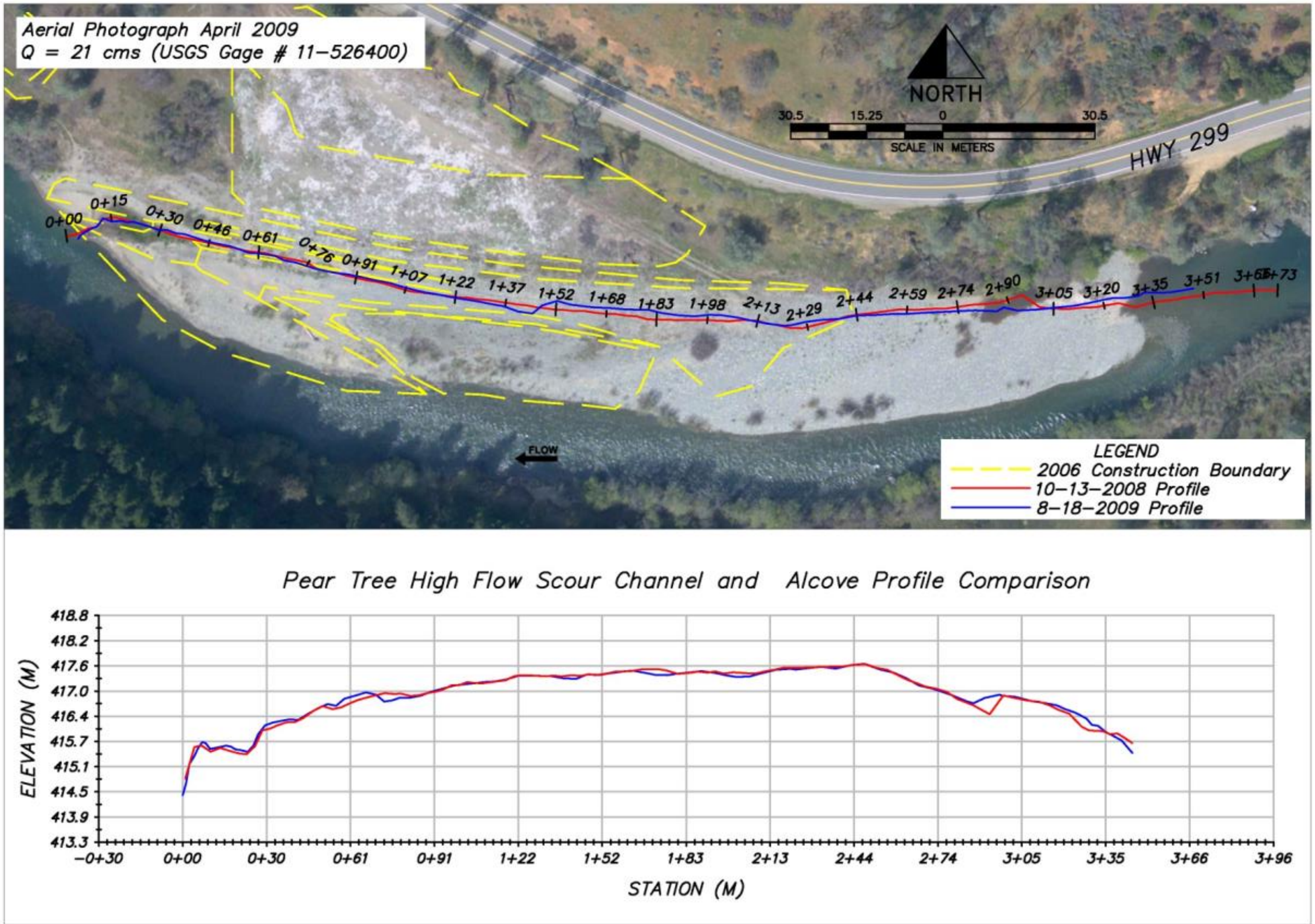


Figure 2–1. Pear Tree high-flow scour channel and alcove comparison between as-built conditions (10-13-08) and post-ROD releases (8-18-09). Each major 2006 construction feature has its own yellow boundary (as depicted in Figure A–3).

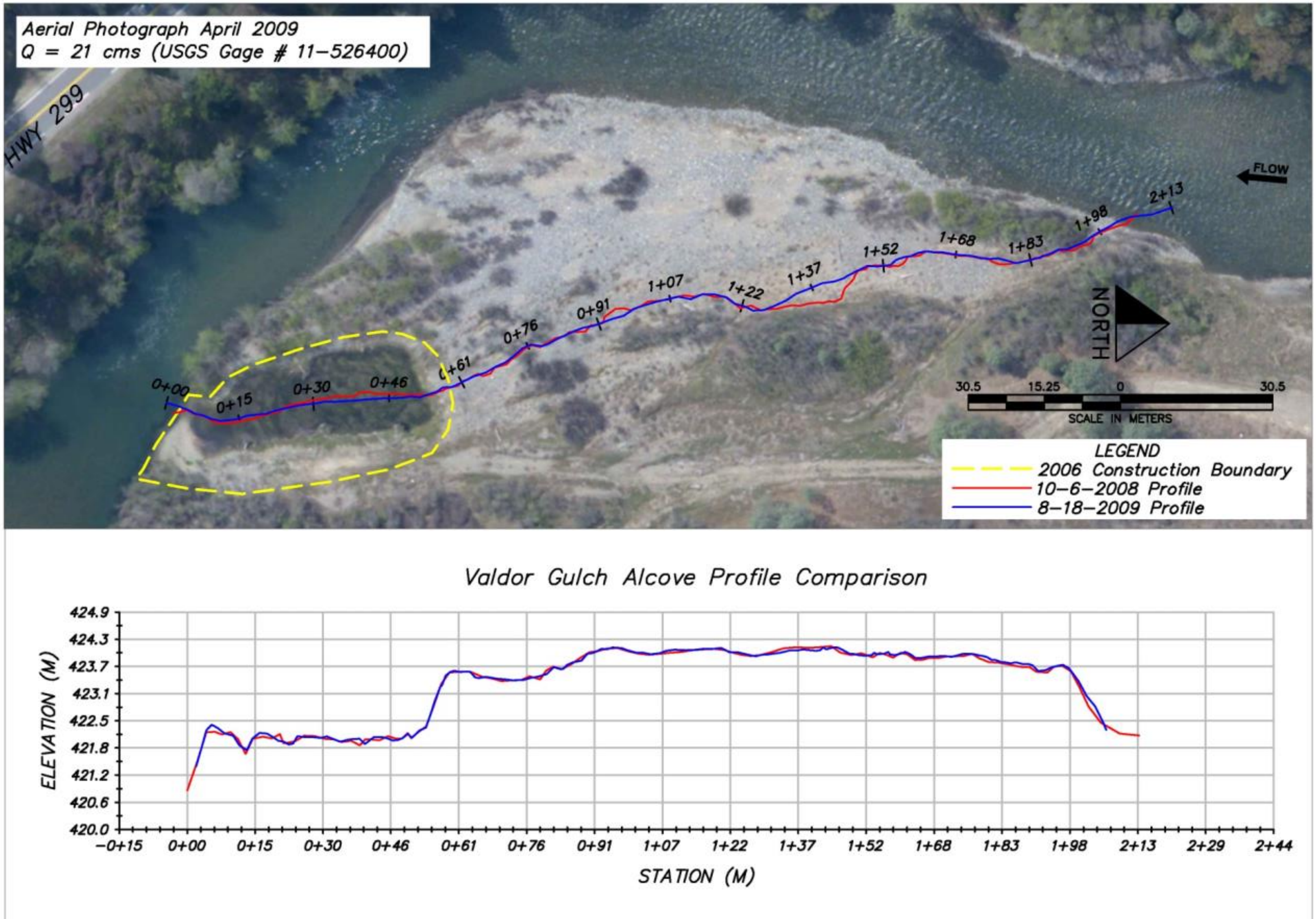


Figure 2–2. Valdor Gulch alcove profile comparison.

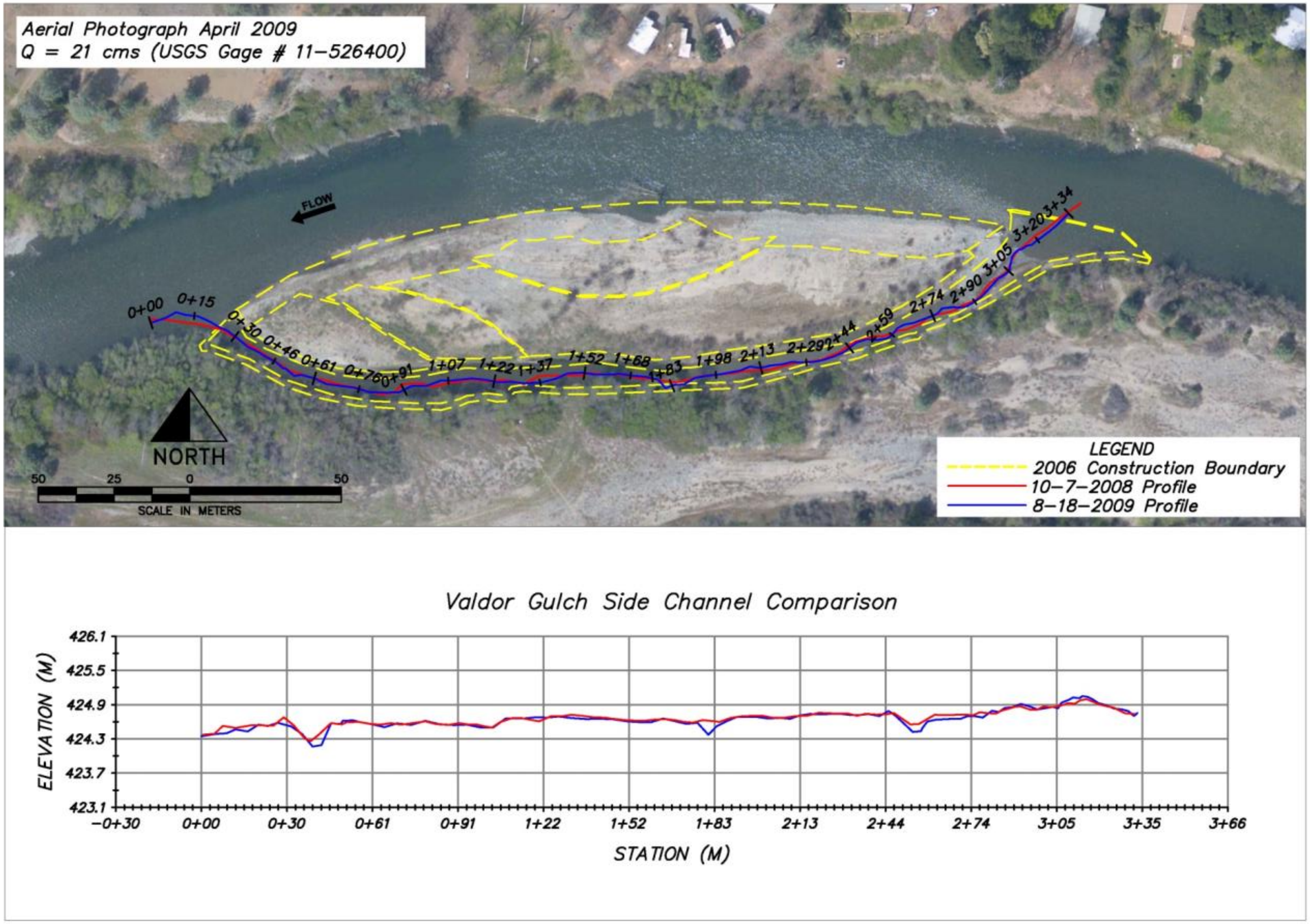
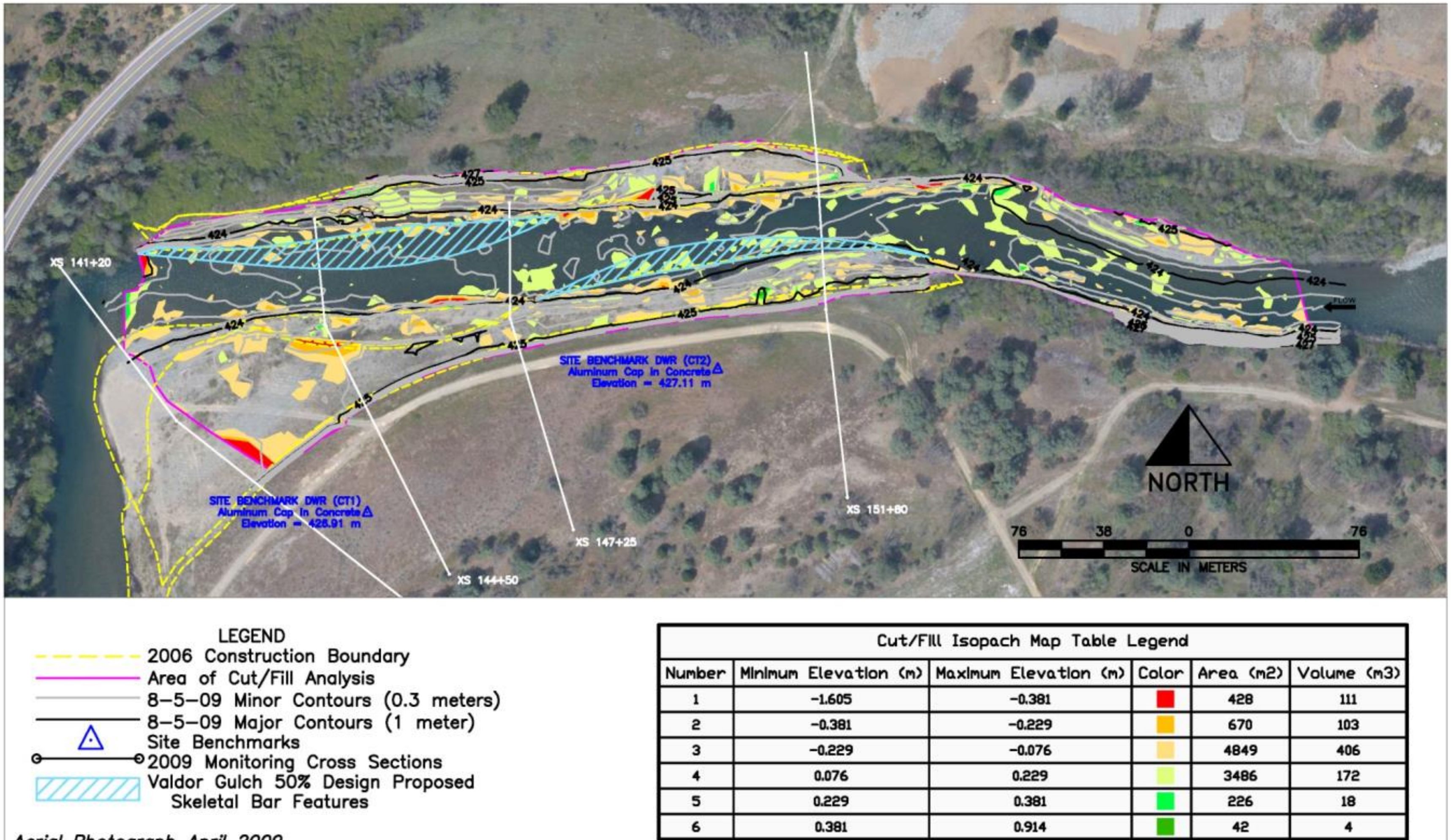


Figure 2–3. Valdor Gulch side channel profile comparison. Each major 2006 construction feature has its own yellow boundary as depicted in Figure A–6.



Cut/Fill Isopach Map Table Legend

Number	Minimum Elevation (m)	Maximum Elevation (m)	Color	Area (m2)	Volume (m3)
1	−1.605	−0.381	red	428	111
2	−0.381	−0.229	orange	670	103
3	−0.229	−0.076	light orange	4849	406
4	0.076	0.229	light green	3486	172
5	0.229	0.381	green	226	18
6	0.381	0.914	dark green	42	4

Cut/Fill between −0.076 m and 0.076 m assumes no change and is not shown.

Figure 2–4. Valdor Gulch pre- and post-ROD isopach map release comparison. Each major 2006 construction feature has its own yellow boundary as depicted in Figure A–6.

2.3.2.3. Bed Mobility Monitoring

Bed mobility was monitored using marked rock sets at cross sections 151+80 and 166+75 (Figures 2–5, 2–6; Appendix C). The marked rock set at cross section 151+80 was placed across a developing point bar (post-construction) and spanned two textural facies. D_{84} rocks were placed in both facies; however, D_{50} rocks were only placed in the streamward facies because D_{50} for the landward facies (6 mm [0.24 in]) was so small that rocks of that size could not be physically set as an experiment. The following results describe bed mobility across this developing bar.

- Winter peak flow: D_{84} mobility occurred at the two most landward rocks, and D_{50} mobility occurred on the two most streamward rocks. In addition, although no D_{50} rocks were set in the landward facies, it was assumed from the D_{84} result that the D_{50} also moved on this portion of the bar (total D_{84} mobility = 15%; total inferred D_{50} mobility is 44% resulting from the winter peak flow).
- Spring release: D_{84} mobility occurred again in the landward facies at the back edge of the bar, but also for several additional rocks in the low-flow channel (total D_{84} mobility = 54%). Where measured, D_{50} mobility was very similar to the D_{84}, and the same inference is made for mobility in the landward facies (D_{50} rocks moved where D_{84} rocks moved; total inferred D_{50} mobility is 71%).

The marked rock set at cross section 166+75 was installed on two different surfaces: (1) a constructed low terrace and (2) a developing point bar. Similar to cross section 151+80, the D_{50} rocks on the constructed terrace were too small to physically set as an experiment (7 mm [0.28 in]) and, as a result, only D_{84} rocks were set on this surface. Both D_{84} and D_{50} rocks were set farther downslope on the developing point bar.

- Winter peak flow: Only 1 of 14 D_{84} rocks mobilized from the cross section (the streamward-most on the point bar), and no D_{50} rocks moved.
- Spring release: 2 of 14 D_{84} rocks moved on the point bar, on opposite ends (the farthest landward rock and the farthest streamward rock). Rocks on the constructed terrace did not move but were buried with a thin veneer of sand. Four of seven streamward D_{50} rocks moved (total D_{50} mobility = 57 percent).

2.3.2.4. Bed Scour Monitoring

Bed scour and redeposition were monitored using scour chains at the same cross sections used for the bed mobility experiments (Figure 2–5, Figure 2–6; Appendix D). Four scour chains were installed on cross section 151+80. Scour chains were set among the marked rocks on the developing point bar at the following stations: 106.2, 109.3, 112.2, and 115.5.

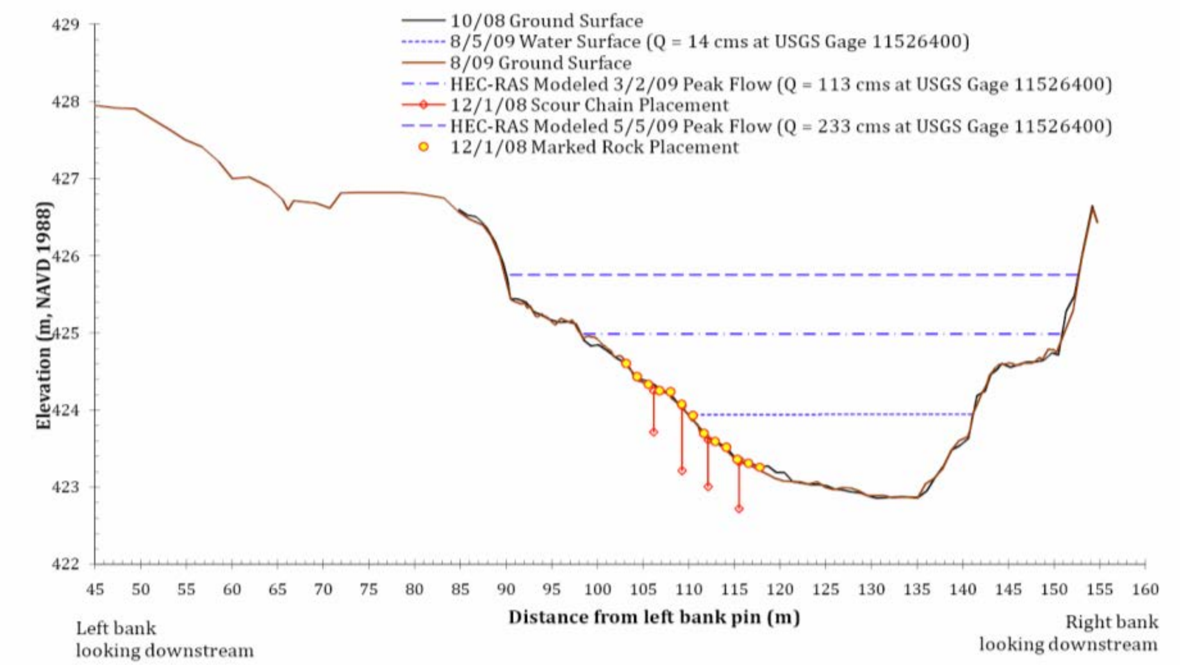


Figure 2–5. Valdor Gulch cross section 151+80.

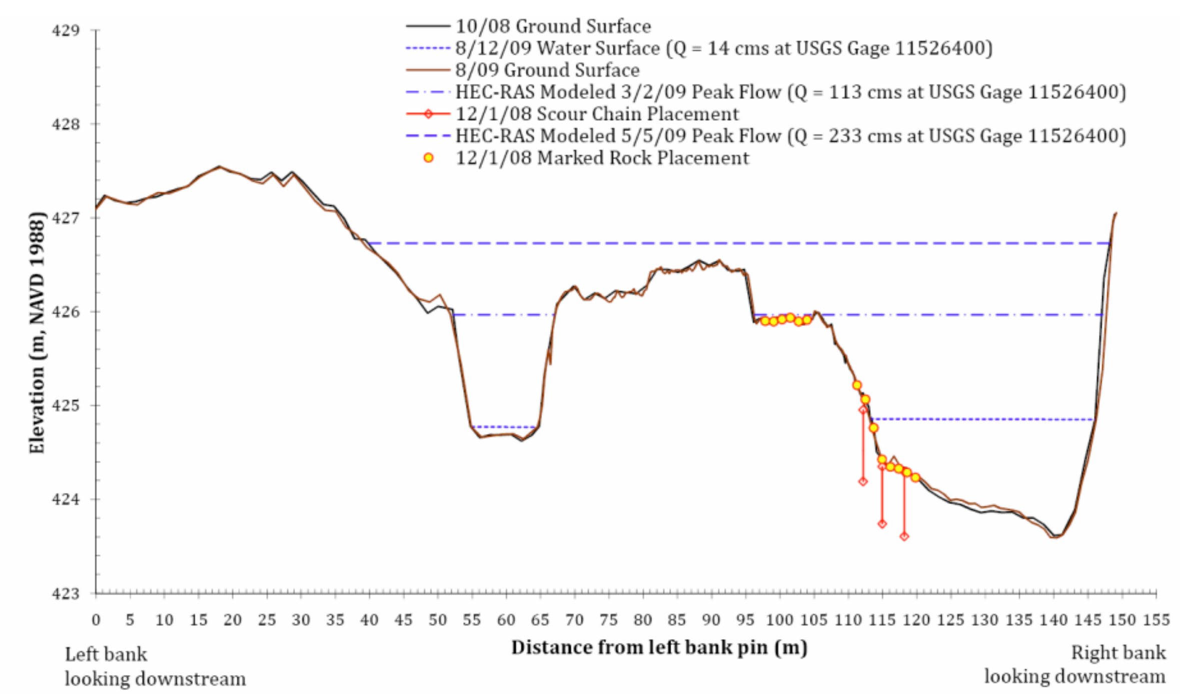


Figure 2–6. Valdor Gulch cross section 166+75.

- Scour resulting from the spring release was deepest at the two landward-most chains, measuring 4.1 and 2.0 cm (1.6 and 0.8 in) at stations 106.2 and 109.3, respectively. Scaling these depths by the bed surface D_{84} at the location where the chain is set yields relative scour depths of 0.3 D_{84} and 0.2 D_{84}, respectively. The remaining two scour chains did not record any scour.
- Redeposition following the spring release was also recorded only at the two landward-most chains, measuring 5.8 and 2.8 cm (2.3 and 1.1 in) at stations 106.2 and 109.3, respectively. Deposition did not occur at the remaining two chains.

Three scour chains were installed on cross section 166+75. Scour chains were set among the marked rocks on the developing point bar at the following stations: 112.1, 114.9, and 118.2. Scour chains were not installed on the constructed terrace.

- Scour resulting from the spring release showed a similar pattern to the scour on cross section 151+80; the deepest scour was recorded on the landward-most chain (13.0 cm [5.1 in], relative scour = 1.0 D_{84}), the middle chain recorded less scour (5.1 cm [2.0 in], relative scour = 0.4 D_{84}), and no scour was recorded by the streamward-most chain.
- Redeposition following the spring release also showed a similar pattern to the scour on cross section 151+80; the most redeposition occurred where the greatest scour was measured (6 cm [2.4 in] at the landward-most chain). However, unlike cross section 151+80 where the redeposition thickness was slightly greater than the measured scour, measured redeposition on cross section 166+75 was equal to or less than the measured scour depth (maximum redeposition was 7 cm [2.8 in]).

2.3.2.5. Valdor Gulch Geomorphic Discussion

Six geomorphic priority questions have been asked for Valdor Gulch (Table 1–3). *Priority Question G–1* asks whether process-based TRFE geomorphic management targets are being met by annual releases. The TRFE Dry WY peak flow monitoring geomorphic objective is to mobilize rocks as large as D_{84} on bar flank features. Bed mobility results from the 113-cms (3,990-cfs) winter peak flow (which is closest to a Dry WY 127-cms [4,500-cfs] release magnitude) show that only some of the D_{84} rocks on the bar flanks moved (D_{84} mobility across these surfaces ranged from 0% to 15%), suggesting TRFE management targets for a Dry WY were likely not met. However, the mobility recorded was in response to a 113-cms (3,990-cfs) instantaneous flow rather than a 127-cms (4,500-cfs) 5-day release, which would have resulted in more mobility across these surfaces and a better chance at meeting Dry WY bed mobility objectives.

The Wet WY peak flow monitoring geomorphic objectives are to:

1. Mobilize >1.0 D_{84} depth on alternate bar flanks, cleansing gravels and transporting all sizes of sediments, and
2. Initiate channel migration.

In the context of meeting Wet WY bed scour objectives, only one of six scour chains at the site recorded a relative scour depth equal to 1.0 D_{84} (cross section 166+75, station 112.1); the remaining chains did not meet this target, and many recorded no scour at all. From these results, Wet WY bed scour management targets were not met at Valdor Gulch.

Priority Question G–2 asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features. Using the isopach map from the topographic analysis (Figure 2–4), it appears the alluvial features are, at a minimum, being maintained. No new alluvial feature development was observed in the field or can be discerned from the topographic analysis; however, the topographic change portrayal of the site is limited to changes greater than 0.08 m (3 in).

Priority Question G–3 asks whether channel migration can be encouraged by only removing vegetation/berms on opposite banks in advance of high-flow releases or natural floods (i.e., without putting anything within the active channel to force thalweg adjustment). In the comparison of pre- and post-spring-release cross-section topography, only cross section 141+20 shows a shifting thalweg (moving approximately 9.1 m [29.9 ft] between WY 2007 and WY 2008, and approximately an additional 4.5 m (14.7 ft) between WY 2008 and WY 2009). By contrast, none of the other cross sections monitored in WY 2009 have shown any changes suggesting channel migration. However, cross section 141+20 is located on a 90-degree bedrock bend in the main channel, with a constructed surface along the inside of the bend (Figure 2–2), making this cross section the most susceptible to geomorphic change at the site. (The other cross sections are located in a relatively straight, uniform, and hydraulically simple reach.) In addition, the isopach map shows subtle depositional changes with scour hotspots (>0.03 m [1 in] deposition and >0.15 m [5.9 in] scour) occurring along and within the constructed meander benches. These changes all occurred in areas where vegetation removal was a part of site construction, and therefore vegetation removal can be considered a likely contributing factor to the observed WY 2009 geomorphic changes.

Priority Question G–4 asks if design meander wavelengths and radii of curvature are maintained with high-flow releases, natural floods, and sediment regime, and whether these features exert themselves upstream and downstream of the constructed area or enhance local channel migration of the mainstem Trinity River. The design meander wavelength for Valdor Gulch is approximately 305 m (1,000 ft) and was based on pre-construction local channel morphology. The site design included the removal of vegetated berms along left and right banks. The geometry of the constructed banks alternated from gently sloping between the floodplain (170-cms [6,000-cfs] inundation surface) and the low-flow edge, to low and flat benches along the low-flow edge designed to encourage increased channel sinuosity and migration via bank scour and deposition. The WY 2009 topographic changes along these constructed areas are subtle, and general patterns are not conclusive beyond the geomorphic changes summarized for Priority Question G–2. In the context of radius of curvature, sinuosity, and alternate bar formation/maintenance, no apparent patterns have established, suggesting the WY 2009 spring release was not large enough to significantly alter the bed surface through this reach to show a noticeable difference using this analysis method.

Priority Question G–5 asks if alcoves maintain themselves with high-flow releases and natural floods. The longitudinal profile analysis shows that the alcove, near its confluence with the mainstem Trinity River, aggraded approximately 0.15 m (6 in) in WY 2009. This has resulted in its isolation from the mainstem during low flows. The alcove does not appear to have maintained itself.

Priority Question G–6 asks if side channels are maintaining themselves with high-flow releases and natural floods. Aside from the side channel entrance aggradation and local scour areas seen on the longitudinal profile, no other topographic changes resulting from the WY 2009 spring release were noted. Side channel function appears to have been maintained in WY 2009 (i.e., the side channel was flowing during summer baseflows), but the side channel entrance should be monitored in the future because additional aggradation has the potential to affect side channel function (by changing the entrance geometry, which could result in less side channel flow during low mainstem flows).

2.3.3. Conner Creek

Five cross sections were monitored: 265+40, 260+05, 252+35, 247+40, and 241+60 (Figure A–7; Appendix B). Monitoring occurred following the spring peak flow of 233 cms (8,230 cfs) recorded at the Trinity River above North Fork Trinity River gaging station (Table 2–3).

2.3.3.1. Cross Section Topography

Changes seen at each cross section were:

- Cross section 241+60: The most significant change on this cross section occurred along the near-vertical right bank, which retreated 1.8 m (5.9 ft), likely as a result of the WY 2009 spring release. (Survey notes from October 2009 describe the bank as being undercut.) No other topographic changes appear to have occurred on this cross section in WY 2009. Unlike the other cross section included in this monitoring, this cross section was not surveyed in 2007 and therefore no additional changes can be documented.
- Cross section 247+40: The topography surveyed on this cross section in October 2008 did not plot correctly due to a reference elevation error which cannot be resolved. Because of this error, WY 2009 topographic changes cannot be evaluated. Changes on this cross section between October 2007 and August 2009 show significant scouring within the low-flow channel: the thalweg has scoured approximately 0.46 m (1.5 ft) and has shifted toward the right bank by approximately 1.8 m (5.8 ft; from station 3.9 to station 5.8), the channel near the low-flow right bank between station 21.3 and station 32.2 has

scoured up to 0.6 m (2.0 ft), and the stretch from station 34.4 to station 39.6 also shows scour up to 0.43 m (1.4 ft).

- Cross section 252+35: Topographic changes along this cross section are minor, with the exception of a small portion of the low-flow channel between station 11.9 and station 14.9, where the bed has scoured approximately 0.21 m (0.7 ft). Other significant changes were not apparent across the remainder of the cross section. Additional scouring has occurred in the low-flow channel since the October 2007 post-construction survey (suggesting net scour and a slight increase in cross section area).
- Cross section 260+05: The WY 2009 surveys do not show apparent net topographic change. The differences between the October 2009 and April 2009 surveys are minor (up to 0.06 m [2.4 in]) and localized. Changes since October 2007 suggest the cross section has scoured up to 0.15 m (6 in) along the right portion of the low-flow channel from station 24.4 to 37.2.
- Cross section 265+40: Net topographic change was not apparent in WY 2009. The most significant topographic changes can be seen on the berm separating the main channel from the right bank side channel. The August 2009 survey suggests portions of this surface aggraded from the WY 2009 spring release; however, this flow did not completely inundate the berm surface, and topographic changes above the 233-cms (8,230-cfs) elevation are likely due to differences in survey rod placement between surveys, as described above. More significant changes have occurred on this cross section since October 2007; the left bank from station 7.6 to station 2.1 has retreated by up to 2.4 m (7.9 ft), the thalweg has scoured up to 0.24 m (0.8 ft) between station 7.6 and 14.6, and the channel has aggraded also up to 0.24 m (0.8 ft) between station 14.6 and station 37.2.

2.3.3.2. Connor Creek Geomorphic Discussion

Overall, WY 2009 topographic change was minor at this site. Most of the cross sections show some local topographic variation, possibly resulting from the combination of winter flood flows and the spring release, but most cross sections do not appear to show any net change in cross-section geometry (i.e., no significant increase or decrease in cross-section area). More significant changes in cross-section topography have occurred since the site was constructed in 2007; topographic differences between the October 2007 post-construction survey (McBain & Trush and HVT, unpublished data) and the WY 2009 surveys show more significant (and uniform) channel changes which vary by cross section (some have aggraded and others have scoured).

One geomorphic priority question is asked for Connor Creek (Table 1–3). Priority Question G–3 asks whether channel migration can be encouraged by only removing vegetation/berms on opposite banks in advance of high-flow releases or natural floods (i.e., without putting anything within the active channel to force thalweg adjustment). The only cross section where channel migration is occurring is 247+40. Since October 2007, the thalweg there has scoured approximately 0.45 m (1.5 ft) and has shifted toward the right bank by approximately 1.8 m (5.8 ft). Other cross sections surveyed in WY 2009 did not indicate change that suggests channel migration is occurring, even though these cross sections experienced both a 113-cms (3,990-cfs) flood and a 233-cms (8,230-cfs) flood, but only cross section 247+40 showed some lateral movement. Instantaneous floods up to 233 cms (8,230 cfs) are causing very little channel migration at this site, despite attempts to encourage it via the bank rehabilitation design features.

2.3.4. Hocker Flat

Specific geomorphic monitoring activities at Hocker Flat included topographic surveys, bed mobility monitoring, and bed scour and redeposition monitoring. Monitoring included five cross sections: 358+89, 340+17, 326+90, 314+15, and 309+51 (Figure A–9, B–10, B–11; Appendix B). Monitoring occurred following both the winter and spring peak flows (Table 2–3). Due to the magnitude of flows experienced during these two flood events, results of winter flood geomorphic monitoring were compared to Dry WY TRFE objectives and results of the spring ROD release geomorphic monitoring are compared to Wet WY TRFE objectives.

2.3.4.1. Cross-Section Topography

WY 2009 topographic change at each cross section appears minimal across constructed surfaces. Prior to WY 2009, cross-section surveys were last conducted in August 2006 following the WY 2006 spring ROD release, which was estimated to be 303 cms (10,700 cfs) at Hocker Flat (McBain & Trush and HVT 2007). The most significant topographic changes seen on the cross-section plots since WY 2006 include the following:

- Cross section 309+51: In WY 2009, this cross section aggraded from 0.09 to 0.24 m (0.3–0.8 ft). Additional topographic variation can be seen on the cross-section plots between station 51.8 and 67.1, which is a debris pile. Topographic changes at this cross section have been confined to the low-flow channel. Since WY 2006, the low-flow channel has lowered approximately 0.15–0.37 m (0.5–1.2 ft) between stations 123.4 and 134.1. (This includes the thalweg.)
- Cross section 314+15: In WY 2009, the cross-section plot shows minor aggradation (up to 0.08 m [3.2 in]) from station 100.1 to 114.3. Detectable net topographic change has not occurred on this cross section since the first post-spring release survey in August 2006, except for within the low-flow channel. Erosion has occurred along the leading point bar edge between station 88.4 and 103.6, which has lowered approximately 0.12–0.15 m (0.4–0.5 ft).
- Cross section 326+90: Although bed mobility and bed scour experiments show bed mobilization and scour occurred in WY 2009 (see following sections), repeated cross-section surveys give no indication of ongoing bed scouring or aggrading trends. No net topographic change has been detected on this cross section since the first post-spring release survey in August 2006.

- Cross section 340+17: Similar to cross section 326+90, no net topographic change has been detected on this cross section since the first post-spring release survey in August 2006.
- Cross section 358+89: The changes along this cross section in WY 2009 appear negligible except for some localized pool filling between station 77.7 and 80.7. Above the low-flow channel and across the constructed surface, topographic change was not observed between WY 2006 and WY 2009 or within WY 2009. The most significant topographic change following WY 2006 at Hocker Flat can be seen at this cross section. Since August 2006, topographic changes on this cross section have been limited to the low-flow channel, including 0.21–0.3 m (0.7–1 ft) of aggradation in the main channel landward of the medial bar (approximately station 30.4 to 56.4), approximately 0.15 m (0.5 ft) of medial bar scour (approximately station 60.1 to 70.1), and up to approximately 0.15–0.24 m (0.5–0.8 ft) of pool filling (approximately station 73.2 to 80.8).

2.3.4.2. Bed Mobility Monitoring

Bed mobility was monitored in WY 2009 using marked rock sets at cross sections 314+15, 326+90, and 358+89 (Figure 2–7, 2–8, and 2–9; Appendix C).

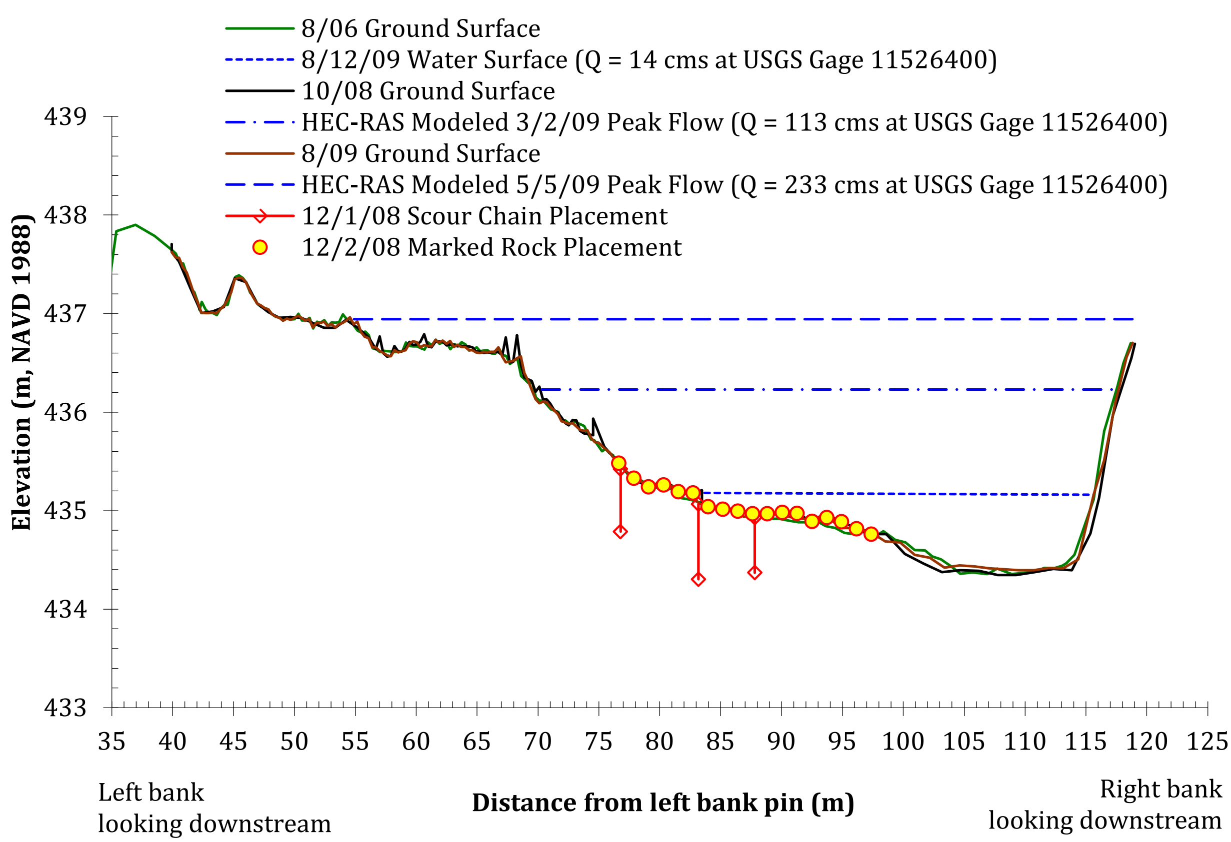


Figure 2–7. Hocker Flat cross section 314+15.

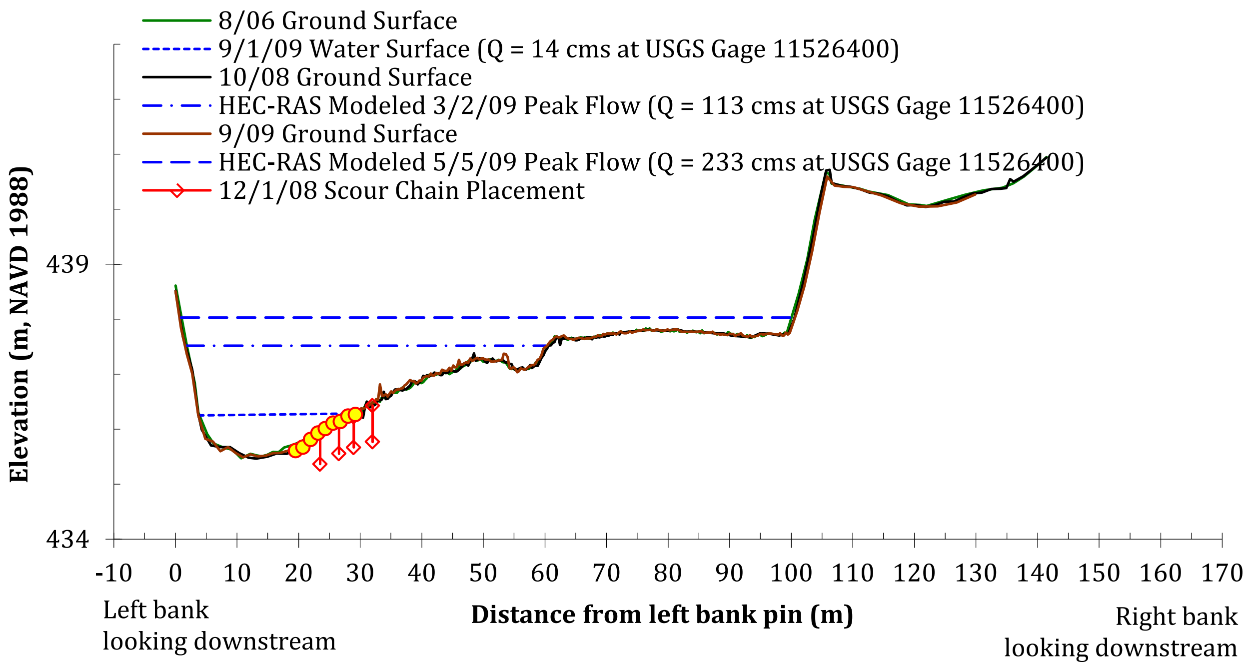


Figure 2–8. Hocker Flat cross section 326+90.

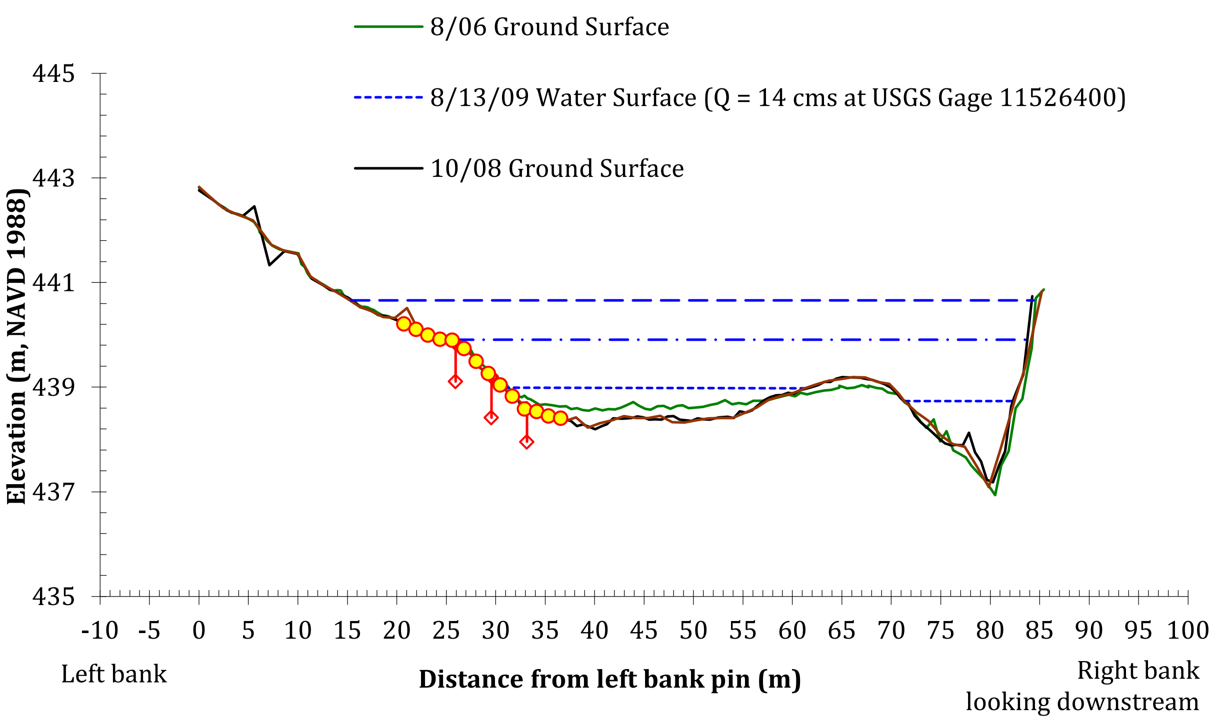


Figure 2–9. Hocker Flat cross section 358+89.

2.3.4.2.1. Cross Section 314+15

In WY 2006, marked rock placement at cross section 314+15 included the constructed low terrace and left bank point bar. The terrace rocks showed little movement in response to the WY 2006 spring release and were left in place for future monitoring. Since WY 2006 these rocks have remained in place and have not moved (Figure 2–10). Because of this, marked rocks for WY 2009 were set across the bar only; 18 D_{84} and D_{50} pairs were set within a single textural facies. The following bullets describe mobility measured from the winter peak flow and spring release:

- Winter peak flow (3,990 cfs): two D_{84} and D_{50} rocks moved on the point bar. Two adjacent D_{84} rocks moved at station 90.2 and 91.4, but their corresponding D_{50} rocks did not move. Both of the D_{84} rocks moved approximately 0.6 m (2 ft) downstream, which suggests their initial placement was hydraulically unstable. They likely relocated slightly downstream to a more stable position. It is also possible that the D_{50} rocks were shielded by larger boulders immediately upstream, preventing their movement. The D_{50} rocks that did move were slightly landward, at stations 85.3 and 87.8.

Figure 2–10. Photographs of cross section 314+15 from the left bank facing the main channel. Flow is from right to left. Left photograph shows marked rock set on constructed terrace following the spring 2006 release (309 cms [10,900 cfs] at the site). Right photograph shows the same rock set in April 2009. These rocks have not been mobilized by any flows since May 2006.

- Spring release flow (8,230 cfs): between station 83.8 and 97.5 (the streamward-most rocks in this set), all 12 D_{50} rocks were mobilized, and 11 of the 12 D_{84} rocks moved (all except station 86.3).

WY 2006 results were combined with WY 2009 results to see how bed mobilization increases with discharge by comparing mobility on cross section 314+15 for the portion of the cross section showing D_{84} mobility for all flows monitored (from station 76.2 to 97.5), which includes the entire point bar and bar flank. The 2006 results showed between approximately 70 and 100 percent of marked rocks were mobilized on this cross section for flows above 300 cms (10,600 cfs), but no information was available for lower flows that showed when bed mobility was initiated. By adding the 2009 results, the mobility-discharge relationship was broadened and bracketed mobility from 10 to 100 percent between approximately 100 to 750 cms (3,530 to 26,486 cfs). Results of these combined data show a trend of increasing mobility (percent D_{84} mobilized) as a function of discharge (Figure 2–11). Additional marked rock monitoring at this cross section will add points to this curve and can help better define this relationship.

2.3.4.2.2. Cross Section 326+90

At cross section 326+90, WY 2006 marked rock placement covered most of the constructed right bank low terrace and point bar (from station 21.3 to station 70.1).

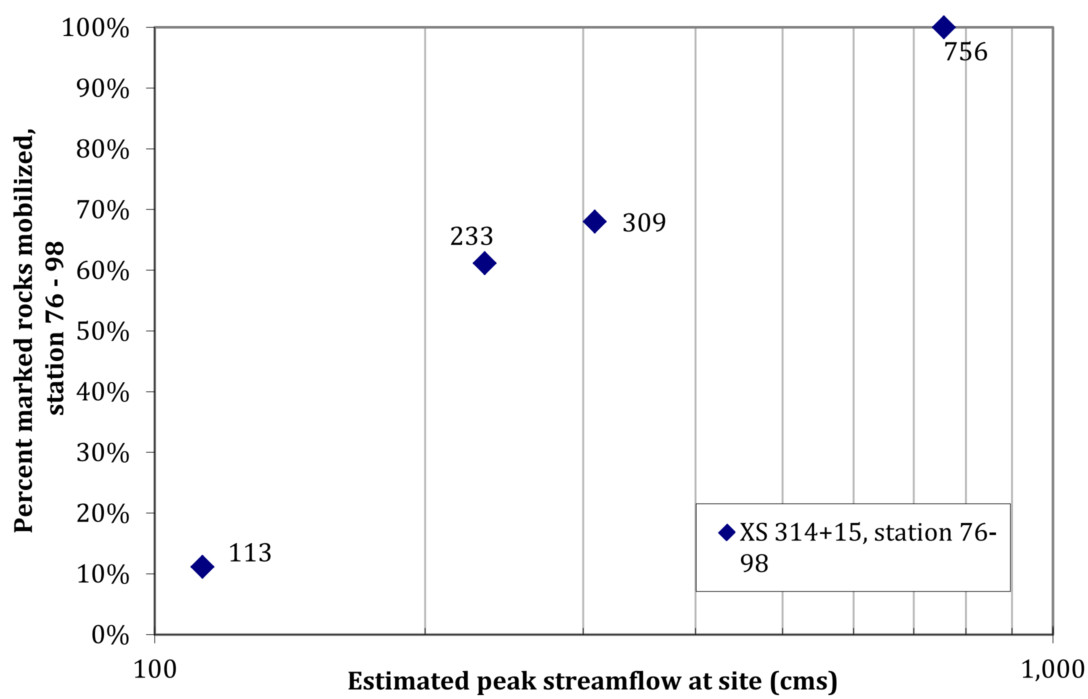


Figure 2–11. Hocker Flat cross section 314+15 D_{84} marked rock mobility results between station 76 and 98, WY 2006 and WY 2009.

The terrace rocks showed very little movement in response to the WY 2006 spring release and were left in place for future monitoring. Since WY 2006, most of these rocks have remained in place and have not moved. (Some individual rocks are missing, assumed either buried or vandalized.) WY 2009 marked rocks were set farther toward the channel, where the most mobility had been previously documented. Both D_{84} and D_{50} rocks were set (n = 9) within a single textural facies. During the winter peak flow, D_{84} rocks did not move and one D_{50} rock moved. During the spring release, all nine D_{50} rocks were mobilized and six D_{84} rocks moved. (All of the streamward-most rocks from station 19.5 to 26.8, except for station 25.6.)

As was done for cross section 314+15, WY 2006 results for cross section 326+90 were combined with the WY 2009 results to see how bed mobilization increases with discharge. Here again, mobility was compared for the portion of the cross section showing D_{84} mobility for all flows monitored (from station 20.7 to 48.2), which includes the bar flank. Results of these combined data also show a trend of increasing mobility (percent D_{84} mobilized) as a function of discharge (Figure 2–12). Additional marked rock monitoring at this cross section will add points to this curve and can help better define this relationship.

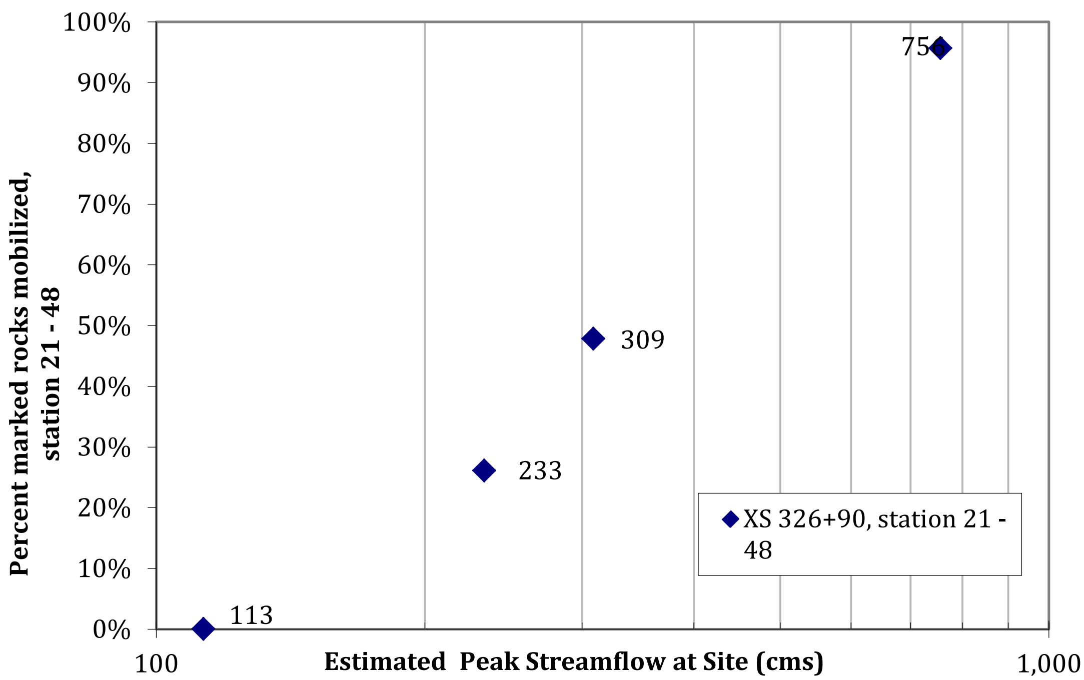


Figure 2–12. Hocker Flat cross section 326+90 D_{84} marked rock mobility results between station 21–48, WY 2006 and WY 2009.

2.3.4.2.3. Cross Section 358+89

In WY 2006, marked rock placement at cross section 358+89 ranged from station 19.5 to station 31.7; 36 percent of the D_{84} rocks moved and 55 percent of the D_{50} rocks moved in response to the 309-cms (10,900-cfs) spring release. Marked rock placement in WY 2009 used the same location as the WY 2006 rocks but extended placement into the wetted channel by an additional 4.9 m (n = 15 rock groups placed in this set). During the winter peak flow, D_{84} rocks did not move and one D_{50} rock moved. During the spring release, both D_{84} and D_{50} rocks moved between station 30.5 and 36.5 (n = 5 rocks). These were the streamward-most rocks in this set.

Unlike cross sections 314+15 and 326+90, a relationship between bed mobility and discharge was not explored due to significant topographic (and hydraulic) changes that occurred at this cross section following the WY 2006 winter peak flow event.

2.3.4.3. Bed Scour Monitoring

Bed scour and redeposition was monitored using scour chains at the same cross sections used for the bed mobility experiments (Figures 2–7, 2–8, and 2–9; Appendix D). The scour chains were installed in December 2008 and monitored once following the spring release. Scour chains were not monitored following the winter flood because scour was assumed to be negligible due to the low peak discharge. Overall, bed scour was recorded at all three monitoring cross sections but was generally shallow; scour depths ranged from 0 to 11.9 cm (0–4.7 in), and redeposition ranged from 4.6 to 17.3 cm (1.8–6.9 in).

At cross section 314+15, three scour chains were set among the marked rocks across the bar and floodplain at stations 76.8, 83.2, and 87.8. Scour was uniform at all three chains, measuring 4.1–5.1 cm (1.6–2.0 in). Scaling these depths by the bed surface, D_{84} yields relative scour depths of 0.3 D_{84} and 0.4 D_{84}, respectively. Redeposition recorded by the chains following the spring release ranged from 6.1 to 8.4 cm (2.4–8.3 in).

At cross section 326+90, four scour chains were set among the marked rocks at stations 23.5, 26.6, 29.0, and 32.0. Scour resulting from the spring release was variable (no trend toward or away from the channel). Scour depths ranged from 4.1 to 11.9 cm (1.6–4.7 in), which translates to relative scour depths of 0.3 to 1.0 D_{84}. Redeposition following the spring release ranged from 5.3 to 17.2 cm (2.1–6.8 in). Redeposition was also variable and did not correlate with scour (i.e., maximum redeposition did not occur where maximum scour occurred).

At cross section 358+89, three scour chains were set among the marked rocks at stations 25.9, 29.6, and 33.2. As at the previous cross sections, scour resulting from the spring release was variable. The bed scoured 3.0 cm (1.2 in) deep at the landward-most scour chain (station 25.9). Scour was not recorded at the middle chain (station 29.6). A scour measurement of 0.3 cm (0.2 in) was recorded in the low-flow channel. (Results for this chain are within measurement error and actual scour may be zero at this location.) Redeposition following the spring release was fairly uniform at all scour chains, ranging from 4.6 to 7.6 cm (1.8–3.0 in).

2.3.4.4. Hocker Flat Geomorphic Discussion

Three geomorphic priority questions were asked for Hocker Flat. *Priority Question G–1* asks whether process-based TRFE geomorphic management targets are being met by annual releases. The TRFE Dry WY peak flow monitoring geomorphic objective is to mobilize the D_{84} on bar flank features. Bed mobility results from the 113-cms (3,990-cfs) winter peak flow (which is closest to a Dry WY release magnitude of 127 cms or 4,500 cfs) show that only some of the D_{84} rocks on the bar flanks moved (D_{84} mobility across these surfaces ranged from 0% to 11%), suggesting TRFE management targets for a Dry WY were likely not met. These results are very similar to the results measured at Valdor Gulch. However, the mobility recorded was in response to a 113-cms (3,990-cfs) instantaneous flow rather than a 127-cms (4,500-cfs) five-day release, which would have resulted in more mobility across these surfaces and a better chance at meeting Dry WY bed mobility objectives.

Since flows close to Wet WY peak magnitude were experienced at this site, scour data were evaluated in the context of the following Wet WY peak flow geomorphic objectives: (1) Mobilize >1.0 D_{84} depth on alternate bar flanks, cleansing gravels and transporting all sizes of sediments, and (2) initiate channel migration at rehabilitation sites. In the context of meeting Wet WY bed scour objectives, only 1 of 10 scour chains recorded a relative scour depth of 1.0 D_{84} (cross section 326+90, station 32.0); the remaining chains did not meet this target. From these results, Wet WY bed scour management targets were not met at Hocker Flat. Wet WY channel migration management targets are discussed below in connection with *Priority Question G–3*.

Priority Question G–2 asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features. Based on the WY 2009 bed mobility and bed scour results, most of the geomorphic “work” that occurred where these experiments were set was within the range of less than one D_{84} thickness at select locations (relative scour depths were predominantly <1.0 D_{84}), suggesting flow thresholds that mobilize, scour, and redeposit coarse bed material were minimally crossed.

Although the WY 2009 mobility and scour experiments suggest little change has occurred (and could suggest the WY 2009 peak flows were not sufficient to maintain alluvial features at this site), observations suggest that the site is indeed maintaining itself. Following the major geomorphic adjustments resulting from the 2006 flood, the channel morphology in the vicinity of the monitoring cross sections has largely remained unchanged, suggesting that to date rehabilitation site implementation, in combination with high-flow releases and natural floods (i.e., from Canyon Creek), has been sufficient to maintain alluvial features at this site.

Priority Question G–3 asks whether channel migration can be encouraged by only removing vegetation/berms on opposite banks in advance of high-flow releases or natural floods (i.e., without putting anything within the active channel to force thalweg adjustment). Changes in WY 2009 cross-section topography do not suggest channel migration is occurring at these locations (and therefore Wet WY channel migration management targets were not met at Hocker Flat).

2.3.5. Lower and Middle Indian Creek

As-built topographic surveys were performed at Middle and Lower Indian Creek; however, geomorphic monitoring was not performed until WY 2009. Specific geomorphic monitoring activities at the Lower Indian Creek site included topographic surveys, which consisted of two cross sections and a side channel longitudinal profile (Figure A–16). Monitoring occurred following the spring release peak flow (153 cms [5,420 cfs]; Table 2–5).

2.3.5.1. Longitudinal Profile Through Side Channel

To help evaluate whether the side channel is functioning as it was intended, the TRRP surveyed thalweg profiles in September 2008 and again in July 2009. The September 2008 profile was surveyed using an auto level with a tape strung down the channel axis, and the July 2009 profile (Figure 2–13) was surveyed using a total station. Unfortunately, the September 2008 pre-spring release survey lacked spatial coordinates (i.e., northing, easting) that relate to the elevations and distances recorded; as a result, the September 2008 survey cannot be shown in planform (although the planform alignment will be similar to the July 2009 planform alignment) nor can the profiles be compared. An attempt was made to adjust the auto level data to the total station data, but the resulting plot showed significant differences between surveys and is not a reliable basis for describing changes.

Table 2–5. Hydrology Used for Sites between Lewiston Dam and Indian Creek

Lewiston Release	Estimated Peak Flow at Indian Creek, Vitzthum Gulch, Lowden Meadows, Bucktail–Dark Gulch, Hoadley Gulch, Lewiston Cableway, Deadwood Creek, Sven Olbertson, and Lewiston Hatchery.	TRFE Monitoring Objective Used for Site Evaluation
122 cms (4,300 cfs) (Dry WY release for five days, May 1–5, 2009)	153 cms (5,420 cfs) (Instantaneous peak flow May 5, 2009)	Dry

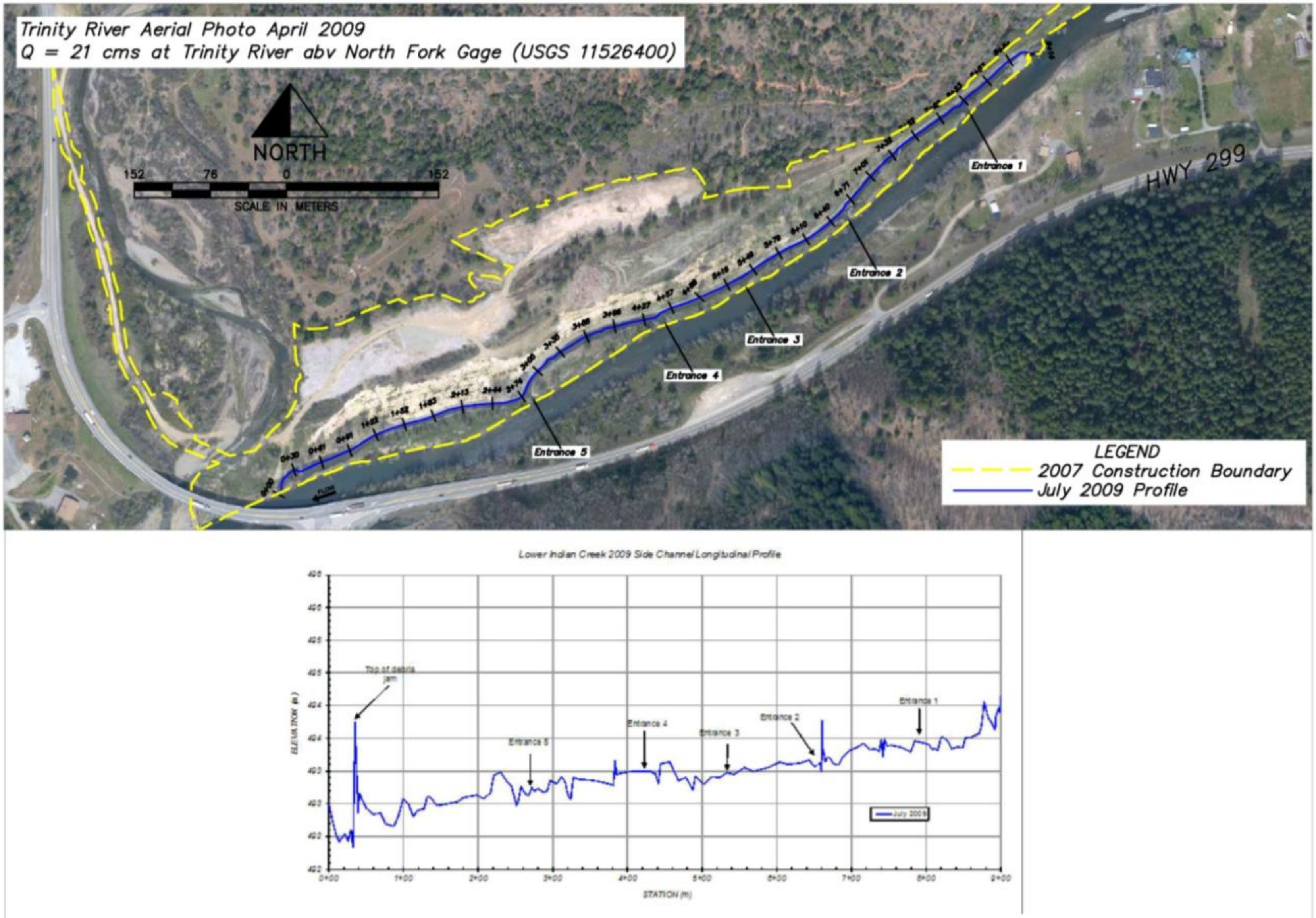


Figure 2–13. Lower Indian Creek longitudinal profile of side channel.

2.3.5.2. Cross-Section Topography

Overall, WY 2009 topographic change at each cross section appears minimal across constructed surfaces (Appendix B). The most significant topographic changes seen on the cross section plots include the following:

- Cross section 1157+90: Changes within the low-flow main channel are within 0.06 m (2.4 in), suggesting minor aggradation may have occurred between stations 9.8 and 13.1 and also between stations 18.3 and 25.9. The two surveys made of the side-channel portion of this cross section, from station 48.8 to approximately station 67.1, do not accord well; the August 2009 survey plots approximately 1.5 m (4.9 ft) right of the October 2008 survey, and this discrepancy has not yet been resolved in the raw survey data. Assuming the stationing is incorrect but the surveyed elevations are correct, the difference in surveyed side channel elevation suggests approximately 0.06 m (2.4 in) of side channel aggradation occurred in WY 2009.
- Cross section 1171+20: The most notable WY 2009 topographic changes occurred within the low-flow channel, between station 50.3 and 85.3. In this portion of the channel, the bed scoured 0.12 m (4.7 in) from station 50.3 to station 61.2, aggraded approximately 0.21 m (8.3 in) between station 71.0 and station 76.2, and again scoured as much as 0.18 m (7.0 in) from station 79.2 to 84.7.

2.3.5.3. Lower and Middle Indian Creek Geomorphic Discussion

Three priority questions have been asked for Lower Indian Creek. *Priority Question G–1* asks whether process-based TRFE geomorphic management targets are being met by annual releases. Cross-section topography was used to evaluate changes in channel geometry (which may also be used as an indicator for geomorphic "work" occurring). Cross section 1157+90 suggests minor aggradation in the main channel and possibly in the side channel, and cross section 1171+20 shows both scour and aggradation in the main-channel. Although these changes show where the bed scoured and redeposited, it is difficult to link these changes to WY objectives without knowing whether alluvial features are developing. Based on field observations at the site, alluvial feature development is subtle (if happening at all). Although flows should have been sufficient to mobilize and scour the bed, the resulting minor topographic change at the site suggests management targets were likely not met.

Priority Question G-2 asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features. Based on results of the cross-section surveys and our field observations, geomorphic changes at the site appear minor, suggesting alluvial feature development at the site is subtle (if happening at all). Although flows should have been sufficient to mobilize and scour the bed, the resulting minor topographic change at the site suggests management targets were likely not met.

Priority Question G–6 asks if side channels are maintaining themselves with high-flow releases and natural floods. A discrepancy in data collection methods prohibited a comparison of the long profile before and after the 2009 peak spring release. However, the side channel entrance was still allowing flow into the side channel at summer baseflows in the July 2009 survey.

2.3.6. Vitzthum Gulch

2.3.6.1. Planform topography

Geomorphic monitoring at Vitzthum Gulch consisted of repeated topographic surveys of the berm notches (Figure A–19, Figure 2–14). Monitoring focused on documenting topographic changes at each notch since the site was constructed in 2007, including topographic changes resulting strictly from the WY 2009 spring release peak flow (153 cms [5,420 cfs]; Table 2–5).

Since construction, berm notch topography has been surveyed four times: September 2007, April 2008, October 2008, and August 2009. For this report, topographic change at the notches was estimated for the period of April 2008 through August 2009 (Figures 2–14, 2–15). This is a similar analysis to what was performed at other rehabilitation sites (e.g., Valdor Gulch, Lewiston Cableway). The isopach maps show topographic changes at each notch between survey periods. The notches show a general trend of greater scour and redeposition at the upstream end of the site, which decreases toward the downstream end. Peak flow at the site between April 2008 and October 2008 was 203 cms (7,160 cfs), resulting from the WY 2008 spring release and tributary accretion, and peak flow at the site between October 2008 and August 2009 was approximately 153 cms (5,420 cfs), resulting from the WY 2009 spring release.

Lateral changes in notch area were also evaluated to see if the notches were growing outward. Notch area changes were estimated by calculating the difference in planform area between surveys below the 57-cms (2,000-cfs) water surface elevation. Although the area below the this elevation does not encompass the total notch area, it is an area common to all surveys for all notches and thereby allows for a direct comparison to be made. The total notch area at Vitzthum Gulch has increased by 45 m^2 (484.4 sq. ft), or approximately a 0.65-percent increase from the original constructed area (Table 2–6).

Cumulative changes for both volume and area are shown graphically (Figure 2–16). Since the notches were constructed, a 13 percent loss of original volume and a slight increase in area below the 57-cms (2,000-cfs) water surface elevation suggests that material has eroded from the notch walls and that either (a) the eroded material has settled in the bottom of the notches, or (b) the eroded material has been removed by flows and new material has been supplied to fill the notches as mainstem flows recede.

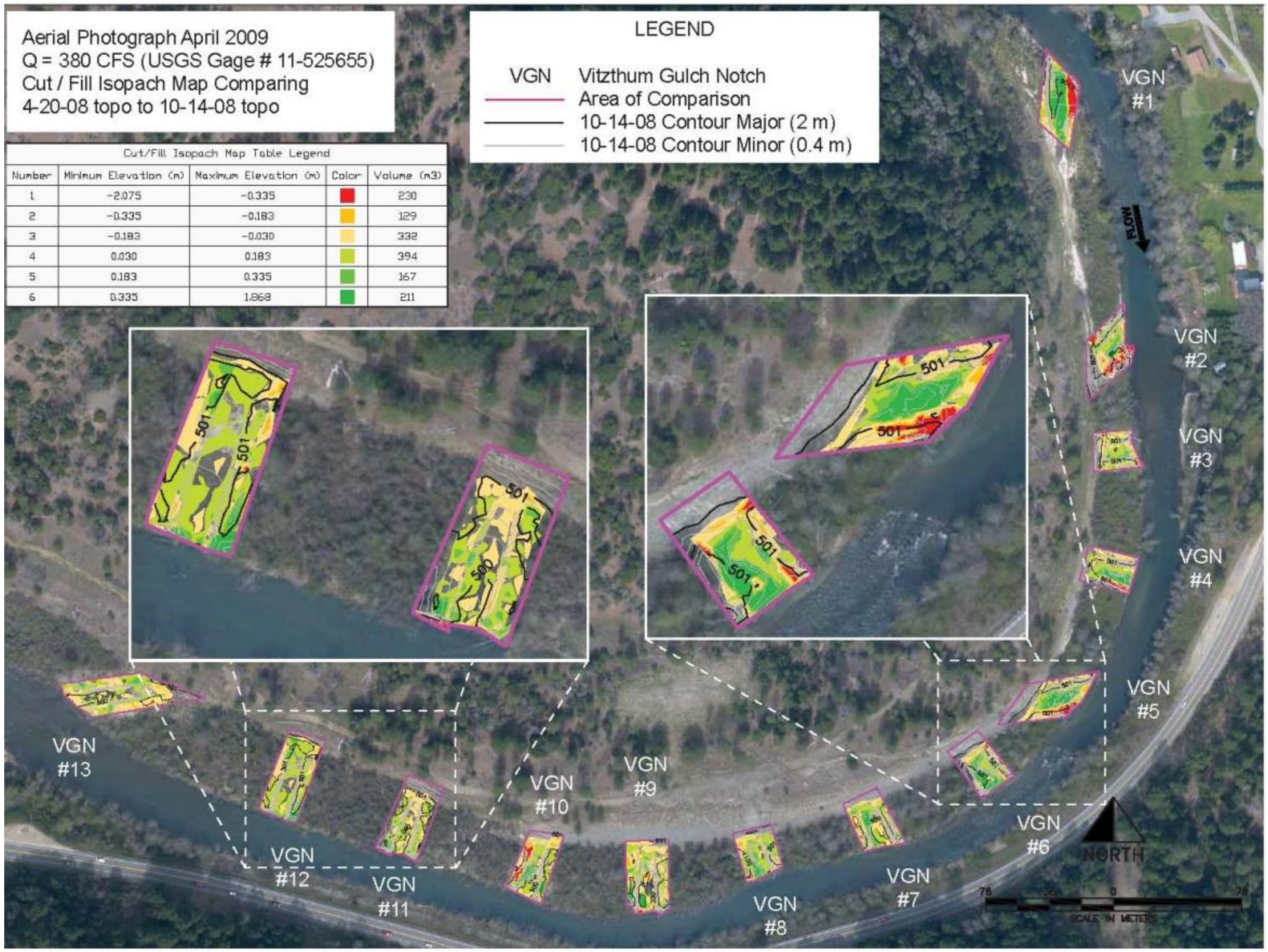


Figure 2–14. Vitzthum Gulch WY 2008 pre- and post-ROD isopach map release comparison.

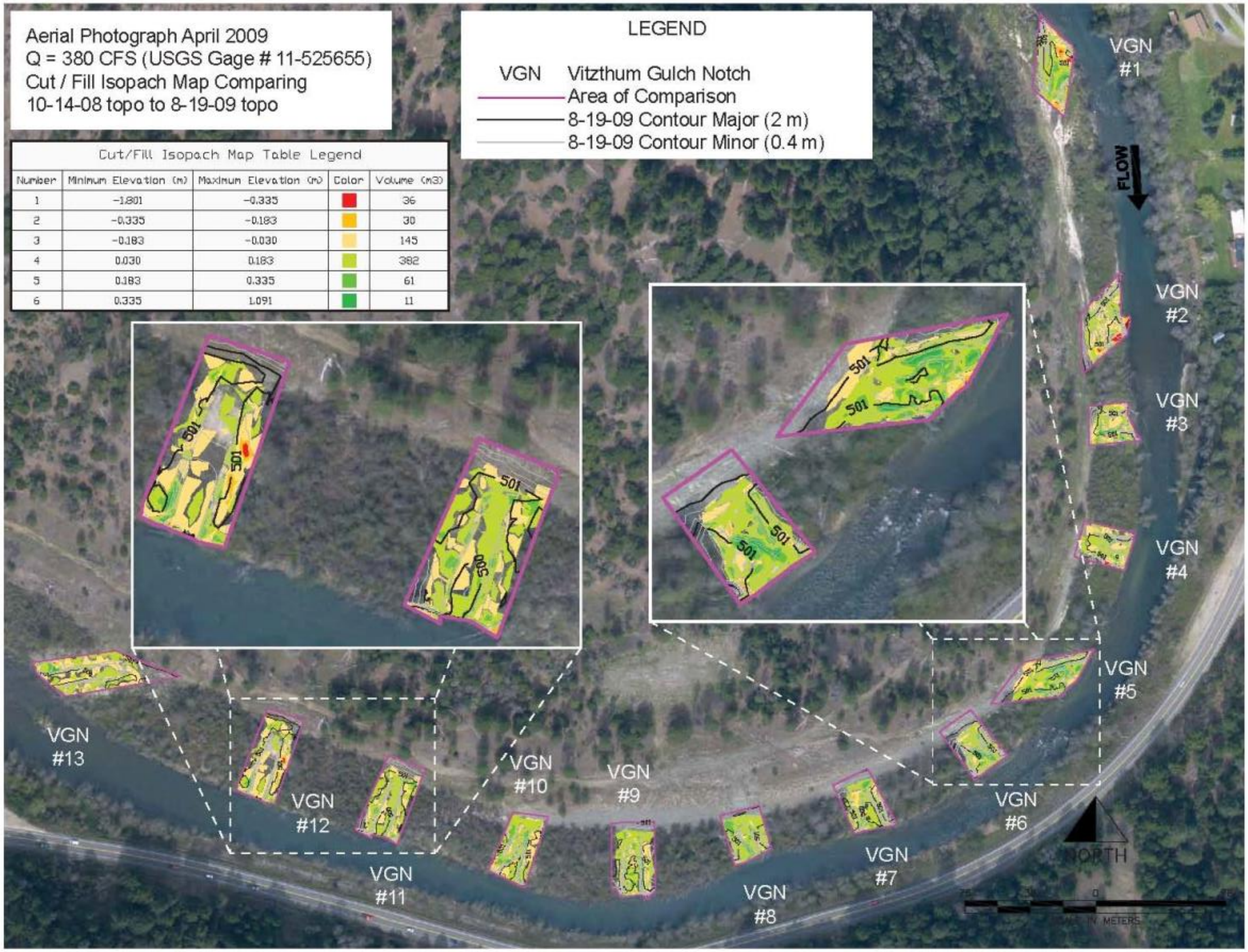


Figure 2–15. Vitzthum Gulch WY 2009 pre- and post-winter flood and ROD isopach map release comparison.

Table 2–6. Summary of Changes in Total Area of All Vitzthum Gulch Berm Notches Following Notch Topographic Surveys

Date	Notch Area Below 57 cms (2,000 cfs) Water Surface Elevation (m^2)	Peak Streamflow Between Surveys	Change in Notch Area (All Notches, m^2)	Percent Change in Notch Area (All Notches)
Apr 2008 (as-built)	6,839	n/a	n/a	n/a
Oct 2008	7,004	203 cms (7,160 cfs) May 9, 2008	+165	+2.4
Aug 2009	6,884	153 cms (5,420 cfs) May 5, 2009	–120	–1.7
		TOTAL	–45	0.65

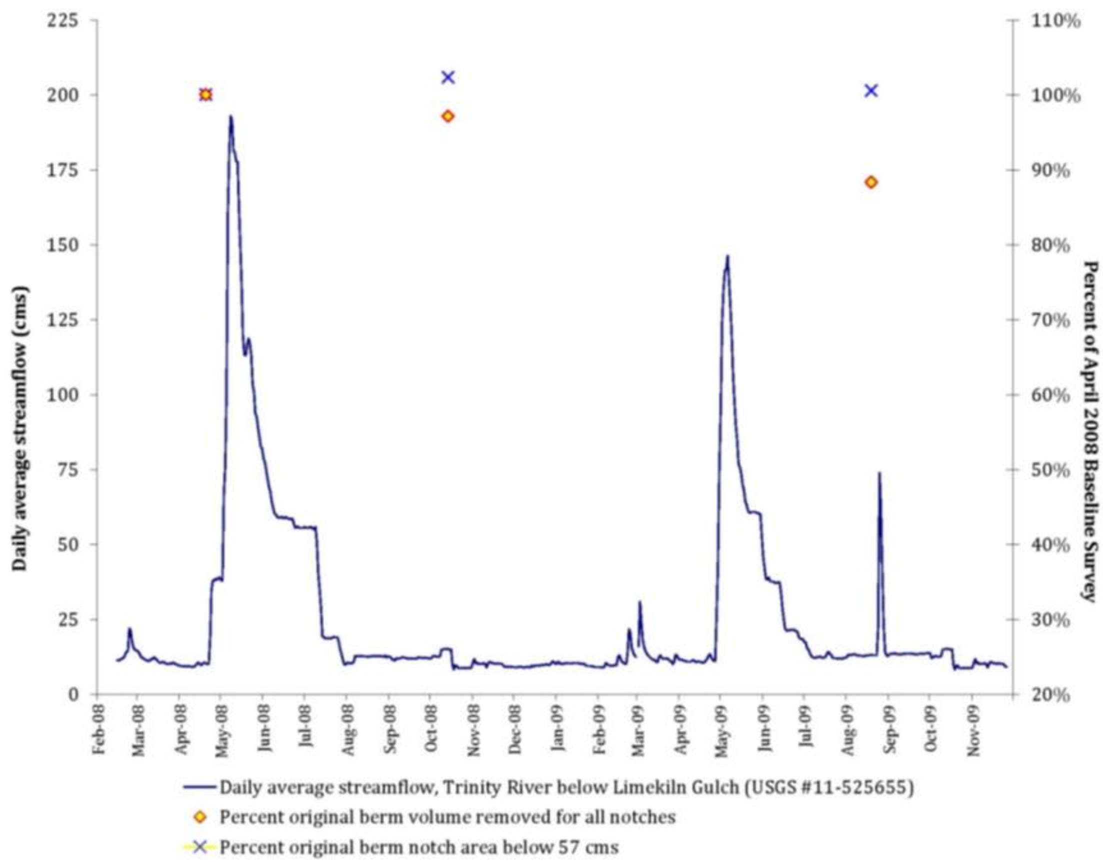


Figure 2–16. Vitzthum Gulch cumulative change in berm notch total volume and total area, April 2008 to August 2009.

The design expectation for this site was for the notches to facilitate berm erosion and ultimately lead to berm removal. Since construction, the high-flow events in 2008 and 2009 (approximately 184 cms [6,500 cfs] for seven days in 2008 and the 153 cms [5,420 cfs] for a single-day peak flow in 2009) have caused minor adjustment of notch area (>1%) and notch filling (13% net aggradation) but have been generally too low to generate the anticipated inter- and intra-notch erosion. Larger flows may be capable of creating greater change, but will likely only occur during the next Wet or Extremely Wet WY release.

2.3.6.2. Vitzthum Gulch Geomorphic Discussion

Two priority questions have been asked for Vitzthum Gulch. *Priority Question G–2* asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features; and *Priority Question G–7* asks if berm punching destabilizes the berm enough such that subsequent high-flows are able to cause additional berm removal. Site construction and high flows have not removed the berms, and the notches have remained in generally the same configuration as when they were constructed. These results most likely are due to the relatively low-magnitude flows at the site since its construction in winter 2007, which have not been large enough to remove the riparian vegetation between the berms as intended.

Field observations indicate that the notches appear relatively unchanged. Topographic surveys detected more subtle lateral and vertical changes within each notch, which can provide insight into how the notches have performed so far. The isopach maps (figures 2–14, 2–15) show how the berm notches have changed in response to flows, where some portions of each notch have scoured, and where other portions of each notch have filled. The total notch volume at Vitzthum Gulch has been reduced (filled) by 325 m^3 (11,477 ft^3) of sediment, or approximately a 13-percent reduction of the original cut volume (Table 2–7).

Table 2–7. Summary of Changes in Total Volume of all Vitzthum Gulch Berm Notches Following Notch Topographic Surveys. Volumes below are compared to the as-built total notch cut volume of 2,502 m^3.

Date	Scour Volume (m^3)	Fill Volume (m^3)	New Volume of All Notches (m^3)	Change in Notch Volume (All Notches, m^3)	Percent Change in Notch Volume (All Notches)	Peak Streamflow Between Surveys (Trinity River at Limekiln Gulch)
Oct 2008	690	772	2,421	+81	–3.26 (Apr 2008 to Oct 2008)	203 cms (7,160 cfs) May 9, 2008
Aug 2009	211	454	2,177	+244	–10.04 (Oct 2008 to Aug 2009)	153 cms (5,420 cfs) May 5, 2009
TOTAL	901	1,226	2,177	+325	–12.98 (Apr 2008 to Aug 2009)	

2.3.7. Bucktail and Dark Gulch

Specific geomorphic monitoring activities at the Bucktail–Dark Gulch site included planform topographic surveys, cross section surveys at six cross sections: 1821+30, 1789+30, 1785+70, 1781+10, 1779+90, and 1771+90), and bed mobility monitoring (Figure A–21, A–22). Monitoring occurred in response to the spring release peak flow (131 cms [4,630 cfs]; Table 2–5). Monitoring results are compared to Dry WY TRFE objectives.

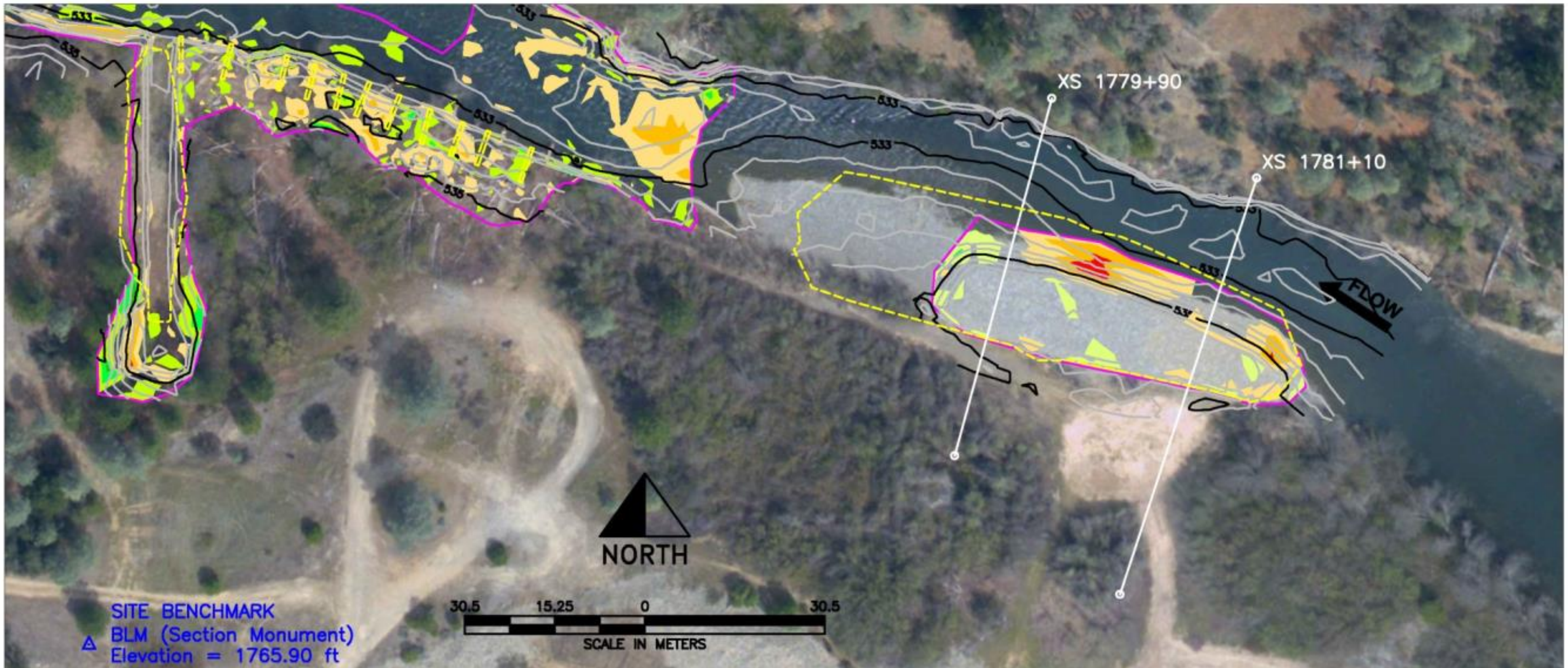
2.3.7.1. Planform topography

Topography was surveyed along the left bank pre- and post-spring release to:

1. Evaluate changes at the constructed coarse sediment recruitment pile (assumed scour) and in the reach immediately downstream (assumed deposition),
2. Look at the expected effects of root wads placed during construction on local scour, and
3. Evaluate changes in-channel radius of curvature, sinuosity, and alternate bar formation/maintenance (Figures 2–17, 2–18).

On the coarse sediment recruitment pile, the isopachs show scour occurred mainly along the bar flank (between the top of the constructed bar and the low-flow edge) from the upstream end of the bar to approximately cross section 1779+90, with the deepest scour exceeding 0.38 m (1.25 ft) between cross sections 1779+90 and 1781+10. Minor aggradation occurred at isolated areas on the bar surface and on the downstream end of a mid-bar topographic break where the constructed bar loses elevation and transitions to a lower gravel bar surface, just downstream of cross section 1779+90.

Downstream of the coarse sediment recruitment pile, topographic surveys concentrated on the left bank between the top of the berm and the low-flow edge, with the exception of a small section of the main channel that was surveyed between the right and left bank just downstream of the coarse sediment recruitment pile (Figure 2–17). Downstream of the coarse sediment recruitment pile, the isopach map shows variable scour and aggradation up to 0.38 m (1.25 ft) along the left bank. As the channel bends to the left and continues around the downstream bend, the isopach map shows a pattern of alternating scour and aggradation up to 0.38 m (1.25 ft) along the left bank, with a few small localized areas where scour depths exceeded 0.38 m (1.25 ft). This pattern is likely a result of the root wads placed during construction, which were designed to trap coarse sediments and facilitate bar formation. Although localized scour was measured around the root wads, the 127-cms (4,500-cfs) release did not mobilize and deposit enough sediment from the recruitment pile to begin building a bar.



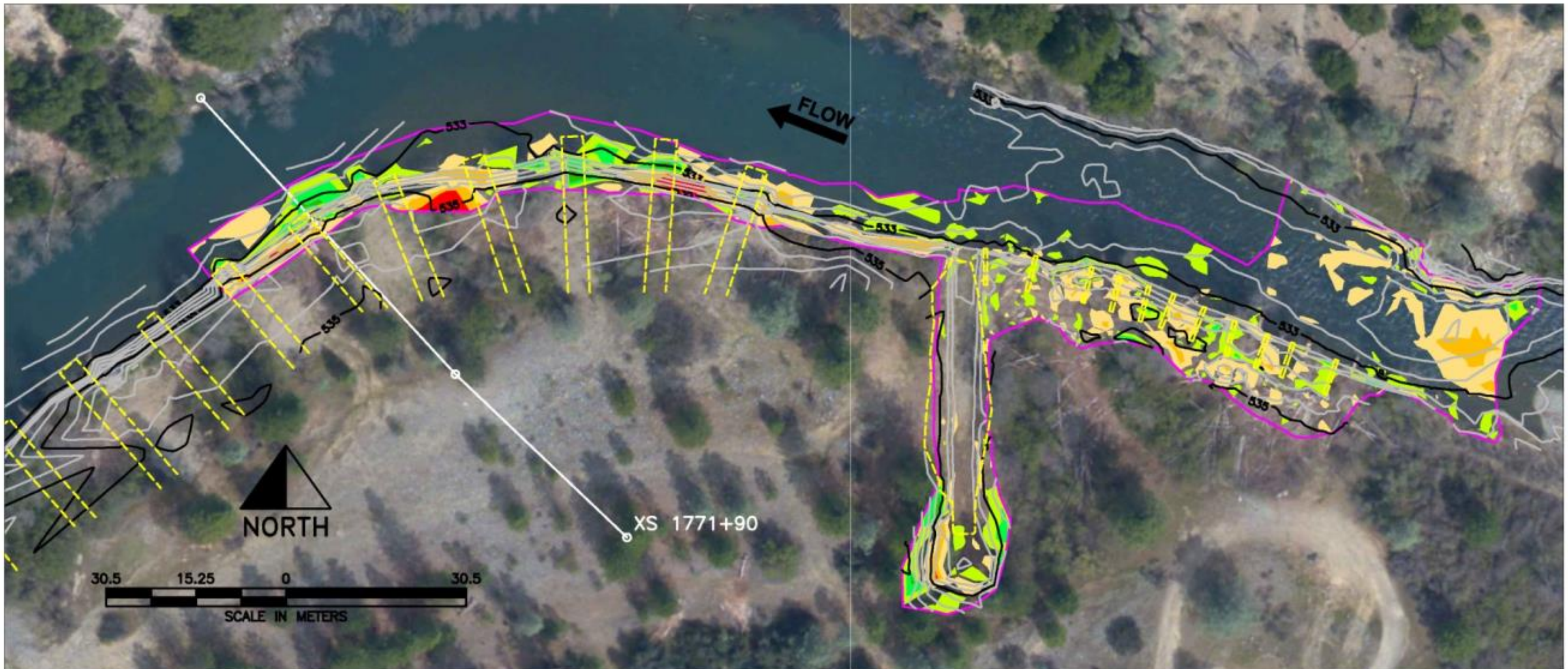
LEGEND
2008 Construction Boundary
Area of Cut/Fill Analysis
8–3–09 Minor Contours (0.4 m)
8–3–09 Major Contours (2 m)
Site Benchmarks
2009 Monitoring Cross Sections

Aerial Photograph April 2009
Q = 8 cms (USGS Gage # 11–525500)

Cut/Fill Isopach Map Table Legend					
Number	Minimum Elevation (m)	Maximum Elevation (m)	Color	Area (m^2)	Volume (m3)
1	–0.982	–0.381	red	17	1
2	–0.381	–0.229	orange	71	7
3	–0.229	–0.076	light orange	182	25
4	0.076	0.229	light green	111	4
5	0.229	0.366	green	2	0

Cut/Fill between –0.076 m and 0.076 m assumes no change and is not shown.

Figure 2–17. Bucktail pre- and post-ROD isopach map release comparison (upstream portion).



LEGEND
2008 Construction Boundary
Area of Cut/Fill Analysis
8-3-09 Minor Contours (0.4 meters)
8-3-09 Major Contours (2 meters)
Site Benchmarks
2009 Monitoring Cross Sections

Aerial Photograph April 2009
Q = 8 cms (USGS Gage # 11-525500)

Cut/Fill Isopach Map Table Legend

Number	Minimum Elevation (m)	Maximum Elevation (m)	Color	Area (m^2)	Volume (m3)
1	-0.817	-0.381		46	4
2	-0.381	-0.229		174	17
3	-0.229	-0.076		744	77
4	0.076	0.229		524	44
5	0.229	0.381		100	8
6	0.381	0.701		16	1

Cut/Fill between -0.076 m and 0.076 m assumes no change and is not shown.

Figure 2–18. Bucktail pre- and post-ROD isopach map release comparison (downstream portion).

2.3.7.2. Cross Section Topography

Overall, WY 2009 topographic change varied by cross section at this site; some cross sections show virtually no change (e.g., cross section 1771+90), whereas others show some significant changes (e.g., cross section 1785+70; Appendix B). More specific descriptions of the changes seen on each cross section are:

- Cross section 1771+90: Little to no topographic change occurred on this cross section following the spring release. At station 97.8, a single topographic high point was surveyed in March 2009 that was not present in the July 2009 survey. A review of the survey notes did not reveal any unusual feature, so this feature may be an anomaly.
- Cross section 1779+90: Topographic change on this cross section was also minimal. Cross section 1779+90 shows small variations at the channel thalweg (at approximately station 53.3) and a developing scour channel on the back edge of the coarse sediment recruitment pile from station 14.3 to station 18.0. In addition, the cross section plot shows slight aggradation up to 0.12 m (4.7 in) across the top of the coarse sediment recruitment pile between station 22.9 and 31.7.
- Cross section 1781+10: Most of the topographic changes on this cross section were between the left bank pin and the landward edge of the coarse sediment recruitment pile. The plotted cross section shows uniform aggradation of approximately 0.06–0.09 m (2.4–3.5 in), with a subtle scouring (possibly an extension of the developing scour channel) between station 32.0 and 36.6. Also similar to cross section 1779+90 is the slight aggradation up to 0.12 m (4.7 in) across the top of the coarse sediment recruitment pile between station 38.1 to 46.4.
- Cross section 1785+70: This cross section shows the most significant topographic change at the site resulting from the WY 2009 spring release. Up to 0.3 m (1 ft) of main-channel aggradation occurred between stations 45.4 and 56.4. Additional aggradation (up to approximately 0.12 m [4.7 in]) can also be seen across the bottom of the constructed side channel.
- Cross section 1789+30: The most notable topographic changes on this cross section were a small area of scour along the right bank of the low-flow main-channel (approximately 0.12 m (4.7 in) from station 54.9 to 57.3) and some deposition on the top of the right bank at station 64.0. Adjustments were made at station 64.0 to correct for an apparent field survey error to complete our interpretation.
- Cross section 1821+30: This cross section was installed and surveyed in August 2009 across the constructed surface at Dark Gulch. Pre-spring release topography was not surveyed and therefore the pre- and post-spring release topography cannot be compared.

2.3.7.3. Bed Mobility Monitoring

Bed mobility was monitored using marked rock sets at cross sections 1779+90 and 1781+10 (Figures 2–19, 2–20). The marked rock set at cross section 1779+90 was placed along the streamward edge of the constructed coarse sediment recruitment pile and across the low-flow channel almost to the thalweg, from station 31.1 to 51.8 (*n* = 18 rock groups set over a single textural facies). All D_{84} and D_{50} rocks from station 37.2 to 51.8 were mobilized by the 131-cms (4,630-cfs) spring release (72% of the total marked rock set). The five landward-most D_{84} and D_{50} pairs remained in place.

As was done at cross section 1779+90, the marked rock set at cross section 1781+10 was placed across the top surface of the constructed coarse sediment recruitment pile and continued across the low-flow channel almost to the thalweg, from station 40.2 to 61.0 (*n* = 18 rock groups set over a single textural facies). When the site was revisited to document mobility from the spring release, all rocks were missing from the cross section, with the exception of a few that were grouped into a single pile on the constructed coarse sediment pile surface (suggesting vandalism); however, because this marked rock set was on the same surface and close to the set on cross section 1779+90, it is likely that these rocks were also mobilized by the spring release, like those on cross section 1779+90. It is unknown if the rocks were tampered with before or after the spring release. Therefore the monitoring results on this cross section are unreliable.

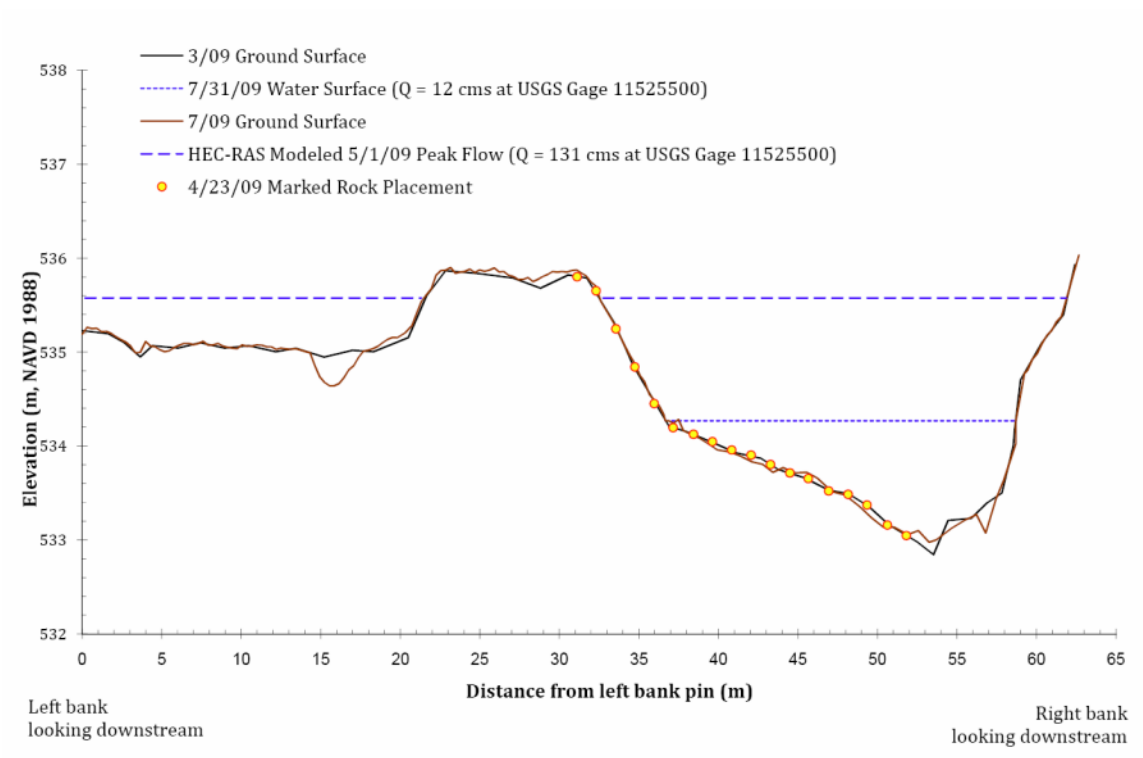


Figure 2–19. Bucktail cross section 1779+90.

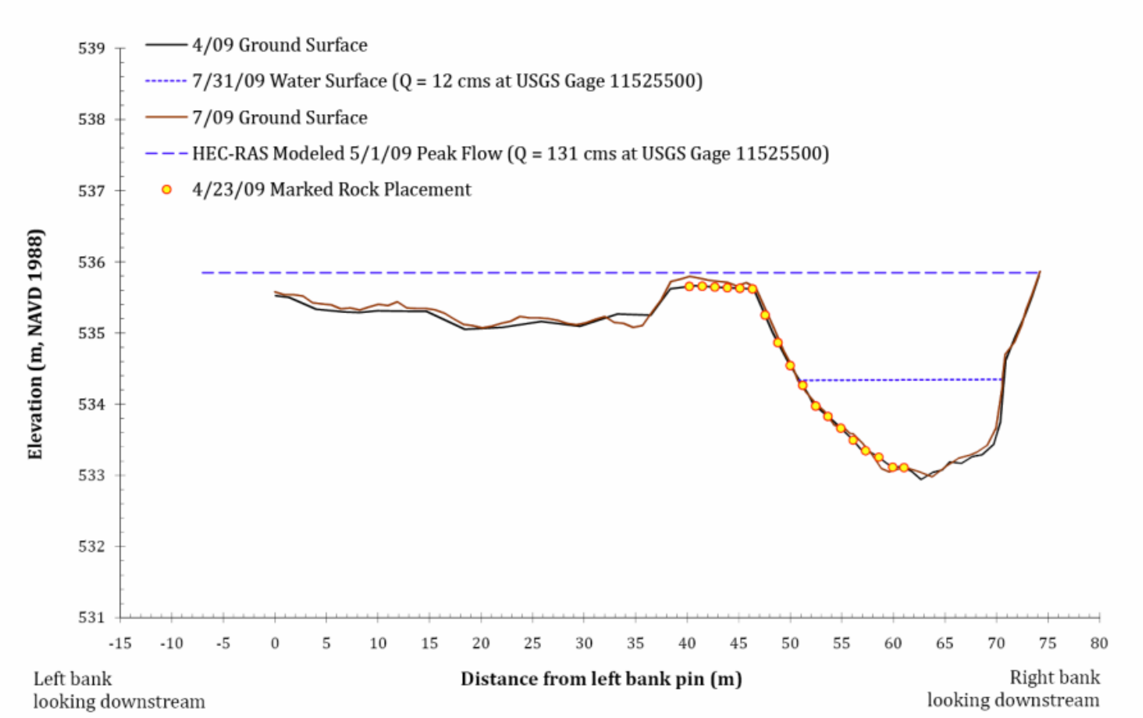


Figure 2–20. Bucktail cross section 1781+10.

2.3.7.4. Bucktail–Dark Gulch Geomorphic Discussion

Four geomorphic priority questions have been asked for the Dark Gulch/Bucktail site. *Priority Question G–1* asks whether process-based TRFE geomorphic management targets are being met by annual releases. The TRFE Dry WY peak flow monitoring geomorphic objective is to mobilize rocks as large as D_{84} on bar flank features. Bed mobility results from the 131-cms (4,630-cfs) spring release peak flow show that most of the D_{84} rocks on the bar flank moved (D_{84} mobility was 72%), suggesting that the Dry WY management target was met. However, rocks higher up on the slope of the constructed coarse sediment recruitment pile did not move. The bed mobility results are supported by the isopach map (Figure 2–17); however, between the cross sections, the isopach map shows net scour depths in excess of 0.38 m (1.24 ft), suggesting that all particle sizes on this portion of the bar flank were mobilized by the spring release. These combined results suggest that the WY 2009 spring release likely met TRFE geomorphic management targets for a portion (but not all) of the coarse sediment recruitment pile.

Priority Question G–2 asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features. To achieve alluvial complexity, treatments at this site included constructing the coarse sediment recruitment pile, adding root wads to the left bank downstream of the sediment recruitment pile, and flow management. Although some bed mobility was measured at the coarse sediment recruitment pile, topographic changes from our experiments show the volume of material removed from the bar and from the downstream root wads by local scouring was not enough to create the sediment recruitment and bar formation as intended by the channel design. The flow experienced (i.e., 127 cms [4,500 cfs]) may be too low to cause these anticipated changes.

Priority Question G–3 asks whether channel migration can be encouraged by only removing vegetation/berms on opposite banks in advance of high-flow releases or natural floods (i.e., without putting anything within the active channel to force thalweg adjustment). The vegetation removal at this site was different from that at other rehabilitation sites: vegetation notches were cut into the berm but the bulk of the adjacent vegetation was left in place, and the notched areas were backfilled with a combination of coarse sediment and large wood. Monitoring was performed on the left bank, which is where the topographic mapping documented bed scour and aggradation (not on the opposite bank, as this Priority Question asks). The cross-section surveys do not suggest migration is occurring. Results from the planform topographic mapping show that some localized scour and fill occurred along the left bank at the downstream end of the site during the WY 2009 spring release, but no migration. It was originally expected that channel migration could occur along the left bank (because the right bank is bedrock), but additional root wads were added during site construction and compromised this expectation.

Priority Question G–4 asks if design meander wavelengths and radii of curvature are maintained with high-flow releases, natural floods, and sediment regime, and whether these effects exert themselves upstream and downstream of the constructed area or enhance local channel migration of the mainstem Trinity River. The answer given for Priority Question G–3 also applies here. This experiment was likewise compromised by the root wads; if the recruitment pile does supply sediment to the left bank during future high-flow events, some meander development is expected. However, if the recruitment pile does not deliver coarse sediment to this bank and the root wads remain in place, lateral migration or changes in radius of curvature or wavelength is not expected.

2.3.8. Hoadley Gulch

Specific geomorphic monitoring activities at Hoadley Gulch included topographic surveys and bed mobility monitoring. One cross section (1990+50; Figure A–24) was monitored, in response to the spring release peak flow (131 cms [4,630 cfs]; Table 2–5).

2.3.8.1. Longitudinal Profile Through Side Channel

As a part of site construction, a side channel was built along the right bank. To help evaluate whether the side channel is functioning as it was intended, longitudinal profile surveys were conducted before and after the spring release to evaluate: (1) if the side channel entrance is staying open and (2) if the side channel is increasing in complexity (Figure 2–21). The side channel has two entrances, which merge at longitudinal profile station 5+79. Both entrances remained open following the 2009 spring release. The longitudinal profile through the upstream side-channel entrance shows almost 0.3 m (1.0 ft) of scour (lowering the hydraulic control) at station 8+50, and the downstream side-channel entrance at approximately station 7+60 also shows lowering, which continues downstream for approximately 12 m (40 ft). In planform, the location of the thalweg in the April 2009 and the July 2009 surveys has changed position along most of the side channel, suggesting the channel is adjusting to its new construction.

Based on field observations and from the profile in Figure 2–22, the WY 2009 spring release brought about many changes in side-channel thalweg location and elevation. Fluctuating gains and losses in the side-channel thalweg elevation can be seen for the entire side-channel length; however, the most notable elevation changes include as much as approximately 0.6 m (2.0 ft) of scour between stations 2+00 and 2+50, and as much as approximately 0.45 m (1.48 ft) of aggradation between stations 0+50 and 1+00. Field observations noted that the areas of scour are commonly associated with wood structures placed during construction, and areas that aggraded commonly occurred where vegetation was left in place during construction.

2.3.8.2. Cross Section Topography

Surveys of cross section 1990+50 in April 2009 and again in November 2009 documented topographic changes resulting from the spring release (Appendix B). Overall, WY 2009 topographic change at cross section 1990+50 shows approximately 0.09 m (3.54 in) of aggradation in the thalweg (between station 15.2 and station 18.9) and some slight erosion of the constructed coarse sediment recruitment pile at the low-flow edge (between station 26.2 and station 33.0). In addition, side-channel aggradation as great as 0.3 m (1.0 ft) occurred between station 47.5 and station 52.7. On this cross section, the greatest topographic change occurred in the side channel, and there was very little net topographic change across the constructed bar as a result of the WY 2009 spring release (Figure 2–22).

2.3.8.3. Bed Mobility Monitoring

Bed mobility was monitored using a marked rock set (n = 14 rocks total; Figure 2–22). The marked rocks were installed in April 2009 and then monitored in June 2009 following the spring release. Rock placement extended across the top of the coarse sediment recruitment pile and into the low-flow channel. This rock set was vandalized (many rocks had been thrown upstream of the cross section), and therefore results cannot be used.

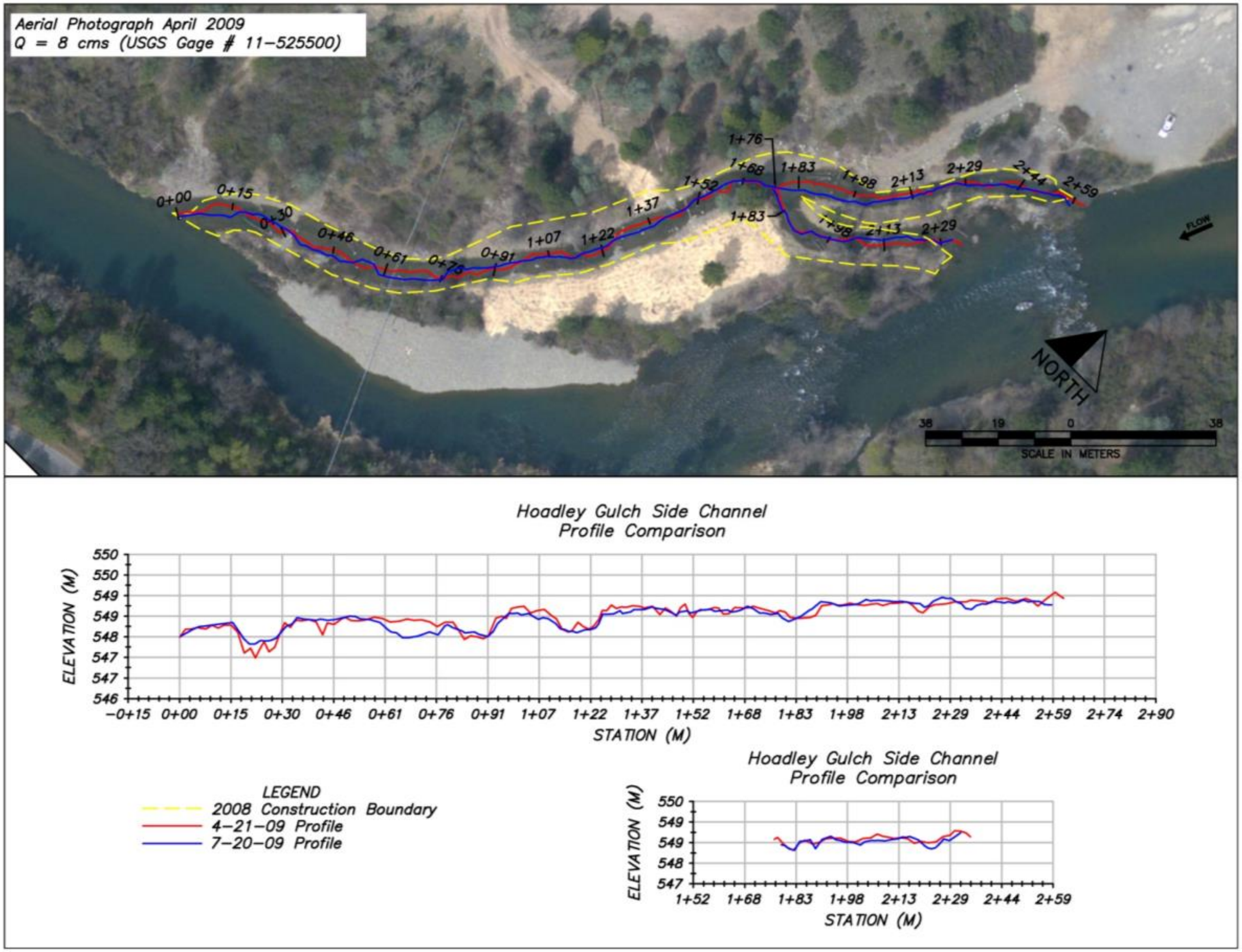


Figure 2–21. Hoadley Gulch side channel profile comparison.

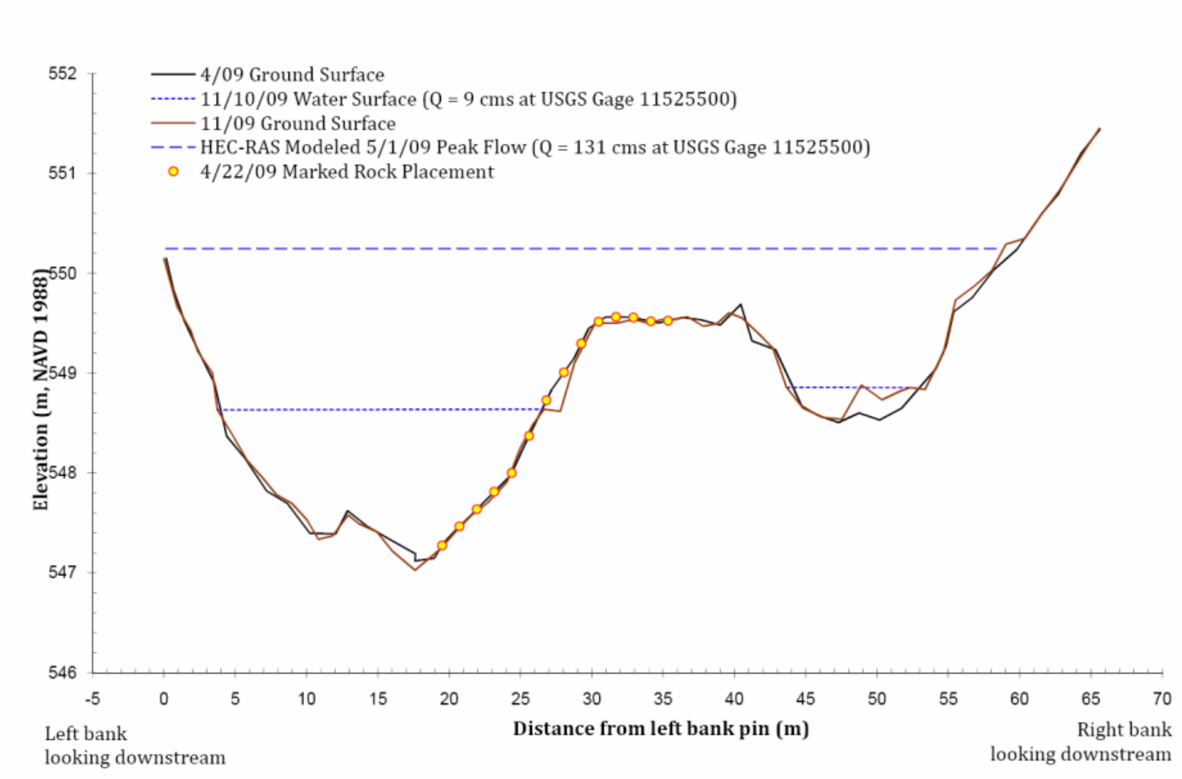


Figure 2–22. Hoadley Gulch cross section 1990+50.

2.3.8.4. Hoadley Gulch Geomorphic Discussion

Three geomorphic priority questions were identified based on the site construction. *Priority Question G–1* asks whether process-based TRFE geomorphic management targets are being met by annual releases. This question cannot be directly assessed because the marked rock set was vandalized and bed mobility results are unknown. In lieu of these results, cross-section topography was reviewed to see if net topographic changes (i.e., net scour) show where marked rocks would have mobilized. Based on the pre-release and post-release topography, net scour occurred between stations 26.2 and 32.9, suggesting marked rocks placed within these stations may have mobilized. Of the six D_{84} and D_{50} pairs within this stationing, four are on the constructed bar flank and two are on the bar surface (Figure 2–22). It is possible that a portion of the bar flank was mobilized, and TRFE management targets for a Dry WY may have been met.

Priority Question G–2 asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features. The single cross section used at this site shows no significant net topographic change, suggesting the bar is self-maintaining so far. New alluvial features were not observed at the site.

Priority Question G–6 asks if side channels are maintaining themselves with high-flow releases and natural floods. The longitudinal profile surveys suggest that the side channel at this site is maintaining itself; the side-channel entrances have remained open and have shown some scouring (suggesting flow entrance thresholds may now be lower), and the side-channel thalweg has shifted location and has shown scour and fill as great as about 0.6 m (2.0 ft). These adjustments are likely due in part to the site being relatively new; its surfaces are more erosion-prone than those at older rehabilitation sites that have experienced more floods and greater revegetation. Future Dry WY releases may not cause as much change as observed in WY 2009.

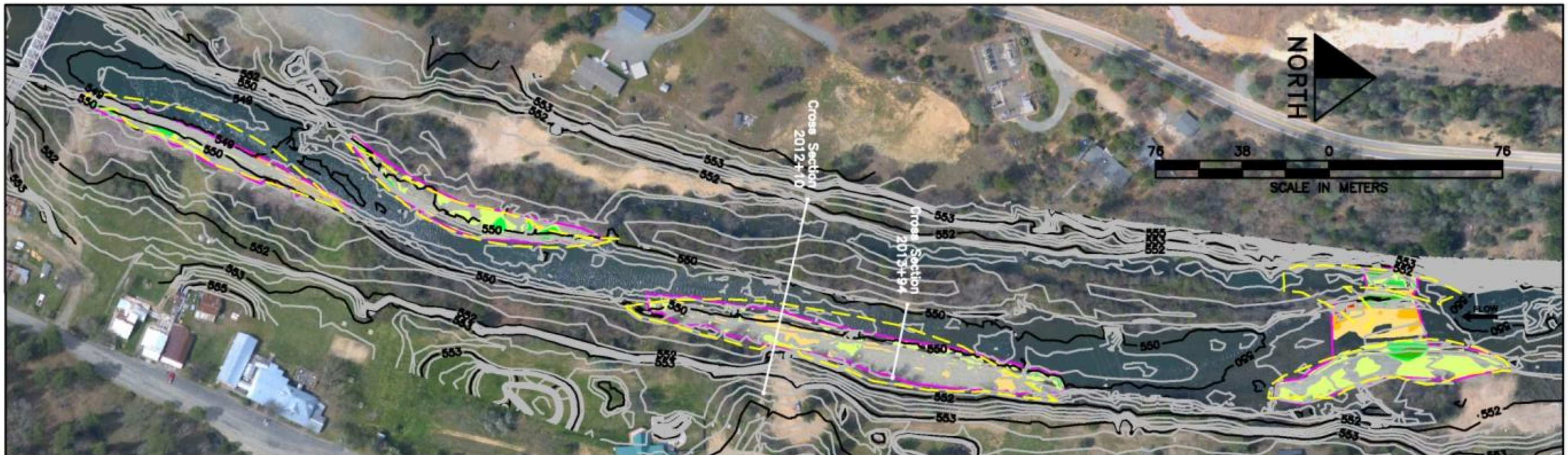
2.3.9. Lewiston Cableway

Specific geomorphic monitoring activities at the Lewiston Cableway site included topographic surveys and bed mobility monitoring. Two cross sections were monitored (2013+94 and 2012+10; Figure A–26), in response to the spring release peak flow (131 cms [4,630 cfs], Table 2–5). Monitoring results are compared to Dry WY TRFE objectives.

2.3.9.1. Planform Topography

Topography was surveyed pre- and post-spring release to evaluate changes in the constructed coarse sediment recruitment piles (scour) and in the reach immediately downstream (deposition), and also to evaluate resulting changes in the in-channel radius of curvature, sinuosity, and alternate bar formation/maintenance (Figure 2–23). Surveyed topography was limited to the areas that changed since the previous ground-surface survey, including recently constructed points bars and the main wetted channel. The exception was a small portion of the main channel at the upstream end of the site. The topography surveyed during the IHAP monitoring was combined with photogrammetry, LiDAR, and Total Station survey data to construct the final topography used in the analysis. Overall bar topographic changes were:

- At the upstream end of the site, the main channel was scoured, the left bank point bar aggraded, and the right bank side channel entrance also aggraded. Scour and aggradation in this portion of the site were as much as 0.38 m (1.25 ft).
- The point bar at the USGS cableway, which includes both monitoring cross sections, showed variable scour and aggradation as great as 0.23 m (0.75 ft). These results are corroborated by the cross-section topography and bed mobility experiments (described below).
- The downstream right bank point bar showed aggradation as great as 0.38 m (1.25 ft) with comparatively very little scour.
- The downstream left bank point bar (just upstream of the Old Lewiston Bridge) showed scour on the upstream half of the bar, locally greater than 0.38 m (1.25 ft) deep, and aggradation on the downstream end of the bar as great as 0.38 m (1.25 ft).



LEGEND
- 2008 Construction Boundary
- Cut/Fill Area of Analysis
- 7–2009 Minor Contours (0.4 meters)
- 7–2009 Major Contours (2 meters)
- 2009 Monitoring Cross Sections

Aerial Photograph April 2009
Q = 8 cms (USGS Gage # 11–525500)

Cut/Fill Isopach Map Table Legend

Number	Minimum Elevation (m)	Maximum Elevation (m)	Color	Area (m2)	Volume (m3)
1	–0.757	–0.381	red	71	7
2	–0.381	–0.229	orange	231	24
3	–0.229	–0.076	light orange	823	94
4	0.076	0.229	light green	2046	192
5	0.229	0.381	green	343	51
6	0.381	1.128	dark green	194	23

Cut/Fill between –0.76 m and 0.076 m assumes no change and is not shown.

Figure 2–23. Lewiston Cableway pre- and4 post-ROD isopach map release comparison.

2.3.9.2. Cross-Section Topography

Overall WY 2009 topographic change varies by cross section at this site (Appendix B). Cross section 2012+10 shows distinct bed lowering at the coarse sediment recruitment pile and in the thalweg, creating a slight net increase in channel cross-sectional area (and a decrease of in-channel confinement). Conversely, cross section 2013+14 shows more subtle changes with no apparent net change in cross-sectional area or confinement. More specific descriptions of the changes seen on each cross section are:

- Cross section 2012+10: Topographic differences between April 2009 and August 2009 show main-channel scour at the constructed coarse sediment recruitment pile and at the channel thalweg. Scour at the coarse sediment pile occurred between station 26.5 and 36.6, with the most pronounced scour (as much as 0.3 m [1.0 ft]) between station 26.5 and 32.6. Net scour of as much as 0.09 m (3.54 in) occurred in the thalweg approximately between station 38.1 and 44.1. The constructed side channel shows slight aggradation at the 12-cms (435-cfs) water surface (approximately 0.03 m [1.18 in]).
- Cross section 2013+14: Topographic change on this cross section was variable. The cross-section plots show net aggradation across the constructed coarse sediment recruitment pile (from station 0.9 to approximately station 17.7), followed by net scour (from approximately station 17.6 to station 29.9). Aggradation ranged up to approximately 0.09 m (3.54 in) and net scour ranged up to approximately 0.06 m (2.36 in).

2.3.9.3. Bed Mobility Monitoring

Bed mobility was monitored using marked rock sets at both monitoring cross sections (Figure 2–24, 2–25). Marked rock sets were installed in April 2009 and then monitored in June 2009 following the spring release (Appendix C).

The marked rock set at cross section 2012+10 was placed across the top surface of the constructed coarse sediment recruitment pile and across almost the entire width of the low-flow channel (*n* = 20 rock groups set; Figure 2–24). All D_{84} and D_{50} rocks on this cross section were gone when the site was inventoried in June 2009 and were not found downstream. Two interpretations were made in the field: (1) all rocks moved as a result of the spring release peak flow, or (2) the rock set was vandalized. Foot traffic at the site is common, which makes this cross section a risky location at which to use marked rock experiments. However, after reviewing the results from the cross-section survey, which showed significant erosion of the coarse sediment recruitment pile, it seems more likely that the results recorded in the field are genuine and the spring release mobilized all D_{84} and D_{50} rocks on the cross section.

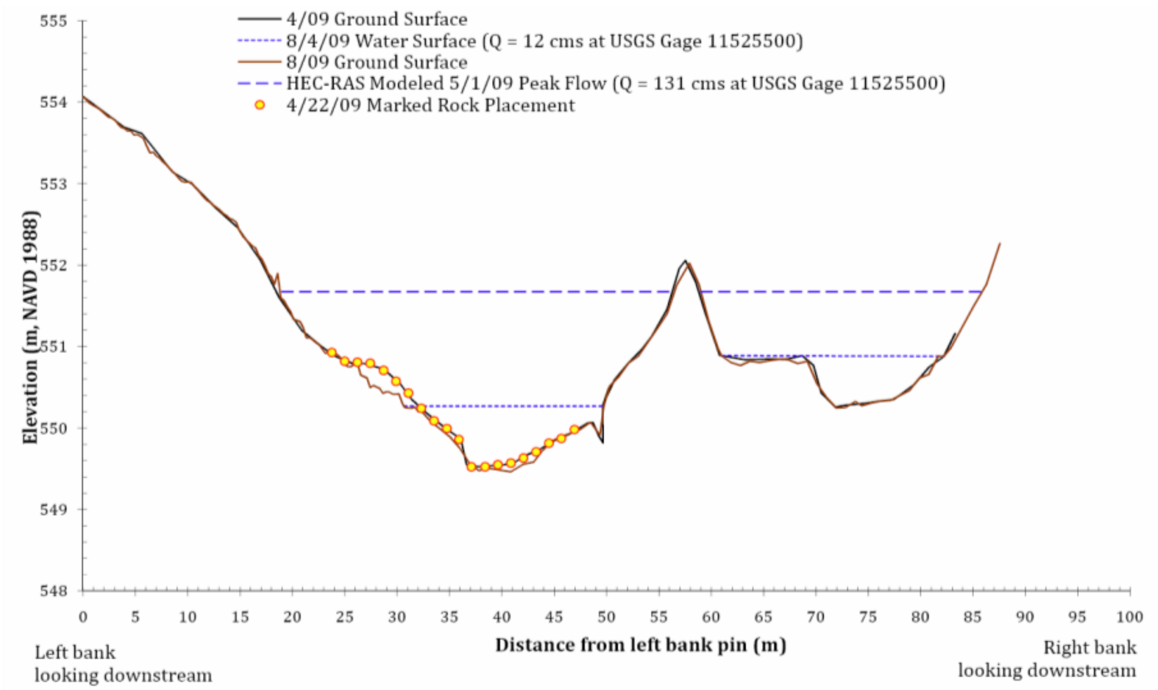


Figure 2–24. Lewiston Cableway cross section 2012+10.

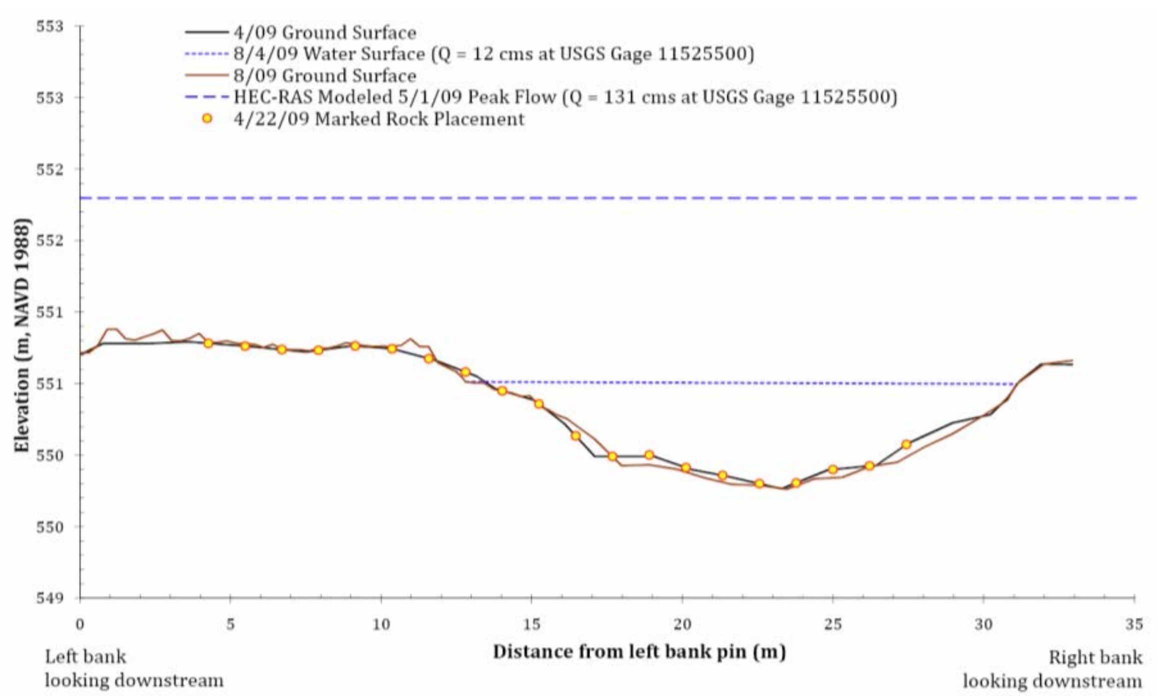


Figure 2–25. Lewiston Cableway cross section 2013+94.

The marked rocks at cross section 2031+14 were placed in a manner very similar to that used at cross section 2012+10: marked rocks were set across the top surface of the constructed coarse sediment recruitment pile and continued across the low-flow channel, past the thalweg, and up toward the right bank (n = 20 rock groups set; Figure 2–25). Mobility results show five D_{84} rocks and eight D_{50} rocks moved in response to the spring peak release (25% and 40%, respectively). D_{84} movement was irregular, with individual rocks having moved from individual stations between station 11.6 and 23.8. D_{50} movement was more uniform, with a single group of adjacent rocks between station 17.7 and 26.2 having moved.

2.3.9.4. Lewiston Cableway Geomorphic Discussion

Four geomorphic priority questions have been asked for the Lewiston Cableway site. *Priority Question G–1* asks whether process-based TRFE geomorphic management targets being met by annual releases. The TRFE Dry WY peak flow monitoring geomorphic objective is to mobilize the D_{84} on bar flank features. At both cross sections, the streamward edge of the constructed coarse sediment recruitment pile can be considered a bar flank. For this portion of the marked rock set, Dry WY bed mobility management targets were met on cross section 2012+10 (100% D_{84} mobility was achieved over the bar flank) but were only partially met on cross section 2013+94, where only three of seven D_{84} rocks (43%) moved.

Priority Question G–2 asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features. The point bars were constructed as coarse sediment recruitment piles and were built to over-confine the channel relative to the pre-construction low-flow channel geometry. Site construction also included removing boulder grade control structures (two at this site, at station 2015+00 and station 2019+50, and one just downstream of the Old Lewiston Bridge). Combined, these actions increased the hydraulic energy gradient through the site and likely facilitated some coarse sediment recruitment from the constructed bars. Following the spring release, the number and areal extent of alluvial features surveyed at the site remained the same, and scour and fill on these surfaces was generally minor such that their complexity was not significantly increased.

Priority Question G–3 asks whether channel migration can be encouraged by only removing vegetation/berms on opposite banks in advance of high-flow releases or natural floods (i.e., without putting anything within the active channel to force thalweg adjustment). The implementation design did not remove vegetation on the opposite banks, so this question is largely undetermined. While the bar creation should direct water towards the right bank, the existing vegetation would need to be undercut or toppled, neither of which occurred during the WY 2009 spring release. It may take larger releases to remove or topple the left bank vegetation (e.g., Wet or Extremely Wet WY releases).

Priority Question G–4 asks if design meander wavelengths and radii of curvature are maintained with high-flow releases, natural floods, and sediment regime, and whether these effects exert themselves upstream and downstream of the constructed area or enhance local channel migration of the mainstem Trinity River. Based on the results shown in Figure 2–23, little topographic change occurred on the upper left bank point bar. Similarly, the lower left bank point bar showed little overall change but some scouring was concentrated at the upstream end. Since bank erosion did not occur on the opposite banks (outside bends), no change in radius of curvature occurred; this will not happen until channel migration occurs.

2.3.10. Sven Olbertson

Specific geomorphic monitoring activities at the Sven Olbertson site included topographic surveys along two cross sections (Figure A–28). At this site, monitoring occurred in response to the spring release peak flow (131 cms or 4,630 cfs, measured at Lewiston (Table 2–5)).

2.3.10.1. Longitudinal Profile Through Side Channel

To determine whether the side channel is functioning as it was intended, longitudinal profile surveys were conducted before and after the spring release to evaluate (1) if the side channel entrance is staying open and (2) if the side channel is increasing in complexity (Figure 2–26). Based on field observations and the profile surveys, many changes in side-channel thalweg location and elevation occurred in response to the WY 2009 spring release. The primary entrance to the side channel is at the upstream end of the site at longitudinal profile station 15+46. The longitudinal profile surveys show some aggradation in the mainstem channel upstream of the entrance, but the entrance itself shows no change in elevation. The April 2009 and the July 2009 surveys show the thalweg has changed position along much of the side channel, most notably between stations 2+00 and 5+00 and between stations 7+00 and 9+00. Both of these sections show aggradation resulting from the spring release.

Downstream of the side channel entrance, fluctuations in side channel thalweg elevation (gains and losses) can be seen for the entire side channel length; however the most notable elevation changes include as much as approximately 1.2 m (3.9 ft) of aggradation between stations 7+00 and 8+00, as much as approximately 1.1 m (3.6 ft) of aggradation between stations 14+00 and 14+20, and as much as approximately 0.9 m (3.0 ft) of aggradation at the side channel entrance. Notable scour, as much as approximately 0.6 m (2.0 ft), can be seen between stations 5+00 and 5+30. Field observations noted that scour areas were commonly associated with bedrock boulders and large wood placed in the channel as part of construction. An existing bedrock ledge at Station 5+30 was slightly exposed during construction and became even more exposed following the spring release. This bedrock control reduces side-channel slope between Station 5+40 and Station 11+20, causing some deposition within the side channel. In addition, some of the constructed pools associated with large wood and boulder placements at the side channel entrance also filled as a result of the spring release.

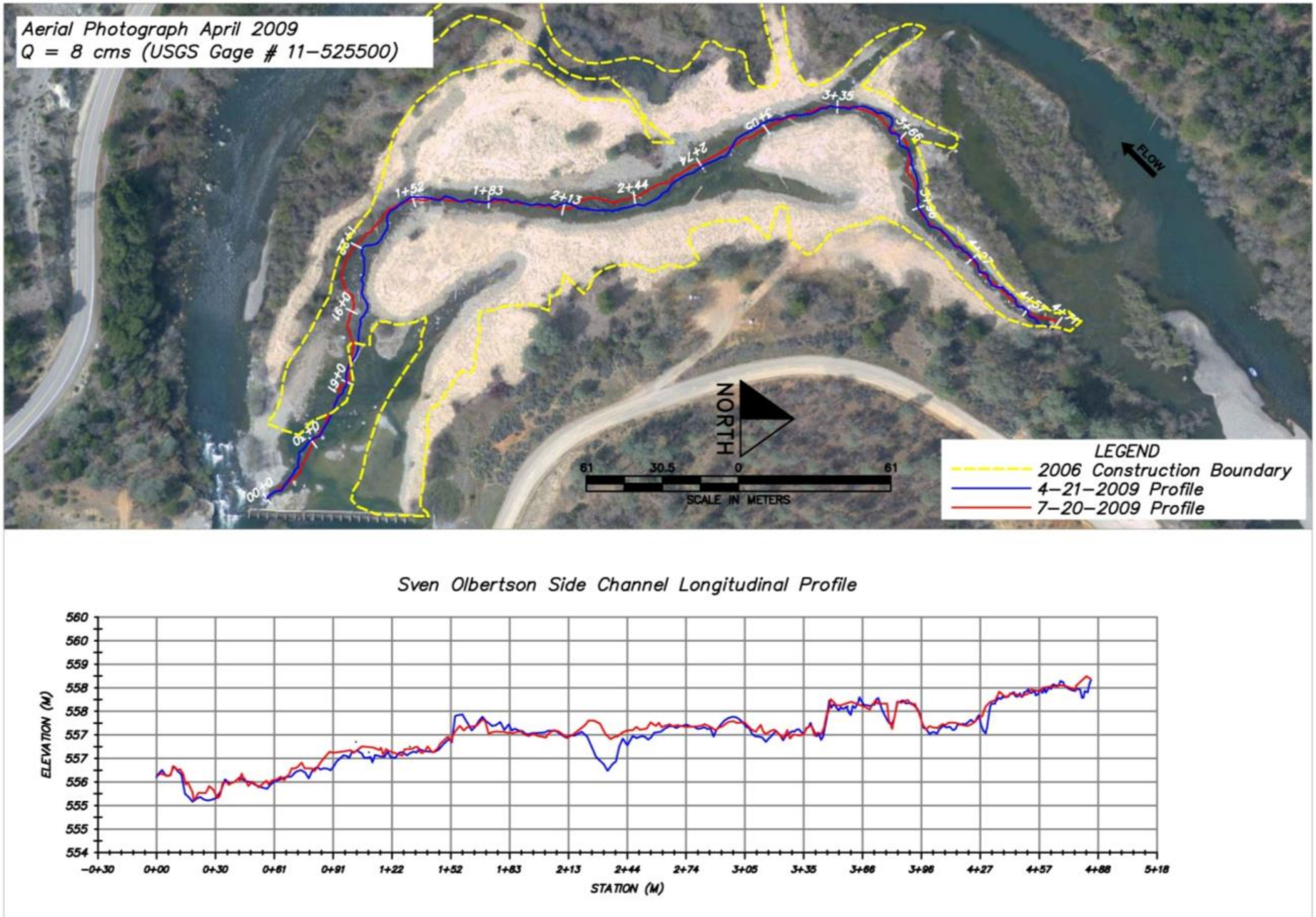


Figure 2–26. Sven Olbertson side channel longitudinal profile.

2.3.10.2. Cross-Section Topography

Two cross sections were surveyed at this site: 2064+40 and 2069+80 (Appendix B). Cross section 2069+80 showed relatively little topographic change compared to cross section 2064+40, which showed changes as great as approximately 0.6 m (2.0 ft), all from aggradation (e.g., from approximately station 64.0 to station 70.1, and from approximately station 143.3 to station 149.4). The apparent scour from station 180.0 to station 187.4 is a result of graphical interpolation of right and left bank survey points and is not real (i.e., channel topography below the water surface was not surveyed).

2.3.10.3. Sven Olbertson Geomorphic Discussion

Two priority questions were identified for this site. *Priority Question G–2* asks whether rehabilitation site implementation, in combination with high-flow releases and natural floods, increases and maintains the number, areal extent, and complexity of alluvial features. Of the two cross sections surveyed at this site, one shows no significant net topographic change (cross section 2069+80), but the other shows aggradation as great as 0.6 m (2.0 ft) in the mainstem and in the constructed side channel. Although planform mapping would better capture site topographic changes, the cross sections show some change is occurring, and the measured deposition suggests the site may be self-maintaining so far.

Priority Question G–6 asks if side channels are maintaining themselves with high-flow releases and natural floods. The longitudinal profile surveys suggest that the side channel at this site is maintaining itself. The side channel entrance has remained open, and significant scouring and filling has occurred along the entire length of the side channel. In addition, the side channel thalweg has shifted location. These adjustments are likely due in part to the site being newly constructed; its surfaces are more erosion-prone than those at other rehabilitation sites that are older and have experienced more floods and greater revegetation. Future Dry WY releases may not cause as much change as observed in WY 2009.

2.3.11. Lewiston Hatchery

Geomorphic monitoring at the Lewiston Hatchery coarse sediment augmentation site consisted of a pre- and post-spring release topographic survey of the gravel augmentation reach below Lewiston Dam downstream to the upper end of the Sven Olbertson site (Figure A–29). Monitoring occurred in response to the spring release peak flow (131 cms [4,630 cfs]; Table 2–5).

2.3.11.1. Planform Topography

Between 2007 and 2008, 5,487 m^3 (6,000 yd^3) of coarse sediment was placed at the site. The topography was surveyed before and after the WY 2009 spring release to evaluate the volumetric change in placed coarse sediments, and the net change was computed. The isopach color intensity increases with increased topographic change, from orange to red where the bed lowered and from light green to dark green where the bed aggraded. The map shows localized areas of scour (cut) and deposition (fill), and translate to approximately 153 m^3 (200 yd^3) of material scoured in the mapped area and 306 m^3 (400 yd^3) of material was deposited as a result of the WY 2009 spring release.

2.3.11.2. Lewiston Hatchery Geomorphic Discussion

One priority question has been asked for the Lewiston Hatchery site. *Priority Question G–8* asks how much of the augmented coarse sediment placed in the Lewiston Hatchery reach is being transported to downstream reaches, and how the results of this transport can inform future coarse sediment augmentation efforts. Based on the topographic differences, 153 m^3 (200 yd^3) of material mobilized from the site and was transported downstream, and the site was replenished by twice the volume, presumably from historic upstream coarse sediment augmentation sources. It is likely that a larger magnitude and longer duration release would have mobilized more coarse sediment from the site.

2.4. Discussion

2.4.1. Water Year Targets

Priority Question G–1 monitored whether or not water year geomorphic management targets (bed mobility) were met.

Bed mobility was monitored at five sites, and at two of these sites bed scour was also monitored. Depending on where the monitoring site was located, mainstem flows varied in magnitude due to tributary accretion (see Hydrologic Context section for a detailed explanation). As a result, these flows provided a fortunate opportunity to evaluate both Dry and Wet WY management targets where bed mobility was monitored.

The bed mobility management target for a Dry WY is to mobilize D_{84} sediments on bar flank features (from TRFE Table 8.8), and the bed mobility/scour management target for a Wet WY is to mobilize sediments > 1.0 D_{84} deep on alternate bar flanks, cleansing gravels and transporting all sizes of sediments (from TRFE Table 8.6). Results for both WY types are summarized in Tables 2–8 and 2–9.

With respect to the Dry WY bed mobility results at Valdor Gulch and at Hocker Flat (Table 2–8), note that the winter peak was a 113-cms (3,990-cfs) instantaneous flow rather than a 127-cms (4,500-cfs) five-day release. Presumably a five-day release would have resulted in greater mobility across these monitoring surfaces. Although it is assumed a slightly higher magnitude and a substantially longer duration would be more effective at meeting Dry WY mobility objectives, this condition was not measured. Similarly, the results in Table 2–9 reflect an instantaneous peak flow of 233 cms (8,230 cfs), and the same assumption is made that the physical "work" performed by the instantaneous peak flow event is comparable to a sustained flow of the same or similar magnitude. Monitoring should continue at these (and other) sites

Table 2–8. Monitoring Results at the Following Sites Were Evaluated with Respect to Dry WY Bed Mobility Management Targets

Site	Flow	Target met?
Lewiston Cableway	Spring ROD release	Yes
Hoadley Gulch	Spring ROD release	Probably
Dark Gulch / Bucktail	Spring ROD release	Yes
Hocker Flat	Winter Peak	No
Valdor Gulch	Winter peak	No

to evaluate the effects of sustained flow duration in meeting management targets specific to ROD releases.

2.4.2. Channel Migration and Improvements in Alluvial Function

Priority Questions G–2 through G–4 sought to examine the extent to which the mainstem channel has responded to management actions (i.e., removal of riparian berms, changes in designed meander wavelengths, ROD releases). Channel migration, alluvial features, and propagation of change upstream and downstream of rehabilitation sites were monitored at five sites (Valdor Gulch, Connor Creek, Hocker Flat, Bucktail–Dark Gulch, and Lewiston Cableway). In most instances, only minor changes in topography were observed, indicating features are being maintained, but the mainstem channel and associated alluvial features have not been substantially altered. For example, at Conner Creek, only one of five monitored cross sections (247+40) showed some lateral movement. The conclusion to date is that instantaneous floods as large as 233 cms (8,230 cfs) are causing very little channel migration at Conner Creek, despite attempts to encourage it through the implementation of the rehabilitation design. Many sites have yet to experience Wet or Extremely Wet WY types. Change in channel migration may be more apparent after sites have experienced greater magnitude flow releases.

Table 2–9. Monitoring Results at the Following Sites Were Evaluated with Respect to Wet WY Bed Mobility/Scour Management Targets

Site	Flow	Target met?
Hocker Flat	Spring ROD release	No
Valdor Gulch	Spring ROD release	No

2.5. References

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CHAPTER 3. RIPARIAN AND LARGE WOOD STORAGE ASSESSMENT OF TRINITY RIVER RESTORATION PROGRAM CHANNEL REHABILITATION SITES

3.1. Introduction

A dynamic riparian community is a characteristic of functioning alluvial rivers and provides critical components of fish and wildlife habitats. As part of the restoration strategy adopted by the ROD (USDOI 2000), restoration of geofluvial processes, in conjunction with mechanical channel rehabilitation, coarse sediment augmentation, and flow management, will help restore a dynamic riparian community along the upper Trinity River. IAP riparian objectives include key quantitative targets, by water year type, for riparian vegetation management as part of the strategy originally recommended by the TRFE (USFWS and HVT 1999). As with the fluvial geomorphic assessments, both Dry and Wet WY riparian management targets were evaluated for sites monitored downstream of Canyon Creek (Table 3–1).

The difference between "good" and "bad" riparian vegetation has been much debated, since fish often occupy flooded riparian vegetation. A setting of clean, open gravel bars without riparian vegetation is not a universally desirable condition, nor is the presence of woody riparian vegetation along the low-flow channel universally "bad." Undesirable riparian vegetation is defined using the following criteria: (1) densely distributed, (2) in a continuous band within the 300cfs to 2000cfs inundation zone, (3) more than 3 years old, and (4) especially, has initiated the riparian berm-building process. While the TRFE identifies specific management targets related to flow and sediment rehabilitation, the broader programmatic riparian

Table 3–1. Summary of Trinity River Riparian Objectives

TRFE (Table 8.8)		IAP Independent of Water Year Type
Dry Water Year Type	**Wet Water Year Type**	
Inundate gravel bars to prevent riparian seedling initiation.	Encourage establishment and growth of riparian vegetation on floodplains. Discourage or prevent riparian vegetation initiation along the low water margin. Increase the species and age diversity of riparian vegetation. Scour up to 2-yr-old woody riparian vegetation growing along the low water margin.	Establish and maintain riparian vegetation that supports fish and wildlife. Promote diverse native riparian vegetation on different geomorphic surfaces that contributes to complex channel morphology and high quality aquatic and terrestrial habitat. Prevent riparian vegetation from exceeding thresholds leading to encroachment that simplifies channel morphology and degrades aquatic habitat quality.

vegetation objectives were only recently defined in the IAP. The monitoring strategies identified in the IAP were applied in this study.

Five priority riparian questions are evaluated in WY 2009 monitoring. Data was collected at sites to address the priority question; however, not all questions were addressed at every site (Table 3–2). For WY 2009 the riparian related priority questions were:

R–1) Are process-based TRFE riparian targets being met by annual flow releases (riparian scour along low-flow edge, riparian recruitment on floodplains)?

R–2) Does the combination of bank rehabilitation, high-flow releases, and natural floods increase and maintain the areal extent, species richness, age diversity, and vertical structure of riparian vegetation on floodplains?

R–3) What is the effect of fine sediment supply (or lack thereof) in riparian seedling initiation/establishment along the low-flow channel margins?

R–4) How is large wood storage changing at constructed sites over time?

3.2. Methods

During WY 2009, riparian monitoring was primarily intended to measure changes resulting from the spring 2009 peak release and winter flood peaks. Some monitoring also included evaluating the effect of fine sediment on the ability of riparian hardwood seeds to germinate. Specific riparian monitoring activities and their related TRFE objectives included documenting pre-winter and/or pre-spring release topographic conditions, riparian woody plant locations at selected cross sections, and changes in hardwood density following the spring 2009 spring release.

Table 3–2. IHAP Riparian Vegetation Priority Questions Addressed at Each Monitoring Site

Priority Question	Sven Olbertson	Deadwood Creek	Lewiston Cableway	Hoadley Gulch	Bucktail–Dark Gulch	Vitzthum Gulch	Indian Creek	Upper Reading	Hocker	Connor Creek	Valdor Gulch	Pear Tree
R–1	X	X	X	X	X		X		X		X	X
R–2	X	X	X	X	X	X	X	X	X	X	X	
R–3	X			X	X		X					
R–4	X	X	X	X	X		X		X	X	X	X
R–5						X						

The area of regenerating, regrowing, and remnant vegetation was also documented in the fall 2008 and again in fall 2009.

3.2.1. Vegetation and Large Wood Mapping

The baseline location, composition, and structure of riparian vegetation were characterized at 10 sites before construction. The riparian vegetation, exotic hardwoods, and substrate were mapped in the field on the most recent ortho-rectified aerial photographs (scaled to 1:1,800) at the same scale as that used in the riparian vegetation inventory (McBain & Trush 2005), but in greater detail.

Specific tasks included:

1. Mapping current riparian stand types at each site using current series level nomenclature (defining patch sizes at the sites prior to any future restoration).
2. Digitizing the field maps. Discrete patches of riparian vegetation were mapped and labeled using a modified series classification system (Sawyer and Keeler-Wolf 1995).
3. Mapping large wood visible on the scaled aerial photos during the site visit.

Following construction, vegetation at each site was mapped and attributed according to the following broad categories: (1) open ground, (2) natural riparian woody plant seed regeneration, (3) regrowth of woody plants that were incompletely removed during construction and were re-sprouting, (4) remnant vegetation not removed during construction, (5) revegetation of plants following construction as mitigation to improve long-term riparian habitat, (6) herbaceous plants, (7) naturally recruited or placed large wood pieces greater than 20 cm (8 in), (8) open water, (9) human disturbance, and (10) aquatic emergent vegetation. In addition to the broad categories, the maximum age of the majority of seedlings in different regenerating patch types was estimated up to 3 years old. Polygons were drawn around different vegetation patches, large wood pieces or accumulations, human disturbance, and barren areas in the field. Polygons drawn around large wood may enclose one piece or several pieces of wood accumulated in one location.

Following the field mapping component, polygons were digitized and entered into GIS-compatible software using a California state plane zone 1 US feet NAD83 coordinate system. Then the following analytical steps were taken:

1. Determination of areal extent of all plant stand types;
2. Comparison to previously mapped patch areas, types, and locations;
3. Evaluation of the locations and extent of patches dominated by 1, 2, and 3 year woody plants; and
4. The GIS database was updated and queried with each subsequent monitoring event to detect changes in the areal extent of different patch types.

3.2.2. Band Transects

Band transects were used to document riparian hardwood recruitment locations, riparian vegetation structural changes, and species distribution along a cross section. The band transects were integrated with geomorphic and hydrologic monitoring at each site to relate riparian changes to channel morphology, annual flow regimes, and bed mobility and scour. Specific objectives of band transect sampling were:

1. Document bank position of riparian hardwood initiation, establishment, and mortality at bank rehabilitation sites;
2. Document current riparian hardwood demographics within discrete vegetation layers, correlating these demographics with distance from and elevation above the wetted stream channel;
3. Relate riparian hardwood recruitment patterns to flow timing and riparian woody plant seed dispersal patterns; and
4. Relate initiation and establishment patterns to inter- and intra-annual streamflow variations (e.g., magnitude, timing, duration, frequency, and rate of change), woody riparian hardwood physiology, and riparian hardwood phenology.

Riparian hardwood establishment trends and vegetation structure have historically been evaluated using band transects (McBain & Trush and HVT 1997, 2004, Bair 2001, McBain & Trush 2006). The band transect sampling designs are useful because they can be used to easily associate water surface elevation and discharge relationships to riparian vegetation colonization patterns. Specific tasks included:

1. Establishing, monumenting, and surveying vegetation band transects following previously defined protocols (Bair 2001);
2. Surveying the ground surface along the band transect;
3. Sampling plants in 1.5-m (4.9-ft), 5-m (16.4-ft), and 10-m (32.8-ft) nested band transects along two cross sections at a site following previously defined protocols (McBain & Trush 2006);
4. Taking digital photos of band transects;
5. Entering and completing a QA/QC of data;
6. Classifying and plotting sampled woody plants on selected cross sections in 1-, 2-, and 3-yr age classes;
7. Associating woody plant densities and bank locations with six ROD discharges and the corresponding water surface elevations;
8. Comparing changes in hardwood densities for different age classes from previous monitoring
9. Overlaying geomorphic monitoring results on the cross section to establish the mechanisms that changed hardwood densities; and
10. Evaluating whether we are approaching our 3-year window on woody plants along the low flow channel.

As with riparian mapping, hardwoods were classified by age overlaid on transects. The current riparian hardwood age structure was related to the benchmark water surface elevations.

Hardwood location data collected along transects were translated into a cross section station and ground surface elevation (i.e., the coordinate system used in establishing the cross sections). Once the hardwood data was converted, the bank locations of hardwoods were evaluated and zones of seedling initiation and establishment were defined. The hardwood location data collected in the field was translated to cross section coordinates using a spreadsheet formula that interpolated the plant's ground surface elevation from surveyed ground surface elevations and distances from the left bank pin. Using this procedure, the seedlings were overlaid on the cross section. Computed seedling density and frequency for plant species (Bonham 1989, Kent 1992) was used in encroachment risk analyses.

Riparian woody plants typically will encroach and induce berm formation if they become established below the 57-cms (2,000-cfs) water surface elevation and are not scoured within three years of establishment (Bair 2003). Therefore, encroachment risk was assessed using the "red-yellow-green" analysis for those 1-, 2-, and 3-yr-old hardwoods growing in dense, continuous bands below the 57-cms (2,000-cfs) water surface elevation (McBain & Trush and HVT 2004). Those plants that posed the greatest threat of becoming permanently established along the low water edge, but could still be potentially removed by streamflows achieving deep subsurface scour (e.g., 3-yr-old plants), were coded red; streamflows exceeding 241 cms (8,500 cfs) are hypothesized to cause widespread mortality in the 3-yr-old age class growing along the low water edge. Two-year-old hardwoods were coded yellow, because they may induce encroachment but are still vulnerable to channelbed surface scour caused by ROD flows of 241 cms (8,500 cfs) or greater. One-year-old hardwoods were coded green, because they are highly susceptible to channelbed surface scour induced by flows of 170 cms (6,000 cfs) or greater and are not considered an encroachment risk. Those older than three years were not considered because they have passed beyond the threshold of vertical scour that can be induced by managed streamflow releases alone (and will therefore continue to grow to maturity).

3.2.3. Riparian Vegetation and Large Wood

For riparian monitoring, sites were selected that possessed as many of the following features as possible: (1) multiple design elements (e.g., alcoves, side channels, feather edges, berm notches, floodplains) to inform future bank rehabilitation site designs, (2) alluvial features suitable to assess the risk of riparian encroachment, and (3) availability of fish habitat data. Post-construction riparian mapping was completed at 10 sites to characterize the planform area and patch types of riparian vegetation on both exposed bars and constructed floodplains. Monitoring was completed between October 2008 and September 2009.

3.2.4. Riparian Monitoring

WY 2009 riparian monitoring was primarily intended to measure changes resulting from the spring 2009 ROD release and winter flood peaks. Some monitoring also included evaluating the role of fine sediment on the ability of riparian hardwood seeds to germinate. Specific riparian monitoring activities and their related IAP/TRFE objectives included:

- Documenting pre-winter and/or pre-spring release topographic conditions and riparian woody plant locations at selected cross sections, and then documenting changes in hardwood density following the spring 2009 ROD release. Results of this monitoring effort are used in evaluating TRFE floodplain vegetation establishment and low water seedling encroachment prevention objectives; bed mobility and bed scour monitoring results are interpreted to indicate the causes of observed changes in woody plant density on alluvial deposits.
- Documenting the area of regenerating, regrowing, and remnant vegetation in the fall 2008 and again in fall 2009. Results of this monitoring effort are used in evaluating the TRFE floodplain vegetation establishment objective and the low-water seedling encroachment objective. Mapping results can also be used to inform future bank rehabilitation site design development and assess whether regulatory vegetation targets are being met.
- Documenting the role of fine sediment in inhibiting or facilitating the germination and first year survival of woody plant seedlings.

The specific tasks conducted to help answer priority questions and address monitoring objectives were completed between October 2008 and November 2009 (Table 3–3). Where available and appropriate, historic monitoring results were also incorporated into the analysis (Table 3 4).

3.2.5. Large Wood

Large wood is currently installed as part of most Trinity River rehabilitation sites. The goal of this inventory was to evaluate the effects of large wood on a localized scale, particularly in relation to geomorphic processes and changes in habitat. The survey was designed to help refine techniques for wood installation in future restoration sites. A large wood inventory on all wood installations occurring as part of the Trinity River Restoration Program (USFWS unpublished data) was previously conducted, beginning in 2006. The survey has been repeated annually to evaluate the effects of flow events and the longevity of the installations.

3.3. Results (Site Specific Results And Discussion)

3.3.1. Pear Tree

Specific riparian monitoring activities at Pear Tree Gulch included evaluating changes in areas of remnant, regrowing, and regenerating vegetation (Table 3–3). Post-construction vegetation mapping and band-transect surveys were conducted in WY 2006 to link the initiation and establishment of riparian vegetation to geomorphic processes and the WY 2006 hydrograph (McBain & Trush and HVT 2007). Riparian monitoring at Pear Tree Gulch was conducted in fall 2008 and summer 2009 (Table 3–3).

3.3.1.1. Vegetation Mapping

In 2009, the total vegetated area mapped was 3.2 hectares (8.0 acres) and accounted for 69.8 percent of the mapped area (Figure 3–1). In 2009, open ground continued to decrease, comprising only 8.3 percent of the area. Herbaceous patch types have increased in area since 2008 and accounted for 30 percent of the area. Non-native grassland was the most abundant herbaceous patch type and typically grew on sites that were formerly sweetclover. Remnant woody vegetation was the largest woody riparian patch type and accounted for 34 percent of the vegetated area. Pure stands of regenerating seedlings decreased substantially in 2009 (0.03 hectares [0.08 acres]) and were reduced to small pockets of fine sediments deposited along the low water edge.

Table 3–3. Summary of WY 2009 Riparian Monitoring Activities at Rehabilitation Sites

Site	Fall 2008 (pre-winter flood):	Summer 2009 (post-spring release):
Pear Tree Gulch	Vegetation Map	Vegetation Map
Valdor Gulch	Band Transect (3x), Vegetation Map	Band Transect (3x), Vegetation Map
Connor Creek	Vegetation Map	Vegetation Map
Hocker Flat	Band Transect (3x), Vegetation Map	Band Transect (3x), Vegetation Map
Upper Reading Creek		Band Transect (1x)
Lower Indian Creek	Band Transect (2x), Vegetation Map	Band Transect (2x), Bulk Samples (6x), Vegetation Map
Middle Indian Creek	Vegetation Map	Vegetation Map
Vitzthum Gulch	Vegetation Map	Vegetation Map
Bucktail–Dark Gulch	Site Under Construction	Band Transect (3x), Bulk Samples (6x), Vegetation Map
Hoadley Gulch	Site Under Construction	Vegetation Map; Bulk Samples (6x),
Lewiston Cableway	Site Under Construction	Band Transect (2x), Vegetation Map
Deadwood Creek	Site Under Construction	Vegetation Map
Sven Olbertson	Site Under Construction	Band Transect (2x), Bulk Samples (6x), Vegetation Map

At the upstream end of Pear Tree, the point bar is still mostly open with multiple seedling age classes (Figure E–1); this portion of the site was not rehabilitated (Figure A–2, E–3). Although older seedlings have survived at the upstream end of the site, they have been disturbed frequently enough by winter floods and/or spring releases to prevent detrimental encroachment.

Sand has been deposited along the low water edge and in the backwater alcove area (e.g., the R5 and R7 activity area, Figure A–3), and many willows have resprouted. The presence of the older resprouting willows encourages additional deposition as they continue to grow larger (currently ~3–5 m [10–16 ft] tall).

Following rehabilitation, narrowleaf willow is still the most common and dominant riparian hardwood at the site. Limited amounts of natural regeneration were documented in 2008 and 2009 (Figure E–1, Figure E–2); however, the low-water channel margin is being reclaimed by willows that are resprouting because of incomplete removal during rehabilitation (Figure E–1). Willows growing from root sprouts are larger than seedlings of a similar age (i.e., the size of a 2-yr-old root sprout is much greater than a 2-yr-old seedling) and also grow along the low-water margin.

3.3.1.2. Large Wood

Compared to sites that have been constructed since 2008, the total quantity of large wood originally placed at Pear Tree was small (four pieces). Since construction, the overall amount of placed large wood remained approximately the same since between 2008 and 2009 (e.g., four pieces and 0.0004 hectares in 2008 and three pieces and 0.0006 hectares in 2009).

3.3.1.3. Pear Tree Riparian and Large Wood Discussion

Two riparian Priority Questions were assessed with data collected during the IHAP study in 2008 and 2009. *Priority Question R–1* asks if process-based riparian targets are being met by annual flow releases. Currently ROD flows, in combination with tributary accretion, are capable of inhibiting hardwood seedling establishment along the 13-cms (450-cfs) water surface. Flood events in WY 2008 and 2009 have been capable of scouring the low water edge of young seedlings; however, flood flows have been unable to remove root sprouts, which resulted in a gradual increase in narrowleaf willows along the channel margin.

While Pear Tree is still largely open, the willow band that is forming parallel to the main channel is approximately 3–5 m (10–16 ft) tall with several age classes interspersed. Although there is some structural diversity at present, the stems are likely to become similar in height over the next five years and will continue to trap fine sediment, resulting in undesirable berm-like conditions. Since construction, the floodplains have been dominated by herbaceous patch types such as sweetclover, Brickellia, and non-native grassland.

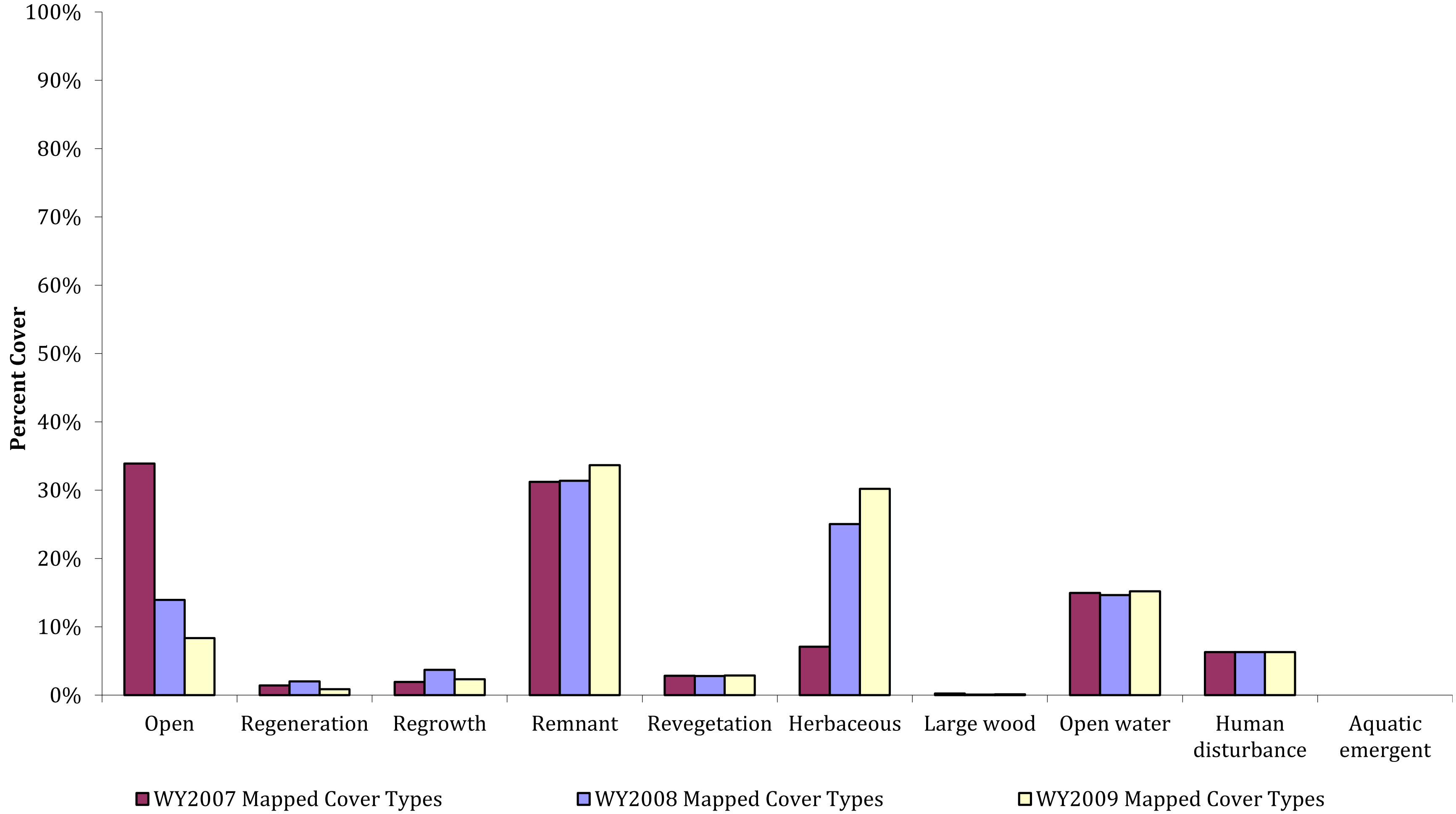


Figure 3–1. Percent of the total area that each mapped cover type occupies within the Pear Tree rehabilitation site area for cover types mapped in 2007, 2008, and 2009.

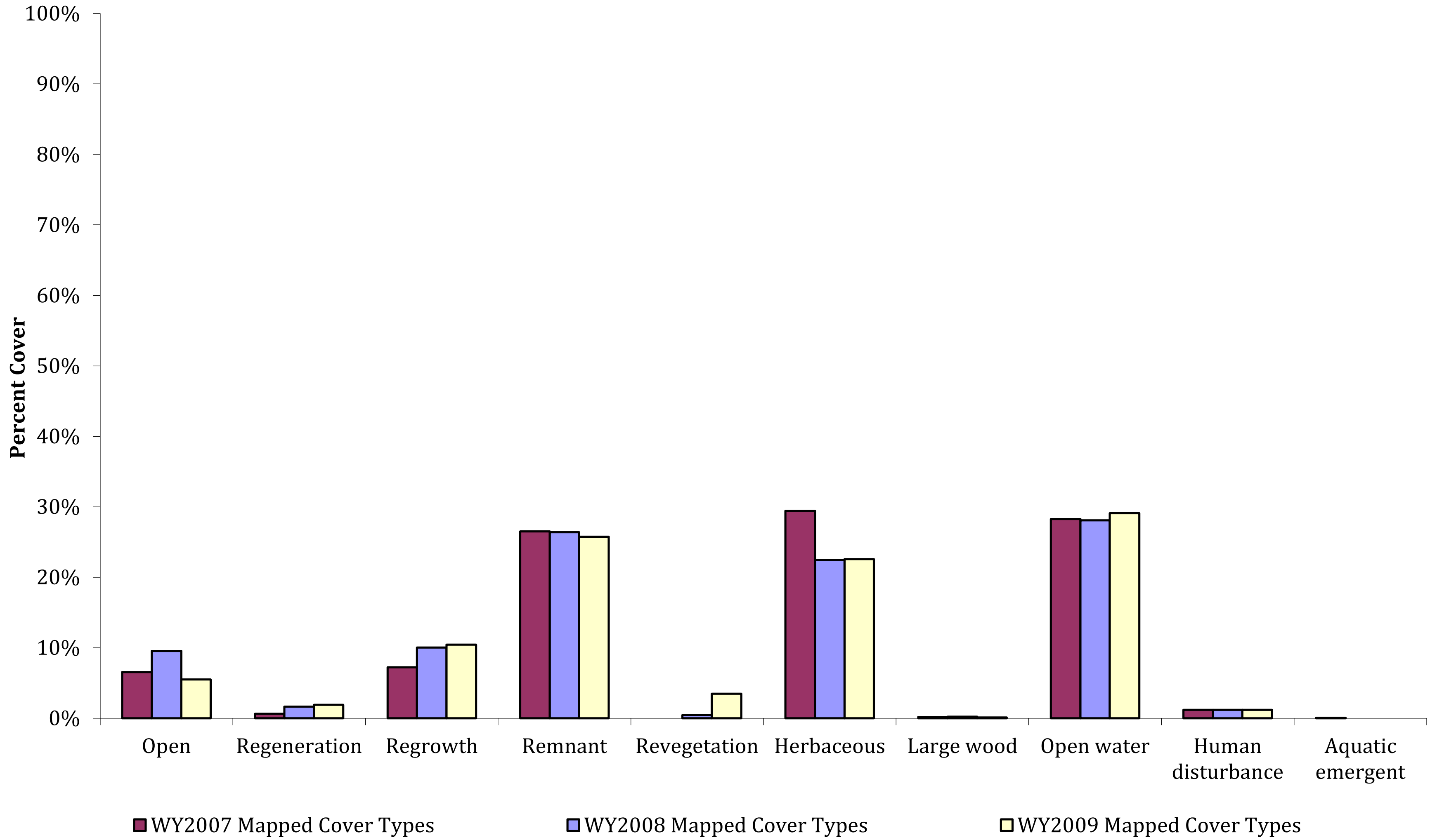


Figure 3–2. Percent of the total area that each mapped cover type occupies within the Lower and Upper Valdor rehabilitation site areas for cover types mapped in 2007, 2008, and 2009.

Priority Question R–4 asks if wood storage is changing over time. Changes in the quantity of large wood or the location of placed large wood were not documented during WY2009. New pieces of wood were not recruited at Pear Tree during the 2008–09 monitoring period, and large wood storage at the Pear Tree rehabilitation site has not changed since construction.

3.3.2. Valdor Gulch

Specific riparian monitoring activities at Valdor Gulch included evaluating changes in hardwood demography along three band transects at discrete locations within the site and mapping areas of remnant, regrowing, and regenerating vegetation throughout the entire site (Table 3–3). Band transect monitoring occurred on three cross sections: 141+20, 151+80, and 166+75 (Figures E–4, E–5).

3.3.2.1. Vegetation Mapping

In 2007, 2008, and 2009, the total mapped area at Valdor Gulch was approximately 14.9 hectares (36.7 acres; Figures E–4 to E–6). Following rehabilitation, narrowleaf willow was still the most common and dominant riparian hardwood at the site. Natural seedling regeneration was documented in 2008 and 2009 along the low-water margin throughout most of the site. In 2008 and 2009, the two largest mapped vegetation areas at the site were from the regrowth of willows along the low-water channel margin and revegetation (Figure 3–2). Valdor Gulch is rapidly returning to pre-construction vegetation patterns as willows resprout. Regrowth since 2007 has increased and now covers an area similar to pre-construction conditions due to incomplete root removal during rehabilitation. Additional results for 2007 and 2008 can be found in Appendix E.

In 2009, the total vegetated area increased slightly to 9.5 hectares (23.5 acres) and accounted for 64 percent of the mapped area (Figure 3–2). The area of open ground decreased between 2008 and 2009 and covered 5.5 percent of the area. In 2009, many areas that were formerly mapped as open had converted to areas dominated by regrowth from plants that were initially removed during construction. Remnant vegetation covered a similar area as in 2007 and was 25.7 percent of the mapped area.

The mapped area associated with revegetation increased in 2009 to 3.5 percent (Figure 3–2). Overall, the revegetated plants on constructed surfaces are still young and most locations seem to be growing slowly. At the constructed side channel at the upstream end of Valdor Gulch, plantings intermingle with root sprouts on the medial bar and grow in a ring that shadows the channel margins (where vegetation removal was targeted); however, the central area of the bar is mostly open (where revegetation was targeted). Hardwood plantings near the upstream end of the medial bar are growing better overall than plantings near the downstream end. Plantings toward the upstream end of the medial bar are taller — in excess of 4–6 m (~13–20 ft) in some cases — in contrast to plantings toward the downstream end, which are shorter and mostly less than 3 m (~10 ft). Some plantings, especially those closer to the side channel, are growing vigorously. Other plantings, like those closer to the main channel, are growing more slowly. Cottonwoods seem to be doing very well at the medial bar site. The difference in growth rates between planting areas could be due to substrate differences between planting locations, how planting material was handled before and during revegetation, and/or whether the planted hardwood cutting actually was planted into the late season groundwater.

The area of regrowing vegetation was 10.4 percent in 2009 and similar to the area mapped in 2008. Narrowleaf willow regrowth along the side channel margin in upper Valdor Gulch has formed a dense thicket. Dense willow regrowth along the side channel margins may not be problematic because of the aquatic habitat benefits, although the willow regrowth is uniform and lacks a multi-structured canopy. Ideally, the plantings on the bar floodplain will continue to grow and eventually provide desired multi-layered canopy structure (i.e., herb, shrub, and tree layers).

The area where seedlings were mapped increased slightly since 2008 and accounted for 1.8 percent of the area. Seedling locations were similar between 2008 and 2009, although the seedling areas expanded slightly in 2009. At the downstream end of Valdor Gulch, patches of young-of-year seedlings were also frequent along the feathered edges and point bar. However, the lack of older seedlings along the low-flow channel margin at lower Valdor Gulch suggests that flows were sufficient to scour the majority of seedling from the 2008 cohort — a result corroborated by band transect sampling. Small, narrow bands of seedlings occur along the top of the medial bar and along the main channel in upper Valdor Gulch, with a few seedling patches along the side channel where a bar is forming or where there are patches of exposed fine sediment downstream of a placed log. In upper Valdor Gulch, the medial bar margins along the mainstem and the side channel had both young-of-year dominated stands and mixed patches with young-of-year and 1-year seedlings together. The presence of 1-year-old seedlings near the low-flow channel of the medial bar suggests that flow may have been sufficient to scour those seedlings in the immediate vicinity of the 13-cms (450-cfs) water edge but were not sufficient to scour out all the seedlings from the 2008 cohort (a result corroborated by band transect sampling; see Band Transect 151+80 Results, Appendix E).

The area of large wood initially placed or naturally occurring at Valdor Gulch was small. Mapped wood locations may consist of one piece or several pieces of accumulated wood. Since construction, the overall number of polygons associated with large wood increased from 23 in 2007 to 33 in 2008, but the total area encompassed by the polygons did not change. The number of polygons and mapped area associated with large wood decreased in 2009 (21 polygons).

3.3.2.2. Valdor Gulch Riparian and Large Wood Discussion

Two riparian Priority Questions were assessed with data collected in 2006, 2008, and 2009. Detailed data results from earlier mapping and individual band transects can be found in Appendix E.

Priority Question R–1 asks if process-based riparian targets are met by annual flow releases. Currently, ROD flows in combination with tributary accretion are capable of inhibiting hardwood seedling establishment along the 13-cms (450-cfs) water surface. Spring 2009 flood peaks scoured approximately 90 percent of the 2008 cohort and 90 percent of the 2007 cohort. Survivors from the 2008 and 2007 cohort were intermixed with the 2009 seedlings. However, ROD flows in combination with tributary accretion have been insufficient to promote hardwood establishment on constructed floodplain surfaces at Valdor Gulch. Three years after construction, in fall 2009, 99 percent of naturally regenerating hardwoods sampled (including young-of-year and 1-year-old seedlings) occurred between the 13- and 57-cms (450- and 2,000-cfs) water surface levels.

Peak 2009 flows mostly inhibited seedling-caused detrimental riparian encroachment near the 13-cms (450-cfs) water edge. Detrimental encroachment is presently a low risk at Valdor Gulch overall because young-of-year and 1-year-old seedlings make up the bulk of the seedlings at the site (Figure 3–3). The presence of 2-year-old seedlings along the low-water edge indicates there is some risk that seedling-induced detrimental encroachment may occur at Valdor Gulch; however, the threat from seedlings is not as great as from regrowth.

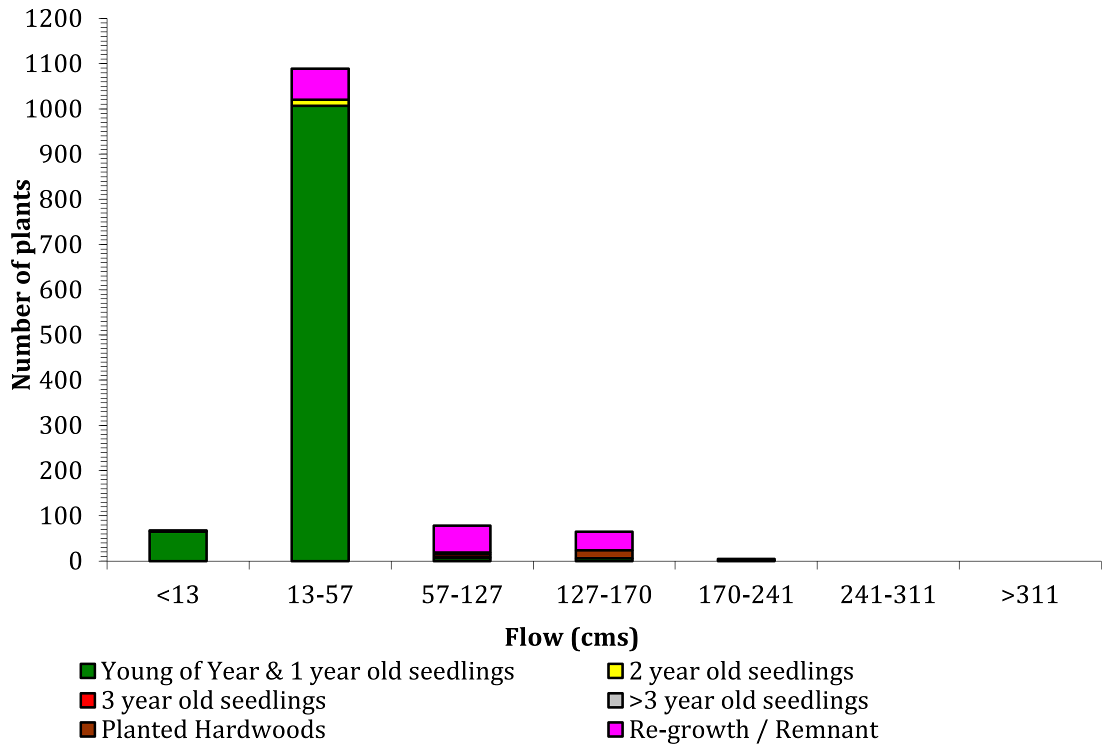


Figure 3–3. Valdor Gulch rehabilitation site WY 2009 Red-Yellow-Green analysis. The total number of seedlings at each site is the combined total of seedlings sampled along transects at each site.

Root sprout-induced detrimental riparian encroachment has not been inhibited between the 13- and 57-cms (450- and 2,000-cfs) water surface levels (Figure 3–4). Root sprout size has increased between these two levels since 2008, and it is unlikely that the root sprouts will ever be scoured from the low-water edge. Root sprouts will ultimately exert more of a geomorphic influence than seedlings in the re-formation of the riparian berm at Valdor Gulch because the root sprouts along the low-water margin are unlikely to be removed by flood flows and have the same ability to trap fine sediments and form berms as younger, more easily removed seedlings of similar stem ages.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains the areal extent, species richness, and age diversity of riparian vegetation on floodplains. Several benches were constructed at Valdor Gulch that should be inundated by flows between 57 and 170 cms (2,000 and 6,000 cfs). A constructed floodplain is a type of constructed bench that is designed to be inundated by flows greater than 170 cms (6,000 cfs). There is 1.8 m (5.8 ft) of elevation difference between the 170- and 13-cms (6,000- and 450-cfs) water surfaces at band transect 141+20. Floodplain inundation is needed to encourage deposition of fine sediment on the floodplain and seedling regeneration. Streamflows greater than 127 cms (4,500 cfs) are needed to create suitable soil

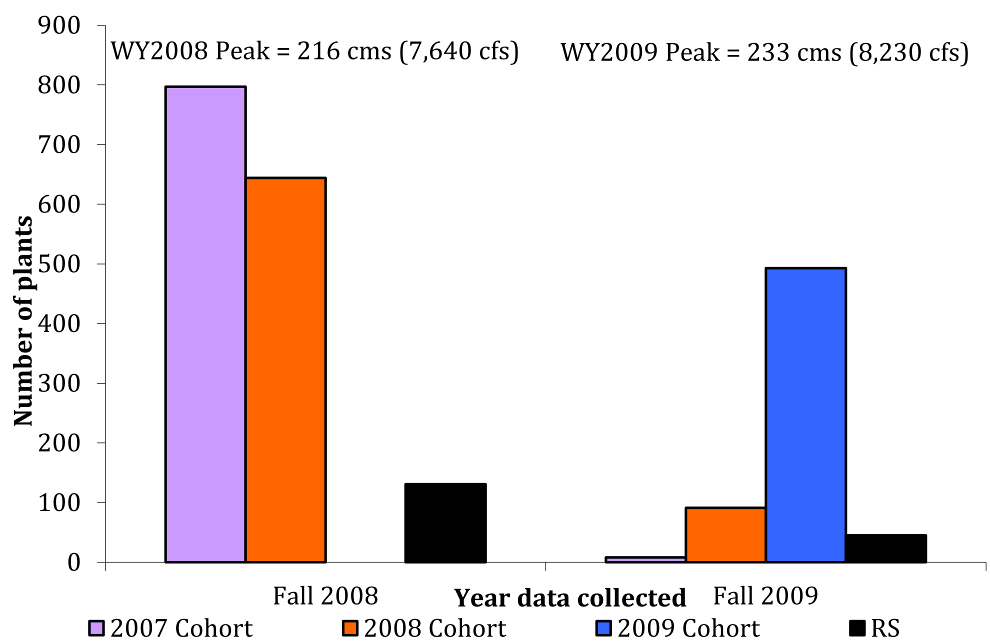


Figure 3–4. Valdor Gulch rehabilitation site WY 2008–09 seedling demographics within the 13–57 cms (450–2,000 cfs) ROD discharge inundation zone (RS = resprout growth). The total number of seedlings at each site is the combined total of seedlings sampled along transects at each site.

moisture on constructed floodplains to facilitate seed germination on the floodplain. Ground surfaces should provide suitable surface moisture for 14–21 days to facilitate successful seed germination and primary root growth. Streamflows greater than 170 cms (6,000 cfs) inundate constructed floodplains, and seeds can no longer germinate on the surface. Daily average flows greater than 127 cms (4,500 cfs) at Valdor Gulch occurred for 19 days in WY 2009, 12 days in WY 2008, and 5 days in WY 2007. Flows have inundated the floodplain for short periods in WY 2008 and WY 2009. The short periods of floodplain inundation have been adequate to rework the floodplain surface, causing localized deposition of fine sediments and remixing of gravels and cobbles. However, streamflow magnitude, duration and the rate of streamflow recession since 2007 (post-construction) have been insufficient to promote seedling regeneration on constructed floodplains above the 127-cms (4,500-cfs) water surface level in lower Valdor Gulch.

Three years after construction is too early to detect whether the combination of ROD flows and physical rehabilitation have increased the structural diversity, species richness, and areal extent of riparian vegetation at Valdor Gulch. The constructed floodplains, feathered edges, and point bar toward the downstream end of the site are evolving to look very similar to pre-construction conditions. During 2008 and 2009 monitoring, narrowleaf willow was the most common species sampled. If current trends continue, that is, if flows are unable to scour existing plants, then extensive narrowleaf willow regrowth will likely continue to promote fine-sediment deposition. Currently, the greatest amounts of sand deposition occur around remnant vegetation and established regrowth (i.e., large willow resprouts). In many instances at Valdor Gulch, large regrowing willows occur between the feathered edge and the constructed floodplain. The combination of sand deposition and increased riparian vegetation growth will lead to the formation of a riparian berm in the pre-construction location, which could potentially cut off floodplain inundation. At the upstream end of Valdor Gulch, the constructed side channel is filling in slightly and the upstream side channel entrance is aggrading. Remnant narrowleaf willow root-wads have re-sprouted vigorously along the side channel margins. This regrowth has trapped sand deposits, causing the stream bank to build.

Priority Question R–4 asks if wood storage is changing over time. Large wood storage is not increasing at Valdor Gulch. Compared to sites that have been constructed since 2008, the total quantity of large wood originally placed at Valdor Gulch was small and the amount of new wood pieces coming into Valdor or being recruited from Valdor was small. Since construction in 2007, the overall amount of placed large wood has decreased. In most cases, once a placed piece of wood is transported away from the rehabilitation site, it is not replaced from an upstream source.

3.3.3. Conner Creek

Riparian monitoring activities at Connor Creek included evaluating changes in area of remnant, regrowing, and regenerating vegetation (Table 3–3, Figure A–7). Mapping has been conducted every year at Connor Creek since 2005; McBain &

Trush and HVT 2007). For this study, riparian monitoring at Connor Creek was conducted in fall 2008 and summer 2009 (Table 3–3). Additional riparian results can be found in Appendix E.

3.3.3.1. Vegetation Mapping

In 2007, 2008, and 2009, the total mapped area at Connor Creek was 9.2 hectares (22.7 acres) (Figure E–16 – Figure E–18). Following rehabilitation, narrowleaf willow was still the most common and dominant riparian hardwood regenerating at the site; however, large stands of remnant cottonwood could facilitate a shift in plant species composition. Remnant vegetation stands were the largest patch type at Connor Creek (Figure 3–5). Natural regeneration was documented on constructed lower elevation benches in 2007, 2008, and 2009; however, some portions of the 13-cms (450-cfs) channel margin were being reclaimed by resprouting willows because of incomplete removal during rehabilitation.

Since 2007, the area of seedling regeneration has decreased while the area of regrowth has continued to increase (Figure 3–5). The downstream end of Connor Creek is rapidly returning to pre-construction vegetation patterns due to resprouting willows. Regrowth since 2007 has increased and now covers an area similar to pre-construction conditions because of incomplete root removal during rehabilitation.

Before construction in 2006, a large portion of the site was already open ground or dominated by herbaceous plants. Higher streamflows were initially intended (1) to inundate these areas during the seed dispersal of target species to promote seedling regeneration and/or (2) to scour the surface and reset the herbaceous succession cycle. Changes in mainstem channel morphology at the upstream end of Connor Creek resulting from the 2006 peak floods (816 cms [28,800 cfs]) altered the inundation frequency of the 187-cms (6,600-cfs) floodplain (activity area R3 and R4, Figure A–8). Much of the open ground left over immediately after construction has been covered with sweetclover, an herbaceous biannual plant (Figure 3–5).

Large areas of high-quality riparian vegetation were avoided during construction. The riparian vegetation that remained after construction (i.e., remnant vegetation) was dominated by black cottonwood and has a well-developed and layered canopy structure. Unlike many riparian areas within the Trinity River that are dominated by a single species (e.g., white alder or narrowleaf willow), remnant vegetation at Conner Creek has a diversity of species, including mature black cottonwood, white alder, narrowleaf willow, arroyo willow, Oregon ash, and others.

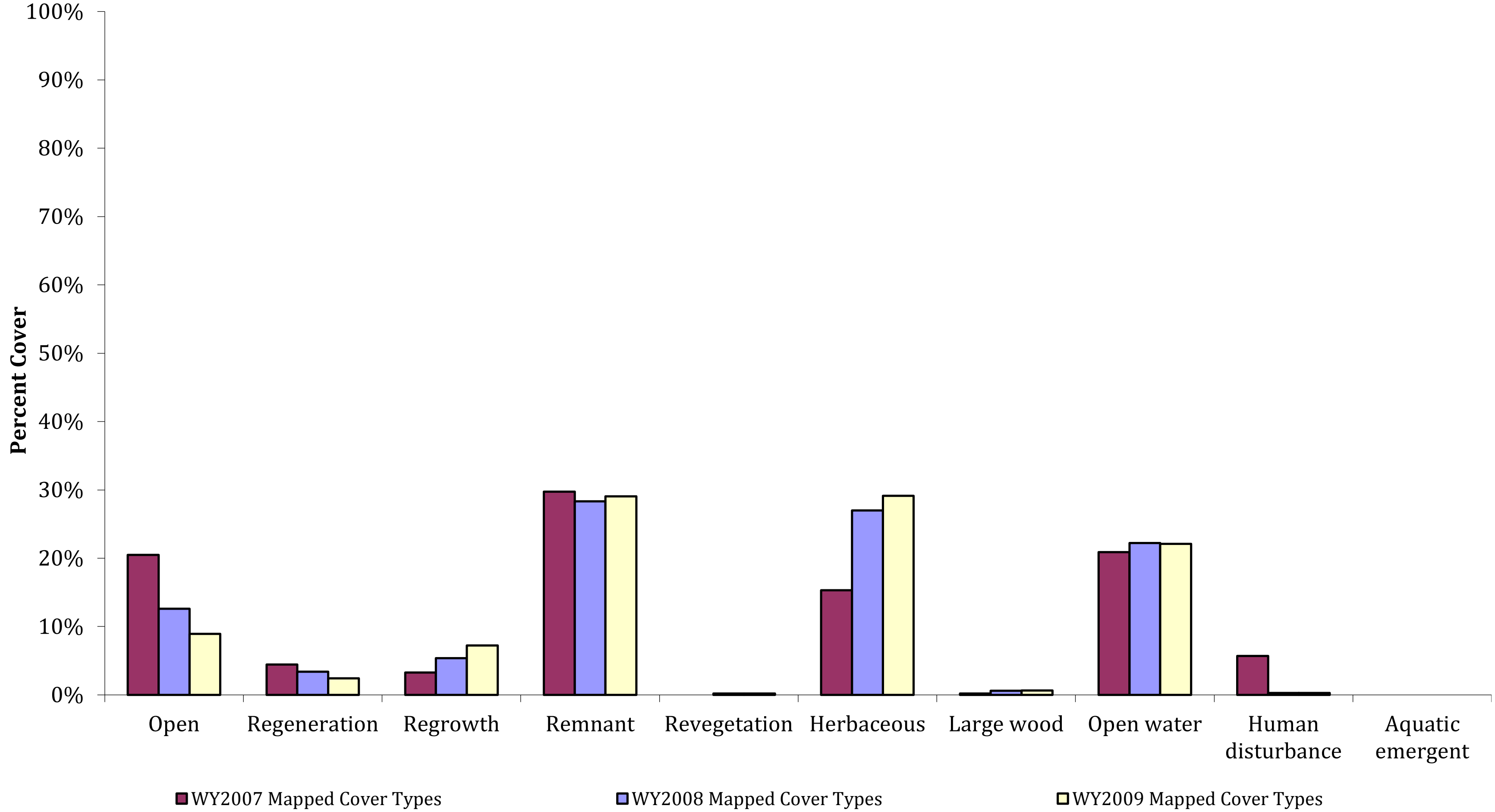


Figure 3–5. Percent of the total area that each mapped cover type occupies within the Connor Creek rehabilitation site area for cover types mapped in 2007, 2008, and 2009.

In 2009, the total vegetated area increased slightly to 6.2 hectares (15.3 acres) and accounted for 67.5 percent of the mapped area. Open ground accounted for 8.9 percent of the mapped area in 2009, with herbaceous plants occupying the majority of locations previously mapped as open in 2007 and 2008. Remnant vegetation was 29.0 percent of the mapped area, similar to the area mapped in 2007 and 2008. Revegetation accounted for less than 1 percent of the mapped area in 2009 and remained approximately the same as in 2007 and 2008 (Figure 3–5). Overall, revegetated plants on constructed surfaces seem to be growing slowly and are susceptible to being overwhelmed by root sprouts and herbaceous weeds. Regrowth accounted for 7.2 percent of the mapped area, nearly twice the area mapped in 2007. The increase in cover of regrowth documented in 2009 was due to a shift in dominance within patch types that were previously identified as regenerating seedlings with some root sprouts.

The area that contained seedlings reduced to 1.9 percent in 2009. The continuing decrease in seedling area was due to the continuing increase in willow regrowth within patches where predominantly seedlings were originally observed in 2007 and 2008. Many of the locations where seedlings were mapped in 2009 have 2- and 3-year-old seedlings. Mapped seedlings in 2009 were located either on naturally occurring bar surfaces or constructed surfaces that were intended to be inundated at 13 cms (450 cfs).

In 2009, the constructed 170-cms (6,000-cfs) floodplains had multiple riparian hardwood species and age classes (activity area R5, Figure A–8). Extensive narrowleaf willow regrowth has covered the constructed floodplain and is the dominant species on the floodplain. It is very unlikely that peak flood flows will scour the regrowing willow from the floodplain. The dominance of narrowleaf willow will most likely be altered if cottonwoods or other tree species get established and can shade out the narrowleaf willow.

Most of the large wood mapped at Connor Creek was associated with large debris rafts that were deposited in the remnant riparian areas after the 816-cms (28,800-cfs) flood in WY 2006. Much of the wood at Connor Creek is naturally recruited (i.e., it was not augmented by design and construction activities) and has steadily increased from 10 mapped polygons in 2007 to 17 in 2009 (Figure 3–5).

3.3.3.2. Connor Creek Riparian and Large Wood Discussion

One riparian Priority Questions was assessed at Connor Creek with data collected in 2008 and 2009. *Priority Question R–2* asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains areal extent, species richness, and age diversity of riparian vegetation on floodplains. Three years after construction, the combination of ROD flows and physical rehabilitation have set the site on a trajectory that suggests that the structural diversity, species richness and areal extent of riparian vegetation have and will continue to increase at Connor Creek. In spite of willow regrowth, a variety of age classes and species have colonized the constructed 170-cms (6,000-cfs) floodplain. Regrowth and colonization on the 187-cms (6,600-cfs) floodplain is currently heterogeneous, consisting of narrowleaf willow root sprouts, a variety of willow seedlings, remnant white alders and cottonwoods, and planted black cottonwoods and arroyo willows. In 5 to 10 years, the species richness and variety of sources (e.g., seedlings, root sprouts, remnant, and planted) will contribute to a multi-layered canopy. There is a risk that the feathered edge will become dominated by root sprouts (as seen in the 2009 mapping effort). If this happens, the floodplain will probably lose some of its function and the area will become an extension of the existing riparian berm. The constructed high-flow scour channel that drains into the floodplain has remained relatively unvegetated with woody plants. Much of the high-flow channel was covered by herbaceous patch types in 2009. There has not been extensive regrowth of willows. Since construction, the low-flow (13-cms [450-cfs]) inundation benches have become colonized with establishing hardwoods (activity area R2, Figure A–8). In 2009, the low-flow bench surfaces were dominated by 4-yr-old seedlings, with a smaller portion being 1-yr-old and young-of-year seedlings. Observations of channelbed mobility and scour results at other nearby sites (e.g., Valdor Gulch and Hocker Flat) suggest that, although the overall cover of vegetation on these surfaces is not dense, ROD-prescribed streamflows are not likely to scour away establishing plants on these lower elevation benches. In the near future, it is very likely that willow thickets will cover the lower elevation benches and continue to trap fine sediment until the surfaces are no longer inundated by design flows (i.e., 57 and 127 cms [2,000 and 4,500 cfs]).

Priority Question R–4 asks if wood storage is changing over time. Large wood storage is increasing at Connor Creek, which naturally had more large woody debris than other sites constructed in 2005 and 2006. Remnant riparian vegetation, especially a stand of remnant black cottonwoods, captures debris rafts, thus continuing to retain large wood at the site. The total quantity of large wood placed at Connor Creek was small but the amount of new wood pieces coming into Connor Creek was greater than that mapped at other sites. Since construction in 2007, the overall large wood mapped since 2007 has increased.

3.3.4. Hocker Flat

Riparian monitoring activities at Hocker Flat included evaluating changes in hardwood demography along three band transects and areas of remnant, regrowing, and regenerating vegetation (Table 3–3). Mapping has been conducted every year at Hocker Flat since WY 2005, and band transect monitoring occurred in WY2003 and WY2005 through WY 2009 (McBain & Trush and HVT 2004, 2007; Table 3–4). Riparian monitoring at Hocker Flat was conducted in the fall of 2008 and the summer of 2009. Band transects were monitored on three cross sections: 314+15, 326+90, and 340+17 (Figures E-25, E-28, E-31).

Table 3–4. Summary of All Riparian Monitoring Activities at Rehabilitation Sites since WY 2005

[WY 2005 was the date of construction for the first post-ROD channel rehabilitation sites. Monitoring conducted under the 2009 IHAP is summarized under the WY 2009 column, although riparian analyses in this report included consideration of all data collected since 2005, when available. BT = band transect vegetation mapping.]

Site	WY2005	WY2006	WY2007	WY2008	WY2009
Pear Tree	Map, BT (9/05)	Constructed fall 2006	Map, BT(12/06)	Map	Map
Elk Horn	Map, BT (9/05)	Constructed fall 2006	Map, BT(12/06)	Abandoned–No survey	Abandoned–No survey
Valdor Gulch	Map, BT (9/05)	Constructed fall 2006	Map, BT(12/06)	Map (10/08)	Map, BT (10/08+8/09)
Connor Creek	Map, BT (9/05)	Constructed fall 2006	Map, BT(12/06)	Map (10/08)	Map
Hocker Flat	Constructed fall 2005	Map, BT(12/05)	Map, BT(10/06)	Map (10/08)	Map, BT (10/08+8/09)
Upper Reading Creek	None	None	None	None	BT (12/09)
Lower Indian Creek	None	Map, BT (12/06)	Constructed fall 2007	Map (10/08)	Map, BT (10/08+8/09)
Middle Indian Creek	None	Map, BT (12/06)	Constructed fall 2007	Map (10/08)	Map
Vitzthum Gulch	None	None	Constructed fall 2007	Map (10/08)	Map
Bucktail–Dark Gulch	None	Map, BT (10/06)	None	Constructed fall 2008	Map, BT (10/08+8/09)
Hoadley Gulch	None	None	None	Constructed fall 2008	Map
Lewiston Cableway	None	None	None	Constructed fall 2008	Map, BT (10/08+8/09)
Deadwood Creek	None	None	None	Constructed fall 2008	Map
Sven Olbertson	None	Map, BT (9/06)	None	Constructed fall 2008	Map, BT (10/08+8/09)

3.3.4.1. Vegetation Mapping

Hocker Flat was revegetated in spring 2006. In 2007, 2008, and 2009, the total mapped area at Hocker Flat was 20.0 hectares (49.5 acres; Figures E–19 through E–24). Following rehabilitation, narrowleaf willow was still the most common and dominant riparian hardwood regenerating at the site. Remnant vegetation and herbaceous stands are the largest patch types at Hocker Flat (Figure 3–6); however, most of the constructed floodplains remain unvegetated. Natural regeneration has been restricted to the 13-cms (450-cfs) water edge in 2007, 2008, and 2009; however, portions of the 13-cms (450-cfs) channel margin were also being reclaimed by resprouting willows due to incomplete removal during rehabilitation. Willows growing from root sprouts are larger than seedlings of a similar age (i.e., the size of a 2-year-old root sprout is much greater than a 2-year-old seedling) and often also grow along the low-water margin.

Since 2007, the area of seedling regeneration has decreased while the area of regrowth has continued to increase (Figure 3–6). Many constructed portions of the 13-cms (450-cfs) water edge are returning to pre-construction vegetation patterns due to willow regrowth. Regrowth since 2007 has increased and now covers an area similar to pre-construction conditions as a result of incomplete root removal during rehabilitation.

Before construction in 2005, a large portion of the site was already open ground or dominated by herbaceous plants. An herbaceous biannual plant, sweetclover, colonized much of the open ground immediately after construction (Figure 3–6). Since the initial sweetclover colonization, constructed open areas have converted into non-native grassland or to yellow star-thistle grassland, or have remained open. Streamflows greater than 142 cms (5,000 cfs) inundate constructed floodplains often during the seed dispersal of target species and therefore do not promote seedling regeneration. Streamflows since 2006 have not caused sufficient surface scour to reset the herbaceous succession cycle.

3.3.4.2. Hocker Flat Riparian and Large Wood Discussion

Two riparian Priority Questions were assessed with data collected in WY 2008 and WY 2009. *Priority Question R–1* asks if process-based riparian targets are met by annual flow releases. Currently, ROD flows, in combination with tributary accretion, have limited hardwood seedling establishment along the 13-cms (450-cfs) water surface, but the process of detrimental encroachment has started. Channelbed scour along the 13-cms (450-cfs) water edge was variable. At the downstream end of the site, scour from WY 2009 removed few seedlings; however, the amount of scour along the channel margin and related seedling mortality was higher at the upstream end of the site.

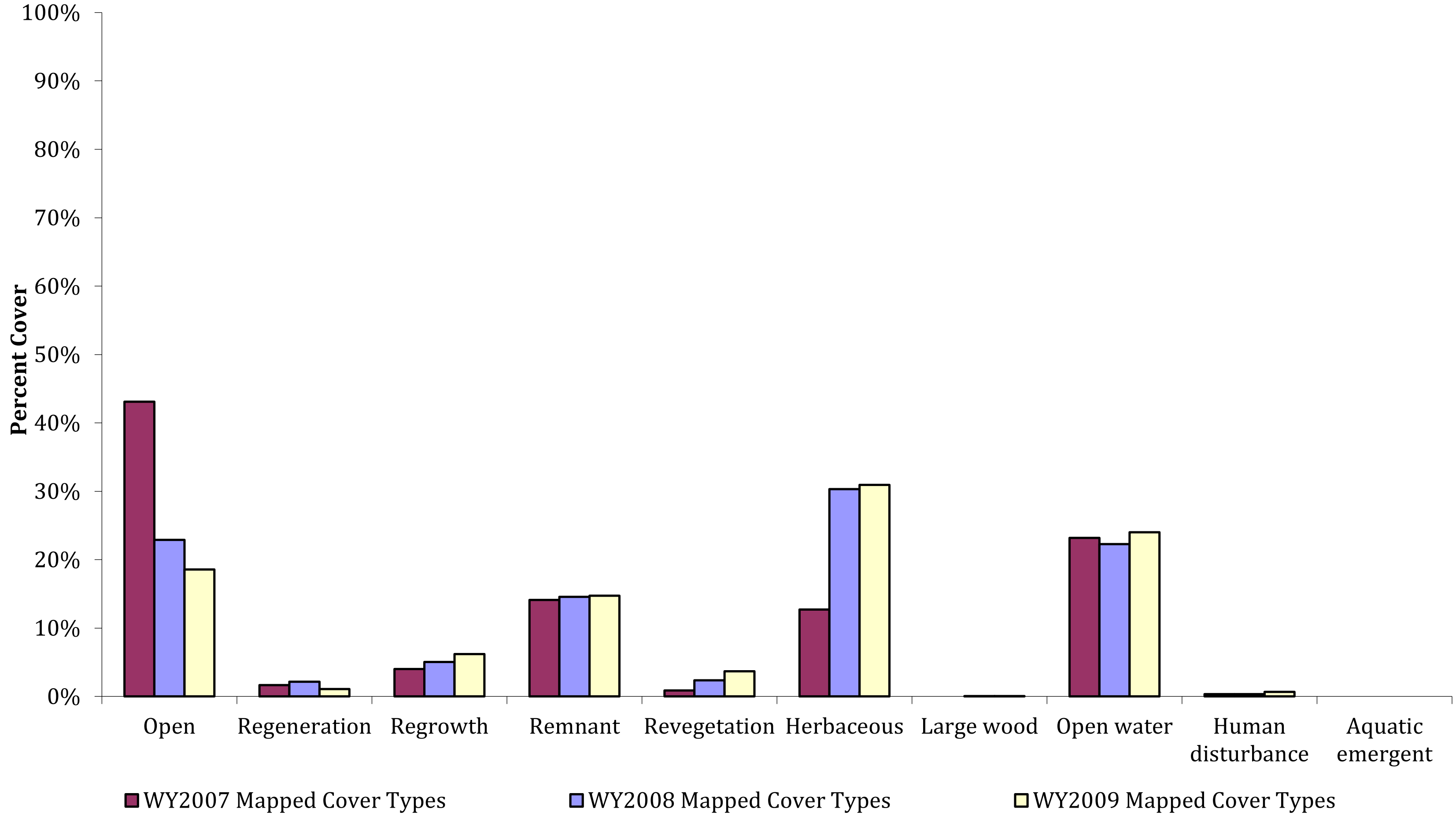


Figure 3–6. Percent of the total area that each mapped cover type occupies within the Hocker Flat rehabilitation site area for cover types mapped in 2007, 2008, and 2009.

The pattern of Normal and Dry WYs since 2006 has allowed root sprouts and seedlings to become established. WY 2009 flood peaks scoured approximately 9 percent of the 2008 cohort and 75 percent of the 2007 cohort, far less than the 90-percent mortality needed to inhibit detrimental encroachment (Figure 3–7). A fine-sediment berm is developing in at least one location along the 13-cms (450-cfs) water edge (e.g., 326+40). Survivors from the 2008 and 2007 cohort were intermixed with the 2009 seedlings and root sprouts (Figure 3–8). Detrimental encroachment is presently a high risk at Hocker Flat overall because young-of-year, 1-year-old, and 2-year-old seedlings make up the bulk of the seedlings at the site (Figure 3–8). The presence of 2-year-old seedlings along the low-water edge indicates there is a risk that seedling-induced detrimental encroachment is starting; however, the threat from seedlings is not as great as that from regrowth (Figure 3–8).

Root sprout-induced detrimental riparian encroachment has not been inhibited between the 13- and 57-cms (450- and 2,000-cfs) water surfaces (Figure 3–8). Root sprout size has increased since 2008, and it is unlikely that the root sprouts will ever be scoured from the low-water edge. Root sprouts will ultimately exert more of a geomorphic influence than seedlings in the re-formation of the riparian berm at Hocker Flat because they are not likely to be removed by flood flows and have the same ability to trap fine sediments and form berms as younger, more easily removed seedlings of similar ages.

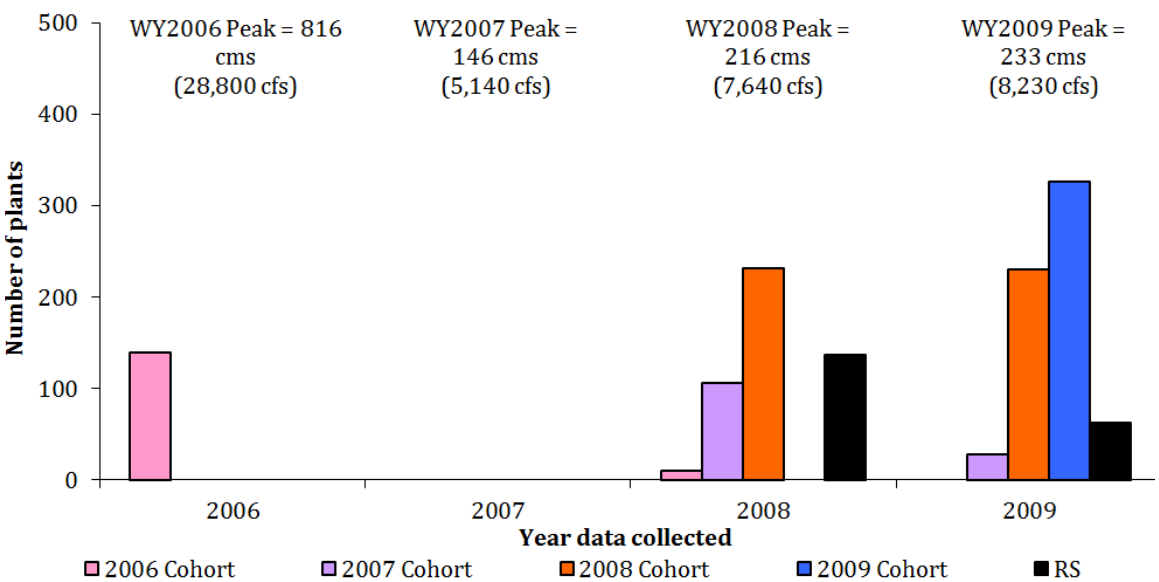


Figure 3–7. Hocker Flat Rehabilitation site WY 2008–09 seedling demographics within the 13- to 57-cms (450- to 2,000-cfs) ROD discharge inundation zone. The total number of seedlings at each site is the combined total of seedlings sampled along transects at each site. (RS = resprout growth.)

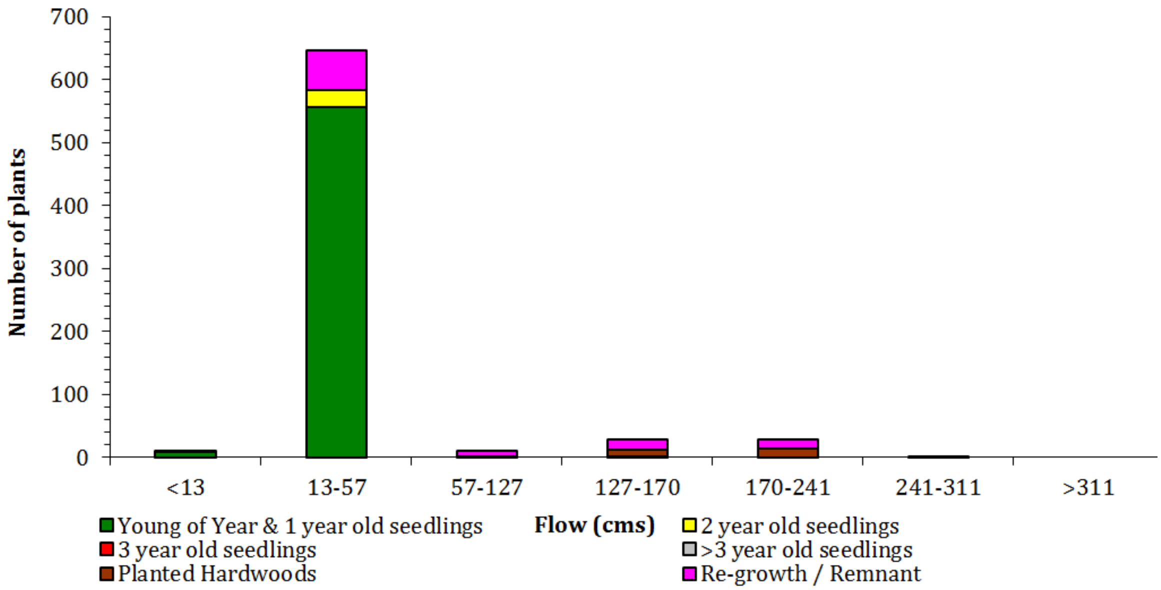


Figure 3–8. Hocker Flat Rehabilitation site WY 2009 Red-Yellow-Green analysis. The total number of seedlings at each site is the combined total of seedlings sampled along transects at each site.

ROD flows, in combination with tributary accretion, have been insufficient to promote hardwood establishment on constructed floodplain surfaces at Hocker Flat. Three years after construction, in fall 2009, 99 percent of naturally regenerating hardwoods sampled (including young-of-year and 1-year-old seedlings) occurred between the 13- and 57-cms (450- and 2,000-cfs) water surfaces.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains areal extent, species richness, and age diversity of riparian vegetation on floodplains. Hocker Flat was the first rehabilitation site built after the ROD was signed; five years after construction, the combination of ROD flows, physical rehabilitation, and revegetation have increased species richness and areal extent of riparian vegetation at Hocker Flat compared to pre-construction vegetation patterns. However, the regeneration of natural woody plant seedlings has not contributed much to the increase in complexity, and naturally regenerated seedlings have not established themselves on constructed floodplain surfaces. Regrowing willows and revegetated woody plants are the primary riparian vegetation growing above the 127-cms (4,500-cfs) water surface level at Hocker Flat. Constructed floodplain surfaces at Hocker Flat were designed to be inundated 0.3 m (1 ft) deep at 170 cms (6,000 cfs; e.g., activity area R2, R4, R5, and R6, Figure A–12). Floodplain inundation is needed to encourage deposition of fines on the floodplain and seedling regeneration. At Hocker Flat, streamflows of 127 cms (4,500 cfs) are needed to create saturated soils at the surface of constructed floodplains. In addition, ground surfaces should be saturated for at least 21 consecutive days to facilitate successful seed germination and primary root growth. Streamflows greater than 170 cms (6,000 cfs) inundate the constructed floodplain 0.3

m (1 ft) deep, with the result that seeds can no longer germinate on the ground surface. Daily average flows greater than 127 cms (4,500 cfs) at Hocker Flat occurred for 19 days in WY 2009, 12 days in WY 2008, and 5 days in WY 2007. Flows inundated the floodplain for short periods in WY 2008 and WY 2009 and were adequate to rework the floodplain surface, causing localized deposition of fine sediments and remixing of gravels and cobbles. Seedlings were documented on constructed floodplain surfaces in 2006, but those seedlings failed to establish. In addition, streamflow magnitude and duration since 2006 have been insufficient to promote further seedling initiation on constructed floodplains at Hocker Flat.

3.3.5. Lower and Upper Reading Creek

Riparian monitoring activities at the Upper Reading Creek rehabilitation site included documenting pre-construction vegetation along one band transect (Table 3–3, Figure A–14). WY 2009 flood peaks were 113 and 233 cms (3,990 and 8,230 cfs) for the winter and spring peaks, respectively.

3.3.5.1. Band Transect 1096+85

Band transect 1096+85 was the only band transect monitored at the Upper Reading Creek and was collocated with cross section 1096+85 (Figure A–14). Band transect 1096+85 intersects the upstream end of a side channel in the middle portion of the rehabilitation site (e.g., activity area R2, Figure A–15). The band transect was sampled along the right bank portion of the cross section, which will be rehabilitated in WY 2010. The unrehabilitated left bank was not monitored. The band transect begins below the 13-cms (450-cfs) water surface, extends across the current riparian vegetation and associated sediment berm, crosses the high-flow side channel and the pre-dam fossilized bar surface, and terminates at the toe of a dredger tailing pile.

3.3.5.2. Pre-Construction Cover Types

In the location where 1096+85 intersects the future rehabilitation site, a white alder patch occurs along the mainstem channel. The white alder patch transitions into an open area that is sparsely covered with non-native grasses (Figure 3–9). The white alder patch will be avoided during construction where feasible.

3.3.5.3. Pre-Construction Initiation and Establishment Trends

In fall 2009, 20 woody plants more than 3 years old were measured on the band transect (Figure 3–9). Seedlings or regrowth were not documented along the mainstem. Seventy-five percent of the woody plants documented were mature white alders, which all seem to belong to one age class. Three mature arroyo willows and two mature black cottonwoods were also documented. Qualitatively, the black cottonwoods seem to be younger than the white alders. All sampled woody plants occurred between the 127- and 311-cms (4,500- and 11,000-cfs) water surface levels.

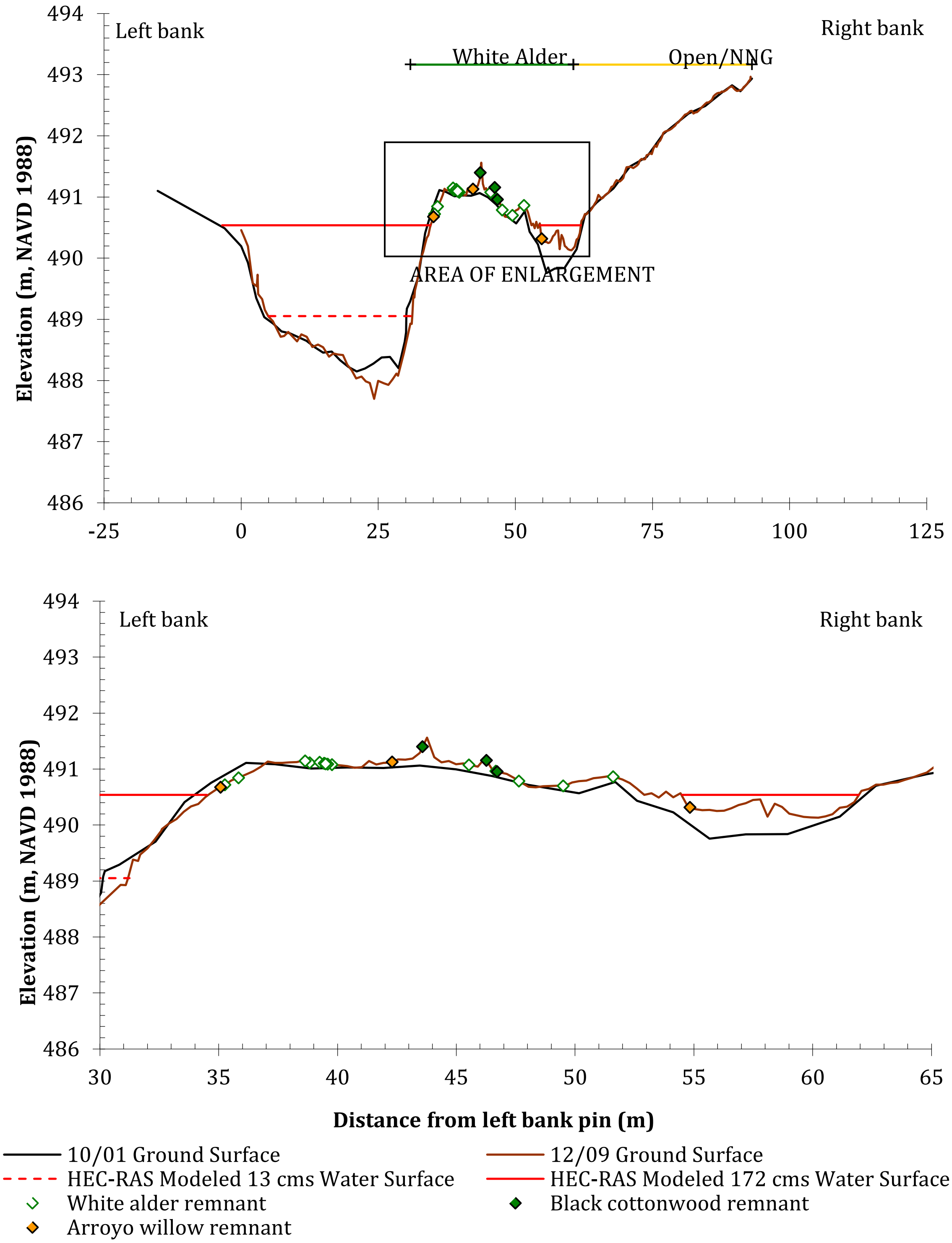


Figure 3–9. Upper Reading Creek: Cross section 1096+85 (above) and enlarged segment of the same cross section (below).

3.3.5.4. Lower and Upper Reading Creek Riparian Discussion

One riparian Priority Question was assessed at the Upper Reading Creek rehabilitation site with data collected in 2009. *Priority Question R–2* asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains areal extent, species richness, and age diversity of riparian vegetation on floodplains. The sampling this year was intended to characterize site vegetation attributes before construction. With the combination of ROD flows and physical rehabilitation, the proposed project should change the current physical and vegetation attributes. Plant species richness should increase and new age classes should regenerate at the site. Channel rehabilitation will also increase the diversity in riparian vegetation edge and vertical structure at the site.

3.3.6. Lower and Middle Indian Creek

Before construction, vegetation mapping and band transects were conducted in WY 2006 to quantify baseline riparian vegetation conditions (McBain & Trush and HVT 2007). Riparian monitoring activities at the Lower Indian Creek rehabilitation site included evaluating changes in hardwood demography along two band transects; areas of remnant, regrowing, and regenerating vegetation; and locations of placed large wood (Table 3–3, Figure A–16). Riparian monitoring at the Lower Indian Creek and Middle Indian Creek sites (i.e., band transects and mapping) was conducted pre-construction in WY 2006 and 2008, and post-construction in WY 2009 (Table 3–4).

3.3.6.1. Vegetation Mapping

In 2006, 2008, and 2009 the total mapped area at Lower Indian Creek was 17.8 hectares (44.0 acres; Figures E–35 through E–38). Pre-rehabilitation in WY 2006 the mapped vegetated area was 13.8 hectares (34.0 acres). Post-rehabilitation, black cottonwood, white alder, and narrowleaf willow are the most common and dominant riparian hardwoods at the site. Remnant vegetation stands are the largest patch type at Lower Indian Creek (Figure 3–10). The area of open water has increased since rehabilitation, due to the construction of a side channel. Construction avoided as many of the mature black cottonwoods as possible (Figure E–35). Revegetation occurred in 2008, and Lower Indian Creek is the only rehabilitation site where revegetation took place one year following construction. Willow regrowth and hardwood seedlings have been documented post-construction. Observations in WY 2008 and 2009 documented (1) natural seedling regeneration on constructed floodplain surfaces and along the side channel and (2) willow regrowth along the 13-cms (450-cfs) side channel margin, constructed high-flow channels, and the mainstem.

In 2006, 2008, and 2009, the total mapped area at the Middle Indian Creek was 7.1 hectares (17.5 acres; Figures E–37 and E–38). Following rehabilitation, white alder and narrowleaf willow were the most common and dominant riparian hardwoods at the site; however, large stands of remnant cottonwood could facilitate a shift in plant species composition in the future. The Middle Indian Creek is unlike other rehabilitation sites because woody riparian vegetation was not cleared along the 13-cms (450-cfs) water edge; the riparian understory was primarily removed. Remnant vegetation stands are the largest patch type at the Middle Indian Creek (Figure 3–11). Human disturbance has increased since rehabilitation, primarily because the clearing of the understory has promoted access and increased vehicular traffic. Seedlings were not documented on constructed surfaces in 2008 and 2009; however, locations where vegetation was cleared were being reclaimed by resprouting willows because of incomplete removal during rehabilitation.

In spite of increased vehicle traffic, Middle Indian Creek is rapidly returning to pre-construction vegetation patterns due to the regrowth of riparian vegetation. The combination of regrowth and remnant vegetation covers an area similar to pre-construction conditions documented in 2006.

Large areas of high-quality riparian vegetation were avoided during construction. In some locations, the riparian vegetation that remained after construction (i.e., remnant vegetation) was black cottonwood, which could provide a seed source for nearby rehabilitation projects.

In 2009, the total vegetated area for Lower Indian Creek was 12.3 hectares (30.5 acres) of the 17.8 hectares (44.0 acres) mapped and accounted for 69.4 percent of the mapped area (Figure 3–10). Open ground constituted 2.8 percent of the mapped area. Sweetclover had colonized many of the open constructed surfaces and was responsible for the reduction in open area between WY 2008 and WY 2009. Remnant vegetation covered 44.6 percent of the mapped area, which represented a slight reduction in area since WY 2008. Revegetation accounted for 9.1 percent of the area one year after planting. Seedling regeneration accounted for 1.4 percent of the mapped area and decreased from WY 2008. Sweetclover grew over the previous year's surviving seedlings and covered many of the suitable nursery site locations on the constructed floodplain surfaces. The area of willow regrowth stayed the same between WY 2008 and WY 2009 (Figure 3–10). Mapped regrowth in 2009 was primarily limited to the constructed side channels and consisted primarily of narrowleaf and dusky willows.

The 2009 total vegetated area for the Middle Indian Creek site increased to 4.3 hectares (10.6 acres) and accounted for 60.7 percent of the mapped area (Figure 3–11). The area of open ground decreased in 2009, with regrowing plants occupying locations previously mapped as open in 2008 (Figure E–37, Figure 3–11). Remnant vegetation increased slightly and was 41.6 percent of the mapped area, similar to the area mapped in 2008. Regrowth accounted for 4.6 percent of the mapped area, about the same as in 2008. Seedling regeneration was not documented in 2009. The Middle Indian Creek rehabilitation has had little effect on the canopy structure and dominant riparian overstory plant species.

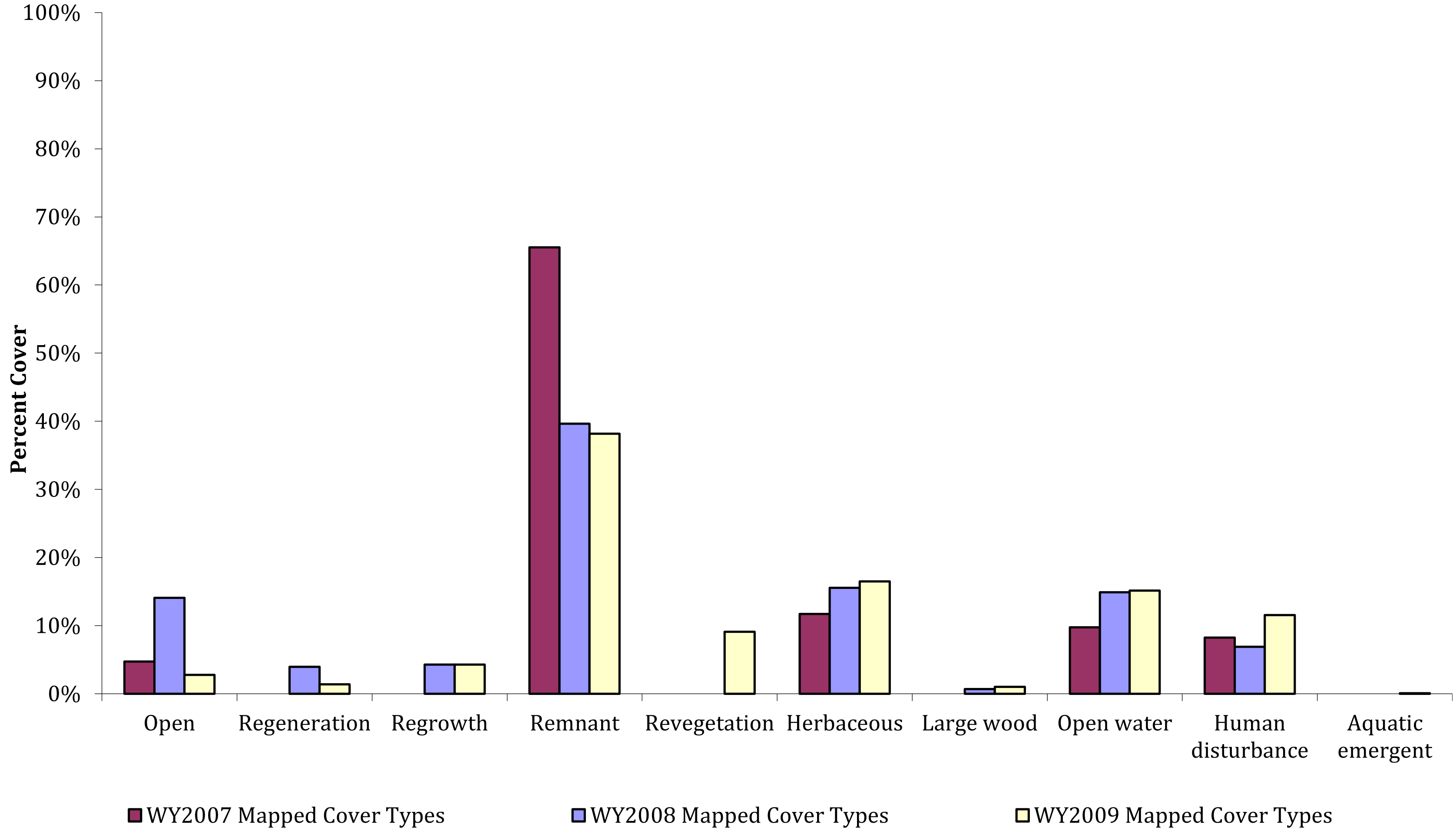


Figure 3–10. Percent of the total area that each mapped cover type occupies within the Lower Indian Creek rehabilitation site area for cover types mapped in 2008 and 2009.

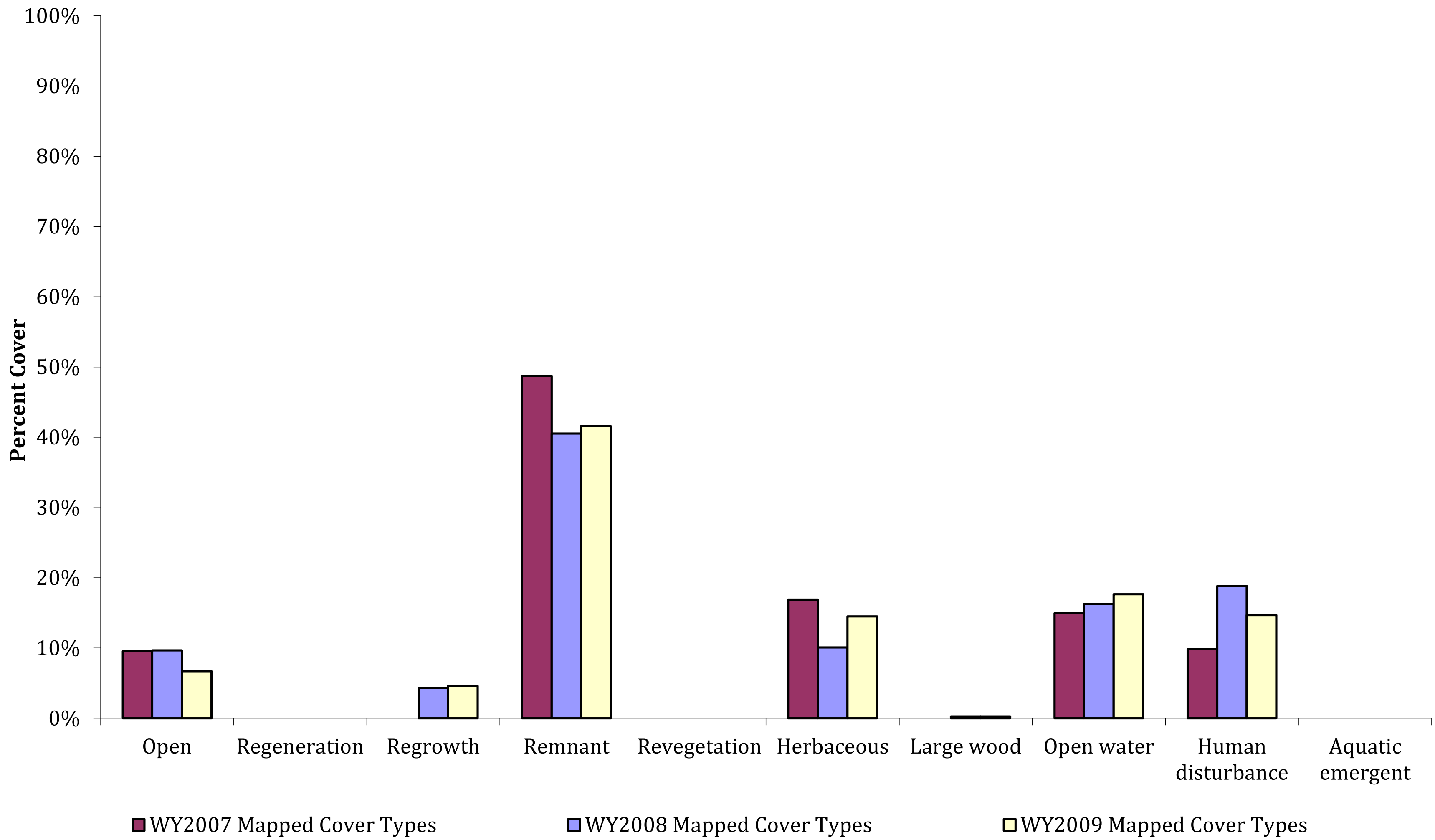


Figure 3–11. Percent of the total area that each mapped cover type occupies within the Middle Indian Creek rehabilitation site area for cover types mapped in 2008 and 2009.

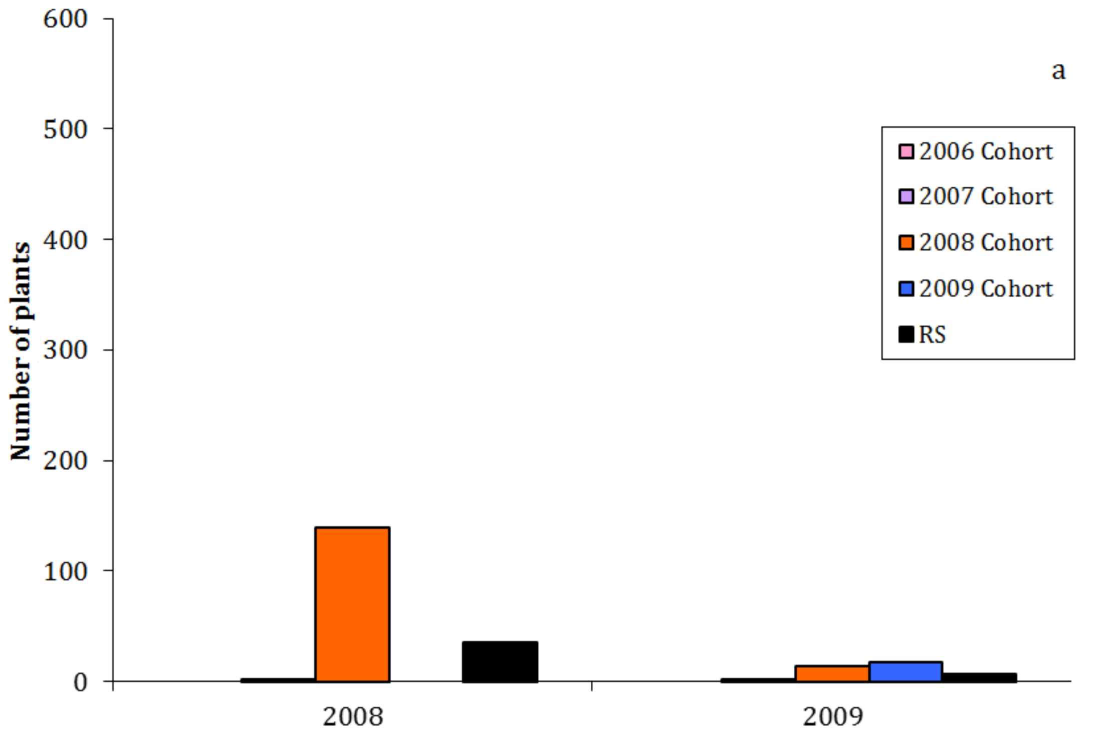
The large wood mapped at the Lower Indian Creek site was placed during construction. In 2008, 61 polygons were observed; 72 polygons were observed in 2009. At the Middle Indian Creek site, the largest amounts of large wood mapped in 2008 (12 polygons) and 2009 (8 polygons) consisted of naturally recruited debris rafts on the mid-channel bar and in locations along the left bank where large wood was placed. The Middle Indian Creek site has more naturally recruited wood than most other sites downstream; however, most of the wood there was augmented by design and construction activities (Figure 3–11).

3.3.6.2. Lower and Middle Indian Creek Riparian and Large Wood Discussion

Three riparian priority questions were assessed at the Middle and Lower Indian Creek rehabilitation sites with data collected in 2009. *Priority Question R–1* asks if process-based riparian targets are met by annual flow releases. The Lower Indian Creek site was monitored during the first two years after construction. One objective for a Dry WY identified in the TRFE was to prolong the inundation of low-elevation bar surfaces during woody plant seed dispersal to prevent seedling germination. Remnant vegetation and WY 2009 streamflows limited seedling regeneration to side-channel margins and constructed floodplain surfaces. Fewer than 50 woody plant seedlings occurred below the 57-cms (2,000-cfs) water surface level on the band transects, and most of those desiccated in the first year of growth (Figures 3–12, 3–13). Ramping rates down from 127 to 13 cms (4,500 to 450 cfs) probably caused the desiccation and may be a more desirable way to inhibit seed germination in dry years than trying to inundate low-lying bars, because it requires less water.

Currently, it is unclear whether ROD flows, in combination with tributary accretion, are capable of inhibiting hardwood seedling establishment along the 13-cms (450-cfs) water surface at Middle Indian Creek. Seedlings have not been documented since construction in 2007, but flood events in WY 2008 and WY 2009 have been unable to remove root sprouts, which has resulted in a gradual increase of narrowleaf willows in cleared areas.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains areal extent, species richness, and age diversity of riparian vegetation on floodplains. One year after construction, the combination of ROD flows, physical rehabilitation, and revegetation has changed the physical and vegetation attributes throughout the Lower Indian Creek site. Black cottonwood regeneration has been widespread and abundant here, unlike at other rehabilitation sites. Furthermore, the majority of seedling regeneration occurred on constructed floodplain surfaces. Plant species richness has increased through revegetation and seedling regeneration, and new age classes have regenerated in several locations. Channel rehabilitation has also increased the diversity in riparian vegetation edge and vertical structure at the site. The presence of remnant black cottonwood trees close to the constructed areas has contributed structure to the vegetation and has supplied a valuable seed source for regeneration. Overall the Lower Indian Creek site has diverse riparian vegetation, which will continue to expand in the future.



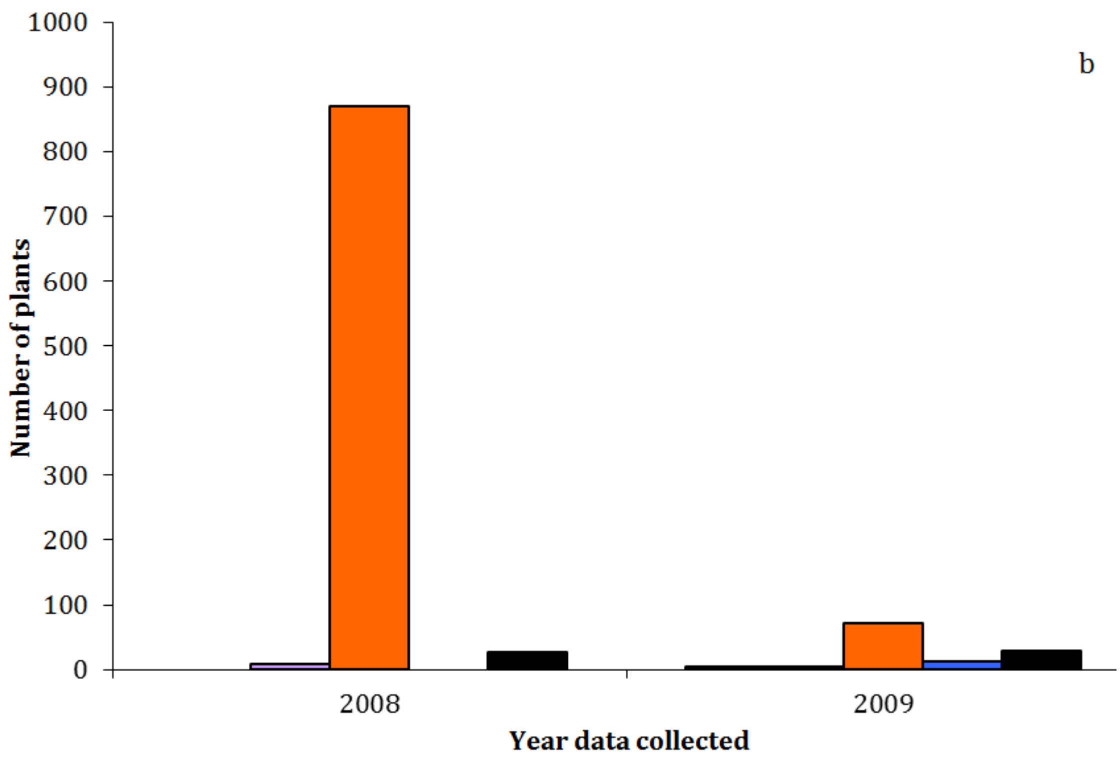


Figure 3–12. Lower Indian Creek rehabilitation site WY 2008–09 seedling demographics. The total number of seedlings is the combined total of seedlings sampled along transects within each zone. Shown above are (a) seedlings within the 13–57 cms (450–2,000 cfs) ROD discharge inundation zone and (b) seedlings within the 57–127 cms (2,000–4,500 cfs) ROD discharge inundation zone.

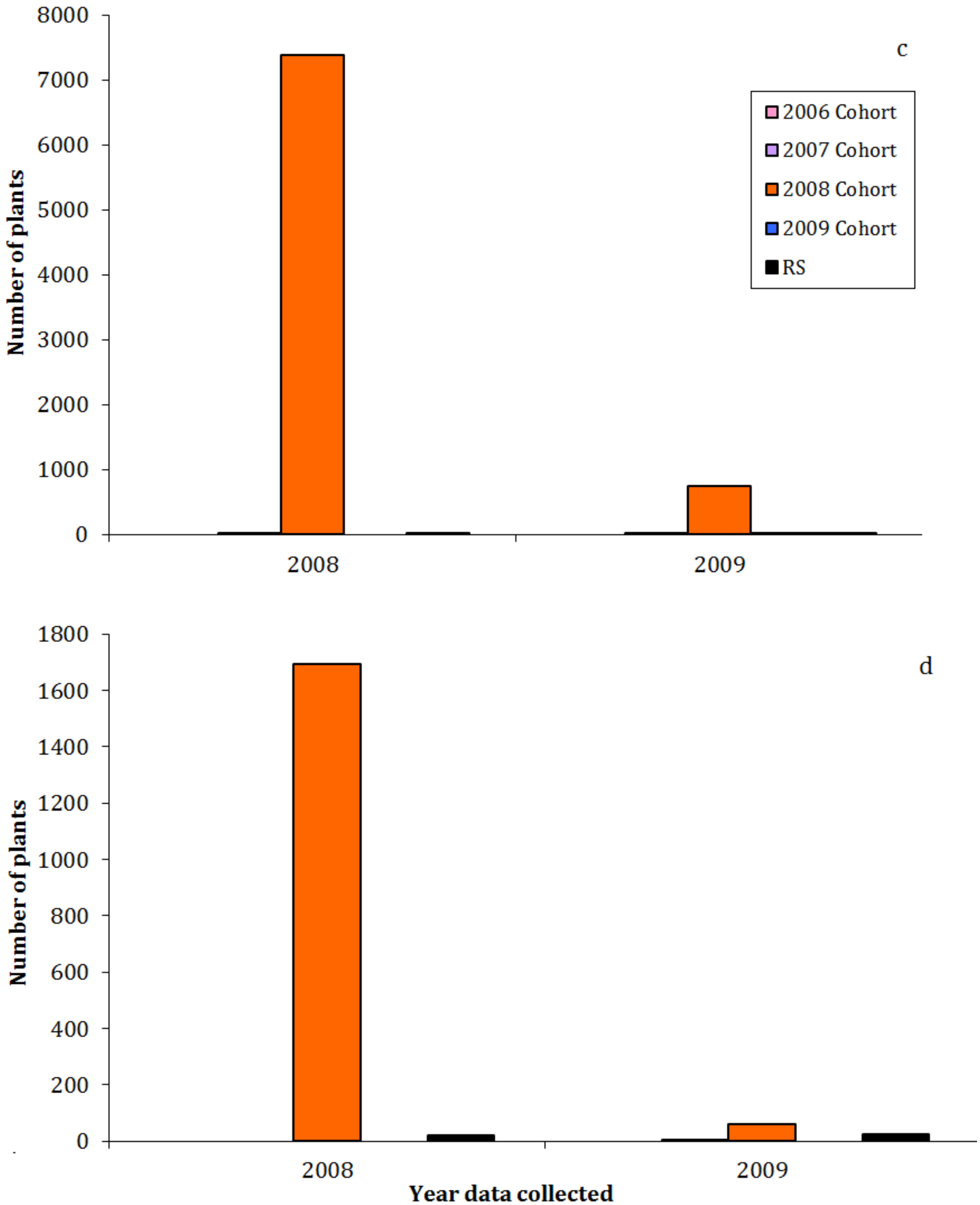


Figure 3–12 (continued). Lower Indian Creek rehabilitation site WY 2008–09 seedling demographics. Shown above are (c) seedlings within the 127–170 cms (4,500–6,000 cfs) ROD discharge inundation zone and (d) seedlings within the 170–241 cms (6,000–8,500 cfs) ROD discharge inundation zone. WY 2008 peak discharge was 133 cms (4,700 cfs), and WY 2009 peak discharge was 153 cms (5,420 cfs).

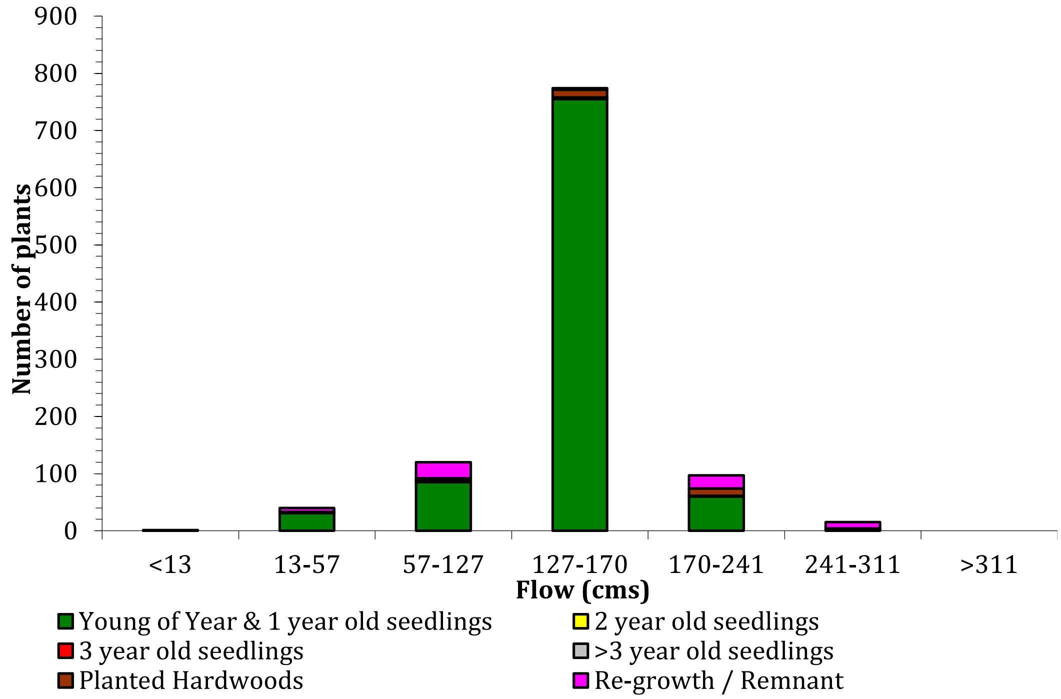


Figure 3–13. Lower Indian Creek rehabilitation site WY 2009 Red-Yellow-Green analysis.

Three years after construction, the effects of physical rehabilitation cannot be readily detected at the Middle Indian Creek site. Current riparian vegetation structure is largely a function of construction activities. There are large remnant trees throughout the berm with a re-sprouting willow and blackberry understory. Since only above-ground stems were removed during rehabilitation (i.e., roots were left as is), the plant species associated with riparian berm and detrimental riparian encroachment are regrowing rapidly. The presence of remnant trees contributes structure to the vegetation and provides seed sources for appropriate nearby sites.

Priority Question R–3 explores the effect of fine-sediment supply in riparian seedling initiation/establishment along the low-flow channel margin. The large quantities of woody plant seedlings at the Lower Indian Creek site are a result of the high quantity of fines in the substrate and a viable seed source close to the constructed surfaces. The highest numbers of seedlings occurred at Lower Indian Creek and were associated with substrates in which more than 60 percent of the sample had grain sizes less than 2 mm (Figure 3–14). Previous studies showed that seeds did not successfully germinate on constructed floodplain surfaces and side channels where modified Wolman pebble counts indicated that the surface substrate had less than 15 percent of the pebble count smaller than 2 mm (0.08 in; Bair 2001). However, based on the overall sampling results from constructed floodplain surfaces and side channels, substrates need a minimum of 15 percent of the overall composition smaller than 2 mm (0.08 in) to promote woody plant seed germination

(Figure 3–14). Substrates with a higher percent composition of finer textured particles (like the Lower Indian Creek rehabilitation site) were better for seed germination due to a higher capillary fringe (and therefore less opportunity for desiccation) and fewer interstitial air pockets (which are fatal to roots).

Priority Question R–4 asks if wood storage is changing over time. Large wood at Indian Creek did increase slightly, although this increase is most likely a result of construction activities in 2007, including recruitment from remnant vegetation left along the side channel and banks.

3.3.7. Vitzthum Gulch

Specific IHAP riparian monitoring activities at the Vitzthum Gulch bank rehabilitation site included evaluating changes in areas of remnant, regrowing, and regenerating vegetation and in locations of placed large wood during the falls of 2008 and 2009 (Table 3–3, Figure A–19). Revegetation did not take place at Vitzthum Gulch. Mapping was conducted in 2008 and 2009 at Vitzthum Gulch (Table 3–4). WY 2009 flood peaks at Vitzthum Gulch were 35 cms (1,230 cfs) and 153 cms (5,420 cfs) for the winter and spring peaks, respectively.

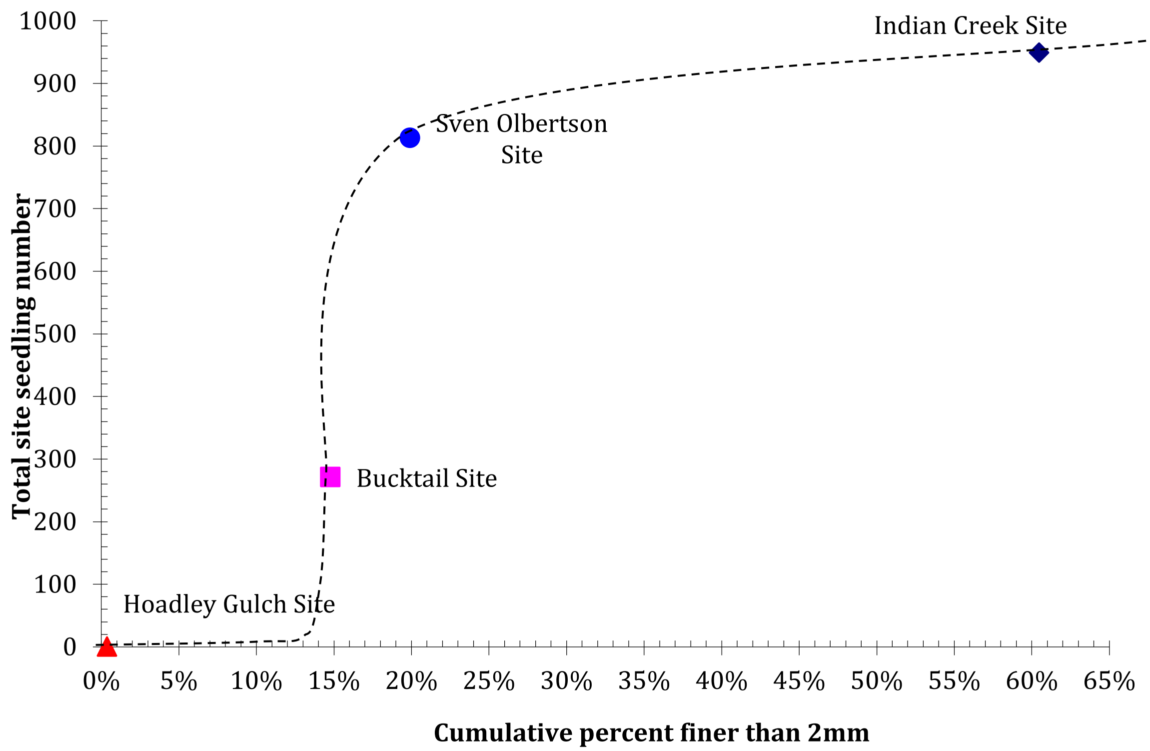


Figure 3–14. Seedling relationship to substrate. The total number of seedlings at each site is the combined total of seedlings sampled along transects at each site.

3.3.7.1. Vegetation Mapping

In 2006, 2008, and 2009 the total mapped area at Vitzthum Gulch was 11.2 hectares (27.6 acres; Figures E–44 and E–45). Following rehabilitation, white alder and narrowleaf willow were the most common and dominant riparian hardwoods at the site. The Vitzthum Gulch site is unlike other rehabilitation sites because 12 notches of fine sediment and woody riparian vegetation were removed perpendicular to the 13-cms (450-cfs) water edge. Remnant vegetation stands are the largest patch type at Vitzthum Gulch. Open water has increased since rehabilitation, primarily because berm notching created shallow alcoves that were inundated at 8.5 cms (300 cfs) in 2008 (Figure E–44). Seedlings were documented on fine sediments deposited in notches after construction (Figure 3–15).

Since 2007, the area of seedling initiation has gone down while the area of regrowth has continued to go up (Figure 3–15). The notches at Vitzthum Gulch are rapidly returning to pre-construction vegetation patterns due to willows that are resprouting and fine sediment deposition in notches. The combination of regrowth and remnant vegetation covers an area similar to pre-construction conditions documented in 2006.

In 2009, the total vegetated area increased to 8.4 hectares (20.7 acres) and accounted for 75 percent of the mapped area (Figure 3–15); the vegetated area was 81.6 percent of the mapped pre-construction area in 2006. The area of open ground decreased in 2009 from 5.8 to 1.2 percent, with sweetclover growing in locations previously mapped as open in 2008 (Figure E–45, Figure 3–15). The colonization of previously bare ground by sweetclover was a primary reason herbaceous patches increased from no cover in 2008 to 4.5 percent of the mapped area in 2009. Overall, five other herbaceous patch types (e.g., bentgrass, aquatic emergents, flat nutsedge, river sedge, and Mexican tea) were mapped only at Vitzthum Gulch, in association with the berm notches, and not at other bank rehabilitation sites. Remnant vegetation decreased slightly to 64.7 percent of the mapped area, similar to the area mapped in 2008. One-year-old seedlings were the most abundant regenerating patch type that was mapped. Regrowth accounted for 5.4 percent of the mapped area, about the same as in 2008. The resprouting areas are filling in and becoming denser rather than spreading out to cover more area. The area where seedlings initiated decreased in 2009 and accounted for only 0.4 percent of the mapped area. The decrease in mapped seedlings is likely due to the increase in the area and abundance of regrowth.

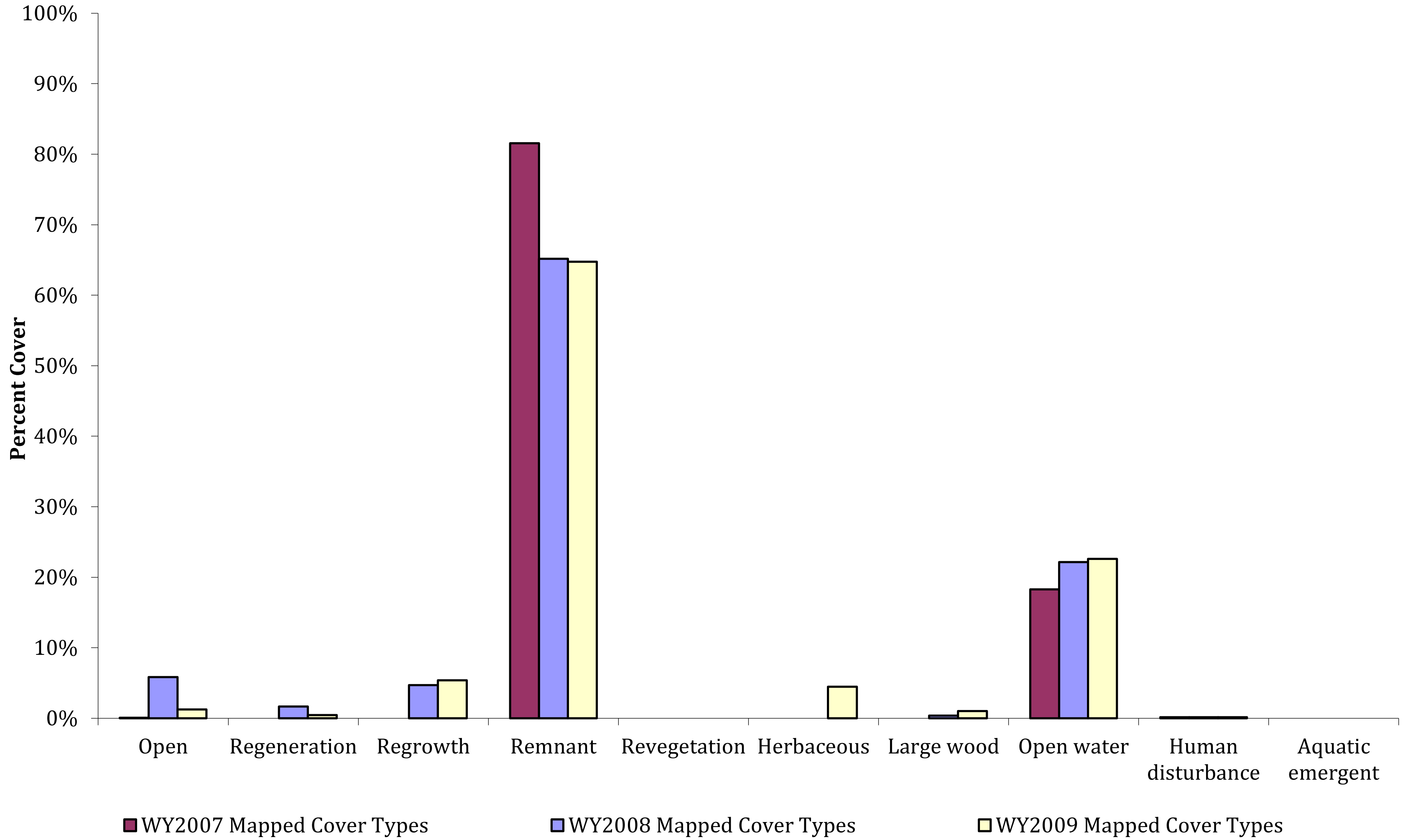


Figure 3–15. Percent of the total area that each mapped cover type occupies within the Vitzthum Gulch rehabilitation site area for cover types mapped in 2008 and 2009.

3.3.7.2. Large Wood Storage

The largest amounts of large wood mapped at Vitzthum Gulch were associated with the berm notches. Large wood was placed at the notch openings on the main channel margin, as well as within some of the notches. Pre-project mapping in 2006 showed no polygons associated with large wood. Site construction resulted in a large initial increase in the area of large wood mapped in 2007 (28 polygons). The area and number of polygons associated with the mapped wood has modestly increased (to 33 polygons today).

The amount of large wood at the site has increased since 2006 and was 1 percent of the mapped area in 2009.. Almost all of the large wood at the site was placed during construction and has not been removed by floods, nor has more large wood been naturally recruited (Figure 3–15).

3.3.7.3. Vitzthum Gulch Riparian and Large Wood Discussion

Two riparian Priority Questions were assessed at the Vitzthum bank rehabilitation site with data collected in 2008 and 2009. *Priority Question R–2* asks if site rehabilitation, in combination with high-flow releases and natural floods, increases and maintains areal extent, species richness, age diversity, and vertical structure of riparian vegetation on floodplains. Three years after construction, the influence of TRFES streamflows and physical rehabilitation at Vitzthum Gulch is rapidly disappearing. Current riparian vegetation structure at Vitzthum Gulch is unchanged outside of the berm notches and is regrowing in fresh sediment deposits where notches were constructed in the berm.

Priority Question R–5 asks if berm punching destabilizes the berm enough that subsequent ROD releases and natural floods continue to remove the remnant vegetation. The riparian berm does not seem to be unraveling as a result of constructed berm notches. The highest discharge at Vitzthum Gulch was 203 cms (7,160 cfs) in WY2008. Post-1997 flood observations indicated that flows above 450 cms (16,000 cfs) are needed to remove individual alder trees growing on the berm, and flows of 680 cms (24,000 cfs) are required to remove portions of the riparian berm. It is very unlikely that flow magnitude above Weaver Creek will ever reach a threshold that could remove the remaining riparian berm before the notches refill with fine sediment and the site reverts to the pre-construction condition (McBain & Trush and HVT 1997, McBain & Trush 1998 unpublished data).

3.3.8. Bucktail and Dark Gulch

Riparian monitoring activities at the Bucktail–Dark Gulch rehabilitation site included evaluating changes in hardwood demography along two band transects and areas of remnant, regrowing, and regenerating vegetation (Table 3–3, Figures E-46, E-47). Monitoring was conducted in WY 2006, in WY 2008 pre-construction, and in WY 2009 post-construction (Table 3–4).

3.3.8.1. Vegetation Mapping

In 2006 and 2009, the total mapped area at Bucktail–Dark Gulch was 31.5 hectares (77.8 acres; Figures E–46 and E–47). Pre-rehabilitation, in WY 2006, the mapped vegetated area was 18.2 hectares (45.0 acres). Post-rehabilitation, white alder and narrowleaf willow are the most common and dominant riparian hardwoods at the site (Figures E–46 and E–47). Remnant vegetation stands are the largest patch type at Bucktail–Dark Gulch. Open water has increased and open land area decreased since rehabilitation due to the construction of side channels. Construction avoided as much of the existing vegetation as possible. Willow regrowth and hardwood seedlings were documented following construction.

A small amount of natural seedling regeneration was documented on constructed floodplains and channel margins in 2009 (Figure 3–16). Willow regrowth has occurred along the 13-cms (450-cfs) channel margin due to incomplete removal during rehabilitation. Stems growing from willow root sprouts are larger than seedlings of a similar age (i.e., a 2-year-old stem from a root sprout is much larger than a 2-year-old seedling). Willow regrowth and seedlings often grow intermixed along the 13-cms (450-cfs) water edge.

In 2009, the total mapped vegetated area was 16.4 hectares (40.6 acres) and accounted for 52.1 percent of the mapped area (Figure E–47). In 2009, the area of open ground was 16.3 percent of the mapped area due to construction. Remnant vegetation was 33.84 percent of the mapped area.

One year after construction, revegetation accounted for 3.1 percent of the area, seedling regeneration accounted for 0.2 percent of the mapped area, and the regrowth of willows removed during construction accounted for 3.1 percent of the mapped area (Figure 3–16). In 2009, patches of young-of-year seedlings were far less extensive than root sprouts. Mapped regrowth in 2009 was primarily limited to the constructed floodplain and alongside channels. The majority of resprouting plants were narrowleaf and dusky willows.

The large wood mapped in 2009 (84 polygons) at the Bucktail–Dark Gulch channel rehabilitation had been placed during construction.

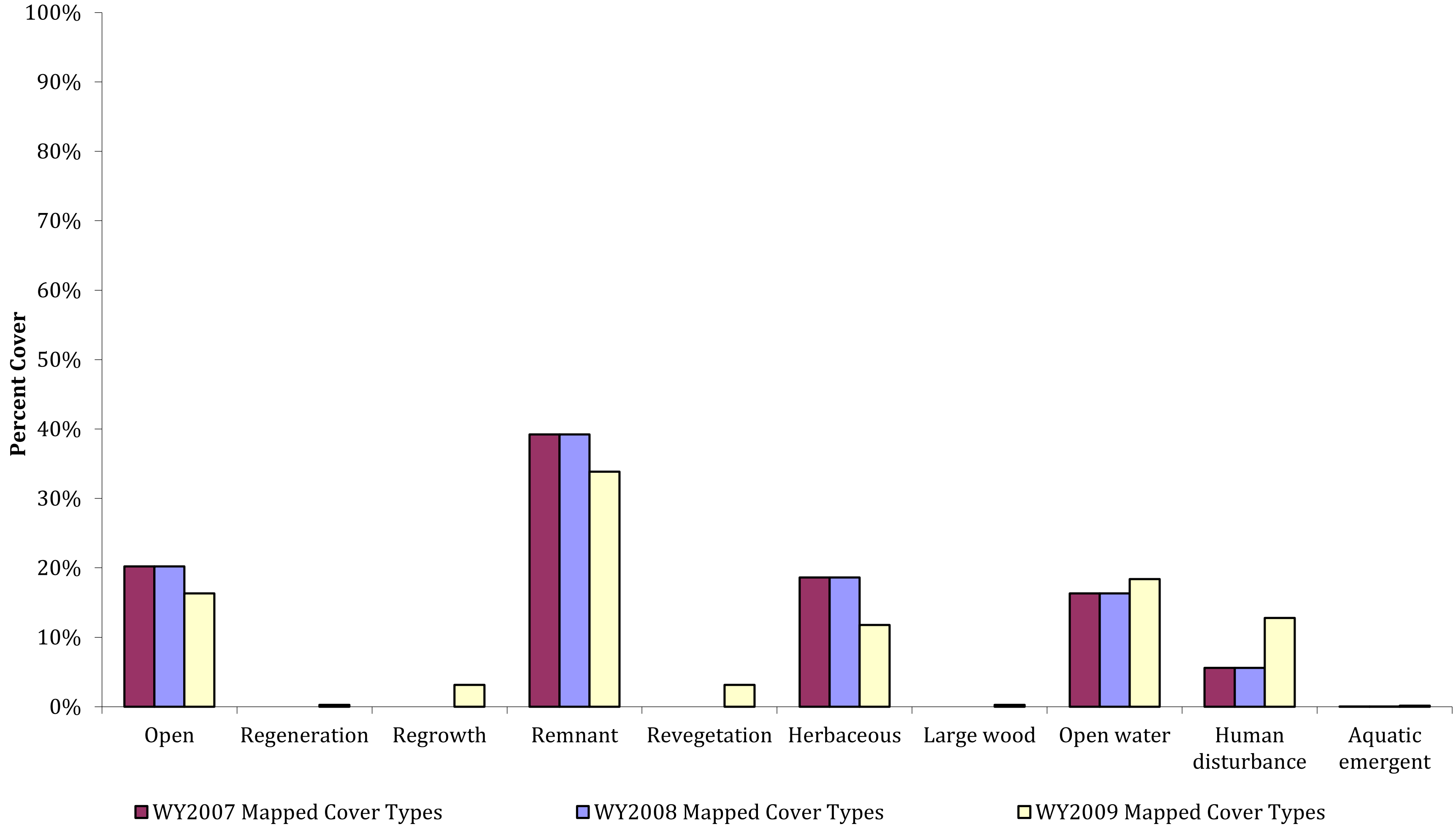


Figure 3–16. Percent of the total area that each mapped cover type occupies within the Bucktail–Dark Gulch rehabilitation site area for cover types mapped in 2009.

3.3.8.2. Bucktail–Dark Gulch Riparian and Large Wood Discussion

Four riparian priority questions were assessed at the Bucktail–Dark Gulch rehabilitation site with data collected in 2009. *Priority Question R–1* asks if process-based riparian targets are met by annual flow releases. Monitoring at Bucktail–Dark Gulch occurred one year after the site was constructed. One objective for a Dry WY type identified in the TRFE was to prolong the inundation of low-elevation bar surfaces during the majority of woody plant seed dispersal periods to prevent seedling germination. The combination of remnant vegetation and WY 2009 streamflows limited seedling regeneration to side channel margins. Seedlings were not documented along the mainstem channel. As a result, the number of seedlings that pose an encroachment threat are low along the 13-cms (450-cfs) water surface (Figure 3–17).

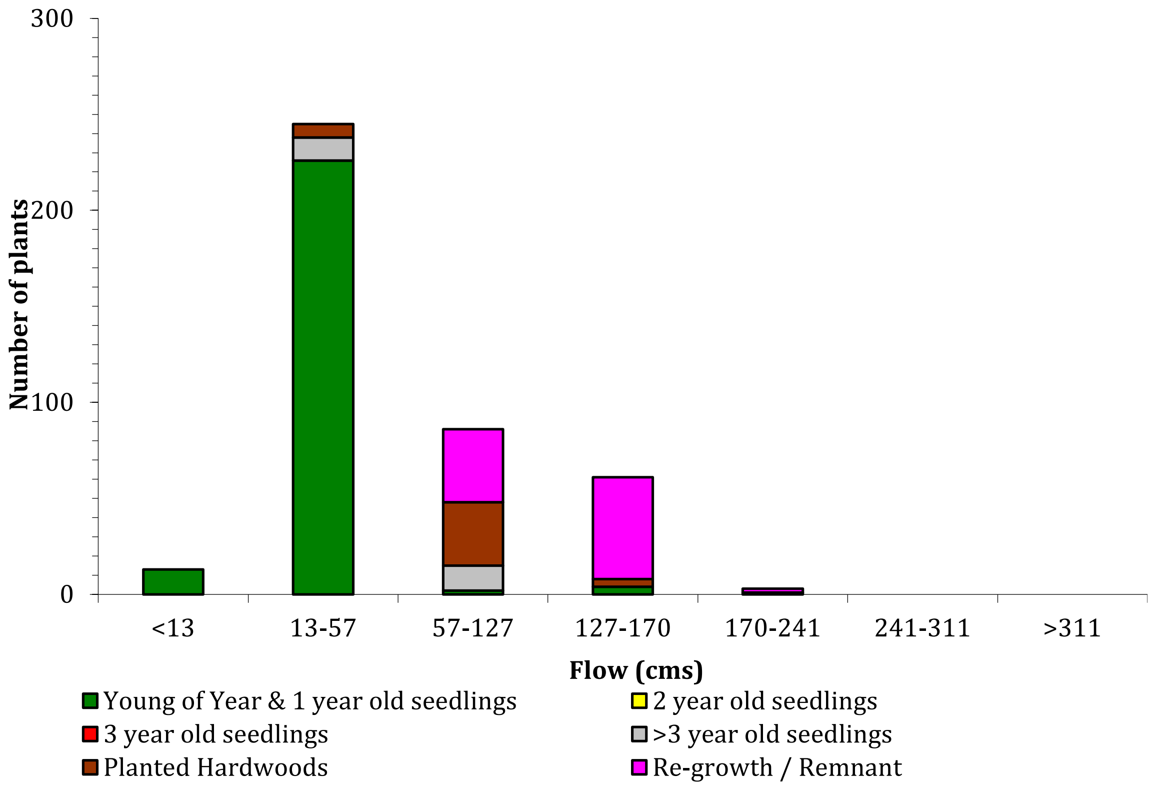


Figure 3–17. Bucktail–Dark Gulch rehabilitation site WY 2009 Red-Yellow-Green analysis. The total number of seedlings at each site is the combined total of seedlings sampled along transects at each site.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains areal extent, species richness, and age diversity of riparian vegetation on floodplains. One year after construction, the combination of ROD flows, physical rehabilitation and revegetation have changed the physical and vegetation attributes throughout the Dark Gulch site. New age classes have regenerated along the side channels. Channel rehabilitation has also increased the diversity of riparian vegetation edge and vertical structure at the site. The presence of remnant senescent trees contributes structure to the vegetation and may provide large wood in the near future. No seedling regeneration was documented on constructed floodplain surfaces. It is possible that constructed floodplain surfaces may develop the necessary conditions for natural woody plant recruitment with future floods. The constructed floodplain surface was inundated in WY 2009; however, fine-sediment deposition was not documented on the constructed floodplain surface and few nursery sites were observed. Overall, the Bucktail–Dark Gulch site has diverse riparian vegetation, which will continue to expand in the future.

Priority Question R–3 explores the effect of fine-sediment supply in riparian seedling initiation/establishment along the low-flow channel margin. The low number of documented seedlings at the Bucktail–Dark Gulch site may be a result of the low quantity of fines in the substrate. The Bucktail–Dark Gulch site had the second lowest amount of fines in the floodplain substrate sampled, and most of the seedlings observed occurred alongside channels and not on the constructed floodplains where bulk samples were taken (Figure 3–14). Based on the band transect and bulk sampling results at constructed floodplain surfaces and side channels, substrates need to have a minimum of 15 percent of the overall composition with grain sizes smaller than 2 mm (0.08 in) to promote woody plant seed germination (Figure 3–14). Substrates with a higher composition of finer textured particles were better for seed germination due to a higher capillary fringe (and therefore less opportunity for desiccation) and fewer interstitial air pockets (which are fatal to roots). It is possible that the lack of fine sediment in the constructed floodplain surface may inhibit future seedling regeneration.

Priority Question R–4 asks if wood storage is changing over time. No new pieces of wood were recruited at Bucktail–Dark Gulch during the 2009 high flows. Overall, large wood storage at this site has not changed since construction.

3.3.9. Hoadley Gulch

Riparian monitoring activities at the Hoadley Gulch rehabilitation site included evaluating the area of remnant, regrowing, and regenerating vegetation in the first year following construction (Table 3–3, Figure A–24). Monitoring was conducted in 2003 and 2009 at Hoadley Gulch (Table 3–4).

3.3.9.1. Vegetation Mapping

In 2003 and 2009, the total mapped area at Hoadley Gulch was 4.3 hectares (10.4 acres; Figure E–53). The 2003 pre-construction mapped vegetated area was 3.0 hectares (7.3 acres). Following rehabilitation, white alder and narrowleaf willow were the most common and dominant riparian hardwoods at the site. Remnant vegetation stands are the largest patch type at Hoadley Gulch (Figure 3–18). Open water has slightly increased since rehabilitation, due to the side-channel construction; however, most of the remnant vegetation around the side channel was preserved and continues to provide cover and shade over the constructed side channel. The mapped area of open ground increased to 3 percent following construction. Revegetation, willow regrowth, and hardwood seedlings were also documented following construction but collectively covered less than 3.5 percent of the mapped area.

In 2009, the total mapped vegetated area was 2.7 hectares (6.8 acres) and accounted for 65.1 percent of the mapped area. In 2009, open ground was 4.5 percent of the mapped area due to construction. Remnant vegetation was 53.9 percent of the mapped area. Regrowth accounted for 0.2 percent of the vegetated area and occurred primarily along the constructed side channel and the constructed floodplain. Regrowth and seedling initiation were observed in areas approximately the same size. Seedlings accounted for 0.3 percent of the mapped area in 2009; no seedlings were observed at Hoadley Gulch in 2003. Revegetation was 2.8 percent of the mapped area in 2009. Stands of young-of-year seedlings grew along the side channel in the revegetated area with a few root sprouts intermixed. No seedlings were documented along the mainstem 13-cms (450-cfs) water edge one year following construction.

The large wood mapped in 2009 (10 polygons) at the Hoadley Gulch channel rehabilitation was placed during construction. Large wood was not observed at the site before construction and naturally recruited wood was not documented in 2009.

3.3.9.2. Hoadley Gulch Riparian and Large Wood Discussion

Four riparian Priority Questions were assessed at the Hoadley Gulch rehabilitation site with data collected in 2009. *Priority Question R–1* asks if process-based riparian targets are met by annual flow releases. Monitoring at Hoadley Gulch occurred one year after the site was constructed. That was too early to detect whether ROD flows are capable of inhibiting hardwood seedling establishment along the 13-cms (450-cfs) water edge at the Hoadley Gulch rehabilitation site. Channel rehabilitation constructed a gravel bar of coarse sediment in the mainstem channel; the placed coarse sediment had no measurable fine sediment, and no seedlings were documented along the 13-cms (450-cfs) water edge (Figure 3–14). The constructed gravel bar had insufficient fine sediment to promote seedling germination, so its composition, rather than high flows, is what has inhibited seedling regeneration at Hoadley Gulch. Flood events in WY 2009 were unable to remove root sprouts, which will result in a gradual increase in narrowleaf willows in cleared areas (Figure 3–18). Seedlings have been documented since construction in 2008 along the side channel and on constructed floodplain surfaces in desirable locations for future riparian vegetation development.

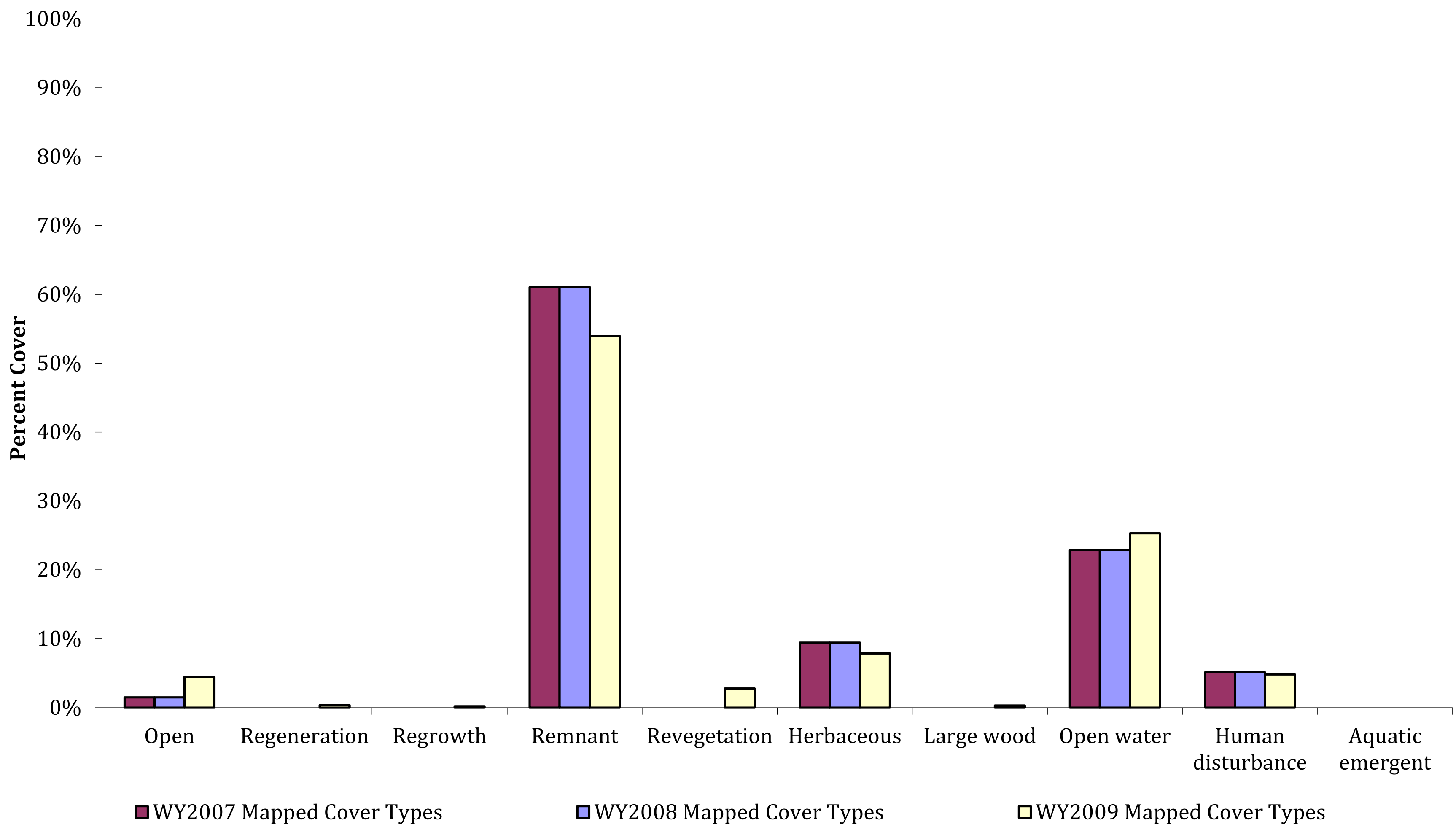


Figure 3–18. Percent of the total area that each mapped cover type occupies within the Hoadley Gulch rehabilitation site area for cover types mapped in 2009.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains the areal extent, species richness, and age diversity of riparian vegetation on floodplains. The combination of ROD flows and physical rehabilitation has changed the physical and vegetation attributes that existed immediately after construction. Black cottonwood and other willow seedlings were observed along the side channel at Hoadley Gulch. Current riparian vegetation structure at Hoadley Gulch is largely a function of construction activities; however, 2009 seedling regeneration will transform the site in less than ten years if the seedlings survive. More age classes now exist at the site and there is greater diversity in riparian vegetation edge and vertical structure at the site. The presence of remnant trees contributes structure to the vegetation, provides seed sources for appropriate nearby sites, and provides shade for the side channel.

Priority Question R–3 explores the effort of fine sediment supply in riparian seedling initiation/establishment along the low-flow channel margin. Riparian hardwoods need exposed fine-textured substrates to germinate. The constructed bar at Hoadley Gulch had no measureable fine sediment in the bulk sample (Figure 4–45), and no seedlings were observed along the 13-cms (450-cfs) water's edge. Substrates with a higher percent composition of finer textured particles were better for seed germination due to a higher capillary fringe (and therefore less opportunity for desiccation) and fewer interstitial air pockets, which are fatal to roots.

Priority Question R–4 asks if wood storage is changing over time. No new pieces of wood were recruited at Hoadley Gulch during the 2009 high flows, and large wood storage at the Hoadley Gulch rehabilitation site has not changed since construction.

3.3.9.3. Lewiston Cableway

Riparian monitoring activities at the Lewiston Cableway rehabilitation site included evaluating changes in hardwood demography along two band transects and areas of remnant, regrowing, and regenerating vegetation (Table 3–3, Figure A–26). The channel rehabilitation project avoided disturbing most of the existing riparian vegetation. Monitoring was conducted in WY 2003 and WY 2009 at Lewiston Cableway (Table 3–4).

3.3.9.3.1. Vegetation Mapping

In 2003 and 2009, the total mapped area at Lewiston Cableway was 5.1 hectares (12.5 acres; Figure E–54). The WY 2003 pre-rehabilitation mapped vegetated area was 2.8 hectares (7.0 acres). Following rehabilitation, white alder and narrowleaf willow are the most common and dominant riparian hardwoods at the site. Remnant vegetation stands are the largest patch type at Lewiston Cableway (Figure 3–19). Open water has decreased and open area has increased since rehabilitation due to the construction of an alternating bar sequence. Construction of the alternating bar sequence avoided much of the existing vegetation, and most of the remnant vegetation was preserved. Willow regrowth and hardwood seedlings have not been documented after construction (Figure 3–19).

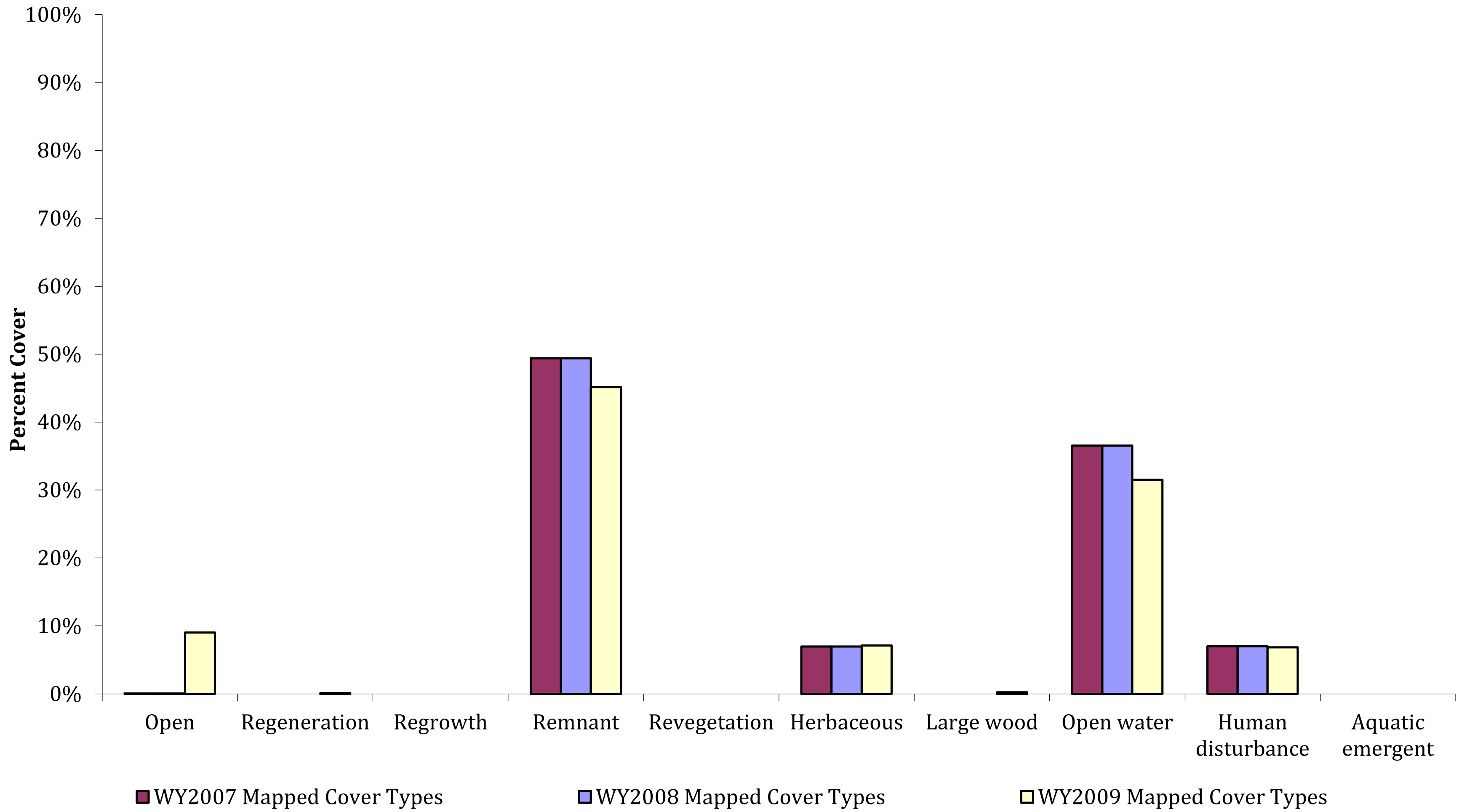


Figure 3–19. Percent of the total area that each mapped cover type occupies within the Lewiston Cableway rehabilitation site area for cover types mapped in 2009.

In 2009, the total mapped vegetated area was 2.6 hectares (6.5 acres) and accounted for 52.4 percent of the mapped area (Figure 3–19). In 2009, the area of open ground was 9 percent of the mapped area due to construction. Remnant vegetation was 41.6 percent of the mapped area. Seedlings and willow regrowth were not mapped because site construction ended in 2008 and no regrowth or seedlings were observed in 2009.

The large wood mapped at the Lewiston Cableway rehabilitation site was placed during construction. In 2009, eight polygons were mapped, no large wood was observed at the site before construction, and no naturally recruited wood was documented (Figure 3–19). Placed large wood covered 0.2 percent of the mapped area in WY 2009.

3.3.9.3.2. Lewiston Cableway Riparian and Large Wood Discussion

Two riparian priority questions were assessed at the Lewiston Cableway rehabilitation site with data collected in 2009. *Priority Question R–1* asks if process-based riparian targets are met by annual flow releases. Monitoring at Lewiston Cableway occurred one year after the site was constructed. ROD flows in WY 2009 were capable of inhibiting hardwood seedling establishment along the 13-cms (450-cfs) water edge at the Lewiston Cableway rehabilitation site. One objective for a Dry WY type identified in the TRFE was to prolong the inundation of low-elevation bar surfaces during the majority of woody plant seed dispersal to prevent seedling germination. The alternating bar sequence that was constructed in 2008 confined the low-water channel. The constructed bars of the alternate bar sequence increased low-water confinement, which lowered the channelbed mobility thresholds from those identified in the TRFE. The net result was that portions of the constructed channel bar surface mobilized at lower discharges than those predicted in the TRFE. In addition, the constructed gravel bar consisted of coarse sediment and had no measureable fine sediment. The lack of fine sediment inhibited germination along the 13-cms (450-cfs) water edge.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains areal extent, species richness, age diversity and riparian vegetation on floodplains. The combination of ROD flows and physical rehabilitation has not changed the physical and vegetation attributes that existed immediately after construction. No new age classes have regenerated at the site. However, channel rehabilitation has increased the diversity in riparian vegetation edge and vertical structure at the site. The presence of remnant trees contributes structure to the vegetation and provides seed sources for appropriate nearby sites.

Priority Question R–4 asks if wood storage is changing over time. New pieces of wood were not recruited at Lewiston Cableway during the 2009 high flows, and large wood storage has not changed since construction.

3.3.9.4. Deadwood Creek

Riparian monitoring activities at the Deadwood Creek rehabilitation site included evaluating the area of remnant, regrowing, and regenerating vegetation and the locations of placed large wood in the first year following construction (Table 3–3, Figure A–27). Revegetation did not occur at Deadwood Creek. Monitoring was conducted in 2003 and 2009 (Table 3–4).

3.3.9.4.1. Vegetation Mapping

In 2003 and 2009, the total mapped area at Deadwood Creek was 2.1 hectares (5.2 acres; Figure E–56). The 2003 pre-rehabilitation mapped vegetated area was 1.7 hectares (4.2 acres). Following rehabilitation, white alder and narrowleaf willow were the most common and dominant riparian hardwoods at the site. Remnant vegetation stands are the largest patch type at Deadwood Creek (Figure 3–20). Open water has increased since rehabilitation, due to the side channel construction. Open ground was not mapped prior to construction, but open ground made up over 10 percent of the mapped area in 2009. Regrowth and seedlings were also documented following construction (Figure 3–20).

In 2009, the total mapped vegetated area was 1.4 hectares (3.4 acres) and accounted for 65.1 percent of the mapped area (Figure 3–20). In 2009, the area of open ground was 11.5 percent of the mapped area, due to construction, and remnant vegetation accounted for 47.8 percent of the mapped area. Regrowth accounted for 2.9 percent of the vegetated area and occurred primarily along the constructed side channel and in cleared areas. Areas where regrowth was documented were larger than areas where seedling initiation was observed. Seedlings accounted for 0.4 percent of the mapped area in 2009; however, no seedlings were observed at Deadwood Creek in 2003. Stands of young-of-year seedlings with root sprouts intermixed were abundant at Deadwood Creek along the constructed side channel.

The large wood mapped at the Deadwood Creek channel rehabilitation site was placed during construction. Post-construction, eight polygons were observed in 2009. Large wood was not observed at the site before construction, and no naturally recruited wood was documented in 2009 at Deadwood Creek.

3.3.9.4.2. Deadwood Creek Riparian and Large Wood Discussion

Two riparian priority questions were assessed at the Deadwood Creek rehabilitation site with data collected in 2009. *Priority Question R–1* asks if process-based riparian targets are met by annual flow releases. Monitoring at Deadwood Creek occurred one year after the site was constructed. It is too early to detect whether ROD flows are capable of inhibiting hardwood seedling establishment along the 13-cms (450-cfs) water edge at the Deadwood Creek rehabilitation site. Flood events in WY 2009 were unable to remove root sprouts, which will result in a gradual increase in narrowleaf willows in cleared areas (Figure E–56). Seedlings have been documented since construction in 2008. However, seedling regeneration took place in 2009 after

TRFE flood peaks, and thus a change in seedling area cannot be measured until following years and flood events.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains the areal extent, species richness, and age diversity of riparian vegetation on floodplains. It is not apparent whether the combination of ROD flows and physical rehabilitation has changed the physical and vegetation attributes that existed immediately after construction. Floodplains were not constructed at Deadwood Creek, and the current riparian vegetation structure is largely a function of construction activities. More age classes now exist at the site, and there is greater diversity in riparian vegetation edge and vertical structure at the site. The presence of remnant trees contributes structure to the vegetation and provides seed sources for appropriate nearby sites.

Priority Question R–4 asks if wood storage is changing over time. No changes in the quantity of large wood or in the location of placed large wood were documented during mapping. New pieces of wood were not observed at Deadwood Creek during the 2009 monitoring and thus large wood storage has not changed since construction.

3.3.9.5. Sven Olbertson

Riparian monitoring activities at the Sven Olbertson rehabilitation site included evaluating changes in hardwood demography along two band transects and areas of remnant, regrowing, and regenerating vegetation (Table 3–3, Figure A–28). Riparian monitoring (i.e., band transects and mapping) was conducted at the Sven Olbertson site in WY 2006 and WY 2008 pre-construction and in WY 2009 post-construction (Table 3–4).

3.3.9.5.1. Vegetation Mapping

In 2006 and 2009, the total mapped area at the Sven Olbertson site was 8.0 hectares (19.7 acres; Figure E–58). In WY2006, prior to rehabilitation, the mapped vegetated area was 4.6 hectares (11.4 acres). Following rehabilitation, white alder and narrowleaf willow are the most common and dominant riparian hardwoods at the site; however, there are some mature black cottonwoods close to the constructed side channel. Remnant vegetation stands are the largest patch type at Sven Olbertson (Figure 3–21). The area of open water and open ground has decreased since rehabilitation, due to the construction and revegetation of a more defined set of side channels and high-flow channels. Construction avoided as much of the existing vegetation as possible. Riparian vegetation was not removed along the mainstem channel. Willow regrowth and hardwood seedlings have been documented post-construction (Figure 3–21). Natural seedling regeneration was documented only along constructed side-channel margins in 2009. Willow regrowth along the 13-cms (450-cfs) side-channel margin was documented in WY 2009 due to incomplete removal during rehabilitation.

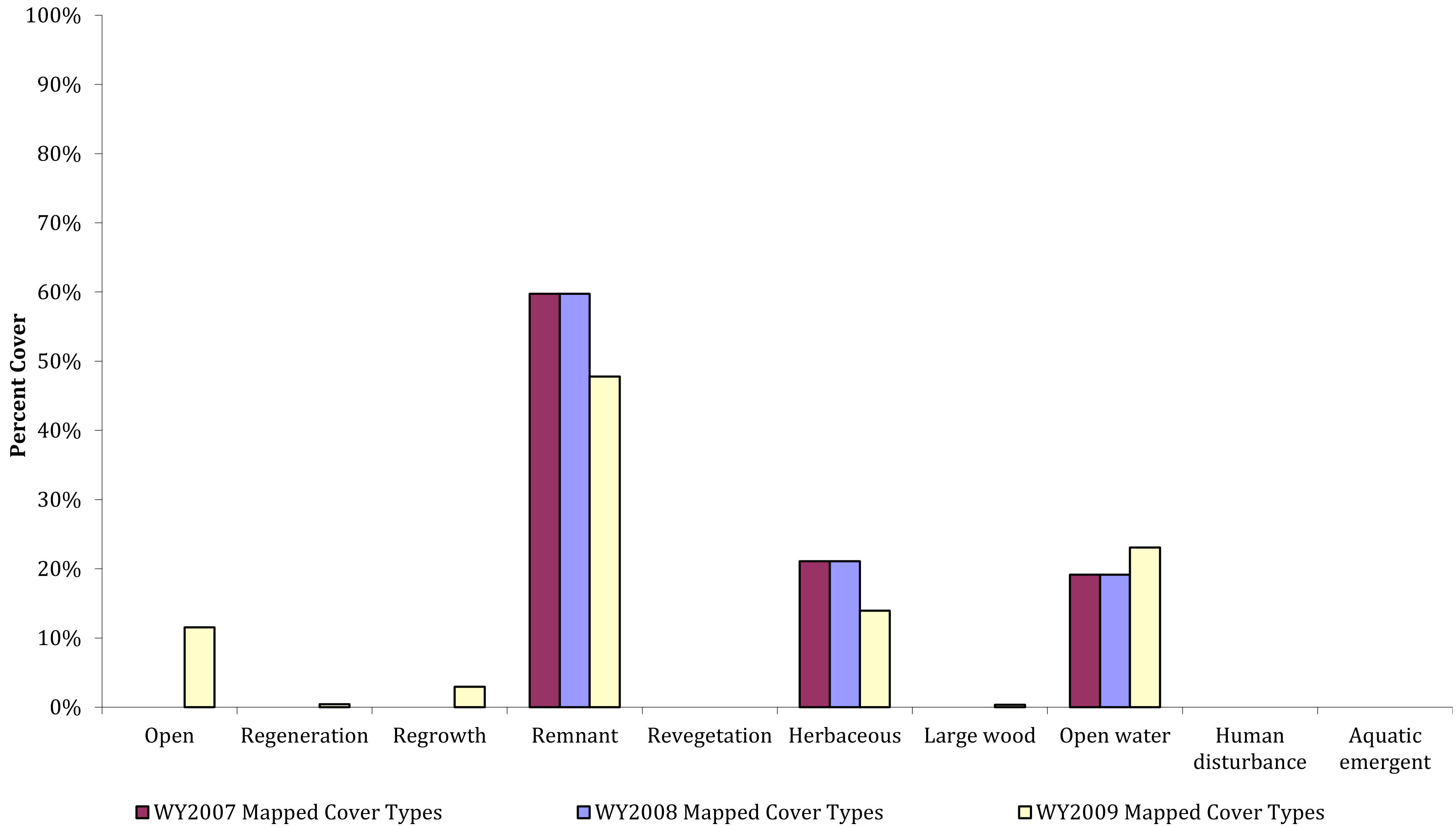


Figure 3–20. Percent of the total area that each mapped cover type occupies within the Deadwood Creek rehabilitation site area for cover types mapped in 2009.

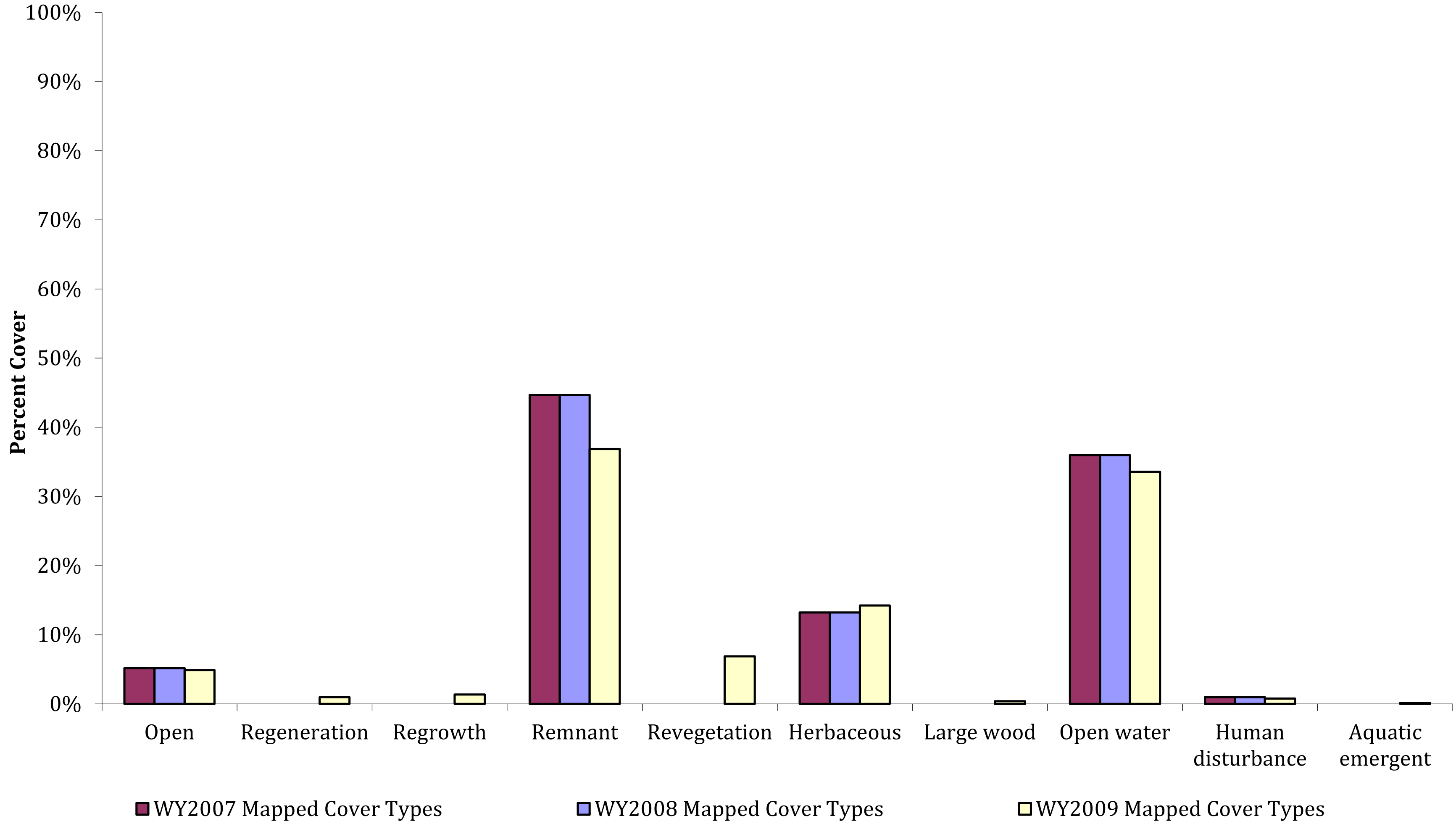


Figure 3–21. Percent of the total area that each mapped cover type occupies within the Sven Olbertson rehabilitation site area for cover types mapped in 2009.

In 2009, the total mapped vegetated area was 4.8 hectares (11.9 acres) and accounted for 60.3 percent of the mapped area (Figure 3-21). Sven Olbertson is the only rehabilitation site where, one year after construction, the vegetated area is larger than it had been before construction. In 2009, the area of open ground was 4.9 percent of the mapped area, a reduction from the pre-construction area. Remnant vegetation was 36.9 percent of the mapped area. One year after construction, revegetation accounted for 6.9 percent of the mapped area, seedling regeneration 1.0 percent, and willow regrowth 1.4 percent (Figure 3–21). Mapped regrowth in 2009 was primarily limited to the constructed side channels and was primarily narrowleaf and dusky willows.

The large wood mapped at the Sven Olbertson side channel rehabilitation was placed during construction. In WY 2009, 23 polygons were mapped. Large wood was not documented at the site before construction, and no naturally recruited wood was documented in WY 2009 (Figure 3–21). Placed large wood covered 0.5 percent of the mapped area in WY 2009.

3.3.9.5.2. Sven Olbertson Riparian and Large Wood Discussion

Three riparian priority questions were assessed at the Sven Olbertson rehabilitation site with data collected in 2009. *Priority Question R–1* asks if process-based riparian targets are met by annual flow releases. Monitoring at Sven Olbertson occurred one year after the site was constructed. One objective for a Dry WY type identified in the TRFE was to prolong the inundation of low-elevation bar surfaces during the majority of woody plant seed dispersal to prevent seedling germination. The combination of remnant vegetation and WY 2009 streamflows limited seedling regeneration to side-channel and alcove margins. Seedlings were not documented along the mainstem channel.

Priority Question R–2 asks if bank rehabilitation, in combination with high-flow releases and natural floods, increases and maintains the areal extent, species richness, and age diversity of riparian vegetation on floodplains. The combination of ROD flows, physical rehabilitation, and revegetation has changed the physical and vegetation attributes throughout the Sven Olbertson site. New age classes have regenerated along the side channels. Channel rehabilitation has also increased the diversity of riparian vegetation edge and vertical structure at the site. The presence of remnant black cottonwood trees close to the constructed areas contributes structure to the vegetation and may provide a valuable seed source for future regeneration events. Overall, the Sven Olbertson site has diverse riparian vegetation which will continue to expand in the future.

Priority Question R–3 explores the effect of fine-sediment supply in riparian seedling initiation/establishment along the low-flow channel margin. The large quantities of woody plant seedlings at the Sven Olbertson rehabilitation site are a result of the high quantity of fines in the substrate. The Sven Olbertson site had the second highest amount of fine sediment in the side channel substrate sampled where most of the seedlings occurred (Figure 3–14). Based on the band transect and bulk sampling results at constructed floodplain surfaces and side channels, substrates need a minimum of 15 percent of the overall composition with grain sizes smaller than 2 mm (0.08 in) to promote woody plant seed germination (Figure 3–14). Substrates with a higher percent composition of finer textured particles (like the Sven Olbertson side channel) were better for seed germination due to a higher capillary fringe (and therefore less opportunity for desiccation) and fewer interstitial air pockets (which are fatal to roots).

3.4. Discussion

3.4.1. Water Year Targets

Priority Question R–1 monitored whether or not water year riparian management targets were met.

Riparian results indicated seedlings were successfully scoured at Pear Tree and Valdor, the two most-downstream sites monitored. Riparian management targets were not met at Hocker Flat, where regrowing willows are likely to form a monotypic band along the mainstem water edge in the next 5 to 10 years. Monitoring conducted at Indian Creek and five additional upstream sites was inconclusive, due to the short period of time between construction and monitoring (which minimizes the time plants have to re-establish and grow). Continued annual monitoring of all water-year types is necessary to determine if core geomorphic and riparian management targets are met, especially considering that WY 2009 results are variable and not all fundamental management targets have been met (Table 3–5).

Table 3–5. Overview of TRFE and IAP Riparian Scour and Recruitment Targets for Monitored Sites

Site	Was Scour Target Met?	Was Floodplain Recruitment Target Met?
Pear Tree	Yes	No
Valdor Gulch	Yes	No
Hocker Flat	Yes	No
Indian Creek	Yes	Yes
Bucktail–Dark Gulch	Yes	Too early to tell
Hoadley Gulch	Too early to tell	Too early to tell
Lewiston Cableway	Yes	No
Sven Olbertson	Yes	No

3.4.2. Riparian and Large Wood-Related Monitoring

Priority Question R–2 assessed changes in areal extent, species richness, age diversity, and vertical structure of floodplain vegetation after rehabilitation at 10 sites. At six sites, it was too soon after rehabilitation to be able to detect changes in riparian vegetation parameters because there has not been sufficient time between construction and monitoring to allow for plant growth. Improvement was observed at four sites: Connor Creek, Lower Indian Creek, Bucktail–Dark Gulch, and Sven Olbertson. At Hocker Flat, natural seedling regeneration has not contributed to the increase in complexity, and no natural seedlings have become established on constructed floodplains. Monitoring should be continued as seedlings have time to sprout and grow in upcoming years.

Priority Question R–3 examined the effect of fine-sediment supply on seedling initiation and establishment at four sites. Substrates with a higher percent composition of finer textured particles—like the Lower Indian Creek and Sven Olbertson rehabilitation sites—were better for seed germination because they provided a higher capillary fringe (and therefore less opportunity for desiccation) and fewer air pockets (which are fatal to roots). It is possible that the lack of fine sediment in the constructed floodplains may inhibit future seedling regeneration, as was observed at Hoadley Gulch.

Priority Question R–4 assessed changes in large wood storage at nine rehabilitation sites since construction. At six of the sites, large wood storage decreased. With the exception of Valdor Gulch, these sites were closest to Lewiston Dam (Bucktail–Dark Gulch and upstream), where the input of large wood is low. Slight increases in large wood storage were observed at Conner Creek, Hocker Flat, and Indian Creek. Wood was not placed during construction at Hocker Flat; thus all large wood mapped at the site originated from natural recruitment.

3.4.3. Root Regrowth

While riparian scour targets have been met at downstream sites (i.e., Valdor Gulch and Pear Tree), ROD flows were unable to scour root sprouts (i.e., roots remnant from construction). Root sprouts in the Canyon Creek suite were unaffected by ROD flows. At Valdor Gulch, post-construction regrowth has allowed willows to regenerate similar to pre-construction conditions due to incomplete root removal during rehabilitation. A sediment berm has formed, and the low-water channel has begun to simplify. At Conner Creek, because of root regrowth and potential berm development, the floodplain could lose some function, and the area will become an extension of the existing riparian berm. At Hocker Flat, re-encroachment, assisted by remnant roots, has already begun.

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CHAPTER 4. ESTIMATION OF CHINOOK SALMON AND COHO SALMON REARING-HABITAT AREA AT SPECIFIC REHABILITATION SITES ON THE TRINITY RIVER

4.1. Introduction

The primary hypothesis of the TRFE (USFWS and HVT 1999) is that the mechanical manipulation of the channel, in combination with coarse sediment augmentation and release of geofluvial flows, will dramatically increase riverine habitat quantity, quality, and diversity. Design and implementation of channel rehabilitation projects, as well as all management actions, are to be conducted under an adaptive management framework. The goal of this assessment was to evaluate the effectiveness of TRRP restoration actions to determine the changes in salmonid habitat resulting from both mechanical channel rehabilitation and restoration of fluvial processes necessary to create and maintain riverine habitats. This assessment evaluated the salmonid habitat response to mechanical rehabilitation and geofluvial flows at specific channel rehabilitation sites within the project reach. This assessment will address objective 2.11 (Assessment 1H) of the TRRP's Integrated Assessment Plan (Trinity River Restoration Program and ESSA Technologies 2009). Results will contribute to the TRRP's adaptive management by providing short-term feedback to improve management actions, specifically channel rehabilitation, coarse-sediment augmentation, and annual flow management, and by providing information for long-term trend monitoring.

Three high-priority fish habitat questions were assessed at channel rehabilitation sites through site-specific analyses. *Priority Questions F–1 through F–3* are fundamental to assessing the outcomes of core TRRP management actions, including the degree to which overarching TRRP objectives have been met.

- F–1) What was the change in Chinook salmon and coho salmon rearing habitat at winter base flow resulting from construction of channel rehabilitation sites (pre-/post-construction assessment)?
- F–2) How do channel rehabilitation treatments alter the flow-habitat relationships and habitat availability at these locations?
- F–3) What were the quantity and quality of Chinook salmon and coho salmon rearing habitat at winter base flow at selected channel rehabilitation sites before construction in 2009?

4.2. Methods

4.2.1. Habitat Guild Definitions

The methodology applied to monitor fish habitat was a map-based effort and included several components.

Habitat assessment techniques were developed at the Indian Creek rehabilitation site on the Trinity River in 2007 and applied to an extended area in 2008 (Goodman et al. 2010). Habitat guilds were defined (Table 4–1) and mapped using the protocol described in Goodman et al. (2010). For this report, optimal Chinook salmon rearing habitat includes areas that meet both depth/velocity (DV) and cover (C) criteria. Suitable Chinook salmon rearing habitat includes areas that meet either DV or C but not both. The optimal and suitable habitats together make up the total Chinook salmon rearing habitat (total habitat). Unsuitable Chinook salmon rearing habitat includes areas that meet neither of these criteria. Coho salmon rearing habitat was limited to areas that meet both DV and C criteria, and all other areas were considered unsuitable habitat.

4.2.2. Habitat Mapping

The fish habitat surveys identified areas that met guild definitions within each area at a specific streamflow. The data were developed as a series of spatially referenced geographic information system (GIS) layers. For Chinook salmon and coho salmon rearing habitat, a single layer was created for each guild (fry and presmolt) based on depth and velocity criteria. Separate layers demarcating in-water escape cover and the river bank were also created. Flow-to-habitat relationships were developed by conducting repeat surveys at the same location during multiple streamflow conditions.

Surveys began at the top of a study site and crews worked downstream collecting GPS points to demarcate the bank and perimeter of each guild area. At each GPS point, data collection began at the bank and worked toward mid-channel by measuring appropriate habitat variables for each layer. A polyline shapefile was used to demarcate the perimeter of complex habitat areas and to facilitate accurate data post-processing. Water depth and mean column velocity were determined at each measuring point. Hand-held flow meters were used to measure velocity. The cover layer delineated and categorized areas of in-water cover as either open or

Table 4–1. Guilds and Their Associated Habitat Criteria for Fish Habitat Mapping as Part of the 2008 Trinity River Site Assessment (Goodman et al. 2010)

Habitat Guild	Variable	Criteria
Chinook salmon and coho salmon fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column velocity	0 to 0.12 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood
Chinook salmon and coho salmon presmolt (50 to 200 mm)	Depth	>0 to 1 m
	Mean column velocity	0 to 0.24 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood

within reach of escape cover. GPS points were taken with a Trimble ProXH receiver using a tablet PC in Trimble Terrasync (ver. 3.21). All data were referenced to projection NAD 1983 State Plane California I FIPS 0401, and the distance unit was U.S. survey feet. When needed, GPS points were offset using either a Laser Atlanta Advantage or Trupulse 360 laser range finder with internal compass and inclinometer. The laser range finders were calibrated and tested daily or when their batteries were changed, as per manufacturer recommendations. This procedure was repeated downstream, delineating areas that met guild definitions to produce a spatially explicit planar representation at each survey area.

Rehabilitation site assessments consisted of implementing the rearing-habitat surveys described above at rehabilitation site locations. Surveys were targeted for the water years before and after construction to evaluate changes from this management action. Additionally, we plan to resurvey a proportion of these sites in subsequent years to evaluate how changes in the physical and biological characteristics at the sites (via high flows and gravel augmentation) have influenced salmonid habitat.

Rehabilitation site assessment surveys were conducted during the 8.5-cms (300-cfs) release from Lewiston Dam that extended from October to April. Four of the sites (Sven Olbertson, Lewiston Cableway, Hoadley Gulch and Bucktail–Dark Gulch) were post-construction assessments that were compared to pre-construction data collected by Goodman et al. (2010). Deadwood Creek, which had a relatively low level of mechanical alteration, was the only channel rehabilitation site constructed in 2008 where rearing habitat was not surveyed. The remaining two sites (Reading Creek and Lowden) were pre-construction assessments to be revisited after construction. These were the only two channel rehabilitation sites planned for construction in 2010.

At selected locations, rearing-habitat surveys were conducted under multiple streamflow conditions. The multiple streamflow assessments were targeted for areas with channel rehabilitation site design features that would alter the streamflow-to-habitat relationships. These features include floodplain re-contouring, side-channel construction or modifications, point-bar construction, and other channel reshaping treatments. Sample sites included one location each at Lewiston Cableway, Lowden and Reading Creek, and two locations at Bucktail–Dark Gulch. These surveys were conducted during Lewiston Dam releases between 8.5 and 56.6 cms (300 and 2,000 cfs) and were applied during stable streamflows planned in coordination with the TRRP Flow Workgroup.

In many cases the site assessment boundaries for surveys conducted during the 8.5-cms (300-cfs) release (base flow) from Lewiston Dam include areas upstream and downstream of the construction areas. These site boundaries were selected on a case-by-case basis to facilitate evaluation of channel changes outside of construction areas that may occur due to restored physical processes. For comparative purposes in the across-site analysis, habitat data were limited to segments within the construction areas. Habitat quantities were normalized to facilitate across-site comparisons by dividing habitat area by the channel length (approximated by the river centerline) at each site, resulting in a density value of square meters of habitat per meter of channel length.

Discharges were taken at each side channel found within any of the rehabilitation sites being evaluated. Measurements were targeted to occur at similar mainstem discharges if they did not occur on the same day of habitat mapping. All discharge measurements and calculations were performed using a Sontek Flowtracker ADV handheld device.

Several additional analyses were conducted for the across-site analysis which were not covered in the site-specific analysis. A post-construction assessment was conducted at Lower Indian Creek during the systemic fish habitat assessment (at single streamflow). This information was of particular interest since the Lower Indian Creek site was built in 2007 and had experienced two spring peak streamflow events. A post-construction survey of Hocker Flat, reported in Goodman et al. (2010), was conducted at four streamflows. Hocker Flat was constructed in 2005 and post-construction conditions were surveyed in 2008. Only data from the post-construction evaluations at Hocker Flat were included because the pre-construction assessments had used alternative habitat criteria not appropriate for direct comparison with the other study sites. The level of restoration effort applied at each channel rehabilitation site was quantified using construction area. Construction area was quantified using the TRRP_RehabSites_AsBuilt.shp shapefile (TRRP unpublished data). Spoil areas were not included in the treatment area calculations. The level of effort (construction areas) was compared to the amount of habitat measured during winter base flow, post-construction, to help evaluate the amount of habitat change observed relative to the extent of construction that occurred.

4.3. Results

4.3.1. Lower Reading

Pre-construction rearing-habitat surveys were conducted at the Lower Reading Creek rehabilitation site (rkm 148.70–149.50) during the late winter and spring of 2009. During the time of mapping it was unknown what type of rehabilitation work, if any, would occur within the Upper Reading Creek site. A base flow map covering approximately 800 m (2,625 ft) of the lower site was produced at a discharge of 9.9 cms (348 cfs; Table 4–2). A portion of the rehabilitation site was mapped at multiple flows ranging from 9.9 to 62 cms (348–2,190 cfs). The area extends over 745 m (2,444 ft) of mainstem river, and the project there was intended to evaluate the effects on rearing habitat resulting from construction of the R-4 floodplain, R-5 main channel meander, IC-4 and IC-5 transverse bars, and IC-6 point bar (McBain & Trush and HVT Fisheries, 2010, Figure A–15). This multi-flow section is referred to as Lower Reading Creek (A) (Figure 4–1). At the Lower Reading Creek site during base flow, total pre-construction fry and presmolt habitat was 3,640 and 4,934 m^2 (39,181 and 53,109 sq. ft), respectively. Of this, 14.7 percent was optimal (DV, C) for fry and 14.9 percent for presmolt. Streamflow-habitat relationships at Lower

Reading Creek (A) exhibited two different shapes for optimal and total rearing habitat. Optimal rearing-habitat (DV, C) areas were higher at winter and summer base flows, then demonstrated sharp decreases during the 21.3-cms (752-cfs) streamflow, then continuously increased through the highest mapped discharge. The relationship between streamflow and total rearing habitat displayed a similar trend during the lower discharges: available habitat was highest at the two lowest flows then decreased sharply during the 21.3-cms (752-cfs) streamflow. Then the total rearing-habitat values stayed relatively constant as flows increased.

Table 4–2. Habitat Conditions Before Construction at the Lower Reading Creek Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook salmon and coho salmon fry (<50 mm fork length [FL]) and presmolt (50–200 mm FL).

Evaluation Type	Life stage	Discharge (cms)	Habitat category (m^2)			
			DV, C	DV, No C	No DV, C	Total
Lower Reading Pre-construction	Fry	9.9	535	2,599	506	3,640
	Presmolt	9.9	733	3,893	309	4,934
Lower Reading (A) Pre-construction	Fry	9.9	495	2,302	450	3,247
		13.3	474	2,035	647	3,157
		21.3	272	1,251	820	2,343
		36.5	405	522	1,330	2,257
		62.0	656	337	1,468	2,462
	Presmolt	9.9	683	3,475	263	4,420
		13.3	690	2,845	431	3,967
		21.3	436	2,019	655	3,110
		36.5	603	930	1,132	2,665
		62.0	859	545	1,265	2,670

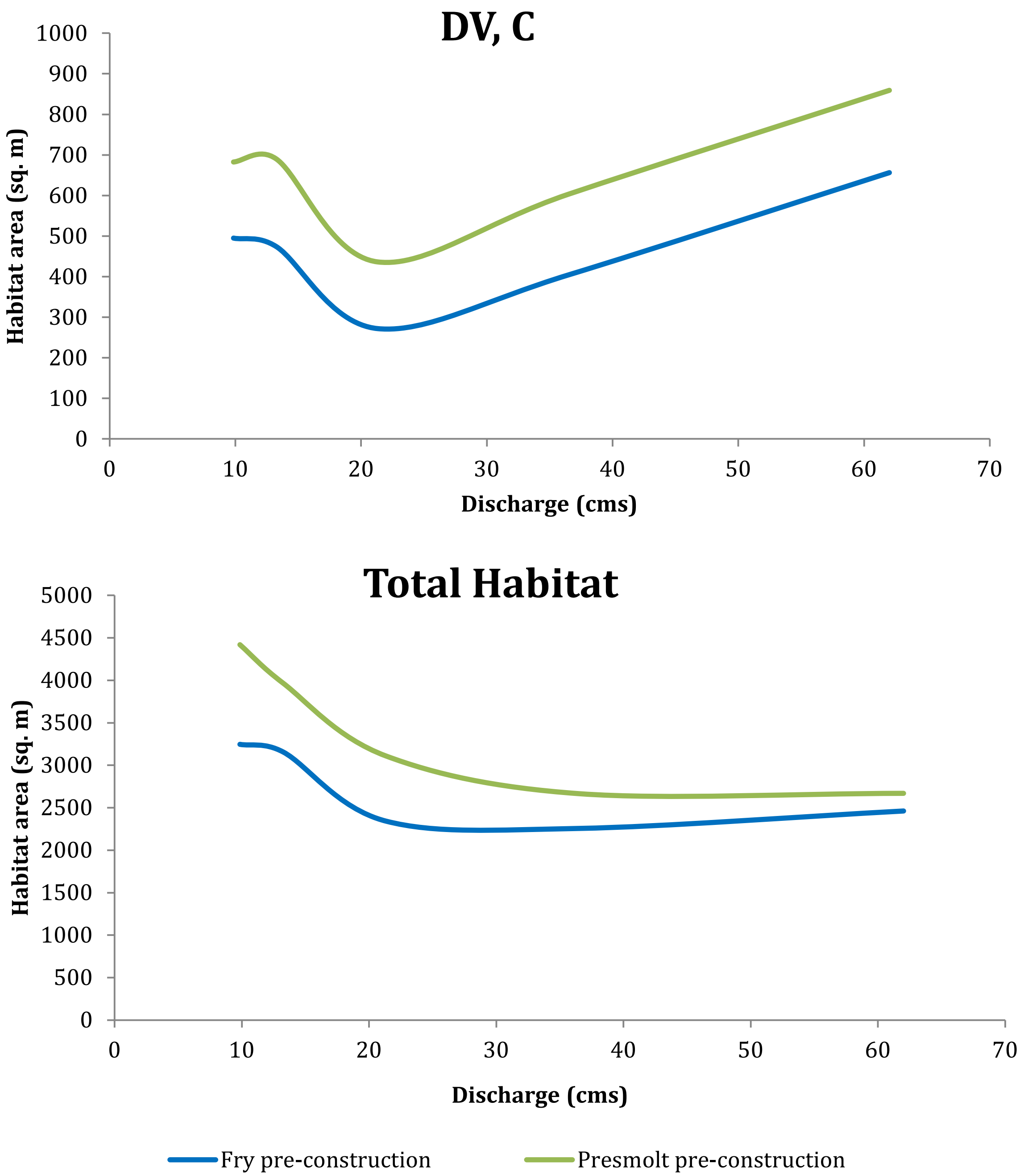


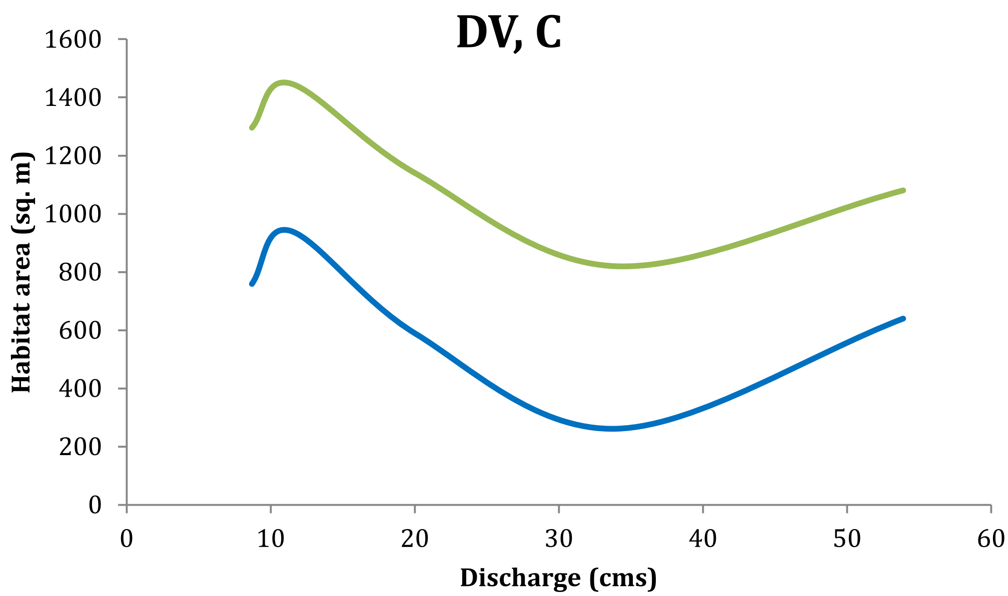
Figure 4–1. Pre-construction estimates of Chinook salmon and coho salmon rearing habitat by streamflow at Lower Reading Creek (A) rehabilitation site. Optimal Chinook and coho salmon habitat was defined as areas within depth/velocity and in-water escape cover (DV, C) criteria. Total Chinook salmon rearing habitat (total habitat) was defined as areas that met any combination of depth/velocity or in-water escape cover criteria. The fry life stage is defined as fish <50 mm FL and presmolt as 50 to 200 mm FL.

4.3.2. Lowden

Pre-construction rearing-habitat surveys were conducted at the Lowden site (rkm 168.43–169.25) during the late winter and spring of 2009 (Figure A–20). A base-flow map covering 815 m (2,674 ft) was produced at a discharge of 8.7 cms (307 cfs). Total habitat for fry and presmolt was 3,528 and 5,188 m^2 (37,975 and 55,843 sq. ft), respectively (Table 4–3). Optimum habitat (DV, C) made up 23.8 percent of the fry habitat and 26.7 percent of the presmolt habitat. A portion of the rehabilitation site was mapped at multiple flows ranging from 8.7 to 53.9 cms (307–1,903 cfs). This multi-flow section was 695 m (2,280 ft) long and will be referred to as Lowden (A). The project there was intended to evaluate the effects that the IC–2 forced meander bar, R–1 side channel, R–2 wetland pond, and R–5 floodplain construction had on available rearing habitat. Pre-construction streamflow to habitat relationships were somewhat similar to those observed at the Lower Reading Creek rehabilitation site. Fry and presmolt optimal rearing habitat was at its largest extent (Figure 4–2) during the 11.4-cms (403-cfs) flow, then decreased, reaching its smallest extent during the 34.0-cms (1,200-cfs) discharge, and then increased again at the highest mapped flow. Fry total rearing habitat changed very little throughout the range of flows that were mapped. Total available habitat for presmolt was highest during the lowest flow mapped (8.7 cms or 307 cfs) then decreased and leveled through the two highest mapped discharges.

Table 4-3. Habitat Conditions Before Construction at the Lowden Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook and coho salmon fry (<50 mm FL) and presmolt (50–200 mm FL).

Evaluation Type	Life stage	Discharge (cms)	Habitat category (m^2)			
			DV, C	DV, No C	No DV, C	Total
Lowden Pre-construction	Fry	8.7	840	1,349	1,344	3,528
	Presmolt	8.7	1,386	3,009	793	5,188
Lowden (A) Pre-construction	Fry	8.7	759	1,009	1,328	3,091
		11.4	941	548	1,695	3,184
		20.0	588	136	2,192	2,916
		34.0	261	11	2,528	2,800
		53.9	640	0	2,563	3,203
	Presmolt	8.7	1,296	2,450	786	4,533
		11.4	1,448	1,392	1,188	4,029
		20.0	1,139	381	1,641	3,161
		34.0	820	95	1,970	2,885
		53.9	1,081	7	2,123	3,210



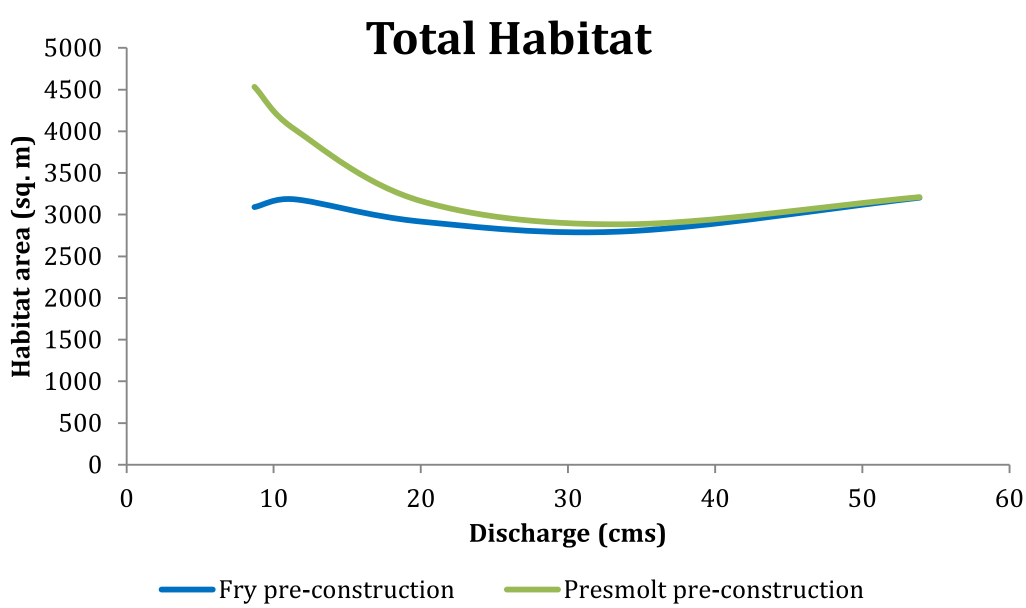


Figure 4–2. Pre-construction estimates of Chinook salmon and coho salmon rearing habitat by streamflow at Lowden (A) rehabilitation site. Optimal Chinook salmon and coho salmon habitat was defined as areas meeting both depth/velocity and in-water escape cover (DV, C) criteria. Total Chinook salmon rearing habitat (total habitat) was defined as areas that met any combination of depth/velocity or in-water escape cover criteria. The fry life stage is defined as fish <50 mm FL and presmolt as fish 50 to 200 mm FL.

4.3.3. Bucktail–Dark Gulch

Pre-construction rearing-habitat surveys were conducted at the Bucktail–Dark Gulch rehabilitation site during the late winter and spring of 2008. A base-flow map of the entire site (rkm 169.5–172.2) was produced showing conditions during a discharge of 10.3 cms (363 cfs). The base-flow post-construction assessment was conducted in the fall of 2009, when the discharge was 8.6 cms (304 cfs). Based on the post-construction survey, fry and presmolt rearing total habitat increased 28 and 21 percent, respectively (Table 4–4; Figure 4–3). Two areas were designated for flow-habitat mapping: (1) Upper Dark Gulch, which incorporated a future right-bank side channel (rkm 171.8–172.2; Figure A–21), and (2) the Bucktail site (Figure A–22), which included a future right-bank side channel as well as a left-bank coarse sediment addition (rkm 170.5–170.9). These two areas were mapped at multiple flows ranging from 8.6 to 60.9 cms (304–2,149 cfs). Total habitat increased at both the Bucktail and Upper Dark Gulch flow-habitat areas at all flows post-construction (Figure 4–4; Figure 4–5). The largest gains were realized in the depth/velocity (DV, no C) habitats at the highest flow mapped at Upper Dark Gulch, where fry habitat increased by 2,338 percent (Table 4–5). Optimal habitat (DV, C) increased post-construction at the lowest flow for both sites and was slightly reduced post-construction at the highest flows.

Table 4–4. Habitat Conditions at Winter Base Flows Before and After Construction at the Entire Bucktail–Dark Gulch Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook and coho salmon fry (<50 mm FL) and presmolt (50–200 mm FL). Side channels that did not exist before construction are designated with a length 0. NA indicates data not collected.

Evaluation type	Location	Length (m)	Life stage	Disch. (cms)	Habitat category (m^2)			
					DV, C	DV, No C	No DV, C	Total
Bucktail–Dark Gulch pre-construction	Main channel	2,608	Fry	10.3	2,864	5,718	4,753	13,335
			Presmolt	10.3	4,331	11,425	3,286	19,043
	Side channel 1	0	Fry	0.0	0	0	0	0
			Presmolt	0.0	0	0	0	0
	Side channel 2	0	Fry	0.0	0	0	0	0
			Presmolt	0.0	0	0	0	0
	Side channel 3	47	Fry	0.0	0	299	0	299
			Presmolt	0.0	0	299	0	299
	Entire site	2,608	Fry	10.3	2,864	6,017	4,753	13,634
			Presmolt	10.3	4,331	11,724	3,286	19,341
Bucktail–Dark Gulch post-construction	Main channel	2,608	Fry	8.5	3,523	8,011	4,268	15,802
			Presmolt	8.5	5,168	13,650	2,705	21,523
	Side channel 1	222	Fry	0.9	97	370	152	619
			Presmolt	0.9	154	599	95	847
	Side channel 2	214	Fry	<0.1	186	577	32	794
			Presmolt	<0.1	198	608	19	825
	Side channel 3	178	Fry	NA	10	270	15	295
			Presmolt	NA	10	322	15	347
	Entire site	2,608	Fry	8.5	3,815	9,228	4,467	17,510

Presmolt	8.5	5,530	15,179	2,834	23,543

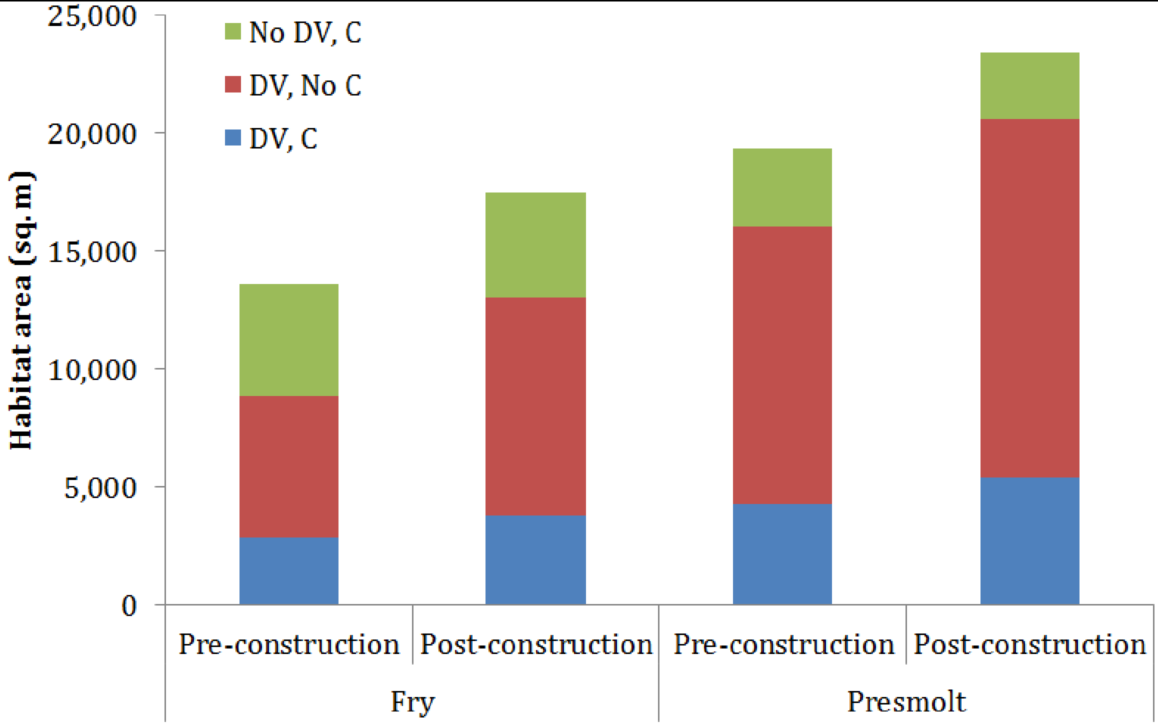


Figure 4–3. Chinook salmon and coho salmon rearing-habitat quantities at the entire Bucktail–Dark Gulch rehabilitation site (rkm 169.5–172.2). Pre-construction estimates were conducted at 10.3 cms (363 cfs) in 2008 and post-construction at 8.6 cms (304 cfs) in 2009. Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

Mainstem and side-channel habitat areas were separated in order to evaluate the constructed side channel’s effects on changes in habitat. Discharges were measured at both newly constructed side channels. The Upper Dark Gulch side channel carried only 10 percent of the flow through that site but accounted for much higher percentages of the total fry and presmolt habitat: 22 and 21 percent, respectively, at low flow and 44 and 46 percent, respectively, at the highest measured flows (Figure 4–6). The results were even more disproportional for the Bucktail side channel , which carried only 0.3 percent of the flow through that site but accounted for the following percentages of the site’s total fry and presmolt habitat: 34 and 29 percent, respectively, at low flow and 51 and 54 percent, respectively, at the highest measured flow (Figure 4–7).

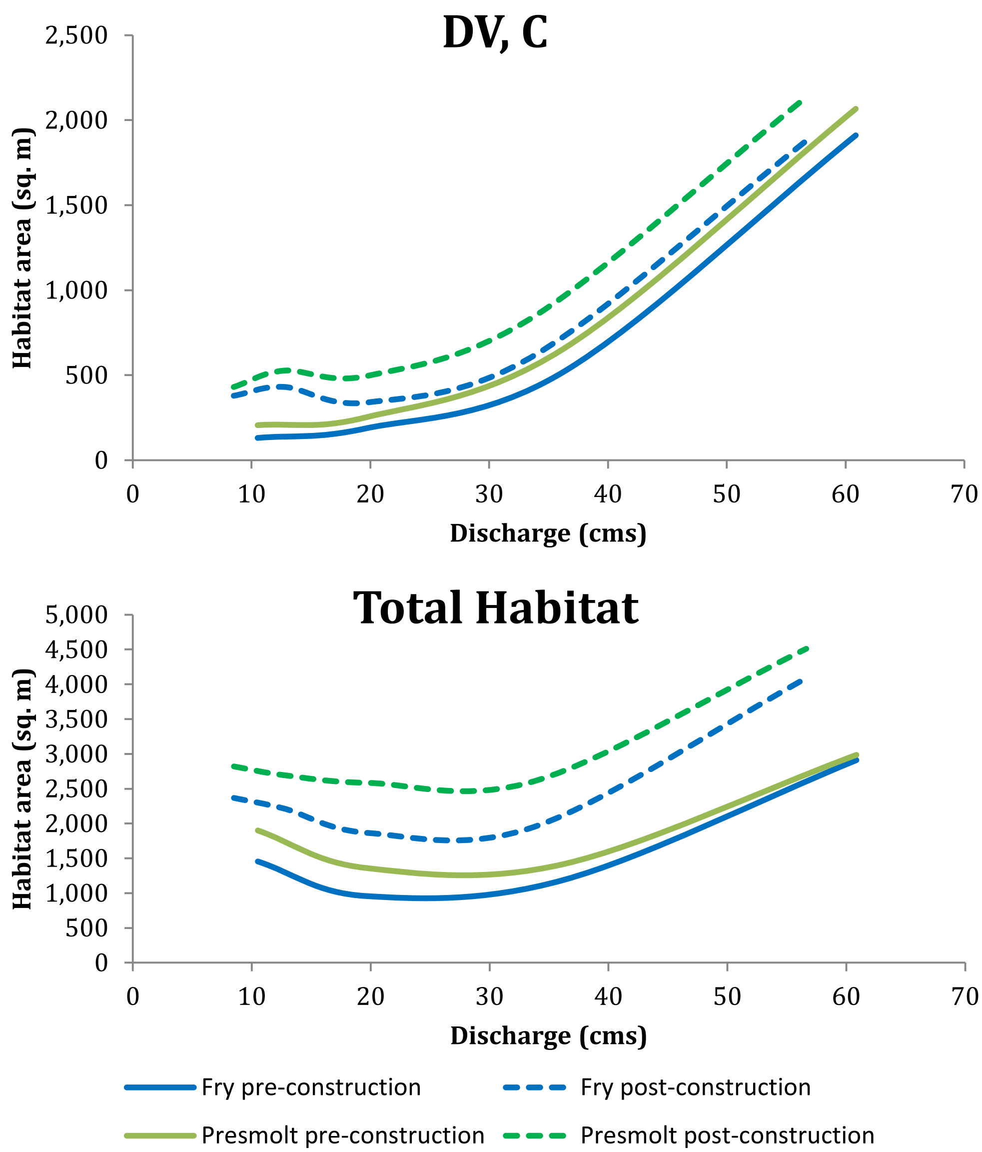


Figure 4–4. Pre-construction estimates of Chinook salmon and coho salmon rearing habitat by streamflow at Bucktail rehabilitation site. Optimal Chinook salmon and coho salmon habitat was defined as areas meeting both depth/velocity and in-water escape cover (DV, C) criteria. Total Chinook salmon rearing habitat (total habitat) was defined as areas that met any combination of depth/velocity or in-water escape cover criteria. The fry life stage is defined as fish <50 mm FL and presmolt as 50 to 200 mm FL.

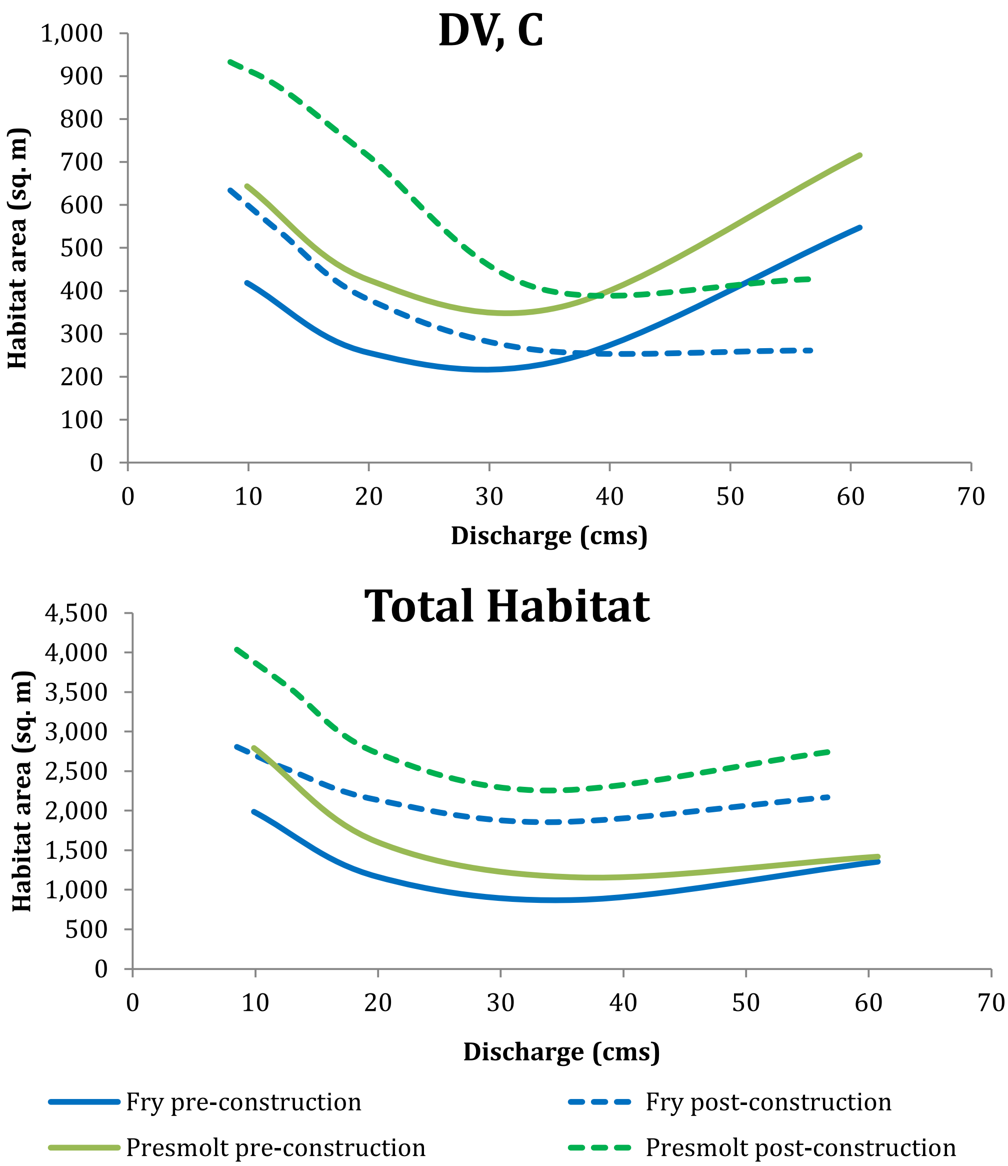


Figure 4–5. Pre-construction estimates of Chinook salmon and coho salmon rearing habitat by streamflow at Upper Dark Gulch rehabilitation site. Optimal Chinook salmon and coho salmon habitat was defined as areas meeting both depth/velocity and in-water escape cover (DV, C) criteria. Total Chinook salmon rearing habitat (total habitat) was defined as areas that met any combination of depth/velocity or in-water escape cover criteria. The fry life stage is defined as fish <50 mm FL and presmolt as 50 to 200 mm FL.

Table 4–5. Habitat Conditions Before and After Construction at Bucktail and Upper Portions of the Dark Gulch Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook salmon and coho salmon fry (<50 mm FL) and presmolt (50–200 mm FL).

Evaluation Type	Life stage	Discharge (cms)	Habitat category (m^2)			
			DV, C	DV, No C	No DV, C	Total
Bucktail pre-construction	Fry	10.5	131	1,131	192	1,455
		19.6	187	490	282	958
		36.2	519	171	500	1,190
		60.9	1,911	173	827	2,911
	Presmolt	10.5	206	1,577	117	1,900
		19.6	252	893	217	1,361
		36.2	655	399	364	1,418
		60.9	2,066	248	672	2,986
Bucktail post-construction	Fry	8.5	379	1,817	172	2,367
		12.7	431	1,509	273	2,214
		19.8	341	1,064	460	1,866
		34.0	624	469	872	1,966
		56.6	1,875	885	1,328	4,089
	Presmolt	8.5	431	2,269	120	2,820
		12.7	527	1,989	177	2,694
		19.8	499	1,790	302	2,591
		34.0	854	1,072	642	2,568
		56.6	2,132	1,306	1,072	4,510
Upper Dark Gulch pre-construction	Fry	9.9	418	1,135	432	1,986
		19.9	256	394	516	1,166
		36.3	241	102	530	872
		60.7	547	44	763	1,355
	Presmolt	9.9	644	1,942	207	2,793
		19.9	426	835	346	1,607
		36.3	365	387	405	1,157
		60.7	716	108	595	1,419
Upper Dark Gulch post-construction	Fry	8.5	634	1,659	514	2,806
		12.7	534	1,353	629	2,516
		19.8	382	806	961	2,149
		34.0	262	693	899	1,855
		56.6	261	1,073	835	2,169
	Presmolt	8.5	933	2,888	215	4,036
		12.7	871	2,395	292	3,558
		19.8	724	1,407	619	2,749
		34.0	407	1,093	755	2,255
		56.6	427	1,644	669	2,740

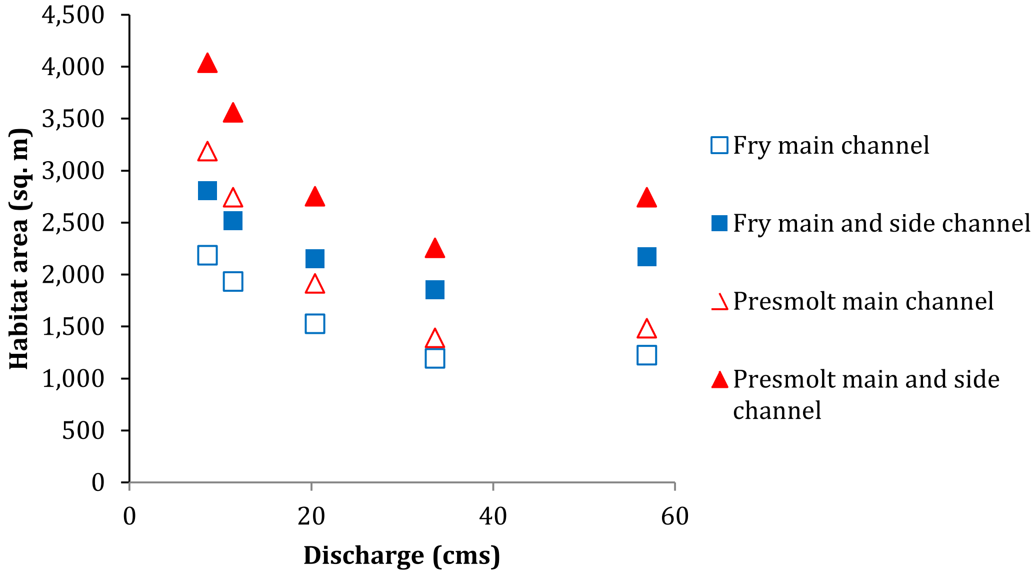


Figure 4–6. Constructed side channel effects on Chinook salmon total rearing-habitat quantities at Upper Dark Gulch rehabilitation site (rkm 171.8–172.2). Habitat plotted as the sum of all areas that meet depth/velocity and in-water escape cover criteria in the study area with and without the constructed side channel.

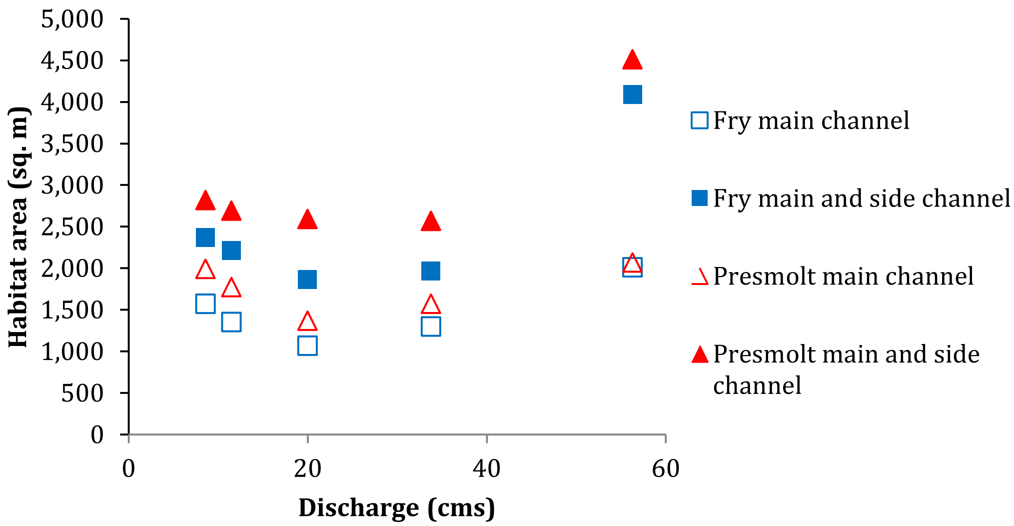


Figure 4–7. Constructed side channel effects on Chinook salmon total rearing-habitat quantities at the Bucktail rehabilitation site (rkm 170.5–170.9). Habitat plotted as the sum of all areas that meet depth/velocity and in-water escape cover criteria in the study area with and without the constructed side channel.

4.3.4. Hoadley Gulch

Pre-construction rearing-habitat surveys at Hoadley Gulch (rkm 176.5–177.3; Figure A–24) were conducted in late winter of 2008, when the flow was at 8.7 cms (307 cfs); post-construction surveys were finished in the fall of 2009 at a flow rate of 8.6 cms (304 cfs). Total fry and presmolt rearing habitat increased 35 and 6 percent, respectively (Table 4–6; Figure 4–8). An increase of 64 percent was observed in the combination of the two habitat types that included cover for fry and presmolt (DV, C + No DV, C). A slight reduction was observed in suitable presmolt habitat (DV, no C) post-construction. Throughout the mainstem portion of this site, there was a 578-m^2 (6,222-sq.-ft) decrease in total presmolt habitat after construction and spring flows. A major feature of the Hoadley Gulch site was the constructed side channel on the right bank, which had two constructed entrances and one exit. Flows at both entrances were measured while the stream, overall, was at its winter base flow of 8.6 cms (304 cfs). Flow into the upper entrance was 0.38 cms (13.4 cfs), but at the opening that had been intended as the lower "entrance," measurements showed a return flow (back into mainstem) of 0.13 cms (4.5 cfs). The side channel construction at Hoadley Gulch accounted for an increase of 857 and 1,191 m^2 (9,225 and 12,820 sq. ft) of total habitat for fry and presmolt, respectively (Figure 4–9).

Table 4–6. Habitat Conditions at Winter Base Flows Before and After Construction at Hoadley Gulch Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook salmon and coho salmon fry (<50 mm FL) and presmolt (50–200 mm FL).

Evaluation type	Location	Length (m)	Life stage	Disch. (cms)	Habitat category (m^2)			
					DV, C	DV, No C	No DV, C	Total
Hoadley pre-construction	Main channel	795	Fry	8.7	945	3,459	760	5,164
			Presmolt	8.7	1,338	8,673	367	10,378
	Side channel	0	Fry	0	0	0	0	0
			Presmolt	0	0	0	0	0
	Entire site	795	Fry	8.7	945	3,459	760	5,164
			Presmolt	8.7	1,338	8,673	367	10,378
Hoadley post-construction	Main channel	795	Fry	8.6	1,231	3,759	1,134	6,124
			Presmolt	8.6	1,803	7,437	560	9,800
	Side channel	240	Fry	0.25	196	553	108	857
			Presmolt	0.25	244	886	61	1,191
	Entire site	795	Fry	8.6	1,427	4,312	1,242	6,981
			Presmolt	8.6	2,047	8,323	621	10,991

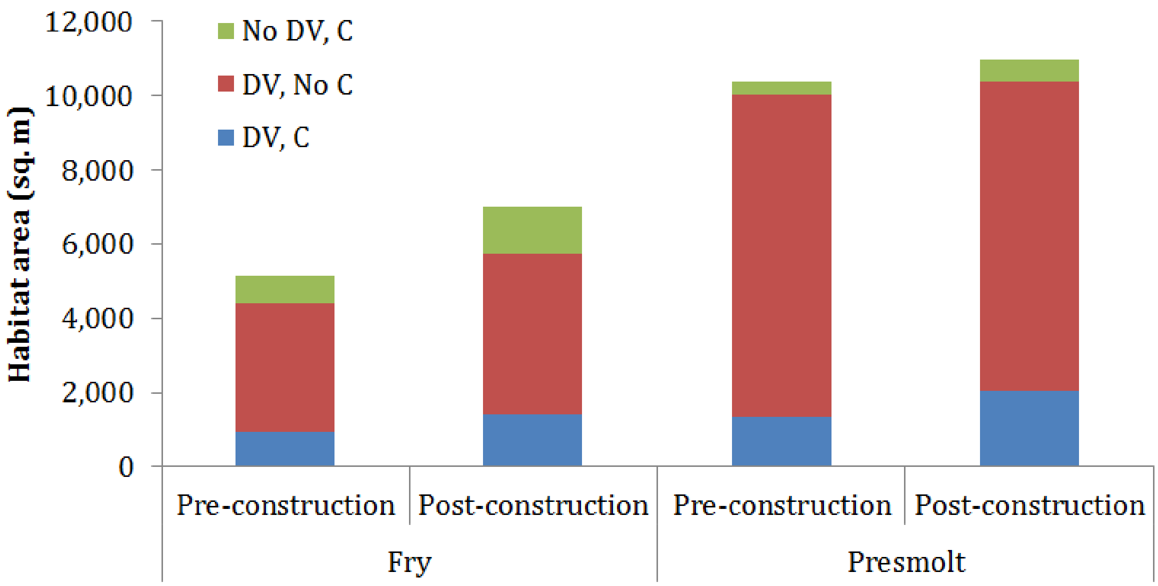


Figure 4–8. Chinook salmon and coho salmon rearing-habitat areas at the entire Hoadley Gulch rehabilitation site (rkm 176.5–177.3), inclusive of the side channel feature. Habitat areas were estimated at a flow rate of 8.7 cms (307 cfs) in 2008 (pre-construction) and at 8.6 cms (304 cfs) in 2009 (post-construction). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

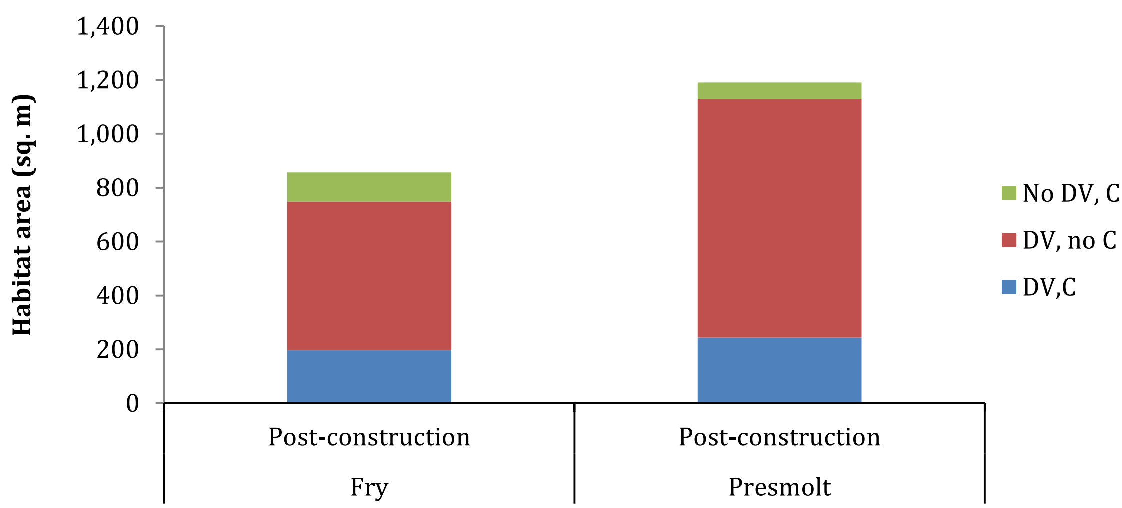


Figure 4–9. Chinook salmon and coho salmon rearing-habitat areas within the constructed side channel at Hoadley Gulch rehabilitation site (rkm 176.5–177.3) at mainstem flow of 8.6 cms (304 cfs). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

4.3.5. Lewiston Cableway

Pre-construction rearing-habitat surveys were conducted at Lewiston Cableway rehabilitation site during the late winter and spring of 2008. A base-flow map of the entire site (rkm 177.3–178.0; Figure A–26) was produced at a discharge of 8.6 cms (305 cfs; Table 4–7). The base-flow post-construction assessment was conducted in the fall of 2009 at a discharge of 8.7 cms (307 cfs). At winter base flow, total fry and presmolt rearing habitat across the whole site increased by 53 and 36 percent, respectively, post-construction (Figure 4–10). Mainstem habitat areas were isolated from side-channel habitat to compare the two treatment types (gravel bar additions and side-channel opening). Total available fry habitat in the mainstem at winter base flow increased by 2 percent post-construction (gravel bars additions), and presmolt total available habitat decreased 4 percent post-construction in the mainstem. Therefore the increases in habitat quantity can be attributed to the mechanical alteration of the side-channel entrance to allow streamflow at winter baseflow. At a mainstem flow of 8.6 cms, the side channel did not have streamflow pre-construction and accepted 15 percent or 1.3 cms (47 cfs) discharge post-construction.

Table 4–7. Winter Baseflow Habitat Conditions Before and After Construction at Lewiston Cableway Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook and coho salmon fry (<50 mm FL) and presmolt (50–200 mm FL).

Evaluation type	Location	Length (m)	Life stage	Disch. (cms)	Habitat category (m^2)			
					DV, C	DV, No C	No DV, C	Total
Cableway pre-construction	Main channel	705	Fry	8.6	1,250	2,205	582	4,037
			Presmolt	8.6	1,586	4,199	246	6,031
	Side channel	0	Fry	0	0	0	0	0
			Presmolt	0	0	0	0	0
	Entire site	705	Fry	8.6	1,250	2,205	582	4,037
			Presmolt	8.6	1,586	4,199	246	6,031
Cableway post-construction	Main channel	705	Fry	8.7	1,085	2,419	632	4,137
			Presmolt	8.7	1,390	4,098	327	5,816
	Side channel	380	Fry	1.33	1,030	532	477	2,039
			Presmolt	1.33	1,204	896	302	2,403
	Entire site	705	Fry	8.7	2,115	2,951	1,109	6,175
			Presmolt	8.7	2,595	4,995	629	8,219

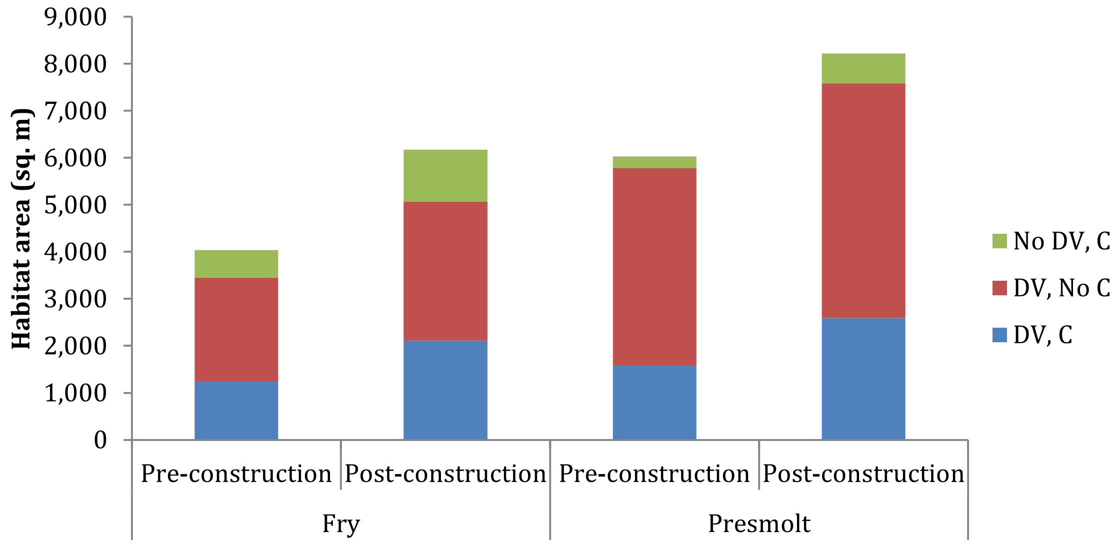


Figure 4–10. Chinook and coho salmon rearing-habitat areas at the entire Lewiston Cableway rehabilitation site (rkm 177.3–178.0). Habitat areas were estimated at a flow rate of 8.7 cms (307 cfs) in 2008 (pre-construction) and at 8.6 cms (304 cfs) in 2009 (post-construction). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

The Lewiston Cableway rehabilitation site was mapped at a range of flows over an area that included the entire side channel on the right bank. We will refer to this area as Lewiston Cableway (A). Lewiston Cableway (A) exhibited increases in total habitat at all flows post-construction (Table 4–8; Figure 4–11). The largest gains realized at the highest flow occurred in the suitable habitat type (No DV, C) at 47 and 45 percent for the fry and presmolt, respectively. A major feature of the rehabilitation design at Lewiston Cableway was the addition of alternating coarse sediment gravel bars. Habitat polygons were divided into mainstem and side-channel categories to examine the effects constructed bars had on the different qualities of habitat. Analysis of the mainstem habitat showed similar trends for both fry and presmolt guilds (Figures 4–12, 4–13). At all flows except winter base flow, there was a positive change in habitat for both fry and presmolt total habitat along the mainstem portion. The only reduction in habitat (presmolt) and smallest increase (fry) was observed at the lowest flow. The suitable habitat (DV, no C) had the highest increases whereas the optimal habitat (DV, C) had the lowest gains and some reductions in habitat post-construction at the 8.7- and 34.5-cms (308- and 1,217-cfs) flows.

4.3.6. Sven Olbertson

Pre-construction rearing-habitat surveys were conducted at the Sven Olbertson rehabilitation site during the late winter and spring of 2008, and a base flow map of the entire site (rkm 178.94–179.6; Figure A–28) was produced at a discharge of 8.6 cms (304 cfs). Construction occurred in the summer of 2008. The base-flow post-construction assessment was conducted in the fall of 2009 at a discharge of 8.6 cms (304 cfs). Based on the post-construction survey, fry and presmolt total rearing habitat increased 67 and 57 percent, respectively (Table 4–9; Figure 4–14). These increases can mostly be attributed to the construction of a side channel on the left bank connecting the Bear Island side channel to the backwatered area above the old fish weir. Discharges were measured in the three constructed side-channel entrances and one side-channel outlet post-construction (Table 4–10). The total discharge flowing through the side channel (SC 5, Figure A–25) was 1.1 cms (37.5 cfs), and the mainstem flow at Lewiston was 8.9 cms (316 cfs).

Table 4–8. Habitat Conditions Before and After Construction at Lewiston Cableway (A) Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook and coho salmon fry (<50 mm FL) and presmolt (50–200 mm FL).

Evaluation Type	Life stage	Discharge (cms)	Habitat category (m^2)			
			DV, C	DV, No C	No DV, C	Total
Cableway (A) pre-construction	Fry	8.6	1,010	1,351	392	2,753
		11.1	454	795	581	1,829
		19.3	1,549	2,156	500	4,205
		34.3	2,881	413	2,150	5,443
		57.2	5,602	279	3,902	9,783
	Presmolt	8.6	1,261	2,342	141	3,744
		11.1	547	1,399	488	2,433
		19.3	1,753	2,923	296	4,972
		34.3	3,767	1,007	1,264	6,037
		57.2	6,560	457	2,944	9,962
Cableway (A) post-construction	Fry	8.6	1,731	2,193	843	4,767
		11.1	2,288	1,404	1,157	4,849
		19.9	3,369	1046	2,040	6,455
		34.5	4,181	834	3,835	8,850
		52.7	6,084	258	5,754	12,095
	Presmolt	8.6	2,029	3,732	545	6,306
		11.1	2,619	2,681	826	6,126
		19.9	3,964	2,036	1,446	7,446
		34.5	5,382	1,677	2,634	9,693
		52.7	7,555	480	4,282	12,317

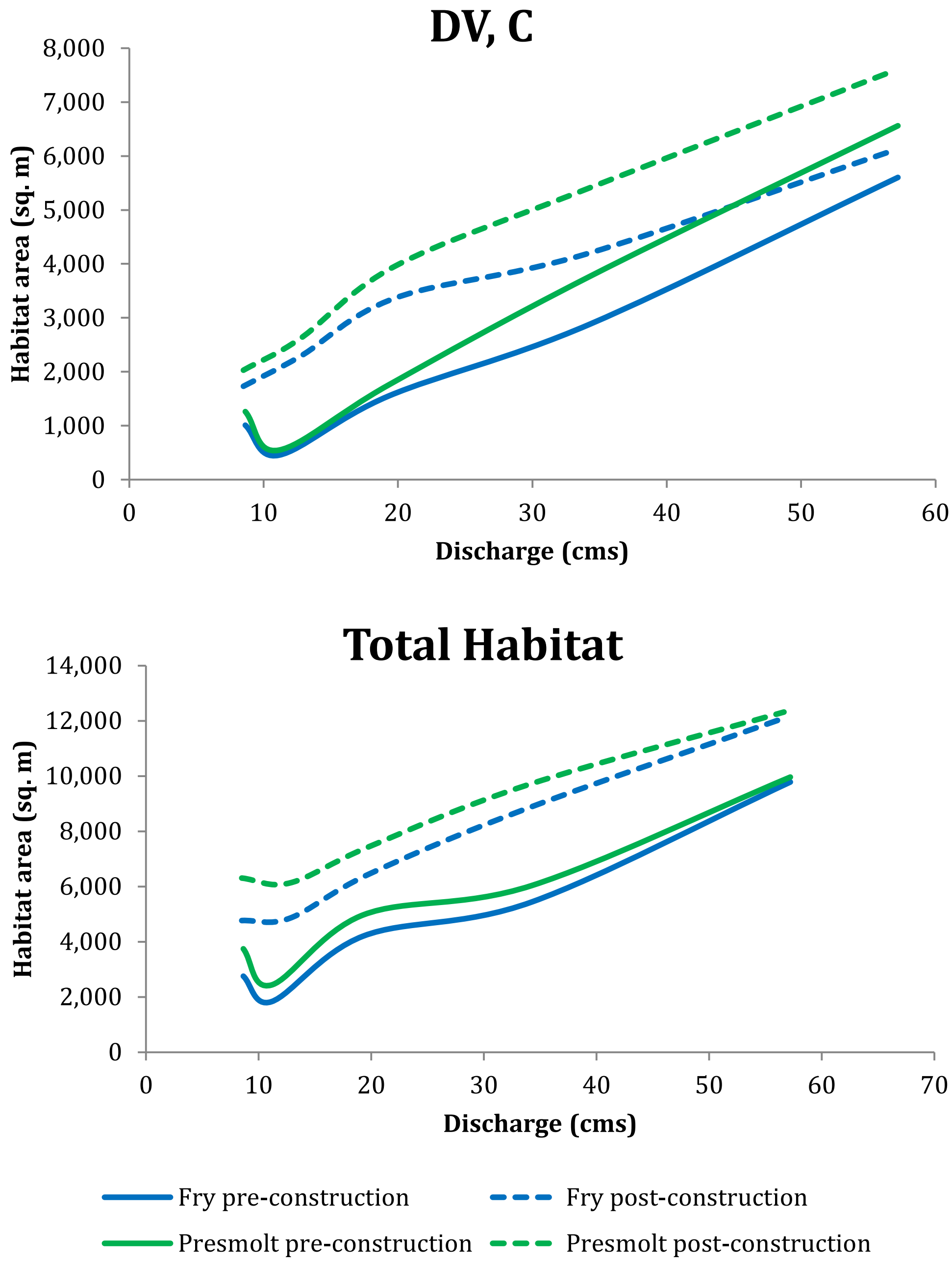


Figure 4–11. Estimates of Chinook and coho salmon rearing habitat by streamflow at Lewiston Cableway (A) rehabilitation site. Optimal Chinook and coho salmon habitat was defined as areas meeting both depth/velocity and in-water escape cover (DV,C) criteria. Total Chinook salmon rearing habitat (total habitat) was defined as areas that met any combination of depth/velocity or in-water escape cover criteria. The fry life stage is defined as fish <50 mm FL and presmolt as 50 to 200 mm FL.

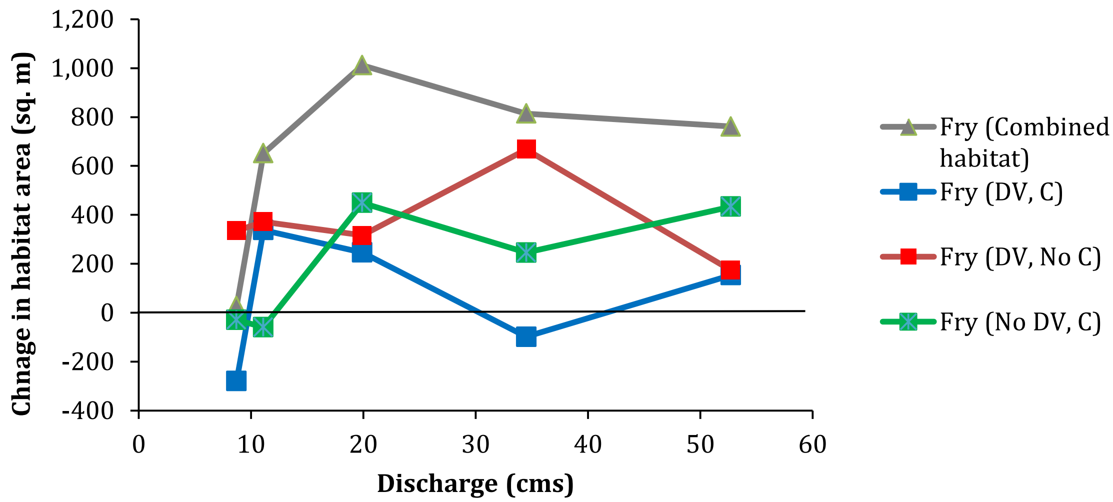


Figure 4–12. Change in fry rearing-habitat area in the mainstem portion of the Lewiston Cableway (A) rehabilitation site (post-construction habitat area minus pre-construction habitat area). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

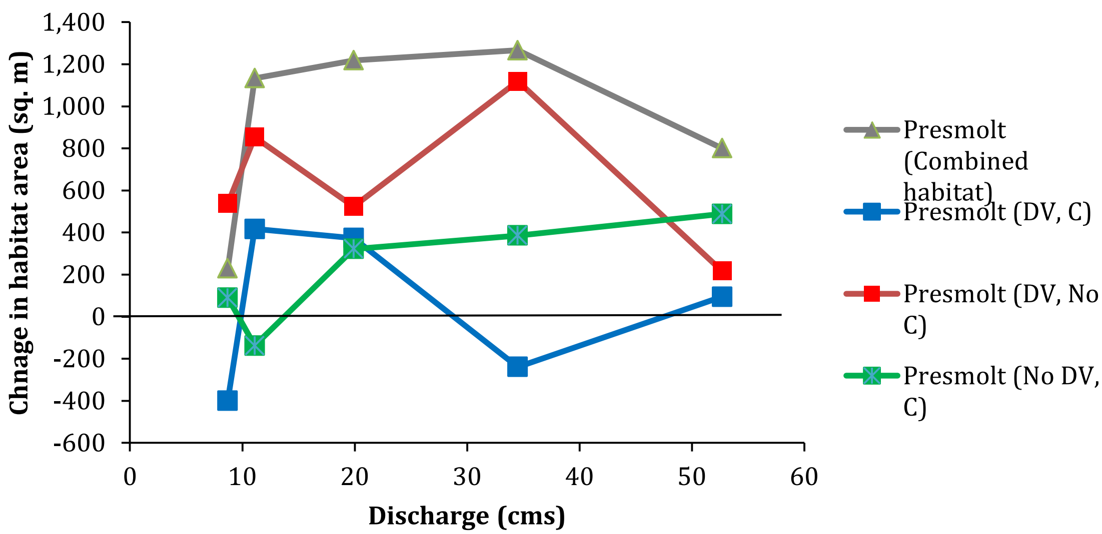


Figure 4–13. Change in presmolt rearing-habitat area in the mainstem portion of the Lewiston Cableway (A) rehabilitation site (post-construction habitat area minus pre-construction habitat area). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

Table 4–9. Winter Baseflow Habitat Conditions Before and After Construction at Sven Olbertson Rehabilitation Site. Habitat category columns show areas meeting the depth/velocity dual criteria of rearing habitat for Chinook salmon and coho salmon fry (<50 mm FL) and presmolt (50–200 mm FL).

Evaluation type	Location	Length (m)	Life stage	Disch. (cms)	Habitat category (m^2)			
					DV, C	DV, No C	No DV, C	Total
Sven Olbertson pre-construction	Main channel	659	Fry	8.6	914	3,367	310	4,591
			Presmolt	8.6	1,065	5,524	159	6,747
	Side channel	261	Fry	NA	253	1,801	82	2,136
			Presmolt	NA	279	2,192	56	2,526
	Entire site	659	Fry	8.6	1,167	5,168	392	6,727
			Presmolt	8.6	1,344	7,715	214	9,274
Sven Olbertson post-construction	Main channel	659	Fry	8.6	790	3,916	297	5,004
			Presmolt	8.6	926	5,899	162	6,987
	Side channel	520	Fry	1.06	2,071	2,655	1,508	6,234
			Presmolt	1.06	3,165	4,010	414	7,589
	Entire site	659	Fry	8.6	2,861	6,571	1,805	11,238
			Presmolt	8.6	4,091	9,909	576	14,576

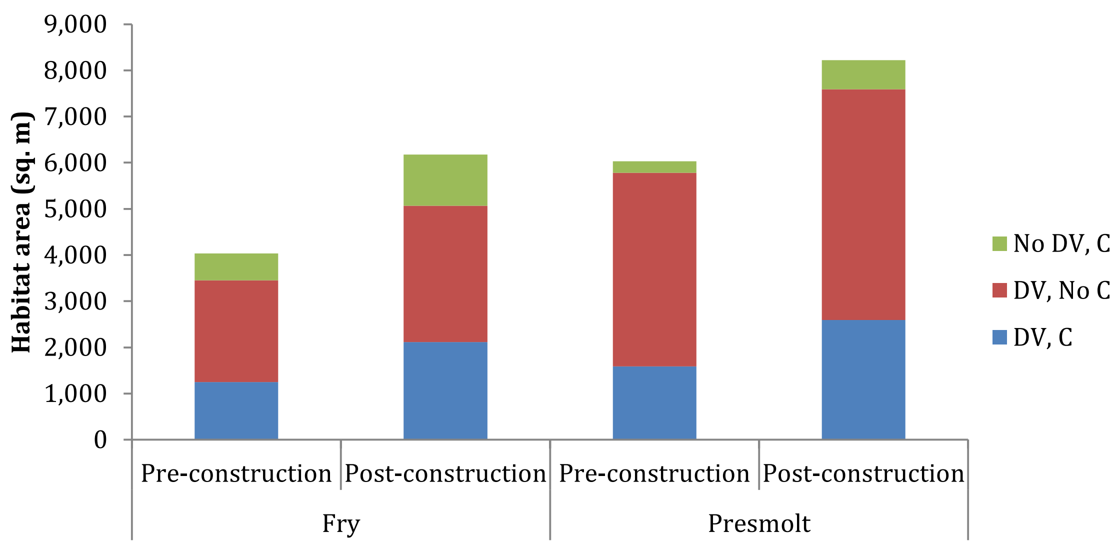


Figure 4–14. Chinook and coho salmon rearing-habitat areas at the entire Sven Olbertson rehabilitation site (rkm 178.94–179.6). Habitat areas were estimated at a flow rate of 8.6 cms (304 cfs) in both 2008 (pre-construction) and 2009 (post-construction). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

Table 4–10. Discharges Within Sven Olbertson Side Channels. Measurements for 2009/2010 year were taken on 01/15/10 with a mainstem discharge of 8.9 cms (316 cfs). Measurements for the 2010/2011 year were taken on 04/04/11 with a mainstem discharge of 8.5 cms (301 cfs).

Location	2009/2010		2010/2011	
	CMS	CFS	CMS	CFS
SC1	0.25	9	0.03	0.9
SC2	0.57	20	0.15	5.4
SC3	0.15	5.4	0.48	17.1
SC4	0.14	4.8	0.008	–0.3
SC5	1.1	37.5	0.34	12

To further investigate the habitat gains of the sites, habitat areas associated with the side channel were isolated from the mainstem to compare changes in habitat between the two. Once the two areas were separated, increases of 192 and 200 percent of fry and presmolt total habitat, respectively, were realized in the side channels (Figure 4–15) compared to increases of only 9 and 4 percent for fry and presmolt, respectively, in the mainstem (Figure 4–16). Within the side-channel area, optimal habitat (DV, C) increased by 718 and 1,034 percent for fry and presmolt, respectively.

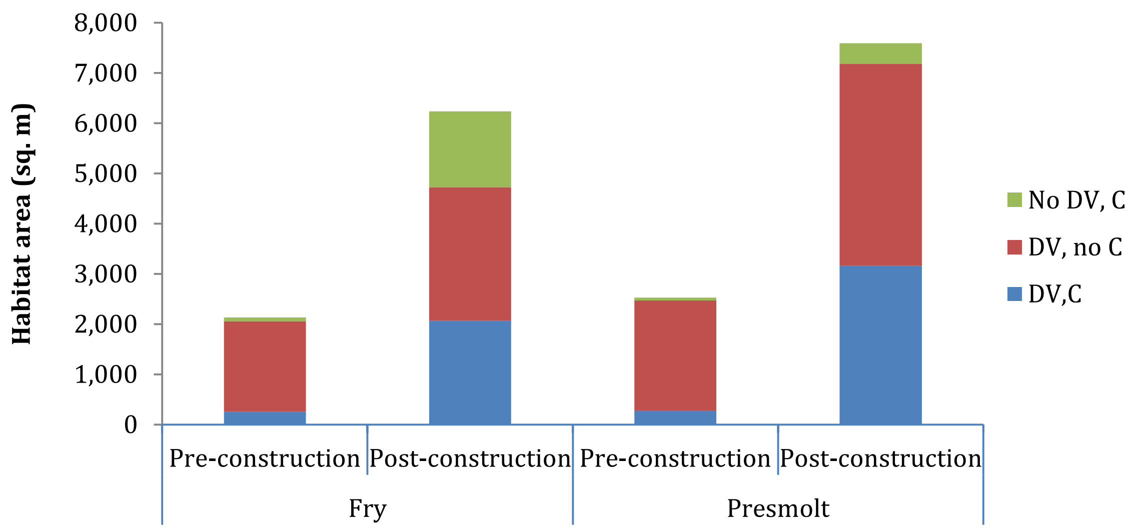


Figure 4–15. Chinook and coho salmon rearing-habitat quantities within the constructed side channel at Sven Olbertson rehabilitation site (rkm 178.94–179.6). Habitat areas were estimated at a flow rate of 8.6 cms (304 cfs) in both 2008 (pre-construction) and 2009 (post-construction). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

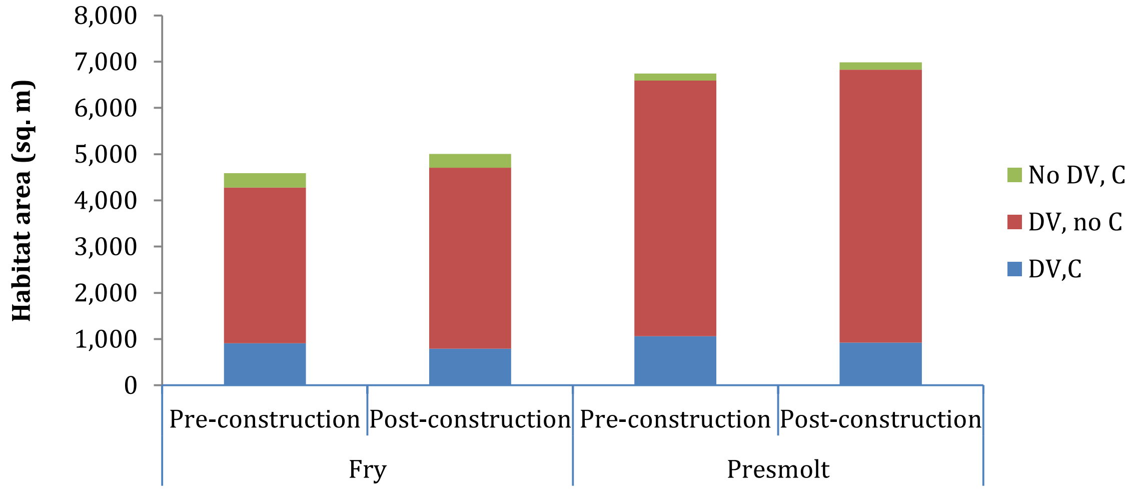


Figure 4–16. Chinook and coho salmon rearing-habitat quantities within the mainstem channel at Sven Olbertson rehabilitation site (rkm 178.94–179.6). Habitat areas were estimated at a flow rate of 8.6 cms (304 cfs) in both 2008 (pre-construction) and 2009 (post-construction). Habitat categories correspond to combinations of depth/velocity and in-water escape cover criteria.

4.3.7. Cross-Site Comparisons

Evaluating change in habitat areas (post-construction habitat area minus pre-construction habitat area) across channel rehabilitation sites provides a frame of reference to evaluate the relative initial changes in rearing habitat for Chinook salmon and coho salmon through different treatment types (Figure 4–17). Dark Gulch and Sven Olbertson rehabilitation sites provided the highest initial post-construction increases in rearing habitat. Hoadley Gulch, a short site, provided the lowest increase of the mapped sites. Rehabilitation actions at Hoadley Gulch were mostly restricted to 270 m (886 ft) of mainstem length. The density of total habitat at rehabilitation sites measured at winter base flow of 8.5 cms (300 cfs) ranged from 2.4 to 16.9 square meters per meter of channel length (7.9 and 55.5 sq. ft/ft) for fry and 4.0 to 22.1 square meters per meter of channel length (13.1 and 72.5 sq. ft/ft) for presmolt (Figure 4–18). Sven Olbertson, with its multiple side channels, had the highest habitat densities of the five sites evaluated. Hocker Flat, a single thread channel, had the lowest habitat densities.

The mean habitat density of the entire the project reach was compared to habitat density values at rehabilitation sites at similar flows. The mean project reach density was calculated using the restoration reach habitat estimates and dividing by its total length (see Restoration Reach Results; Figure 4–19). Mean habitat densities within the restoration reach, measured during a 12.7-cms (450-cfs) dam release, were estimated to be 5.4 and 6.8 m^2/m of channel (17.7 and 22.3 sq. ft/ft) for total fry and presmolt rearing habitat, respectively, and 1.6 and 1.8 m^2/m (5.2 and 5.9 sq. ft/ft) of optimal rearing habitat.

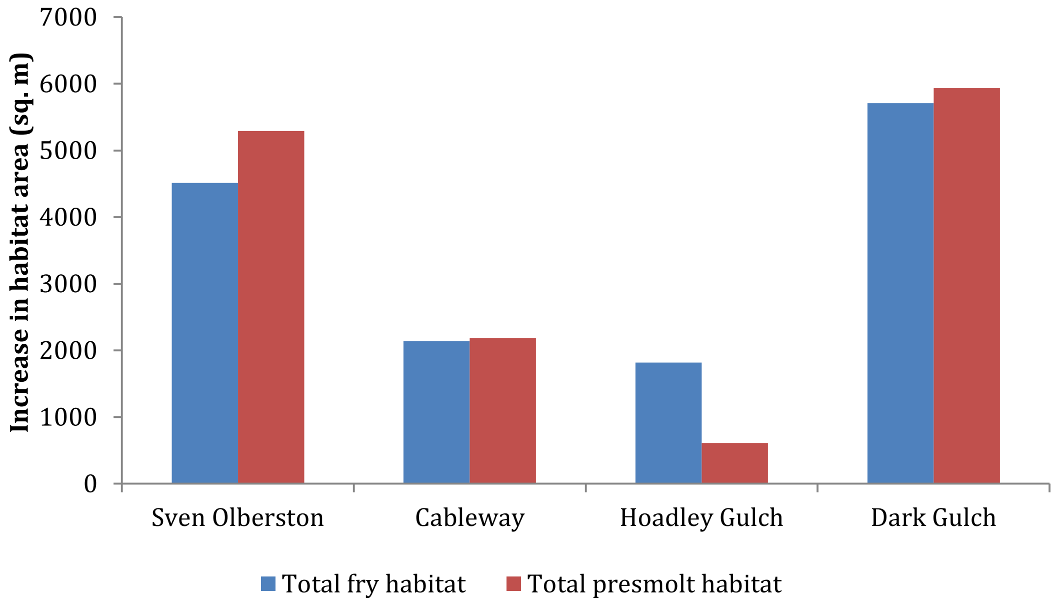


Figure 4–17. Change in habitat area at restoration sites from pre-construction to post-construction condition at a flow of 8.6 cms (304 cfs).

Most of the rehabilitation sites have densities of total habitat and optimal habitat which are higher than the project reach average. Hocker Flat habitat densities three years post-construction were below the restoration reach average while Lewiston Cableway had the highest densities.

Habitat density for optimal and total habitat was calculated at five flows for the three post-construction flow-habitat sites investigated in 2009 and for Hocker Flat (investigated in 2008) (Figure 4–20). Habitat density was the highest at Lewiston Cableway across all mapped flows. Of particular interest at Lewiston Cableway is the continuously increasing habitat density values exhibited with increasing flows. This was the first site investigated that demonstrated this increasing trend with flows. The pattern can be attributed to the low-lying floodplain at Lewiston Cableway, as well as the decision to leave almost all of the vegetation and trees within this site during and after construction. An element that increased habitat at Lewiston Cableway was a wooded grassy alcove along the mainstem in the middle of the site, which was inundated even at lower flows post-construction, whereas it hadn't been before construction. The higher water elevation in this mainstem section was caused by the addition of gravel in the form of alternating bars during construction. At flows between 20 and 40 cms (706 and 1,413 cfs), this helped mitigate the loss of habitat within the side channel (due to faster velocities). At the top of the side channel is a secondary (previously constructed) side channel which turns into an alcove at lower flows; this channel had large amounts of cover and accounted for much of the optimal habitat.

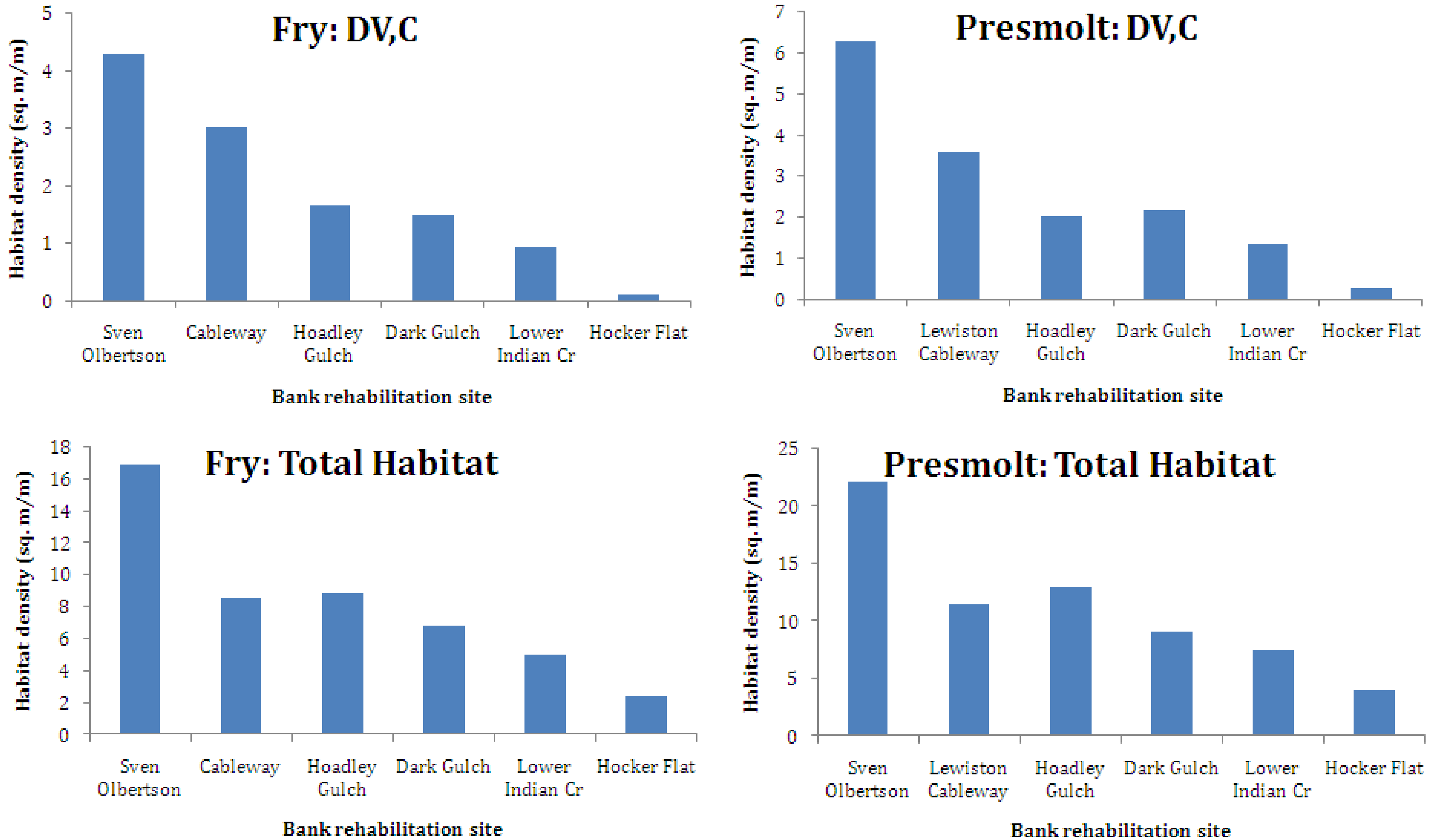


Figure 4–18. Post-construction habitat density by channel rehabilitation site. DV,C indicates optimal Chinook salmon and coho salmon rearing habitat; total habitat indicates all qualities of Chinook rearing habitat. For this analysis, habitat areas were evaluated during the winter base dam release of 8.5 cms (300 cfs). Hocker Flat was evaluated in summer 2008; all other surveys were conducted in summer 2009. The fry life stage indicates fish <50 mm FL and presmolt 50 to 200 mm FL.

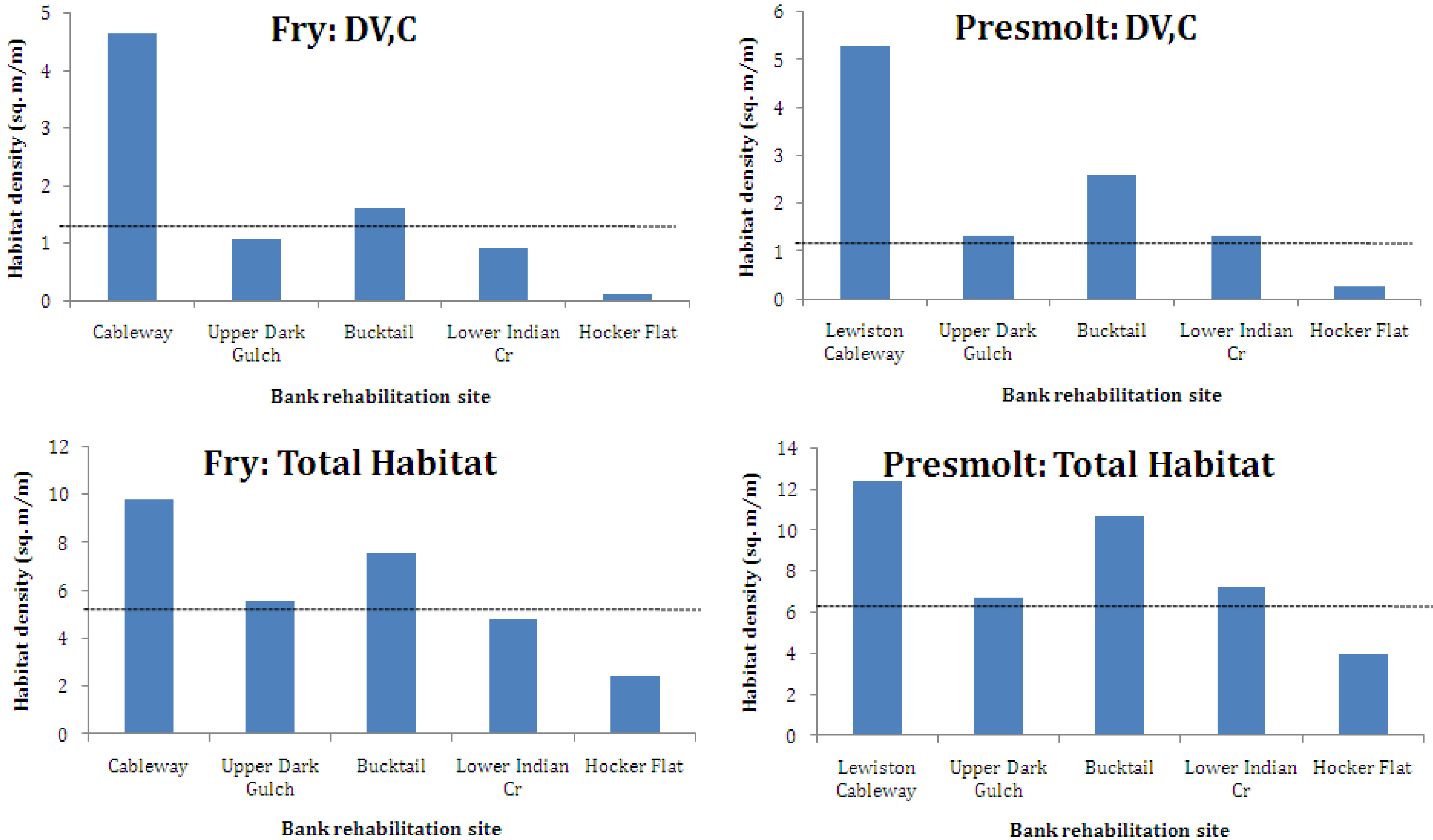


Figure 4–19. Post-construction habitat density by channel rehabilitation site. DV,C indicates optimal Chinook salmon and coho salmon rearing habitat; total habitat indicates all qualities of Chinook rearing habitat. For this analysis, habitat areas were evaluated during the summer base dam release of 12.7 cms (450 cfs). Dotted lines indicate mean values within the primary restoration reach at 12.7 cms (450 cfs). Hocker Flat was evaluated in summer 2008; all other surveys were conducted in summer 2009. The fry life stage indicates fish <50 mm FL and presmolt 50 to 200 mm FL.

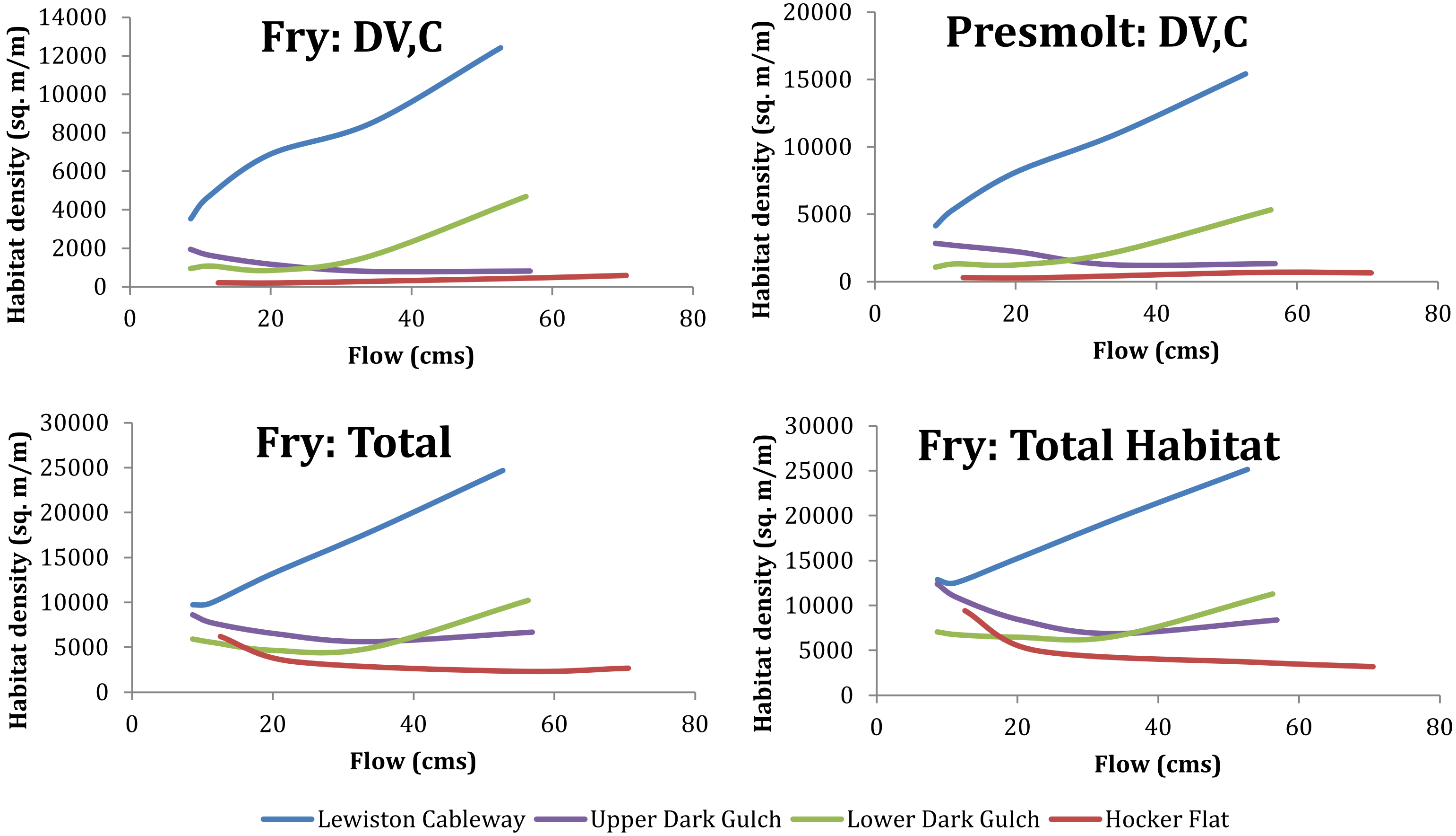


Figure 4–20. Post-construction rearing-habitat density across streamflow (Flow) at multiple channel rehabilitation sites. DV,C indicates high quality Chinook salmon and coho salmon presmolt rearing habitat; total habitat indicates all qualities of rearing habitat. Streamflow was measured at each site for this analysis. Hocker Flat was evaluated in summer 2008; all other surveys were conducted in summer and fall 2009. The fry life stage indicates fish <50 mm FL and presmolt 50 to 200 mm FL.

Upper Dark Gulch demonstrates the alternative to conditions at Lewiston Cableway. Optimal habitat values were the highest during the lowest mapped flows at Upper Dark Gulch. Optimal habitat then decreases with increasing flows due to the removal of vegetation during construction at this site. The single thread channel design, vegetation removal, and lack of woody debris additions at Hocker Flat produced the lowest values of optimal habitat at all flows.

The treatment area varied between channel rehabilitation sites from 5,822 m^2 (62,668 sq. ft) at Hoadley Gulch to 69,372 m^2 (746,714 sq. ft) at Hocker Flat, with a mean of 36,988 m^2 (398,136 sq. ft; Figure 4–21). Habitat area also varied across sites, with optimal Chinook salmon habitat and total coho salmon habitat ranging from 186 to 3,501 m^2 (2,002 to 37,685 sq. ft) for fry and 421 to 5,077 m^2 (4,532 to 54,648 sq. ft) for presmolt at Hocker Flat and Dark Gulch, respectively. The variation in total Chinook salmon habitat between channel rehabilitation sites ranged from 2,392 to 15,859 m^2 (25,747 to 170,705 sq. ft) for fry and 3,472 to 21,235 m^2 (37,372 to 228,572 sq. ft) for presmolt at Hoadley Gulch and Dark Gulch, respectively.

The variation in treatment area did not directly relate to habitat area. The channel rehabilitation site with the largest treatment area, Hocker Flat, also had the smallest area of optimal Chinook salmon and coho salmon habitat at 186 and 421 m^2 (2,002 and 4,532 sq. ft). However a relationship did exist among the channel rehabilitation sites constructed in 2008, which included Sven Olbertson, Hoadley Gulch, Lewiston Cableway, and Dark Gulch. Among these sites, as treatment area increased so did rearing-habitat area for both total and optimal habitat types. The Lower Indian Creek and Hocker Flat channel rehabilitation sites, constructed before 2008, did not follow the same relationship of treatment area to habitat area.

Side channels are a design feature common to many TRRP channel rehabilitation sites. Discharge, length, and total Chinook salmon habitat quantities were compared between the channel rehabilitation sites that have this design feature (Table 4–11). The main-channel discharge was 8.6–8.7 cms (304–307 cfs) at all sites except Lower Indian Creek, where it was 13.4 cms (473 cfs). Side-channel discharge was measured at all sites except Lower Indian Creek. The side-channel discharge ranged from less than 0.1 to 1.3 cms (3.5–46 cfs) at Bucktail and Lewiston Cableway, respectively. Total habitat areas within side-channel features were evaluated relative to main channel length (Table 4–11; Figure 4–22). Four of the six side channels had 623 to 2,039 m^2 (6,706–21,948 sq. ft) of fry habitat and 827 to 2,403 m^2 (8,902–25,866 sq. ft) of presmolt habitat, and in extent they ranged from 186 to 380 m (610–1,247 ft) of main channel length. More variation in total rearing-habitat area occurred between the two longest side channels, Sven Olbertson and Lower Indian Creek. The Sven Olbertson side channel had the highest habitat value of all side channels, yet it was not as long as the one at Lower Indian Creek. The Lower Indian Creek channel was the longest side channel but had less habitat area than side channels less than half its length.

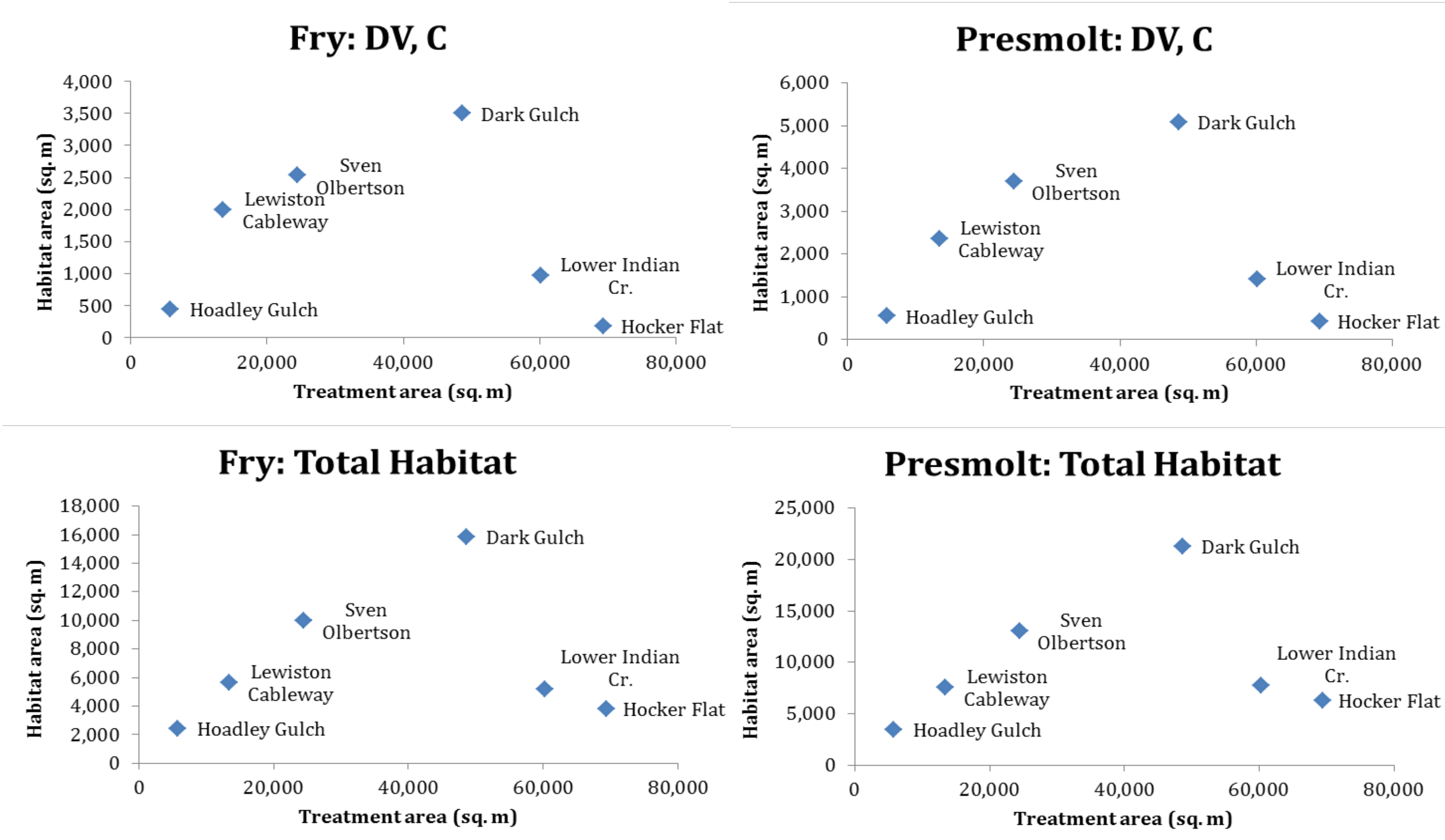


Figure 4–21. Post-construction habitat area related to the size of channel rehabilitation treatments at channel rehabilitation sites. DV,C indicates high-quality Chinook salmon and coho salmon presmolt rearing habitat, and total habitat indicates all qualities of Chinook salmon rearing habitat. Site-specific streamflows evaluated in this analysis ranged from 8.6 to 20.3 cms (302–718 cfs). Hocker Flat was evaluated in summer 2008; all other surveys were conducted in summer and fall 2009. The fry life stage indicates fish <50 mm FL and presmolt 50 to 200 mm FL.

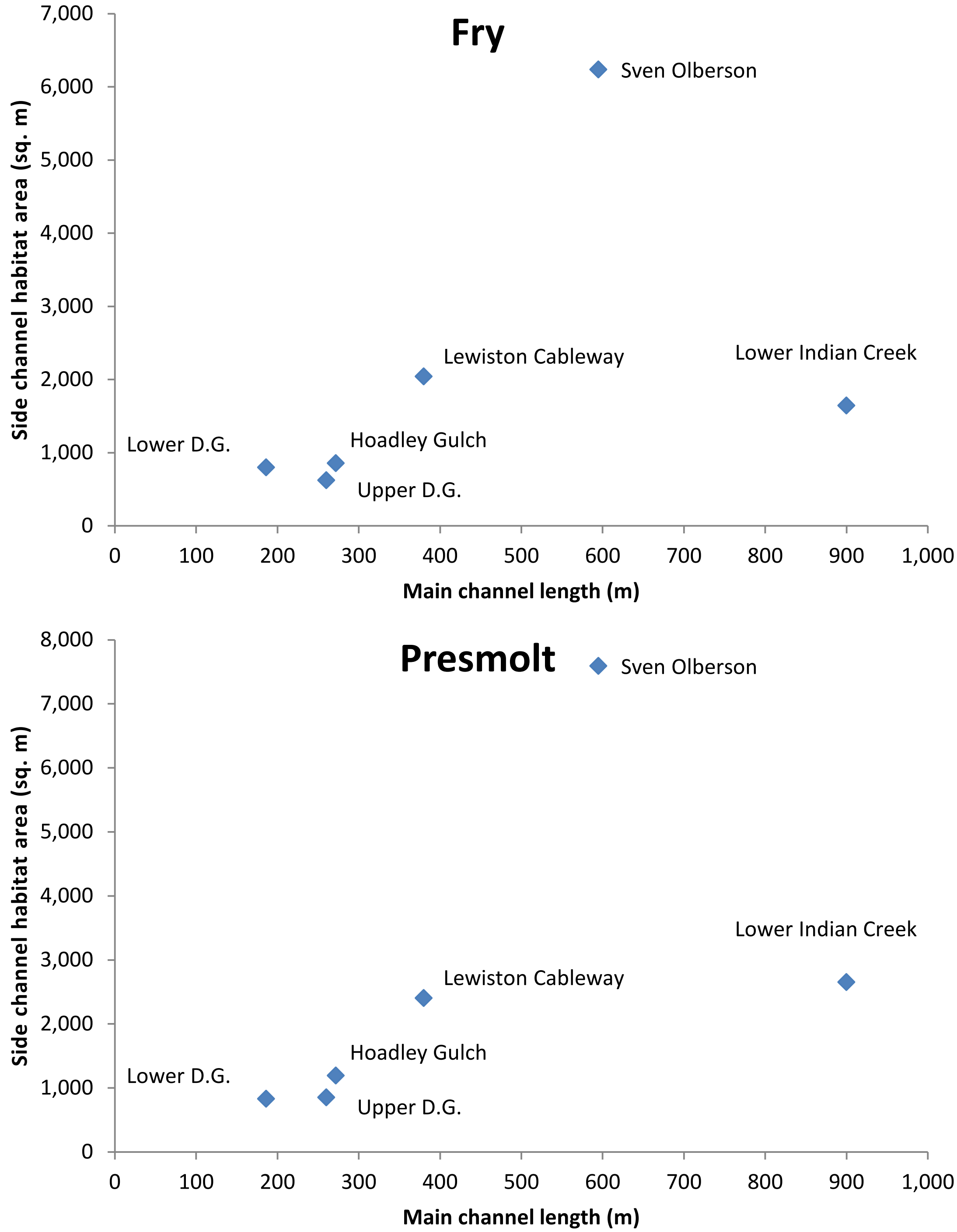


Figure 4–22. Side-channel habitat plotted against main-channel length at channel rehabilitation sites. Site-specific main channel discharges range from 8.6 to 13.4 cms (304–473 cfs). Habitat measured as total rearing habitat. The fry life stage indicates fish <50 mm FL and presmolt 50 to 200 mm FL.

Table 4–11. Side-Channel Attributes at Channel Rehabilitation Sites. Main-channel discharge is measured by proximal USGS gauges. Side-channel discharges were measured by a handheld flow meter. Main-channel length is measured along the channel centerline. Total rearing habitat relates to fry and presmolt habitat areas within the side channel. Fry and presmolt habitat density is calculated as the habitat area within the side channel divided by main-channel length.

Site	Main-channel discharge (cms)	Side-channel discharge (cms)	Main-channel length (m)	Total fry habitat (m^2)	Fry habitat density (m^2/m)	Total presmolt habitat (m^2)	Presmolt habitat density (m^2/m)
Sven Olbertson	8.6	1.1	595	6,234	10.5	7,589	12.8
Lewiston Cableway	8.7	1.3	380	2,039	5.4	2,403	6.3
Hoadley Gulch	8.7	0.3	272	857	3.2	1,191	4.4
Upper Dark Gulch	8.6	0.9	260	623	2.4	851	3.3
Bucktail	8.6	<0.1	186	797	4.3	827	4.4
Lower Indian Creek	13.4	NA	900	1,644	1.8	2,652	2.9

4.4. Discussion — Site-Specific Priority Fish Habitat Questions

4.4.1. Lower Reading Creek

Preconstruction conditions were outlined in the results section. No discussion warranted until post-construction conditions are reported.

4.4.2. Lowden Meadows

Preconstruction conditions were outlined in the results section. No discussion warranted until post-construction conditions are reported.

4.4.3. Bucktail–Dark Gulch

Priority question F–1 examines the change in Chinook salmon and coho salmon rearing habitat at winter base flow resulting from construction of rehabilitation sites (pre/post-construction assessment). Post-construction fry and presmolt habitat increased at winter base flows for the entire Bucktail–Dark Gulch rehabilitation site. However, these increases (28% and 21%) immediately post-construction were marginal relative to the targeted change of at least 400 percent (U.S. Fish and Wildlife Service and HVT 1999). The winter rearing period is critical for Chinook salmon and coho salmon fry and presmolts. At this location, streamflows do not fluctuate much during the winter rearing period, making this a particularly critical flow for restoration effects. Although spawning habitat was not assessed at this site, it is of interest that, in 2009, redd/carcass monitoring crews observed 16 redds in the constructed Upper Dark Gulch side channel and zero redds in the Bucktail side channel (Chamberlain et al. in prep). The discrepancy between the two side channels was likely due to the low stream flow in the Bucktail channel at spawning discharges (<0.1 cms [3.5 cfs]).

Priority question F–2 asks how selected channel rehabilitation treatments alter the flow-habitat relationships and habitat availability. Most of the increases in optimal habitat at lower flows can be attributed to the use and installation of large woody debris in the side channels and mainstem banks. The flow-habitat relationship was mostly unchanged at the Bucktail site post-construction, although habitat increased at all flows for both guilds. A major change in the flow-optimal habitat relationship was observed at the Upper Dark Gulch rehabilitation site. Pre-construction optimal habitat at Upper Dark Gulch created a "U" shape in the flow-habitat graph. Large gains of suitable fry and presmolt habitat (236% and 329%, respectively) were observed at the Upper Dark Gulch site following construction. This was largely due to the lowering of the floodplain between the side channel and mainstem allowing water to overtop the banks of the side channel at the 56.6-cms (1,998-cfs) flow rate (Figure 4–23). Lower values of optimal habitat at higher flows can be attributed to the removal of vegetation during construction.

4.4.4. Hoadley Gulch

Priority question F–1 examines the change in Chinook salmon and coho salmon rearing habitat at winter base flow, resulting from construction of rehabilitation sites (pre/post-construction assessment). There was a large increase in total fry habitat (35 percent) but only a slight increase in total presmolt habitat (6 percent). Construction of the Hoadley Gulch side channel accounted for all the increases in presmolt habitat at this site. The side channel was designed to have water entering at two locations (McBain & Trush and HVT Fisheries 2007). At 8.6 cms (304 cfs), the secondary channel was supplying water from the side channel back into the main channel. The second side-channel opening had very slow velocities at this discharge rate, which resulted in a high proportion of Chinook and coho salmon rearing habitat. Inflow through the second entrance was observed (but not measured) at higher flows (56.6 cms [2,000 cfs]).

The total habitat in the mainstem increased but in one category there was a decrease in mainstem habitat. The decrease in DV, No C presmolt habitat noted in the mainstem primarily occurred in two areas: the gravel bar addition and the lower portion of the site. The gravel addition filled in fry and presmolt habitat along that margin where there was vegetation and pushed it out to the edge of the constructed bar. At the lower portion of the site, deposition of gravel in the center of the main channel decreased water depths and caused velocities to increase, decreasing areas of habitat.

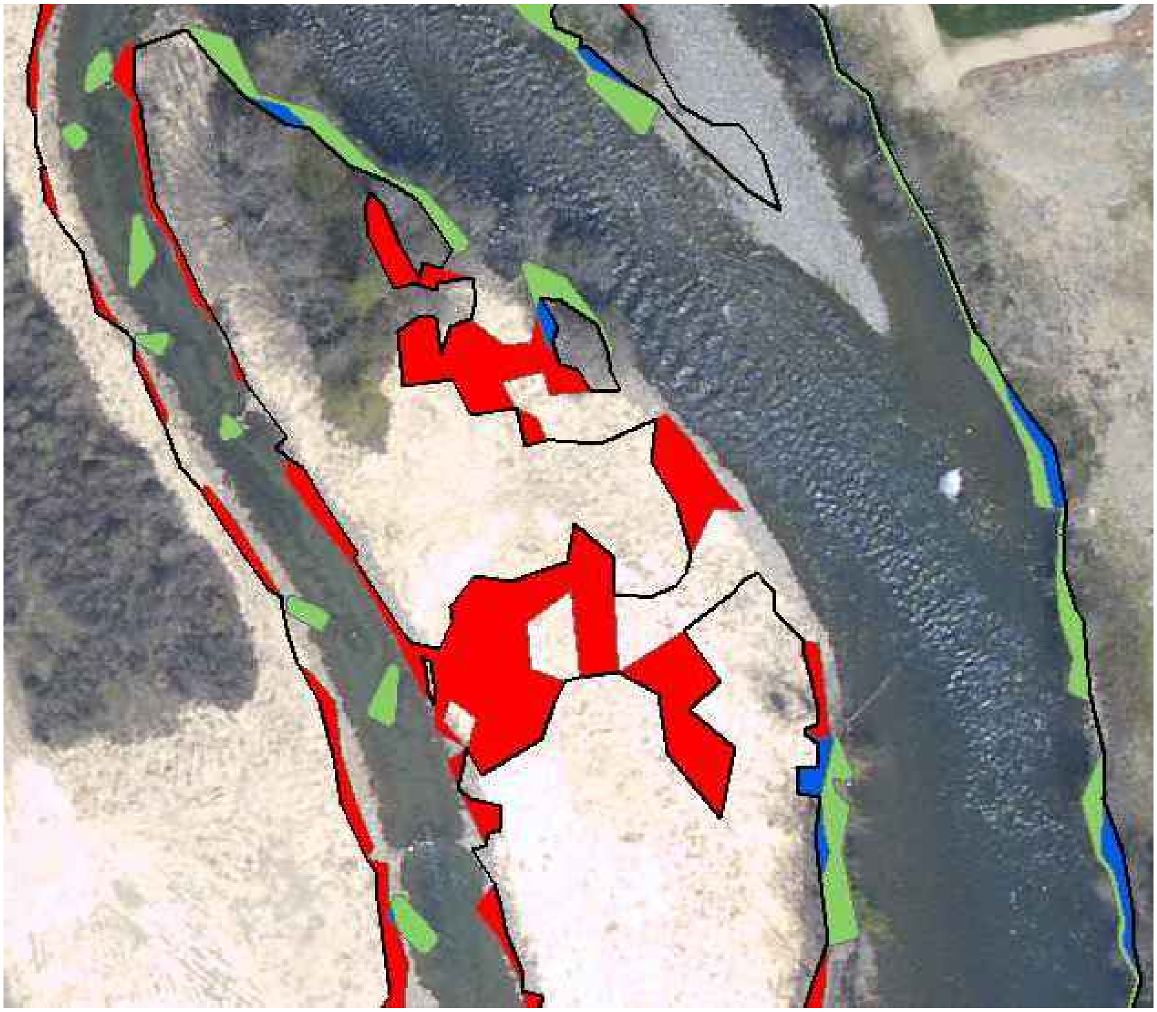


Figure 4–23. Increases in Chinook salmon and coho salmon fry habitat across the floodplain at Upper Dark Gulch post-construction. Blue areas represent optimal habitat (DV, C), red areas represent suitable habitat (DV, no C), green areas represent medium-quality habitat (no DV, C), and black lines represent the edge of the water.

4.4.5. Lewiston Cableway

Priority question F–1 examines the change in Chinook salmon and coho salmon rearing habitat at winter base flow resulting from construction of rehabilitation sites (pre/post-construction assessment). The reopening of the side channel (once called Miller Side Channel) on the right bank accounted for most of the habitat gains (53% and 36%, respectively) for fry and presmolt total habitat. Prior to construction, the side channel had been cut off at lower flow rates by gravel at the entrance. It began to flow again at around 18.4 cms (650 cfs). Pre-construction mapping showed more suitable habitat at the 19.3-cms (680-cfs) flow because the side channel was barely flowing and velocities were slow. Year-round flow in the side channel has resulted in rearing-habitat gains during winter base flow, a critical time for rearing fry and presmolt salmon.

Priority Question F–2 asks how selected channel rehabilitation treatments alter the flow-habitat relationships and habitat availability at these locations. Post-construction flow-habitat relationships indicate that total habitat is generally greater than was available pre-construction, and the large decrease in habitat observed between flows of 8.6 and 19.3 cms (300 and 680 cfs) in the pre-construction channel form was eliminated. Rehabilitation designs at Lewiston Cableway called for little to no removal of trees and vegetation. For that reason, the optimal habitat did not decrease post-construction, as had occurred at other previous rehabilitation sites (e.g., Hocker, Upper Dark Gulch, and Lower Indian Creek).

4.4.6. Sven Olbertson

Priority question F–1 examines the change in Chinook salmon and coho salmon rearing habitat at winter base flow resulting from construction of rehabilitation sites (pre/post-construction assessment). The post-construction habitat assessment at Sven Olbertson detected the highest gains during winter base flows in fry and presmolt rearing habitat at any site evaluated in 2009. The multi-entrance side channel with alcoves and a large slow-water area at the downstream end is a valuable addition to this section of river. The large increase in optimal fry and presmolt habitat (DV,C) can be partly attributed to the installation of large woody debris during construction and vegetative growth that occurred since construction. This area receives a large number of spawning Chinook salmon, coho salmon, and steelhead (Figure 4–24). In 2009, 67 redds were observed by the redd/carcass crews within the newly created sections of the Sven Olbertson side channel (Chamberlain et al. in prep).

4.4.7. Across-Site Comparison

4.4.7.1. Streamflow to habitat relationships

Before implementation of the ROD, because of the artificial confinement of the Trinity River channel, increasing streamflow would result in a decrease in habitat area for rearing Chinook salmon and coho salmon until the riparian berms were overtopped (USFWS and HVT 1999). The riparian berms had confined the river channel in many areas, not allowing the river to expand onto the natural floodplain. This effect may also have led to a population bottleneck for rearing Chinook salmon and coho salmon.

A beneficial result of the restoration actions would be to reduce or remove the dip in the streamflow-to-habitat relationships that was observed for Chinook salmon and coho salmon rearing habitat. Post-construction rearing-habitat densities across streamflows were evaluated at multiple channel rehabilitation sites. At some sample sites, such as Lewiston Cableway and Bucktail, rearing habitat did not decrease with increasing streamflow. Other sites, including Upper Dark Gulch and Hocker Flat, exhibited decreases in rearing habitat with streamflow.

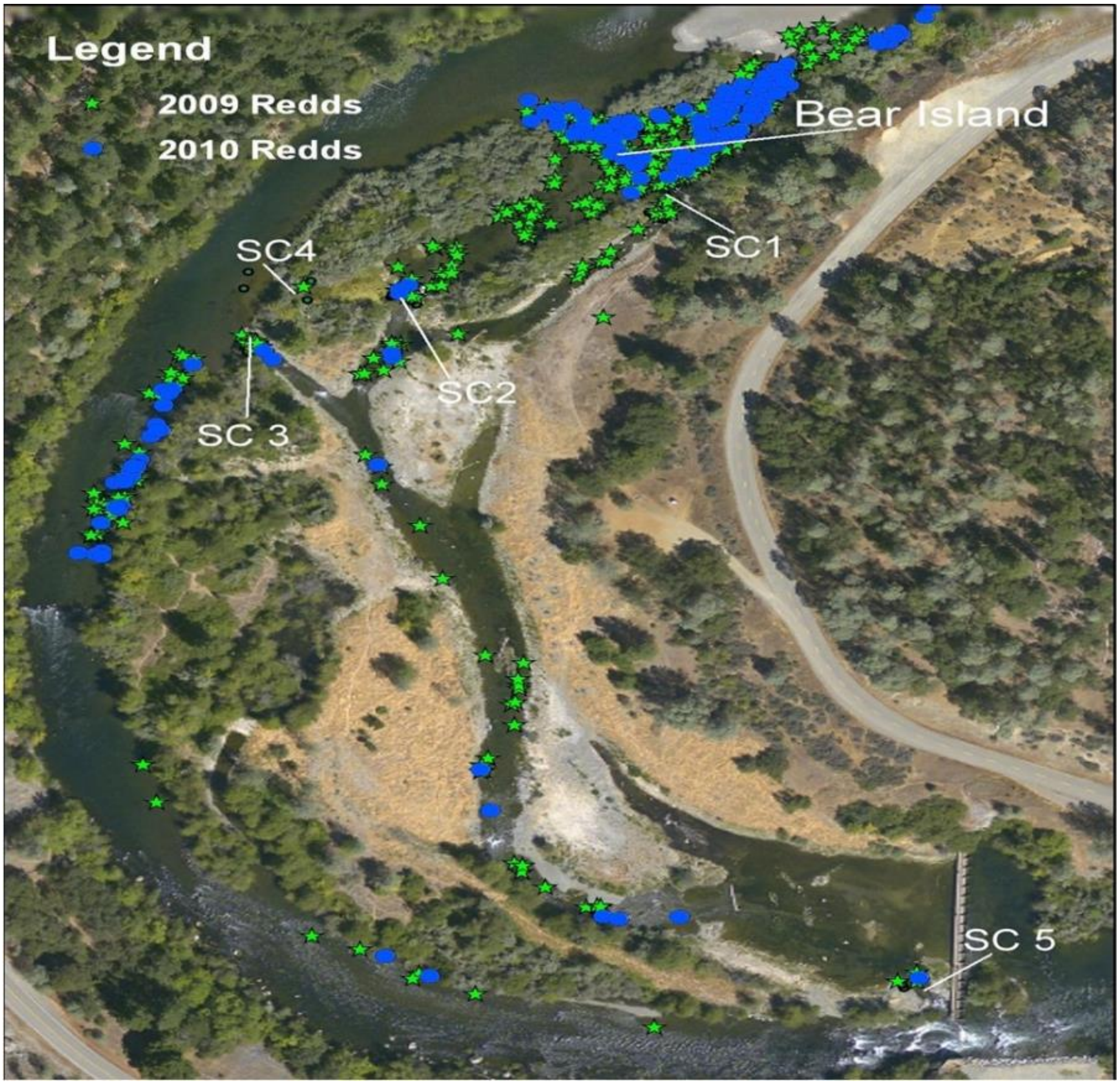


Figure 4–24. Overview of Sven Olbertson and Bear Island side channels. Discharge measurement locations for each opening are labeled.

The differences in streamflow-to-habitat relationships across channel rehabilitation sites are related to specific treatment types and channel configurations at each site. For example, at Lewiston Cableway, little vegetation was removed during construction and riparian berms are not present. As streamflow increases, water inundates the vegetation, creating escape cover and low-velocity habitats. In addition, after the water overtops the banks it is able to spread onto the floodplain, creating a direct relationship between streamflow and habitat density. In contrast, at Hocker Flat, much of the vegetation was removed, no large wood was installed, and the floodplain was recontoured, leaving little structural complexity. This treatment type yielded a low density of high-quality Chinook salmon and coho salmon habitat three years after construction (measurements at this site were taken in 2008). The floodplain recontouring treatment type enables water to spread onto the floodplain as streamflow increases, resulting in coarse sediment deposition and the development of mid-channel bars. The bars do create habitat at lower streamflows, but as streamflow increases they are submerged and provide little velocity shelter. In addition, little structural complexity exists on the floodplain to reduce water velocities and create rearing habitats. At Hocker Flat these factors contribute to the inverse relationship between rearing-habitat density and streamflow.

4.4.7.2. Level of Effort

Different levels of effort have been applied at each channel rehabilitation site. To date, no assessment has been made to evaluate if larger channel rehabilitation sites initially produce more rearing habitat. This question was analyzed, in a very cursory manner, by comparing the level of effort applied at each site relative to the post-construction habitat area at a single streamflow. For this analysis, treatment area was used as the best available surrogate for restoration effort. Treatment area is defined as area of construction from the TRRP design shapefile exclusive of spoils areas. This analysis looked only at the habitat during winter base flow. However, we recognize that restoration actions are intended for other functions such as recovery of healthy river attributes, and future evaluations must take these factors into consideration. However, habitat at winter base flows are of fundamental importance to rearing salmonids, so our analysis focused on that particular aspect of habitat. Design and implementation costs for each site would be a more desirable metric, but these were not available for individual channel rehabilitation sites.

A direct relationship was observed between treatment area and rearing habitat for sites constructed in 2008, with larger sites containing more habitat. This relationship seems logical, but was not consistent at all channel rehabilitation sites. For example, Hocker Flat was the first bank rehabilitation site constructed and is also included in this analysis. Interestingly this site contained the lowest post-construction quantities of optimal rearing habitat. Similarly, the area of total habitat at this site is among the smallest observed. Lower Indian Creek was constructed in 2007 and had the second largest treatment area in the analysis. This site, similar to Hocker Flat, had low values of rearing habitat relative to the level of restoration effort applied at the site. This channel rehabilitation site has a side channel running almost the entire length of the site, a treatment type applied in all of the 2008 channel rehabilitation sites.

The discrepancy in the treatment area to habitat area relationship at the sites constructed in 2008 and prior years indicated that treatment area is not the only controlling variable for habitat area at the channel rehabilitation sites. The discrepancy may be related to differences in treatment types and specific designs of each treatment. This analysis indicated not only the importance of the level of effort applied at each bank rehabilitation site but the specific treatments and designs that are applied at each site to maximize the benefit of the channel rehabilitation actions. In the future, instead of only looking at the winter base flow of 8.5 cms (300 cfs), we could plot the integral of the flow-to-habitat curve from 8.5 to 56.6 cms (2,000 cfs) at each site against the treatment area to give a better idea of the effect of construction across flows.

4.4.7.3. Side channel evaluations

Thus far, the highest habitat density values observed in the project area have occurred at sites where side channels have been created or enhanced. However, there are large variations in quality and quantities of habitat across constructed channels. Total fry habitat densities at Sven Olbertson are nearly six times that of Lower Indian Creek. There are a number of lessons to be learned by comparing these two constructed side channels. Lower Indian Creek side channel is relatively straight, has steep banks, and has one constant gradient almost continuously. Consequently, it has constant velocities that afford little opportunity for habitats dependent upon slow velocities. The Sven Olbertson side channel is more sinuous, has gently sloped sides, includes alcoves and backwaters, and reflects more of a pool/drop morphology. Therefore, much of the length of the Sven Olbertson side channel has slopes near zero with short sections built in that account for most of the drop within the site. Confining the drop to specific sections of channel (steep riffles or drops) allows the other sections to accommodate low velocities and therefore to have higher habitat values.

A trait which both the Sven Olbertson and Lower Indian Creek side channels share is the presence of multiple entrances or exits. This is a beneficial feature to include in future designs. Entrance conditions can change yearly based on flows, gravel recruitment, or other factors. Building multiple entrances can help ensure the long-term success of a side channel. For example between the 2009–10 and 2010–11 seasons, we documented major changes in discharge within the multiple constructed channels at Sven Olbertson.

During the 2009 redd/carcass survey, 67 redds were documented within the Sven Olbertson constructed side channel. In 2010, only 11 redds were observed (Chamberlain et al. in prep). Also, a large reduction in redd creation was observed in the lower half of what’s known as the “Bear Island side channel.” This channel feeds measuring points SC1 and SC2 of the Sven Olbertson site. The changes in redd abundance can be attributed to deposition of coarse sediment at the head of Bear Island. This deposition reduced the flow into the Bear Island channel and subsequently into the SC1 and SC2 channels below it, causing a major reduction in observed redds through this area. In 2010, SC3 was the primary source of water for the constructed side channel, but in 2009 it was the smallest source. This observation provides a prime example why multiple side channel openings are a worthy element of future designs. Although no habitat surveys are planned in the next year or two at Sven Olbertson, the habitat team will continue to monitor the evolution of discharges within the side channels.

The location of any side-channel opening can be critical to the long-term function of the channel. The use of hard points such as large woody debris can dramatically influence channel morphology, pool formation, hydraulic conditions and long-term flow into a side channel (Abbe et al. 2003). Placed improperly, they can also shorten the lifespan of a side channel. The Bucktail side channel has very little current moving through it at base flow. During construction, a log was improperly placed on the upstream side of the opening. This is causing fine sediment deposition behind the log and is threatening to close off the channel. In this case, the wood was placed without a trained technician supervising the operator (D.J. Bandrowski pers. comm.). This simple mistake could seal off the side channel to low flow and spoil the effort and money spent to build it. Wood structures placed on the downstream end of side-channel openings will help deflect water into the channel and transport substrate down the main channel, helping maintain the opening for many years. The TRRP should ensure that all important wood placements are supervised on site by trained technicians.

4.5. References

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CHAPTER 5. ESTIMATION OF CHINOOK SALMON AND COHO SALMON REARING-HABITAT AREA WITHIN THE PRIMARY RESTORATION REACH OF THE TRINITY RIVER

5.1. Introduction

The restoration strategy for the Trinity River is designed to restore fluvial-geomorphic processes downstream of Lewiston Dam. This strategy is intended to lead to increased channel complexity and result in systemic increases in salmonid habitat quantity and quality (USFWS and HVT 1999). These changes are anticipated to be more prominent above the confluence of the North Fork Trinity River, hereafter referred to as the primary restoration reach. The restoration strategy is made up of four components: (1) mechanical channel rehabilitation, (2) flow management to drive fluvial processes that create and maintain salmonid habitats and provide suitable thermal regimes, (3) coarse sediment augmentation, and (4) watershed restoration. Although maximum change in rearing habitat is anticipated at channel rehabilitation sites, we hypothesize that the restoration strategy will create synergistic effects, improving habitat throughout the primary restoration reach (Barinaga 1996, USFWS and HVT 1999).

This assessment evaluates the effects of restoration on Chinook salmon and coho salmon rearing-habitat area within the primary restoration reach following the Integrated Assessment Plan objective 3.2.1 (Trinity River Restoration Program and ESSA Technologies Ltd. 2009). The questions addressed in this assessment include:

1. What is the quantity and quality of Chinook salmon and coho salmon rearing habitat within the primary restoration reach at 13 cms (450 cfs) Lewiston dam release (priority question F–4.)?
2. Is there a correlation between fry and presmolt rearing-habitat quantities?
3. Is there a correlation between rearing-habitat area and site-specific characteristics?
4. How should sites be revisited to evaluate the status of and trends in rearing-habitat area with implementation of restoration actions?

5.2. Methods

The restoration reach rearing-habitat assessment study design includes the following components: (1) sample site definitions, (2) sample site selection protocol, and (3) revisit design. Sample sites were defined as 400-m (1,300-ft) segments of the 142-cms (5,000-cfs) centerline shapefile derived from HEC-RAS modeling (Figure 5–1; TRRP unpublished data). This sample site size was selected based on survey efficiency and recommendations from multidisciplinary planning meetings in anticipation that it will, if appropriate for specific study objectives, be adopted by other disciplines in future assessments. The sample universe was defined as the primary restoration reach. Units were selected using the generalized random

Figure 5–1. Systemic rearing-habitat assessment sample sites on the Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River. Shown here are 32 400-m (1,300-ft) sample units from panels 1 and 2 of the rotating panel revisit design. Sample units were selected using the GRTS protocol.

tessellation stratified (GRTS) sample unit selection protocol (Stevens and Olsen 2004). The sample was not further stratified as suggested in the FY2009 proposal (USFWS et al. 2008) due to complications in selecting stratification variables appropriate for multidisciplinary assessments.

A rotating panel revisit design was developed to evaluate status and trends in habitat availability through time (McDonald 2003; Table 5–1). The rotating panel design divides the sites into five "panels," each including 16 GRTS sample sites within it. Two panels are sampled within each year, representing 20 percent of the primary restoration reach. In the following year of sampling, one of the panels is repeated and one new panel is added until all five panels are sampled. In the fifth year the first panel is sampled again and the sixth year the first two panels are sampled again. The five panels make up 50 percent of the sample universe.

Table 5–1. The Rotating Panel Revisit Sampling Design for the Rearing-Habitat Assessment on the Trinity River, CA. Each panel is unique (sampling without replacement) and composed of randomly selected spatially balanced sample units utilizing GRTS.

Panel	Year				
	2009	2010	2011	2012	2013
1	X				X
2	X	X			
3		X	X		
4			X	X	
5				X	X

In the summer of 2009, rearing-habitat surveys were conducted on panels 1 and 2 using methods described in Goodman et al. (2010). All surveys were conducted during summer base flows with the Lewiston Dam release of 12.7 cms (450 cfs). Quantities of fry and presmolt habitat that met the various habitat variable conditions (Table 5–2) were estimated for the following categories: (1) meeting both depth/velocity and cover criteria, (2) meeting depth/velocity but not cover criteria, (3) meeting cover but not depth/velocity criteria, and (4) total habitat, defined as the sum total of types 1 through 3. For this report, total Chinook salmon rearing habitat (total habitat) includes all areas that meet any combination of depth/velocity or cover criteria. Optimal Chinook salmon rearing habitat includes areas that meet both depth/velocity and cover criteria. Suitable Chinook salmon rearing habitat includes areas that meet either depth/velocity or cover criteria but not both. Unsuitable Chinook salmon rearing habitat includes areas not meeting either set of criteria. Coho salmon rearing habitat is limited to areas that meet both depth/velocity and cover criteria, and all other areas are considered unsuitable habitat.

Table 5–2. Guilds and Their Associated Habitat Criteria for Fish Habitat Mapping as Part of the 2008 Trinity River Site Assessment (Goodman et al. 2010)

Habitat guild	Variable	Criteria
Chinook salmon and coho salmon fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column velocity	0 to 0.15 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood
Chinook salmon and coho salmon presmolt (50 to 200 mm)	Depth	>0 to 1 m
	Mean column velocity	0 to 0.24 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood

The resulting habitat quantities were analyzed to develop restoration reach estimates of habitat categories. Sample error was estimated using a neighborhood variance estimator developed for use with GRTS sample designs (Stevens and Olsen 2002). The neighborhood variance estimator incorporates spatial location of sample units into error estimation. Analyses were conducted using the "spsurvey" program (Kincaid and Olsen 2009), and the results are presented as cumulative distribution function plots, which display the distribution of rearing-habitat quantities and the associated error within the sample.

The effects of physical characteristics on habitat quantities were evaluated at GRTS sample units. For simplicity, this analysis was limited to the total and optimal (within depth/velocity and cover criteria) habitat categories. The initial step was to develop and test a set of predictor variables that may affect habitat availability at each site (the response variable). Predictor variables included channel rehabilitation site construction, side-channel length, bank length, distance from dam, and elevation change. Channel rehabilitation site construction was coded as: (1) pre-ROD rehabilitation site or (2) post-ROD rehabilitation site, if either type of rehabilitation encompassed more than 25 percent of the 400-m (1,300-ft) sample unit; otherwise the site was coded as (3) no known channel restoration. Pre-ROD rehabilitation actions include habitat improvement actions that were implemented on the Trinity River prior to the signing of the ROD, including side-channel improvements and other off-channel habitat features, grade control installations, and feathered edges. These actions were implemented by a variety of public agencies, both Federal and State. Post-ROD rehabilitation sites are those constructed since the signing of the ROD. Side-channel length was measured along side-channel centerlines estimated from mapped wetted channel areas, a product of the habitat mapping survey. Bank length was measured during habitat surveys using GPS survey techniques (Goodman et al. 2010). Distance from dam was estimated using the river centerline shapefile. Elevation change at each site was estimated by averaging the elevations of the low-flow waterline on each bank at the top and bottom of each site. Low-water lines were developed by Woolpert, Inc., using a combination of the 2009 LiDAR and orthoimagery and assigned elevations based on the nearest bare earth LiDAR return values (Woolpert, Inc. 2009).

The data set was analyzed for correlations between predictor variables and habitat categories. Continuous variables, including side-channel length, bank length, distance from dam and elevation change, were assessed for correlation with habitat area using the non-parametric Spearman's correlation coefficient ρ (rho). Spearman's correlation coefficient is a measure of statistical dependence between two variables (Zar 2005). The non-parametric Mood's median test was used to evaluate the effects of bank rehabilitation, a categorical variable. The median test evaluates differences between the median values of groups that include outlying values, in this case bank rehabilitation categories (Siegel and Castellan 1988). Analyses were conducted in the program SPSS for Windows (ver. 11.0.1). Multivariate analyses was not conducted due to the small sample size (n = 32).

5.3. Results

Estimates of rearing-habitat area were developed for fry and presmolt in the four habitat categories (Table 5–3). The total rearing-habitat estimate for fry was 343,201 m^2 (3,694,185 sq. ft). Optimal fry rearing habitat accounted for 26 percent of the total estimated habitat. Suitable depth-velocity habitat accounted for 41 percent of the total, and suitable cover habitat accounted for 33 percent of the total fry rearing habitat. The total presmolt rearing-habitat estimate was 436,613 m^2 (4,699,663 sq. ft). Optimal presmolt habitat accounted for 27 percent of the total, and suitable depth-velocity habitat accounted for 54 percent. Suitable cover presmolt habitat accounted for 19 percent of the total presmolt rearing-habitat estimate. For fry, the standard error (SE) in restoration reach estimates ranged from 7 percent for habitat within depth/velocity criteria to 20 percent for habitat within cover areas. For presmolt, the SE in restoration reach estimates ranged from 7 percent for habitat areas within depth/velocity criteria and for total habitat area, to 25 percent for habitat within cover criteria.

For total fry habitat, a small proportion of sample units had high quantities relative to the rest of the sample (Figure 5–2). Of the 32 units sampled, 29 had total fry habitat measurements less than 2,592 m^2 (27,900 sq. ft) and the other 3 had measurements of 4,180, 4,656, and 10,008 m^2 (44,993, 50,117, and 107,725 sq. ft, respectively). Similar uneven sample distributions were seen for fry habitat meeting the criteria for cover by not for depth/velocity and also for habitat meeting both criteria. In both cases a small proportion of the sample had much higher habitat estimates. Fry habitat areas that met the criteria for depth/velocity but not for cover were more evenly distributed. Presmolt habitat measurements had a similar uneven distribution

Table 5–3. Restoration Reach Estimates of Rearing-Habitat Categories and Descriptive Statistics. Estimates are for the Trinity River from Lewiston Dam to the confluence of the North Fork Trinity River and are in square meters. Fry life stage corresponds to fish <50 mm FL and presmolt 50–200 mm FL. Habitat areas that meet either depth/velocity or in-water escape cover criteria are considered “suitable” Chinook salmon habitat. Habitat areas that meet both criteria are considered “optimal” Chinook or coho salmon habitat. Total habitat indicates the sum total of Chinook salmon habitat types.

Life stage	Habitat	Estimate	SE	Lower 95%	Upper 95%
Fry	Depth/velocity	140,845	9,956	121,332	160,357
	Cover	114,182	22,995	69,113	159,252
	Depth/velocity cover	88,174	12,143	64,375	111,974
	Total	343,201	32,433	279,633	406,769
Presmolt	Depth/velocity	234,178	15,590	203,621	264,734
	Cover	84,813	21,323	43,020	126,606
	Depth/velocity cover	117,623	14,040	90,105	145,141
	Total	436,613	31,482	374,909	498,318

among sample units that varied by habitat category (Figure 5–3). In the case of total presmolt habitat, most sample units had quantities less than 3,283 m^2 (35,338 sq. ft) except for three units that had 5,676, 5,828, and 10,122 m^2 (61,096, 62,732 and 108,952 sq. ft), respectively. These were the same units that had high measurements of total fry habitat. Similar to fry habitat, presmolt habitat qualities had uneven distributions for habitat meeting the criteria for cover by not for depth/velocity and for habitat meeting both criteria. Areas that met the criteria for depth/velocity but not for cover had a more even distribution of habitat availability. In summary, most sample units had similar quantities of rearing habitat, although a few sites had notably higher quantities.

Of the 32 sample units, 18 did not have any channel rehabilitation activity, 6 had pre-ROD rehabilitation actions, and 8 had post-ROD rehabilitation actions. Side-channel lengths at the sample units ranged from 0 or no side channel to 560 m ($\bar{x}$= 90, SE = 25; 0 to 1,837 ft) and 19 of the units did not have side channels. Bank length ranged from 810 to 2,206 m ($\bar{x}$ = 1,119, SE = 61; 2,657 to 7,238 ft), and the distance from the dam ranged from 3 to 61 rkm ($\bar{x}$ = 33, SE = 3; 1.86 to 38 rm). Elevation change within a site ranged from 0.08 to 1.80 m ($\bar{x}$ = 0.88, SE = 0.08; 0.26 to 5.9 ft).

Correlation was assessed between response variables, which for this analysis were limited to total and optimal habitat (depth/velocity and cover) areas. The Spearman's ρ correlation coefficient between total fry and presmolt rearing-habitat areas was 0.948 with a *p*-value (significance) <0.001 (Figure 5–4). Similarly for optimal habitat areas the correlation between fry and presmolt habitat areas was ρ = 0.980 with $p < 0.001$. Due to this high and significant correlation, subsequent analyses were limited to presmolt habitat.

The site-specific variables were assessed against total presmolt habitat area (Figure 5–5). A positive correlation was identified between total presmolt habitat and bank ($\rho = 0.440$, $p = 0.012$) and side-channel length ($\rho = 0.574$, $p = 0.001$). A significant negative correlation was identified for distance from dam ($\rho = –0.440$, $p = 0.012$). No significant correlation was identified between elevation change and total presmolt habitat area ($\rho = 0.162$, $p = 0.375$). A significant difference was also identified between bank rehabilitation site categories ($\chi^2 = 6.500$, d.f. = 2, $p = 0.039$; Figure 5–6). The highest median value was assigned to post-ROD sites (median = 2,607, SE = 540, $n = 8$), then pre-ROD sites (median = 2,499, SE = 1,290, $n = 6$) and finally areas with no known bank rehabilitation actions (median = 2,049, SE = 107, $n = 18$).

The three sample units closest to Lewiston Dam had higher habitat values than the other sample units for total presmolt habitat estimates. The highest value was at the sample unit at the confluence with Rush Creek. This unit had 10,122 m^2 (108,952 sq. ft) of total presmolt habitat, which is 4,294 m^2 (46,220 sq. ft) more habitat area than any other site. This site was a pre-ROD rehabilitation site where a series of off-channel backwater areas were constructed on the left bank. In addition, Rush Creek adds coarse sediment and streamflow to the Trinity River in the middle of the site, adding to the channel complexity. Low-flow side channels not did exist, although a high-flow side channel was present on the left bank. The entrance and exit of the high-flow side channel also create additional areas of backwater-type habitats. Due to the complexity of the site, bank length was 1,452 m (4,764 ft) and is greater than the sample mean. The channel elevation changed by 0.93 m (3 ft) within the unit, which was a larger elevation change than the sample mean. Interestingly, most of the site was very low gradient glide-type habitat, and the elevation change was in a relatively short riffle-type section near the bottom of the site.

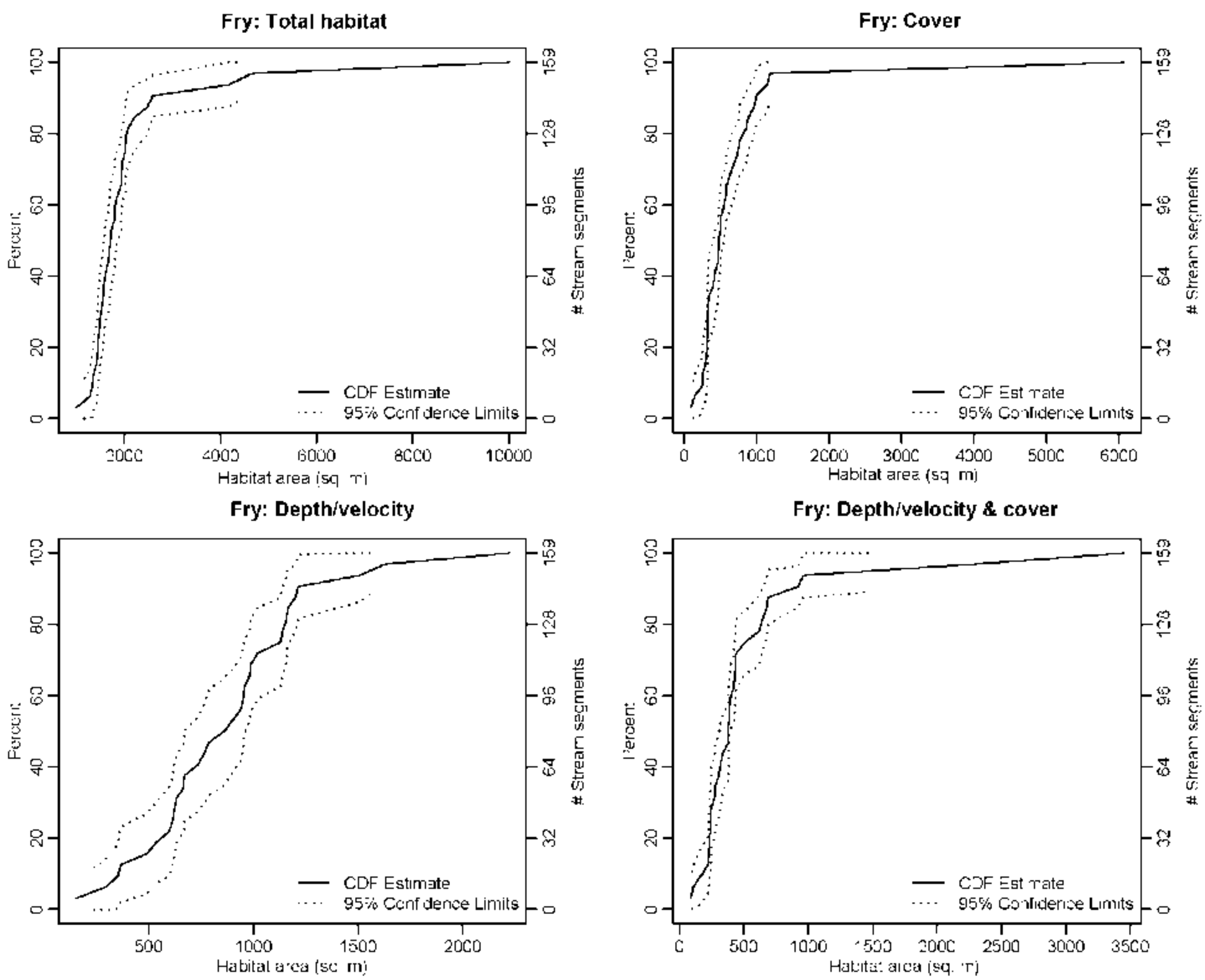

Figure 5–2. Cumulative distribution functions of fry habitat from 32 GRTS sample units. Fry life stage corresponds to fish <50 mm FL. Habitat areas that meet either the depth/velocity criteria or the in-water escape cover criteria, but not both, are defined as suitable habitat. Habitat areas that meet both criteria are optimal habitat. Total habitat indicates the sum of the suitable and optimal habitat types. The primary y-axis corresponds to the percent of the restoration reach estimated to contain the specific quantity of rearing habitat. Alternatively, the secondary y-axis indicates the number of 400-m segments estimated to contain the specific quantity of rearing habitat.

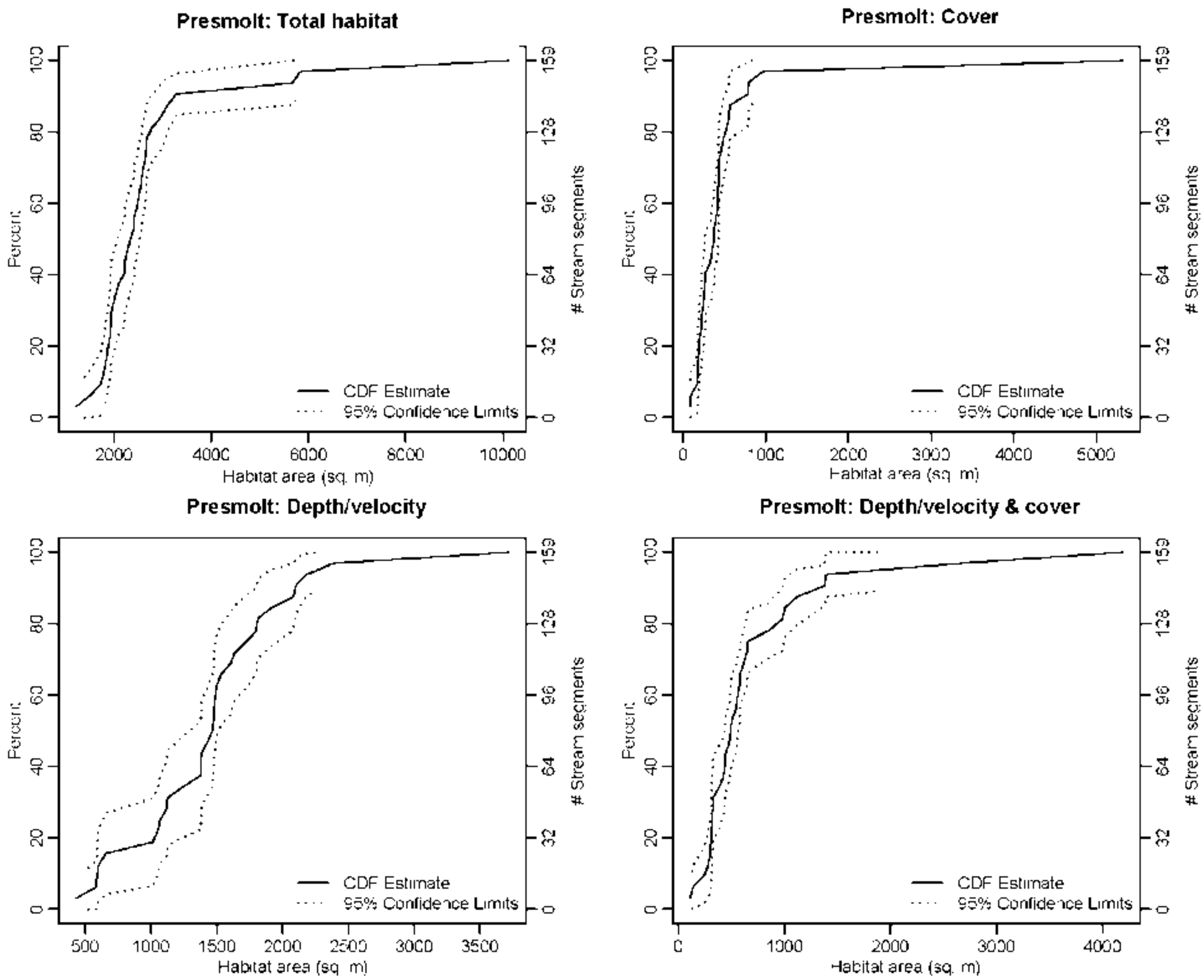

Figure 5–3. Cumulative distribution functions of presmolt habitat from 32 GRTS sample units. Presmolt life stage corresponds to fish 50–200 mm FL. Habitat areas that meet either the depth/velocity criteria or the in-water escape cover criteria, but not both, are defined as suitable habitat. Habitat areas that meet both criteria are optimal habitat. Total habitat indicates the sum of the suitable and optimal habitat types.

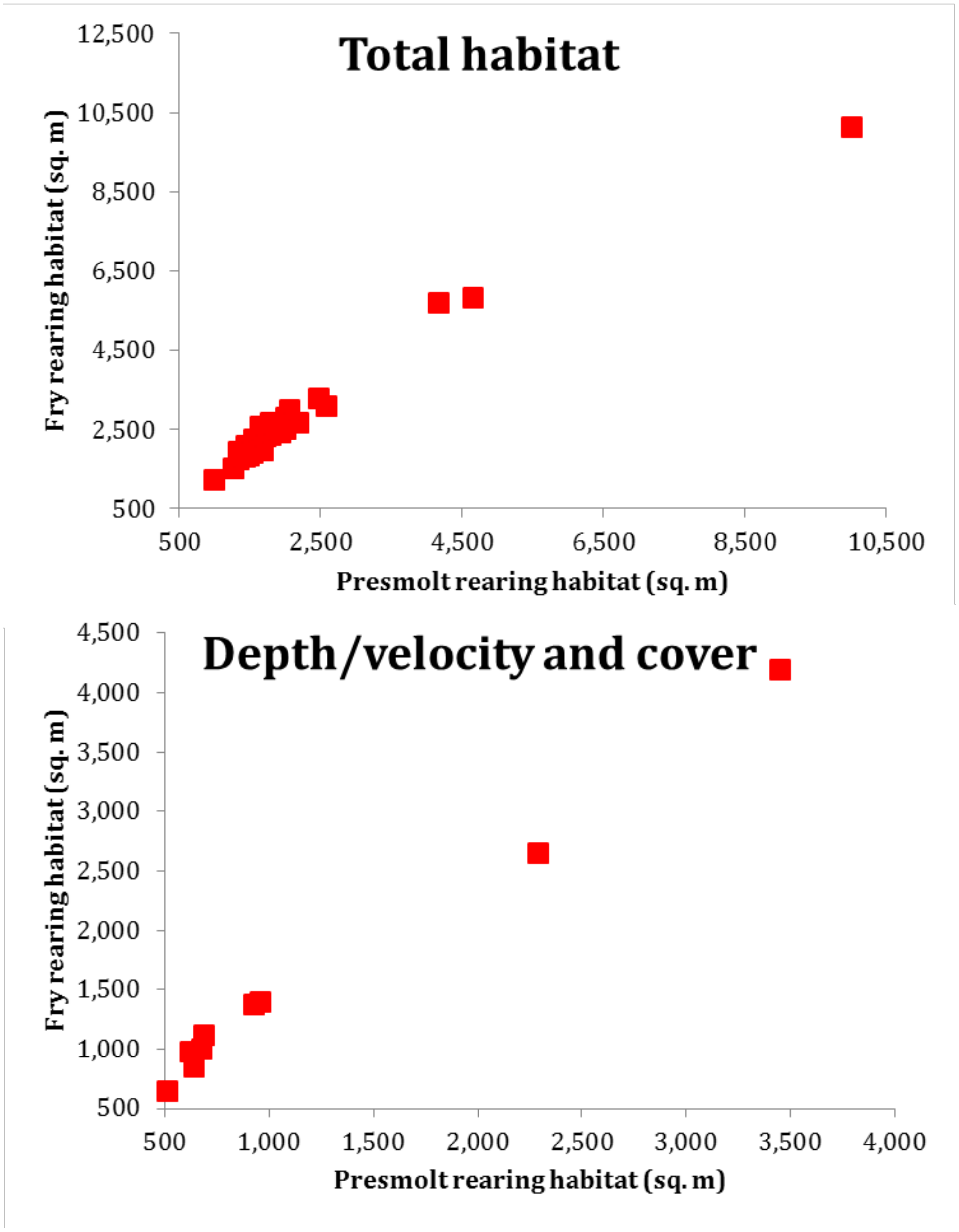

Figure 5–4. Scatter plot and linear regression of fry and presmolt habitat areas measured at GRTS sites. Habitat categories evaluated include total habitat (the summation of all areas meeting any combination of the depth/velocity and cover criteria) and optimal habitat (areas meeting both types of criteria).

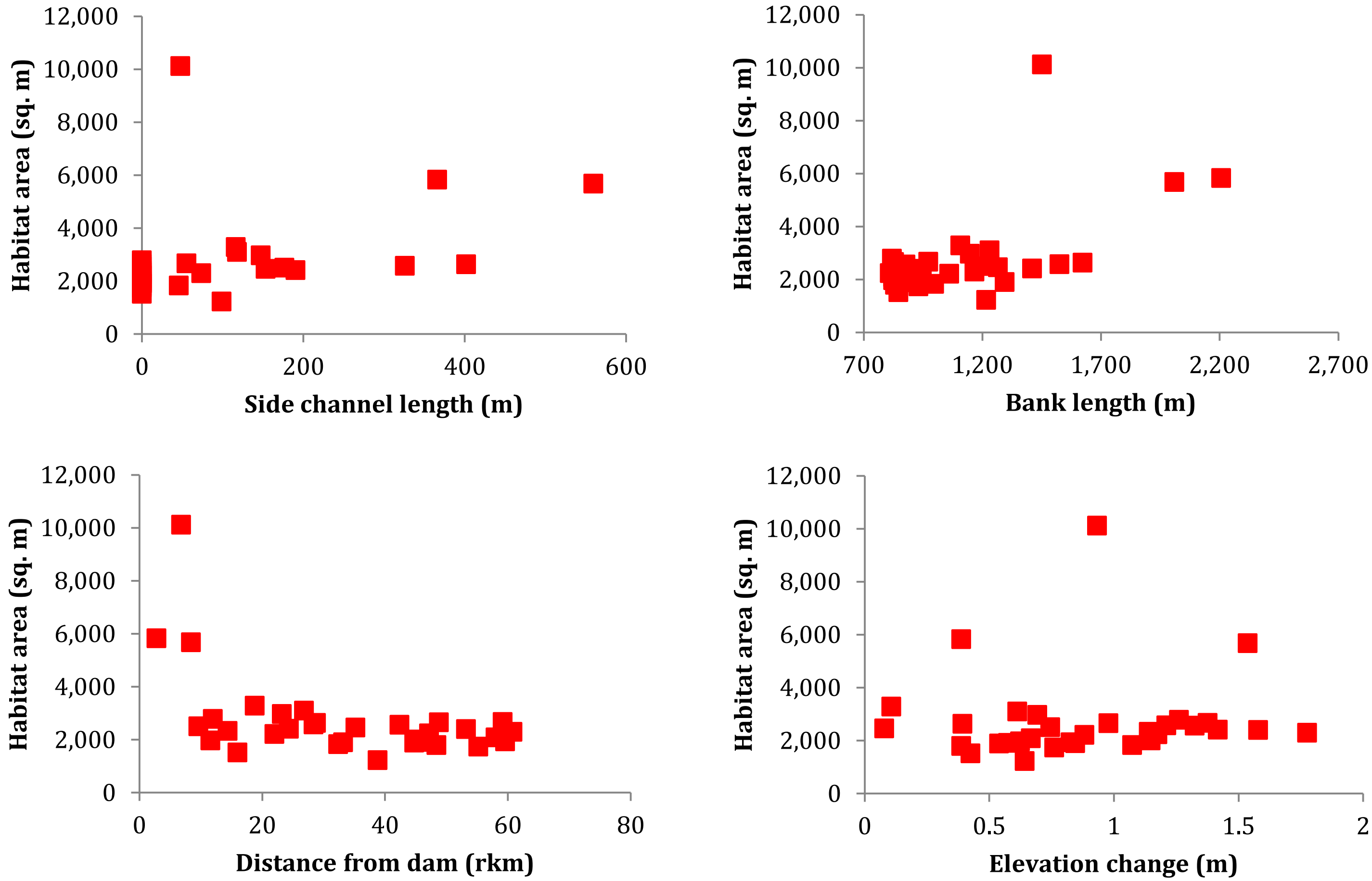

Figure 5–5. Total presmolt rearing-habitat area at GRTS sites by side-channel length, bank length, distance from Lewiston Dam, and elevation change.

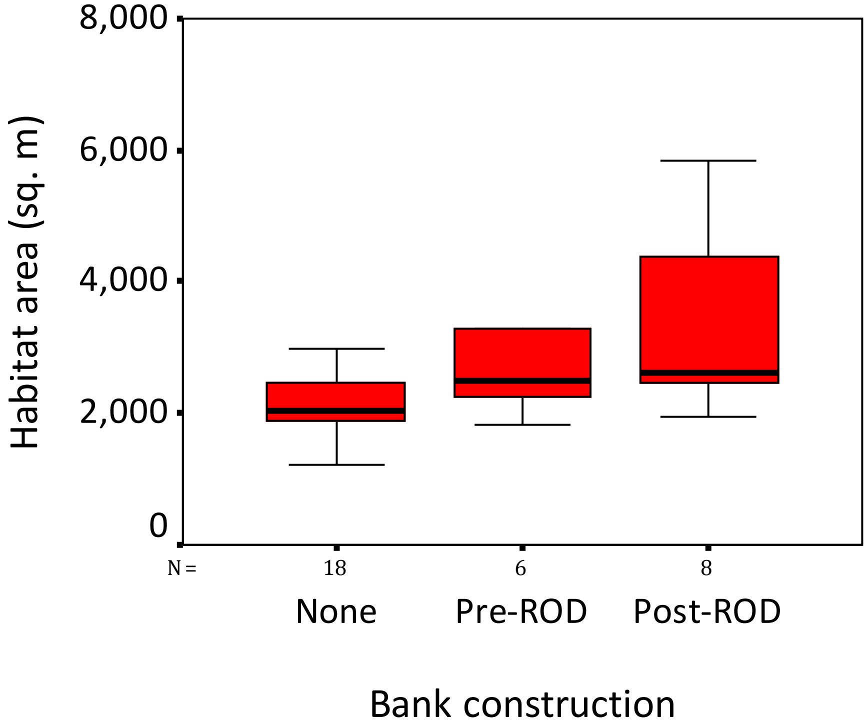

Figure 5–6. Total presmolt habitat by bank construction category at GRTS sample units. The following variables are represented in the plot: (1) a horizontal line is drawn at the median observation, (2) the boxes represent the first (Q1) and third quartile (Q3) values, (3) whiskers are defined by the values adjacent to the lowest and highest observations using the following limits: (a) lower limit: Q1–1.5×(Q3–Q1) and (b) upper limit: Q3+1.5×(Q3–Q1).

A sample unit near the town of Lewiston had the second highest quantity of total presmolt habitat: 5,828 m^2 (62,732 sq. ft), which was 3,090 m^2 (33,261 sq. ft) more than the sample mean. This site is located completely within the Lewiston Cableway channel rehabilitation site constructed in 2008. The rehabilitation project modified an existing side channel on the right bank, removed riffle-control structures from the main channel, constructed a series of alternating bars, and added large wood to the channel. The side channel in the site was 366 m (1,201 ft), longer than the mean side channel length of the 32 sample sites, and the bank length was 2,206 m (7,238 ft), nearly twice that of the mean and the highest of all sample units. The elevation change in the site was 0.39 m (1.28 ft) and was less than half that of the sample mean.

The third outlier for total presmolt habitat availability in the GRTS sample was located 0.4 rkm (0.3 rm) downstream of Salt Flat Road Bridge, located partially within the Dark Gulch channel rehabilitation site. This sample had 5,676 m^2 (61,096 sq. ft) of total presmolt habitat area, 2,939 m^2 (31,635 sq. ft) more than the sample mean. It contains 149 m (489 ft) of a constructed side channel and a constructed feathered edge feature. Upstream of the construction, the site includes several side channels that were present before construction. There was 560 m (1,837 ft) of side channel within this sample unit, more than six times the mean value. The bank length at the site was 2,009 m (6,591 ft), the second highest value in the sample. The elevation change was 1.54 m (5.05 ft) and higher than the sample mean.

The site-specific variables were assessed against optimal habitat area (Figure 5–7). As with total habitat area, optimal habitat had a negative correlation with distance from dam ($\rho = -0.800$, $p < 0.001$). No significant correlations were identified between optimal presmolt habitat area and side channel length ($\rho = -0.325$, $p = 0.070$), bank length ($\rho = -0.215$, $p = 0.237$), or elevation change ($\rho = -0.293$, $p = 0.104$). In addition, no significant difference in the amount of optimal habitat area was identified between channel rehabilitation site categories ($\chi^2 = 2.180$, d.f. = 2, $p = 0.336$; Figure 5–8).

In the case of optimal habitat, the two sample units closest to Lewiston Dam had the largest areas, which were also outlying values for total presmolt habitat. The highest value was in the sample unit at the confluence with Rush Creek. This sample had 4,195 m^2 (45,155 sq. ft) of optimal presmolt habitat, 1,540 m^2 (16,576 sq. ft) more habitat area than any other site. As described above for total presmolt habitat, this site was a pre-ROD rehabilitation site, was close to Lewiston Dam, and had a large amount of bank length and a large elevation change. The sample unit closest to Lewiston Dam also had a high habitat value, with 2,654 m^2 (28,567 sq. ft) of optimal presmolt habitat, 1,917 m^2 (20,631 sq. ft) more than the sample mean. As described above for total presmolt habitat, this sample unit was a post-ROD channel rehabilitation site and had a large amount of side-channel length, the highest bank length of all sample units, and a small elevation change.

5.4. Discussion

This study represents the first estimate of Chinook salmon and coho salmon rearing-habitat quantity in the primary restoration reach since the Trinity River Flow Evaluation and implementation of the ROD (USFWS and HVT 1999; U.S. Department of the Interior 2000). Although the estimate produced by this study was developed at an intermediate point in the restoration process, it provides a benchmark that will be used to evaluate future progress toward one of the primary restoration goals of increasing rearing habitat. One of the technical issues identified in the Integrated Assessment Plan (IAP) was the need to establish quantitative restoration goals for increases in rearing-habitat area; this task has not yet been completed (Trinity River Restoration Program and ESSA Technologies Ltd. 2009). Once completed, the habitat data collected by this study can be used to assess the progress in attaining the target(s).

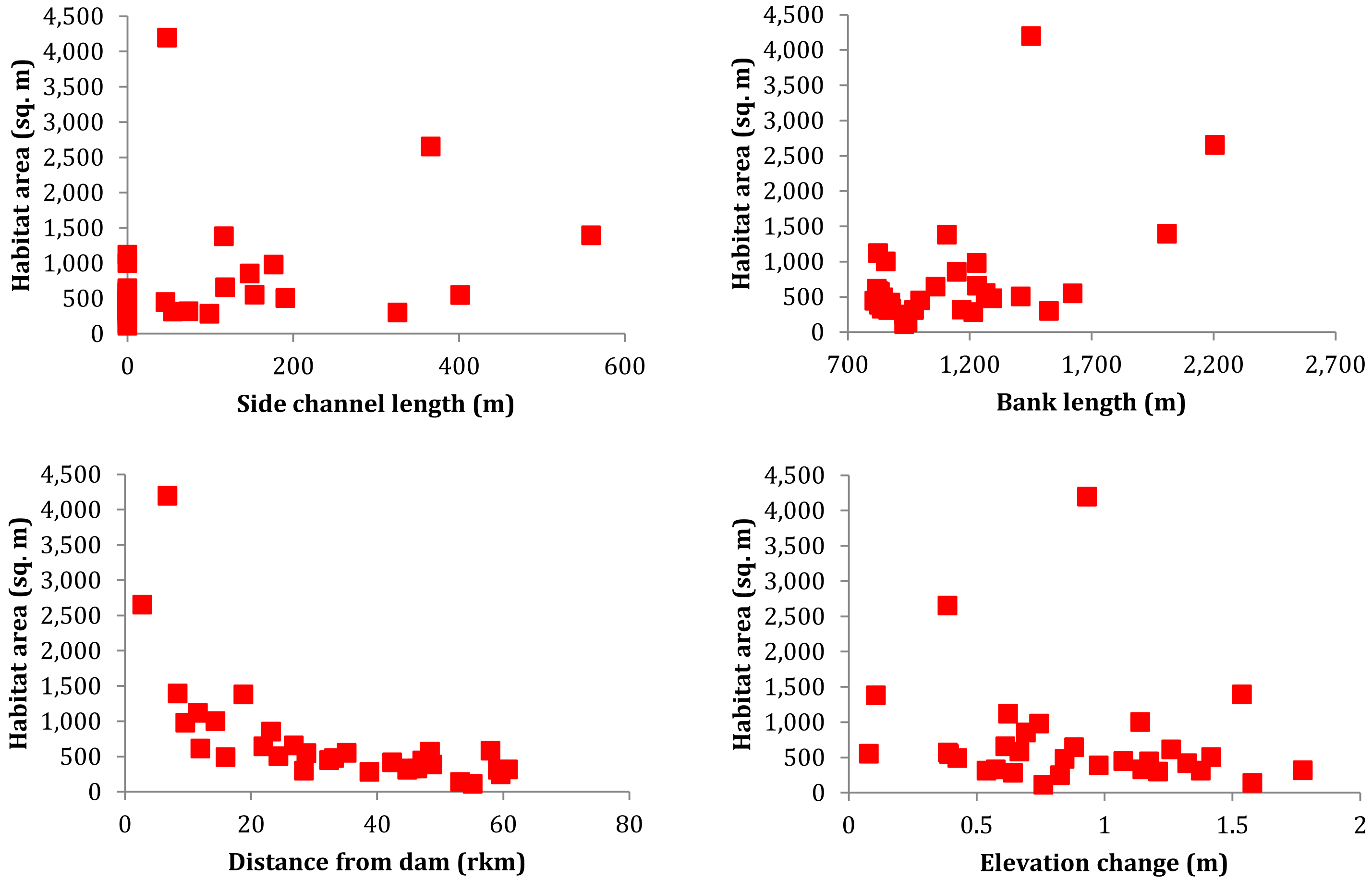

Figure 5–7. Optimal presmolt rearing-habitat area at GRTS sites by side-channel length, bank length, distance from Lewiston Dam, and elevation change.

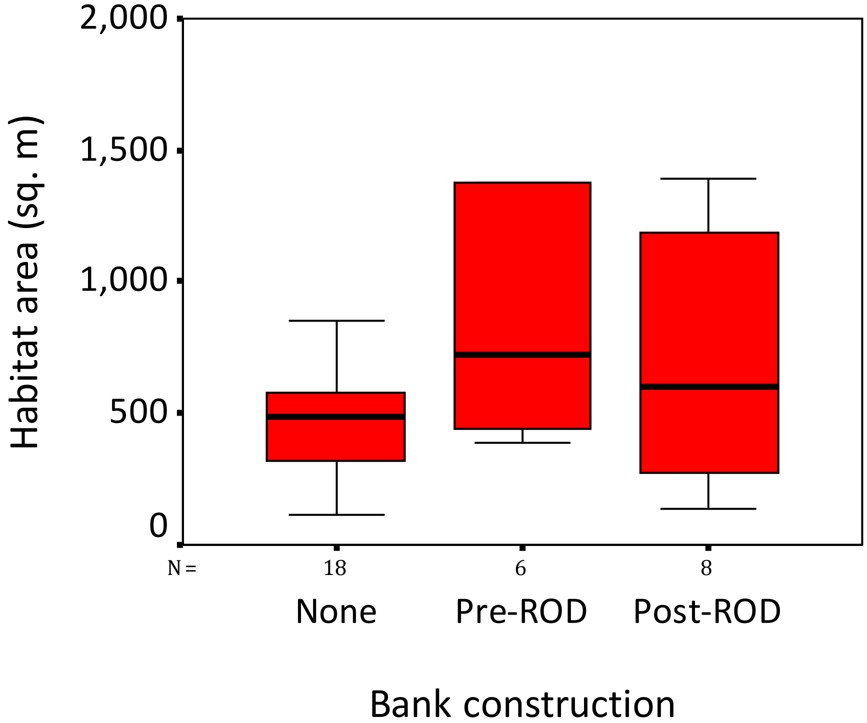

Figure 5–8. Optimal presmolt habitat by bank construction category at GRTS sample units. The following variables are represented in the plot: (1) a horizontal line is drawn at the median observation, (2) the boxes represent the first (Q1) and third quartile (Q3) values, (3) whiskers are defined by the values adjacent to the lowest and highest observations using the following limits: (a) lower limit: Q1–1.5×(Q3–Q1) and (b) upper limit: Q3+1.5×(Q3–Q1).

The GRTS sampling framework was developed following the recommendations of the IAP and the Science Advisory Board (Andrews et al. 2006; Trinity River Restoration Program and ESSA Technologies Ltd. 2009). One of the primary benefits of a probabilistic sample is that it establishes an objective, inferential basis for extrapolating data from sample sites to a population (the restoration reach) while avoiding bias and other pitfalls commonly associated with representative reach or representative mesohabitat sampling designs (Williams 1996; Stevens and Jensen 2007; Williams 2010). In addition, GRTS provides spatial balance of sample sites, ideal for evaluating variables in systems like the Trinity River, where longitudinal gradients may exist (Stevens and Olsen 2004). Finally, GRTS facilitates the use of a neighborhood variance estimator that improves the efficiency of the resulting population estimates by incorporating the relative locations of sample units into error estimation (Stevens and Olsen 2002).

The rotating panel revisit design was developed for the specific purposes of evaluating the Trinity River restoration strategy and facilitating the adaptive management process by balancing annual status estimates with trend evaluation. Its benefits can be elucidated by hypothetical examples. Take for example a design in which a set of sample units are visited annually to measure habitat area. This revisit design provides information on the trend of the variables at the sites, but if this information is to be extrapolated, one must assume that changes at these sites represent changes in the rest of the system. This assumption may be hard to validate, particularly where a variety of restoration actions have been implemented, with localized effects. In contrast, consider a design that randomly selects new sample units annually. This design provides a good estimate of annual status but no information about restoration actions and their effects at specific locations. The revisit design presented herein balances the two previous examples. The design rotates new samples units into the study to reduce reliance on a fixed set of sites while revisiting some locations to evaluate site-specific changes. Applying this study design annually will document the synergistic effects of restoration actions and improve the understanding of how the Trinity River responds to specific management actions, such as the differential effects of variable water-year-type streamflow allocations.

From the samples evaluated in 2009, several patterns were apparent in rearing-habitat availability in the Trinity River. First, a small proportion of the sample units had much higher values than the rest of the units. These units suggest the potential for increases in habitat area at other locations. In addition, these sites were close to Lewiston Dam. If the habitat areas at these sites reflect a longitudinal gradient in habitat area, this may be an important component to consider for planning future restoration actions. For example, currently, the spawning distribution is highly skewed, with most salmonid redds occurring close to Lewiston Dam (Chamberlain et al. unpublished data). We hypothesize that distributing redds across the restoration reach will lead to increased survival through early life history stages by decreasing density-dependent mortality factors (Trinity River Restoration Program and ESSA Technologies Ltd. 2009). These factors include, for instance, redd superimposition and competition for rearing habitats and food resources (McNeil 1964; Hayes 1987; van den Berghe and Gross 1989). The other necessary component for increasing production would be proximal rearing-habitat area available to support the progeny of the distributed spawners. Therefore, applying additional restoration effort to increase rearing-habitat area away from Lewiston Dam may help accomplish restoration goals.

Studying the relationship between the physical attributes of the GRTS sample sites and habitat area at those sites elucidated some additional patterns. For example, the correlation between bank length, side-channel length, and total presmolt rearing habitat may be a useful tool and easy to incorporate as a metric for future restoration designs. In addition, the significant differences in total presmolt habitat between the nonrehabilitated sites, the pre-ROD rehabilitated sites, and the post-ROD rehabilitated sites suggests that channel rehabilitation activities are increasing habitat area at these locations (see Chapter 4). In contrast, distance from the dam was the only variable significantly correlated to optimal habitat. The relationship between optimal habitat and site-specific variables should be investigated using additional variables. Some variables for future exploration should include channel shapes/types or degrees of channel confinement that would facilitate the slow, shallow rearing habitats and deposition of woody debris or benches for cultivation of beneficial aquatic vegetation. In addition, riparian vegetation types may be an additional variable to add into future analyses.

Interestingly, there was no correlation between elevation change and rearing-habitat area. *A priori* assumptions were that within the sample universe, lower elevation changes would correlate with higher habitat values, but this was not the case. This lack of correlation may be related to the way elevation change was coded in the dataset. Take for example, the Rush Creek sample which had the highest value of habitat area (both total and optimal) but an intermediate elevation change. Much of the elevation change occurs within a short distance, and there is very little elevation change in the rest of the site. Future evaluations should focus on recoding this variable to better describe site characteristics, such as including the length or proportion of the site within various gradient categories.

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CHAPTER 6. DIEL AND LONGITUDINAL EFFECTS ON CHINOOK SALMON AND COHO SALMON REARING-HABITAT USE

6.1. Introduction

Rearing habitat was identified as the primary limiting factor of salmonid production in the Trinity River (USFWS and HVT 1999), and one of the goals of the Trinity River Restoration Program is to increase rearing-habitat area through implementation of a host of restoration actions described in the Record of Decision (U.S. Department of the Interior 2000). Rearing-habitat studies have been applied to assess changes resulting from the restoration actions, and they also provide insight for improvement of future actions (USFWS et al. 2008; Goodman et al. 2010).

Several assumptions are inherent to the habitat mapping technique applied to study restoration effects. For example, it is assumed that habitat categories relate to differential habitat qualities and that higher quality habitats support higher densities of target species. This assumption was tested by Goodman et al. (2010), who found significant differences in fish use between various habitat categories and higher densities of fish in higher quality habitats.

Although the initial study was a valuable first step in evaluating fish use of rearing-habitat categories, additional assumptions were left untested. For example, the initial study was conducted at Lewiston Cableway and Hoadley Gulch channel rehabilitation sites, which make up a contiguous segment of river, are close to the dam, and are areas of heavy spawning. These locations were selected under the *a priori* assumption that habitats would be seeded but not hyper-saturated with fish. Redd densities decrease downstream from Lewiston Dam (Chamberlain et al. unpublished data) and it is uncertain what effect increased distance from the dam has on fish use of rearing-habitat categories. The previous validation study also assumed that daytime fish use of habitat categories is similar to nighttime use.

The assessment presented herein builds on previous work by testing an additional set of assumptions. The questions addressed in this assessment include:

1. What abundances of Chinook salmon and coho salmon fry and presmolt occur within rearing-habitat categories by day and by night (priority question F–6)?
2. Are habitat categories predictors of habitat quality at night?
3. How do the results compare to the validation study conducted by Goodman et al. (2010)?

6.2. Methods

Habitat mapping was applied at Lowden Meadows as part of the pre-construction component of a channel rehabilitation site assessment (Section 4.2.2). To improve the efficiency of the study, this location was also used to evaluate fish use of rearing-habitat areas. The Reading Creek bank rehabilitation site was included in the sampling design presented in the FY2009 proposal, which would have facilitated within-year and across-site comparisons (USFWS et al. 2008). Sampling was not possible at Reading Creek due winter storms and the resulting elevated streamflows in major tributaries such as Weaver Creek (just upstream of Reading Creek channel rehabilitation site).

At Lowden Meadows, habitat areas were processed to develop polygons that delineated the entire channel into habitat categories using methods from Goodman et al. (2010). In summary, fry and presmolt habitat that met the various habitat variable conditions (Table 6–1) were delineated for the following categories: (1) meeting both depth/velocity and cover criteria, (2) meeting depth/velocity but not cover criteria, (3) meeting cover but not depth/velocity criteria, and (4) total habitat, defined as the sum total of types 1 through 3. For this chapter, optimal Chinook salmon rearing habitat includes areas that meet both depth/velocity and cover criteria. Suitable Chinook salmon rearing habitat includes areas that meet either depth/velocity or cover criteria but not both. Unsuitable Chinook salmon rearing habitat includes areas not meeting either type of criteria. Coho salmon rearing habitat is limited to areas that meet both depth/velocity and cover criteria, and all other areas are considered unsuitable habitat.
A priori, sampling unit sizes were set to range from 12 to 31 m^2 (129–334 sq. ft). This size range was selected, based on prior experience, to be large enough to reduce sample variance while small enough to facilitate efficient data collection with the desired number of sample units. The following steps were used to create the sampling units:

1. Units within the desired size range were preserved.

All polygons greater than 31 m^2 (334 sq. ft) were divided into smaller units using a grid function in Xtools Pro (Data East) and ArcMap (ESRI).

Table 6–1. Guilds and Their Associated Habitat Criteria for Fish Habitat Mapping as Part of the 2009 Trinity River Site Assessment (Goodman et al. 2010)

Habitat Guild	Variable	Criteria
Chinook salmon and coho salmon fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column velocity	0 to 0.15 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood
Chinook salmon and coho salmon presmolt (50 to 200 mm)	Depth	>0 to 1 m
	Mean column velocity	0 to 0.24 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood

3. All sampling units smaller than 12 m^2 (129 sq. ft) were removed from the sample frame.

The resulting sampling units had an average size of 27 m^2 (89 sq. ft; n = 966) for fry and 27 m^2 (89 sq. ft; n = 957) for presmolt habitats.

A stratified random sample was applied to select polygon segments by habitat category, targeting 20 samples per stratum. Single-pass snorkel surveys were applied for fry and presmolt habitat areas. Snorkel surveys were also applied during the day (8 a.m. to 4 p.m.) and the night (10 p.m. to 3 a.m.) within a 24-hour period. Sample timing was designed to target fish developmental phases. Fry sample units were surveyed for fish up to 50 mm (2 in) FL on March 9 and 10, 2009, and presmolt sample units for fish between 50 and 200 mm (2 and 8 in) FL on April 13–15, 2009.

Fish sampling targeted Chinook salmon and coho salmon. Although not the primary objective of this study, brown trout were enumerated to document their presence and abundance. All sizes of brown trout were counted during each sampling period. Dive segment perimeters were located using high-resolution aerial photography, Trimble ProXH GPS, mobile demand xTablet T8700 tablet PCs, and TruPulse 360B laser range finders, and Mobile Demand xTablet T8700 tablet PCs running ArcPad (from Esri). To sample each unit, a diver swam from the down-current edge of the unit moving up-current, enumerating fish that occurred within each sample unit with a single pass count. The outer extents of the polygons were then demarcated with colored rocks and a numerical marker. Divers then returned to the sample areas the following night and conducted counts in the same dive areas using Pelican Nemo and Stealthlight submersible lights.

Chinook salmon density at Lowden Meadows was tested for changes in fish counts among habitat categories and between day- and night-time. The interaction between among habitat categories and between day- and night-time was also tested. We implemented a generalized linear model (GzLM; McCullagh and Nelder 1989) with a Poisson family (log) link function at $\alpha = 0.05$ using the following equation:

$$g(\mu) = \text{offset}(\log(\text{size})) + \beta_O + \beta_{time}\, time + \beta_{habitat}\, habitat + \beta_{(time \times habitat)}\, time \times habitat$$

Where $\mu = E(Y)$. Y is the fish count at each sample segment. The diel category (time) and the habitat category (habitat) were covariates of observation Y. β_{time} and $\beta_{habitat}$ are the linear coefficients, and $\beta_{(time \times habitat)}$ is the interaction coefficient. The model was offset by sample unit area. Generalized linear modeling was conducted using R Commander (Fox 2005).

A separate analysis (Goodman et al. 2010) compared the density of fish in rearing-habitat areas between Lowden Meadows collected in 2009 and those at Lewiston Cableway and Hoadley Gulch collected in 2008. Lowden Meadows is located approximately 9 rkm (6 rm) downstream from the Lewiston Cableway and Hoadley

Gulch sample sites. Comparisons were made using a GzLM analysis with a Poisson family (log) link function at $\alpha = 0.05$ using the following equation:

$$g(\mu) = \text{offset}(\log(\text{size})) + \beta_O + \beta_{site}\,\text{site} + \beta_{habitat}\,\text{habitat} + \beta_{(site \times habitat)}\,\text{site} \times \text{habitat}$$

Where $\mu = E(Y)$. Y is the daytime fish count at each sample segment. The study site and year category (site) and the habitat category (habitat) were covariates of observation Y. β_{site} and $\beta_{habitat}$ are the linear coefficients, and $\beta_{(site \times habitat)}$ is the interaction coefficient. The model was offset by sample unit area. Care must be given to the interpretation of this analysis due to the potential for combined effects from location (or distance from dam) and year differences within the site variable.

6.3. Results

In 2009, between 16 and 20 daytime and nighttime samples were collected for the various habitat categories for both fry and presmolt fish use (Table 6–2). Although 20 sample units were targeted for each stratum, this was not always possible. Four fry and seven presmolt units were too shallow to be sampled effectively (<8 cm [3 in]) and were removed from analyses, and two fry sample units outside of depth/velocity criteria could not be sampled due to high water velocities.

Chinook salmon occurred in higher densities than other fishes in the sample (Table 6–3). Coho salmon presmolts were observed in higher densities than brown trout. However, only 22 coho salmon fry were counted within the sample. This resulted in lower densities of coho salmon fry than brown trout. Brown trout were not the primary target of this study and therefore will not be analyzed further.

Table 6–2. The Number of Dive Segments Selected for Validation of Chinook Salmon and Coho Salmon Fry (<50 mm FL) and Presmolt (50–200 mm FL) Habitat. Habitat include those that meet both the depth/velocity and escape cover criteria (DV, C), those that meet one set of criteria but not the other (DV, No C *or* No DV, C) and those that meet neither (No DV, No C).

Life stage	**Habitat category (Quality)**			
	DV, C (optimal)	**DV, No C (suitable)**	**No DV, C (suitable)**	**No DV, No C (unsuitable)**
Fry	20	16	20	18
Presmolt	18	16	19	20

Table 6–3. Mean Fish Density and Standard Error by Species, Life Stage, and Sampling Event (Sample) in 2009. Fry counts include fish <50 mm FL (2 in), and presmolt counts include fish 50 to 200 mm FL (2 to 8 in). Brown trout were not differentiated by size class.

Species	Life Stage	Sample	Habitat Category (mean fish per m^2 and SE)			
			DV, C	DV, No C	No DV, C	No DV, No C
Chinook Salmon	Fry	Day	2.41 ± 0.52	0.38 ± 0.14	0.55 ± 0.19	0.00 ± 0.00
		Night	2.95 ± 0.41	2.27 ± 0.38	0.80 ± 0.24	0.00 ± 0.00
	Presmolt	Day	2.67 ± 0.42	0.95 ± 0.19	0.67 ± 0.14	0.04 ± 0.03
		Night	3.72 ± 0.41	1.43 ± 0.48	0.70 ± 0.13	0.11 ± 0.07
Coho Salmon	Fry	Day	0.05 ± 0.02	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00
		Night	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	Presmolt	Day	0.83 ± 0.12	0.20 ± 0.13	0.19 ± 0.09	0.00 ± 0.00
		Night	0.37 ± 0.07	0.05 ± 0.03	0.07 ± 0.06	0.00 ± 0.00
Brown Trout	All	Day	0.06 ± 0.02	0.09 ± 0.03	0.02 ± 0.01	0.00 ± 0.00
		Night	0.09 ± 0.02	0.17 ± 0.04	0.12 ± 0.03	0.03 ± 0.01

Differences in Chinook salmon and coho salmon densities were observed between habitat categories (Figure 6–1). In all cases the highest fish densities were within optimal habitats. For both life stages of Chinook salmon and for coho salmon presmolts, suitable habitats had intermediate densities. In all cases the lowest fish densities were within unsuitable habitats.

Differences between daytime and nighttime densities differed by habitat category, species, and life stage. For Chinook salmon, more fish were generally observed in nighttime samples. This was particularly the case for Chinook salmon fry and areas that met the depth/velocity criteria (D/V, no C). Coho salmon densities showed an opposite pattern with lower densities at night. For coho salmon fry, only one fish was observed in nighttime samples.

Generally, sample unit size variation within each habitat category did not have a direct relationship to fish counts as represented by smoothed, locally weighted polynomial regression analysis (Figure 6–2). However, there were some exceptions to this: for example, larger areas meeting the depth/velocity and cover criteria had higher counts of Chinook salmon fry. Another example was a decrease in coho salmon presmolt count in larger sample units meeting the depth/velocity criteria.

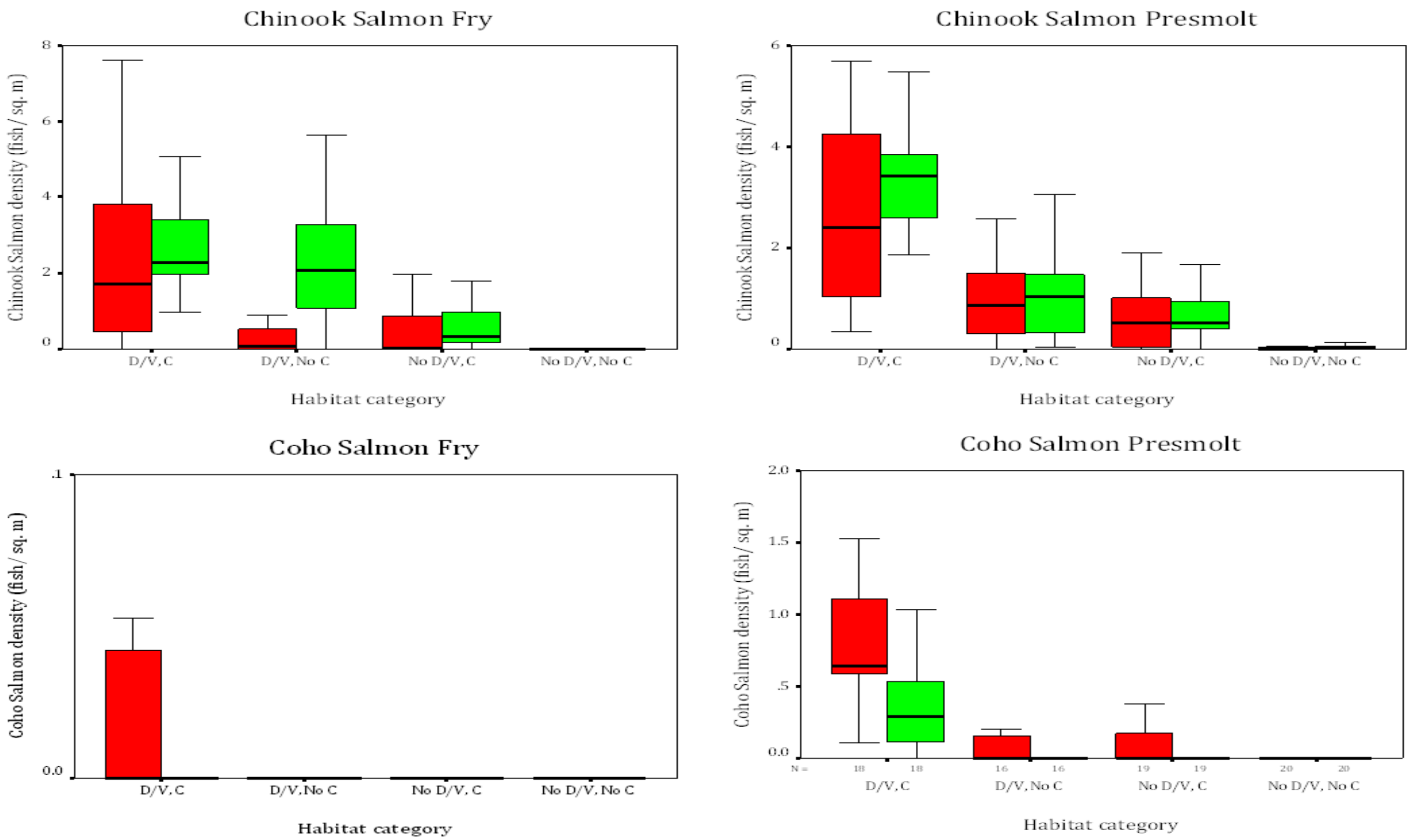

Figure 6–1. Fry and presmolt density differences between four habitat categories and between daytime (red) and nighttime (green) samples. The four habitat categories are combinations of depth/velocity (either DV for areas that meet both the dual criteria or No DV for those that don't) and proximity to escape cover (either C for areas that meet the criterion or No C for those that don't). The following variables are represented in the plot: (1) a horizontal line is drawn at the median observation, (2) the boxes represent the first and third quartile values (Q1 and Q3), (3) whiskers are defined by the values adjacent to the lowest and highest observations using the following limits: (a) lower limit, Q1–1.5×(Q3–Q1), and (b) upper limit, Q3+1.5×(Q3–Q1).

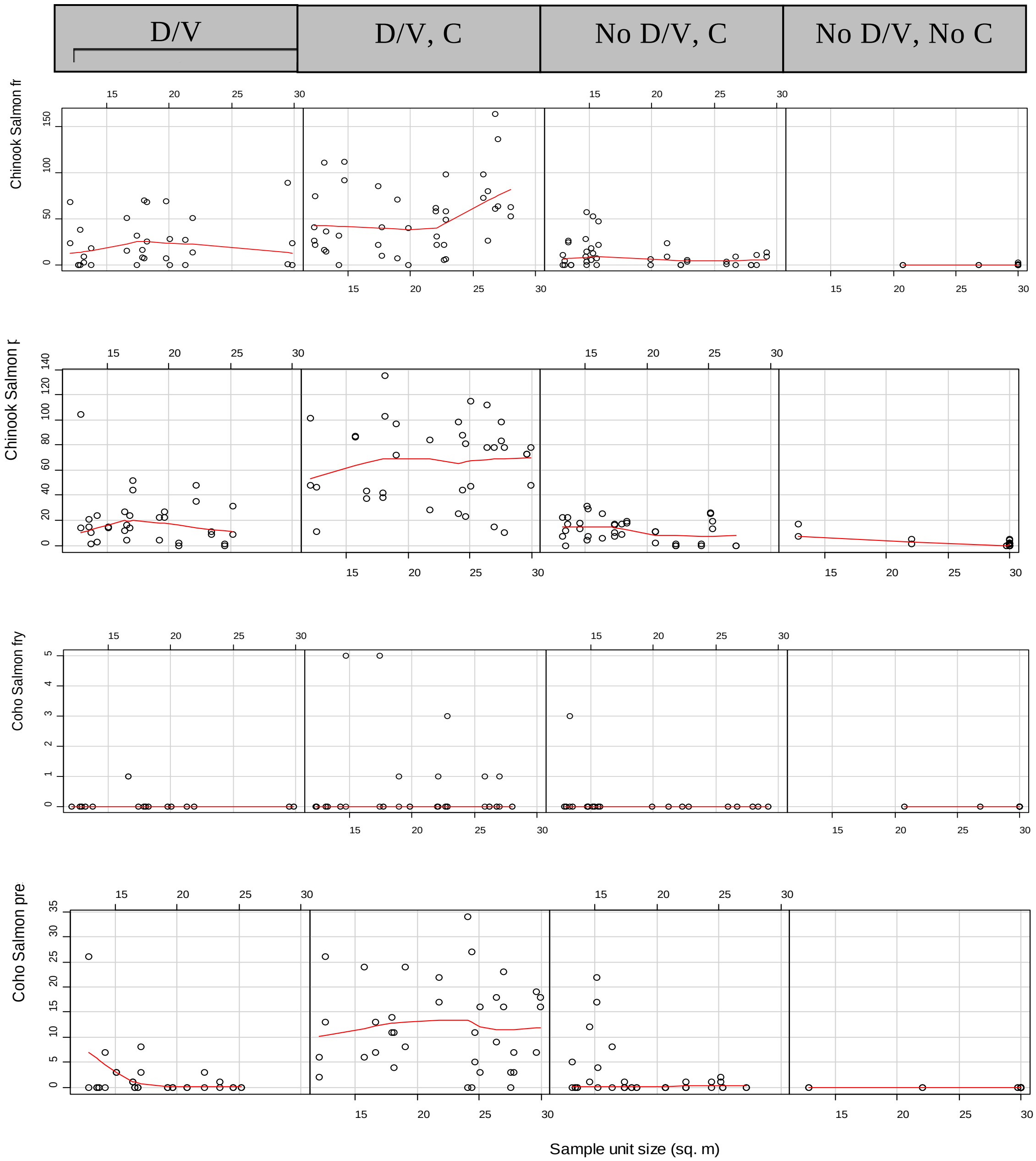

Figure 6–2. The effects of sample unit size on daytime and nighttime fish counts at Lowden Meadows, conditioned by rearing-habitat category. The four habitat categories are combinations of depth/velocity (either DV for areas that meet both the dual criteria or No DV for those that don't) and proximity to escape cover (either C for areas that meet the criterion or No C for those that don't). Solid lines represent a smoothed, locally weighted polynomial regression.

Generalized linear modeling was used to evaluate differences in fish density between habitat categories and sample timing. This analysis was limited to Chinook salmon due to the low abundance of coho salmon within the sample. For Chinook salmon fry, all factors in the model were significant at $\alpha = 0.05$ (Table 6–4). The model null deviance was 6,544.5 (d.f. = 147) and residual deviance was 2,344.5 (d.f. = 140); additional residual diagnostics are presented in Appendix E. The most fish were predicted within optimal habitat during nighttime, which had 8.35 fish per m^2 (SE = 1.39) more than suitable habitats (depth/velocity) during the day. In contrast, night-time samples of unsuitable habitats had the lowest associated fish density predictions, with 5.54×10^{-3} fish per m^2 (SE = 7.77) when compared to suitable (depth/velocity) habitats during day-time.

Table 6–4. Parameter Estimates of the Generalized Linear Model (GzLM) for Chinook Salmon Fry (<50 mm FL) and Presmolt (50 to 200 mm FL) Densities in 2009. The model includes the four categories of habitat based on depth/velocity and cover combinations and diel covariates. The model is offset by sample unit size.

Parameter	Estimate	Std. Error	χ^2	Pr > χ^2
Chinook salmon fry				
Depth/velocity (intercept)	–1.0722	0.0995	–10.775	<0.001
Depth/velocity and cover	1.9263	0.1047	18.396	<0.001
Cover	0.2771	0.1252	2.213	0.0269
Outside of depth/velocity and cover	–4.5029	0.7141	–6.306	<0.001
Night	1.8726	0.1069	17.520	<0.001
Night X depth/velocity and cover	–1.6762	0.1156	–14.501	<0.001
Night X cover	–1.4690	0.1451	–10.122	<0.001
Night X outside of depth/velocity and cover	–2.5657	1.2294	–2.090	0.0369
Chinook salmon presmolt				
Depth/velocity (intercept)	–0.1131	0.0620	–1.824	0.0682
Depth/velocity and cover	1.0350	0.0696	14.879	<0.001
Cover	–0.3804	0.0916	–4.152	<0.001
Outside of depth/velocity and cover	–3.6014	0.2743	–13.128	<0.001
Night	0.3662	0.0807	4.538	<0.001
Night X depth/velocity and cover	–0.0396	0.0907	–0.437	0.6622
Night X cover	–0.3393	0.1244	–2.727	0.0064
Night X outside of depth/velocity and cover	0.7082	0.3199	2.214	0.0268

Generalized linear modeling predicted similar effects for Chinook salmon presmolt densities. The model null deviance was 5990.6 (d.f. = 145) and residual deviance was 1861.4 (d.f. = 138). All model factors were significant at $\alpha = 0.05$, with the exception of the interaction term between nighttime and depth/velocity and cover. Similar to the fry model, the highest fish densities were predicted during nighttime within optimal habitat. In this case, 3.90 fish per m^2 (SE = 1.27) more were predicted during nighttime in optimal habitat than in suitable habitat (depth/velocity) during the daytime. The lowest fish densities were predicted in unsuitable habitats during the daytime with 2.73×10^{-2} fish per m^2 (SE = 1.32) relative to suitable habitats (depth/velocity) sampled during the daytime.

A separate analysis compared daytime habitat use at Lowden Meadows evaluated in 2009 to Lewiston Cableway and Hoadley Gulch from 2008. In general, more fish were observed at Lewiston Cableway and Hoadley Gulch than at Lowden Meadows (Figure 6–3). This was the case in all instances except where low densities of fish were observed (such as coho salmon presmolts in habitats that met the cover criteria but not depth/velocity).

Sample unit size did not have a strong effect on fish counts within each habitat category, as shown by a smoothed, locally weighted polynomial regression analysis (Figure 6–4), but there were several exceptions to this general rule. For example more fish were counted in larger sample units in the following categories: Chinook salmon fry in habitats meeting both the depth/velocity and cover criteria, and Chinook salmon presmolt either depth/velocity or cover criteria. In addition, fewer fish were observed in larger sample units in the case of Chinook salmon presmolts in areas meeting neither criterion.

Generalized linear modeling was used to evaluate differences in fish densities between habitat categories and site/year effects. This analysis was limited to Chinook salmon due to the low abundance of coho salmon within the sample. For Chinook salmon fry, most factors in the model were significant at $\alpha = 0.05$ except cover (Table 6–5). The model null deviance was 11,294.7 (d.f. = 148) and residual deviance was 4,174.4 (d.f. = 141). At Lewiston Cableway and Hoadley Gulch, the highest fish densities were predicted within optimal habitat, with 3.06 fish per m^2 (SE = 1.04) more than suitable habitats (depth/velocity). At Lowden meadows in optimal habitat a predicted 0.93 fish per m^2 (SE = 1.29) of suitable habitat (depth/velocity) at Lewiston Cableway and Hoadley Gulch. Unsuitable habitats at Lowden Meadows had the lowest predicted fish densities in the model with 1.50×10^{-3} fish per m^2 (SE = 2.47) relative to suitable habitats at Lewiston Cableway and Hoadley Gulch.

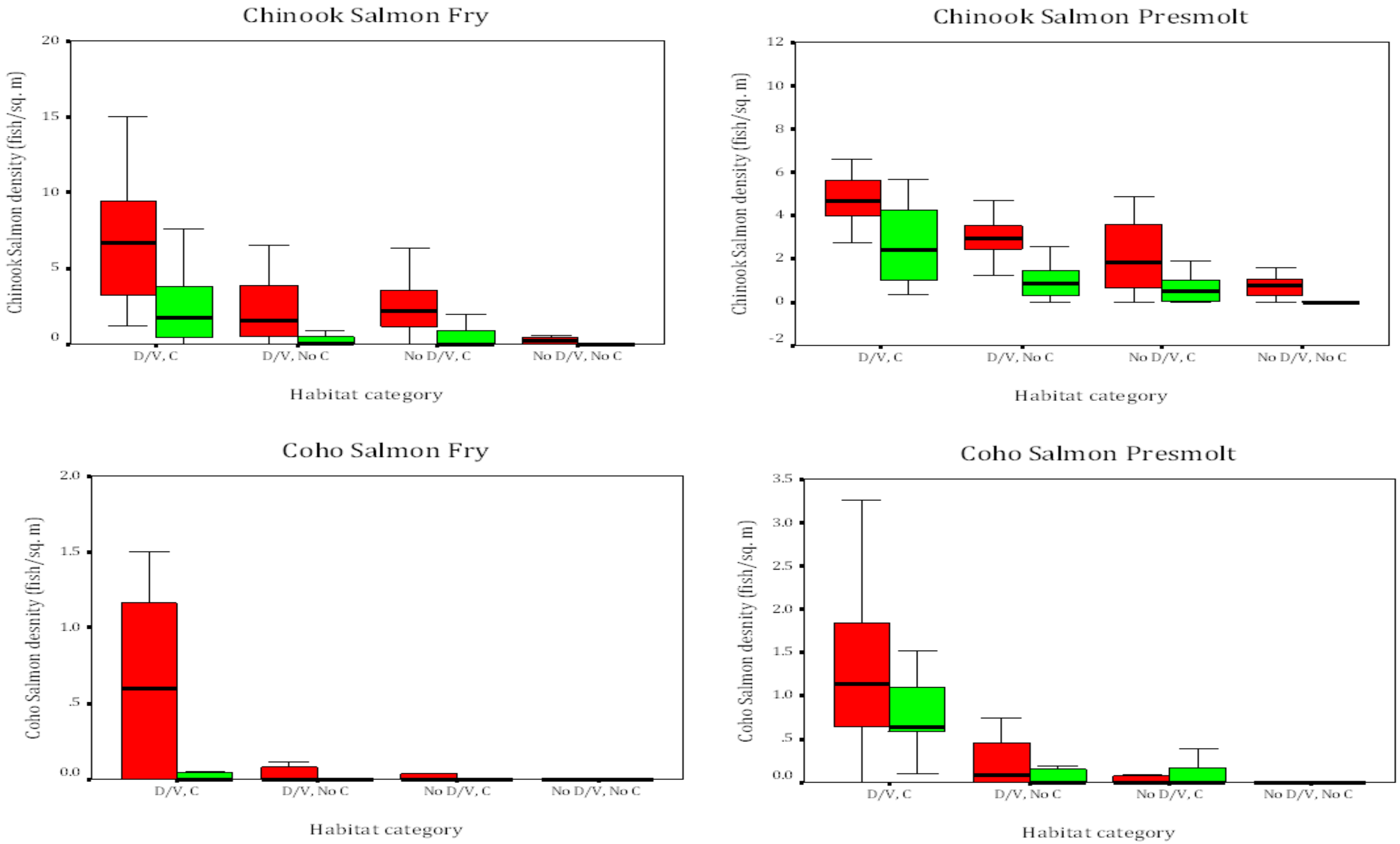

Figure 6–3. Fry and presmolt density differences between four habitat categories and between daytime (red) and nighttime (green) samples. The four habitat categories are combinations of depth/velocity (either DV for areas that meet both the dual criteria or No DV for those that don't) and proximity to escape cover (either C for areas that meet the criterion or No C for those that don't). The following variables are represented in the plot: (1) a horizontal line is drawn at the median observation, (2) the boxes represent the first and third quartile values (Q1 and Q3), (3) whiskers are defined by the values adjacent to the lowest and highest observations using the following limits: (a) lower limit, Q1–1.5×(Q3–Q1), and (b) upper limit, Q3+1.5×(Q3–Q1).

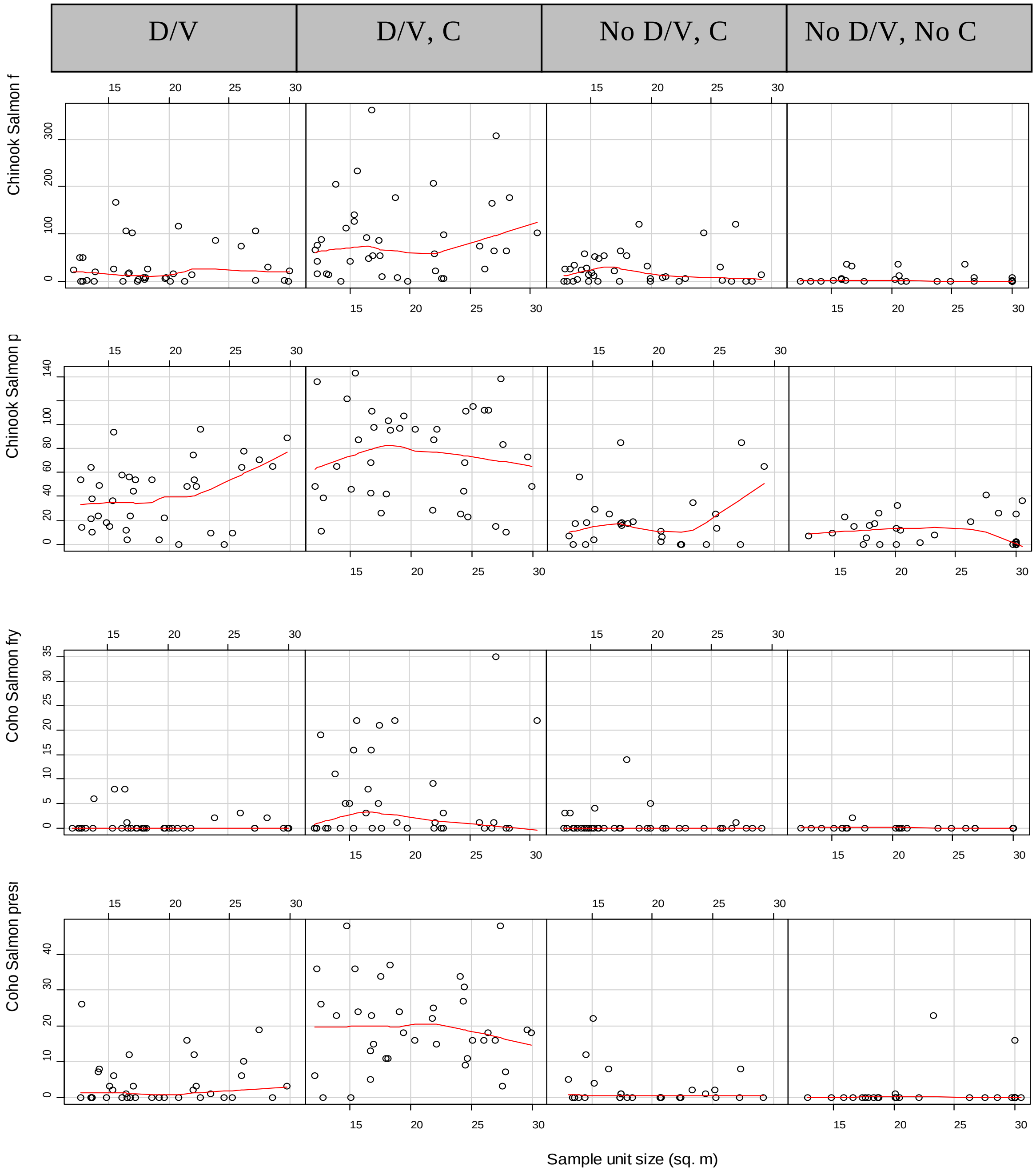

Figure 6–4. The effects of sample unit size on fish counts conditioned by rearing-habitat category at Lewiston Cableway, Hoadley Gulch and Lowden Meadows. The four habitat categories are combinations of depth/velocity (either DV for areas that meet both the dual criteria or No DV for those that don't) and proximity to escape cover (either C for areas that meet the criterion or No C for those that don't). Solid lines represent a smoothed, locally weighted polynomial regression.

Table 6–5. Parameter Estimates of the Generalized Linear Model (GzLM) for Chinook Salmon Fry (<50 mm FL) and Presmolt (50 to 200 mm FL) Densities Comparing Site/Year and Habitat Category Effects. Factors included in the model are location/year and four categories of habitat based on depth/velocity and cover combinations. The model is offset by sample unit sizes. Lewiston Cableway and Hoadley Gulch Sites were sampled in 2008; Lowden Meadows was sampled in 2009.

Parameter	Estimate	Std. Error	χ^2	Pr > χ^2
Chinook salmon fry				
Depth/velocity (intercept)	0.9271	0.0316	29.287	<0.0001
Depth/velocity and cover	1.1184	0.0374	29.872	<0.0001
Cover	-0.0309	0.0474	–0.651	0.5153
Outside of depth/velocity and cover	–1.6423	0.0810	–20.277	<0.0001
Lowden Meadows	–1.9993	0.1044	–19.147	<0.0001
Lowden Meadows X depth/velocity and cover	0.8079	0.1112	7.265	<0.0001
Lowden Meadows X cover	0.3080	0.1339	2.300	0.0215
Lowden Meadows X outside of depth/velocity and cover	–2.8608	0.7187	–3.981	0.0001
Chinook salmon presmolt				
Depth/velocity (intercept)	1.1249	0.0287	39.212	<0.0001
Depth/velocity and cover	0.4742	0.0373	12.719	<0.0001
Cover	–0.3649	0.0607	–6.015	<0.0001
Outside of depth/velocity and cover	–1.4179	0.0626	–22.649	<0.0001
Lowden Meadows	–1.2381	0.0683	–18.118	<0.0001
Lowden Meadows X depth/velocity and cover	0.5608	0.0789	7.106	<0.0001
Lowden Meadows X cover	–0.0155	0.1099	–0.141	0.8880
Lowden Meadows X outside of depth/velocity and cover	–2.1836	0.2817	–7.760	<0.0001

Generalized linear modeling predicted similar effects for Chinook salmon presmolt densities. The Chinook presmolt model null deviance was 6271.7 (d.f. = 139) and residual deviance was 1,741.2 (d.f. = 132). For Chinook salmon fry, most factors in the model were significant at $\alpha = 0.05$ except the interaction term of Lowden Meadows and cover. As with the fry model, the highest fish densities were predicted in optimal habitat at Lewiston Cableway and Hoadley Gulch, with 1.61 fish per m^2 (SE = 1.04) more fish than suitable habitats (depth/velocity). Optimal habitats at Lowden Meadows were predicted to have 0.82 fish per m^2 (SE = 1.20) of suitable habitats at Lewiston Cableway and Hoadley Gulch. Unsuitable habitats at Lowden Meadows had the lowest predicted fish densities in the model with 7.91×10^{-3} (SE = 1.51) less fish than suitable habitats at Lewiston Cableway and Hoadley Gulch.

6.4. Discussion

Rearing fish distributions within a stream channel can be described as behavior patterns that minimize mortality risk while maximizing growth (Metcalfe et al. 1999). For rearing Chinook salmon or coho salmon, these variables include energetic considerations. For example, low-velocity areas reduce the energetic demands on fish to maintain position in a stream channel. Shallow and structurally complex areas are also important components of their habitats that can provide pockets of low-velocity areas (Rimmer et al. 1984; Cunjak and Power 1987). Escape cover, a component of structurally complex areas, reduces predation risk, adding to conceptual rearing-habitat models (Hardy et al. 2006). In rearing Atlantic Salmon, escape cover has been shown to be preferred over areas that provide velocity shelters, emphasizing the importance mortality risks play in their distribution (Valdimarsson and Metcalfe 1998). Rearing salmonids will aggressively defend these preferred habitats, theoretically regulating the density of occupants and forcing subordinate fish into less preferred areas (McMahon and Hartman 1989; Gregory and Griffith 1996).

If relative fish abundance is assumed to be a measure of habitat preference, the results of this study fit this model. The highest densities of Chinook salmon and coho salmon were in slow, shallow areas close to in-water escape cover. These areas theoretically have the lowest mortality risk and provide living space for energy conservation. Coho salmon were found almost exclusively in these areas. This observation could help explain the lower density of coho salmon within the study site generally, but it also aligns with hypotheses of the importance of these habitat types for the species (McMahon and Hartman 1989). Areas that met only the cover or the depth/velocity criteria, but not both, were less preferred habitats. Theoretically, these areas are providing either shelter from predation with less slow, shallow living space or more living space with a higher risk of predation. These results support the findings of Goodman et al. (2010) and the assumptions of preference for the habitat categories applied in that study. In addition, this work supplements the previous study by investigating variation in fish use by diel differences and the mixed factor of site/year.

Diel shifts in habitat use have been documented in salmonids (Heggenes et al. 1993; Hubert et al. 1994; Banish et al. 2008; Bradford and Higgins 2001) and can be related to the ratio of mortality risk to feeding success (Metcalfe et al. 1999). Juvenile salmonids are visual predators feeding primarily upon drifting macroinvertebrates (Wankowski and Thorpe 1979), and foraging efficiency is greatest during daylight (Fraser and Metcalfe 1997). Interestingly, this does not coincide with food availability, which is greatest at night (Waters 1962). These factors are balanced by the increase in mortality risk during daytime due to visual predators of fry and juvenile salmonids and lead to daytime concealment behaviors (Fraser and Metcalfe 1997; Metcalfe et al. 1999).

The diel shifts in habitat preference observed for Chinook salmon in the current study support a daytime concealment behavior pattern, with more fish observed during nighttime surveys. This pattern was not observed for coho salmon, although this may be a biased result related to their low abundance within the sample units. Chinook salmon fry showed differences in habitat preference between day and night samples, with more fish observed in shallow, low-velocity areas without cover at night. This shift in habitat preference was not observed for Chinook salmon presmolts.

Nocturnal feeding may be an adaptive advantage in the presence of daytime predators. This is not the case with nocturnal piscivores such as non-native brown trout (Heggenes et al. 1993), further intensifying predation risk to native salmonids. The occurrence of brown trout in the Trinity River has been persistent through time (e.g., Moffet and Smith 1950; Pinnix and Quinn 2009). Population levels are not well understood, nor are their impacts on populations of native fishes in the Trinity River. During the study, brown trout were observed consuming Chinook salmon fry, further emphasizing the potential impact of these non-native predators.

Longitudinal differences in fish abundance may be related to different controls. For example, strong associations have been identified between brown trout densities and redd locations (Beard and Carline 1991). Observations in the current study support this association for Chinook salmon. Higher abundances of fish were observed at the Lewiston Cableway and Hoadley Gulch sites, which are approximately 9 rkm (5.6 rm) upstream of Lowden Meadows. This coincides with a consistent pattern of decreasing redd densities downstream of Lewiston Dam (Figure 6–5). Interpretation of this pattern is confounded by interannual variation such as differential spawner densities, survival rates, and releases from the hatchery, which is located at Lewiston Dam. However while the densities of fish observed in rearing-habitat categories differed between locations, the pattern of use among rearing-habitat categories was similar and supports the assumption of preferential use of rearing-habitat categories.

6.5. References

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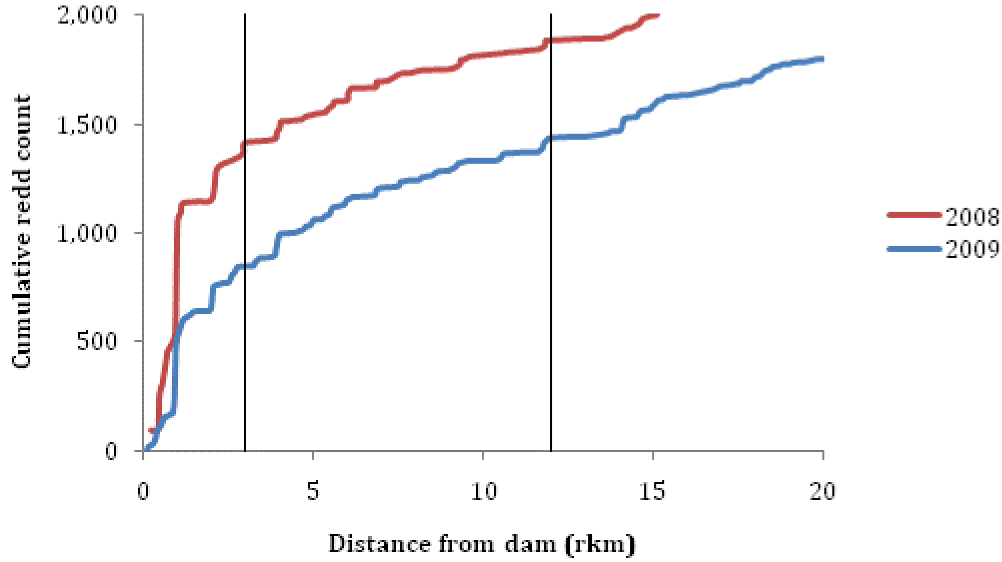

Figure 6–5. Rearing validation study locations, cumulative redd counts and distance from Lewiston Dam indicating a reduction in redd density from Cableway and Hoadley Gulch to Lowden Meadows study sites. Cumulative redd count data adapted from Chamberlain et al. (in prep.).

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CHAPTER 7. REDEFINING CHINOOK SALMON SPAWNING HABITAT IN THE TRINITY RIVER

7.1. Introduction

The restoration strategy for the Trinity River is designed to restore fluvial-geomorphic processes downstream of Lewiston Dam. It is anticipated that this strategy will lead to increased channel complexity and substantial increases in salmonid habitat quantity and quality (USFWS and HVT 1999; Locke et al. 2008). Habitat studies have been applied to assess changes resulting from the restoration actions and to provide insight for the improvement of future actions (USFWS et al. 2008; Goodman et al. 2010). Chinook salmon and coho salmon rearing habitat is considered the primary limiting factor for salmonid populations and has been the primary focus of recent habitat studies. However, the restoration strategy anticipates substantial increases in spawning habitat from management actions, which should also contribute to increasing fish populations.

In a precursor study, Goodman et al. (2010) mapped salmonid spawning habitat using depth, velocity, and substrate habitat suitability criteria from the Trinity River Flow Evaluation Study (TRFE; USFWS and HVT 1999). In this study, mapped spawning habitat did not overlap with actual redd locations at acceptable levels, with only 36 percent of redds constructed within mapped habitat areas. Improved validation is necessary to apply this technique and evaluate the effects of restoration actions on spawning habitat.

In an attempt to improve the spawning habitat evaluation technique, the approach was expanded to include alteration of the depth, velocity, and substrate criteria, an evaluation of the traditional criteria (depth, velocity and substrate), and an evaluation of additional physical variables (e.g., geomorphic feature, distance to shore, etc.) used to map spawning habitat. Finally this information is compared to physical variables applied in previous evaluations of spawning habitat use in the Trinity River. The goal of this study is to develop methodologies to evaluate the effects of restoration on Chinook salmon spawning habitat (Integrated Assessment Plan Objective 2.1, Trinity River Restoration Program and ESSA Technologies 2009). The questions addressed in this assessment include:

1. How can we refine the spawning habitat assessment methodology (priority question F–7)?
2. What variables or combination of variables best predict spawning habitat?
3. How does current spawning habitat use compare to that observed before restoration efforts?

7.2. Methods

The first component of this study compared spawning habitat mapping predictions to redd locations, similar to what Goodman et al. (2010) had done. This study was applied in a 7-rkm study reach from Old Bridge in Lewiston to Bucktail boat ramp (rkm 170.2 to 177.3), a reach similar to the one studied by Goodman et al. (2010). The assessment was limited to main-channel habitats (no side channels) within the study reach. This iteration of the study differed from its predecessor by the criteria used to define spawning habitat. A depth criterion was set at 0.15 to 0.76 m (6 to 30 in), the same applied in the previous assessment. Focal velocity measured at 0.12 m (4.8 in) above the bed surface was applied rather than mean column velocity, following Hampton (1988). The range of water velocities was the same as that applied in the previous study and ranged from 0.15 to 0.79 m/s (0.5 to 6.0 ft/s). Substrate particle size criteria ranged from 13 to 102 mm (0.5 to 4.0 in), which is smaller than the 50- to 150-mm (2- to 6-in) diameter mapped in the previous study. The updated criteria fit within the coarse sediment augmentation size distribution and also align with Chinook salmon substrate use in other California river systems (Kondolf and Wolman 1993, Lock et al. 2008). Areas that met the criteria were mapped in the study reach using the same methods applied by Goodman et al. (2010). Finally, the mapped spawning habitat areas were compared to redd pit locations identified by Chamberlain et al. (unpublished data).

The second component of the investigation was modeled after Mull and Wilzbach (2007), which evaluated habitat variables used to define coho salmon spawning habitat in a small northern California stream by comparing redd locations to areas where redds were not constructed. For this study, it was assumed areas with redds were preferred habitat and areas without redds were not preferred habitat. In 2008, 399 redds (56 redds/rkm) were constructed within the study boundaries and in 2009, 485 (68 redds/rkm) were constructed in the same area (Figure 7–1). Sixty redds constructed before November 6, 2009, were randomly selected within the study reach. These redds were assumed to be constructed by Chinook salmon based on low detections of other species in weekly carcass surveys (Chamberlain et al. unpublished data, CDFG unpublished data). To select areas without redds, a polygon was developed of the wetted channel in ArcMap from georeferenced aerial photography. Areas where spawning occurred in 2008 and 2009 were excluded from the sample by buffering redd pit location GPS points by a 5-m (16-ft) radius and clipping these areas out of the wetted-channel polygon. The buffer size was selected to be large enough to encompass published values on the size of Chinook salmon and coho salmon redds (Groot and Margolis 2003). The resulting polygon was divided using a 3 m^2 (32.3 ft^2) grid to develop a sampling framework that was appropriate to measure habitat variables. The resulting polygons had an average size of 8.2 m^2 (26.9 ft^2). Sixty of the 26,221 polygons were selected to represent non-used areas. The following habitat variables were evaluated at each sample unit: depth, mean column velocity, focal velocity, surface substrate composition, distance to bank, distance to nearest redd, cover within 3 m (9.8 ft), and geomorphic characteristic (pool or run tail). Water velocity was measured with a SonTek FlowTracker® flow meter. Mean column velocity was measured at 0.6 times depth for areas 1 m (3 ft) deep or an average between measurements at 0.3 and 0.7 times depth at deeper locations. Focal velocity was measured at 0.12 m (4.8 in) above the bed surface, following Hampton (1988). Surface substrate was estimated using Wolman pebble

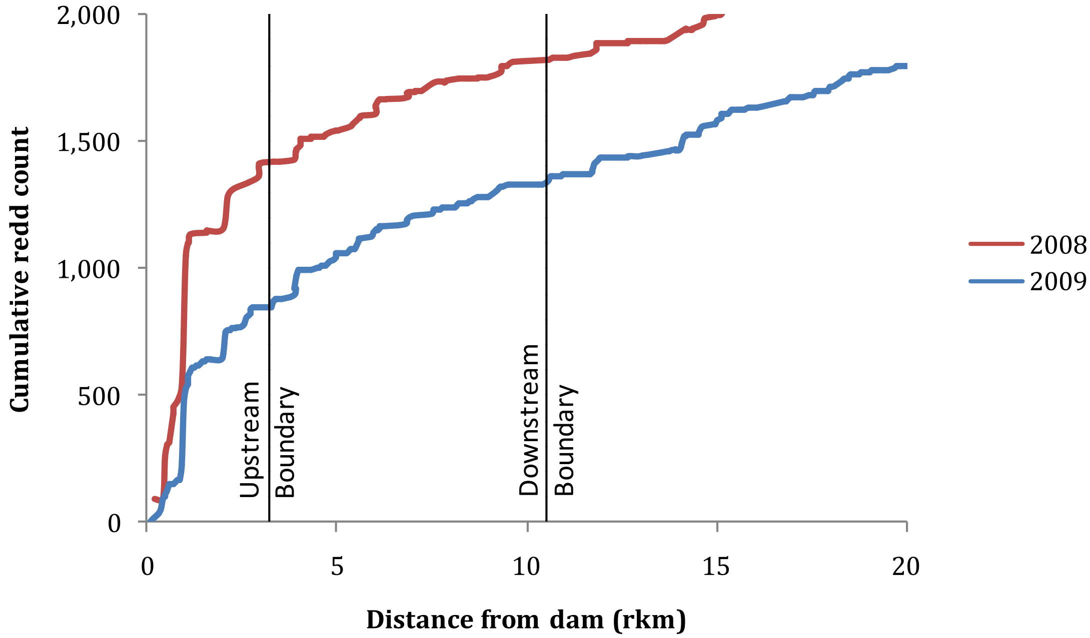

Figure 7–1. Cumulative redd counts within study reach boundaries. Upstream and downstream study site boundaries identified with black lines. Spawning data adapted from Chamberlain et al. (unpublished data).

counts with 100 measurements along the secondary axis per sample unit (Wolman 1954, Leopold 1970). For this study, the Wolman pebble count was modified to restrict sampling to the area of interest. All particles were measured to the nearest millimeter except for those smaller than 4 mm or larger than 512 mm, which were counted. For samples at redds, all measurements were taken 0.15 m (0.5 ft) upstream of disturbed substrate to simulate pre-construction conditions, following Hampton (1988). For samples not at redds, measurements were taken around each polygon centroid.

Analyses were conducted by comparing the variables of areas with redds to areas without redds. Univariate analyses for continuous variables were conducted using a Mann-Whitney test for independent samples at $\alpha = 0.05$ and for binary variables using a two-sample equality of proportions test (χ^2). Depth, mean column velocity, focal velocity, distance to bank, and distance the nearest redd were continuous variables, while cover, pool and run tail, and surface substrate were categorical variables. Additionally, differences in substrate were analyzed by taking the proportion of each sample that was medium gravel to small cobble or 11 to 90 mm (0.4 to 3.5 in) diameter along the secondary axis. Multivariate analyses were conducted by first testing for intercorrelation between predictor variables. Then a series of *a priori* multivariate models were developed with Generalized Linear Models (GzLM) using the binomial (logit) family link functions (McCullough and Nelder 1989). The models were developed to test variables commonly used in

PHABSIM (Waddle 2001) and in salmonid spawning habitat assessments (depth, velocity, and substrate) as well as some additional habitat variables. Nine models were developed, including a full model with all variables. The models were compared using the Akaike Information Criterion corrected for small sample sizes (AIC_c; Burnham and Anderson 2002).

An additional analysis compared the depth, mean column velocity, and particle size distribution at redd locations to the TRFE Chinook salmon habitat suitability criteria (HSC) to evaluate for changes in spawning habitat use (USFWS and HVT 1999). Caution should be used in interpreting this analysis. The HSC data presented in the TRFE were collected over a larger section of the river, and substrate sizes were based on visual estimates rather than pebble counts. We assumed a D_{70} in the current study was comparable to visual estimates of the dominant substrate size applied in the TRFE.

7.3. Results

Of the 380 redds that occurred within the study area, 210 (55%) fell within areas identified as spawning habitat. A buffer analysis indicated that an additional 23 percent of the total redds occurred within 3 m (10 ft) of mapped habitat areas (Table 7–1). Similarly, 32 of the 60 (53%) randomly selected redds with associated habitat measurements fell within the mapped spawning habitat. None of the 28 redds that were outside of predicted spawning habitat areas were outside of more than one habitat criteria range. Ten redds were outside of the water depth criteria range, three were outside of focal velocity range, and three were outside of surface substrate range. Twelve redds were within depth, velocity and substrate criteria, but were outside of mapped habitat areas.

Information on habitat variables (depth, mean column velocity, focal velocity, etc.) was collected at 60 redds and 60 randomly selected unused areas. Depths at redds were significantly shallower than at unused locations (Mann-Whitney test statistic $U = 1416.000$, $p = 0.044$; Table 7–2). The mean column velocity was significantly higher at redds ($U = 1209.000$, $p = 0.002$) than at unused locations. Focal velocity

Table 7–1. The Effects of Increasing Habitat Area Buffers on the Correlation Between Mapped Spawning Habitat and Redd Locations

Buffer (m)	Number of total redds within mapped habitat areas	Percent of total redds
0.0	210	55
0.5	234	62
1.0	258	68
1.5	274	72
2.0	282	74
2.5	291	77
3.0	296	78

Table 7–2. Univariate Comparisons of Habitat Variables at Redds (Used) and at Unused Locations. "Cover within 3 m" and "Pool or run tail" are binary variables presented as proportions ± standard error. For all other variables, the values given are mean ± standard error. An asterisk (*) indicates a significant difference using a Mann-Whitney test for continuous or two sample test for proportions (χ^2) for binary variables at $\alpha = 0.05$.

Variable	Unused	Used
Depth (m)	0.675 ± 0.047	0.532 ± 0.026*
Mean column velocity (m/s)	0.374 ± 0.0471	0.504 ± 0.029*
Focal velocity (m/s)	0.366 ± 0.0477	0.414 ± 0.024*
Medium gravel to small cobble (11–90 mm)	0.57 ± 0.024	0.768 ± 0.015*
Distance to shore (m)	6.082 ± 0.637	7.198 ± 0.549
Distance to redd (m)	436.390 ± 41.152	28.941 ± 9.445*
Cover within 3 m	0.370 ± 0.060	0.230 ± 0.060
Pool or run tail	0.200 ± 0.050	0.770 ± 0.060*

was higher at used locations than at unused locations (U = 1372.500, p = 0.025), but the difference was less than that observed for mean column velocity. The proportion of the substrate that was medium gravel to small cobble (11–90 mm; 0.43–3.54 in) was significantly greater at redd locations (Figure 7–2; U = 610.000, p<0.001). Distance to shore did not vary between used and unused areas (U = 1485.000, p = 0.098). Distance to the nearest redd was significantly lower at redds than at unused locations (U = 90.000, p<0.001). The proportion of redds that were within 3 m (10 ft) of cover did not differ significantly from unused locations (χ^2 = 2.5397, p = 0.111). A greater proportion of redds occurred in pools or run tails than at unused locations (χ^2 = 38.5762, p<0.001).

Mean column velocity and focal velocity had a significant Pearson correlation at 0.883 (p<0.001; Table 7–3). Due to the high correlation, focal velocity was not used in multivariate modeling. All other variables had a Pearson correlation less than 0.5.

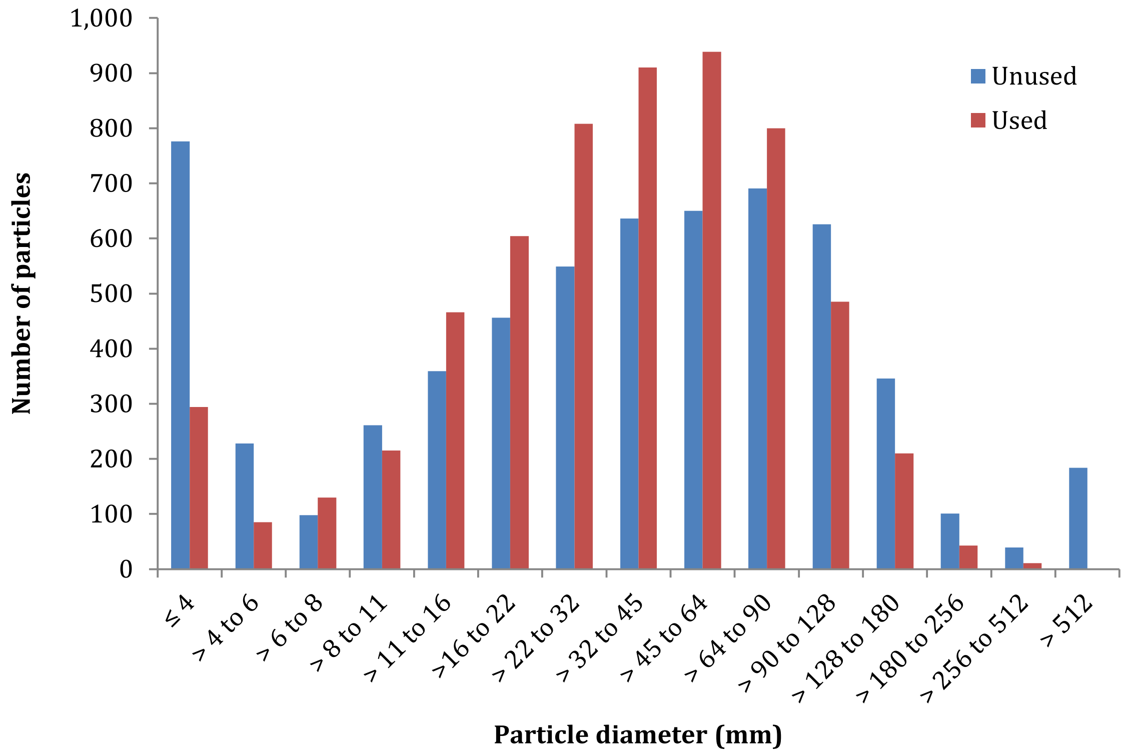

Figure 7–2. Particle diameter histogram at redds (used) and unused locations. Particle diameters are based on 60 Wolman pebble counts at each location. Pebble counts are binned using a half-phi scale. Particles equal to or smaller than 4 mm (0.16 in) and greater than 512 mm (1.7 ft) were not measured.

Table 7–3. Pearson Correlation Coefficients of Habitat Variables Assessed for Spawning Habitat

A high correlation was identified between mean column velocity and focal velocity.

Variable	Depth (m)	Mean column velocity (m/s)	Focal velocity (m/s)	Cover within 3 m	Distance to shore (m)	Pool or run tail	Distance to redd (m)
Mean column velocity (m/s)	–0.12						
Focal velocity (m/s)	–0.18	0.88					
Cover within 3 m	–0.01	–0.44	–0.37				
Distance to shore (m)	0.19	0.26	0.19	–0.48			
Pool or run tail	–0.22	–0.03	–0.05	–0.16	0.17		
Distance to redd (m)	0.31	–0.21	–0.16	0.25	–0.22	–0.44	
Med. grav. to sm. cobble	–0.17	0.25	0.21	–0.25	0.24	0.41	–0.40

Nine *a priori* GzLM were applied to develop descriptive models to compare habitat variables at redds and unused locations. The full model, including all variables analyzed in the multivariate analysis, provided the best approximations (Table 7–4). Distance to nearest redds and substrate were significant in the full model (Table 7–5) and occurred in the top three models. The null and residual deviance of the full model were 166.355 (d.f. = 119) and 38.902 (d.f. = 112), respectively; additional model diagnostics are presented in Appendix G. Within the full model, cover within 3 m (10 ft), mean column velocity, presence on a pool or run tail, and substrate were useful predictors of redd locations; all other variables were not useful. The model that included only water depth, mean column velocity, and proportion of medium gravel to small cobble surface substrate covariates was a poor predictor of redd locations.

Chinook salmon spawning habitat use observed differed from that described in the TRFE HSC studies. The dominant substrate particle size at redds stated in the TRFE was larger than what we observed (Figure 7–3). Dominant substrate size given in the TRFE was small cobbles (77 to 150 mm; 3 to 6 in); in this study, it was split between medium and large gravel (26 to 76 mm; 1 to 3 in). In addition, the TRFE reported a higher proportion of redds occurring at shallow depths and lower velocities.

Table 7–4. Generalized Linear Models (GzLM) Predicting Chinook Salmon Spawning Areas Based on Habitat Variables. The models are listed by habitat covariates with the number of covariates (k), Akaike Information Criterion corrected for small sample sizes (AIC_c), change in AICc from the best approximating model (ΔAIC_c), and Akaike weights (w_i). Models with the highest w_i and the lowest AIC_c are those that best fit the data. Full model includes all habitat variables.

Model	K	AIC_c	ΔAIC_c	w_i
Full model	8	56.2	0	0.43
Velocity, depth, substrate, distance to redd	5	57.51	1.31	0.22
Velocity, depth, substrate, pool or run tail, distance to redd	6	57.64	1.44	0.21
Substrate, pool or run tail, distance to redd	4	58.44	2.24	0.14
Pool or run tail, distance to redd	3	65.83	9.63	0
Velocity, depth, substrate, pool or run tail	5	100.71	44.52	0
Velocity, depth, substrate	4	117.57	61.37	0
Velocity, depth, substrate, cover	5	119.57	63.37	0
Velocity, depth, substrate, distance to shore	5	119.74	63.54	0

Table 7–5. Parameter Estimates of the Best Approximating Generalized Linear Model (GzLM) for Chinook Salmon Spawning Habitat. Parameters include mean column velocity, presence of cover within 3 m, water depth, distance to nearest redd, distance to shore, proportion of surface substrate with medium gravel to small cobbles and presence on pool and run tail measured at redds (*n* = 60) and at unused locations (*n* = 60).

Parameter	Estimate	Std. Error	χ^2	Pr > χ^2
(Intercept)	–6.8574	2.9861	–2.30	0.0217
Velocity	3.5080	2.1026	1.67	0.0952
Cover	1.8730	1.5075	1.24	0.2141
Depth	–2.2069	2.3295	–0.95	0.3435
Distance to redd	–0.0189	0.0052	–3.65	0.0003
Distance to shore	–0.2009	0.1234	–1.63	0.1037
Substrate	12.8289	4.6538	2.76	0.0058
Pool or run tail.	2.1340	1.1043	1.93	0.0533

7.4. Discussion

The lack of overlap between mapped spawning habitat areas and redd locations indicates that the mapped areas were not good predictors of spawning habitat availability. The lack of validation of the salmonid spawning habitat assessment method is similar to the results of Goodman et al. (2010). In the current study, a higher proportion of redds was found within predicted spawning habitat areas than in previous studies (55% versus 36%), which was most likely due to the change in mapped dominant substrate size criteria. Although this result was an improvement from the previous evaluation, it fell short of the acceptable level for implementation as a restoration assessment technique (i.e., ≥70% of redds within mapped habitat, which was used as a general guideline for guild development). Interestingly, buffer analyses indicated that a high proportion of redds were close to mapped habitat areas and more than 70 percent of redds within the study area were within 1.5 m (4.9 ft) of mapped habitat areas.

An estimated 20 percent of redds met guild definition criteria but did not fall within mapped areas (12 of the 60 redds with habitat measurements). Several factors may have caused this error. It is possible that the redd locations occurred in habitat areas less than the *a priori* set minimum polygon size of 2 m^2 (22 sq. ft). Measurement error may have resulted from: (1) not identifying the areas that contained spawning or (2) positioning errors from survey techniques when identifying the redd pit locations or mapping habitat. Another potential source of error is changes in the river between the time of variable measurements at redds (Nov. 2008) and habitat mapping surveys (April 2009). Redd construction has been shown to alter stream habitat characteristics (Gottesfield et al. 2008). Although no high-flow events or mechanical alteration occurred within the study reach between surveys, changes may have resulted from redd construction that occurred after November 2008.

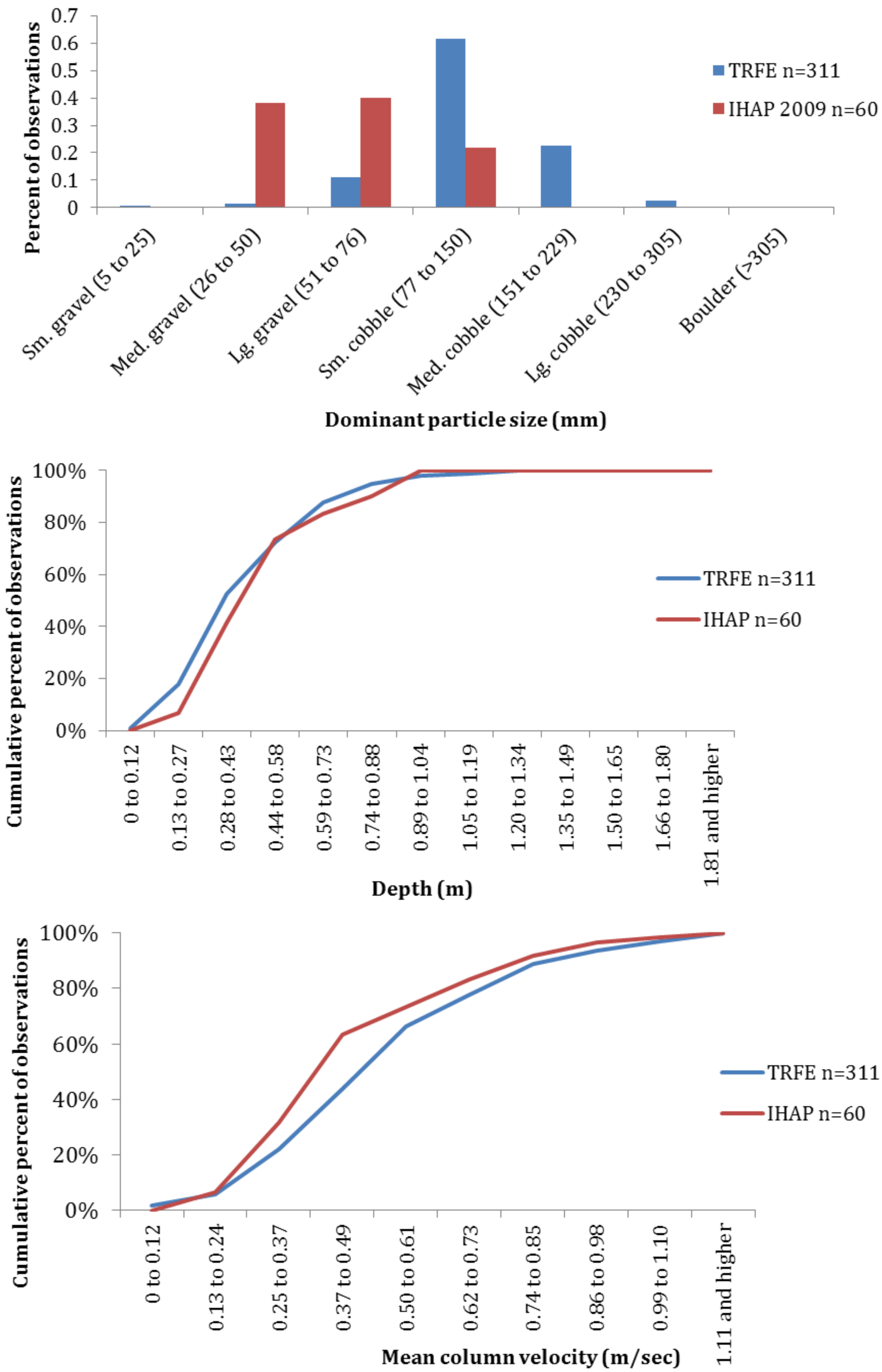

Figure 7–3. A comparison of habitat measurements at Chinook salmon redds to habitat suitability criteria in the Trinity River Flow Evaluation.

Traditional salmonid spawning habitat assessment models include depth, velocity and substrate attributes (Gard 2006). The simplicity of traditional models has been called into question, and it has been suggested that additional variables are needed to accurately predict spawning habitat (Shirvell 2007). In the Trinity River, multivariate modeling indicated that spawning habitat was best approximated with more variables. The best approximating model included water velocity, escape cover, water depth, distance to nearest redds, distance to shore, surface substrate, and habitat type. Incorporating these variables into future assessments would improve the predictive power of spawning assessment techniques.

Mulls and Wilzbach (2007) identified a subset of these variables to explain coho salmon spawning habitat. In Freshwater Creek (Humboldt County, CA), substrate, location on a pool or run tail, and proximity to redds were covariates in the best approximating model. Discrepancies may be related to species-specific differences between Chinook and coho salmon and/or habitat preference differences between a small coastal river system (Freshwater Creek) and a large alluvial system (Trinity River). The results of Mulls and Wilzbach (2007) were similar to those of the current study in that models limited to depth, velocity, and substrate performed poorly in predicting spawning use.

Changes in HSC were apparent when contemporary data was compared to the original TRFE HSC. Although differences were seen in all variables (water depth, mean column velocity, and surface substrate composition), arguably the most significant change is in the surface substrate composition. The contemporary data indicates particles used in redd construction were smaller than reported in the previous dataset. The changes may have resulted from restoration efforts and changes in available habitat. In recent years the TRRP's coarse sediment augmentation program has been delivering large quantities of particles between 9.5 and 127 mm (0.38–5 in) secondary diameter (Table 7–6; Lock, et al. 2008) in an attempt to reduce particle sizes in the system. The gravel additions have primarily occurred within the study section or a short distance upstream (up to 3 rkm). The change in habitat use observed between the Trinity River Flow Evaluation and the current study has been influenced by the change in sediments available for spawning in the study area and by other restoration actions.

Table 7–6. Summary of Coarse Sediment Augmentation in the Trinity River from 2003 to 2010. Sediment additions at Lewiston Cableway and Lewiston Hatchery, and the high-flow injections, are upstream of the study area. The Lewiston–Dark Gulch and Sawmill sites are within the study area, and all other sites are downstream of the study area. Data provided by the Trinity River Restoration Program (unpublished data).

Year	Location	Gravel (Metric Tons)	Total per Year (Metric Tons)
2003	Lewiston Cableway	2,721	2,721
2004	None	0	0
2005	None	0	0
2006	Lewiston Hatchery	2,206	2,206
2007	Lewiston Hatchery	5,897	5,897
2008	High-flow injections	3,175	19,631
	Lewiston–Dark Gulch site complex	16,456	
2009	High-flow injections	3,175	10,931
	Sawmill	7,756	
2010	High-flow injections	4,173	42,819
	Lowden, Trinity House Gulch, Reading Creek	38,646	

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CHAPTER 8. PRECISION OF SALMONID REARING-HABITAT MAPPING SURVEYS

8.1. Introduction

Several assumptions are inherent to the habitat mapping technique applied to study restoration effects (Goodman et al. 2010). One of the primary assumptions of the technique and one of the primary tenets of the scientific method is that measurements are repeatable. In addition, when studying restoration effects, the level of measurement error inherent to the assessment technique must be less than the anticipated response or, in this case, the restoration effects. The assessment presented here evaluates precision of the salmonid rearing-habitat mapping survey. The questions addressed in this assessment include:

1. What level of difference is observed between repeat estimates of habitat categories?
2. Is the measurement error in rearing-habitat mapping appropriate for evaluating the effects of restoration on the Trinity River?
3. How do the results of this study compare to precision estimates from other aquatic habitat assessment techniques?

8.2. Methods

The precision of the rearing-habitat mapping technique was assessed by surveying locations twice and comparing the results. Sample units were defined as 400-m (1,312-ft) stream segments of the 142-cms (5,000-cfs) centerline shapefile derived from HEC-RAS modeling (TRRP unpublished data). Using the generalized random tessellation stratified sample unit selection protocol (Stevens and Olsen 2004), units were selected between Lewiston Dam and the confluence of the North Fork Trinity River. To improve the efficiency of this survey design, initial site surveys were conducted during the systemic rearing-habitat survey (See Section 5). After the systemic habitat surveys were completed (n = 32 sample units), an independent team returned to resurvey until the end of the 12.7-cms (450-cfs) water release from Lewiston Dam. This resulted in repeat surveys of the first seven sample units (Figure 8–1).

Surveys were conducted using methods described in Goodman et al. (2010). In summary, we mapped areas of fry and presmolt habitat that met the various habitat variable conditions (Table 8–1). Guilds and their associated habitat criteria for fish habitat mapping as part of the 2008 Trinity River site assessment (Goodman et al. 2010) were estimated for the following categories: (1) habitat meeting both depth/velocity and cover criteria, (2) habitat meeting depth/velocity criteria only, (3) habitat meeting cover criteria only, and (4) total habitat as defined by the sum total of types 1 through 3. For this report, total Chinook salmon rearing habitat (total habitat) includes all areas that meet any combination of depth/velocity or cover criteria. Optimal Chinook salmon rearing habitat includes areas that meet both

Figure 8–1. Sample sites used to evaluate precision of rearing-habitat mapping on the Trinity River. The sample includes seven 400-m (1,312-ft) sample units selected using the GRTS protocol.

depth/velocity and cover criteria. Suitable Chinook salmon rearing habitat includes areas that meet either depth/velocity or cover criteria but not both. Unsuitable Chinook salmon rearing habitat includes areas that meet neither of these criteria. Coho salmon rearing habitat is limited to areas that meet both depth/velocity and cover criteria, and all other areas are considered unsuitable habitat.

Surveys were conducted during the summer months while the water release from Lewiston Dam was 12.7 cms (450 cfs). Between initial and repeat surveys, streamflows from Lewiston Dam were elevated for five days with a peak release of 78 cms (2,750 cfs; mean daily average). This increase in streamflow may have caused changes to habitat availability at the study sites.

Table 8–1. Guilds and Their Associated Habitat Criteria for Fish Habitat Mapping as Part of the 2008 Trinity River Site Assessment (Goodman et al. 2010)

Habitat guild	Variable	Criteria
Chinook salmon and coho salmon fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column velocity	0 to 0.15 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood
Chinook salmon and coho salmon presmolt (50 to 200 mm)	Depth	>0 to 1 m
	Mean column velocity	0 to 0.24 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood

Habitat category estimates of initial and replicate surveys were compared using descriptive statistics and paired t-tests at $\alpha = 0.05$. Mean differences of habitat category estimates were measured as the absolute value of the initial area minus repeat from paired sample units. Percent differences were measured as the average percent pairwise difference.

8.3. Results

Discrepancies were identified in the location and area estimate between replicate surveys. Area estimates varied between surveys at each site (Figure 8–2; Table 8–2). A significant difference was observed in repeat surveys of optimal presmolt habitat with a mean pairwise difference of 52 m^2 (560 sq. ft) or 14 percent. No other significant differences were observed in the dataset. Nonsignificant differences occurred between area estimates of other variables and ranged from 38 m^2 (409 sq. ft) for fry habitat meeting depth/velocity and cover criteria to 255 m^2 (2,745 sq. ft) for total presmolt habitat. Percentage differences ranged from 1 percent for fry habitat that met neither criterion as well as for bank length to 22 percent for presmolt habitat that met the cover but not the depth/velocity criteria. The average pairwise difference between surveys for all habitat categories was 10 percent.

Differences in the location of habitat areas were evaluated qualitatively by looking at the differences in location and size of habitat areas. In general, habitat areas overlapped between repeat surveys (Figure 8–3). However, location discrepancies occurred in all habitat categories including differences in size, shape, and location in some cases. Inclusion/omission errors of smaller habitat areas were also apparent in all habitat categories.

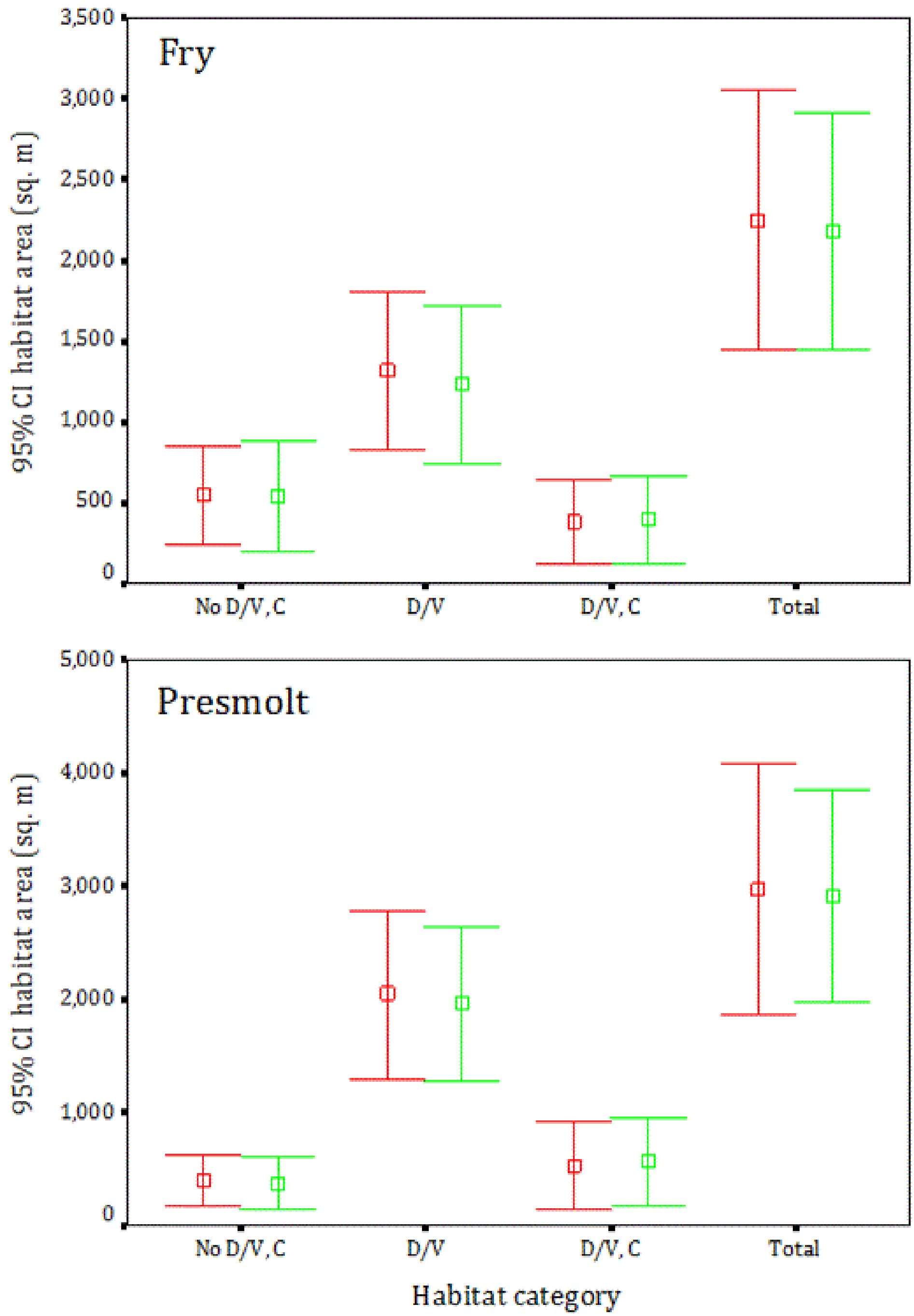

Figure 8–2. Differences in habitat category estimates between initial and repeat surveys at seven 400-m (1,312-ft) sample units for Chinook salmon and coho salmon fry and presmolt rearing habitat. Initial surveys are indicated by red and repeat surveys by green. Error bars are 95-percent confidence intervals around the mean value. Habitat areas meeting either depth/velocity or in-water escape cover, but not both (D/V, No C *or* No D/V, C) are considered suitable habitat. Habitat areas meeting both criteria (D/V, C) are optimal habitat. Total habitat (Total) indicates the sum total of habitat types. Areas meeting neither criterion were not included in the figure.

Table 8–2. Differences in Habitat Category Estimates Between Replicate Surveys at Seven 400-m (1,312-ft) Randomly Selected Sample Locations. All habitat categories are areas in square meters except bank length which is measured in meters. Asterisks indicates significant values at α = 0.05.

Habitat variable, life stage	Mean (range)		Pairwise differences		t	p
	Original	Repeat	Mean (S.E)	%		
Cover, fry	545 (143–998)	545 (115–1102)	58 (13)	12	0.018	0.986
Depth/velocity, fry	1,319 (615–2,222)	1,234 (410–1,810)	154 (50)	14	1.184	0.281
Depth/velocity and cover, fry	383 (87–959)	400 (175–1,005)	38 (10)	16	–0.981	0.365
Total fry	2,247 (1,721–4,180)	2,178 (1,710–3,916)	141 (32)	6	1.154	0.292
Neither depth/velocity nor cover, fry	11,590 (9,300–12,989)	11,719 (9,664–13,250)	151 (50)	1	–2.173	0.073
Cover, presmolt	401 (93–791)	372 (65–686)	67 (18)	22	0.970	0.370
Depth/velocity, presmolt	2,044 (1,382–3,719)	1,963 (960–3,033)	278 (92)	14	0.570	0.590
Depth/velocity and cover, presmolt	528 (138–1,392)	573 (225–1,432)	52 (14)	14	–2.542	0.044*
Total presmolt	2,973 (2,299–5,676)	2,907 (2,292–5,139)	255 (82)	8	0.504	0.632
Neither depth/velocity nor cover, presmolt	10,864 (8,688–12,221)	10,990 (8,947–12,700)	242 (72)	2	–1.131	0.301
Bank length, all	1,174 (819–2,009)	1,177 (818–2,010)	16 (7)	1	–0.266	0.799

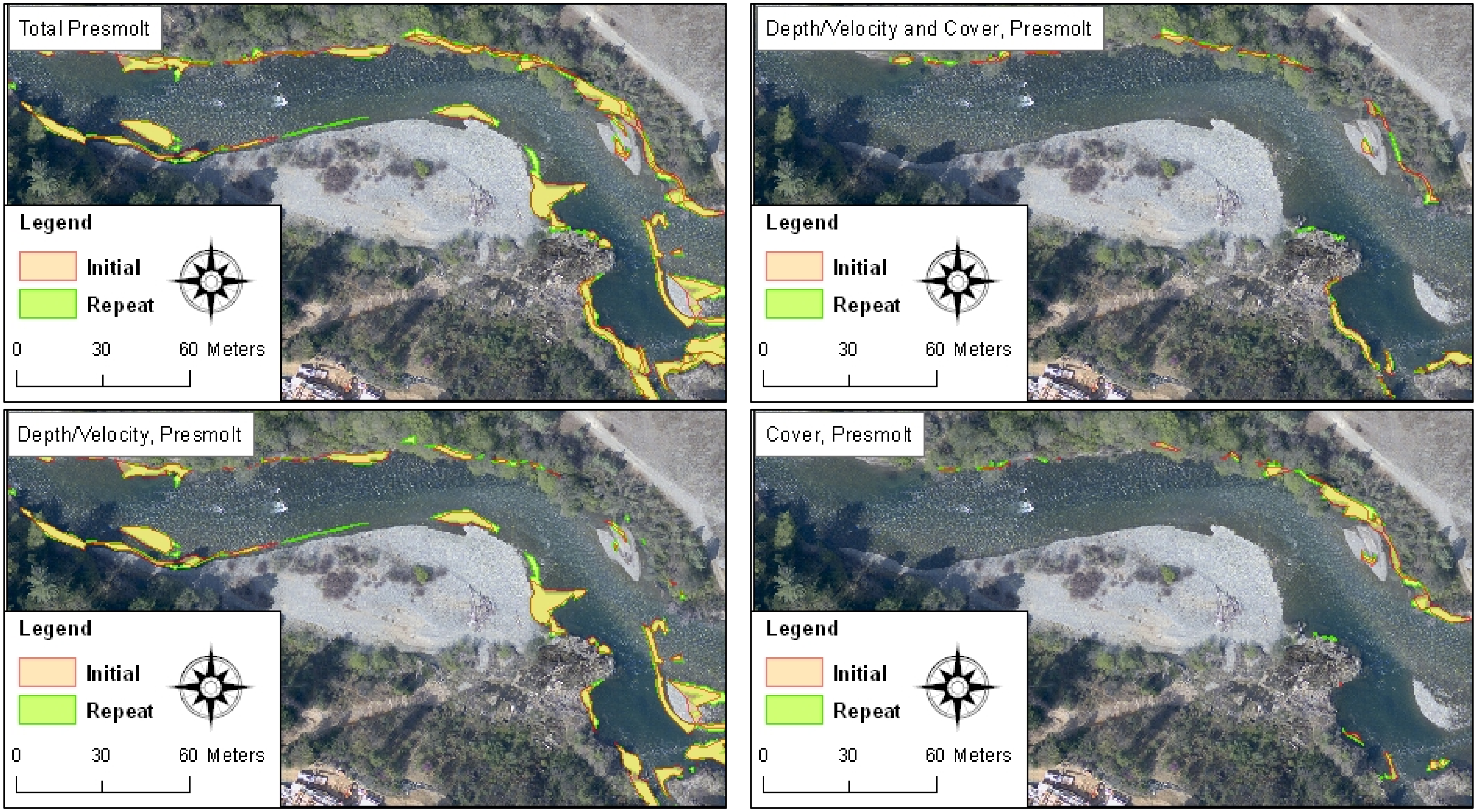

Figure 8–3. An example of differences in location of presmolt habitat categories between repeat habitat mapping surveys.

8.4. Discussion

One of the 11 variables was significantly different between the original and repeat surveys. Although this difference is of concern, it may not affect the interpretation of the habitat mapping-based assessments of the restoration effort. To put this difference in perspective, the observed mean pairwise difference in initial and repeat surveys for presmolt habitat meeting cover but not depth/velocity criteria was approximately 14 percent of the mean variable estimate. Although significant in the paired t-test, this level of difference may not be significant when compared to anticipated restoration effects. One current interim target for the Trinity River restoration effort is a 400-percent increase in salmonid rearing habitat (Trinity River Restoration Program, ESSA Technologies Ltd. 2009), which would be detectable despite the significant difference observed in the current study.

This interpretation provides support for the ability of this technique to evaluate changes in habitat quantities on the Trinity River, but also provides insight for improvement in survey methodology. Components of the survey that should be evaluated include, but are not limited to, increasing surveyor training and reducing GPS error tolerances. Further refinement in the survey technique will lead to more accurate and precise evaluations of changes in habitat estimates from restoration on the Trinity River. For example, reducing GPS tolerances should lead to more accurate GPS solutions, resulting in more accurate and precise spatial representations of rearing-habitat areas.

Some discrepancies between repeat surveys may have resulted from changes in the sample units between surveys. Several factors may have led to such changes. For example, a 78-cms (2,750-cfs; mean daily average) water release from Lewiston Dam occurred between the initial and repeat surveys. Although this release probably did not cause significant channel changes, it could have altered components of rearing habitat such as moving small woody debris. Small woody debris is, by definition, a component of in-water escape cover, but also may have indirect effects on localized velocity fields or eddies and may therefore affect all components of rearing-habitat categories. Vegetation growth also may have occurred between repeat surveys that were separated by up to two months, further altering rearing-habitat characteristics.

The repeatability of different stream habitat assessment techniques has been assessed on the Trinity River and within other systems, and this analysis provides a frame of reference for differences observed in the current study. Goodman et al. (2009) evaluated differences between replicate habitat surveys using the Judgment Based Habitat Mapping methodology. This technique used rapid visual surveys to evaluate habitat quantities, sacrificing accuracy and precision for the ability to survey larger areas. Although the technique allowed for the surveying of long segments of the Trinity River with relatively little effort, this evaluation found it to be irreproducible and inappropriate for evaluating changes from restoration activities. Pairwise differences in the Judgment Based Habitat Mapping assessment variable estimates ranged from 8 to 132 percent at sample units, and the average pairwise percent difference was 47 percent.

Other evaluations have assessed reproducibility in riverine habitat assessment techniques. Whitacre et al. (2007) compared habitat assessment protocols used by Federal agencies in river systems around Idaho and Oregon. Of the 10 stream attributes assessed, they found significant differences between monitoring groups in 9 of them. Similarly, Roper et al. (2010) compared the performance and compatibility of seven monitoring groups in Northeastern Oregon. Although some attributes were measured consistently within each group, none of the groups achieved consistent measurements in all cases.

Estimates of change in habitat quantity through time are the primary use for this data, although spatially explicit representations of habitat areas are also of interest. Spatial differences were qualitatively evaluated but not formally tested in this study. Differences were observed between surveys and should be formally evaluated in the future to better assess the utility of the survey to evaluate river features at a higher resolution than 400-m (1,312-ft) survey segments.

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CHAPTER 9. COMPARISON OF HABITAT MAPPING AND TWO-DIMENSIONAL HYDRODYNAMIC MODEL PREDICTIONS OF SALMONID REARING-HABITAT AVAILABILITY

9.1. Introduction

The restoration strategy for the Trinity River is designed to restore fluvial-geomorphic processes downstream of Lewiston Dam. This strategy is expected to lead to increased channel complexity and result in systemic increases in Salmonid habitat quantity and quality (USFWS and HVT 1999). These changes will likely be more prominent above the confluence of the North Fork Trinity River, hereafter referred to as the primary restoration reach. The restoration strategy is made up of four components including: (1) mechanical channel rehabilitation, (2) flow management to drive fluvial processes that create and maintain salmonid habitats and provide suitable thermal regimes, (3) coarse sediment augmentation, and (4) watershed restoration. Although the maximum change in rearing habitat is anticipated at channel rehabilitation sites, it is hypothesized that the restoration strategy will create synergistic effects, improving habitat throughout the primary restoration reach (Barinaga 1996, USFWS and HVT 1999).

Although habitat mapping has been the primary technique applied to evaluate the effects of river restoration (Chamberlain et al. 2007; Goodman et al. 2010), two-dimensional hydrodynamic models (models hereafter) have been implemented for similar purposes in the Trinity River (Gallagher 1999) and in other river systems in California (Gard 2006). The models have many additional applications that may be useful to the Trinity River Restoration Program, including the ability to predict the effects of restoration site design alternatives on habitat availability (Pasternack et al. 2004) and geomorphic processes (Tompkins et al. 2009). In addition, modeling can be a useful tool in evaluating the effects of dam release alternatives on habitat availability (Annear et al. 2004, Saraeva and Hardy 2009). Despite the potential benefits of this technique, no comparisons have been made to evaluate the potential compatibility of the habitat mapping and modeling techniques.

Two-dimensional hydrodynamic models were developed at Lowden Meadows and Reading Creek channel rehabilitation sites in 2009 before construction (HVT Fisheries et al. 2011). The models were developed to provide a demonstration of the capabilities of the modeling techniques to assess and improve restoration designs. The effort relied primarily on existing data sources for cost efficiency. One of the products of the modeling effort was spatially explicit salmonid rearing-habitat predictions at multiple streamflows, a data type similar to that produced by the habitat mapping surveys.

Rearing-habitat mapping surveys were applied at Reading Creek and Lowden Meadows as the pre-construction component of bank rehabilitation site assessments (See Section 4). The collocation of the two assessment techniques was used as an opportunity to compare and contrast the resulting predictions and evaluate the techniques' compatibility. The questions addressed in this assessment include:

1. How do rearing-habitat area estimates produced by habitat mapping compare to simulations from a two-dimensional hydrodynamic habitat model (priority question F–5)?
2. Do the locations of mapped or predicted habitat areas differ between techniques?

9.2. Methods

Using methods described in Goodman et al. (2010), habitat mapping surveys were conducted at Lowden Meadows and Reading Creek as the pre-construction component of a bank rehabilitation site assessment. In summary, quantities of fry and presmolt habitat that met the various habitat variable conditions (Table 9–1) were estimated for the following categories: (1) habitat meeting the depth/velocity and cover criteria, (2) habitat meeting the depth/velocity criteria only, (3) habitat meeting the cover criteria only, and (4) total habitat as defined by the sum total of types 1 through 3. For this report, total Chinook salmon rearing habitat (total habitat) includes all areas that meet any combination of depth/velocity or cover criteria. Optimal Chinook salmon rearing habitat includes areas that meet both criteria. Suitable Chinook salmon rearing habitat includes areas that meet either criterion but not both. Unsuitable Chinook salmon rearing habitat includes areas that meet neither of the criteria. Coho salmon rearing habitat is limited to areas that meet both criteria, and all other areas are considered unsuitable habitat. Habitat mapping was applied at five streamflows between 8.7 and 53.9 cms (307 and 1,903 cfs) at Lowden Meadows and between 9.9 and 62.0 cms (350 and 2,190 cfs) at Reading Creek.

Table 9–1. Guilds and Their Associated Habitat Criteria for Fish Habitat Mapping as Part of the 2008 Trinity River Site Assessment (Goodman et al. 2010)

Habitat guild	Variable	Criteria
Chinook salmon and coho salmon fry (<50 mm)	Depth	>0 to 0.61 m
	Mean column velocity	0 to 0.15 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood
Chinook salmon and coho salmon presmolt (50 to 200 mm)	Depth	>0 to 1 m
	Mean column velocity	0 to 0.24 m/s
	Distance to Cover	0 to 0.61 m
	Cover type	Open, vegetation, wood

Models were developed in the Multi-Dimensional Surface Water Modeling System software package (McDonald et al. 2005) using the Flow and Sediment Transport Morphological Evolution of Channels model. Model input data included topography derived using a combination of LiDAR data collected in 2005 and photogrammetry data collected in 2007 (Fugro Pelagos, Inc. 2005, TRRP unpublished data). The topographic grid was developed at 1-m (3-ft) resolution, and a constant drag was applied for each model. Discharges were estimated using nearby USGS gauges. Water surface elevations at the downstream model extent were estimated using the Trinity River HEC-RAS model. No model calibration was conducted within the range of streamflows evaluated in this comparison. Ground surveys were conducted to map escape cover for habitat predictions.

The models and ground surveys were compared at the Reading Creek channel rehabilitation site from rkm 148.9 to 149.5 (rm 92.5 to 92.9) and at the Lowden Meadows channel rehabilitation site from rkm 168.5 to 169.2 (rm 104.7 to 105.1). Comparisons were limited to the sections of river where the models and multiple streamflow habitat surveys overlapped.[3] For comparative purposes, model predictions of habitat were generated using the same depth/velocity and cover habitat definitions and streamflows as the habitat mapping surveys.

Three variables were compared at each site across five streamflows: (1) area of the wetted channel, (2) area meeting the depth/velocity criteria, and (3) area of in-water escape cover. These variables represent model-derived products that are comparable to the habitat mapping data and provide more information on the source of differences than more processed products (i.e., combinations of depth/velocity and cover used in rearing-habitat definitions). Habitat density estimates were derived by dividing habitat estimates by the site length and the percent difference calculated as the absolute value of:

$$\text{Percent Difference} = (X_{model} - X_{map})/((X_{model} + X_{map})/2) \times 100$$

9.3. Results

At Reading Creek habitat mapping estimated a higher quantity of area meeting fry and presmolt depth/velocity criteria at all surveyed streamflows when compared to the model predictions. At each streamflow, the estimates from the two techniques differed by 63 to 107 percent for fry and 16 and 59 percent for presmolt (Table 9–2; Figure 9–1). For fry, the largest density differences were at the lowest streamflows, although percent difference was greatest at the highest streamflow. For presmolt, the largest density difference was at 21.3 cms (752 cfs), and the highest percent difference was at the highest measured streamflow. In contrast, in-water escape cover predicted by the model was consistently higher, ranging from 44 to 67 percent

[3] The Reading Creek site habitat mapping data presented in this section covers a shorter area than that presented in the site specific study site (see chapter 4).

Table 9–2. Differences Between Rearing-Habitat Quantities Estimated Using Habitat Mapping and Predicted from Two-Dimensional Hydrodynamic Modeling at Reading Creek and Lowden Meadows Bank Rehabilitation Sites Before Construction. Comparisons were made for estimates of areas that meet depth/velocity criteria for fry and presmolt life stages, area of inundated in-water escape cover (cover), and the area of wetted channel. Density differences were calculated as the absolute value between estimates. Percent difference was calculated as the absolute value of: $(X_{model}-X_{map})/((X_{model}+X_{map})/2)\times100$. Discharge measured as site-specific values from proximal USGS gauging stations.

Site	Disch. (cms)	Density difference (Percent difference)			
		Fry: D/V	Presmolt: D/V	Cover	Wetted channel
Reading Creek	9.9	2.1 (62.7)	1.0 (16.3)	0.9 (43.6)	0.8 (2.3)
	13.3	2.1 (69.8)	0.9 (17.8)	1.3 (51.7)	2.1 (5.4)
	21.3	1.4 (80.5)	1.1 (33.6)	1.8 (67.6)	1.9 (4.8)
	36.5	0.8 (69.6)	0.7 (33.1)	1.7 (47.9)	1.6 (3.8)
	62	1.1 (106.5)	1.0 (59.2)	2.9 (59.9)	2.2 (5.0)
Lowden Meadows	8.7	0.5 (18)	1.0 (16.6)	1.1 (31.4)	0.1 (0.3)
	11.4	0.4 (16.7)	1.1 (22.6)	0.8 (18.4)	0.5 (1.5)
	20	0.3 (21.9)	0.9 (35.2)	1.5 (31.2)	2.2 (6.0)
	34	0.9 (107.6)	1.3 (65.2)	2.8 (51.9)	3.1 (8.2)
	53.9	1.1 (75.6)	1.6 (66.7)	3.8 (58.5)	4.8 (12)

higher than the habitat mapping result. The largest differences were at the highest streamflow, and the largest percent difference was at 21.3 cms (752 cfs).

Model predictions of the wetted channel at Reading Creek were generally greater than mapping estimates, except at 9.9 cms (350 cfs), in which case the mapping estimates were 2 percent lower. At each streamflow, differences in wetted channel estimates between techniques ranged from 2 to 5 percent.

Unlike the results at Reading Creek, the modeled prediction for fry and presmolt areas meeting the depth/velocity criteria at Lowden Meadows was consistently higher than habitat mapping estimates (Figure 9–2). At each streamflow, differences between the estimates from the two techniques ranged from 17 to 108 percent for fry and 17 to 67 percent for presmolt. The density differences were greatest at the highest surveyed discharge, and the magnitude of percent differences generally increased with streamflow for both life stages. As at Reading Creek, the modeled predictions for areas meeting in-water escape cover criteria at Lowden Meadows were consistently higher than habitat mapping estimates. Differences between the estimates from the two techniques ranged from 18 to 59 percent. Except for the lowest flow, differences for in-water escape cover generally increased with discharge, with the smallest difference at 11.4 cms (403 cfs) and the largest difference at 53.9 cms (1,903 cfs). The modeled predictions of wetted channel area at Lowden Meadows were higher than mapping estimates at all surveyed discharges.

At each streamflow, differences between the estimates from the two techniques ranged from 0 to 12 percent. Differences had a direct relationship to streamflow, with the largest differences at the highest streamflows.

A decrease in mapped wetted channel area was observed between 11.4 and 20 cms (403–706 cfs) at Lowden Meadows. This decrease in channel area is not logical since wetted channel area should increase with increasing flows, or at least remain the same depending on channel shape. The observed decrease is likely a product of measurement error inherent to the mapping technique. To estimate the magnitude of this error a linear interpolation analysis was applied between wetted channel measurements at 8.7 and 34 cms (307 and 1,201 cfs) and used to predict the wetted channel density at 20 cms (706 cfs). The predicted value was 0.7 m^2/m (2.3 ft^2/ft) different than the measured value, or 2 percent.

Discrepancies were identified in locations of habitat areas among the results of the two techniques. In the example of Reading Creek at 9.9 cms (350 cfs), large differences in the spatial representation of areas meeting the depth/velocity criteria were apparent between the two techniques (Figure 9–3). Although some areas of overlap existed, the size and shape of the predicted areas were dissimilar. Areas meeting in-water escape cover criteria were predicted in similar locations in some instances, but in general discrepancies existed in size, shape, and location between the model and mapping results. Wetted channel perimeters were generally similar across the two techniques. In this category, larger discrepancies were observed around exposed alluvial deposits with low slopes. In addition, wetted channel perimeters were more similar between mapping and model results on open river banks (downstream left bank in example) than those with thick overhanging riparian vegetation where topographic data collection was more difficult (downstream right bank in example).

9.4. Discussion

Although trends were similar between model predictions and mapping estimates of habitat parameters (depth/velocity, inundated cover, and wetted perimeter), differences were apparent. No validation data was collected as part of this study design, making it difficult to evaluate the difference in accuracy between techniques. If future assessments evaluate this problem, independent and randomly distributed validation datasets should be collected to evaluate the accuracy of the estimates produced from each assessment.

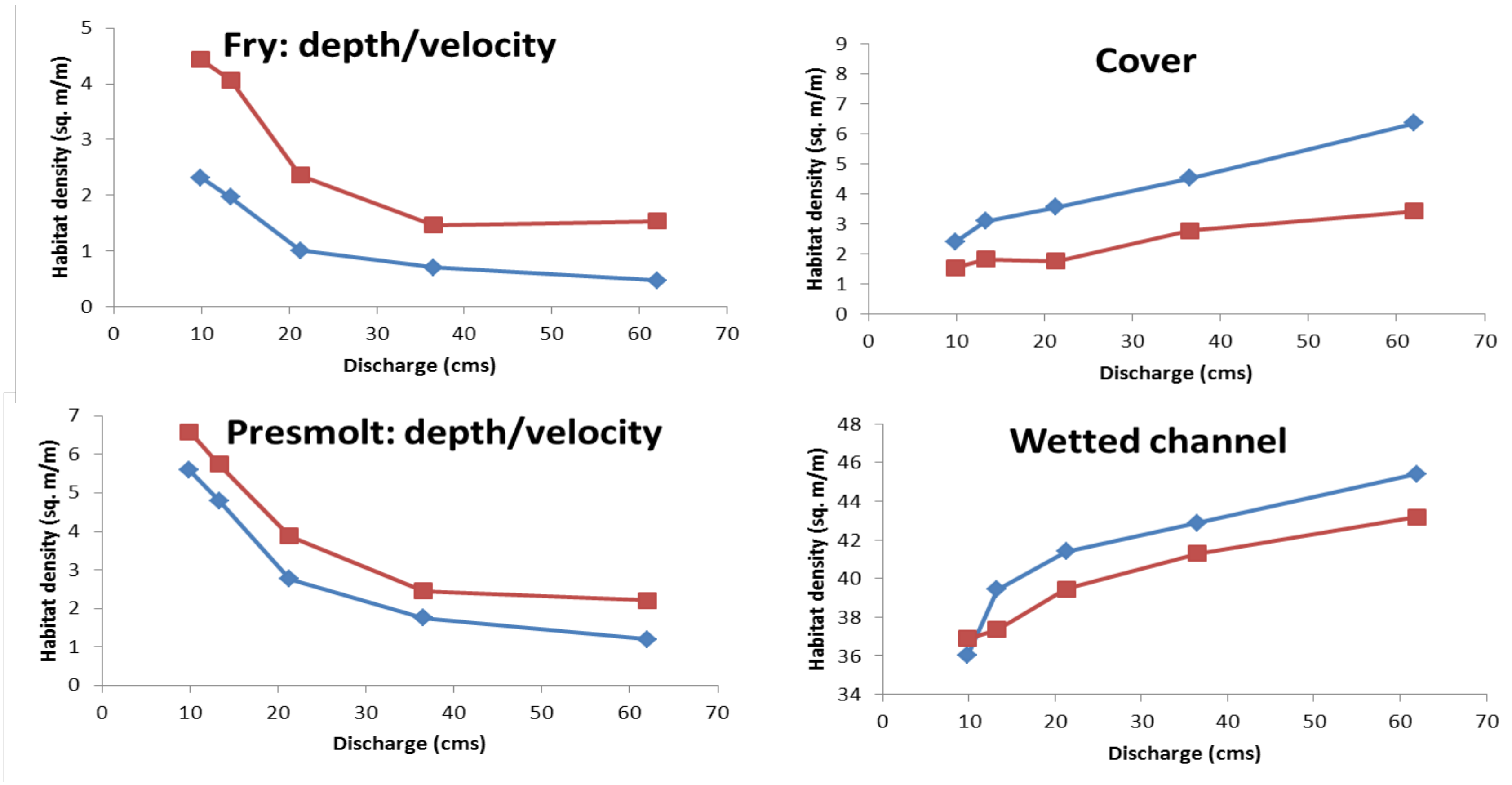

Figure 9–1. Rearing-habitat variables estimated by a two-dimensional hydraulic model (blue) and habitat mapping (red) surveys at Reading Creek bank rehabilitation site before construction. Comparisons were made for estimates of areas meeting depth/velocity criteria for fry and presmolt life stages, area of inundated in-water escape cover (cover), and the area of wetted channel.

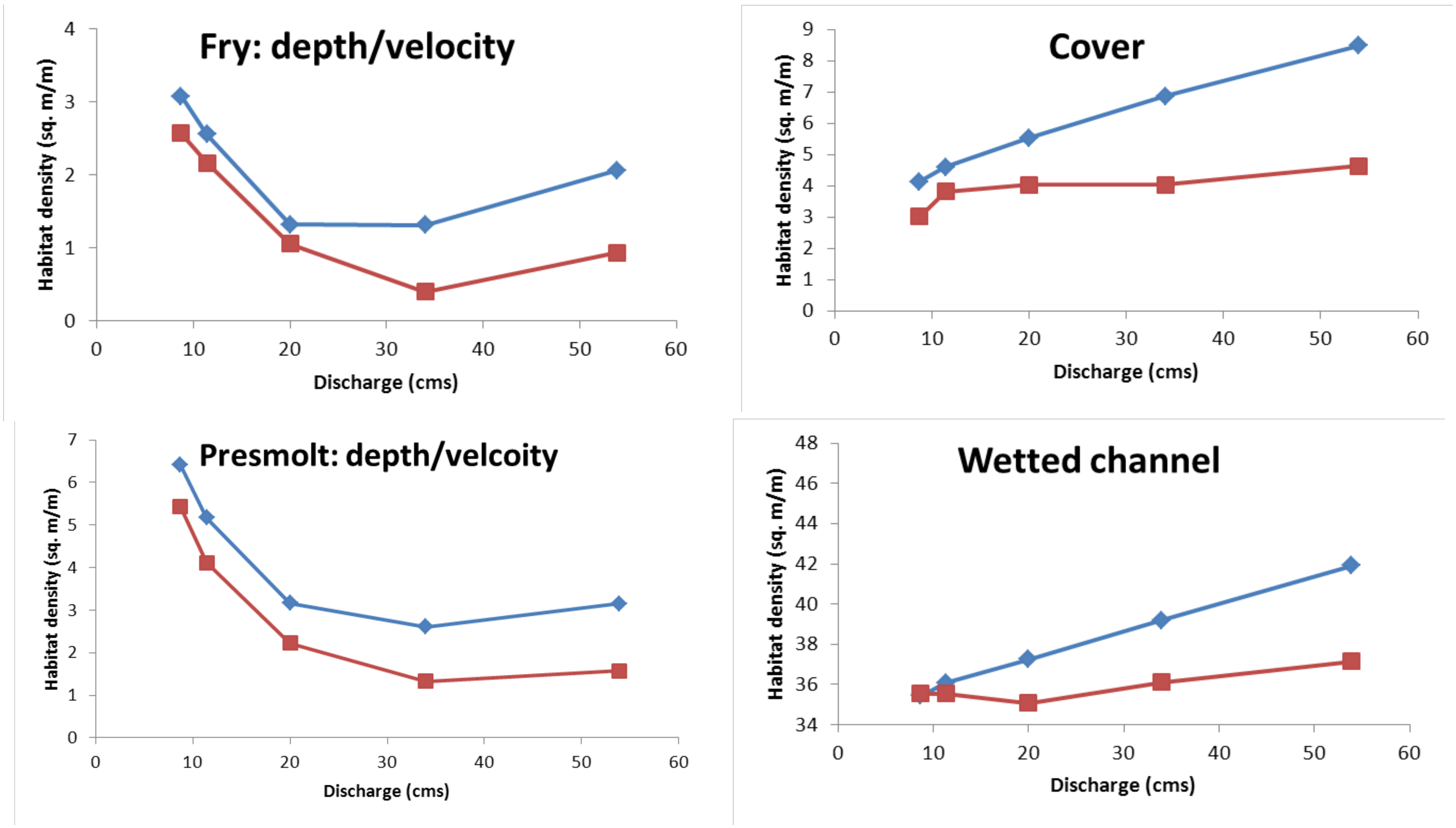

Figure 9–2. Rearing-habitat variables estimated by a two-dimensional hydraulic model (blue) and habitat mapping (red) surveys at Lowden Meadows before construction. Comparisons were made for estimates of areas meeting depth/velocity criteria for fry and presmolt life stages, area of inundated in-water escape cover (cover), and the area of wetted channel.

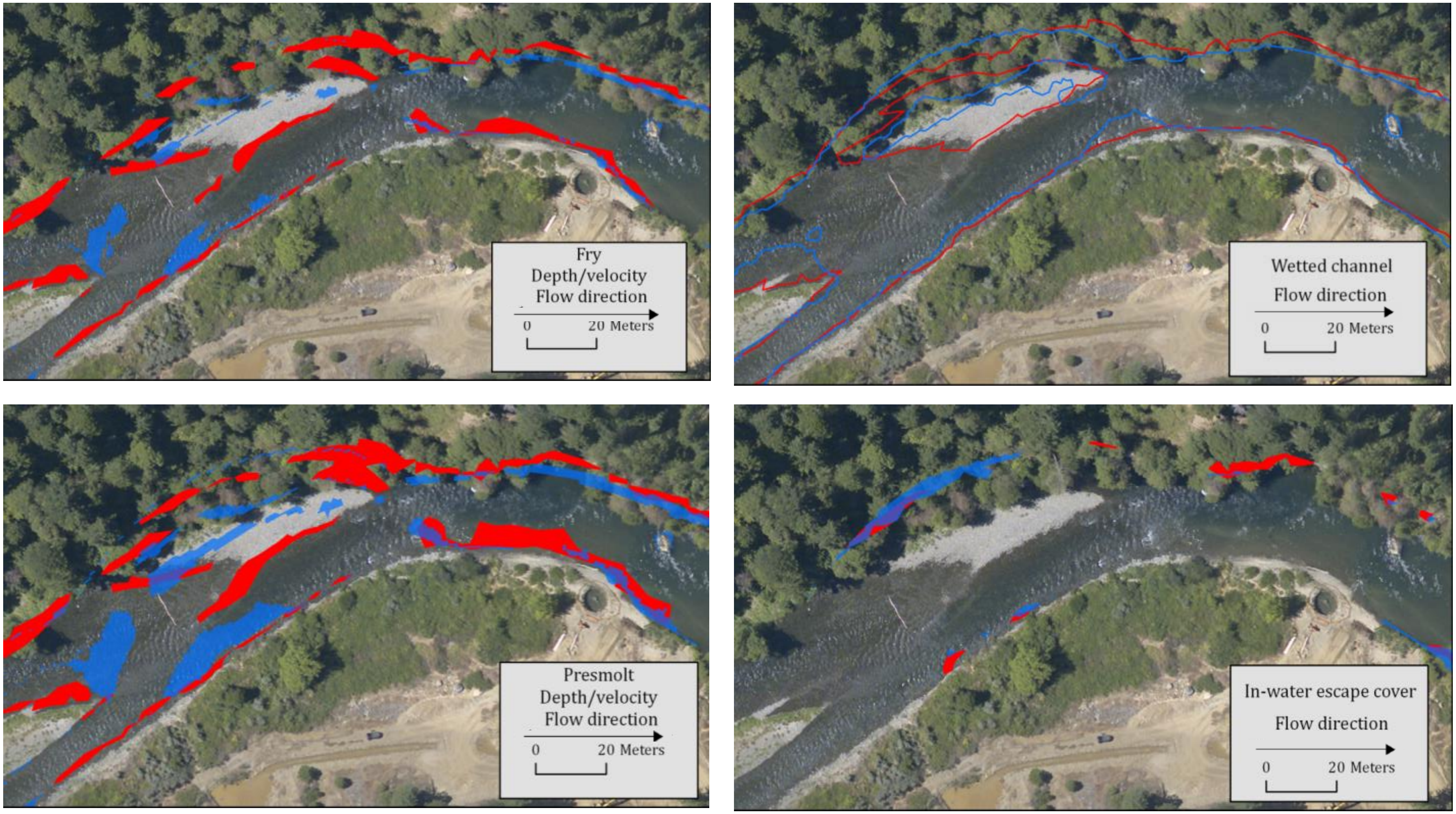

Figure 9–3. Discrepancies between spatially referenced two-dimensional hydrodynamic model predictions and mapping results of presmolt rearing-habitat parameters at Reading Creek at 9.9 cms. Blue indicates model predictions and red indicates mapping results. Depth/velocity and in-water escape cover areas indicated by polygons while wetted channel is indicated by perimeter lines.

Despite the lack of validation data, relevant information can be assumed about the sources of error based on the associated methods. In particular, habitat mapping measures parameters at each surveyed streamflow. Errors inherent to this technique include measurement errors associated with surveying, particularly with referencing positions using GPS and laser rangefinders. Although this error is assumed to be approximately 0.3 m (1 ft) based on manufacturer specifications, it may vary with satellite configuration. Additionally, observer error must be considered. Habitat areas may not be surveyed properly by misrepresenting habitat variable boundaries or by missing areas all together. One example of the error in the mapping technique was observed as a decrease in wetted channel observed between 11.4 and 20 cms (403 and 706 cfs) at Lowden Meadows. This result was not a logical response to increasing streamflow in a riverine system. This error should be considered in light of the highly channelized morphology and steep river banks of the Trinity River at Lowden Meadows. Considering this channel morphology, even marginal increases in wetted channel area with increased streamflow was not anticipated. Therefore the decrease in channel area between the two surveyed flows is likely a modest error. The measurement precision of the habitat mapping technique for wetted channel measurements was estimated to be up to 2 percent (see Section 8), the same level of error observed in the current study.

Measurement and observer error is also inherent to model inputs. For example, remote sensing techniques, such as LiDAR and photogrammetry, have unique errors based site-specific variables such as slope and vegetation types, with higher levels of error noted in heavily vegetated areas (Hodgson and Bresnahan 2004). These errors affect model predictions. Additionally, approximation error is essentially unavoidable when attempting to summarize and predict reality through numerical modeling (Steffler and Blackburn 2002). Factors affecting prediction errors include difficulties in properly describing complex hydraulic factors such as turbulence. Additional errors arise from summarizing continuous environments with a finite number of points, predictions, or equations. Finally, errors in variables such as area of in-water escape cover may be related to the complex, three-dimensional, asymmetrical shapes common to these features when approximated in two dimensions. Take, for example, a conical shaped shrub that has a small circumference at its base and a much larger circumference a couple feet above the ground. When mapped as cover, the shrub is mapped as a planar representation summarizing one circumference for the feature; in this example, the larger circumference a few feet off the ground is mapped. When predicting the area of in-water escape cover, the wetted channel area and the mapped cover are overlaid on each other. In the example above, if the true water elevation is low on the shrub, the model would over-predict the area of in-water escape cover.

This comparison should be considered in light of the data used in developing the models. As previously stated, for cost efficiency the models were primarily developed from pre-existing data sets with no model calibration data within the range of streamflows evaluated in this comparison. It is possible that the resolution of input data was not sufficient to produce accurate predictions. Higher resolution model input data may result in improved concordance between methodologies.

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CHAPTER 10. INTEGRATION OF GEOMORPHIC AND SALMONID REARING-HABITAT ASSESSMENTS

10.1. Introduction

The strategy adopted by the TRRP to restore the fishery resources of the Trinity River is to restore a functioning river through mechanical rehabilitation of the channel, coarse-sediment augmentation, and restoration of physical processes with flow management (USDOI 2000). These management actions are expected to create and maintain salmonid habitats, especially rearing habitats, as the means for restoring the fishery resources of the river (USFWS and HVT 1999). As part of the adaptive management process to evaluate the effectiveness of these actions, a more thorough understanding is needed of how streamflows, channel rehabilitation, and sediment augmentation induce changes in channel morphology and riparian vegetation structure, and how these changes relate to changes in aquatic and riparian habitats (TRRP and ESSA Technologies 2009; Figure 10–1).

This assessment focused on investigating the quantitative functional relationships linking geomorphology and Chinook salmon rearing habitat. The initial analyses were focused on geomorphic links to habitat because (1) the time required to assess the effect of our management actions is short (years rather than decades), (2) these analyses include the results of active management actions that can be modified to achieve desired outcomes, and (3) the TRFE (USFWS and HVT 1999) and the ROD

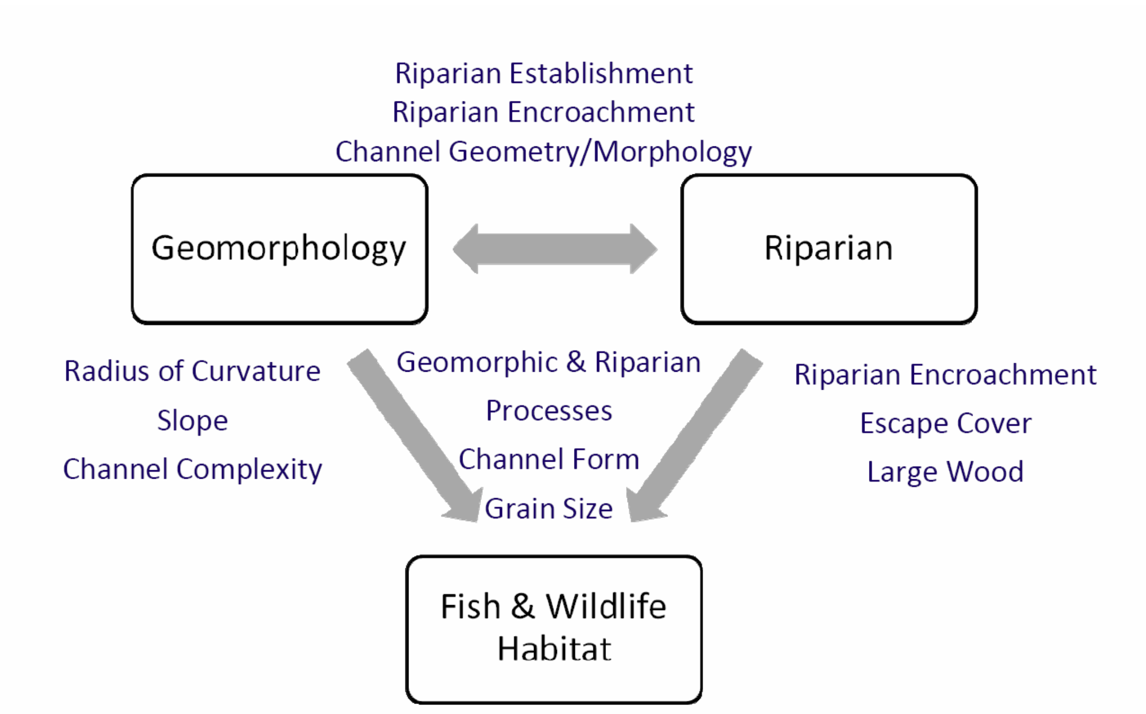


Figure 10–1. Conceptual linkages between physical processes and riparian vegetation, and the effect of these processes on biological habitats.

(USDOI 2000) adopted a physical process-based approach to fishery resource restoration.

Following coordination with TRRP staff and surveying pertinent literature, the five physical variables selected for the 2009 pilot integration analysis included radius of curvature, topographic diversity, shear stress diversity, area of exposed active alluvial surface, and wetted edge length. The following sections present hypotheses describing the anticipated relationships between physical form and processes and fish habitat.

10.1.1. Radius of Curvature

Management actions such as mechanical channel rehabilitation, coarse sediment augmentation, and flow-induced physical processes are expected to change the channel form of the river. These actions should increase channel meander amplitude, shorten the channel meander wavelength, and decrease the radius of curvature (ROC), which in turn will increase the potential for channel migration. As the radius of curvature decreases, it is expected that hydraulic and physical channel diversity will increase, leading to increases in habitat.

10.1.2. Topographic Diversity

The TRFE (USFWS and HVT 1999) identified the simplified, uniform channel shape of the Trinity River as one of the factors that led to significant decreases in rearing habitat. This simplified channel resulted in low topographic diversity, reducing the range of depths available at a single flow and across variable flows. It is expected that changes in channel form, away from the simplified U-shaped channel to one reflective of a river channel with functioning physical processes, will increase instream topographic diversity and this will lead to increases in habitat.

10.1.3. Shear Stress Diversity

As with topographic diversity, the simple, uniform channel geometry, with more uniform depths, also has less variability in water velocities at a specific discharge than a more complex channel. As management actions result in a more complex channel geometry, it is expected that variability in topography will also create variability in velocities, leading to greater depth/velocity combinations available at any one flow and across variable flows. As topographic variability increases, shear stress diversity is expected to increase and fish habitat should increase for a given streamflow.

10.1.4. Length of Wetted Edge

Many proposed channel rehabilitation sites are in locations where a straight, simplified channel currently exists. Channel rehabilitation efforts have introduced coarse sediment and physically rehabilitated the channel morphology to increase sinuosity, in-channel alluvial features, and side-channel length. It is expected that as these actions are completed, along with the-flow induced changes that are anticipated, the sinuosity and complexity of edge features will increase, increasing the length of wetted edge, and leading to increases in habitat.

10.1.5. Area of Exposed Active Alluvial Deposits

As management actions change the channel form of the river, it is expected that alluvial features, specifically active alluvial bars, will become prominent features of the river. While a simple U-shaped channel typically lacks areas where coarse sediment is deposited to form mobile alluvial deposits (i.e., bars), it is expected that the initial channel-rehabilitation actions, sustained with fluvial-geomorphic flows and coarse-sediment augmentation, will result in an increase in the quantity and extent of alluvial bar features. It is expected that habitat will increase with increases in alluvial bars due of the more diverse suite of depth/velocity combinations provided by these features and that bigger features will provide more habitat.

10.2. Methods

Seven sites of varying lengths were selected where habitat mapping and physical process monitoring were conducted in 2009. These integration sites were used for exploratory, integrative assessments: Hocker Flat, Lower Indian Creek, Lowden Meadows, Bucktail–Dark Gulch, Lewiston Cableway, Hoadley Gulch, and Sven Olbertson. Not all sites were used for all analyses. These sites were selected based on a combination of the following factors:

1. Reasonable distribution of sites over the primary management reach (Lewiston Dam to the North Fork Trinity River confluence),
2. Pre- and post-construction fish habitat assessments at most sites, and
3. Pre- and post-construction topographic information at most sites.

10.2.1. Fish Habitat

Total Chinook salmon fry and presmolt habitat and habitat density were used for the analyses investigating the relationship between habitat abundance and physical parameters. (See Chapter 4 for habitat measurement methods.) The specific habitat metric (area or density) associated with each analysis is described in the following sections. Additionally, one analysis used habitat estimates based only on suitable depth and velocity criteria to investigate if there were any differences in outcomes of the analysis. Depending on the analysis, habitat data at different flow levels were sometimes used to ensure compatibility with the physical variables or to evaluate the relationships over a range of flows.

10.2.2. Radius of Curvature

The relationship between ROC and rearing habitat was evaluated for pre-construction conditions at Sven Olbertson, Lewiston Cableway, Hoadley Gulch, Bucktail–Dark Gulch, and Lowden Meadows, and post-construction conditions at Sven Olbertson, Lewiston Cableway, Hoadley Gulch, Bucktail–Dark Gulch, and Hocker Flat.

To derive ROC, the planform location of the thalweg was identified from 2009 aerial photography (Figure 10–2, TRRP unpublished data). The thalweg was selected since it represents the channel form and the transitions between fast water areas, with adjacent slow water areas that provide habitat for fry and juvenile salmonids. Larger section or reach-level ROCs would not be appropriate for the scale of this evaluation. Arc lines were then fitted to the thalweg for each site using AutoCAD Civil 3D v. 2010, and an ROC was computed for each one-half meander wavelength. Once boundaries were set for specific areas with known radii of curvature, habitat layers were overlaid and the amount of habitat associated with each one-half meander section was estimated (Figure 10–3).

Total habitat area based on depth/velocity and depth/velocity/cover criteria only during an 8.5-cms (300-cfs) dam release were utilized for this analysis and constrained to the main channel, excluding side channels. (See Chapter 4 for methods.) Habitat density (habitat area/unit length of channel) was calculated to facilitate comparisons across the different ROC measurements. Using total habitat area (rather than density) could potentially misrepresent the relationship because long, straight study sites could have more habitat area overall than a shorter, more sinuous study site. Habitat density adjusts the habitat area in a river segment to account for long, straight sections of river that have a small habitat area per unit length of channel. The relationship between habitat density (dependent variable) and ROC (independent variable) was evaluated using linear regression, and both variables were natural-log-transformed due to the nonlinear relationship observed in the data.

10.2.3. Topographic Diversity

The relationship between topographic diversity and rearing-habitat area was only evaluated at the area within Lewiston Cableway, where habitat mapping occurred at multiple streamflows (i.e., Lewiston Cableway-A, Figure A–26). Lewiston Cableway-A was selected for this analysis based on availability of pre- and post-construction rearing-habitat data over a range of flows and topographic data. Topographic diversity was evaluated using two techniques: (1) the standard deviation of channelbed distance from a specific water surface plane and (2) the ratio of channelbed surface area to wetted surface area. Side-channel areas were excluded from the analysis.

10.2.3.1. Channelbed Distances Below the Water Surface Plane

The relationship between topographic diversity and rearing habitat was evaluated at two flows and for pre- and post-construction conditions. Topographic diversity of the channelbed was estimated by calculating the standard deviation of distances from the channelbed to the water surface plane (Statzner et al. 1988, Lepori et al. 2005). This analysis included several discrete steps, including the development of a topographic model of the channelbed, division of the study area into equal length segments, and relating the topographic diversity to rearing habitat for each segment.

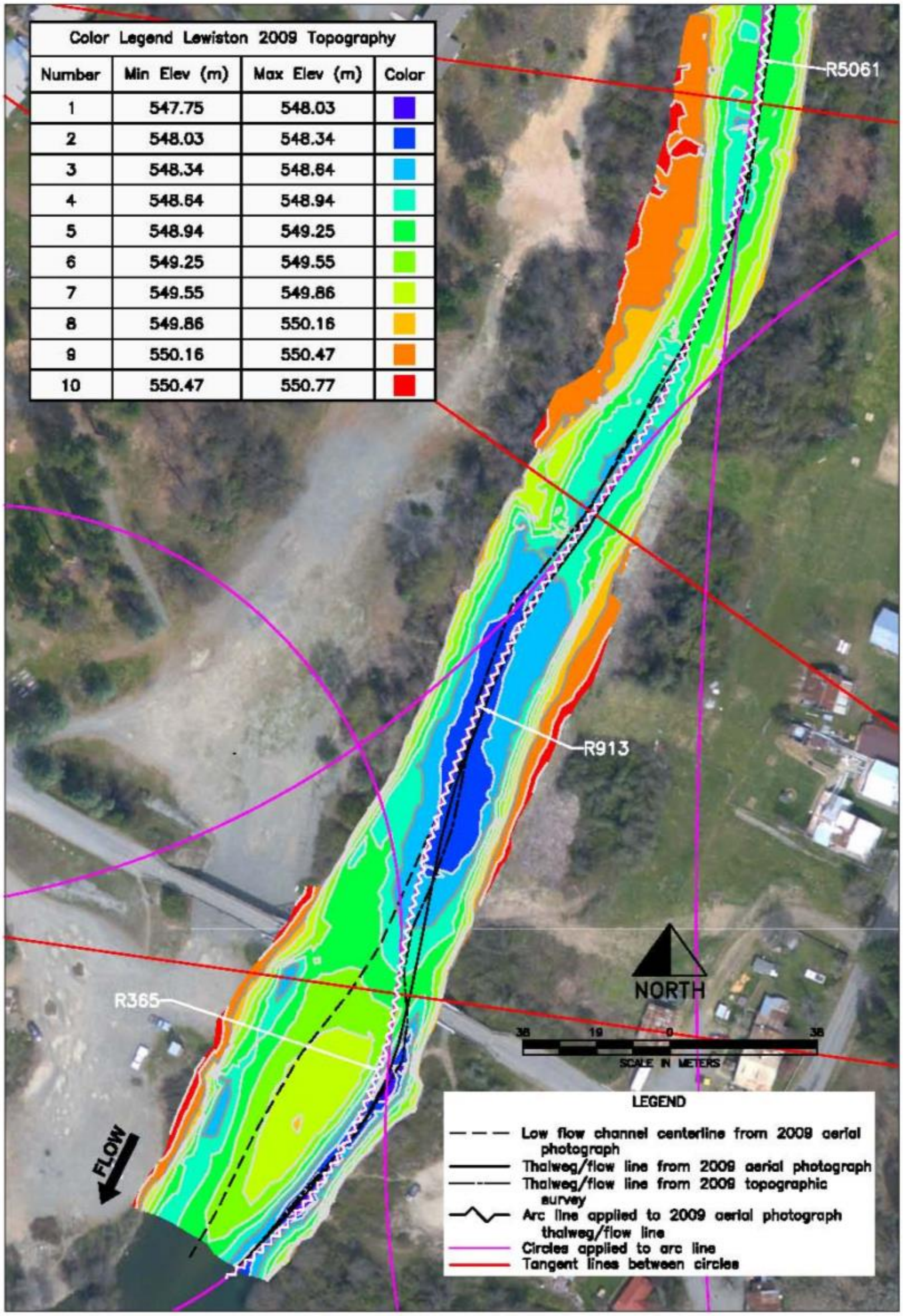


Figure 10–2. Lewiston Cableway channel rehabilitation site illustrating different techniques evaluated to measure the radius of curvature. The techniques were based on using the thalweg as estimated from aerial photography (used in analyses), the thalweg defined from topographic surveys, and the channel centerline estimated from aerial photography.

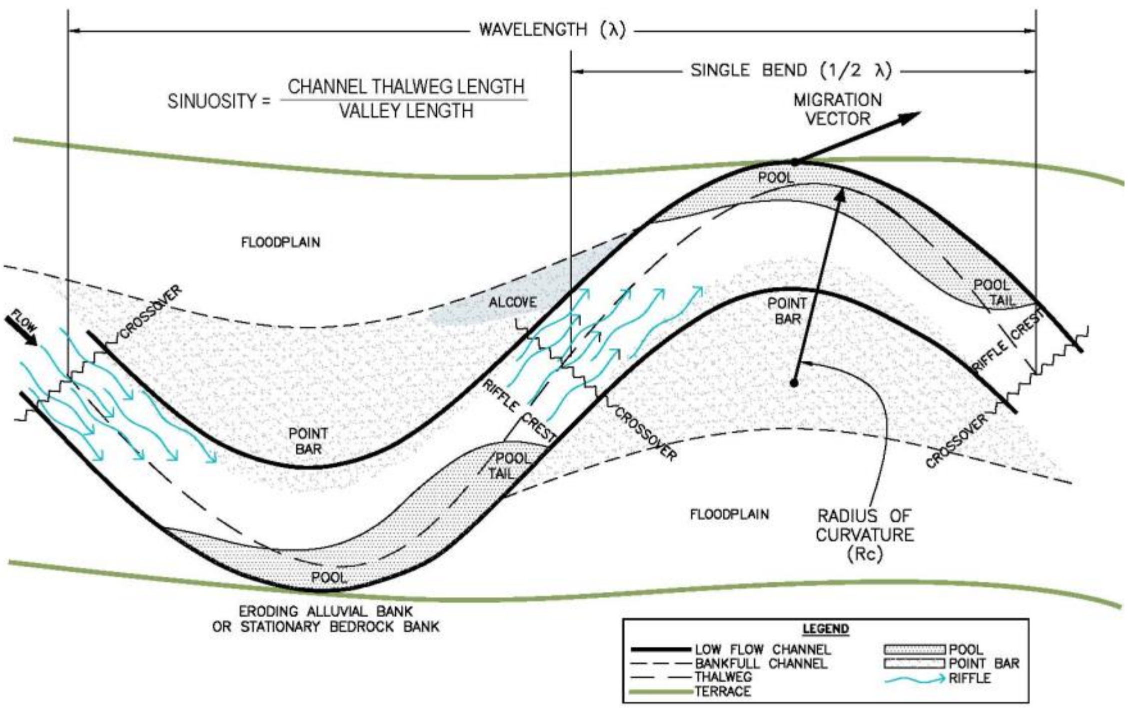


Figure 10–3. Idealized alternating bar sequence illustrating the meander wavelength, sinuosity, radius of curvature, and associated geomorphic units. (Figure adopted from USFWS and HVT 1999.)

The digital terrain model of channelbed topography was derived using a Total Station survey of the channel bathymetry stitched into a combination of existing photogrammetry, LiDAR, and topographic survey data (Wolpert 2009, TRRP unpublished data). A 2-m (6-ft) grid was overlaid on the digital terrain model. Higher resolution grid spacing of 0.3 m (1 ft) was evaluated; however, the spacing of points relative to the resolution of the model was too coarse to support use of a higher resolution grid. The study reach was divided into ten 50-m (164-ft) segments along the 142-cms (5,000-cfs) channel centerline (Figure 10–4). The 50-m segment lengths were deemed to be small enough to allow for a reasonable number of data points but large enough to possibly contain some topographic differences. Habitat values for pre- and post-construction conditions were calculated for a low flow (8.5 cms [300 cfs]) and for a high flow (52.7 cms [1,861 cfs] for pre-construction and 57.2 cms [2,020 cfs] for post-construction). The water surface planes for the two flow regimes were described by a HEC-RAS model. Water surface planes for the high flows were limited to approximately 56.6 cms (2,000 cfs) to avoid the topography associated with berms, and this was the maximum flow for which habitat data were available. Habitat areas at 52.7 cms (1,861 cfs) pre-construction and 57.2 cms (2,020 cfs) post-construction were assumed to be comparable for this analysis. The topographic differences within each stream segment were assessed by computing the distance between the predicted water surface elevation and the channelbed topography at the nodes of a 2-m (6-ft) grid (Figure 10–5).

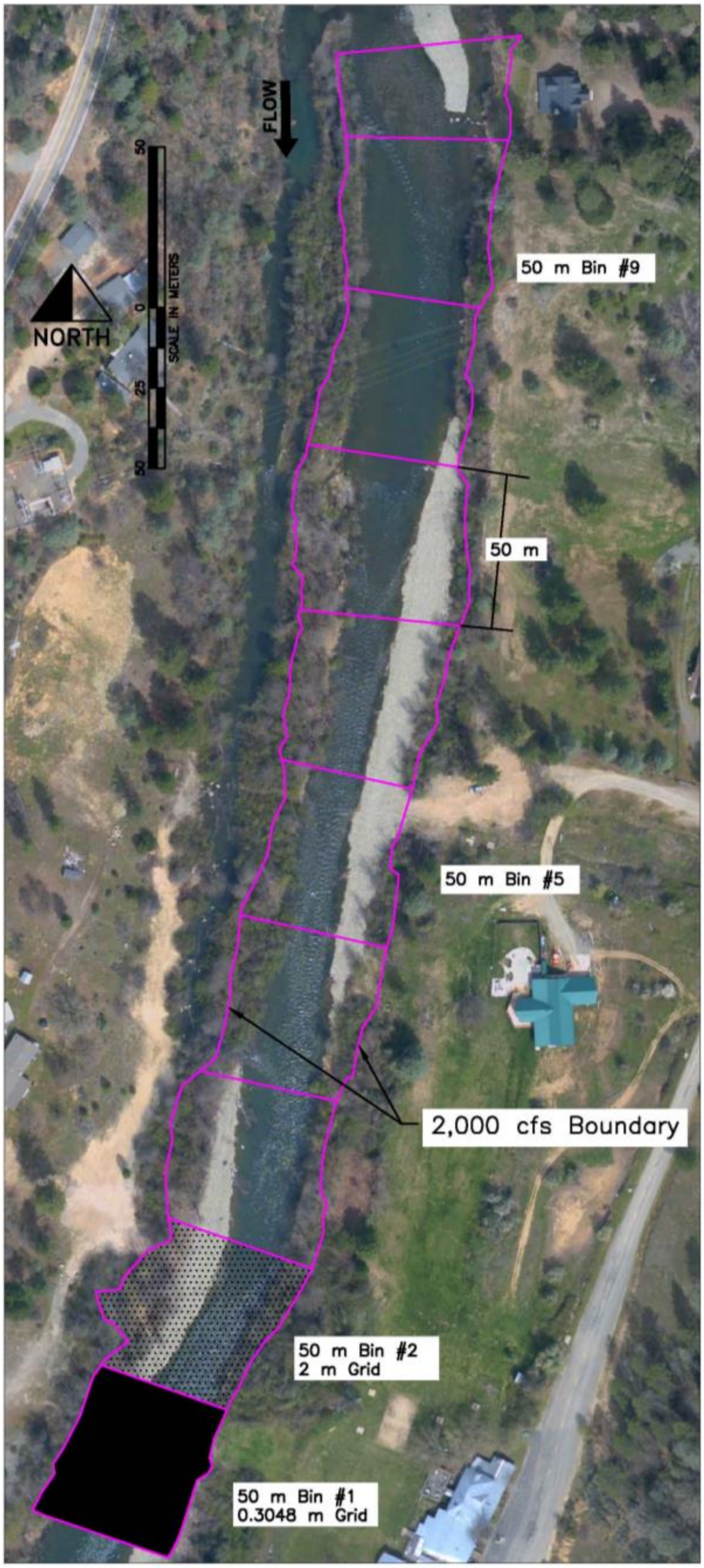


Figure 10–4. Lewiston Cableway channel rehabilitation site illustrating the measurement area (i.e., the 57-cms [2,000-cfs] lateral boundary and the 50-m [164-ft] channel lengths) and the two grid measurement systems (i.e., 0.3- and 2-m [~1- and 6-ft] intervals) used to quantify topographic diversity.

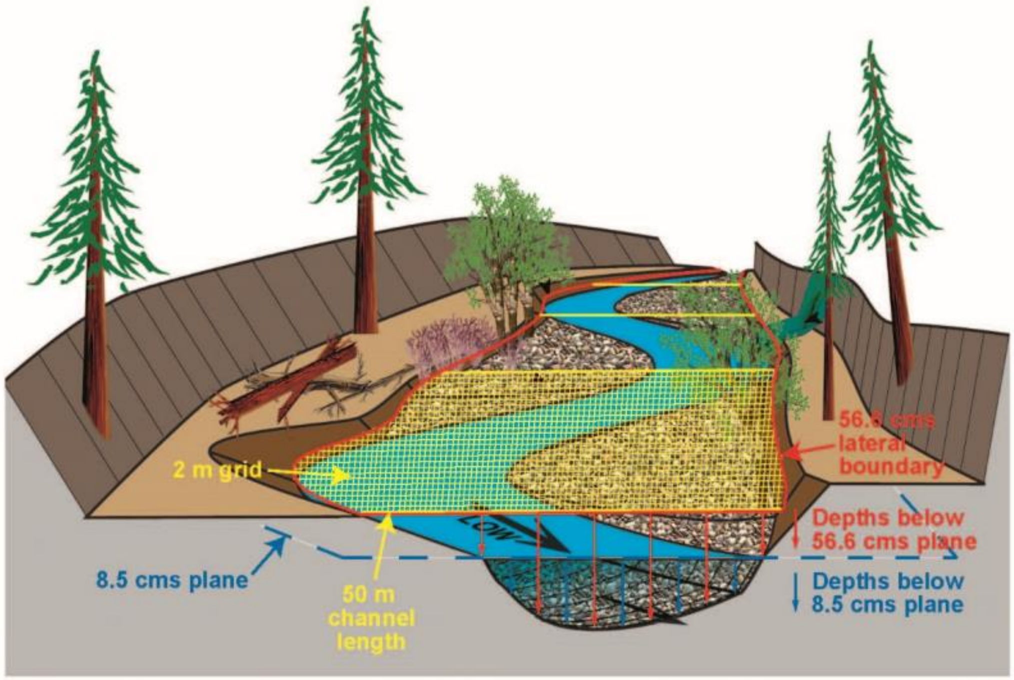


Figure 10–5. Conceptual channel illustrating the 8.5- and 56.6-cms (300- and 2,000-cfs) water-surface planes, the measurement area lateral boundary (i.e., the 56.6-cms [2,000-cfs] flow boundary), the 50-m (164-ft) study segments, and channelbed distances.

Total Chinook salmon fry and presmolt rearing-habitat areas were calculated for each 50-m (164-ft) stream segment for pre- and post-construction conditions at 8.5 cms (300 cfs), for pre-construction conditions at 52.7 cms (1,861 cfs), and for post-construction conditions at 57.2 cms (2,020 cfs). The relationship between habitat (dependent variable) and channelbed diversity (independent variable) was evaluated using linear regression.

10.2.3.2. Channelbed Surface Area to Water Surface Area Ratio

A second evaluation of topographic diversity at the Lewiston-A site compared the 52.7-cms (1,861-cfs) pre-construction and 57.2-cms (2,020-cfs) post-construction water surface and channelbed surface area measurements along each 50-m (164-ft) segment bounded by the wetted edge at those specific flows. The ratio of channelbed surface area to water surface area was used as a metric for topographic variability within each 50-m section. The channelbed surface area was calculated within 50-m (164-ft) bins at Lewiston Cableway-A using the same ground-surface topography that was used in the channelbed distance analysis. (See previous section.) An existing HEC-RAS model was used to predict water-surface elevations at cross-section locations throughout the study reach, and those water-surface elevations were projected onto the appropriate topographic model to generate water-surface areas. Habitat areas at 52.7 cms (1,861 cfs) pre-construction and 57.2 cms (2,020 cfs) post-construction were assumed comparable for this analysis. In each 50-m (164-ft) section, the pre- and post-construction relationships of total fry and presmolt rearing-habitat areas (dependent variables) to the channelbed surface area/water surface area ratio (independent variable) were evaluated using linear regression.

10.2.4. Shear Stress Diversity

The relationship between shear stress diversity and rearing-habitat area was only evaluated at the Lewiston Cableway-A site, which was selected for this analysis based on the availability of post-construction rearing-habitat data at a high stream flow and a calibrated 2-D hydraulic model capable of calculating shear stress values.

A 2-D hydraulic model was developed and calibrated in MD_SWMS (ver. 2.3.12b) for post-construction conditions at the Lewiston Cableway channel rehabilitation site. The topographic data used in the model included a combination of photogrammetry, LiDAR, and Total Station survey data (Hoopa Valley Tribe unpublished data and TRRP unpublished data). Total Station bathymetric survey data were collected in the winter of 2008/2009. The hydraulic model calculated shear stress fields at 2-m (6-ft) grid intervals within main channel areas, excluding the area of the side channel, at a flow rate of 57.2 cms (2,020 cfs; Figure 10–6).

The study area was divided into 50-m (164-ft) stream segments for analyses as applied in the topographic diversity assessment described above (Section 10.2.3). The shear stress diversity of each stream segment was calculated as the standard deviation of shear stress values across 2-m (6-ft) bins. Shear stress diversity was compared to total fry and presmolt rearing-habitat area, limited to main channel areas at a streamflow of 57.2 cms (2,020 cfs), the same as the modeled streamflows. The relationship between habitat (dependent variable) and shear stress diversity (independent variable) was evaluated using linear regression.

10.2.5. Length Of Wetted Edge

The relationship between the length of wetted edge and rearing-habitat area was evaluated at six channel rehabilitation sites. Pre-construction conditions were evaluated at six sites (Sven Olbertson, Lewiston Cableway, Hoadley Gulch, Bucktail/Dark Gulch, Lowden Meadows, and Reading Creek) and post-construction conditions at four sites (Sven Olbertson, Lewiston Cableway, Hoadley Gulch, and Bucktail/Dark Gulch). These sites were selected based on the availability of rearing-habitat data at a comparable streamflow.

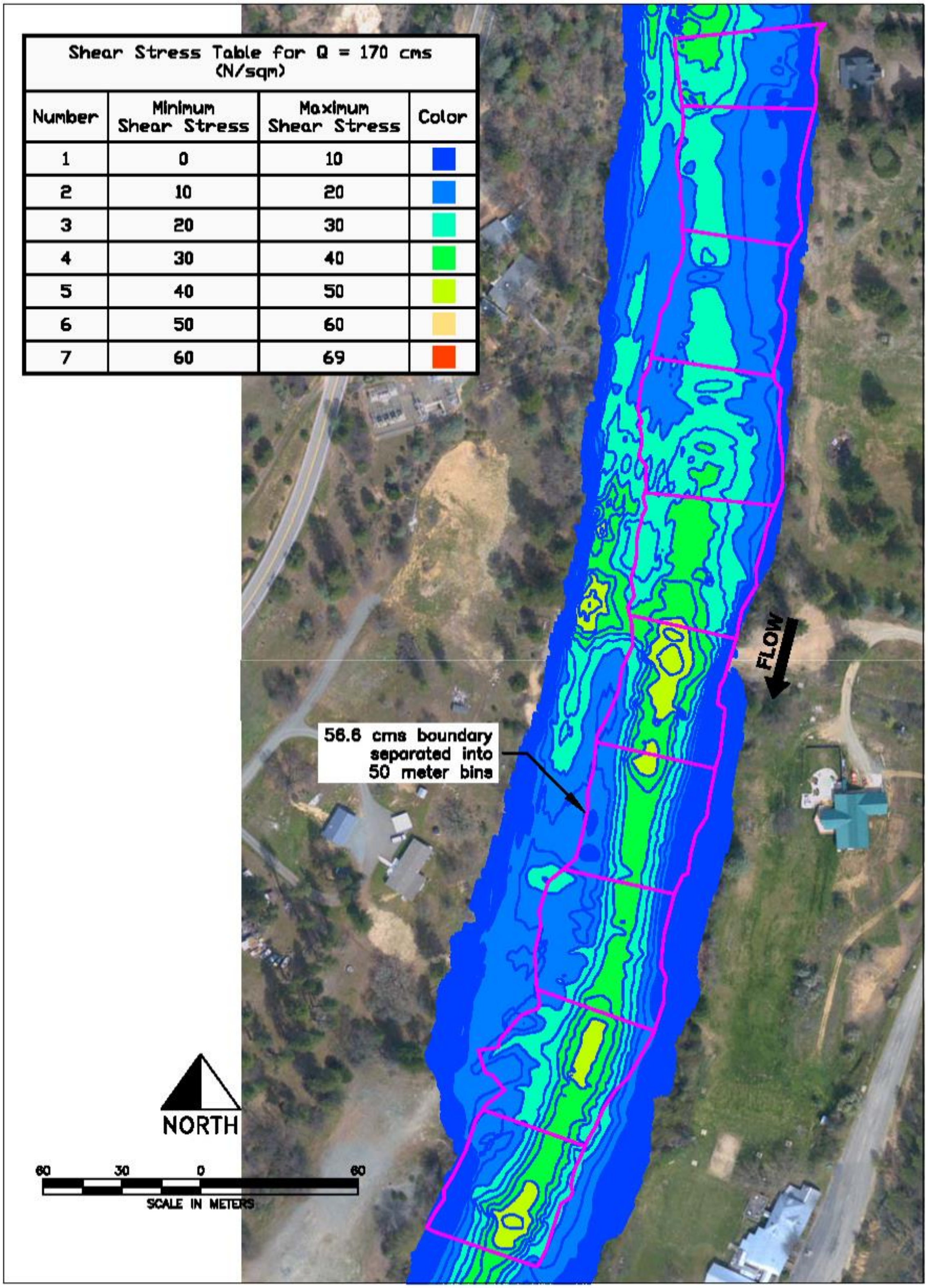


Figure 10–6. Lewiston Cableway channel rehabilitation site illustrating the measurement area (i.e., 57-cms [2,000-cfs] lateral boundary and 50-m [164-ft] channel lengths) and calculated 170-cms (6,000-cfs) shear stress fields.

The amount of rearing habitat and the length of wetted edge was measured during the site-specific habitat assessment (see Chapter 4 for methods) coinciding with an 8.5-cms (300-cfs) release from Lewiston Dam. The length of wetted edge was measured as part of the rearing-habitat survey protocol. Total habitat values and wetted edge lengths were converted to densities by dividing total habitat area or the wetted edge length by the 142-cms (5,000-cfs) mainstem centerline length from 2006, so that values were comparable across sites. Unlike other integration analyses, this analysis included side-channel habitat area and side-channel wetted edge length. The relationship between rearing-habitat density (dependent variable) and relative length of wetted edge (independent variable) was evaluated using linear regression.

10.2.6. Area of Exposed Active Alluvial Deposits

The relationship between exposed active alluvial deposits (exposed bars) and rearing habitat before and following channel rehabilitation was evaluated at four bars at the Lewiston Cableway channel rehabilitation site and one bar at the Bucktail–Dark Gulch channel rehabilitation site. These locations were selected based on the presence of exposed bars and the availability of rearing-habitat data collected at multiple streamflows.

Exposed bars were identified as areas of open gravel that lacked extensive riparian vegetation using 2009 ortho-rectified aerial photography (TRRP unpublished data). The planform of each bar was then defined as the area between the 8.5- and 52.7-cms (300- and 1,861 cfs) water surface boundaries (pre-construction) or between the 8.5- and 57.2-cms (300- and 2,020-cfs) boundaries (post-construction) (Figure 10–7). The 8.5-cms (300-cfs) habitat boundary was identified during topographic surveys at all exposed bars. The 52.7- and 57.2-cms (1,861- and 2,020-cfs) bar boundaries were measured as the wetted edges during the pre- and post-construction rearing-habitat surveys, respectively.

Pre- and post-construction habitat data collected for the site-specific habitat assessment (see Chapter 4 for methods) were used to estimate total fry and presmolt rearing-habitat area within each section of the river associated with the exposed bars. To account for the influence a bar feature has on habitat, not only adjacent to the bar but also upstream and downstream, habitat areas were calculated within the mainstem portion of the channel and in a buffer area extending 15 m (50 ft) above and below the bar feature. The total habitat and exposed bar areas were converted to densities by dividing them by the length along the 142-cms (5,000-cfs) mainstem centerline from 2006 to scale the data for different sized bars. Fry and presmolt habitat density for pre- and post-construction conditions at low flow (8.5 cms), medium flow (~20 cms) and high flow (52.7 cms for pre-construction and 57.2 cms for post-construction) were compared to the density of exposed alluvial bar surface. The relationship between habitat density (dependent variable) and bar area density (independent variable) was evaluated using linear regression.

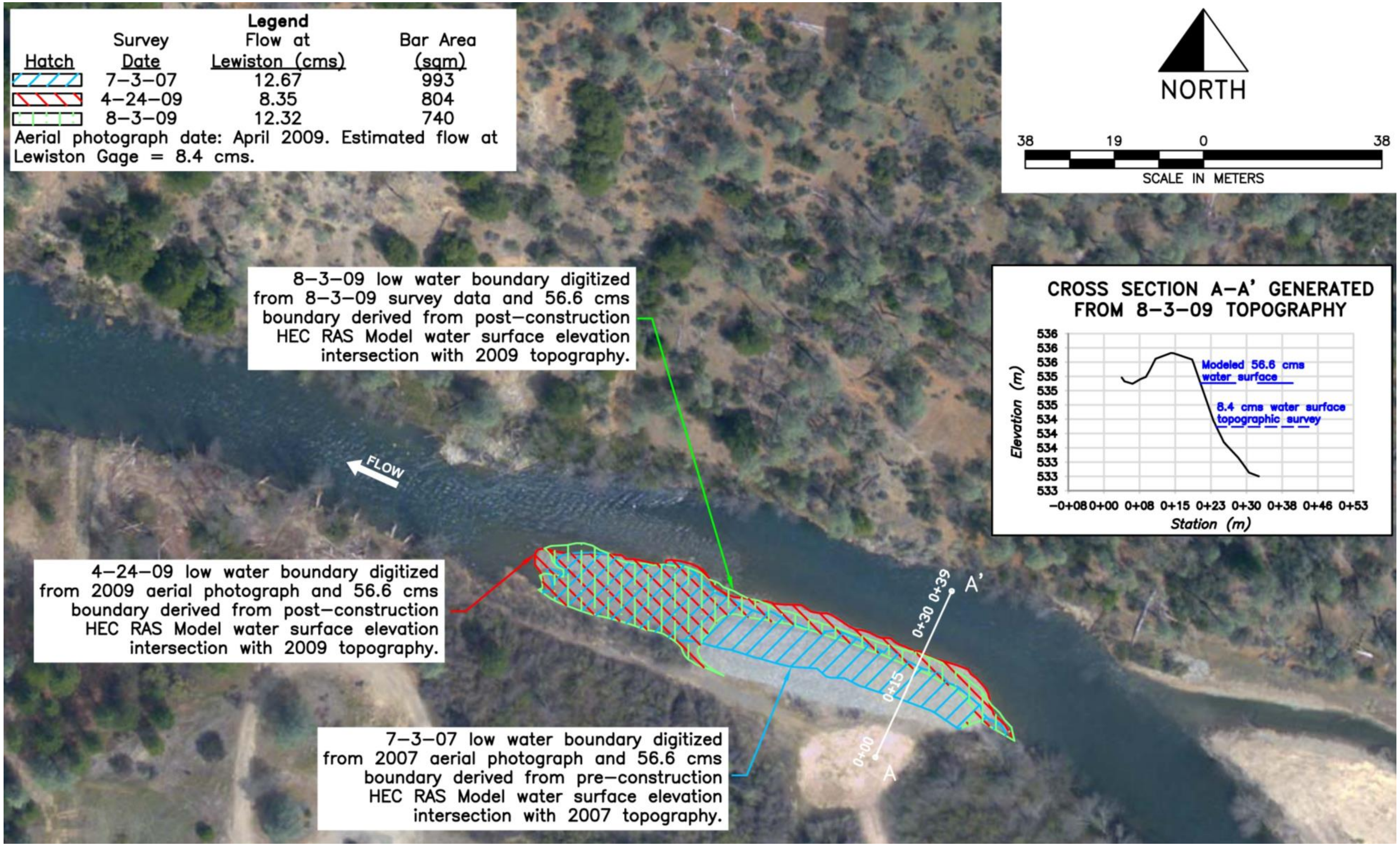


Figure 10–7. Dark Gulch/Bucktail channel rehabilitation site illustrating how exposed bar area was measured using pre- and post-construction topography, channel bathymetry, and water surfaces generated from a one-dimensional HEC-RAS model.

10.3. Results

10.3.1. Radius Of Curvature

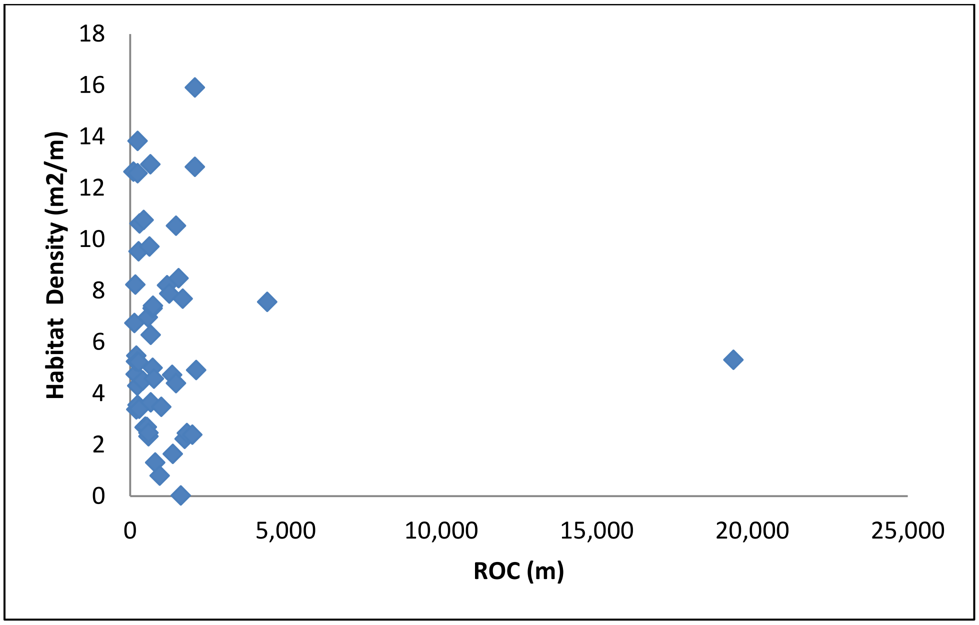
A total of 52 pre-construction and 55 post-construction habitat and ROC data pairs were generated. ROC ranged from 108 to 19,399 m (354–63,645 ft) for pre-construction conditions and from 137 to 29,138 m (449–95,597 ft) for post-construction conditions.

Fry habitat density ranged from 0.02 to 15.9 m^2/m (0.07–52.2 ft^2/ft) for pre-construction conditions and from 0.4 to 29.4 m^2/m (1.3–96.5 ft^2/ft) for post-construction conditions. Data were widely scattered with no obvious relationship between fry habitat density and ROC for pre-construction conditions (r^2=0.03, F=1.39, p=0.244; Table 10–1; Figure 10–8). Three of the ROC values (>7,500 m or 24,600 ft) were substantially greater than all the other ROC values, and the dataset was re-analyzed without these data. Excluding the data with the larger ROC values did not greatly improve the relationship (r^2=0.04, F=1.99, p=0.165; Table 10–2). For the post-construction conditions, habitat density was highly variable at the lowest values and decreased at higher ROC values, with a weak but significant relationship (r^2=0.10, F=5.991, p=0.018; Figure 10–9). Excluding the data with the largest ROC values (>7,500 m or 24,600 ft), the relationship was also significant, although still very weak (r^2=0.08, F=4.370, p=0.042). A comparison of pre- and post-construction habitat density and ROC data shows similar variation in habitat density up to ROCs of approximately 1,500 m (4,900 ft), although two post-construction data points have the highest habitat density at the lower range of ROC values (Figure 10–10).

Table 10–1. Regression Statistics for the Relationship Between Natural Log Transformed Habitat Data and Natural Log Transformed Radius of Curvature Data for Pre- and Post-Construction Conditions

Life Stage	Habitat Data Type[1]	Site Condition	r^2	*F*-value	*p*
Fry	All Habitat	Pre-construction	0.03	1.391	0.244
		Post-construction	0.10	5.991	0.018
	Only D/V/C Habitat	Pre-construction	0.02	0.935	0.338
		Post-construction	0.08	4.755	0.034
Presmolt	All Habitat	Pre-construction	0.02	1.114	0.296
		Post-construction	0.12	6.864	0.011
	Only D/V/C Habitat	Pre-construction	0.02	0.792	0.378
		Post-construction	0.10	6.161	0.016

[1] All habitat is the sum of areas that meet depth, velocity, and cover criteria, individually or in combination. D/V/C habitat is the area of habitat that meets depth/velocity or depth/velocity/cover criteria.



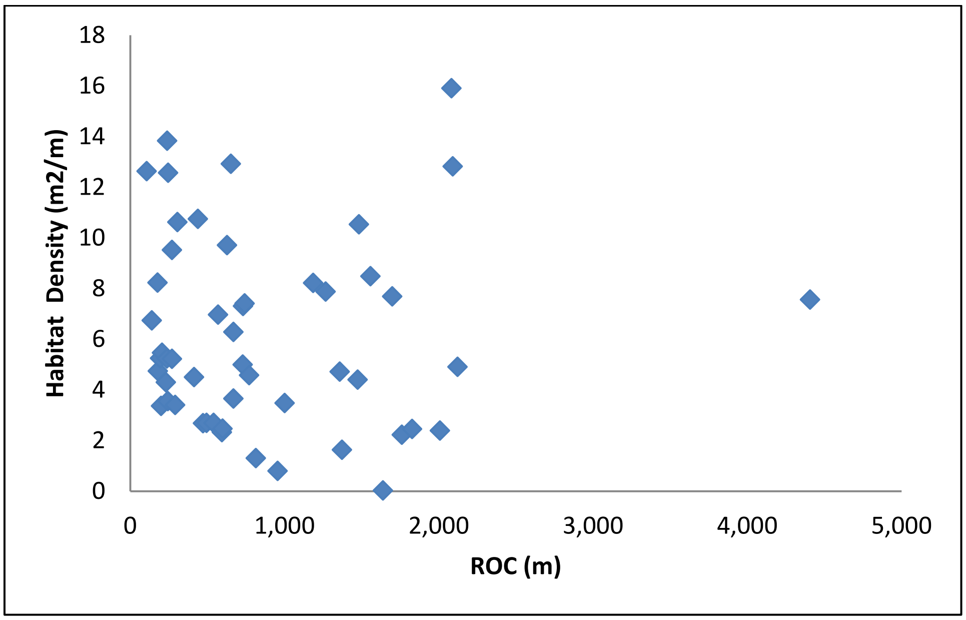
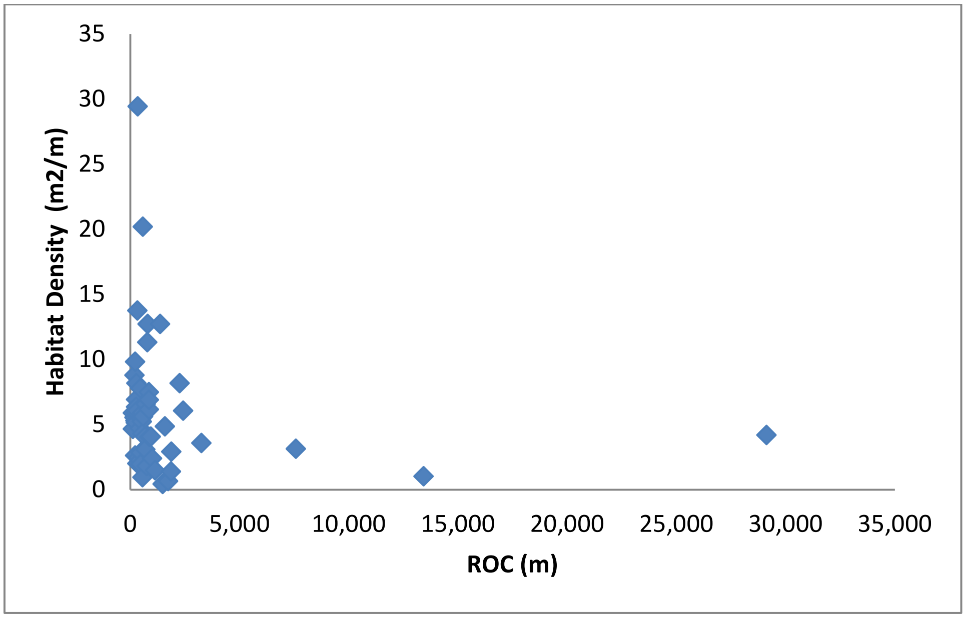


Figure 10–8. Pre-construction fry habitat density vs. radius of curvature (ROC) with all data (upper graph) and excluding the data point with ROC = 19,399 m (lower graph) to better show the scatter of the data at lower range of the ROC values.



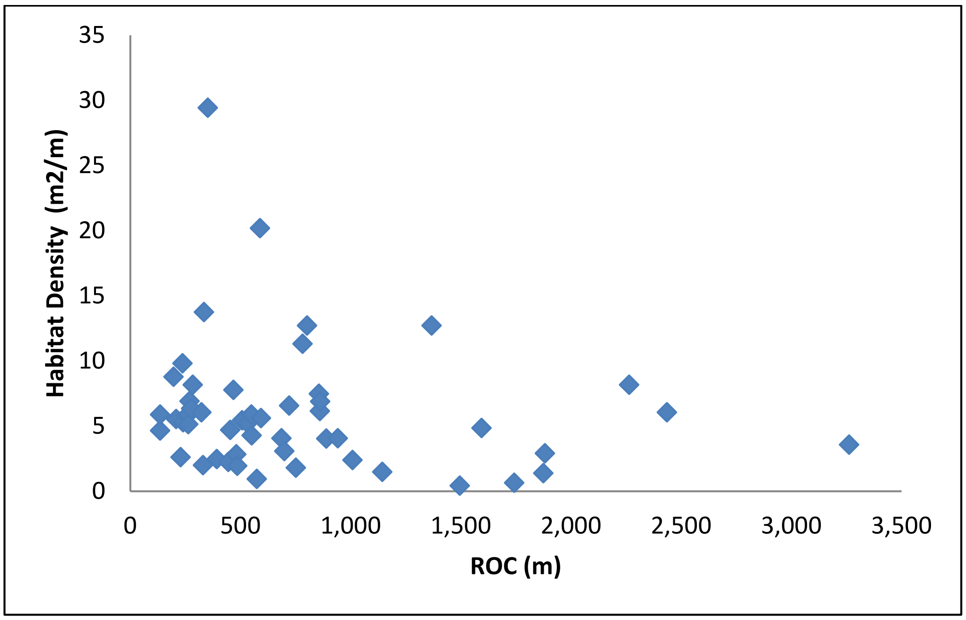


Figure 10–9. Post-construction fry habitat density vs. radius of curvature (ROC) with all data (upper graph) and excluding ROC values above 7,500 m (lower graph) to better show the scatter of the data at lower range of the ROC values.

Table 10–2. Revised Regression Statistics for the Relationship Between Natural Log Transformed Habitat Data and Natural Log Transformed Radius of Curvature Data for Pre- and Post-Construction Conditions (excluding ROC values >7,500 m)

Life Stage	Habitat Data Type[1]	Site Condition	r^2	*F*-value	*p*
Fry	All Habitat	Pre-construction	0.04	1.990	0.165
		Post-construction	0.08	4.370	0.042
	Only D/V/C Habitat	Pre-construction	0.03	1.465	0.232
		Post-construction	0.07	3.988	0.051
Presmolt	All Habitat	Pre-construction	0.02	1.228	0.273
		Post-construction	0.08	4.257	0.044
	Only D/V/C Habitat	Pre-construction	0.02	0.843	0.363
		Post-construction	0.08	4.062	0.049

[1] All habitat is the sum of areas that meet depth, velocity, and cover criteria, individually or in combination. D/V/C habitat is the area of habitat that meets depth/velocity or depth/velocity/cover criteria.

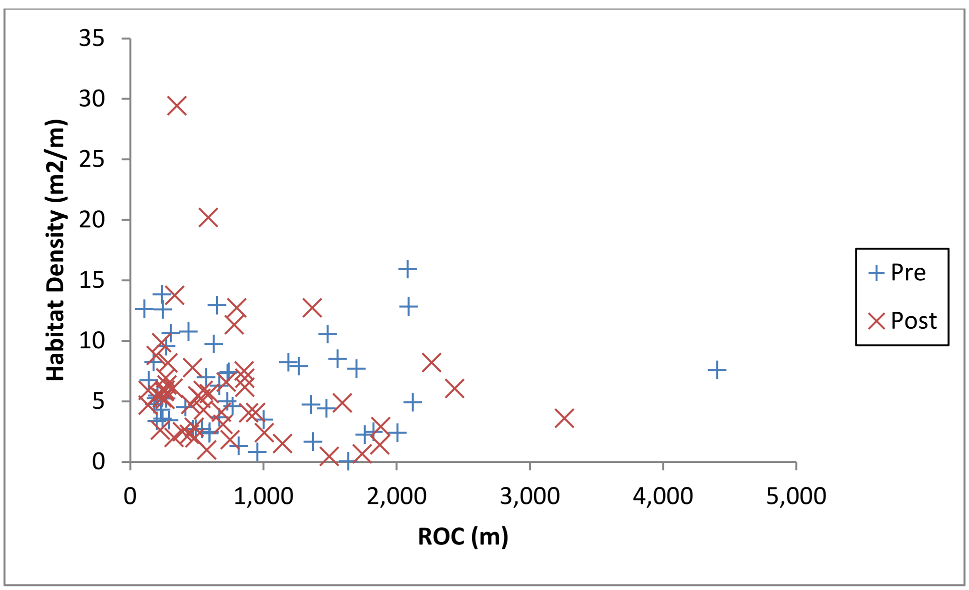
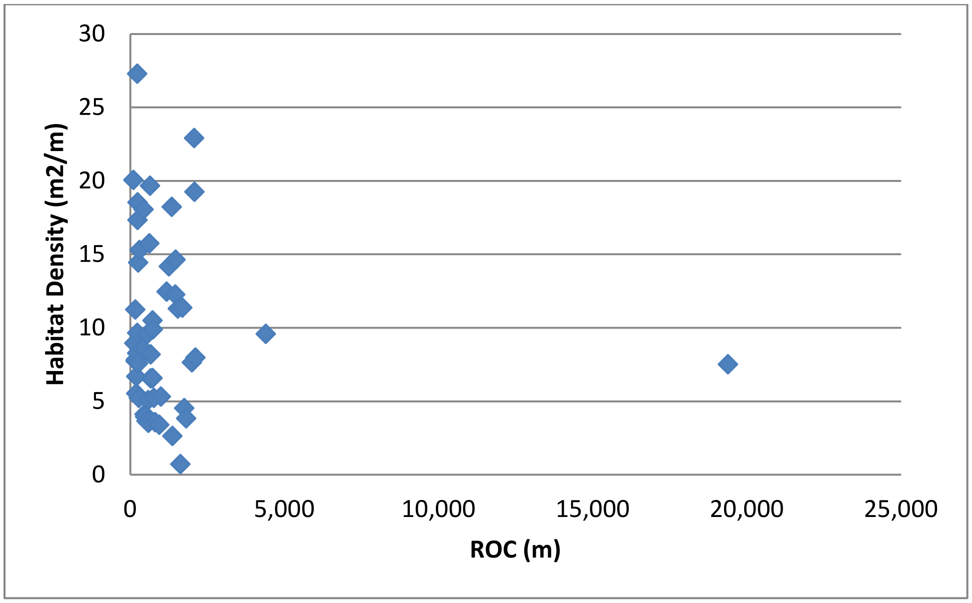


Figure 10–10. Pre- and post-construction fry habitat density vs. radius of curvature (ROC) excluding ROC values above 7,500 m to better show the scatter of the data at lower range of the ROC values.



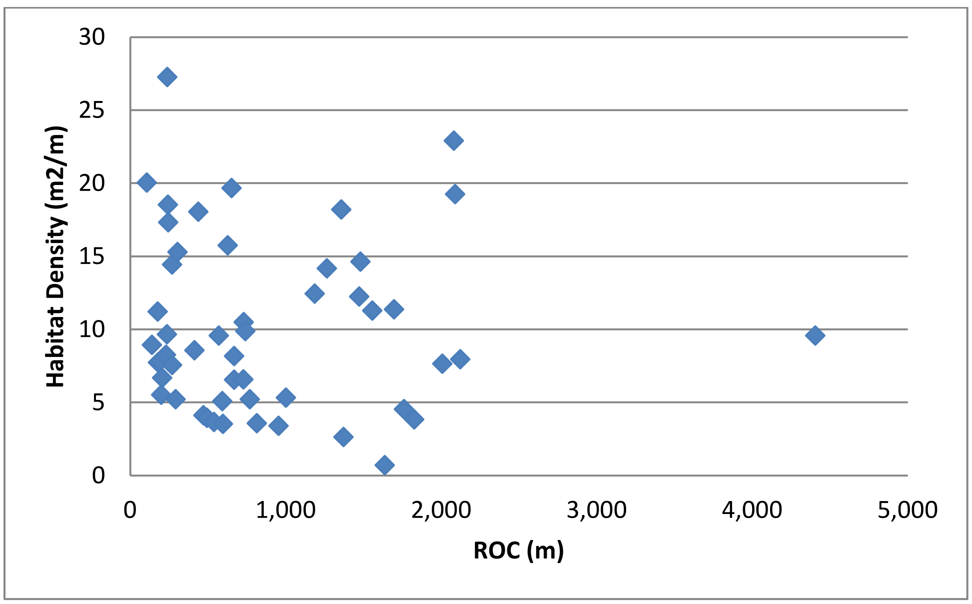


Figure 10–11. Pre-construction presmolt habitat density vs. radius of curvature (ROC) with all data (upper graph) and excluding the data point with ROC 19,399 m (lower graph) to better show the scatter of the data at lower range of the ROC values.

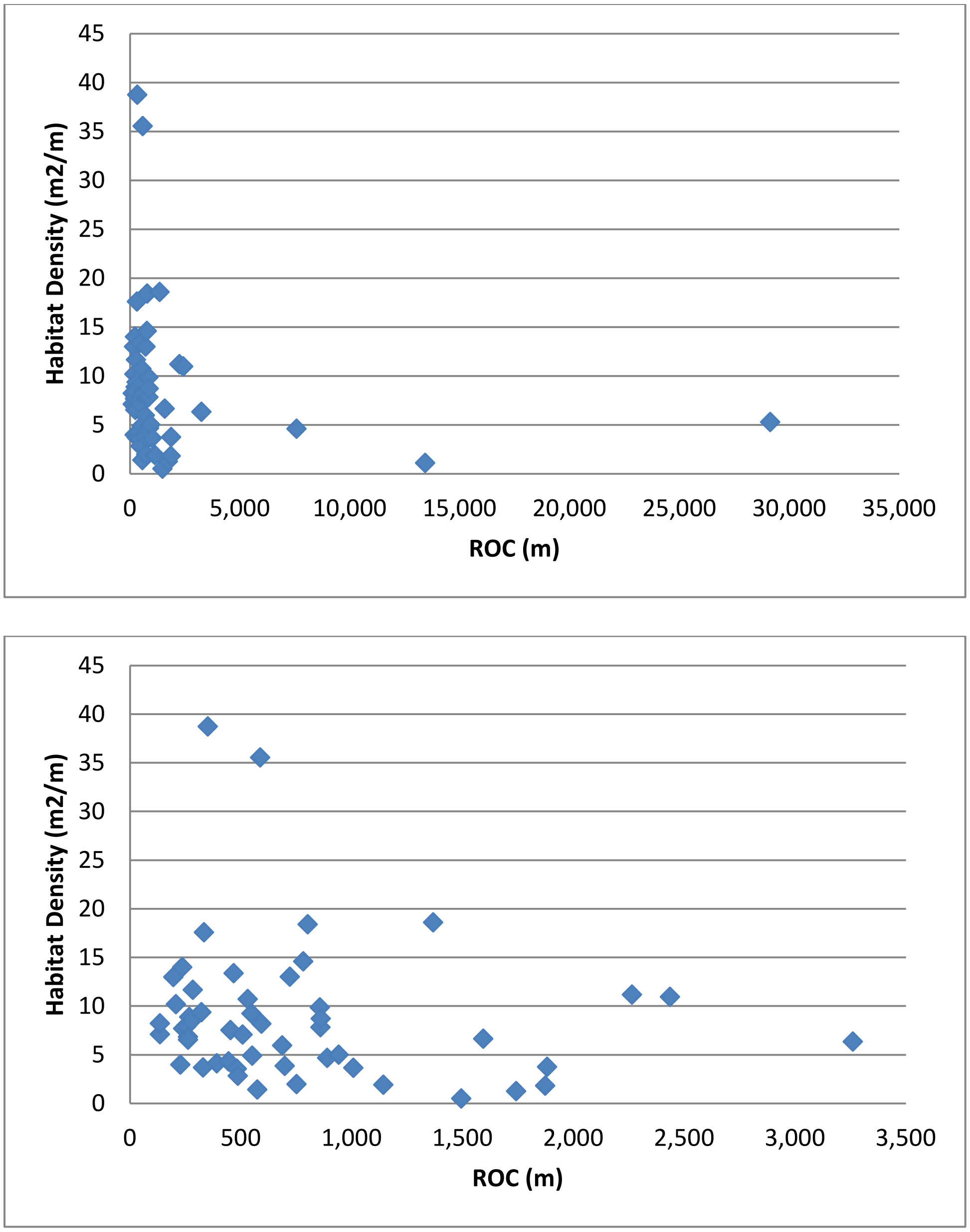


Figure 10–12. Post-construction presmolt habitat density vs. radius of curvature (ROC) with all data (upper graph) and excluding ROC values above 7,500 m (lower graph) to better show the scatter of the data at lower range of the ROC values.

Presmolt habitat density ranged from 0.7 to 27.3 m^2/m (2.3–89.6 ft^2/ft) for pre-construction conditions and from 0.5 to 38.7 m^2/m (1.6–127 ft^2/ft) for post-construction conditions. Similar to the fry habitat density data, there was no significant relationship between presmolt habitat density and ROC for the pre-construction condition (r^2=0.02, F=1.11, p=0.296; Table 10–1, Figure 10–11). Exclusion of the data from the largest ROC value did not improve the relationship (r^2=0.02, F=1.228, p=0.273; Table 10–2). For post-construction conditions, presmolt habitat density was highly variable at the lowest ROC values and generally decreased as ROC increased (Figure 10–12). There was a weak but significant relationship between presmolt habitat and ROC (r^2=0.12, F=6.86, p=0.011). While still significant, exclusion of data with an ROC above 7,500 m (24,600 ft) slightly weakened the relationship (r^2=0.08, F=4.26, p=0.044). Presmolt habitat density data for pre- and post-construction conditions exhibited similar distributions, although the post-construction data included values with high density at low ROC (Figure 10–13).

Habitat density data based only on habitat areas that met depth/velocity or depth/velocity/cover criteria but no other cover criteria exhibited similar patterns in the distribution of data in relation to ROC (Figure 10–14). The strengths and statistical significance of the relationships between these data and ROC were similar to those that utilized all habitat data categories summed (Tables 10–1 and 10–2). Only a minor difference in the significance of the relationships was found for the post-construction fry habitat density data between the “All Habitat” (r^2=0.08, F=4.370, p=0.042) and the “Only D/V/C Habitat” (r^2=0.07, F=3.988, p=0.051).

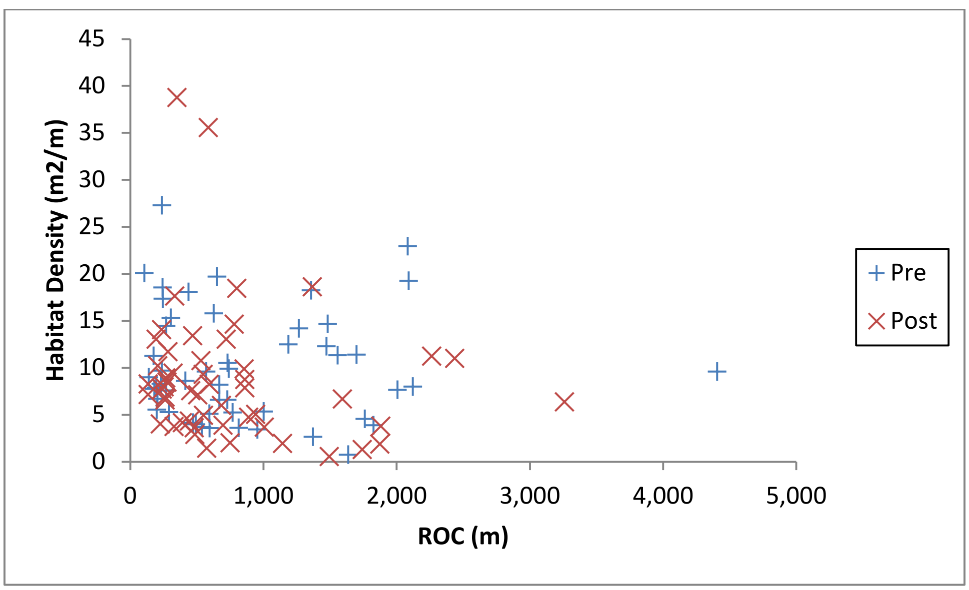


Figure 10–13. Pre- and post-construction presmolt habitat density vs. radius of curvature (ROC) excluding ROC values above 7,500 m to better show the scatter of the data at lower range of the ROC values.

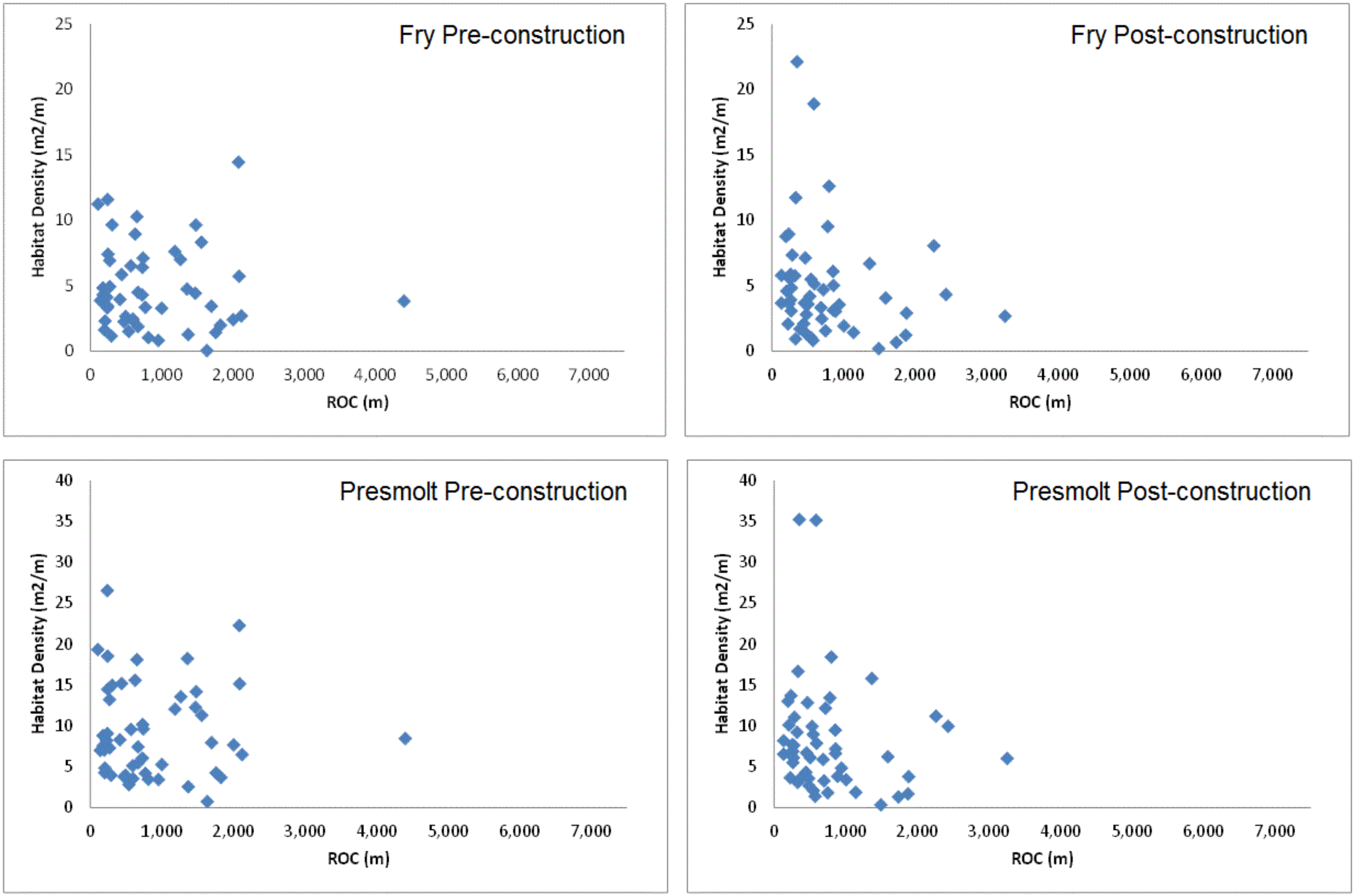


Figure 10–14. Pre- and post-construction fry and presmolt habitat density (only D/V and D/V/C habitat) vs. radius of curvature (ROC), excluding ROC values above 7,500 m to better show the scatter of the data at lower range of the ROC values.

10.3.2. Topographic Diversity

10.3.2.1. Channelbed Distances Below the Water Surface Plane

Topographic diversity values based on the standard deviation of the distances from the channelbed to the water surface ranged from 0.15 to 0.36 m (0.5–1.2 ft) for the low flow level (8.5 cms or 300 cfs) and from 0.36 to 0.92 m (1.2–3.0 ft) for the high flow level (~56.6 cms or 2,000 cfs) (Figures 10–15 and 10–16; Table 10–3). None of the relationships between topographic diversity and habitat were significant (Table 10–4). While there were no significant relationships, there was an increasing trend of both fry and presmolt habitat with increasing topographic diversity for both pre- and post-construction at the high flow level.

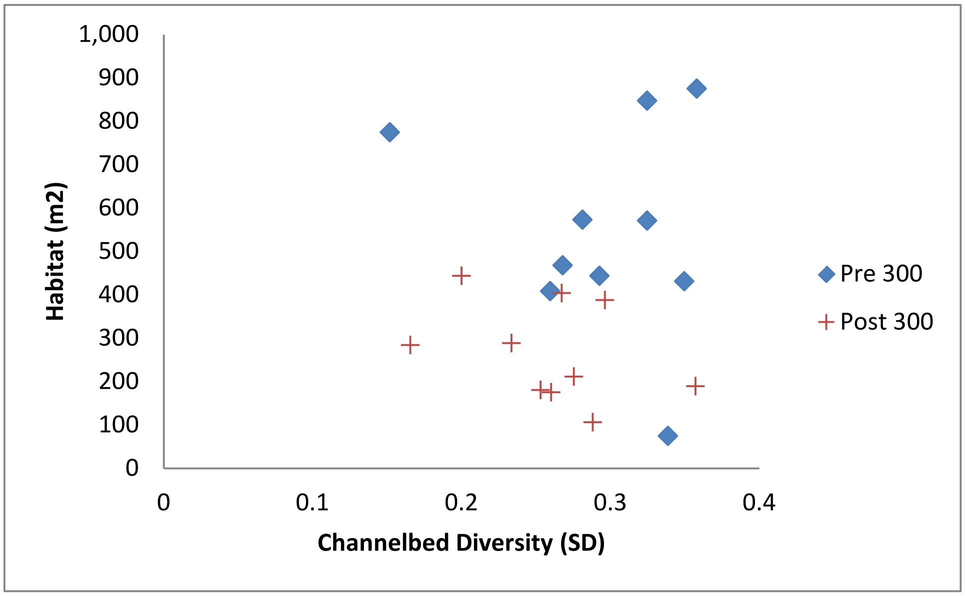
10.3.2.2. Channelbed Surface Area to Water Surface Area Ratio

Total fry habitat for the ten 50-m (164-ft) sections ranged from 226 to 1,664 m^2 (2,433–17,911 ft^2) for the pre-construction condition and from 242 to 1,032 m^2 (2,605–11,108 ft^2) for the post-construction condition (Table 10–5). Total presmolt habitat for the ten 50-m sections ranged from 230 to 1,725 m^2 (2,476–18,568 ft^2) for the pre-construction condition and from 242 to 1,033 m^2 (2,605–11,119 ft^2) for the post-construction condition. The ratio of channelbed surface area to water surface area for the ten 50-m segments ranged from 1.00 to 1.02 for the pre-construction condition and from 1.01 to 1.03 for the post-construction condition.

For the pre-construction condition, this ratio did not have a significant relationship to either the fry habitat (r^2=0.11, F=0.991, p=0.349) or the presmolt habitat (r^2=0.12, F=1.067, p=0.332) (Table 10–6; Figures 10–17 and 10–18, respectively). For the post-construction condition, this ratio had a negative relationship with both the fry and presmolt rearing habitats, with habitat decreasing as the ratio increased (Figures 10–17 and 10–18, respectively). The relationships were significant with both the fry habitat (r^2=0.80, F=32.849, p<0.001) and the presmolt habitat (r^2=0.79, F=29.275, p=0.001) (Table 10–6).

10.3.3. Shear Stress Diversity

Both total fry habitat and total presmolt habitat for the ten 50-m sections ranged from 242 to 1,033 m^2 (2,605–11,119 ft^2) (Table 10–7). Shear stress diversity, as measured by the standard deviation of shear stress estimates for each 50-m segment ranged from 3.3 to 18.9. There were no significant relationships between shear stress diversity and either fry habitat (r^2<0.001, F=0.002, p=0.964) or presmolt habitat (r^2<0.001, F=0.001, p=0.975) (Table 10–8, Figure 10–19).



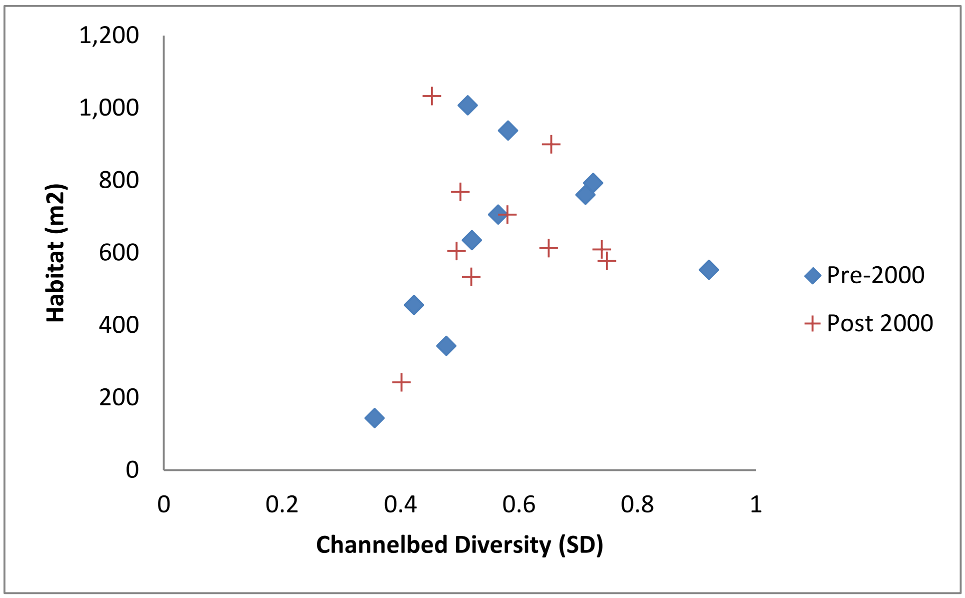
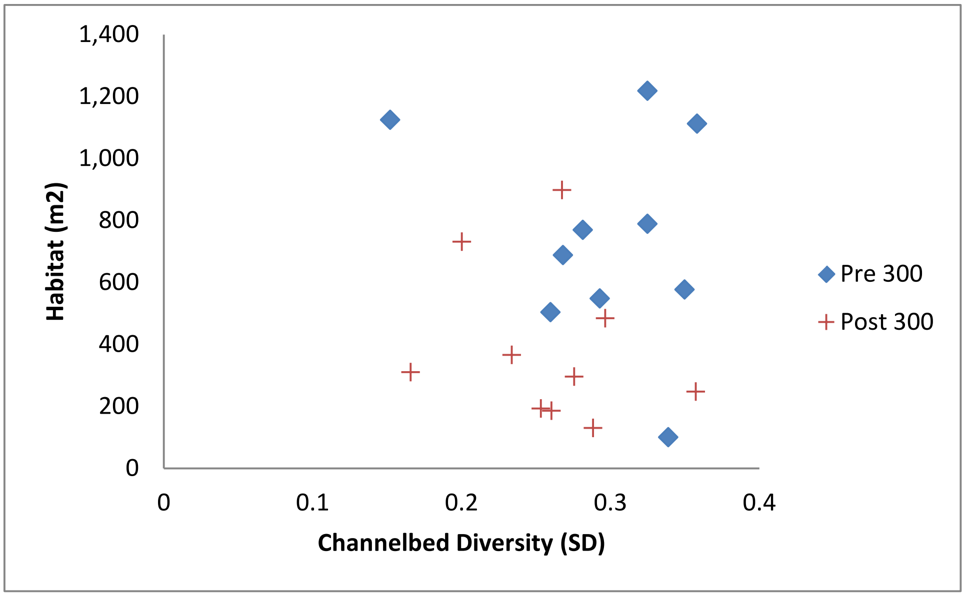


Figure 10–15. Pre- and post-construction fry habitat vs. channelbed diversity based on the standard deviation of distances between the channelbed and water surface at low flow (8.5 cms or 300 cfs, upper graph) and high flow (57 cms or 2,000 cfs, lower graph) conditions.



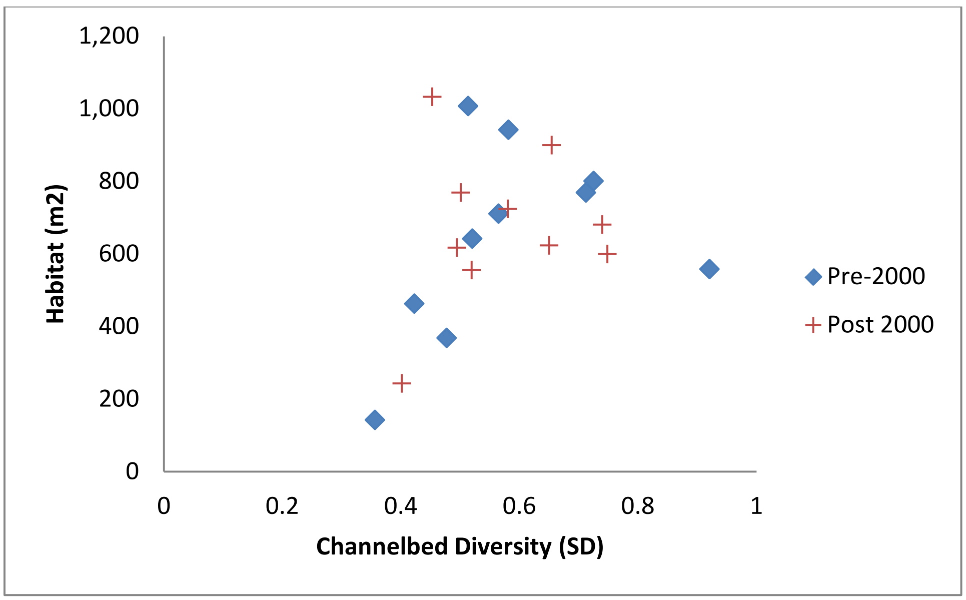


Figure 10–16. Pre- and post-construction presmolt habitat vs. channelbed diversity based on the standard deviation of distances between the channelbed and water surface at low flow (8.5 cms or 300 cfs, upper graph) and high flow (57 cms or 2,000 cfs, lower graph) conditions.

Table 10–3. Minimum and Maximum Values for Fry and Presmolt Habitat (m^2) and Topographic Diversity as Defined as the Standard Deviation of the Distance Between Water Surface Elevation and Channelbed Surface at Low and High Flow Conditions

Life Stage	Flow Level[1]	Site Condition	Diversity		Habitat	
			Min	Max	Min	Max
Fry	Low	Pre-construction	0.15	0.36	75	875
		Post-construction	0.17	0.36	106	443
	High	Pre-construction	0.36	0.92	143	1,007
		Post-construction	0.40	0.75	242	1,032
Presmolt	Low	Pre-construction	0.15	0.36	100	1,218
		Post-construction	0.17	0.36	130	898
	High	Pre-construction	0.36	0.92	142	1,007
		Post-construction	0.40	0.75	242	1,033

[1] Flow Level: Low flow level is approximately 8.5 cms (300 cfs), and high flow level is approximately 57 cms (2,000 cfs).

Table 10–4. Regression Statistics for the Relationships Between Fry and Presmolt Habitat and Topographic Diversity as Defined as the Standard Deviation of the Distance Between Water Surface Elevation and Channelbed Surface at Low and High Flow Conditions

Life Stage	Flow Level[1]	Site Condition	r^2	*F*-value	*p*
Fry	Low	Pre-construction	0.03	0.235	0.641
		Post-construction	0.13	1.236	0.299
	High	Pre-construction	0.15	1.406	0.270
		Post-construction	0.01	0.082	0.782
Presmolt	Low	Pre-construction	0.05	0.448	0.522
		Post-construction	0.05	0.414	0.538
	High	Pre-construction	0.15	1.431	0.266
		Post-construction	0.03	0.224	0.649

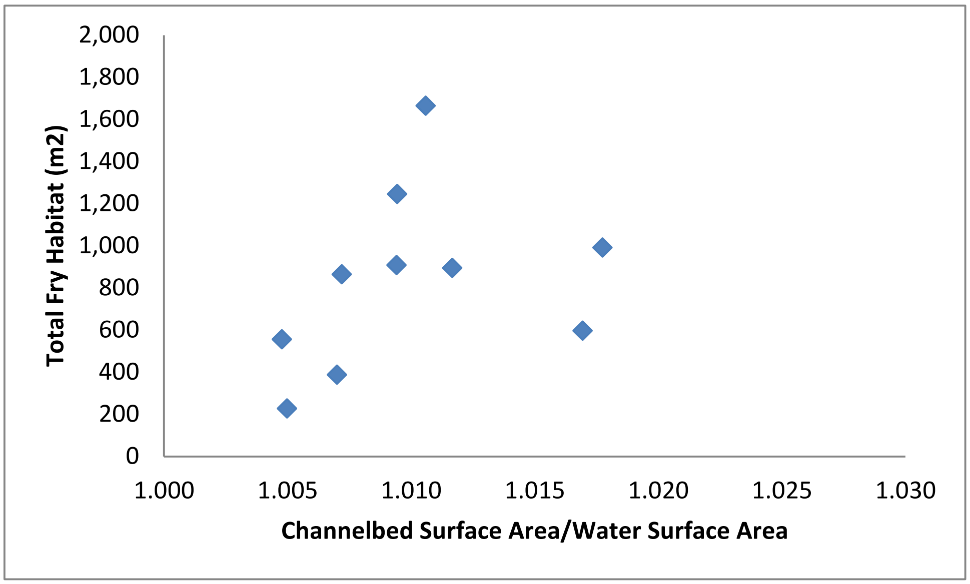
[1] Flow Level: Low flow level is approximately 8.5 cms (300 cfs), and high flow level is approximately 57 cms (2,000 cfs).

Table 10–5. Estimates of Pre- and Post-Construction Fry and Presmolt Habitat (m^2) and the Ratio of Channelbed Surface Area to Water Surface Area

Polygon	Ratio		Fry Habitat		Presmolt Habitat	
	Pre	Post	Pre	Post	Pre	Post
1	1.02	1.02	596	609	641	680
2	1.01	1.02	863	612	934	623
3	1.01	1.02	908	578	1,020	599
4	1.01	1.01	1,244	899	1,302	899
5	1.01	1.02	895	706	942	723
6	1.02	1.01	991	768	1,081	768
7	1.01	1.01	1,664	1,032	1,725	1,033
8	1.00	1.01	556	533	601	555
9	1.01	1.01	387	605	471	617
10	1.01	1.03	226	242	230	242
Min	1.00	1.01	226	242	230	242
Max	1.02	1.03	1,664	1,032	1,725	1,033

Table 10–6. Regression Statistics for the Relationship Between Fry and Juvenile Habitat and the Ratio of Channelbed Surface to Water Surface for Pre- and Post-Construction Conditions

Life Stage	Site Condition	r^2	*F*-value	*p*
Fry	Pre-construction	0.11	0.991	0.349
	Post-construction	0.80	32.849	<0.001
Presmolt	Pre-construction	0.12	1.067	0.332
	Post-construction	0.79	29.275	0.001



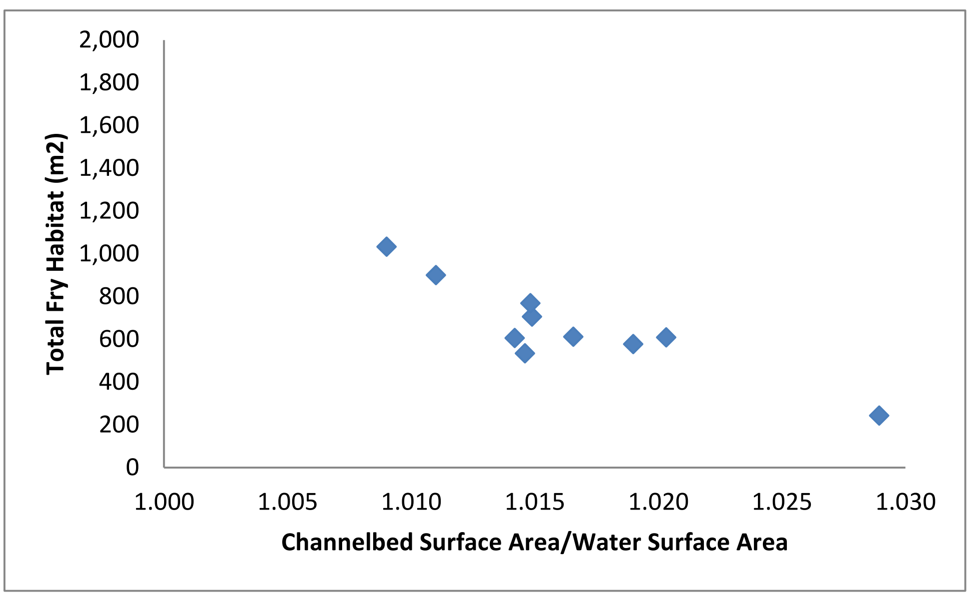
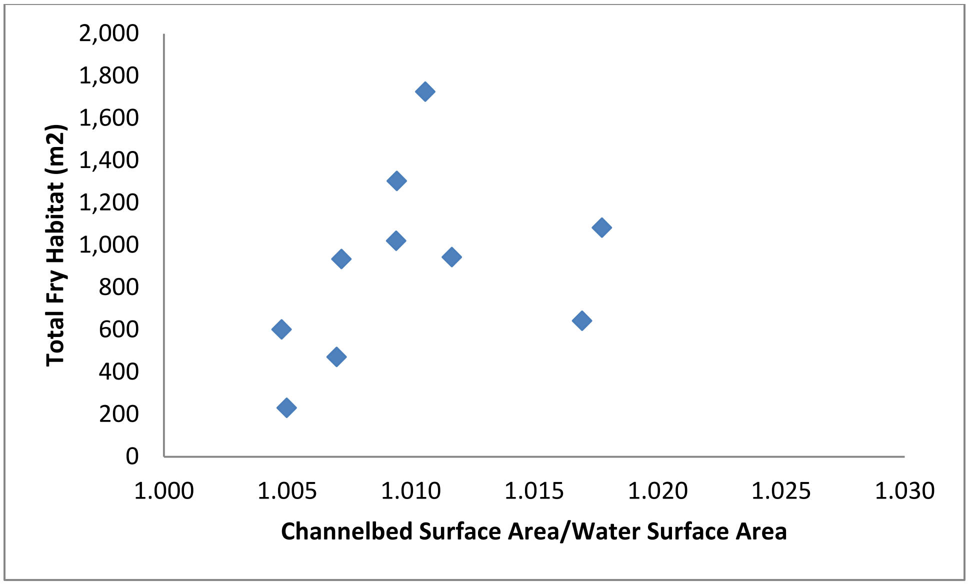


Figure 10–17. Total fry habitat per 50-m (164-ft) segment vs. ratio of channelbed surface area/water surface area for pre-construction (upper graph) and post-construction (lower graph) conditions.



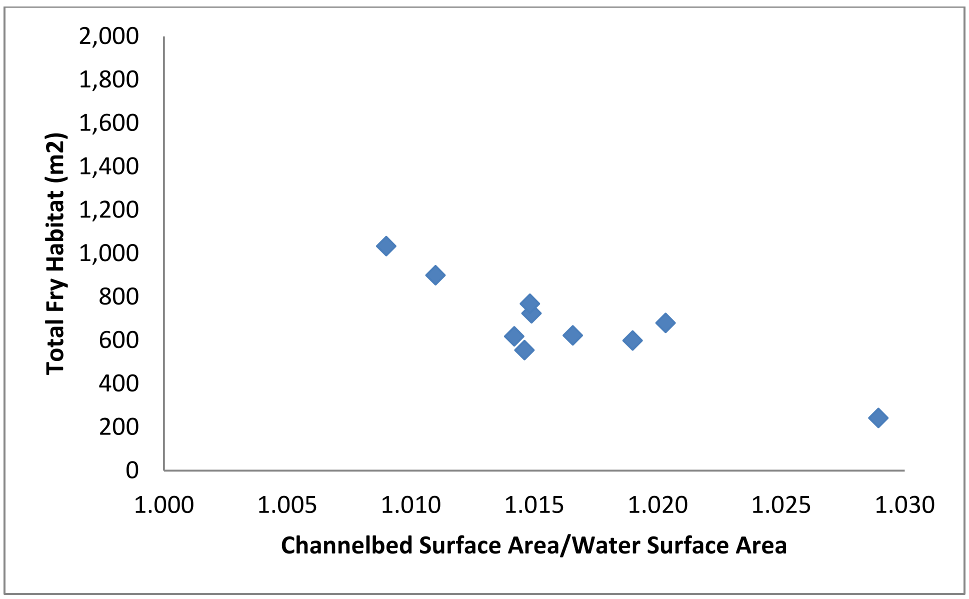


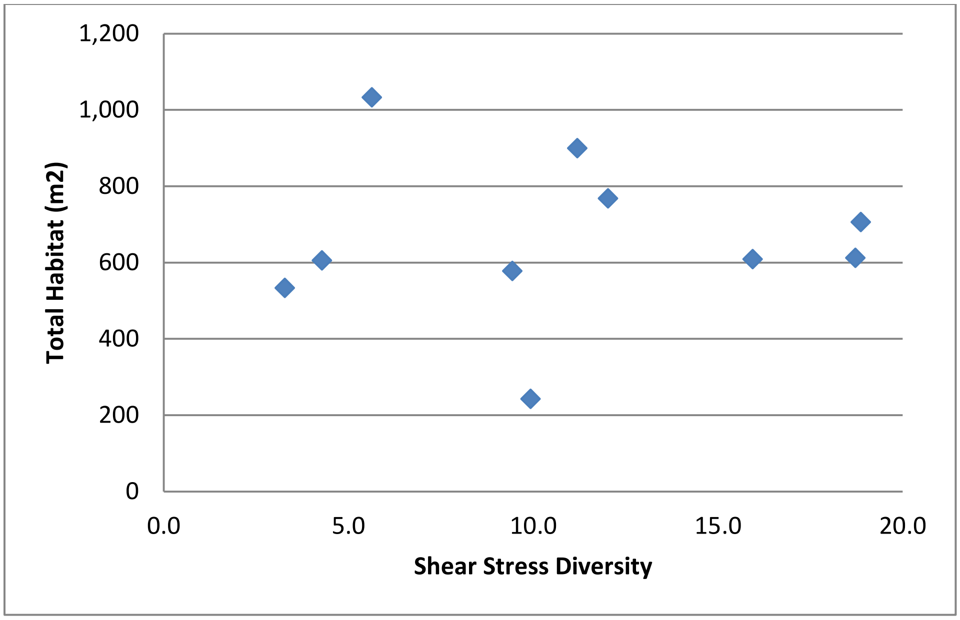
Figure 10–18. Total presmolt habitat per 50-m (164-ft) segment vs. ratio of channelbed surface area/water surface area for pre-construction (upper graph) and post-construction (lower graph) conditions.

Table 10–7. Estimates of Fry and Presmolt Habitat (m^2) and the Standard Deviation of Shear Stress Diversity (SSD) at Lewiston Cableway-A Site, Post-Construction, at a flow rate of 57.2 cms (2,020 cfs)

Section	SSD	Fry Habitat	Presmolt Habitat
Polygon 1	15.9	609	680
Polygon 2	18.7	612	623
Polygon 3	9.4	578	599
Polygon 4	11.2	899	899
Polygon 5	18.9	706	723
Polygon 6	12.0	768	768
Polygon 7	5.6	1,032	1,033
Polygon 8	3.3	533	555
Polygon 9	4.3	605	617
Polygon 10	9.9	242	242
Minimum	3.3	242	242
Maximum	18.9	1,032	1,033

Table 10–8. Regression Statistics for the Relationship Between Fry and Presmolt Habitat and Shear Stress Diversity at Lewiston Cableway-A site, Post-Construction

Life Stage	r^2	*F*-value	*p*
Fry	<0.01	0.002	0.964
Presmolt	<0.01	0.001	0.975



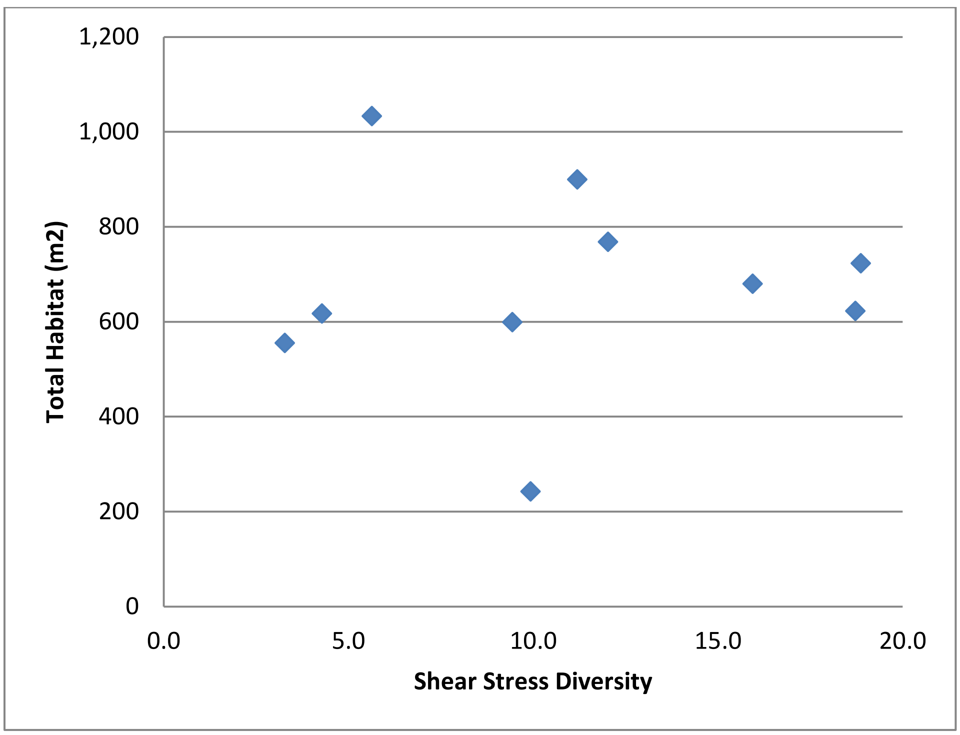


Figure 10–19. Total fry habitat per 50-m (164-ft) segment vs. shear stress diversity for fry habitat (upper graph) and presmolt habitat (lower graph).

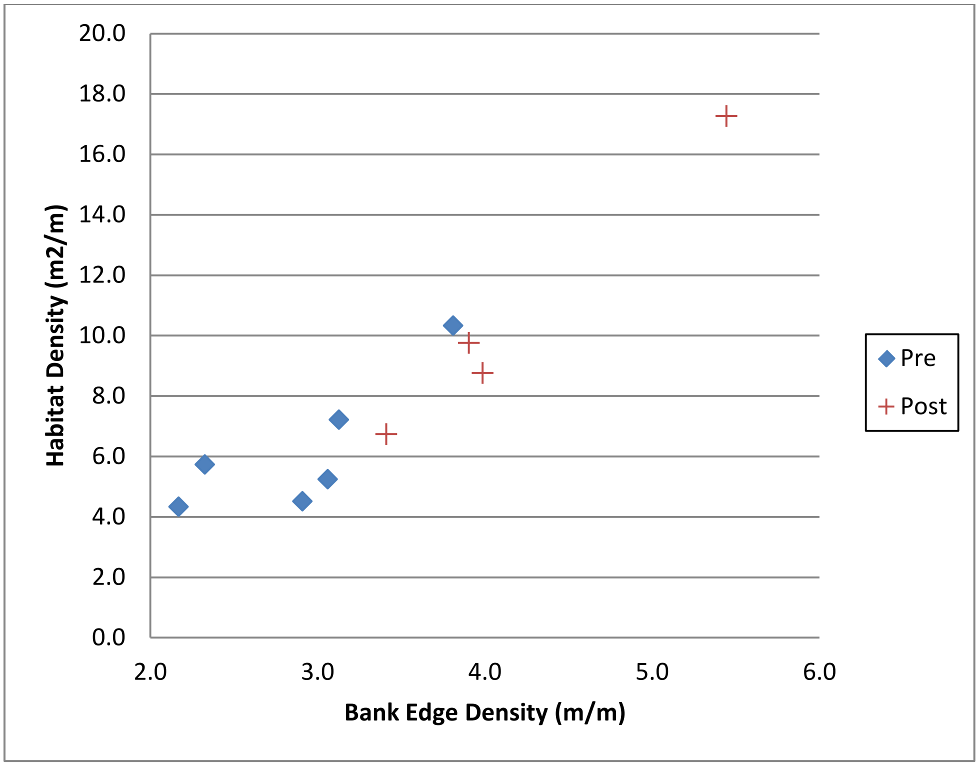
10.3.4. Length of Wetted Edge

Fry habitat density ranged from 4.3 to 10.3 m^2/m (14.1–33.8 ft^2/ft) for the pre-construction condition and from 6.7 to 17.3 m^2/m (22.0–56.8 ft^2/ft) for the post-construction condition, while presmolt habitat density data ranged from 6.1 to 14.5 m^2/m (20.0–47.6 ft^2/ft) and from 9.0 to 22.4 m^2/m (29.5–73.5 ft^2/ft) for pre- and post-construction conditions, respectively. The wetted edge length relative to site length ranged from 2.2 to 3.8 m/m (or ft/ft) for the pre-construction condition and from 3.4 to 5.4 for the post-construction condition.

All of the relationships between habitat density and length of wetted edge relative to site length were positive, indicating a direct relationship (Figure 10–20). For pre-construction conditions, the relationship was not significant at a 95-percent level for either fry habitat density (r^2=0.66, F=7.741, p=0.050) or presmolt habitat density (r^2=0.48, F=3.701, p=0.127) (Table 10–9), although the relationship to fry habitat density was significant at the 90-percent significance level. The post-construction relationship of wetted edge to fry habitat density (r^2=0.98, F=117.095, p=0.008) was significant at the 95-percent level, while its relationship to presmolt habitat density (r^2=0.90, F=18.677, p=0.050) was significant at the 90-percent level but not at 95 percent. When pre- and post-construction data were combined, wetted edge had significant relationships to both the fry (r^2=0.88, F=60.750, p<0.001) and presmolt habitat (r^2=0.76, F=25.551, p=0.001).

10.3.5. Area Of Exposed Active Alluvial Deposits

Fry and presmolt habitat data were available to compare at five bar features during low flow conditions and at three bar features during medium and high flow conditions (Table 10–10). At low flow, fry habitat density ranged from 3.3 to 8.9 m^2/m (10.8–29.2 ft^2/ft) for pre-construction and from 5.2 to 8.1 m^2/m (17.1–26.6 ft^2/ft) for post-construction. Presmolt habitat density ranged from 4.1 to 14.7 m^2/m (13.5–48.2 ft^2/ft) and from 4.2 to 12.4 m^2/m (13.8–40.7 ft^2/ft) for pre- and post-construction conditions, respectively, at low flow. At medium flow, fry habitat density ranged from 1.8 to 7.0 m^2/m (5.9–23.0 ft^2/ft) for the pre-construction condition and from 2.5 to 5.0 m^2/m (8.2–16.4 ft^2/ft) for the post-construction. Presmolt habitat density ranged from 4.4 to 5.4 m^2/m (14.4–17.7 ft^2/ft) and from 3.0 to 5.8 m^2/m (9.8–19.0 ft^2/ft) for pre- and post-construction conditions, respectively. At high flow, fry habitat density ranged from 3.8 to 8.8 m^2/m (12.5–28.9 ft^2/ft) and from 10.4 to 16.4 m^2/m (34.1–53.8 ft^2/ft) for pre- and post-construction conditions, respectively. Presmolt habitat density ranged from 9.8 to 15.4 m^2/m (32.2–50.5 ft^2/ft) for pre-construction conditions and from 11.0 to 16.5 m^2/m (36.1–54.1 ft^2/ft) for post-construction conditions.



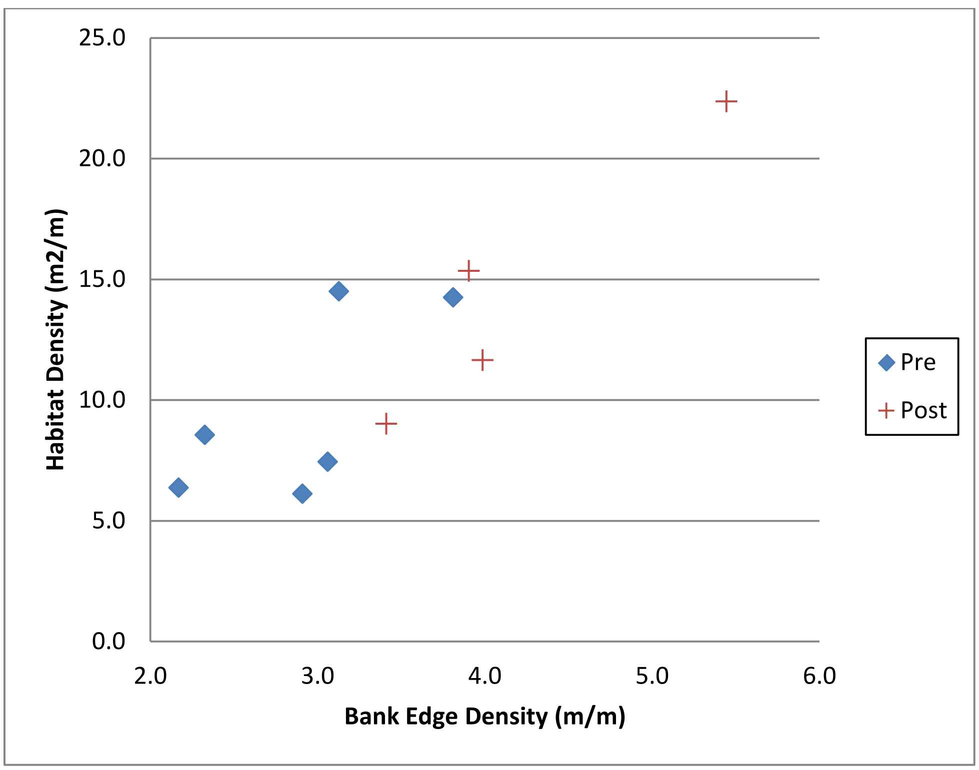


Figure 10–20. Fry (upper graph) and presmolt (lower graph) habitat density vs. length of bank edge relative to site length for pre-construction and post-construction conditions.

Table 10–9. Regression Statistics for the Relationship Between Fry and Presmolt Habitat Density and Wetted Edge Density for Pre-Construction (*n*=6) and Post-Construction (*n*=4) Conditions and for All Data Combined

Life Stage	Site Condition	r^2	*F*-value	*p*
Fry	Pre-construction	0.66	7.741	0.050
	Post-construction	0.98	117.095	0.008
	All	0.88	60.750	<0.001
Presmolt	Pre-construction	0.48	3.701	0.127
	Post-construction	0.90	18.677	0.050
	All	0.76	25.551	0.001

Table 10–10. Estimates of Pre- and Post-Construction Fry and Presmolt Habitat Density and Associated Alluvial Bar Density at Varying Flow Levels

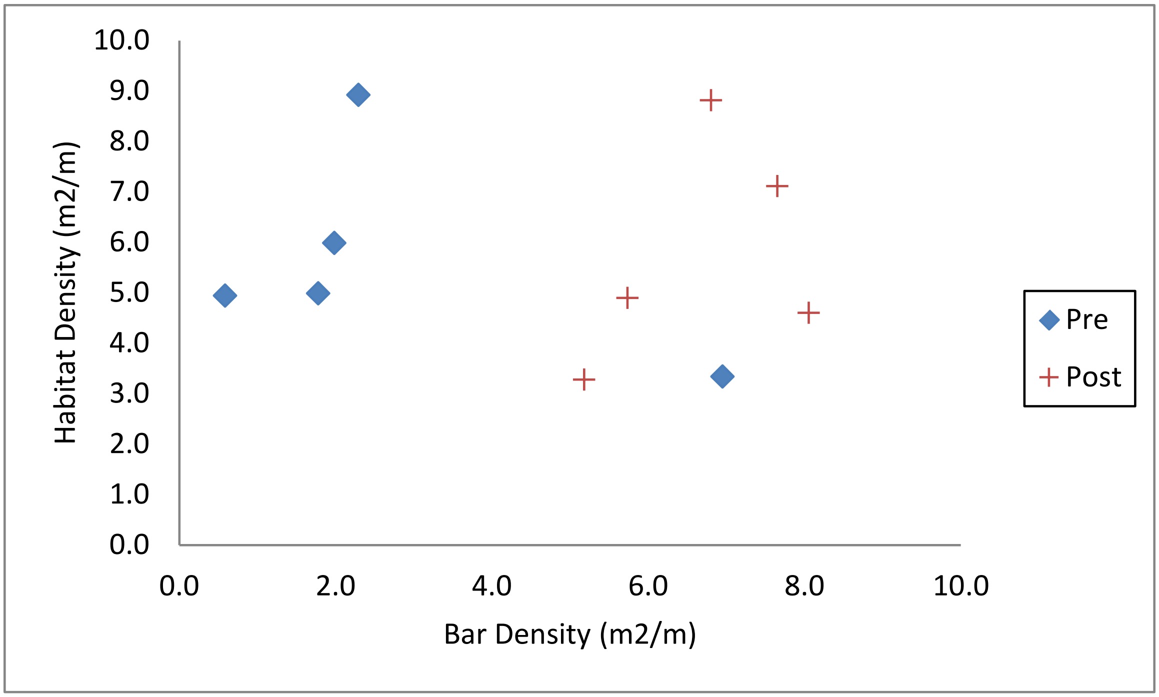
Site Condition	Site	Bar	Discharge (cms)	Bar Density (m^2/m)	Fry Density (m^2/m)	Presmolt Density (m^2/m)
Pre-Construction	Lewiston Cableway	1	8.5	0.6	4.9	7.8
		2	8.5	1.8	5.0	6.7
			11.1	1.8	3.3	4.0
			19.3	1.8	4.4	5.2
			34.3	1.8	10.1	10.6
			57.2	1.8	15.3	15.4
		3	8.5	2.0	6.0	8.0
			11.1	2.0	3.2	4.2
			19.3	2.0	4.1	5.4
			34.3	2.0	6.7	7.3
			57.2	2.0	14.9	15.0
		4	8.5	2.3	8.9	14.7
	Bucktail	1	10.5	7.0	3.3	4.1
			19.6	7.0	3.6	4.4
			36.2	7.0	3.1	4.1
			60.9	7.0	9.5	9.8
Post-Construction	Lewiston Cableway	1	8.5	7.7	7.1	9.2
		2	8.5	8.1	4.6	5.1
			11.1	8.1	4.5	6.0
			19.9	8.1	4.0	4.8
			34.5	8.1	11.7	12.9
			52.7	8.1	16.4	16.5
		3	8.5	5.7	4.9	5.1
			11.1	5.7	4.0	5.5
			19.9	5.7	5.0	5.8
			34.5	5.7	8.8	8.8
			52.7	5.7	13.4	15.4
		4	8.5	6.8	8.8	12.4
	Bucktail	1	8.5	5.2	3.3	4.2
			11.5	5.2	2.6	3.5
			20.0	5.2	2.5	3.0
			33.8	5.2	3.1	3.8
			56.3	5.2	10.4	11.0

For both fry and presmolt habitat densities, the only relationships to alluvial deposit density that were statistically significant were for the pre-construction condition at the high flow level (r^2=1.00, F=2389, p=0.013; Table 10–11; Figures 10–21, 10–22, and 10–23). While all but one of the relationships were not significant, there was a general trend observed at all flow levels that the slope coefficient was positive for all post-construction conditions, suggesting an increase in habitat density with increasing bar density. On the other hand, slope coefficients were negative for all pre-construction conditions, suggesting a decline in habitat density with increasing bar density.

Table 10–11. Regression Statistics for the Relationships Between Fry and Juvenile Habitat Density and Alluvial Bar Density for Pre- And Post-Construction Conditions at Low (n=5), Medium (n=3), and High (n=3) Flow Levels

Life Stage	Flow Level[1]	Site Condition	r^2	*F*-value	*p*
Fry	Low	Pre-construction	0.21	0.795	0.438
		Post-construction	0.19	0.681	0.470
	Medium	Pre-construction	0.94	15.515	0.158
		Post-construction	0.10	0.114	0.793
	High	Pre-construction	1.00	2,191.027	0.014
		Post-construction	0.89	7.857	0.218
Presmolt	Low	Pre-construction	0.21	0.810	0.434
		Post-construction	0.13	0.429	0.559
	Medium	Pre-construction	0.96	21.448	0.135
		Post-construction	0.12	0.141	0.772
	High	Pre-construction	1.00	2,398.986	0.013
		Post-construction	0.62	1.630	0.423

[1] Flow Level: Low flow level is approximately 8.5 cms (300 cfs), medium flow level is approximately 20 cms (700 cfs), and high flow level is approximately 57 cms (2,000 cfs).



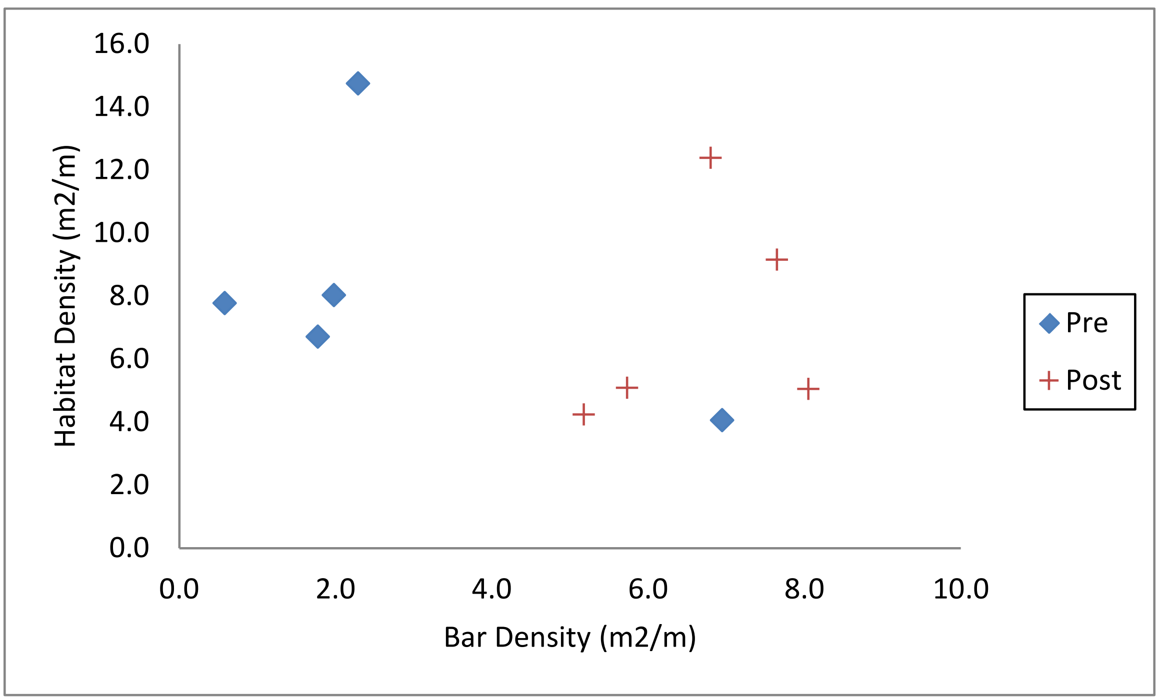
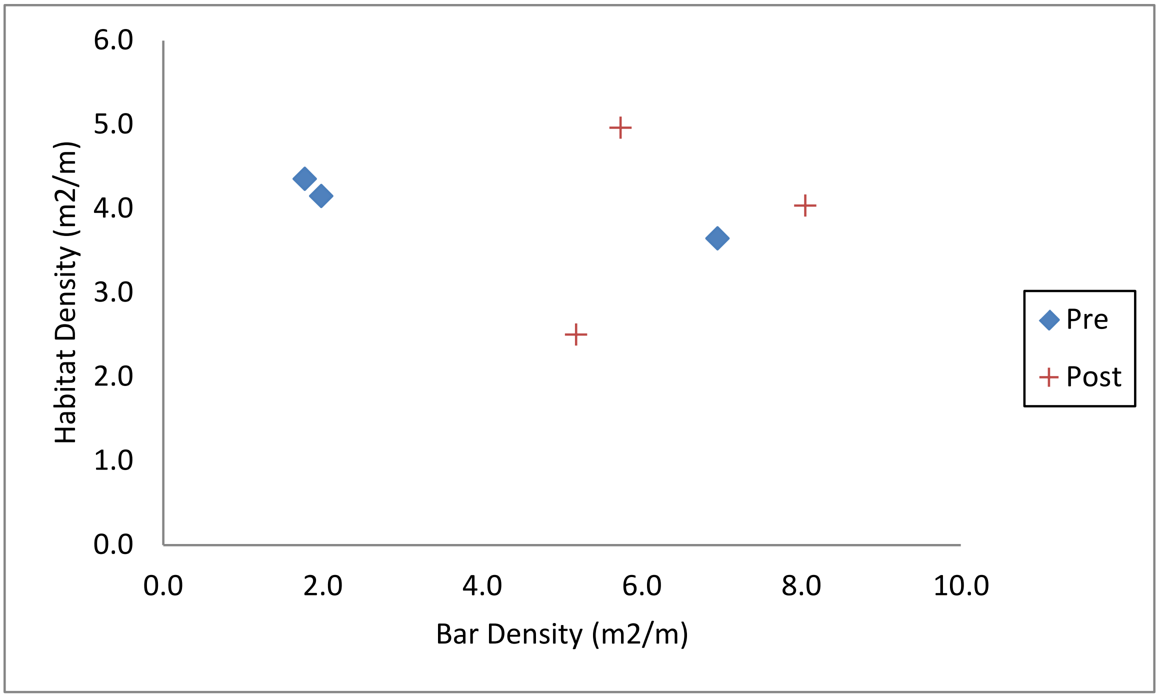


Figure 10–21. Fry (upper graph) and presmolt (lower graph) habitat density at low flow conditions (~8.5 cms or 300 cfs) vs. alluvial bar density. (Bar density based on alluvial bar density from ~8.5 to ~57 cms [~300–2,013 cfs].)



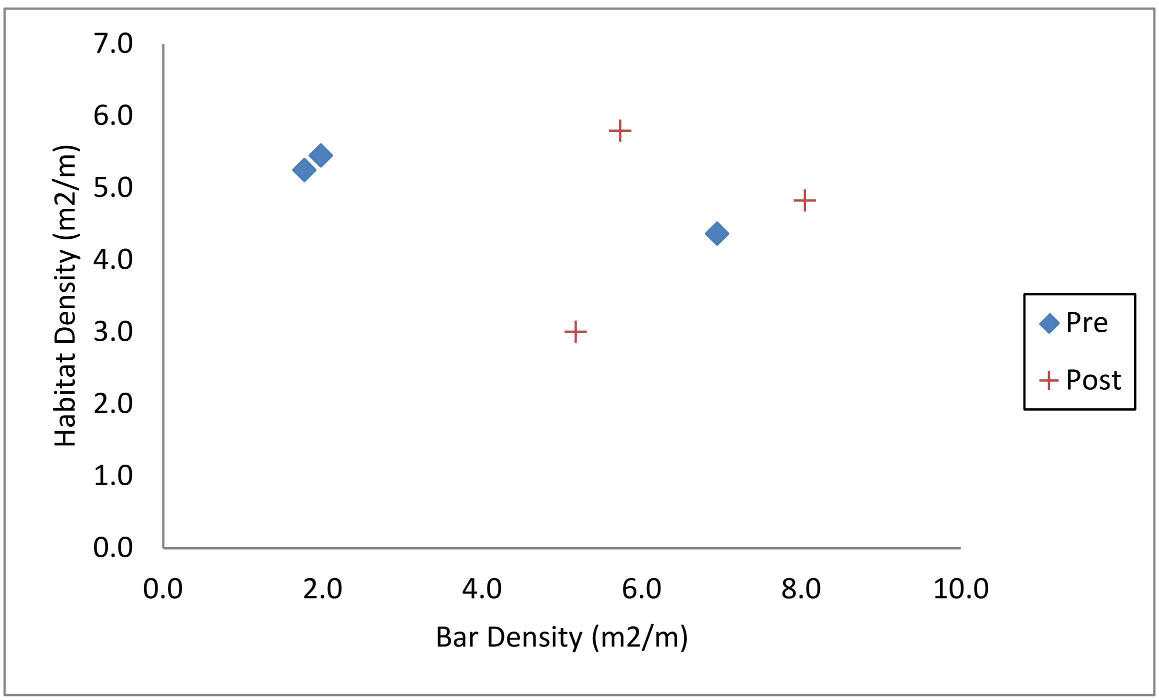
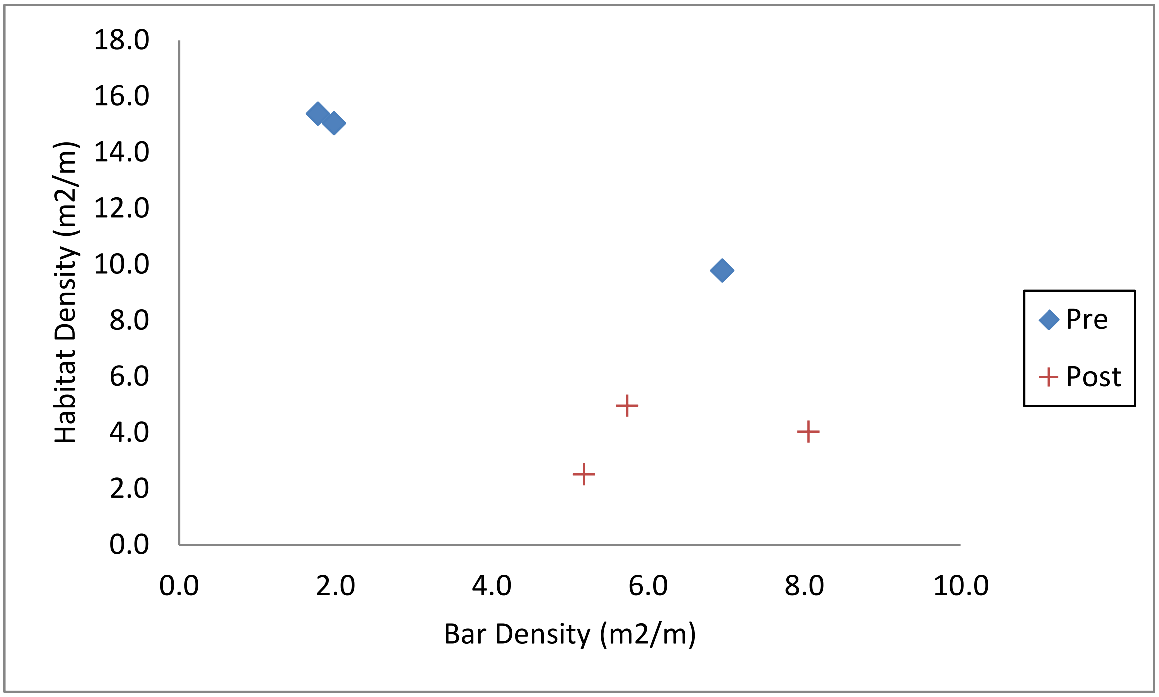


Figure 10–22. Fry (upper graph) and presmolt (lower graph) habitat density at medium flow conditions (~20 cms or 706 cfs) vs. alluvial bar density. (Bar density based on alluvial bar density from ~8.5 to ~57 cms [~300–2,013 cfs].)



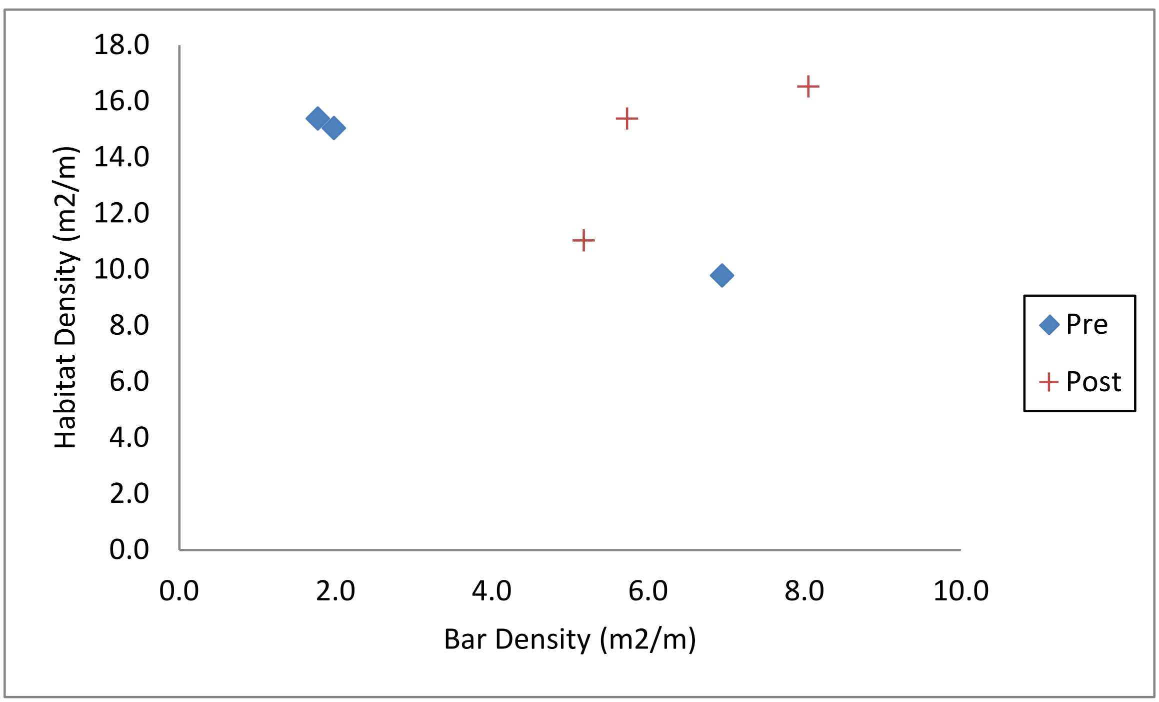


Figure 10–23. Fry (upper graph) and presmolt (lower graph) habitat density at high flow conditions (~57 cms or 2,013 cfs) vs. alluvial bar density. (Bar density based on alluvial bar density from ~8.5 to ~57 cms [~300–2,013 cfs].)

10.4. Discussion

10.4.1. Radius of Curvature

The primary hypothesis for the ROC analysis is that TRRP actions will increase mainstem channel length and thus shorten meander wavelength and decrease ROC. The decrease in radius of curvature is expected to increase hydraulic and physical channel diversity, leading to increases in fry and presmolt rearing habitat. While the analysis conducted for this study did find some significant relationships between ROC and habitat density for the post-construction conditions, the relationships were weak (r^2 ranging from 0.08 to 0.12). A general, nonlinear trend of decreasing habitat density with increasing ROC was observed, but there was substantial variability in the data, especially at the lower range of ROC. While this observation is consistent with the hypothesis of this relationship, the high unexplained variability due to the scatter of data at the lower ROC values needs further investigation. Future investigations into this relationship should consider other factors such as adjacent conditions that may influence this relationship and account for some of the unexplained variability. Additionally, relatively few of the locations surveyed had large ROC values. Future sample designs could consider stratifying by ROC values in an attempt to balance sample distribution.

Analyses for the two types of habitat data (All Habitat and Only D/V/C Habitat) gave very similar results. While the ROC metric primarily addresses a physical condition that will influence hydraulic and physical channel diversity, which in turn influences depth and velocity combinations that provide habitat, ROC will also influence other habitat features such as cover provided by vegetation. Additionally, the two datasets are not independent since the D/V/C habitat is a component of the All Habitat.

Two other techniques for estimating ROC were evaluated at the Lewiston Cableway and Bucktail–Dark Gulch sites, but were not applied in this analysis. The thalweg location was identified using topographic survey data rather than aerial photograph interpretation. This technique provided a similar result to the aerial photograph interpretation despite more intensive data collection requirements. The other method used the channel centerline, as defined by aerial photograph interpretation, as a surrogate for thalweg location. Although repeatable and not data intensive, this technique had a much lower radius of curvature value and was deemed an inappropriate measure because it tracked the river centerline and not the thalweg.

10.4.2. Topographic Diversity

It was hypothesized that changes in channel form, resulting from restoration actions, will increase in-stream topographic diversity which, in turn, will lead to increases in habitat. Relating topographic diversity to rearing-habitat availability was a challenging task. Topographic diversity refers to a variety of depths and topographic conditions within a section of river that is expected to be a desirable trait for the river channel by providing a wide range of depth and flow combinations to meet the physical habitat needs of a wide variety of fish species and life stages. It is also expected that a diverse channel will perform better than a simple channel in maintaining habitat across a range of streamflows. The metric of channelbed diversity as the standard deviations of depth for a specific flow did not show any significant relationships, although the data for the higher flow level evaluated did exhibit increasing habitat with increasing channelbed diversity.

The relationships between the channel topographic diversity metric, based on the ratio of the channelbed surface area to the water surface area, provided different outcomes for pre- and post-construction conditions. While the pre-construction data did not support the hypothesized relationship between habitat and channelbed diversity, as measured by the ratio of channelbed surface area to water surface area, the post-construction data showed an inverse relationship. It is unclear why this is the case and possibly a more extensive sample, not just samples generated from one site, may be needed in order to better understand this result. In addition to being limited to one site, only one flow level was tested which is another aspect of this relationship that should be expanded upon. Another aspect of this physical metric which may be problematic is that the ratios are close to 1.0 and, hence, any error in computing the surface area may have a big effect on the ratio.

The 2009 analysis was limited to the Lewiston Cableway rehabilitation site, and quantifying channel complexity in 50-m (164-ft) sections may not provide sufficient resolution to define habitat (i.e., meso-habitat-pools or riffles). Another alternative for future consideration would be to quantify channel complexity using a more continuous measure (i.e., longitudinal bins of ~1 m), which may identify upstream and downstream effects topographic diversity if they exist. Future efforts will sample 11 sites (2-D GRTS sites), which will allow assessment of how rearing habitat is maintained across flows and also how the topographic diversity influences a suite of species/life stages.

10.4.3. Shear Stress Diversity

It was hypothesized that sections of the river that had more variable shear stress would have greater habitat by providing a greater range of velocities. Shear stress diversity was defined as the standard deviation of shear stresses within a 50-m (164-ft) section of river. There were no apparent relationships between shear stress diversity and rearing habitat in the data used for this evaluation. The shear stress diversity evaluation may have a weakness similar to that discussed in the topographic diversity section with the limited area sampled. While the shear stress diversity metric used for this analysis included all shear stresses values acting on a portion of river, only low shear stress values with slow velocities and/or shallow depths could represent areas for rearing habitat. This may be the one of the reasons why there was no relationship observed between the diversity of shear stress values and rearing habitat. New concepts, such as evaluating the range of shear stresses that occur inside and outside the identified habitats, will be considered among others when moving forward with the future integration analyses.

10.4.4. Length of Wetted Edge

It was hypothesized that as restoration actions are implemented the sinuosity and complexity of edge features will increase, leading to increases in habitat. All relationships evaluated (pre- and post-construction and fry and presmolt) indicated that there was a positive relationship between habitat density and length of wetted edge relative to site length. Although not all of these relationships were significant at the 95-percent significance level, some were at the 90-percent significance level. The analyses conducted suffered from small sample sizes (*n*=6 for pre-construction and *n*=4 for post-construction), but the general relationships appear to be strong. This relationship was also observed in the systemic rearing-habitat assessment (see Chapter 5 for results), in which the highest habitat densities observed were in sections of river that have complex edge features or multiple channels. This relationship has the potential to be used as a design tool for predicting rearing habitat (Yurok Tribal Fisheries Program and Trinity Valley Consulting 2011).

10.4.5. Area of Exposed Alluvial Deposits

It was hypothesized that habitat will increase with increases in alluvial bars, due to the more diverse suite of depth/velocity combinations associated with these features, and that bigger features will provide more habitat. The question of how to properly characterize the amount of habitat created by instream bar features was much discussed during the development of this report. Concerns over accounting for habitats created or affected upstream or downstream of the active bars (eddies, backwaters), which are important components in the conceptual model of the benefits of bars on habitat area, were accommodated by including habitats an arbitrary distance (15 m; 49 ft) upstream and downstream of the bar surfaces. Some of the data suggest that there may be a positive relationship of increasing habitat density with increasing bar density, based on the regression slope coefficients of all post-construction comparisons. However, these analyses were very limited, as they were based on a small dataset with most of the data from one channel rehabilitation site. Future investigations into these relationships should expand the number of bars sampled and the longitudinal distribution along the restoration reach of the river. One improvement over the methodology employed for this report would be to use a fixed analysis boundary for sites sampled over multiple years so that the same area is analyzed each time. Another alternative would be to use a defined area between hydraulic controls such as riffle to riffle or one-half a meander wavelength. Other potential improvements could be evaluating the relationship with respect to bar location within the channel, bar height, and slope.

10.4.6. Integration Insights

While this initial attempt to conduct integrative analyses relating fry and presmolt Chinook salmon habitat to physical parameters did not result in many statistically significant results, the data did support some of the hypothesized relationships and warrants further investigation (Table 10–12). Of the five physical parameters, length of wetted edge relative to site length appeared to be the most promising. Other physical parameters provided mixed results. For example, topographic diversity based on channelbed distances appeared to support the hypothesized relationship but only at the higher flow level evaluated. The area of active alluvial deposits may prove to be useful and should be further investigated, as this analysis suffered from a very small sample size. Topographic diversity based on the ratio of channelbed area to water surface area suggested some support for the hypothesized relationship for the pre-construction data, but the opposite relationship was observed in the post-construction data. The data from the shear stress variability analysis did not support the hypothesized relationship.

Table 10–12. General Results of 2009 Integration Analysis Between Habitat and Physical Parameters

Analysis	Hypothesis	Summary Results
Radius of Curvature (ROC)	Habitat will increase with decreasing ROC	Some support but large variability at low ROC values
Topographic diversity: Channelbed distances	Habitat will increase with increasing topographic diversity	Some support but only at the higher flow level evaluated and not at the lower flow level.
Topographic diversity: Channelbed surface area ratio	Habitat will increase with increasing topographic diversity	Support for pre-construction data but a negative relationship was observed in the post-construction data.
Shear stress diversity	Habitat will increase with increasing diversity of shear stress	No support
Length of wetted edge	Habitat will increase with increasing length of wetted edge	Support with some significant relationships.
Area of active alluvial deposit (bars)	Habitat will increase with increasing areas of active alluvial deposits	May be some support in the post-construction dataset but very limited sample size.

Comparing various types of physical data with rearing-habitat areas is a complex task. Many discussions took place and different types of analysis were attempted during this effort. This was an exploratory exercise with a limited number of sites and replicates, and it is premature to discount specific variables at this time. Some relationships might be obscured by the limited data, sample bias, or the variability within a site, making it hard to tell how the relationship might work at a diverse range of channel-forms (e.g., radius of curvature or channelbed complexity measures). Additionally, only univariate comparisons were used in this initial analysis, and future efforts should consider multivariate analyses. Some of the challenges that arose during the integration analyses should be resolved with the implementation of a GRTS sampling design in 2010. The GRTS sampling design assures a random selection and has the added advantage of selecting a spatially balanced subsample and consistent reach lengths. Also, 11 of the GRTS sites will have a full suite of physical data associated with them, as they will be accompanied by two-dimensional models. This will allow comparisons across a suite of sites and streamflows. The 2010 integration analysis will include additional independent variables, other than those listed above, such as large wood density, channel confinement, geomorphic feature maps, channel slope, and riparian vegetation.

10.5. References

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CHAPTER 11. MANAGEMENT RECOMMENDATIONS

This multi-disciplinary monitoring effort includes results and recommendations stemming from a single year of monitoring during a Dry water year, and they should be considered in that hydrologic and temporal context. Additional monitoring in future years and during other water year types is needed to continue to refine the management recommendations set forth based on 2009 monitoring and analysis as well as to develop new management recommendations. Management recommendations are presented by chapter and channel rehabilitation design feature.

11.1. Geomorphic and Topographic Evaluation of Trinity River Restoration Channel Rehabilitation Projects

- A Dry water year type is not expected to result in an abundance of geomorphic change on the Trinity River. Given this reality, it is recommended that geomorphic monitoring be continued in future years to evaluate fundamental Trinity River Restoration Program (TRRP) management objectives (i.e., bed scour and bed mobility) as well as specific hypotheses that arise as a result of TRRP management actions (e.g., channel migration, side channel and alcove function, feature evolution). Two monitored sites (Hocker Flat and Valdor Gulch) did not meet the Dry or Wet water year bed mobility management targets.[4] Additional monitoring should be conducted to ensure water year targets are evaluated, both systemically and at sites where the targets have not been achieved.
- Priority Question #G-3 asked if channel migration could be encouraged by only removing vegetation/berms on opposite banks prior to high-flow releases/natural floods without putting anything in the channel to force thalweg adjustment. At Valdor Gulch, monitoring results indicated that 2009 stream flows were sufficient to maintain some topographic features but not to improve them throughout the site. Valdor Gulch should be re-evaluated after the 2011 ROD release (11,000 cfs); if channel migration is still not observed, construction of in-channel bars and/or other features should be considered to initiate more substantial topographic change (USFWS and HVT 1999, McBain & Trush 2004).

[4] Because flows downstream of Canyon Creek experienced a Wet water year (due to coincident tributary high flows simultaneous with the ROD Dry water year release), Hocker Flat and Valdor Gulch had the benefit of being evaluated against both Dry and Wet water year objectives. Both sites also did not meet Wet water year bed mobility and scour thresholds.

11.2. Riparian and Large Wood Storage Assessment of Trinity River Restoration Program Channel Rehabilitation Sites

11.2.1. Remove Remnant Root Sprouts

- Root sprout-induced detrimental riparian encroachment has not been inhibited between the 13- and 57-cms (450- and 2,000-cfs) water surface level at Pear Tree, Valdor Gulch, Connor Creek, and Hocker Flat, and shrubs growing from root sprouts are increasing in size rapidly. The root sprouts will ultimately exert more geomorphic influence than seedlings in the re-formation of the riparian berm, because they are not likely to be removed by flood flows and they have the same ability to trap fine sediments and form berms as the more easily removed seedlings of similar ages.
- Results indicate berm re-formation as a result of root sprouts is probable at Pear Tree, Valdor Gulch, Connor Creek, and Hocker Flat sites and is likely to contribute to these sites reverting to pre-construction conditions. It is recommended that the TRRP revisit these sites and re-treat areas where root regrowth has been documented and fully remove remnant root material to improve the viability of these sites, improving the likelihood of long-term self-maintenance of geomorphic processes and salmonid habitat benefits.
- Minimize root regrowth in specific locations where channel migration and bank disturbance is more likely (i.e., not along the entire 120+ m [400+ foot] feathered edge).
- Root growth may be inhibited if future channel rehabilitation includes the over-excavation of existing berms during construction to ensure roots are fully removed.
- Regrowth and seedling regeneration may be further inhibited through the placement of clean coarse sediment as backfill, so that removed plants are less likely to re-sprout (or germinate) close to the low-water edge.

11.2.2. Riparian Regeneration Substrate

- Results show that large quantities of woody plant seedlings were correlated with a high quantity of fines in the substrate and a viable seed source close to the constructed surfaces. The highest numbers of seedlings occurred at Indian Creek and were most common in places where over 60 percent of the surface substrate consisted of particles smaller than 2 mm (0.08 in). Monitored sites with less fine sediment (i.e., Hoadley Gulch) demonstrated far less seedling initiation. Based on the overall sampling results from constructed floodplain surfaces and side channels, substrates need a minimum of 15 percent of the overall composition smaller than 2 mm (0.08 in) to promote woody plant seed germination and thus natural riparian regeneration. Future construction should include fine sediment augmentation for features where riparian regeneration is desired (i.e., higher elevation surfaces such as floodplains and high water scour channels), if existing substrates lack a sufficient fine sediment component.

Increased success of natural riparian regeneration through improved substrate conditions will enable TRRP to better meet the regulatory riparian reestablishment requirements established by the California Department of Fish and Game.

11.3. Estimation of Chinook Salmon and Coho Salmon Rearing-habitat Area at Specific Rehabilitation Sites on the Trinity River

- In-water escape cover is created by features such as wood and vegetation and is a necessary component of optimal Chinook salmon and coho salmon rearing habitat. The installation of large wood at channel rehabilitation sites is one of the primary restoration techniques used by the TRRP to create this habitat feature. A large proportion of habitat improvements observed from construction can likely be attributed to large wood installations, and it is recommended that this treatment type continue. However, the longevity of the benefits of large wood installations is uncertain and should be evaluated through time.
- It is recommended that site designers develop quantitative predictions on the magnitude of change and the time frame anticipated from channel rehabilitation actions. These predictions would facilitate quantitative evaluations of site development and improve TRRP's ability to adaptively manage restoration efforts. In addition, TRRP should continue to evaluate the channel rehabilitation actions to determine if larger habitat gains are attainable or if additional management actions are needed, especially when evaluated in the context of programmatic habitat targets.
- The effect of channel rehabilitation was evaluated at locations designed to alter streamflow-to-habitat relationships. Before implementation of the ROD, the Trinity River had a reduction in habitat availability between 8.5 and 42.5 cms (300 and 1,500 cfs), which was identified as a limiting factor for salmonid populations (USFWS and HVT 1999). This relationship was observed at some, but not all, of the channel rehabilitation sites before construction, with a high level of across-site variation. The effects of channel rehabilitation also varied and did not consistently improve the shape of the streamflow-to-habitat relationship between 8.5 and 42.5 cms (300 and 1,500 cfs). Site designers should evaluate the responses observed based on treatment type and incorporate this information into future designs.
- The highest rearing-habitat densities occurred at sites where side channels were created or enhanced. Side channels with the highest habitat densities are those that have a more sinuous channel form, large wood installed, and varied side slopes constructed to provide habitat at multiple flows. The location or placement of side-channel entrances is critical to their long term success. The combination of management actions (high flows and gravel augmentation) can cause significant changes at side-channel entrances. Construction of multiple entrances as well as the use of hard points, as implemented at Sven Olbertson channel rehabilitation site, is recommended to ensure longevity of the feature.

Monitoring of naturally occurring and constructed side channels and their entrance conditions is recommended to elucidate what conditions can contribute to long-term persistence of these features.

11.4. Estimation of Chinook Salmon and Coho Salmon Rearing-Habitat Area Within the Primary Restoration Reach of the Trinity River

- An estimate of Chinook salmon and coho salmon rearing-habitat area was developed at a single index streamflow for the Trinity River between Lewiston Dam and the confluence with the North Fork Trinity River. This estimate is a first step in a multi-year investigation that will evaluate status and trend of rearing-habitat parameters in relation to restoration implementation. The TRRP should develop habitat targets necessary to meet fishery resource goals so that estimates of existing habitat can be put into context with habitat requirements (TRRP and ESSA Technologies 2009).
- The highest rearing-habitat densities occurred at sample sites close to Lewiston Dam. In planning future restoration actions, the TRRP should consider emphasizing increases in rearing-habitat area farther downstream to improve habitat conditions throughout the restoration reach.
- The relationship between channel rehabilitation sites and rearing-habitat areas was strongest for the post-ROD sites. This finding provides support for the rearing-habitat benefits of the current channel rehabilitation program. Continued monitoring is needed to ensure habitat area continues to increase and meet long-term restoration goals.
- A correlation was identified between fry and presmolt rearing-habitat area estimates. We recommend future rearing-habitat assessments measure presmolt rearing-habitat area and use the correlation to estimate fry rearing-habitat area.

11.5. Diel and Longitudinal Effects on Chinook Salmon and Coho Salmon Rearing-Habitat Use

- Chinook salmon and coho salmon fry and presmolt use was concordant with *a priori* assumptions of habitat qualities and with results of previous validation studies.
- Brown trout use of rearing-habitat areas was documented, and in some cases brown trout outnumbered native salmonids. It is possible that this represents an impediment to realizing TRRP goals. The population size, dynamics, and feeding strategies of brown trout should be evaluated to determine their impacts on restoration of the Trinity River native salmonid populations.

11.6. Redefining Chinook Salmon Spawning Habitat in the Trinity River

- The assessment of Chinook salmon spawning-habitat use evaluated habitat variables in relation to redds and unused locations. Past evaluations used depth, mean column velocity and substrate as predictors for spawning habitat. This study identified additional variables that are also indicative of spawning habitat, such as in-water escape cover, distance to shore, geomorphic features, and distance to other redds. These variables should be used to inform future channel rehabilitation designs whose purpose is to improve Chinook salmon spawning habitat.
  - The study was compared to an evaluation of spawning habitat use conducted before implementation of the TRRP. The most notable difference was that the currently used spawning habitat had smaller pebble sizes than noted previously. In addition, the smaller substrate grain size was concordant with the substrate size ranges currently used in the coarse sediment augmentation program and was indicative of restoration effects.
- This finding is one of the aspects that should be considered in evaluating restoration effects on Chinook salmon spawning habitat availability and quality.

11.7. Precision of Salmonid Rearing-habitat Mapping Surveys

- Differences occurred between repeat rearing-habitat mapping results. However, the level of difference identified between surveys was much lower than observed changes at channel rehabilitation sites and future levels of response anticipated from restoration actions based on interim goals. Therefore, the surveys are appropriate for evaluating rearing-habitat response from restoration actions.
- Actions should be taken to further evaluate errors in the rearing-habitat mapping survey and to improve the accuracy and precision of the methodology.

11.8. A Comparison of Habitat Mapping and Two-Dimensional Hydrodynamic Model Predictions of Salmonid Rearing-Habitat Availability

- Results of the two-dimensional hydrodynamic model and rearing-habitat mapping methodologies differed to varying degrees, and differences were not consistent between variables or sites. In this evaluation, modeling and mapping results were dissimilar. However, this difference does not necessarily indicate a lack of compatibility of the techniques, given that models were developed with input data primarily limited to pre-existing sources. In addition modeling did not include a quantification of error associated with predictions. It is recommended that future comparisons increase the resolution of model input data, quantify error associated with model predictions, and ensure that model calibration data and mapping data are collected at similar flows.

- Given the results of this comparison, the level of error in model predictions should be incorporated into interpreting these results for management decisions. Particular attention should be paid to interpreting model results with unquantified errors.

11.9. Cross-Discipline Integration Recommendations

- Integration analyses evaluated the correlation between variables indicative of physical processes and Chinook salmon and coho salmon rearing-habitat area. Results from the length of wetted edge and rearing habitat comparison were similar in both the site-specific and systemic analyses. The sections of river with the highest densities of habitat occurred where bank length relative to site length was highest. Higher bank length relative to site length are an anticipated response to physical processes which form and maintain complex channel morphologies. Where appropriate, it is recommended that the TRRP continue to consider design features such as multiple channels that have high bank length relative to site length in the channel design process.
- Although some relationships were more apparent than others, it is important to consider that this analysis reflects just one year of sampling at a limited number of sites. It is recommended to continue cross discipline analysis using lessons learned from the 2009 effort.

11.9.1. Berm Notches

- Preliminary data indicate that installing berm notches prior to high-flow releases (192.8 cms, 6,810 cfs) was not sufficient to generate additional berm removal at Vitzthum Gulch to date. Monitoring results indicate notch volume has decreased by 13 percent since construction, which is consistent with observed decreases in rearing habitat (Goodman et al. 2010). Initial increases in fish habitat area quickly dissipated as the notches filled in with fine sediment. Monitoring should be repeated after a higher flow occurs to evaluate whether higher flows (e.g., 311 cms, 11,000 cfs) are more effective at removing the berms, or if additional deposition occurs. If the notches continue to fill in, TRRP should consider revisiting of this site and developing a new site rehabilitation design.

11.9.2. Alcoves

- The two constructed alcoves monitored (Pear Tree and Valdor Gulch) were observed to be depositional and thus not fully functional or self-maintaining at present. However, alcoves are an important habitat feature particularly for rearing salmonids at a range of flows. Future rehabilitation designs will likely benefit from refined alcove design criteria to better ensure appropriate scour and self-maintenance (HVT et al. 2011).

11.9.3. Active Alluvial Deposits

- Active alluvial deposits are anticipated to form throughout the project area in response to management actions. A major question for the TRRP is clarifying the circumstances under which riparian regeneration on active alluvial deposits becomes detrimental. It is recommended that the TRRP conduct adaptive management experiments to evaluate the role large wood, bedrock or other roughness features play in creating vertical and lateral scour on bars to reduce the risk of detrimental riparian encroachment.
- Another possible topic for investigation is the role of coarse sediment supply on alluvial dynamics, bar turnover, and scour. How could coarse sediment be managed to reduce the risk of future detrimental riparian encroachment on active alluvial deposits?

11.9.4. Side-Channel Design Guidelines

- A focused investigation on side-channel entrance conditions is recommended. This assessment would evaluate the entrance design guidelines set in the Channel Design Guide (HVT et al. 2011) by integrating controlled adaptive management experiments focused on previously constructed or naturally occurring side channels.

11.10. Future Direction

- Geomorphic, riparian, and fish habitat assessments should continue as part of the TRRP's evaluation of management actions and their results, namely the creation and maintenance of fish habitat. A critical component of these assessments is ensuring that they are supportive of each other so that multi-disciplinary analyses can be used to evaluate the TRRP restoration strategy.
- Geomorphic assessments should continue to evaluate whether TRFE bed mobility and scour management objectives are being achieved and how topographic, planform, and geomorphic unit diversity is changing, or not, in response to management actions.
- Riparian assessments should continue to evaluate whether TRFE riparian seedling scour mortality objectives are being achieved during natural tributary-induced flood events and ROD high flow releases, and whether natural floods and ROD high-flow releases are preventing detrimental riparian encroachment that could lead to berm development and channel simplification. Additionally, TRFE riparian initiation and establishment objectives on upper bar and floodplain surfaces during ROD high-flow releases for Wet and Extremely Wet WY types should be evaluated, especially in light of the riparian mitigation responsibilities of the TRRP.
- Rearing-habitat assessments should continue to focus on pre- and post-construction evaluations of channel rehabilitation sites. The TRRP anticipates that habitat conditions at channel rehabilitation sites will continue to improve with fluvial processes and riparian development. Although the time scale of

these processes is not well defined, continued monitoring is needed to evaluate the long-term effects of channel restoration sites. These efforts should also focus on evaluating the effectiveness of specific features (i.e., side channels, alcoves, bars, etc.) to provide input to future channel rehabilitation projects. The systemic rearing-habitat evaluation should continue to provide data for trend analyses of habitat availability to evaluate the anticipated changes through time with variable flow regimes and continued implementation of channel rehabilitation projects. Habitat assessments should also be expanded to include an evaluation of habitat at various life stages of salmonid species, most notably spawning and adult holding habitats.

- Ongoing efforts to develop two-dimensional hydrodynamic fish habitat models should continue. The use of models to generate salmonid rearing and spawning habitat estimates based on a randomized sampling design should be a useful tool to assess habitat availability throughout the project reach during the annual flow scheduling and to evaluate potential changes in rearing flows.
- Integration assessments will expand and, where appropriate, should be used for systemic analyses utilizing the randomized sampling design framework initiated in this report. Analyses initiated during this project should be refined and/or expanded, as appropriate, to further evaluate the relationship between management actions, physical and riparian processes, and the creation and maintenance of fish habitat. This information should be useful in evaluating the effectiveness of the TRRP's strategy for restoring fish populations.

11.11. References

HVT et al. (Hoopa Valley Tribe, McBain & Trush, and Northern Hydrology and Engineering). 2011. Channel rehabilitation design guidelines for the mainstem Trinity River.

USFWS and HVT (U.S. Fish and Wildlife Service and Hoopa Valley Tribe). 1999. Trinity River Flow Evaluation Final Report. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, CA and Hoopa, CA.