Water Quality and Aquatic Resources Monitoring Program for the Ralston Afterbay Sediment Management Project

2002 Annual Report

Prepared for:

Placer County Water Agency
Power System
Foresthill, California

Prepared by:

Jones & Stokes

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Prepared for:

Placer County Water Agency
Power System
24625 Harrison Street
Foresthill, CA 95631
Contact: Steve Jones or Jon Mattson
530/885-6917

Prepared by:

Jones & Stokes
2600 V Street
Sacramento, CA 95818-1914
Contact: William Mitchell or Doug Brewer
916/737-3000

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Contents

Page

Tables

On Page

Figures

Follows Page

Acronyms and Abbreviations

Basin Plan	Water Quality Control Plan
BMI	benthic macroinvertebrates
CAMLnet	California Aquatic Bioassessment Laboratory Network
CDFG	California Department of Fish and Game
cfs	cubic feet per second
CSBP	California Stream Bioassessment Procedure
DS	sieve diameter
EPT	Ephemeroptera, Plecoptera, and Trichoptera
MFAR	Middle Fork American River
mm	millimeters
PCWA	Placer County Water Agency
Ralston Afterbay	Ralston Afterbay Reservoir
SPT	sediment-pass-through
USDA	U.S. Department of Agriculture

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Executive Summary

In 2002, the Placer County Water Agency (PCWA) initiated a sediment management project at Ralston Afterbay Reservoir (Ralston Afterbay), a component of the American River Hydroelectric Project on the Middle Fork American River (MFAR). The primary purpose of the sediment management project is to create sediment storage capacity in Ralston Afterbay, maintain operational flexibility of Ralston Dam and Oxbow Powerhouse, and delay the complete sedimentation of Ralston Afterbay.

The sediment management project consists of two components. The first consists of dredging approximately 75,000 cubic yards of sediment from the upstream end of the reservoir and placing the dredged material downstream of Ralston Dam on Indian Bar. The sediment would be configured to allow high flows to mobilize and transport the sediment to reaches downstream of the dam. The second component, termed sediment-pass-through (SPT), consists of reoperating Ralston Dam during high-flow events to pass greater quantities of fine sediment past the dam than pass under current operations.

A secondary objective of the sediment management project is to restore the natural migration of coarse and fine sediment that occurred in the project area before dam construction. This sediment, especially the intermediate-sized material (gravel, pebbles, and cobbles), is critically important for maintaining suitable stream habitat for fish and benthic macroinvertebrates (BMI) (insects and other aquatic organisms that live in or on the streambed). Since the construction of Ralston Dam in 1966, a portion of the total sediment load transported by high flows from the MFAR and Rubicon River above Ralston Afterbay has accumulated in the reservoir, requiring periodic dredging of the reservoir to maintain the reliability of Ralston and Oxbow Powerhouses. As documented for other rivers, the retention of sediment by dams and corresponding reductions in sediment supply to downstream reaches can lead to a reduction in habitat quality in these reaches as high flows continue to transport cobble and finer materials that are not replaced by upstream sources.

SPT operations and sediment placement on Indian Bar constitute a viable and economical approach for managing sediment at Ralston Afterbay while mitigating the long-term effects of sediment retention on aquatic habitat downstream of the dam. The proposed sediment management activities will allow the river to mobilize sediments and carry them downstream as they did naturally before dam construction. The placement of reservoir sediment is expected to reintroduce the small- to intermediate-sized materials that have been historically retained in the reservoir. Analyses of the hydraulic and sediment transport characteristics of the MFAR indicate that increases in the amount of fine sediment resulting from SPT operations and sediment placement will not cause adverse effects on water quality and aquatic resources.

In 2001, PCWA initiated a monitoring program to ensure compliance of the sediment management project with established water quality objectives and to evaluate potential project effects on aquatic habitat and BMI in the MFAR downstream of Ralston Dam. Potential project effects will be evaluated by collecting a minimum of 1 year of water quality data and 2–3 years of aquatic habitat and BMI data before project activities begin and a minimum of 2–3 years of water quality, aquatic habitat, and BMI data after project activities begin. Key water quality, aquatic habitat, and BMI parameters will be monitored at treatment sites below Ralston Afterbay and at control sites above the reservoir. These parameters include turbidity, total suspended solids, substrate size composition, embeddedness, and several measures of the structure and composition of BMI communities that are commonly used as indicators of habitat quality.

Evidence for project effects will be a significant postproject change (adverse or beneficial) in water quality and aquatic habitat conditions in the treatment reaches relative to changes in the control reaches. If these changes constitute an adverse effect on water quality and aquatic habitat conditions downstream of the dam, the magnitude of these changes will be compared to established water quality and habitat thresholds to evaluate project performance and determine whether corrective actions are warranted. The need for corrective actions will also be based on the results of BMI monitoring, which will serve as a key indicator of the biological effects of observed water quality and habitat changes. In addition, these changes will be evaluated in the context of other watershed events and trends that may influence the monitoring results and conclusions. Because of the high degree of variability of natural systems and lack of baseline data, an adaptive monitoring approach will be used to regularly evaluate the monitoring program and determine whether modifications are warranted to improve its performance.

The Indian Bar Pilot Project was initiated in 2002 to demonstrate the effectiveness of sediment disposal in achieving the sediment management objectives. Pebble counts on the Indian Bar sediment pile in 2002 confirmed the presence of large quantities of gravel, pebbles, and cobble that have been historically retained by the reservoir. Based on sediment modeling, these sediments are well within the range capable of being mobilized by high flows that typically occur in the project area (Mussetter Engineering 2001).

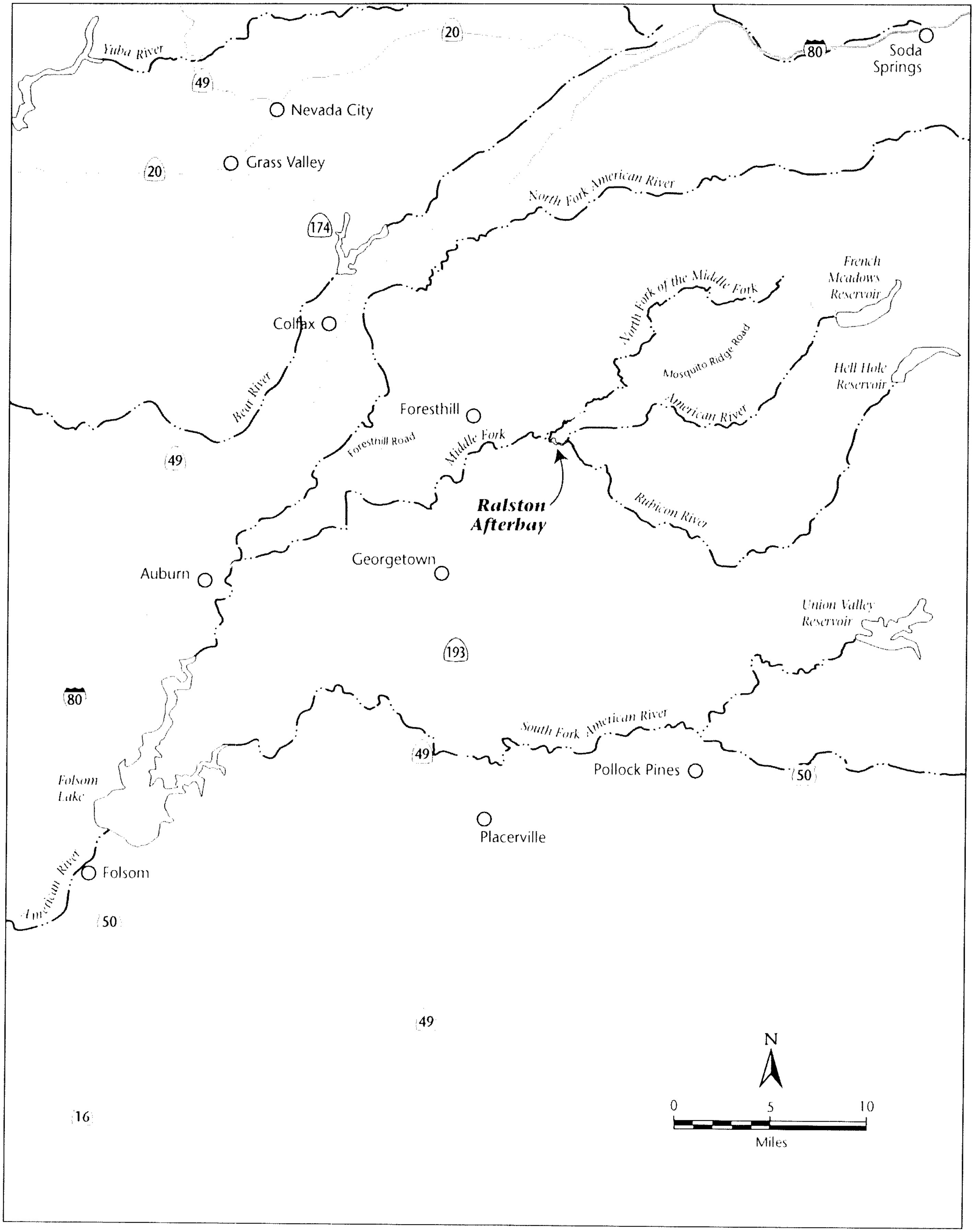
This report presents the results of the second year of preproject monitoring for the sediment management project (2002). The first was conducted in 2001 in accordance with the Water Quality and Aquatic Resources Monitoring Plan (Jones & Stokes 2002b). Several revisions were made to the plan in 2002 to comply with permit requirements and agency requests (Appendix A).

The aquatic habitat and BMI data collected in 2001 and 2002 have established important baseline information on annual and seasonal variability in aquatic habitat and BMI communities, and describe the current status of aquatic habitat and BMI communities in the project area. The results of substrate monitoring in 2002 revealed no significant changes in substrate composition (percent boulders, cobbles, gravel, sand, and silt/clay) in each of the monitoring locations since 2001. As concluded from the 2001 data, spawning habitat for trout is limited in the monitoring reaches by the low abundance of suitable-sized gravel. In addition, the coarse nature of the streambed and very low quantities of fine sediments may limit the diversity and abundance of BMI communities. These potential limitations are most severe in Reaches 3 and 4, in which large cobbles and boulders dominate the streambed. The coarseness of the streambed in these reaches is consistent with the processes of channel scouring and armoring associated with reductions in sediment supply since the construction of Ralston Dam (Stiehr pers. comm.).

The analysis of the BMI data indicated a relatively high degree of seasonal and annual variability in BMI communities. However, while preproject BMI communities have fluctuated over the last 2 years, the various BMI indicators of habitat quality (e.g., California tolerance values) measured in each of the monitoring reaches in 2002 followed the same general patterns observed in 2001. For example, consistent with the substrate monitoring results, the BMI data indicate that aquatic habitat in the reach immediately below Ralston Dam is generally of lower quality than that farther downstream (near Otter and Volcano Creeks) or in the control reaches upstream of Ralston Afterbay.

Preproject water quality data are still needed to meet the minimum requirements of the monitoring plan. Flows over the last 2 years have not been high enough to document baseline water quality conditions under the flow conditions that would occur in the postproject monitoring years. To obtain sufficient water quality data to describe baseline conditions, the monitoring plan requires that turbidity and suspended sediment levels be measured during a storm event (or several storm events) that generate flows within the target range for SPT operations (>3,500 cubic feet per second [cfs] at Ralston Dam). Preproject water quality monitoring will be conducted during the next flow event (or several flow events) that is similar in magnitude to those that will trigger SPT operations in future years.

Flows in winter/spring 2003 did not reach levels capable of mobilizing sediment from the Indian Bar sediment pile, and there was no evidence of any significant preproject changes in substrate composition in the monitoring reaches resulting from the flows in winter/spring 2002. In addition, winter/spring flows in 2003 were not of sufficient magnitude to trigger SPT operations, which require flows of more than 3,500 cfs (measured at Ralston Dam). Therefore, the lack of project



Jones & Stokes

Figure 1
Regional Location

effects to date and the need to conduct 1 year of preproject water quality monitoring provides a valuable opportunity to conduct a third year of preproject monitoring to measure the baseline effects of higher flows (>3,500 cfs measured at Ralston Dam) on substrate conditions and BMI communities.

Introduction

PCWA operates the Middle Fork Project, a series of reservoirs and powerhouses on the MFAR and the Rubicon River in the central Sierra Nevada (Figure 1). The Middle Fork Project includes Ralston Afterbay, a reservoir created by the construction of Ralston Dam in 1966. The dam and reservoir are located on the MFAR at the confluence of the MFAR and the Rubicon River, on the border of Placer and El Dorado Counties. Ralston Afterbay serves as the afterbay for the two largest powerhouses of the Middle Fork Project (Middle Fork and Ralston Powerhouses) and the forebay for Oxbow Powerhouse.

PCWA is implementing a sediment management project at Ralston Afterbay to address continuing sedimentation of the reservoir that threatens the reliability of power generation at the Ralston and Oxbow Powerhouses. PCWA issued and adopted an initial study/mitigated negative declaration for the Ralston Afterbay Sediment Management Project in August 2001. The primary objectives of the sediment management project are to:

- create sediment storage capacity in Ralston Afterbay,
- maintain operational flexibility of Ralston Dam and the Oxbow Powerhouse, and
- delay the complete sedimentation of Ralston Afterbay.

The sediment management project would consist of two independent components. The first would consist of dredging approximately 75,000 cubic yards of sediment from the upstream end of the reservoir and placing the dredged material downstream of the dam on a 7-acre portion of Indian Bar. The sediment would be configured to allow high flows to mobilize and transport it to the river downstream of the dam. The second consists of reoperating the dam during high-flow events to pass greater quantities of fine sediment beyond the dam. SPT operations would be conducted whenever river flows exceed approximately 3,500 cfs.

In 2002, PCWA implemented the Indian Bar Pilot Project to evaluate the first component of the sediment management project and address concerns regarding recreational uses at Indian Bar (Jones & Stokes 2002a). In September 2002, PCWA placed an initial 45,000 cubic yards of sediment on Indian Bar and an additional 28,900 cubic yards at PCWA's existing disposal site at Ralston Ridge. The pilot project includes consideration of potential strategies for increasing the sediment volume at Indian Bar while maintaining or enhancing recreational opportunities. Additional sediment placement locations (e.g., Junction Bar) may be considered in the future.

A secondary objective of the sediment management project is to restore the natural migration of coarse and fine sediment that occurred in the project area before the dam was constructed. This sediment, especially intermediate-sized material (gravel, pebble, and cobble), is critically important for maintaining suitable stream habitat for fish and BMI (Waters 1995). Following construction of a dam, these materials continue to be transported from the reaches below dams but are not replaced from upstream sources, resulting in the loss of important habitat (Kondolf and Matthews 1993). Other effects include scouring and deepening of the channel below the dam and associated increases in substrate size (channel armoring), a process that has been occurring below Afterbay Dam since it was constructed (Stiehr pers. comm.). Efforts to mitigate these effects on salmon and trout streams in California have focused primarily on augmenting the supply of spawning-size gravels (Parfitt and Buer 1980), but these efforts, which include placing gravel on bars and riffles and installing artificial and natural gravel-retaining structures downstream of dams, can be costly and ineffective over the long term. A more satisfactory alternative is to attempt to maintain natural channel features below dams by managing water releases and sediment in ways that preserve as much as possible the geomorphic processes that existed before the dams were constructed (Ligon et al. 1995).

SPT operations and sediment disposal at Indian Bar constitute a viable and economical approach for managing sediment at Ralston Afterbay while mitigating the long-term effects of sediment retention on aquatic habitat downstream of the dam. These sediment management activities would allow the river to mobilize sediments and carry them downstream as occurred naturally before the dam was constructed. Preliminary analyses indicate that these activities would not cause adverse effects on aquatic resources. For reasons stated above, the reintroduction of sediment below the dam is expected to have beneficial effects on stream habitat and aquatic resources downstream of the dam. SPT operations and sediment disposal at Indian Bar are expected to result in relatively small, temporary increases in turbidity and suspended sediment above ambient levels during high-flow events. Also, past analyses and modeling of the hydraulic and sediment transport characteristics of the MFAR indicate that the channel is inherently stable and therefore relatively insensitive to changes in discharge and sediment supply (Harvey pers. comm.).

In 2001, PCWA initiated a monitoring program to ensure compliance of the sediment management project with established water quality objectives and to evaluate potential project effects on aquatic habitat and BMI in the MFAR downstream of Ralston Dam. The primary objectives of the monitoring program are to:

- quantitatively evaluate project compliance with the water quality objectives established by the Central Valley Regional Water Quality Control Board in its Water Quality Control Plan (Basin Plan) (1998),
- quantitatively evaluate project effects on aquatic habitat based on changes or trends in streambed characteristics and BMI populations downstream of the reservoir (treatment area) relative to changes or trends in unaffected areas (control areas), and

- provide PCWA with the results of annual monitoring so that it can evaluate project effects and implement appropriate corrective measures if the data indicate that the sediment management project is adversely affecting water quality and aquatic resources in the MFAR.

This report presents the results of the second year of preproject monitoring for the sediment management project (2002). The first was conducted in 2001 in accordance with the Water Quality and Aquatic Resources Monitoring Plan (Jones & Stokes 2002b). Several revisions were made to the plan in 2002 to comply with permit requirements and agency requests, including:

- identification of target flows and conditions for triggering postproject monitoring and evaluation of SPT operations and sediment disposal at Indian Bar,
- surveying and pebble counts of the Indian Bar disposal site before and after significant entrainment events,
- evaluation of pebble counts as an alternative method for assessing the size composition of riffle substrates at aquatic habitat/BMI monitoring sites,
- modifications and additions to BMI sampling protocols to ensure consistency with the California Stream Bioassessment Procedure (CSBP),
- monitoring of channel cross sections at selected pools upstream and downstream of Ralston Afterbay, and
- continuous water temperature monitoring at the water quality monitoring stations.

The revised plan is contained in Appendix A of this report. In addition to the revisions discussed above, the plan includes a detailed description of the specific objectives, hypotheses, monitoring parameters, sampling design, and analytical methods for water quality, aquatic habitat, and BMI monitoring. The reach selection process, reach descriptions, and photographs are described in the 2001 annual report (Jones & Stokes 2002b).

2002 Monitoring Activities

Water Quality Monitoring

Water quality monitoring activities in 2002 included installing and testing water quality instruments, and training PCWA personnel for field monitoring of turbidity and suspended sediment. No water quality monitoring was conducted in 2001 or 2002 because flows were not high enough to meet the minimum requirements for preproject water quality monitoring.

Substrate Monitoring

Substrate size composition and embeddedness were measured in 2002 to evaluate preproject habitat conditions in each of the monitoring reaches established in 2001 (Table 1, Figure 3 in Appendix A). In 2001, substrate size composition and embeddedness were measured using the methods described by Bain (1999). In 2002, at the request of the California Department of Fish and Game (CDFG), the pebble count method was evaluated as an alternative method for characterizing the size composition of riffle substrates (Bunte and Abt 2001). Pebble counts are considered by CDFG to be a more reliable method for assessing particle size distributions in streams because they minimize potential biases resulting from visual selection of dominant particles.

Table 1. Aquatic Habitat and BMI Monitoring Reach Numbers, Locations, Purposes, and Transects

Reach	Location	Primary Purpose	Substrate Transects	BMI Transects
Reach 1	MFAR above Otter Creek	Treatment	1–8	1, 3, 7
Reach 2	MFAR above Volcano Creek	Treatment	9–15	9, 11, 13
Reach 3	MFAR between North Fork MFAR and Horseshoe Bar	Treatment	16–19	16, 18
Reach 4	MFAR between Ralston Afterbay Dam and North Fork MFAR	Treatment	20–24	20, 23
Reach 5	MFAR above Ralston Afterbay	Control	25–30	25, 27, 29
Reach 6	North Fork MFAR	Control	31–35	31, 33, 35
Reach 7	Rubicon River above Ralston Afterbay	Control	36–44	36, 40, 43

Pebble Count Evaluation

In October 2002, the pebble count method was evaluated by using both the Bain and pebble count methods at the six monitoring sites (transects) in the MFAR above Ralston Afterbay (Reach 5) (Figure 3 in Appendix A). The Bain method is described in the monitoring plan (Appendix A).

Pebble counts were conducted following the methods described by Bunte and Abt (2001). Starting at the same transect location as the Bain method, individual particles were sampled at regular intervals along the transect. The spacing between sampling points was set at the longest diameter (a-axis) of the largest particle to avoid double counting of large particles. A metal pin, held vertically at each sampling point, was lowered until it contacted the substrate. The first particle touched by the metal pin was selected. In areas where the bed was submerged, a facemask was used to identify particles that could not be clearly seen from above the water's surface. The selected particle was picked up and measured using a template with square holes ranging from 2 to 181 millimeters (mm) on a side (Wentworth scale). The particle's sieve diameter (D_S) was recorded in terms of the largest hole size through which the particle could not pass. If the particle could not be dislodged from the bed, a ruler was used to measure or approximate the length of the b-axis (the axis that defines D_S). The embeddedness of pebble and larger particles (>16 mm) was measured as the percentage of the total vertical extent of a particle below the bed surface. Embeddedness was characterized as negligible (<5%), low (5–25%), moderate (25–50%), high (50–75%), or very high (>75%).

For comparative purposes, the pebble count data for individual size classes (D_S) were combined to form size classes that were comparable to those of the Bain method. For example, the number of particles within the 16–22.6 mm, 22.6–32 mm, 32–45 mm, and 45–64 mm size classes were combined to form the pebble size class (16–64 mm) used in the Bain method (Table 2).

Table 2. Particle Size Classes

Particle Size	Bain Size Class (mm)	Wentworth Size Class (mm)
Sand, Silt, and Clay	<2	<2
Gravel	2–16	2–2.8, 2.8–4, 4–5.6, 5.6–8, 8–11.3, 11.3–16
Pebble	16–64	16–22.6, 22.6–32, 32–45, 45–64
Cobble	64–256	64–90.5, 90.5–128, 128–181, 181–256
Boulder	>256	>256

The results of the pebble count evaluation indicated that the pebble count method minimizes bias toward larger particles and provides a more sensitive measure of changes in fine sediment (see "Results"). Therefore, pebble counts were conducted in 2002 to measure substrate size composition and embeddedness at all of the substrate/BMI monitoring riffles established in 2001 (Table 1).

Pebble Counts

Pebble counts were conducted at all of the substrate/BMI monitoring riffles during October 7–19, 2002, when flows downstream of the Oxbow Powerhouse were at minimum levels (approximately 100 cfs).

The pebble count method was also used to measure the size composition of sediment deposited on Indian Bar in 2002. As part of the monitoring program, pebble counts will be used to monitor the composition of the sediment pile over time as flows erode the sediment and new sediment is added. In October 2002, three transects were established perpendicular to the longitudinal axis of the pile. The pile was divided into three segments of equal length, and one transect was randomly placed in each segment. Each transect started at the toe of the pile (nearest to the river), extended up the face of the pile, and ended at the far edge of deposited material. At each transect location, a measuring tape was laid on the surface of the pile and anchored at both ends with metal stakes. Pebble counts were conducted along each transect as described above.

Analytical Methods

Substrate size composition among reaches and years were compared graphically using frequency distributions and percentile values (D_{16}, D_{25}, D_{50}, D_{75}, and D_{84}). The percentile values are the particle sieve diameters for which a certain percentage of the sample is finer. For example, D_{50} is the median particle size because 50% of the sample is finer and 50% is coarser than this diameter. Percentile values were calculated using linear interpolation methods (Bunte and Abt 2001).

Benthic Macroinvertebrate Monitoring

In 2002, BMI riffle communities in each monitoring reach were characterized using a number of metrics that are commonly used as indicators of habitat quality to detect biological impacts resulting from human disturbance. In 2001, invertebrate density, taxa richness, invertebrate productivity, and EPT indices (described below) were used to characterize preproject BMI communities in the monitoring reaches. In 2002, California tolerance values, dominant taxa, and functional feeding groups were added in accordance with the CSBP. These metrics were also computed for the 2001 data for comparative purposes.

In 2002, several changes were made to the sampling and laboratory procedures to ensure consistency with the CSBP and California Aquatic Bioassessment Laboratory Network (CAMLnet) (California Department of Fish and Game 1999, 2003). The sampling design for the monitoring plan is generally consistent with the "non-point source sampling design" of the CSBP. The non-point source sampling design is appropriate for assessing the effects of sediment and other materials that enter streams over large areas rather than from a single point or points. However, the CSBP laboratory procedures differ from that used in 2001 in that the CSBP uses a fixed-count subsample (300 individuals) rather than the entire sample for computing various metrics. Because of potential biases associated with subsampling and concerns about the comparability of metrics generated from subsamples and whole samples, the results of three fully processed (whole) samples were compared with the results of smaller subsamples (300 and 500 individuals) to evaluate the comparability of 2001 and 2002 data.

The following metrics were used to characterize BMI communities in 2001 and 2002:

- **BMI Density:** BMI density is calculated by dividing the total number of invertebrates in a sample by the area of streambed sampled (number of individuals per square meter). Although BMI density can be highly variable and difficult to interpret (Karr and Chu 1999), this metric may be helpful in interpreting trends or changes in other variables (e.g., California tolerance values). This metric was calculated using the procedure described in the CSBP.

- **Taxa Richness:** Taxa richness describes the number of distinct taxonomic groups (family, genus, etc.) in a sample and is a measure of community structure. It is commonly used in bioassessment monitoring because it has been found to vary consistently and systematically with human influence (Karr and Chu 1999). Taxa richness for 2001 and 2002 was calculated using a revised methodology based on CAMLnet recommendations (California Department of Fish and Game 2003). Consequently, the 2001 taxa richness values in this report differ slightly from the values reported in the 2001 annual report (Jones & Stokes 2002b).

- **EPT Index:** EPT stands for the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The EPT index is calculated by dividing the number of individuals in these three orders by the total number of individuals in a sample. The orders included in the EPT index were selected because of their relative intolerance to human disturbance.

- **California Tolerance Value:** The California tolerance value is a metric based on the Hilsenhoff Biotic Index, which uses a set of taxon-specific tolerance values to calculate a community-level tolerance (California Department of Fish and Game 2003). The tolerance value is used as a general index of pollution and disturbance tolerance. Tolerance values range from 0 (highly intolerant) to 10 (highly tolerant); higher tolerance values indicate a greater amount of environmental disturbance. Like taxa richness, the percentages of tolerant and intolerant individuals in a sample have been found to vary consistently and systematically with human influence (Karr and Chu 1999).

- **Dominant Taxa:** Dominant taxa are taxonomic groups (family, genus, or species) that are highly abundant in a community relative to other taxa. Dominant taxa are typically generalists that occur in great abundance throughout their range. The level of dominance of these taxa can be an indicator of the level of disturbance in aquatic systems. The abundance of the most dominant taxon in a habitat is expected to increase in response to environmental disturbance or impairment. A relatively undisturbed environment would be expected to have a more even distribution of taxa in the community. The relative abundance of the five most dominant taxa, calculated by dividing the number of individuals of each taxon by the total number of individuals in the sample, was calculated for each monitoring reach.

- **Functional Feeding Groups:** Functional feeding groups are groups of taxa that are similar in the way they obtain food. The relative abundance of different functional feeding groups has been found to be a useful indicator of community structure and composition. CDFG developed a list of California taxa and grouped them into the following major categories: predator, collector-gatherer, collector-filterer, scraper, shredder, and others. The category “others” includes parasites, macrophyte herbivores, piercing herbivores, omnivores, and wood eaters.

BMI productivity, computed in 2001, was not computed in 2002. In 2001, BMI productivity was calculated by measuring the mass of all invertebrates in each sample and dividing by the area of streambed sampled. The decision to exclude BMI productivity from the monitoring variables for 2002 was based on a review of the potential sources of error associated with this metric and the large amount of effort required to process samples. In addition, the effects of human disturbance do not have a consistent effect on productivity. For example, productivity can increase in response to a disturbance that reduces the abundance of predators, resulting in increases in the abundance and biomass of prey species. Conversely, productivity can decrease in response to a disturbance that reduces the amount of food available for growth and reproduction.

Field Sampling Methods

In 2002, BMI samples were collected at the same sites (riffle locations) and in the same months (June, August, and October) as 2001, with one exception (Table 1). Transect 17 in Reach 3 was not sampled in 2002 because a riffle habitat with sufficient water velocity for BMI sampling (>1 meter per second) was not present at the time of sampling. Transect 17 was originally selected for BMI monitoring at a higher flow when riffle habitat was present. Reach 3 could not be safely or effectively sampled at the flows that occurred at the time of sampling in June and August 2001 (433 and 772 cfs, respectively). Therefore, sampling of Reach 3 in June, August, and October 2002 was timed to coincide with periods of minimum flow (approximately 100 cfs). At this flow, however, most of Transect 17 occurs in slow water upstream of the riffle crest. In October 2001, benthic invertebrates collected at this transect (at a flow of approximately 100 cfs) were primarily species common to lentic (slack water) habitats, which are not comparable to the lotic (flowing water) species collected at other monitoring sites.

BMI samples were collected in the field according to the CSBP non-point source sampling design (California Department of Fish and Game 1999). A square-frame kick net with 500-micrometer Nitex mesh was used to collect benthic invertebrates from three 1- by 2-foot areas along each transect. Samples were placed in Corning Snap-Seal™ jars containing 90% ethanol. Labels indicating the reach, site, stream, and date were placed in each sample jar and on each lid. Samples were then transferred to the laboratory, and a standardized chain-of-custody form was used to track each sample transfer.

Laboratory Methods

Each BMI sample was processed according to the CSBP Professional (Level 3) Laboratory Procedures. Invertebrates were distributed evenly in a tray marked with a 1- by 1-inch square grid. Invertebrates were then removed and counted from randomly selected grids until 300 individuals were removed. Each 300-individual subsample was stored in 70% ethanol and labeled with the original sample data and subsample size. Each invertebrate in the 300-individual subsamples was identified to the required standard taxonomic level. In January 2003, CDFG's Aquatic Bioassessment Laboratory revised the standard taxonomic effort for California (California Department of Fish and Game 2003). Accordingly, the BMI data obtained from the Ralston monitoring sites were adjusted to be consistent with California standards. Specifically, Chironomid midges are now identified to family and Oligochaeta worms are identified to class. Taxonomic data were recorded on standardized data sheets along with subsample size, number of grids picked, and number of invertebrates in each grid.

Analytical Methods

Biological community composition and community richness metrics were compared graphically among reaches, years, and seasons. Composition values, including EPT abundance and functional feeding group distribution, were calculated for each reach by averaging the riffle values. Taxa richness values were calculated for each reach by combining the taxonomic list of the representative riffle transects. Because BMI density is presented per unit area, the density values for each reach are an average value of the three corresponding transects. The analytical methods were consistent with CSBP standards.

Taxonomic Validation

After all 57 samples (representing 57 monitoring sites) were processed, six samples (approximately 10%) were randomly selected for taxonomic validation. These samples, with approximately 300 individuals in each, were sent to EcoAnalysts, Inc., in Moscow, Idaho. Mark Walters of EcoAnalysts conducted an independent taxonomic inventory of the six samples, counting and identifying each invertebrate to standard taxonomic level. The results of the two independent evaluations were then compared to determine whether the taxonomic identifications made by Jones & Stokes taxonomists were consistent with identifications made by EcoAnalysts. The two reviewing taxonomists, Mr. Walters and Patrick Stone of Jones & Stokes, then discussed the results of the validation to resolve all remaining discrepancies.

Subsampling Evaluation

The adequacy of a 300-individual subsample was evaluated by comparing the metric values based on two levels of subsampling (300 and 500 individuals) to the values based on entire samples. Three BMI samples collected in June 2002 from Transects 7 (Reach 2), 25 (Reach 5), and 35 (Reach 6) were selected for the evaluation. Total sample sizes were 4,508, 1,690, and 959 individuals, respectively. The three samples were initially processed according to the CSBP as described above. After 300 individuals were removed from each sample, the same method was used to remove an additional 200 individuals from the remainder of the sample. Finally, the remaining invertebrates in each sample were removed and counted. The individuals in each subsample portion were identified to the standard taxonomic level. BMI metrics were computed for each sample size.

Water Temperature Monitoring

In July 2001, at the request of the U.S. Department of Agriculture (USDA) Forest Service, automated water temperature loggers (Onset Corporation Optic StowAway Temp®) were installed in the MFAR below Ralston Afterbay (at the Foresthill gage), MFAR above Ralston Afterbay (approximately 0.5 mile upstream of its confluence with the Rubicon River), North Fork MFAR (approximately 2.2 miles upstream of its confluence with the MFAR), and Rubicon River (approximately 0.5 mile upstream of Ralston Powerhouse). The loggers were programmed to continuously record water temperatures every hour. The loggers are capable of measuring temperatures from 24–99°F with an accuracy of ±0.40–0.44°F.

Channel Cross Section Monitoring

Stream and laboratory studies have shown that excessive amounts of fine sediments can reduce the quality of aquatic habitat and capacity of a stream or reach to support fish and aquatic invertebrates (Hicks et al. 1991, Waters 1995). In addition, the filling of pools with sediment can also reduce the amount of resting, foraging, and refuge habitat for fish and other aquatic organisms (Bjornn et al. 1977).

In 2002, the USDA Forest Service and CDFG requested monitoring of channel cross sections downstream of Ralston Afterbay to detect potential deposition of sediment in pools during the postproject monitoring period. Past monitoring of streambed elevations and channel contours near the U.S. Geological Survey Foresthill gage by PCWA has shown that the channel downstream of Ralston Afterbay has been deepening since 1981 in response to a lack of sufficient sediment to offset channel losses during high-flow events (Stiehr pers. comm.). With an increase in the amount of sediment available to this reach in future years as a result of the sediment management project, this trend may reverse and lead to reductions in the amount of pool habitat available to fish and aquatic invertebrates.

Because the potential for filling of pools is highest in the depositional reaches selected for substrate and BMI monitoring, channel cross section monitoring locations were established in several representative pools in the MFAR near Otter and Volcano Creeks (Reaches 1 and 2) and the Rubicon River (Reach 7) (Figure 3 in Appendix A). In October 2002, standard surveying techniques were used to measure channel cross sections in two pools in Reach 1, two pools in

Reach 2, and two pools in Reach 7. One transect was established in the deepest portion of each pool. All transect locations were marked in the field with permanent benchmarks (expandable anchors drilled into bedrock). Site maps were drawn for each transect location.

Measurements were taken with an auto level and stadia rod. Measurements were first taken above the low-flow channel at an average horizontal distance of approximately 10 feet and average vertical distance of approximately 5 feet from the water surface. Measurements were taken every 2 feet along the transect to produce a detailed cross section of channel at each location. In some cases, measurements were taken at more frequent intervals to accurately define changes in channel contours associated with bedrock ledges, large rocks, and other significant features.

Results

Substrate Monitoring

Pebble Count Evaluation

The results of the pebble count and Bain method, applied to each transect in Reach 5, are compared in Figure 2. In most cases, the Bain method resulted in particle size distributions with smaller proportions of fines and gravel, and larger proportions of pebbles and cobbles. Therefore, compared to the pebble count method, the Bain method underestimates the proportion of small particles and overestimates the proportion of large particles. This apparent bias may result from the tendency for observers to choose large particles over small ones, especially when visually selecting the dominant particle size within a given area of streambed (Bunte and Abt 2001). The pebble count method reduces this potential bias because the observer selects the first particle contacted by a pin that is dropped vertically at each sampling point along the transect. In addition, the pebble count method provides a more complete characterization of particle embeddedness because each selected particle (gravel and larger particles) receives a score; the Bain method results in a single score for particles in the deepest part of the channel only. Although the pebble count method requires more time than the Bain method, the pebble count method appears to be more sensitive to changes in fine sediment and therefore better able to detect potential project effects. Therefore, the pebble count method was used in 2002 and will be used in future monitoring years to characterize substrate size composition and embeddedness.

Substrate Composition and Embeddedness

The size distribution of riffle substrates measured in each monitoring reach in 2002 is shown in Figure 3. Riffle substrates were dominated by cobbles and boulders (>64 mm diameter), which represented 56–83% of the total samples in

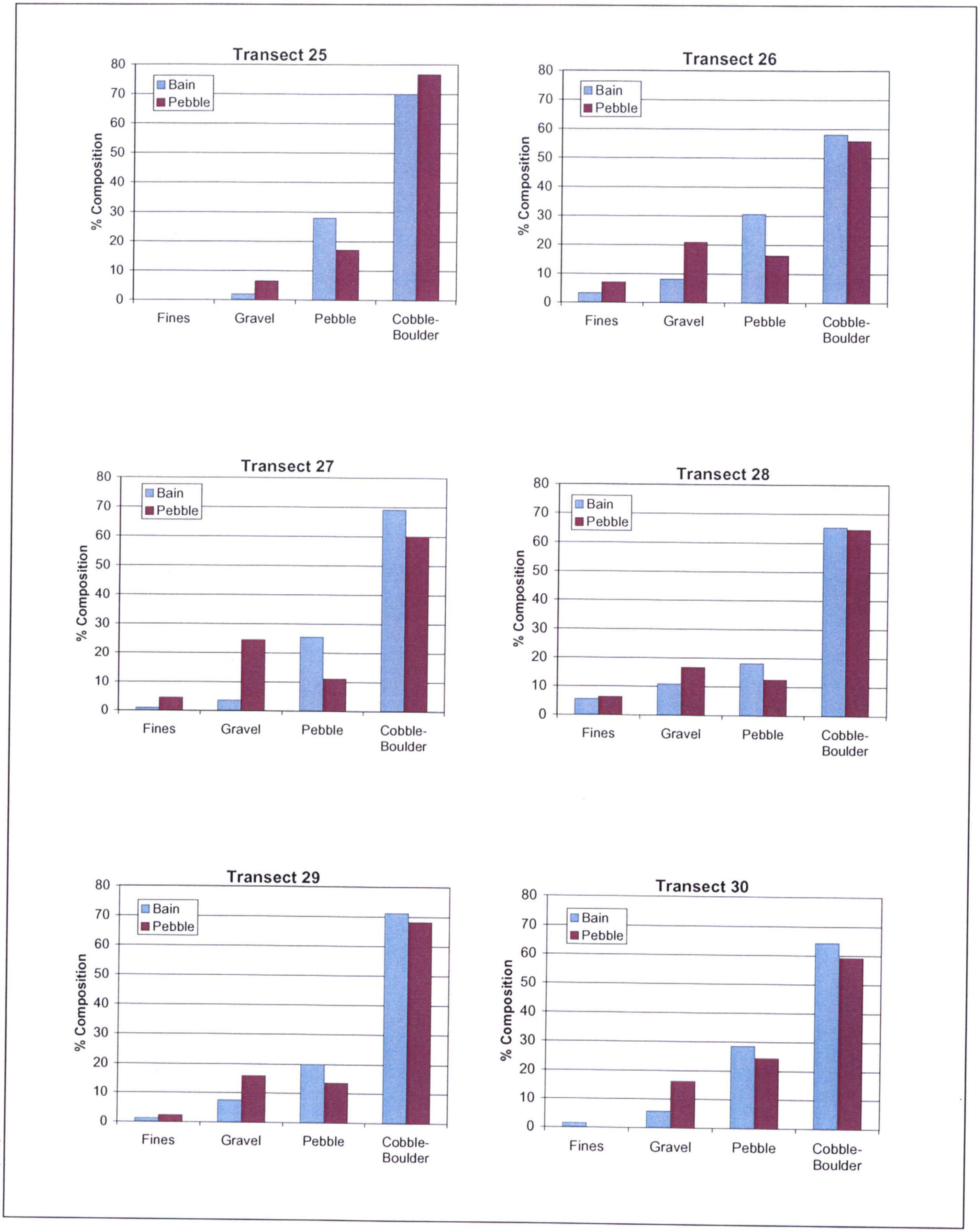


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Figure 2
Size Composition of Riffle Substrates Based on Pebble Counts and Bain Method

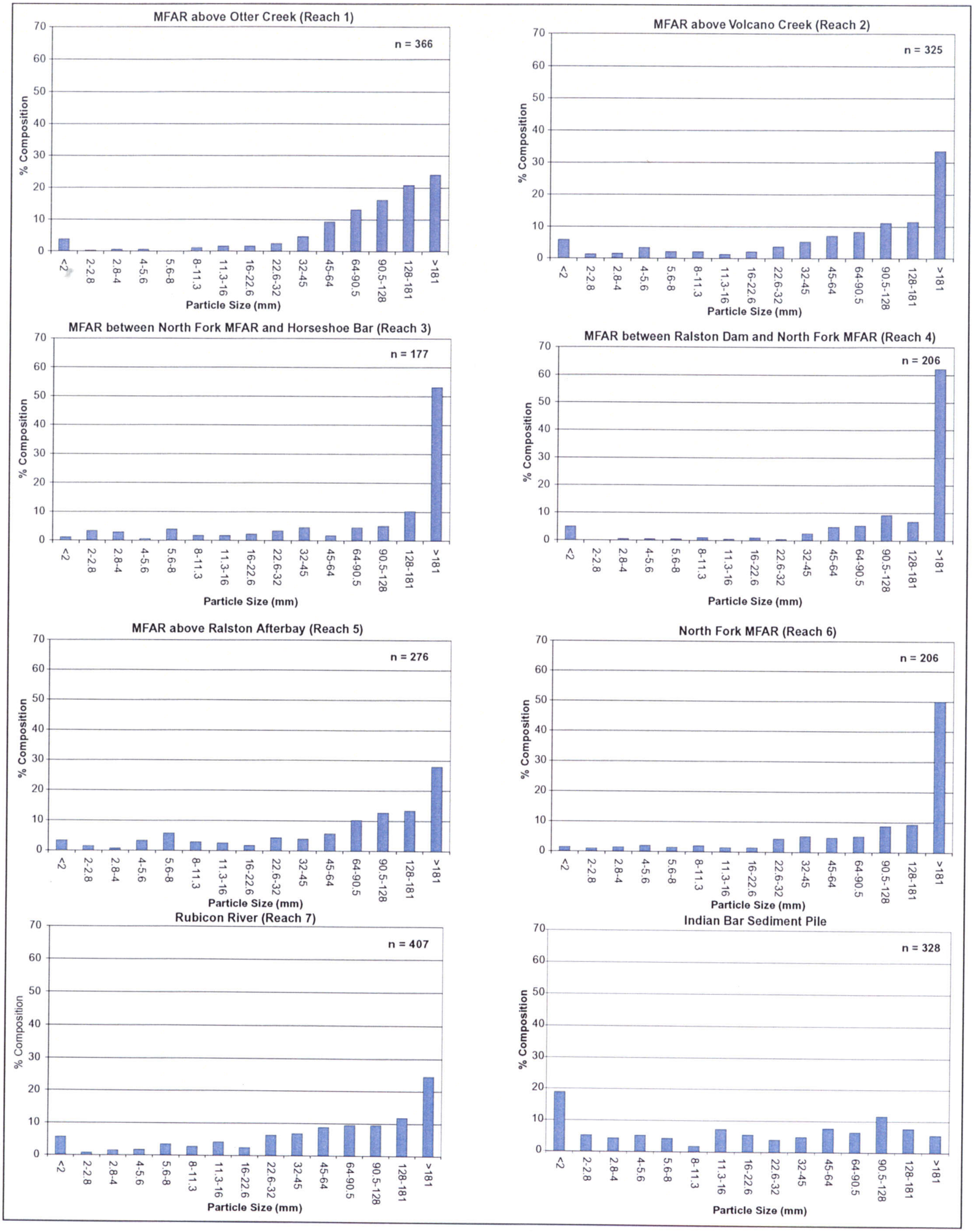

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Figure 3
Size Composition of Substrates in Monitoring Riffles and Indian Bar Sediment Pile in 2002

each reach. The most common size classes in all reaches were large cobbles and boulders (>181 mm diameter), which represented 24–62% of the reach totals. Among the treatment reaches, the proportion of large cobbles and boulders in riffles downstream of Ralston Dam increased with increasing proximity to the dam, with the lowest proportion in Reach 1 (24%) and the highest in Reach 4 (62%). Among the control reaches, Reach 6 had the highest proportion of large cobbles and boulders (50%). Reaches 5 and 7 had similar proportions (24–28%). Small cobbles, gravel, and sand (<2–16 mm diameter) represented 8–20% of the reach totals.

The D_{16}, D_{25}, D_{50}, D_{75}, and D_{84} particle sizes (particle sizes for which a certain percentage of the sample is finer) for the monitoring reaches and Indian Bar are shown in Figure 4. The median percentile values (D_{50}) for the treatment reaches immediately below Ralston Dam (Reaches 3 and 4) and in the control reach in the North Fork MFAR (Reach 6) were the highest of all reaches, ranging from 181–194 mm (large cobble). In contrast, the median percentile values for the treatment reaches near Otter and Volcano Creeks (Reaches 1 and 2) and in the control reaches in the MFAR and Rubicon Rivers above Ralston Afterbay (Reaches 5 and 7) ranged from 78–114 mm (small cobble). The Rubicon River (Reach 7) had the lowest D_{50} (78 mm), reflecting higher proportions of small cobbles and pebbles compared to other reaches.

The size distributions of riffle substrates measured in each reach in 2001 and 2002 are shown in Figure 5. For comparative purposes, the pebble count data collected in 2002 for individual size classes were combined to form size classes that were comparable to those of the Bain method (Table 2).

In general, the 2001 and 2002 particle distributions were similar, with cobbles and boulders composing the majority the samples. In most cases, the proportion of gravel and fine sediments measured in 2001 was somewhat lower than in 2002 and the proportion of larger particles (cobble and boulder) somewhat higher. This general pattern, however, is the same pattern observed when the Bain method and pebble counts are applied to the same transects (Figure 2). This suggests that the differences in particle size distributions between 2001 and 2002 are largely the result of using different methods and that the actual differences in particle distributions are smaller than shown in Figure 5. Therefore, there appears to have been little or no change in the size composition of riffle substrates in any of the reaches between fall 2001 and fall 2002.

The particle embeddedness of riffles in each monitoring reach was generally low, with most particles (75–90% of the reach totals) classified as either <5% to 5–25% embedded (Figure 6). Particles that received moderate, high, and very high values composed 3–17%, 3–8%, and 0 5% of the reach totals, respectively. Although the 2001 and 2002 embeddedness data are not directly comparable, the particle size data and our general observations indicate that that there were no major changes in embeddedness between 2001 and 2002.

The particle size distribution, associated percentile values, and embeddedness of the surface layer of the Indian Bar sediment pile are shown in Figures 3, 4, and 6. Pebble counts indicate that the pile is composed of a relatively even distribution of particle sizes ranging from sand to large boulders. The major size classes (sand, gravel, pebble, cobble/boulder) contributed 19%, 28%, 22%, and 31% of the total pebble count.

Benthic Macroinvertebrate Monitoring

Subsampling Evaluation

BMI density, EPT index, and taxa richness values based on 300-individual, 500-individual, and whole samples are shown in Figure 7.

Estimates of BMI density based on 300- and 500-individual subsamples were generally comparable to those based on whole samples. The results indicate that subsampling is most reliable when densities are less than 2,000 individuals. The estimate of BMI density based on the 300-individual subsample was 31% lower than the whole-sample estimate (Transect 7). Despite the reduced accuracy, the 300-individual subsample was sufficient to detect the higher densities at Transect 7 relative to other transects.

EPT index values based on 300- and 500-individual subsamples were consistent with the values generated from whole samples at all sites (Figure 7). This was true for all measures of relative abundance (EPT index, dominant taxa, California tolerance values, and functional feeding groups) and supports the general conclusion that measures of relative abundance or percent composition are relatively insensitive to sample size (Barbour and Gerritsen 1996, Vinson and Hawkins 1996).

Based on comparisons with whole samples, 300- and 500-individual subsamples were not adequate to describe the differences in taxa richness between sites (Figure 7). The numbers of taxa continued to increase with increasing sample size, with the largest differences observed for Transect 7. This relationship is a common phenomenon resulting from the tendency for samples to include larger numbers of taxa with increasing sample size or area (Vinson and Hawkins 1996).

Based on these results, it was concluded that 300-individual subsamples are adequate for describing differences or trends in BMI community composition and relative abundance of taxa among sites, seasons, and years. Consequently the EPT index, dominant taxa, California tolerance values, functional feeding group, and BMI density served as the primary metrics for examining these differences and trends in 2001 and 2002. Although it is not a reliable measure of reach or temporal (seasonal or annual) differences in BMI communities, taxa richness was used as a general indicator of the community diversity.

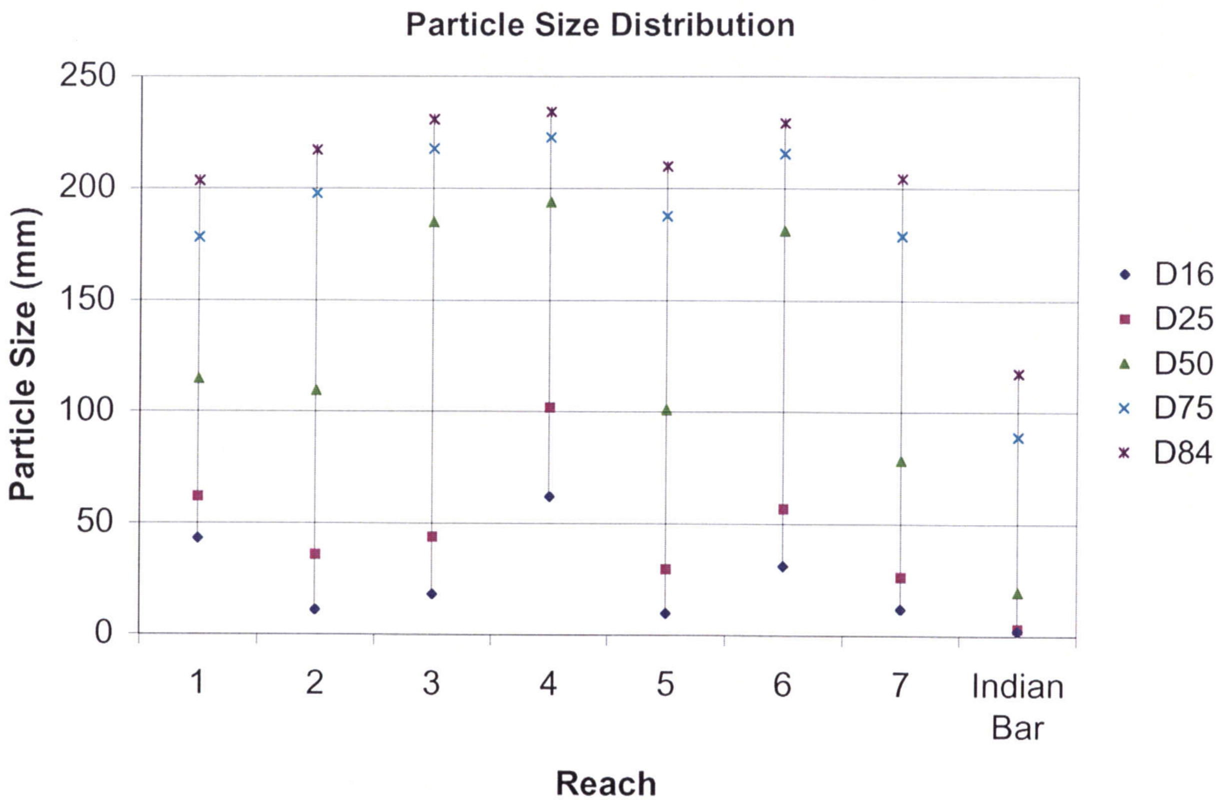

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Figure 4
Particle Size Distributions of Substrates in Monitoring Riffles and Indian Bar Sediment Pile in 2002

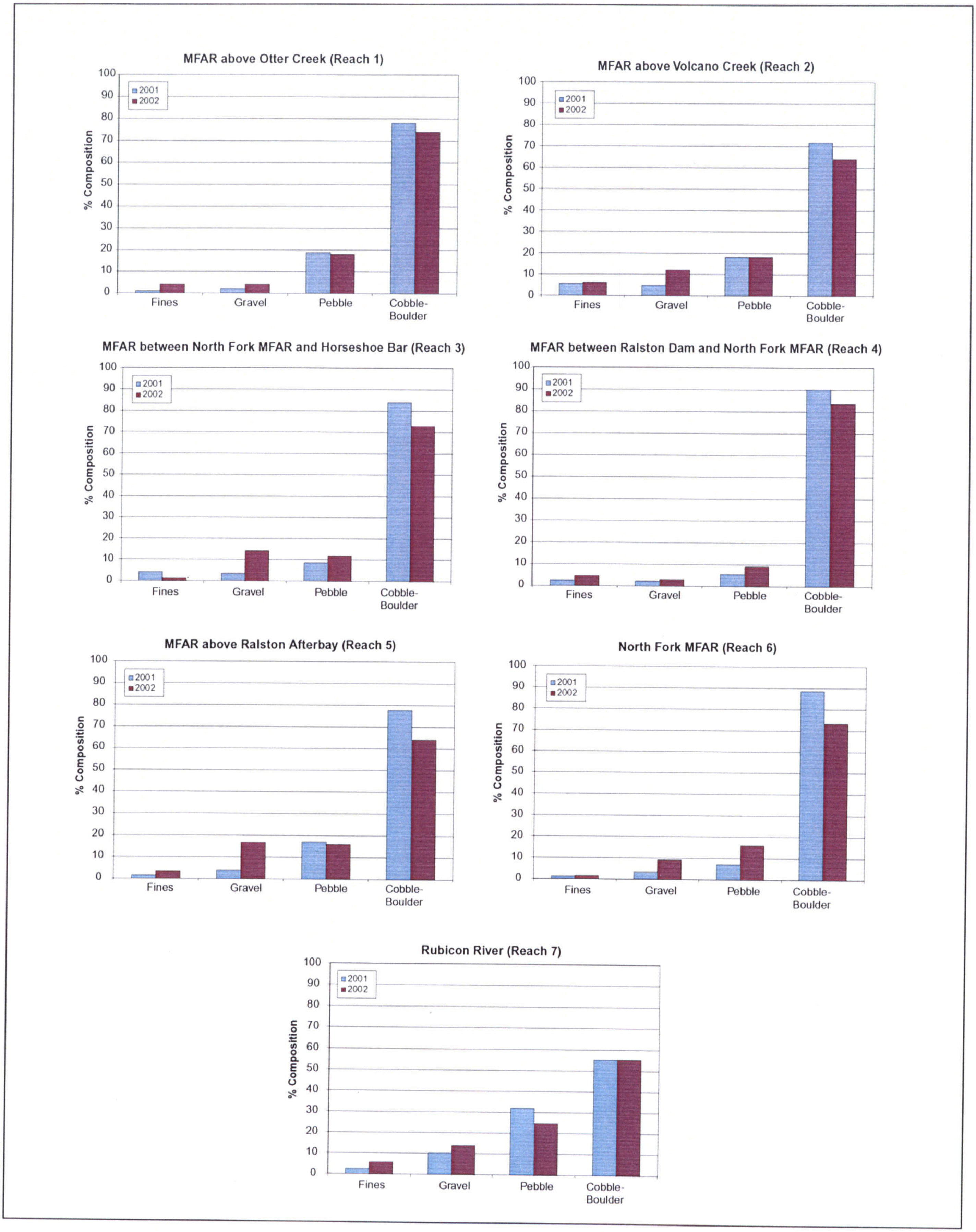

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Figure 5
Size Composition of Substrates in Monitoring Riffles in 2001 and 2002

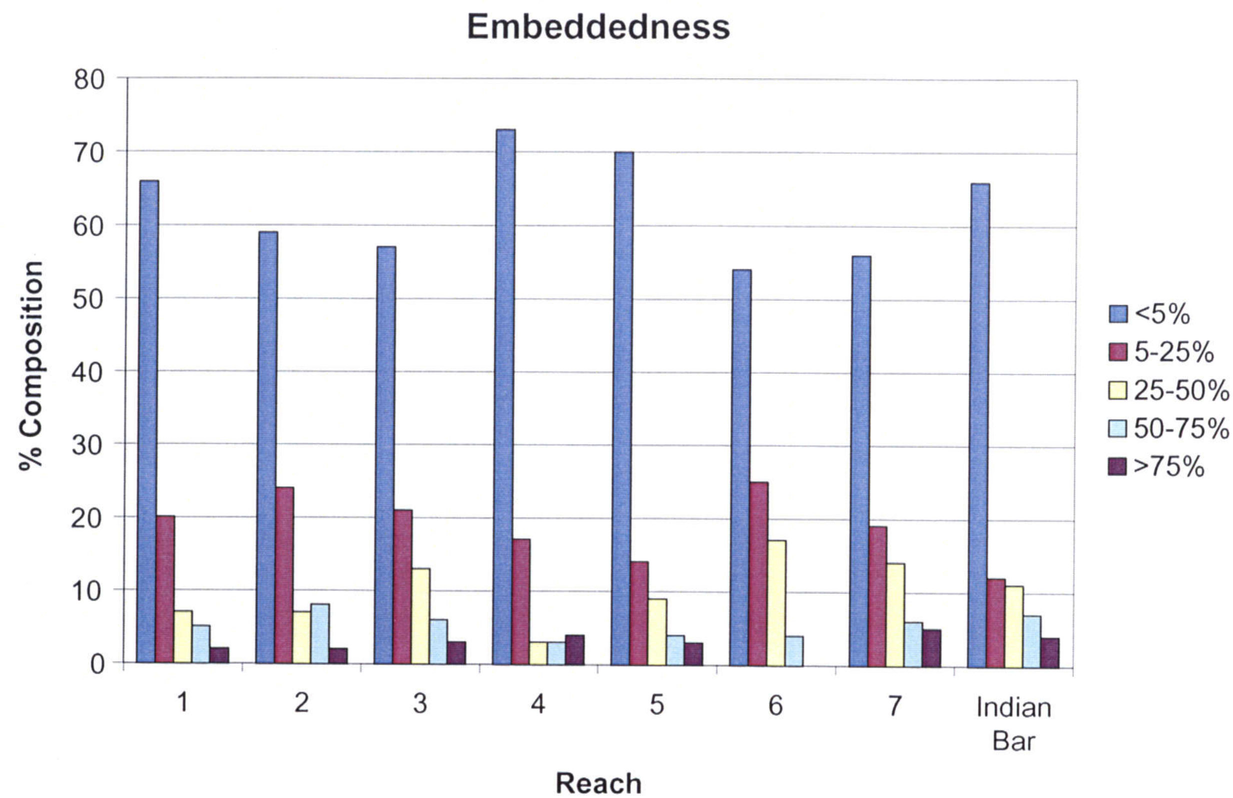

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Figure 6
Particle Embeddedness of Substrates in Monitoring Riffles and Indian Bar Sediment Pile in 2002

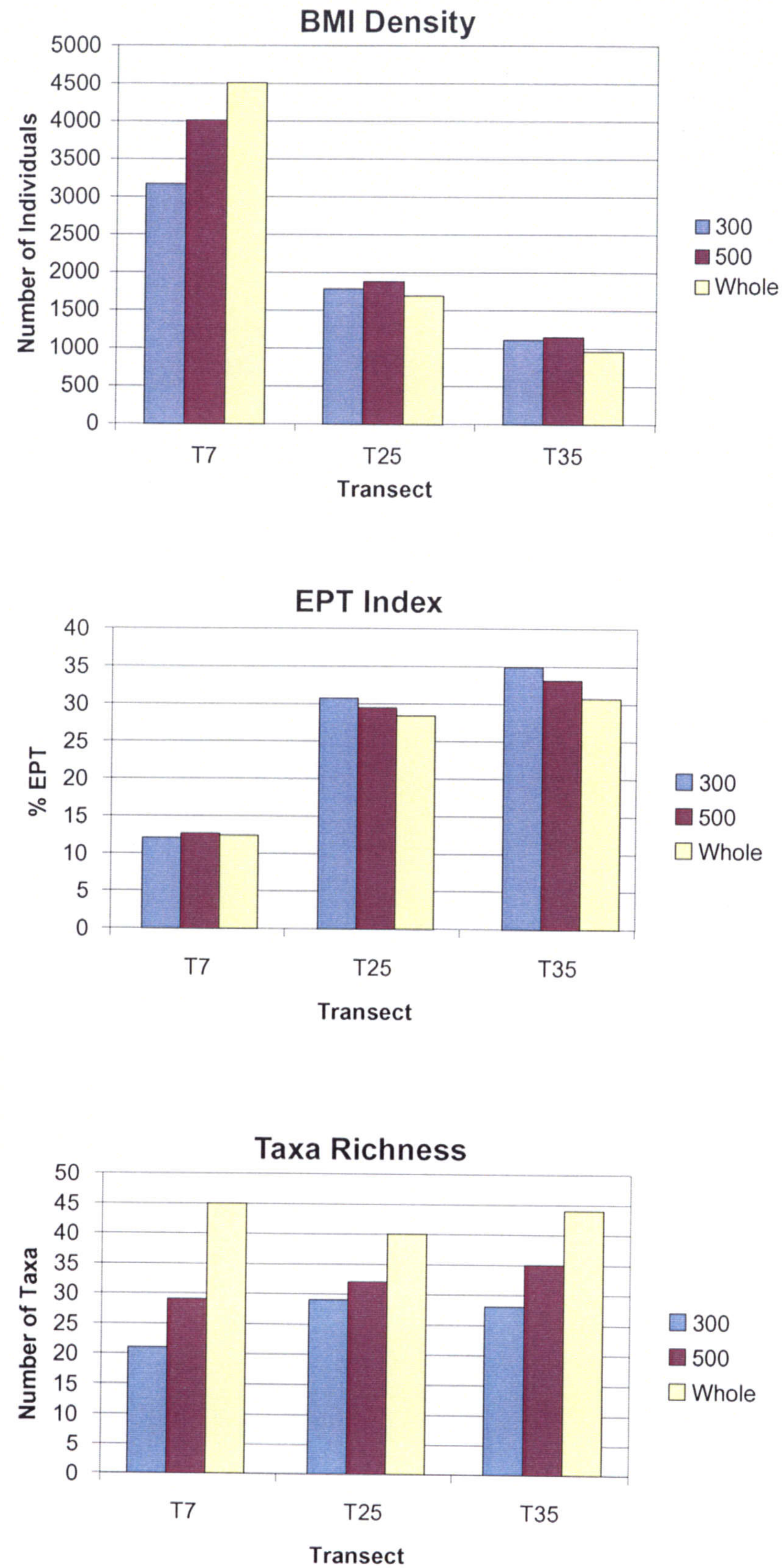

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Figure 7
BMI Density, EPT Index, and Taxa Richness Values Based on 300-Individual, 500-Individual, and Whole Samples

Benthic Macroinvertebrate Metrics

Benthic Macroinvertebrate Density

In 2002, BMI densities were highly variable between reaches and seasons, ranging from 1,894–7,813 individuals (Figure 8). No clear longitudinal (upstream to downstream or control versus treatment reaches) or seasonal patterns were evident. BMI densities were substantially lower at all monitoring reaches in 2001, ranging from 454–3,992 individuals (excluding Reach 3, in which sampling difficulties were encountered) (Figure 8).

EPT Index

In 2002, the lowest EPT values occurred in August and October in the reaches immediately below Ralston Dam (Reaches 3 and 4) (7.7–20.5% and 9.5–16%) (Figure 9). Reach 4 had consistently low values in all sampling months. Reaches 5–7 (control reaches) generally had higher EPT values than Reaches 1–4 (treatment reaches) in June and August. In October, EPT values in Reaches 1–4 decreased in an upstream direction, with the highest values occurring in Reach 1 and the lowest in Reach 4. The same general trends were observed in 2001 (Figure 9).

Taxa Richness

Taxa richness in all monitoring reaches ranged from 16–57 taxa per reach in 2001 (excluding Reach 3) and 28–45 taxa per reach in 2002 (Figure 10).

California Tolerance Value

In 2002, community tolerance values for all reaches and seasons ranged from 3.1–5.4 (Figure 11). Reach 4 had the highest California tolerance values in all sampling months (5.3–5.4), reflecting the dominance of Chironomidae midges (Table 3), a taxon known to tolerate a relatively high degree of environmental disturbance or impairment.

The tolerance values computed for Reach 7 were relatively low in June and August, but increased a full point in October. This increase, marked by the appearance of Chironomidae midges as the dominant taxon (Table 3), could be the result of suction dredge mining, which altered the channel and disturbed a portion of the streambed in summer 2002.

The community tolerance values computed in 2002 were very similar to those in 2001 (Figure 11). In 2001, community tolerance values for all reaches and seasons ranged from 3.0–5.4, with the highest values occurring in Reaches 3 and 4. As in 2002, relatively high tolerance values resulted primarily from the dominance of Chironomidae midges (Table 4). In addition, the tolerance value in

Reach 7 again exhibited a marked increase in October, presumably in response to mining activities in this reach.

Functional Feeding Group Composition

In 2002, collector-gatherer was the dominant functional feeding group in each monitoring reach except Reach 1 (Figure 12). The dominance of collector-gatherers was primarily because of the relatively large numbers of *Baetis* mayflies, Chironominae midges, and Orthocladiinae midges (Table 3). In contrast, collector-filterer was the dominant feeding group in Reach 1 because of the dominance of *Simulium* blackflies and *Hydropsyche* caddisflies. The relative abundance of collector-gatherers was highest in Reaches 3 and 4, in which they comprised 62–76% of the June, August, and October samples. The relative abundance of collector-gatherers in the remaining reaches was generally less than 60% in all months. Although seasonal differences were evident, Reaches 2, 5, and 6 exhibited the most similarity in functional feeding group composition.

In 2001, collector-gatherers dominated Reaches 2–6 because of the dominance of many of the same taxa observed in 2002 (Figure 13). In Reach 1, collector-filterer was also the dominant feeding group, but relatively large numbers of collector-gatherers (*Baetis* and Chironominae) occurred in June. Other notable differences between 2001 and 2002 were the higher proportions of "other" taxa in 2001, including *Brachycentrus* caddisflies (an omnivore) in Reach 2 and *Hydroptila* (a piercing herbivore) in Reach 4.

Dominant Taxa

Baetis was a dominant taxon in almost every sample collected in 2001 and 2002 (Tables 3 and 4). In 2002, this taxon accounted for more than 25% of each June sample from Reaches 2, 3, 5, 6, and 7. Chironominae was rarely the most dominant taxon of a sample (only in Reaches 4 and 7 in August) but was one of the five most dominant taxa in every sample from Reaches 4, 5, and 6 in both 2001 and 2002. In 2002, Orthocladiinae was a highly dominant taxa in Reaches 2, 6, and 7 in August and October, and in Reaches 3, 4, and 5 in all three seasons. Orthocladiinae was extremely abundant in Reaches 2 and 4 in August 2001, where it represented a full 40% of the sample.

Two other taxa were commonly found in large abundance: *Hydropsyche* (Hydropsychidae:Trichoptera) and *Ochrotrichia* (Hydroptilidae:Trichoptera). *Hydropsyche* is a filter feeding caddisfly that is relatively common throughout the Sierra Nevada. This taxon was abundant in samples from Reaches 1, 2, 6, and 7, but was significantly rare or absent from Reaches 3 and 4. Hydrospyche was also less dominant in Reaches 5 and 7 in 2002 than in 2001. *Ochrotrichia* is a very small caddisfly that is classified as a piercing herbivore, meaning that it feeds by piercing individual plant cells and extracting the nutrients. *Ochrotrichia* therefore only occurs in communities with abundant hydrophytic vegetation or aquatic root systems, such as seen with alders (*Alnus* spp.) growing on undercut

Table 3. Dominant Taxa and Relative Abundance by Reach and Month, 2002

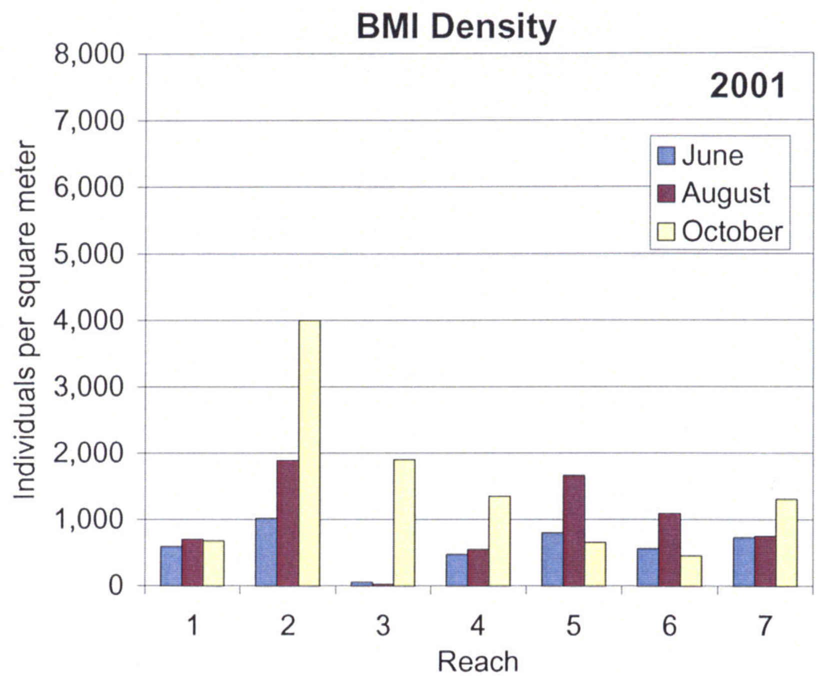
	June		August		October	
Rank	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)
Reach 1						
1	*Simulium*	50.33	*Hydropsyche*	26.06	*Hydropsyche*	28.22
2	*Baetis*	14.63	*Baetis*	16.67	*Rhithrogena*	16.91
3	*Glossosoma*	6.32	*Simulium*	12.98	*Baetis*	7.17
4	*Hydropsyche*	5.10	*Epeorus*	9.17	Chironominae	6.05
5	*Epeorus*	4.32	Simuliidae pupae	5.03	Orthocladiinae	4.93
Reach 2						
1	*Baetis*	36.27	*Baetis*	17.39	Orthocladiinae	18.46
2	*Simulium*	24.89	Orthocladiinae	16.95	*Hydropsyche*	11.23
3	*Epeorus*	4.02	*Hydropsyche*	7.25	*Baetis*	9.57
4	*Serratella*	3.91	*Glossosoma*	6.47	*Rhithrogena*	8.79
5	Lumbriculidae	3.35	*Antocha*	5.35	*Isoperla*	8.57
Reach 3						
1	*Baetis*	37.75	Orthocladiinae	56.73	Naididae	27.44
2	Orthocladiinae	13.93	*Baetis*	6.81	Orthocladiinae	13.13
3	*Epeorus*	10.07	*Antocha*	5.79	*Baetis*	7.41
4	*Optioservus*	3.86	Chironomidae pupae	4.26	*Serratella*	7.07
5	*Hydropsyche*	3.86	*Simulium*	3.75	Chironominae	6.73
Reach 4						
1	Chironominae	32.55	Orthocladiinae	46.79	Chironominae	21.18
2	*Baetis*	14.67	Chironominae	11.32	Orthocladiinae	19.50
3	*Gyraulus*	9.61	Naididae	7.09	*Simulium*	9.08
4	Orthocladiinae	5.90	*Hydroptila*	6.08	*Acentrella*	8.91
5	*Serratella*	4.89	Chironomidae, not distinct	4.22	*Gyraulus*	6.55
Reach 5						
1	*Baetis*	25.78	*Ochrotrichia*	18.82	*Baetis*	21.41
2	Chironominae	15.29	*Baetis*	18.15	Chironominae	13.45
3	*Ochrotrichia*	11.72	*Simulium*	11.69	*Hydropsyche*	12.22
4	*Acentrella*	8.26	Chironominae	8.69	Orthocladiinae	5.04
5	Orthocladiinae	5.80	Orthocladiinae	6.68	*Epeorus*	4.48

	June		August		October	
Rank	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)
Reach 6						
1	*Baetis*	27.28	*Ochrotrichia*	23.87	*Rhithrogena*	18.26
2	Chironominae	14.66	*Baetis*	9.12	*Baetis*	11.95
3	*Ochrotrichia*	7.55	Chironominae	8.45	Chironominae	10.26
4	*Hydropsyche*	6.31	Orthocladiinae	8.22	Orthocladiinae	8.68
5	*Antocha*	5.98	*Helicopsyche borealis*	6.42	*Hydropsyche*	7.22
Reach 7						
1	*Baetis*	33.15	*Baetis*	15.94	Chironominae	18.86
2	*Epeorus*	12.24	*Hydropsyche*	15.61	*Baetis*	12.46
3	*Hydropsyche*	12.01	*Epeorus*	14.16	*Hydropsyche*	7.07
4	*Serratella*	5.45	*Serratella*	7.58	*Psephenus falli*	6.96
5	*Glossosoma*	4.78	Orthocladiinae	6.80	Orthocladiinae	6.85

Table 4. Dominant Taxa and Relative Abundance by Reach and Month, 2001

	June		August		October	
Rank	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)
Reach 1						
1	*Baetis*	29.71	*Hydropsyche*	19.19	*Hydropsyche*	28.38
2	*Hydropsyche*	10.76	*Epeorus*	18.33	*Rhithrogenia*	15.45
3	*Simulium*	7.56	*Simulium*	13.30	*Glossosoma*	14.71
4	*Brachycentrus*	6.98	Chironominae	10.43	Chironominae	12.48
5	*Glossosoma*	6.58	*Baetis*	4.35	Orthocladiinae	3.42
Reach 2						
1	*Brachycentrus*	29.77	*Brachycentrus*	23.08	Orthocladiinae	39.48
2	*Simulium*	14.69	Orthocladiinae	19.33	Naididae	18.84
3	Orthocladiinae	11.76	Chironominae	15.58	Chironominae	9.82
4	*Baetis*	10.61	*Hydropsyche*	8.85	Ephemerellidae	7.41
5	*Serratella*	5.06	*Baetis*	5.45	*Baetis*	3.41
Reach 3						
1	Lumbriculidae	81.82	Lumbriculidae	68.75	Naididae	37.34
2	*Simulium*	2.10	Orthocladiinae	14.06	Chironominae	13.08
3	Orthocladiinae	2.10	*Turbellaria*	6.25	*Simulium*	8.23
4	*Antocha*	2.10	Elmidae	3.13	Orthocladiinae	6.75
5	Chironominae	1.40	Chironominae	1.56	*Ephemerella*	5.38
Reach 4						
1	*Hydroptila*	19.62	Chironominae	21.01	Orthocladiinae	40.67
2	*Simulium*	16.21	Orthocladiinae	17.76	*Simulium*	15.67
3	*Brachycentrus*	10.58	*Hydroptila*	14.26	Chironominae	11.69
4	Orthocladiinae	9.77	*Ochrotrichia*	6.75	*Acentrella*	2.11
5	Chironominae	8.07	*Optioservus*	5.63	*Antocha*	1.12
Reach 5						
1	Chironominae	24.45	*Ochrotrichia*	38.45	Chironominae	17.47
2	*Ochrotrichia*	16.51	Chironominae	13.53	Orthocladiinae	12.89
3	*Baetis*	6.27	*Hydropsyche*	6.68	*Baetis*	11.29
4	*Hydropsyche*	6.02	*Epeorus*	5.92	*Hydropsyche*	7.70
5	Orthocladiinae	5.27	Orthocladiinae	4.91	*Cheumatopsyche*	5.57

	June		August		October	
Rank	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)	Taxa	Relative Abundance (%)
Reach 6						
1	*Ochrotrichia*	39.68	*Ochrotrichia*	19.04	*Hydropsyche*	15.64
2	Orthocladiinae	6.38	Chironominae	14.45	Chironominae	11.89
3	*Hydropsyche*	6.32	*Hydropsyche*	7.73	Orthocladiinae	10.13
4	*Baetis*	4.06	Orthocladiinae	6.96	*Baetis*	6.83
5	Chironominae	3.94	*Baetis*	6.32	*Cheumatopsyche*	6.39
Reach 7						
1	*Hydropsyche*	19.70	*Hydropsyche*	22.07	*Hydropsyche*	25.85
2	*Epeorus*	13.10	*Epeorus*	17.61	Chironominae	13.23
3	*Baetis*	10.89	*Serratella*	8.94	*Baetis*	11.08
4	*Serratella*	5.30	*Baetis*	6.70	*Optioservus*	7.08
5	*Glossosoma*	4.94	Orthocladiinae	5.27	*Cheumatopsyche*	5.54



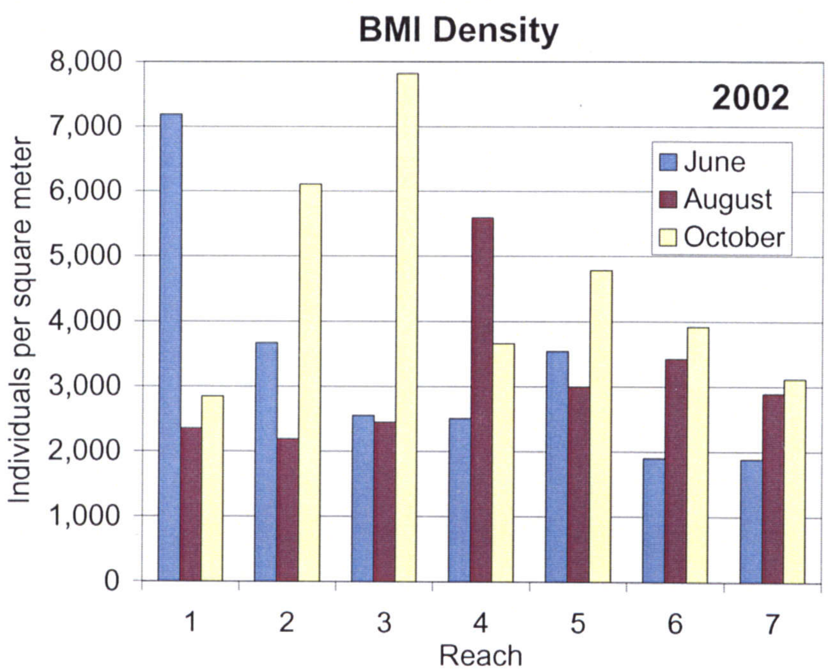


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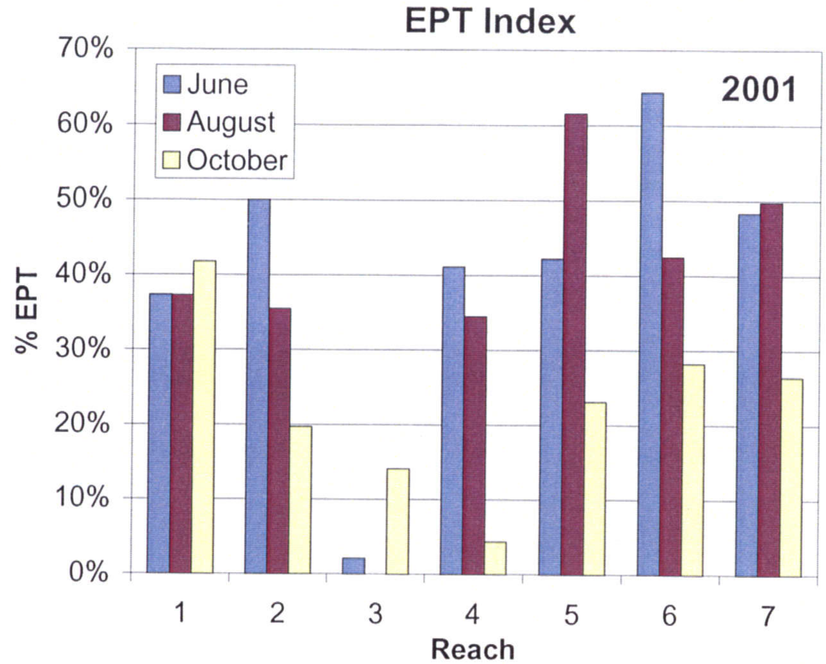
Figure 8
BMI Density by Reach and Month in 2001 and 2002



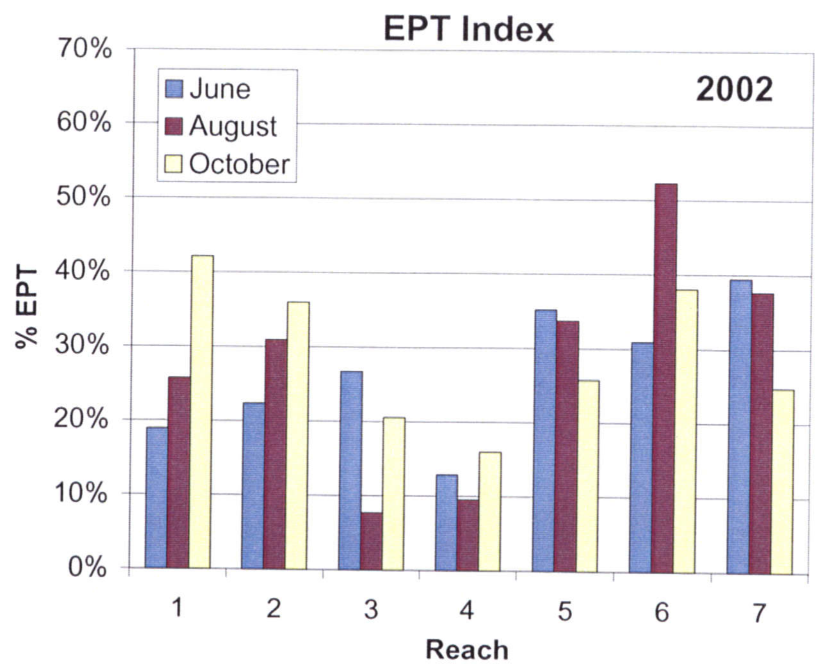


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Figure 9
EPT Index by Reach and Month in 2001 and 2002

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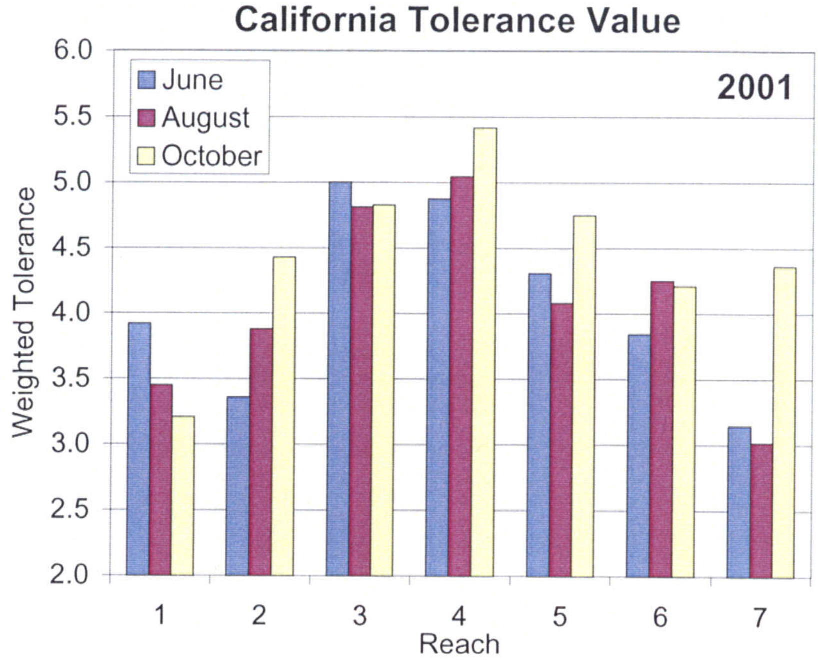
Figure 10
Taxa Richness by Reach and Month in 2001 and 2002



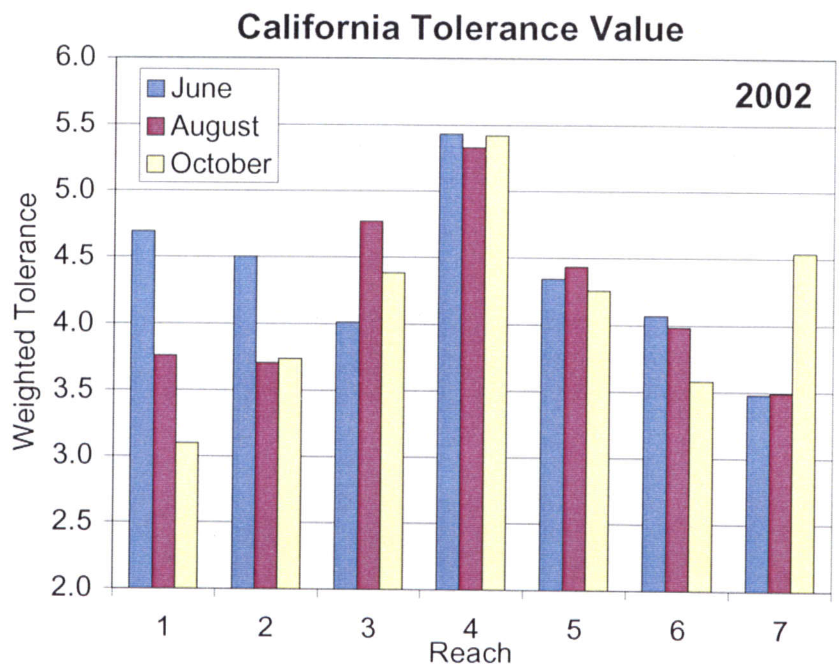


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Figure 11
California Tolerance Values by Reach and Month in 2001 and 2002

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Figure 12
Functional Feeding Group Composition in 2001

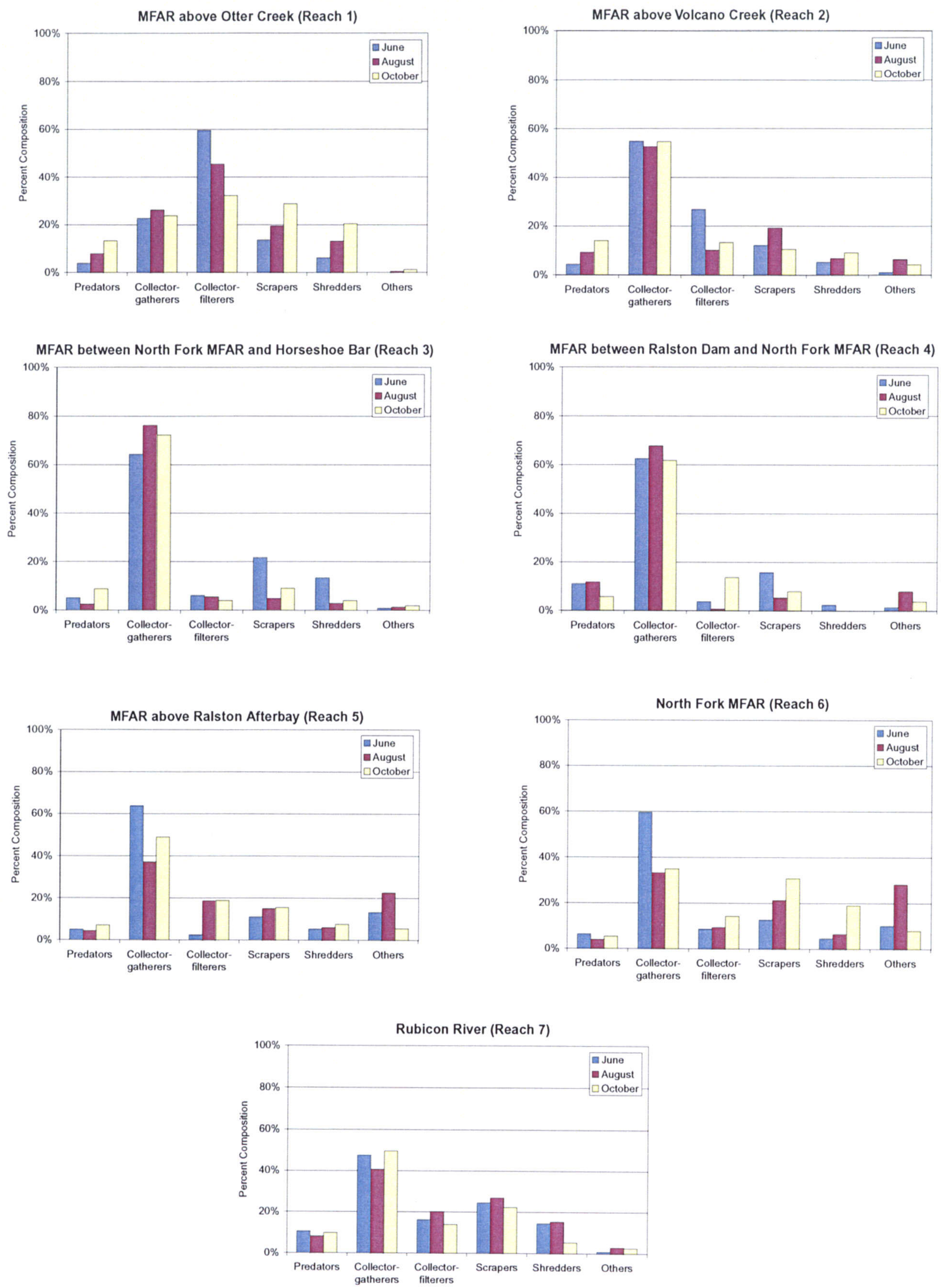

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Figure 13
Functional Feeding Group Composition in 2002

stream banks. This taxon was a dominant member of the benthic community in Reaches 5 and 6 in June and August of both years but not in October, presumably because many individuals metamorphed into adults and left the system by fall. *Ochrotrichia* was also found in Reaches 4 and 7, although in much lower abundance.

Taxonomic Validation

The taxonomic validation performed on approximately 10% (six samples) of the 2002 BMI samples showed that the identifications made at the Jones & Stokes laboratory were consistent with those made at the EcoAnalysts laboratory approximately 88% of the time. The percent similarity between the two taxonomic lists ranged from 77.2–92.86%. In addition, there was an observed enumeration error of approximately 1.17%, ranging from 0.0–2.67%. Mr. Stone and Mr. Walters discussed differences in taxonomic determinations in April 2003. The reviewing taxonomists determined that most discrepancies found were the result of using an outdated reference (Merrit and Cummins 1996) that does not include the most recent taxonomic revisions. Based on results of the taxonomic validation, appropriate corrections were made to the 2002 data set.

Water Temperature

Figures 14 and 15 show the daily mean, minimum, and maximum water temperatures measured at each monitoring location from June 2002–June 2003. Daily water temperatures in the MFAR at the Foresthill gage ranged from 68°F during the annual maintenance period (September–October 2002), when flows were at minimum levels (approximately 100 cfs), to 40°F in February 2003. Daily water temperatures in the MFAR and Rubicon River above Ralston Afterbay exhibited a wider seasonal range, ranging from 77°F in June 2002 to 39°F in February 2003. Daily water temperatures in the North Fork MFAR ranged from 73°F in June to 38°F in February 2003.

Channel Cross Sections

The cross sectional profiles for each monitoring site are shown in Figure 15.

Discussion and Conclusions

Substrate Monitoring

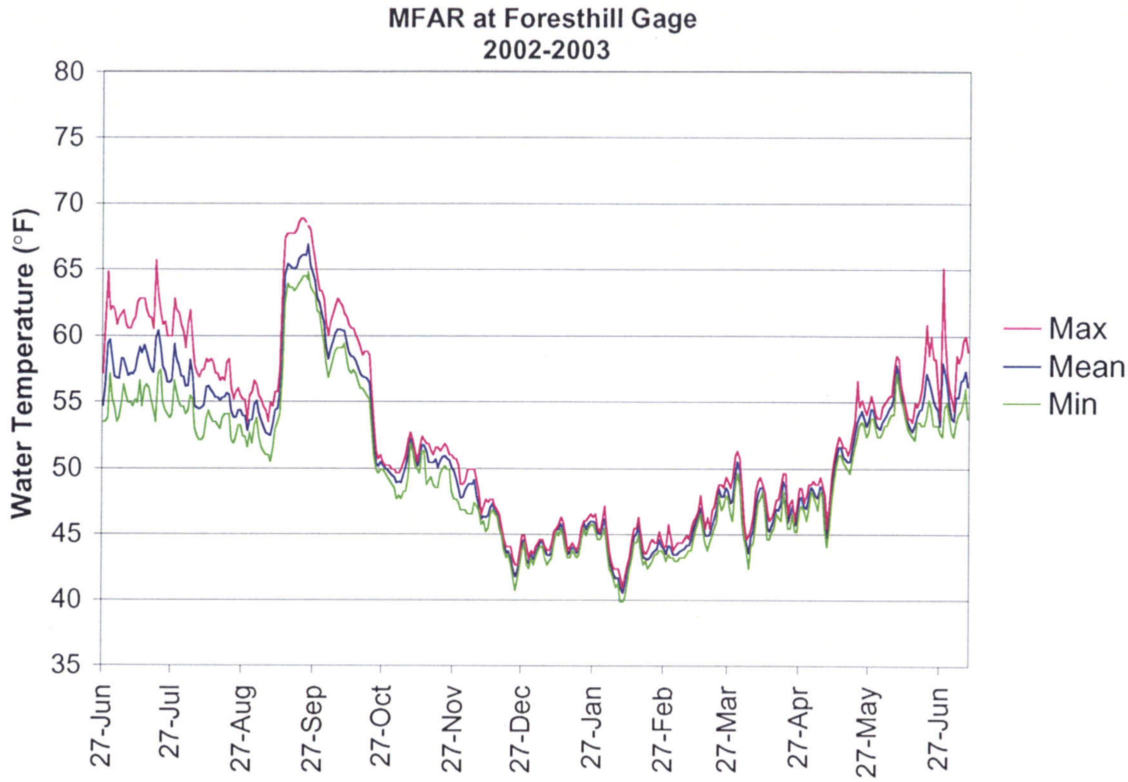
The results of substrate monitoring revealed no significant changes in substrate composition in the monitoring reaches between 2001 and 2002. Adjusting for known biases associated with the Bain method, pebble counts conducted in 2002 indicated that the size composition of riffle substrates in all monitoring reaches was very similar to that measured in 2001.

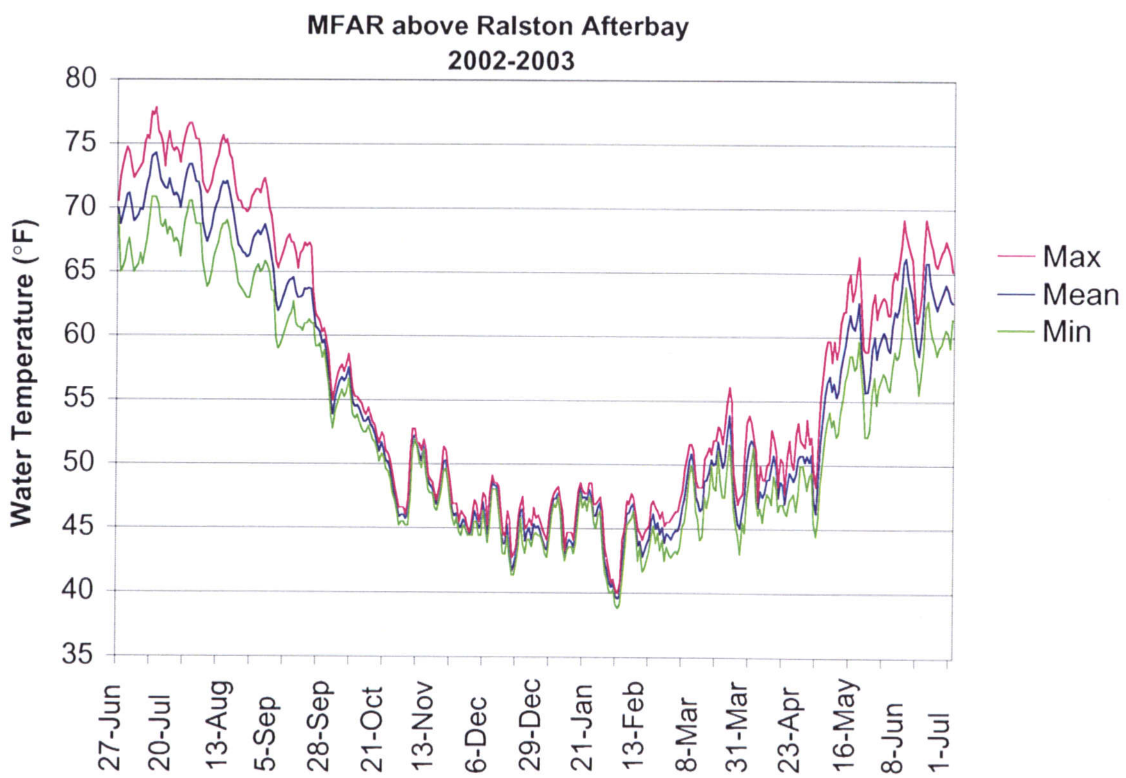
All monitoring reaches continue to be characterized by relatively uniform, coarse-grained substrates with low embeddedness. As discussed in the 2001 monitoring report, these characteristics generally provide suitable habitat conditions for trout and benthic invertebrates. However, spawning habitat for trout is limited in the monitoring reaches by the low abundance of suitable-sized gravel. In addition, the coarse nature of the streambed and very low quantities of fine sediments may limit the diversity and abundance of BMI communities. These potential limitations are most severe in Reaches 3 and 4, in which large cobbles and boulders dominate the streambed. The coarseness of the streambed in these reaches is consistent with the processes of channel scouring and armoring associated with reductions in sediment supply since the construction of Ralston Dam (Stiehr pers. comm.).

The Indian Bar Pilot Project was initiated in 2002 to demonstrate the effectiveness of sediment disposal in achieving the sediment management objectives. The potential benefits of this project component include restoring the natural movement of sediment to the reaches below the dam and replenishing finer materials (gravel, pebble, and cobble) that are critically important for maintaining suitable stream habitat for fish and aquatic invertebrates. Pebble counts on the Indian Bar sediment pile in 2002 confirmed the presence of large quantities of gravel, pebbles, and cobble that have been historically trapped by the reservoir. Based on sediment modeling, these sediments are well within the range capable of being mobilized by high flows that typically occur in the project area every 1–2 years (Mussetter Engineering 2001). Postproject evaluations of the pilot project would begin following a flow event of sufficient magnitude and duration to cause significant erosion of the pile. Because of their proximity to the dam and coarse nature of the streambed, Reaches 3 and 4 will continue to serve as the primary treatment reaches for evaluating the potential benefits of sediment disposal on Indian Bar.

Flows in the winter/spring 2003 did not reach levels capable of mobilizing sediment from the Indian Bar sediment pile, and there was no evidence of any significant preproject changes in substrate composition in the monitoring reaches resulting from the flows in winter/spring 2002). In addition, winter/spring flows in 2003 were not sufficient to trigger SPT operations, which require flows of more than 3,500 cfs (measured at Ralston Dam)[1]. As discussed under "Recommendations," the absence of project effects to date provides a valuable opportunity to conduct a third year of preproject monitoring to measure the baseline effects of higher flows (>3,500 cfs measured at Ralston Dam) on substrate conditions and BMI communities before postproject monitoring begins.

[1] The MFAR flows depicted in Figure 16 were measured at the Foresthill gage and include the contribution of the North Fork MFAR. Consequently, the flows at Ralston Dam were lower than those in Figure 16.





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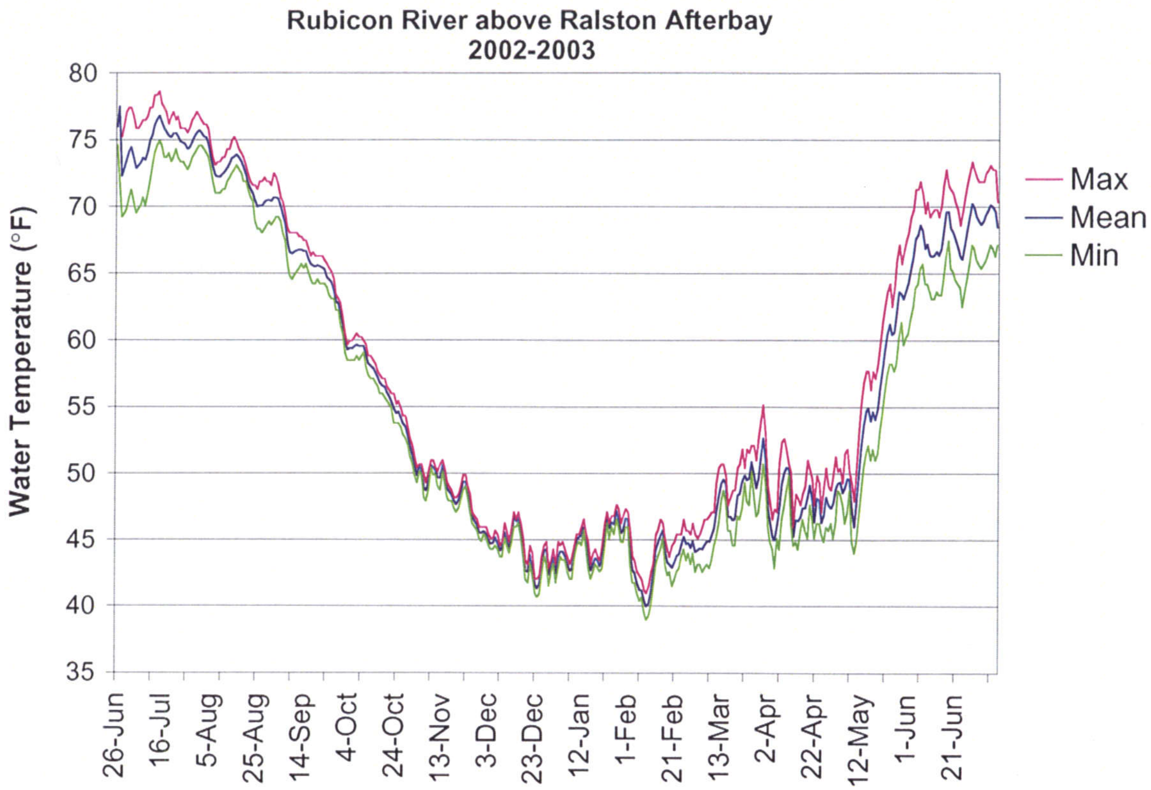
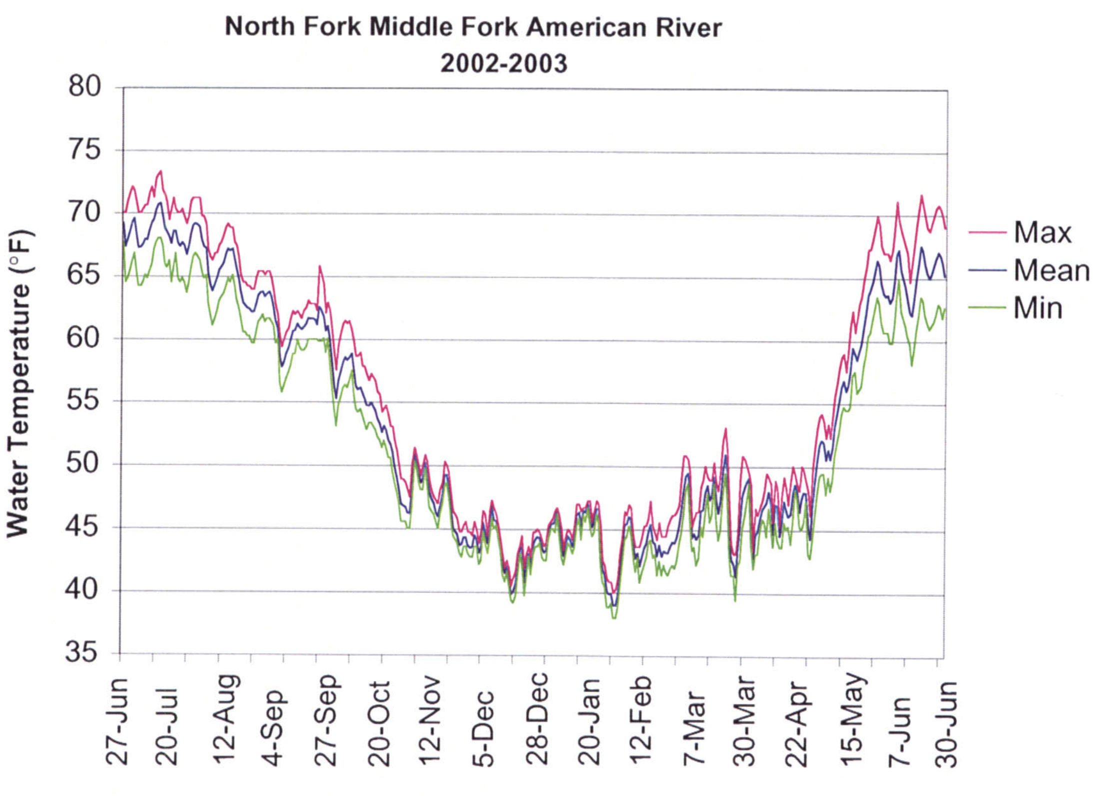
Jones & Stokes

Figure 14
Daily Water Temperatures in the MFAR Upstream and Downstream of Ralston Afterbay, June 2002 – July 2003





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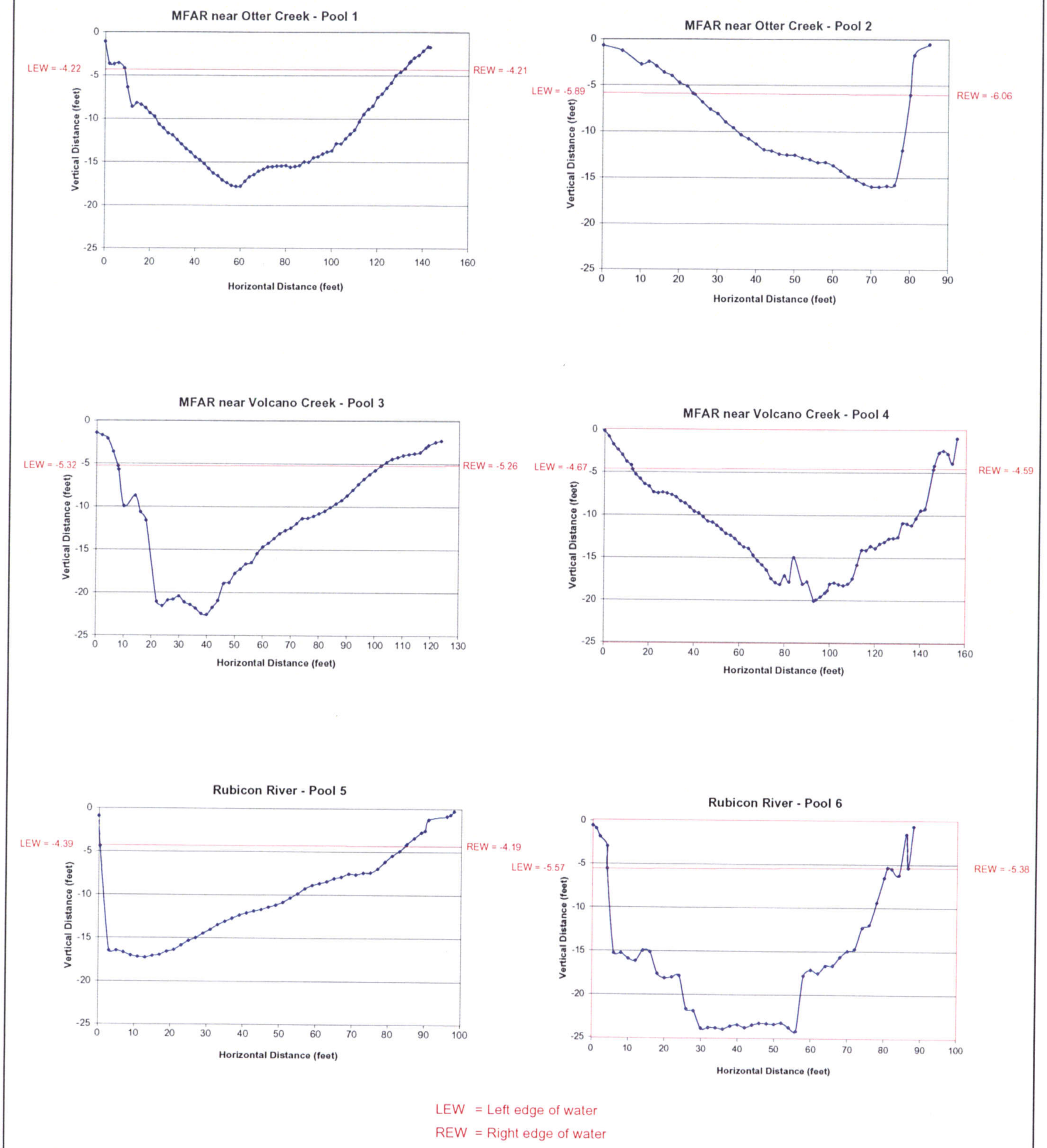
Jones & Stokes

Figure 15
Daily Water Temperatures in the Rubicon River and MFAR, June 2002 – July 2003



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Jones & Stokes

Figure 16
Channel Cross-Sections at Selected Pools in the MFAR and Rubicon Rivers, October 2002

Benthic Macroinvertebrate Monitoring

The results of the second year of preproject BMI monitoring continue to support the general conclusion that aquatic habitat in the project area is in relatively good condition. Results that support this general conclusion include the high taxa richness values, low California tolerance values, and great abundance of intolerant taxa observed in 2 years of baseline monitoring. Biological metrics indicate that the MFAR supports similar quality habitat as other major waterways at similar elevations of the Sierra Nevada such as the Stanislaus and Mokelumne Rivers (Pacific Gas & Electric Company 2002, Garcia and Associates 2000).

Despite a high degree of seasonal and annual variability in BMI communities, several metrics revealed similar patterns in the composition of BMI communities in 2001 and 2002. The 2002 results continue to support the conclusion that the quality of aquatic habitat in the MFAR immediately below Ralston Dam (Reaches 3 and 4) is lower than that in the reaches farther downstream (Reaches 1 and 2) and in the upstream control reaches (Reaches 5–7). Compared to other reaches, Reaches 3 and 4 generally exhibited the highest tolerance values and lowest EPT values in 2001 and 2002. These results reflect the higher proportions of relatively tolerant taxa (e.g., Chironominae, Orthocladiinae) and lower proportions of less tolerant taxa (EPT taxa) in Reaches 3 and 4. Another indicator of reduced habitat quality in Reaches 3 and 4 is the dominance of a single functional feeding group (collector-gatherers). Although this group is a dominant component of all BMI communities in the project area, the remaining treatment reaches (Reaches 1 and 2) and control reaches (Reaches 5–7) support a more diverse assemblage of feeding groups, including higher proportions of collector-filterers. Collector-filterers, such as caddisflies in the families Hydropsychidae, Philopotamidae, and Simulidae, are particularly good indicators of habitat disturbance because of their sensitivity to excessive levels of fine sediment and other forms of pollution (Resh and Jackson 1993).

The BMI communities in the control reaches upstream of Ralston Afterbay (Reaches 5 and 7) and in the North Fork MFAR continued to exhibit signs of good habitat conditions. In fact, these reaches exhibited similar tolerance values and generally higher seasonal taxa richness and EPT values than the reaches downstream of Ralston Dam. The shift in community composition to more tolerant taxa in October 2002 (and perhaps 2001) in the Rubicon River (Reach 7) appeared to be in response to the localized effects of suction dredge mining. For example, a floating dredge was operated approximately 100 feet upstream of Transect 36 (Reach 7) most of the summer season, resulting in the reintroduction of fine sediments previously trapped below coarse material and significant alterations to the physical habitat.

Preproject monitoring of riffle substrates and associated BMI communities in 2001 and 2002 indicate a general relationship between BMI communities and the size composition of riffle substrates. This relationship is consistent with the general observation that riffles with mixtures of intermediate-sized substrates (gravels, pebbles, and small cobbles) and low to moderate amounts of fine sediment support larger, more diverse BMI communities than more uniform substrates of mostly fine (sand and silt) or coarse sediment (large cobbles and boulders) (Minshall 1984).

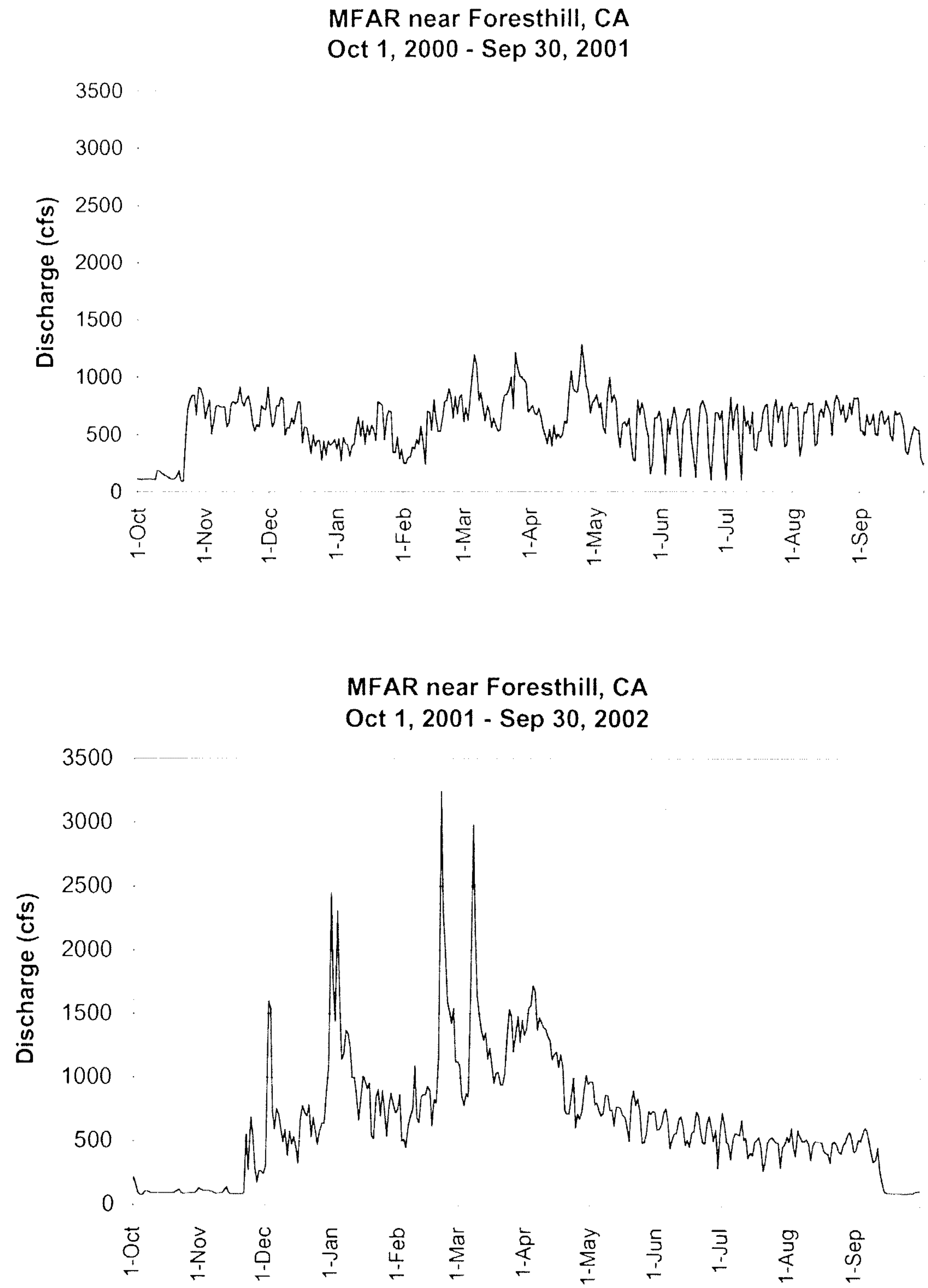
Although substrate conditions play an important role in determining the composition of BMI communities, other factors, acting alone or in combination with substrate, could be contributing to the observed differences in BMI communities between reaches and years. These factors may include water temperature, flow regime, light, food availability, current, and interactions with other organisms. For example, during summer, hydroelectric operations at Ralston Afterbay result in higher, colder flows in the MFAR downstream of Oxbow Powerhouse (Reaches 1–3) than in the reaches above the dam (Reaches 5 and 7) and in the North Fork MFAR (Reach 6). In addition, water temperatures in the MFAR downstream of Oxbow Powerhouse exhibit a marked increase every fall when the powerhouses are shut down for annual maintenance (Figure 14).

Annual and seasonal differences in flows in 2001 and 2002 may have also contributed to the observed variation in BMI communities (Figure 17). Flows in winter/spring 2002 were higher on average (500–1,500 cfs) than in 2001 (400–800 cfs). In addition, daily flows in winter/spring 2002 peaked several times in response to storm runoff, with the largest event resulting in a daily maximum of 3,240 cfs. In contrast, daily flows in 2001 rarely exceeded 1,000 cfs, and no marked peaks occurred in winter and spring. Summer flows in 2001 and 2002 also differed in the magnitude of daily fluctuations.

Recommendations

The aquatic habitat and BMI data collected in 2001 and 2002 have established important baseline information on spatial and temporal variability in aquatic habitat and BMI communities in the project area. However, preproject water quality data are still needed to meet the minimum requirements of the monitoring plan. Preproject water quality monitoring should be conducted during the next flow event (or several flow events) similar in magnitude to those that will trigger SPT operations in future years. This monitoring will also afford the opportunity to conduct a final year of preproject aquatic habitat and BMI monitoring to improve our understanding of baseline conditions, and the effects of high flows and associated suspended sediment and turbidity on aquatic habitat and BMI communities in the absence of the sediment management project.

As discussed in the monitoring plan, the ability to detect and measure project effects on water quality and aquatic habitat downstream of Ralston Afterbay depends on our ability to describe the range of conditions that would exist in the absence of the project (i.e., baseline conditions). Although the use of control reaches helps to describe these conditions, there remain unknown sources of variation between the control and test reaches (e.g., localized differences in sediment loads or transport capacity) that could lead to erroneous conclusions. For example, if, under baseline conditions, high flows trigger a substantial increase in suspended sediment loads and sedimentation in the test reaches but



Jones & Stokes

Figure 17
Daily Flows (in Cubic Feet per Second) Measured in the MFAR at the Foresthill Gage in Water Years 2001 and 2002

not in the control reaches, this could be interpreted as a project effect although project actually contributed very little to the observed increase (unless the cause of the increase is obvious, such as a landslide immediately upstream of the test reaches). To address this risk, the monitoring plan identified the need for preproject monitoring to include at least 1 year in which flows reached the levels that would occur during SPT operations (but without SPT occurring).

Flows over the last 2 years have not been high enough to document baseline water quality conditions under the flow conditions that would occur in the postproject monitoring years. To obtain sufficient water quality data to describe baseline conditions, it is recommended that turbidity and suspended sediment levels be measured during the next storm event (or several storm events) that generate flows within the target range for SPT operations (>3,500 cfs at Ralston Dam). The monitoring plan specifies at least 1 year of preproject monitoring because, on average, only one or two storms each year are likely to produce flows within the target range to meet the minimum data requirements. When flows are expected to exceed 3,500 cfs, turbidity and total suspended sediment sampling should begin when flows reach 3,000 cfs and continue at 4-hour intervals over as wide a range of flows as possible within the target range (>3,500 cfs).

There are now 2 years of baseline data for documenting potential future changes in streambed conditions (substrate size composition and embeddedness) and BMI communities. However, none of the preproject years represents conditions that occur following flow events within the range that would trigger SPT operations (>3,500 cfs). Again, the lack of preproject data at these higher flows increases the risk that there would be insufficient baseline information to effectively distinguish a sediment management project effect from potentially large effects that may occur in the absence of the project. Therefore, we recommend a third year of preproject aquatic habitat and BMI monitoring following a flow event (or several flow events) that generates flows within the target range for SPT operations. Because at least 1 year of preproject water quality monitoring at these flows is required, aquatic habitat and BMI monitoring can be conducted in the same year following water quality monitoring without causing any unnecessary delays in implementing the sediment management project.

In accordance with the streambed alteration agreement with CDFG, the target flows for postproject water quality, aquatic habitat, and BMI monitoring are 3,500, 5,000, and 8,000 cfs. This range was selected because it meets the minimum requirements for SPT operations and provides an evaluation of the effectiveness of these flows in mobilizing sediment from the Indian Bar disposal site. The minimum requirement for postproject monitoring would be the occurrence of at least 1 year in which flows reach or exceed 3,500 cfs (and SPT operations occur) and at least 1 year in which flows reach or exceed 8,000 cfs (and SPT operations occur). No postproject monitoring would be conducted in years following winters in which such events do not occur.

References Cited

Printed References

Bain, M. B. 1999. Substrate. Pages 95–103 in Bain, M. B., and N. J. Stevenson (eds.), *Aquatic habitat assessment: common methods*, 1999. Bethesda, MD: American Fisheries Society.

Barbour, M. T., and J. Gerritsen. 1996. Subsampling of benthic samples: a defense of the fixed-count method. *Journal of the North American Benthological Society* 15(3):386–391.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition.* EPA 841-B-99-002. Washington, DC: U.S. Environmental Protection Agency, Office of Water.

Bjornn, T. C., M. A. Brusven, M. P. Molnau, J. H. Milligan, R. A. Klamt, E. Chacho, and C. Schaye. 1977. *Transport of granitic sediment in streams and its effects on insects and fish.* Bulletin 17. Moscow, ID: University of Idaho, Forest, Wildlife and Range Experiment Station.

Bunte, K., and S. R. Abt. 2001. *Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring.* General Technical Report RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

California Department of Fish and Game. 1999. *California stream bioassessment procedure: protocol brief for biological and physical/habitat assessment in wadable streams.* Rancho Cordova, CA: Water Pollution Control Laboratory/Aquatic Bioassessment Laboratory. Available at URL: http://www.dfg.ca.gov/ cabw/cabwhome.html.

———. 2003. *List of California macroinvertebrate taxa and standard taxonomic effort.* Developed for CAMLnet. Rancho Cordova, CA: Water Pollution Control Laboratory/Aquatic Bioassessment Laboratory.

Central Valley Regional Water Quality Control Board. 1998. *Water quality control plan (basin plan) for the Central Valley region, Sacramento River and San Joaquin River basins.* Sacramento, CA.

Courtemanch, D. L. 1996. Commentary on the subsampling procedures used for rapid bioassessments. *Journal of the North American Benthological Society* 15(3):381–385.

Doberstein, C. P., J. R. Karr, and L. L. Conquest. 2000. The effect of fixed-count subsampling on macroinvertebrate biomonitoring in small streams. *Freshwater Biology* 44:355–371.

Garcia and Associates. 2000. *The distribution and abundance of the benthic macroinvertebrate fauna and fish populations in tributaries leading into and including the North Fork Mokelumne and Mainstem Mokelumne Rivers.* San Anselmo, CA. Prepared for Pacific Gas & Electric Company, Technical and Ecological Services, San Ramon, CA.

Jones & Stokes. 2002a. *Ralston Afterbay Sediment Management Project, Indian Bar Pilot Project.* August. (J&S 00-297.) Sacramento, CA. Prepared for Placer County Water Agency, Foothill, CA.

———. 2002b. *Water quality and aquatic resources monitoring program for the Ralston Sediment Management Project: 2001 annual report.* May. (J&S 01-335.) Sacramento, CA. Prepared for Placer County Water Agency, Foresthill, CA.

Karr, J. R., and E. W. Chu. 1999. *Restoring life in running waters: better biological monitoring.* Covelo, CA: Island Press.

Kondolf, G. M., and M. G. Matthews. 1993. The sizes of salmonoid spawning gravels. *Water Resource Research* 29:2275–2285. In *Assessment of potential for flushing sediments released from South Fork Long Canyon Diversion Dam*, report submitted to PCWA, August 15, 1996.

Ligon, F. K., W. E. Dietrich, and W. J. Trush. 1995. Downstream ecological effects of dams: a geomorphic perspective. *BioScience* 45(3):183–192.

Merritt, R. W., and K. W. Cummins (eds.). 1984. *An introduction to the aquatic insects of North America.* Second edition. Dubuque, IA: Dendall/Hunt Publishing Co.

Minshall, G. W. 1984. *The ecology of aquatic insects.* Praeger, NY: Praeger Publishers. Chapter 12, 358–400 pp.

Mussetter Engineering, Inc. 2001. *Indian Bar sediment disposal site study, Ralston Afterbay, California.* Fort Collins, CO. Submitted to Jones & Stokes, Sacramento, CA, and Placer County Water Agency, Foresthill, CA.

Pacific Gas & Electric Company. 2002. *Spring Gap-Stanislaus Project, FERC Project No. 2130. Volume II, Application for New License. Exhibit E, Water Use and Quality.* San Francisco, CA.

Parfitt, D., and K. Buer. 1980. *Upper Sacramento River Spawning Gravel Study.* Red Bluff, CA: California Department of Water Resources, Northern Division.

Pennak, R. W. 1978. *Fresh-water invertebrates of the United States.* New York, NY: John Wiley and Sons.

Resh, V. H., and J. K. Jackson. 1993. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. In *Freshwater Biomonitoring and Benthic Macroinvertebrates*, D. H. Rosenburg and V. H. Resh (eds.), pp. 195–233. New York: Chapman & Hall.

Resh, V., and D. Rosenberg. 1984. *The ecology of aquatic insects.* Praeger, NY: Praeger Publishers.

Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. *Journal of the North American Benthological Society* 15(3):392–399.

Waters, T. F. 1995. *Sediment in streams: sources, biological effects, and control.* Monograph 7. Bethesda, MD: American Fisheries Society.

Personal Communications

Harvey, M. Hydraulic engineer, Mussetter Engineering, Inc., Fort Collins, CO—2001—memorandum. March 9, 2001 —electronic mail.

Stiehr, P. E., P. L., Watermark Engineering, Inc. November 17, 1999—technical memorandum, *Scour evaluation at Middle Fork American River below Ralston Afterbay.*

Appendix A

Water Quality and Aquatic Habitat Monitoring Plan for the Ralston Afterbay Sediment Management Project Indian Bar Pilot Project (August 2002)

Appendix A

Water Quality and Aquatic Habitat Monitoring Plan for the Ralston Afterbay Sediment Management Project Indian Bar Pilot Project

Executive Summary

Placer County Water Agency (PCWA) is proposing to initiate a pilot sediment management project at Ralston Afterbay Reservoir (Ralston Afterbay), a component of the American River Hydroelectric Project on the Middle Fork American River (MFAR). The primary purpose of the sediment management project is to create sediment storage capacity in Ralston Afterbay, maintain operational flexibility of Ralston Dam and Oxbow Powerhouse, and delay the complete sedimentation of Ralston Afterbay.

The sediment management project consists of 2 components. The first component consists of dredging approximately 75,000 cubic yards (yds) of sediment from the upstream end of the reservoir and placing approximately 48,000 yds of this material downstream of the Ralston Dam on Indian Bar. The sediment will be configured to allow high flows to mobilize and transport the sediment to reaches downstream of the dam. The second component, termed sediment-pass-through (SPT), consists of reoperating Ralston Dam during high flow events to pass greater quantities of fine sediment past the dam than passes under current operations.

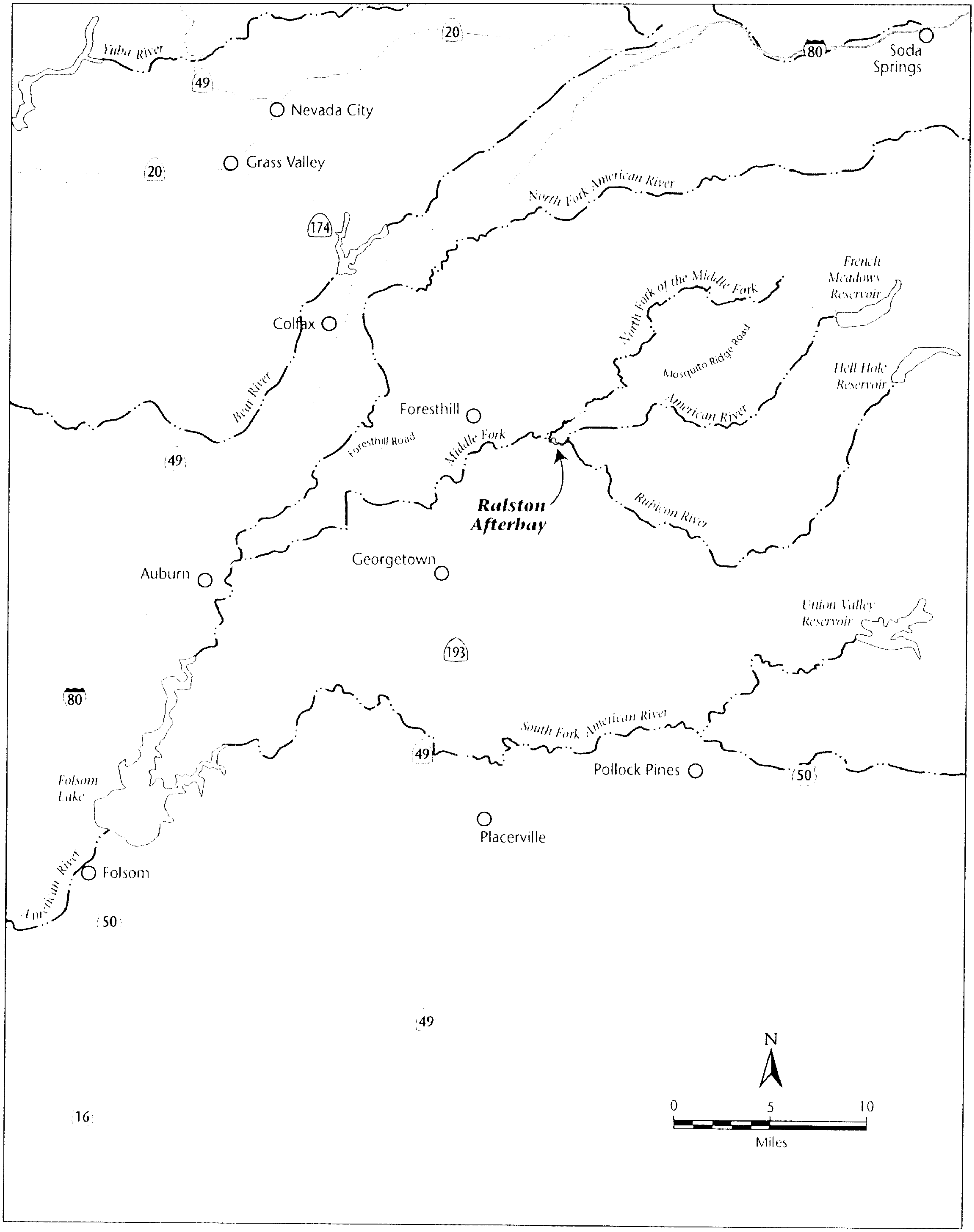
A secondary objective of the project is to restore the natural migration of coarse and fine sediment that occurred in the project area before dam construction. This sediment, especially the intermediate-sized material (gravel, pebbles, and cobbles), is critically important for maintaining suitable stream habitat for fish and benthic macroinvertebrates (BMI) (insects and other aquatic organisms that live in or on the streambed). Since the construction of Ralston Dam in 1966, a portion of the total sediment load transported by high flows from the MFAR and Rubicon River above Ralston Afterbay has accumulated in the reservoir, requiring periodic dredging of the reservoir to maintain the reliability of Ralston and Oxbow Powerhouses. As documented for other rivers, the retention of sediment by dams and corresponding reductions in sediment supply to downstream reaches can lead to a reduction in habitat quality in these reaches as high flows continue to transport cobble and finer materials that are not replaced by upstream sources.

SPT operations and sediment placement on Indian Bar constitute an effective and economic approach for managing sediment at Ralston Afterbay while compensating for the long-term effects of sediment retention on aquatic habitat in potentially sensitive reaches of the MFAR downstream of the dam. The proposed sediment management activities will allow the river to mobilize sediments and carry them downstream as they did naturally before dam construction. The placement of reservoir sediment, composed largely of gravel and larger materials, is expected to have beneficial effects on aquatic habitat downstream of the dam. Analyses of the hydraulic and sediment transport characteristics of the MFAR indicate that increases in the amount of fine sediment resulting from SPT operations and sediment placement will not cause adverse effects on water quality and aquatic resources because the amount of fine sediment affected by the project is small compared to the total amount of fine sediment transported by the MFAR.

In 2001, PCWA initiated a monitoring program to ensure project compliance with established water quality objectives and monitor the effects of the project on aquatic habitat and BMI in the MFAR downstream of Ralston Dam. Potential project effects will be evaluated by collecting a minimum of 1 year of water quality data and 2–3 years of aquatic habitat and BMI data before project activities begin and a minimum of 2–3 years of water quality, aquatic habitat, and BMI data after project activities begin. Key water quality, aquatic habitat, and BMI parameters will be monitored at treatment sites below Ralston Afterbay and at control sites above the reservoir. These parameters will include turbidity, total suspended solids, substrate size composition, embeddedness, and several BMI community and population attributes. Because of the high degree of variability of natural systems and lack of baseline data, an adaptive monitoring approach will be used to regularly evaluate the monitoring program and determine whether modifications are warranted to improve its performance. Evidence for project effects will be a significant postproject change (adverse or beneficial) in water quality and aquatic habitat conditions in the treatment reaches relative to changes in the control reaches. If these changes constitute an adverse effect on water quality and aquatic habitat conditions downstream of the dam, the magnitude of these changes will be compared with established water quality and habitat thresholds to evaluate project performance and determine whether corrective actions are warranted. The need for corrective actions will also be based on the results of BMI monitoring, which will serve as a key indicator of the biological effects of observed water quality and habitat changes. In addition, these changes will be evaluated in the context of other watershed events and trends that may influence the monitoring results and conclusions.

Introduction

PCWA operates a series of reservoirs and powerhouses as part of the American River Hydroelectric Project on the MFAR and Rubicon Rivers (Middle Fork Project) in the central Sierra Nevada (Figure 1). The Middle Fork Project includes Ralston Afterbay, created by the construction of Ralston Dam in 1966



Jones & Stokes

Figure 1
Regional Location

(Photo 1). The dam and reservoir are located on the MFAR on the border of Placer and El Dorado Counties, California.

Ralston Afterbay serves 3 primary purposes. First, it protects public safety and fisheries by regulating the rate of river stage change downstream. Second, it allows the 2 largest powerhouses of the Middle Fork Project—Middle Fork and Ralston Powerhouses—to quickly respond to system electrical needs. Third, it impounds water for power generation at Oxbow Powerhouse.

PCWA is proposing to initiate sediment management at Ralston Afterbay to address continuing sedimentation of the reservoir that threatens the reliability of power generation at Ralston and Oxbow Powerhouses. PCWA issued and adopted an initial study/mitigated negative declaration for the Ralston Afterbay Sediment Management Project in August 2001. The primary purposes of the sediment management project are to create sediment storage capacity within Ralston Afterbay, maintain operational flexibility of Ralston Dam and Oxbow Powerhouse, and delay the complete sedimentation of Ralston Afterbay.

The sediment management project consists of 2 independent components. The first component consists of dredging approximately 75,000 cubic yds of sediment from the upstream end of the reservoir and placing this material downstream of the dam on a 1.96-acre portion of Indian Bar (Photo 2). The sediment will be configured to allow high flows to mobilize and transport it to the river downstream of the dam. The second component of the project will consist of reoperating the dam during high flow events to pass greater quantities of fine sediment beyond the dam. SPT operations will be conducted whenever river flows exceed approximately 3,500 cubic feet per second (cfs).

PCWA is proposing an initial placement of 48,000 cubic yds of sediment on Indian Bar to evaluate the project at a pilot level and to address concerns regarding recreational uses at Indian Bar (Jones & Stokes 2002). This evaluation will include consideration of potential strategies for increasing the sediment volume while maintaining or enhancing recreational opportunities at Indian Bar. Other sediment placement locations (e.g., Junction Bar) may also be considered.

A secondary objective of the project is to restore the natural migration of coarse and fine sediment that occurred in the project area before dam construction. This sediment, especially the intermediate-sized material (gravel, pebble, and cobble), is critically important for maintaining suitable stream habitat for fish and BMI (Waters 1995). Following construction of dams, these materials continue to be transported from the reaches below dams but without replacement from upstream sources, resulting in loss of important habitat (Kondolf and Matthews 1993). Other effects include scouring and deepening of the channel and associated increases in substrate size (i.e., channel armoring), a process that has been occurring below Afterbay Dam since its construction (Stiehr, pers. comm.). Efforts to mitigate these effects on salmon and trout streams in California have focused primarily on augmenting the supply of spawning-size gravels (Parfitt and Buer 1980). These efforts, which include placing gravel on bars and riffles and installing artificial and natural gravel-retaining structures downstream of dams, can be costly and ineffective over the long term. A more satisfactory alternative is to attempt to maintain natural channel features below dams by managing water releases and sediment in ways that preserve, as much as possible, the predam geomorphic processes (Ligon et al. 1995).

SPT operations and placement of sediment on Indian Bar constitute a viable and economic approach for managing sediment at Ralston Afterbay while mitigating for the long-term effects of sediment trapping on aquatic habitat downstream of the dam. The proposed sediment management activities will allow the river to mobilize sediments and carry them downstream as occurred naturally before dam construction. Preliminary analyses indicate that these activities will not cause adverse effects on aquatic resources. For reasons cited above, the reintroduction of sediment below the dam is expected to have beneficial effects on stream habitat and aquatic resources downstream of the dam. Both SPT operations and sediment disposal at Indian Bar are expected to result in relatively small, temporary increases in turbidity and suspended sediment above ambient levels during high flow events. In addition, past analyses and modeling of the hydraulic and sediment transport characteristics of the MFAR indicate that the channel is inherently stable and therefore relatively insensitive to changes in discharge and sediment supply (Harvey pers. comm.).

In 2001, PCWA initiated a monitoring program to test these predictions and ensure compliance of the project with established water quality objectives. The following report presents the monitoring plan and the results of the first year of baseline monitoring activities.

Purpose and Objectives

The purpose of the monitoring program is to evaluate the potential effects of the Ralston Afterbay Sediment Management Project on water quality, aquatic habitat, and BMI in the MFAR downstream of Ralston Dam. The primary objectives of the monitoring program are to:

- quantitatively evaluate project compliance with the water quality objectives established by the Central Valley Regional Water Quality Control Board (RWQCB) in the Water Quality Control Plan (Basin Plan) (Regional Water Quality Control Board 1998), and
- quantitatively evaluate project effects on aquatic habitat based on changes or trends in streambed and BMI populations downstream of the reservoir (treatment area) relative to changes or trends in unaffected areas (control areas), and

PCWA will use the results of annual monitoring to evaluate project effects and implement appropriate corrective measures if the data indicate that the project is adversely affecting water quality and aquatic resources in the MFAR.

Project Area

Ralston Afterbay is located at the confluence of the MFAR and Rubicon Rivers at an elevation of approximately 1,200 feet (ft). Indian Bar is located immediately downstream of Ralston Dam. The project area includes the MFAR watershed from French Meadows Reservoir (5,200 ft elevation) to the confluence the NFAR (600 ft elevation), the Rubicon River watershed from Hell Hole Reservoir (4,600 ft elevation) to Ralston Afterbay, and the North Fork of the MFAR watershed from its headwaters (6,000 ft elevation) to its confluence with the MFAR (1,000 ft elevation). The North Fork of the MFAR enters immediately downstream of Ralston Dam and Oxbow Powerhouse (Figure 1).

Climate

The MFAR watershed is dominated by a Mediterranean-like climate (warm, dry summers and cool to cold, wet winters). Air temperatures vary widely during the year and there is no appreciable precipitation in the summer except for scattered thunderstorms. Average annual precipitation in the form of rain and snow ranges from 60 to 65 inches per year with the majority of it falling between November and April (El Dorado National Forest 2001a). A portion of the watershed lies in the transient rain-on-snow zone, which occurs at elevations between 3,500 and 6,000 ft. Areas experiencing rain-on-snow events are considered to have a higher sensitivity to watershed disturbance than areas with rain- or snow-dominated climates (El Dorado National Forest 2001a and b).

Geology

The MFAR and North Fork of the MFAR watersheds include 2 different geologic units: the Shoo Fly Complex and the Mehrten formation (California Department of Conservation 1992). The rocks of the Shoo Fly geologic unit, comprising approximately 90% of the watershed, are relatively impermeable (El Dorado National Forest 2001a, b, and c). The Mehrten formation comprises approximately 10% of the watershed.

The Rubicon River watershed includes 5 different geologic units: Paleozoic metasedimentary undifferentiated rocks, the Mehrten formation, Mesozoic granitic rocks, Cretaceous-Jurassic plutonic rocks (gabbro), and glacial moraine deposits (California Department of Conservation 1981 and 1982). Paleozoic metasedimentary undifferentiated rocks, comprising approximately 60% of the watershed, are relatively erodible, and are especially erodible when unvegetated. The Mehrten formation comprises approximately 20% of the watershed. The contact zones between the Mehrten formation and adjacent units are often locations where landslides occur (El Dorado National Forest 2001c). Mesozoic granitic rocks, Cretaceous-Jurassic plutonic rocks, and glacial moraine deposits comprise the remaining 20%.

Soils

The MFAR and North Fork MFAR watersheds contain a diverse set of soils with 6 different soil map units described. The major soils in the watershed are the Hurlbut, Rock Outcrop, and Deadwood series associated with the Shoo Fly Complex and the Waca, Ledmount, and McCarthy series associated with the Mehrten formation. With the exception of Rock Outcrop, these soils have a moderate to very high erosion hazard, depending on the slope.

The Rubicon River watershed contains 7 different soil map units. Major soils in the watershed are the Hurlbut and Deadwood series associated with the Shoo Fly Complex; the Waca, Ledmount, and McCarthy series associated with the Mehrten formation; and the Chaix and Zeibright series associated with the granitic rocks and glacial deposits. These soils have a moderate to very high erosion hazard, depending on the slope.

Vegetation

Vegetation within the MFAR, Rubicon River, and North Fork of the MFAR watersheds consists mostly of mixed conifers with true firs at higher elevations. Major species of mixed conifer include ponderosa pine, sugar pine, incense cedar, white fir, Douglas-fir, big leaf maple, California black oak, and interior live oak. Shrub species include deerbrush, mountain whitehorn, Sierra mountain misery, green leaf manzanita, thimble berry, and Sierra currant.

Hydrology

The MFAR watershed upstream of Ralston Afterbay covers approximately 115 square miles. The nearest U.S. Geological Survey (USGS) flow gage, 10 miles upstream at Interbay Dam, represents flow from 90 square miles of the watershed. Flows in the MFAR are substantially attenuated by upstream reservoir storage facilities, including French Meadows Reservoir. A full-range gaging station was in service 500 feet downstream from Interbay Dam from October 1965 until the February 1986 flood, which destroyed the gaging station. According to the 1985 USGS yearbook, the maximum discharge was 9,900 cfs on January 13, 1980. USGS flow records indicate that the average daily flow in the MFAR is about 50 cfs (Hydrosphere Data Products 2000).

The Rubicon River watershed covers about 315 square miles and provides the majority of flow to Ralston Afterbay with an average daily flow of 332 cfs. The unregulated portion of the Rubicon River watershed extends 32 miles upstream to Hell Hole Reservoir. Flows in this reach exhibit large annual and seasonal variation. An historical peak flow of approximately 300,000 cfs occurred when Hell Hole dam failed in December 1964. The North Fork MFAR has a 92-square-mile watershed and enters immediately downstream of Ralston Dam and Oxbow Powerhouse. The North Fork MFAR is unregulated by reservoirs and

Photograph 1. Ralston Afterbay Dam and Reservoir

Photograph 2. Indian Bar

contributes a substantial amount of flow to the MFAR with an average daily flow of 285 cfs, a 1% exceedance flow of 2,400 cfs, and a peak flow of 30,100 cfs recorded in 1980.

PCWA operates a flow gage on the MFAR immediately downstream of the North Fork MFAR confluence and upstream of Horseshoe Bar. The flow records for this site indicate that the average daily flow is 1,150 cfs and the 1% exceedance flow is 6,900 cfs. The January 1997 storm was considered to generate peak flows in the American River basin and its tributaries that were nearly as large as the projected 100-year flood event; however, peak flows were not recorded for the Rubicon River, North Fork MFAR, or MFAR at the Horseshoe Bar gage. PCWA estimated the peak 1997 flow passing Ralston Dam to be about 100,000 cfs. The highest recorded peak flow at the Horseshoe Bar gage, excluding the peak caused by the December 1964 Hell Hole Dam failure, was 123,000 cfs on January 2, 1997.

Geomorphology

The MFAR, Rubicon River, and North Fork MFAR are characterize primarily by steep, canyon-bound channels with a step-pool morphology. Average stream gradient ranges from <1% in the lower reaches of the MFAR to 2% in the MFAR and Rubicon River above Ralston Afterbay. Sediment transport capacity in these systems generally exceeds sediment supplied by eroded canyon walls and upper portions of the watershed. Consequently, fine sediments are easily transported through the system even during relatively small storm events. The channel bed consists largely of bedrock, boulders, and cobbles. The presence of these larger bed materials indicates that transport of larger material occurs only during large storm events (Bechtel Corporation 1997). The sediment transport and geomorphic characteristics of the MFAR watershed are further described below.

Sediment Transport and Geomorphic Characteristics of the Middle Fork American River

For large river basins like the MFAR basin, the amount of suspended sediment carried in the river will depend on a number of hydrologic and hydraulic characteristics as well as the source of sediment. Particles larger than 1.0 millimeter (mm) typically travel as bedload sediment close to or on the bottom; particles less than 0.1 mm generally travel suspended in the water as total suspended solids (TSS); particles between 0.1 mm and 1.0 mm may travel as either bedload or TSS. Sediment sources include organic litter on the soil surface, soil erosion, landslides, and other mass wasting of debris, as well as scouring of existing channel substrate. Sediment transport will vary during a storm in relation to rainfall, runoff, and streamflow conditions. As streamflow increases during a storm, the TSS load and associated turbidity carried in the flow will rise and then typically decrease as the storm passes and streamflow starts to recede (Environmental Protection Agency 1991). Bedload sediment may be mobilized and transported only during extremely high and infrequent flows. The MFAR has sufficient gradient and hydraulic energy to transport sediment at a faster rate than the natural rate of sediment input from watershed sources (Harvey pers. comm.). Consequently, there is very little deposition of sediment in the high gradient reaches of the river.

Potential sources of sediment transport to Ralston Afterbay vary in space and time and include the Rubicon Rivers and MFAR, upstream of the reservoir. The project area that may be affected by the proposed project also includes the MFAR downstream of Ralston Dam. Additional sources of sediment to the project area include sediments residing in Ralston Afterbay, the North Fork MFAR, smaller tributaries downstream of the North Fork MFAR, and the downstream slopes of the MFAR canyon. Given the large watershed area and variability in flows and erosion rates, background variation in sediment transport is expected to be large. Bathymetric surveys of Afterbay indicate that about 1,205,000 yds of course and fine sediments currently reside in the reservoir (Bechtel Corporation 1997). The estimated annual rate of accumulation since 1966 was estimated at 56,000 yds annually (EA Engineering, Science, and Technology 1990); however, a more recent evaluation indicates that the annual rate between 1987 and 1995 was only 36,250 yds (Bechtel Corporation 1997). It was presumed that the higher rate in previous years was a result of residual contribution of sediments to MFAR from the 1964 failure of Hell Hole Dam, which released large quantities of sediment to the river (Bechtel Corporation 1997). Current estimates of annual sediment transport in the MFAR downstream of Ralston Afterbay from natural sources are about 11,000 cubic yds of bedload sediment and 18,000 cubic yds of suspended sediment annually (Ayres Associates 1997). Field observations indicate that there is no accumulation of sediment upstream of the tunnel at Horseshoe Bar, suggesting that the existing sediment load passes through the tunnel (Mussetter Engineering 2001).

The quantity of material proposed to be placed at Indian Bar is approximately 48,000 yds. It is unknown how much fine sediment will be transported downstream during SPT operations; however, only about 20% of the total amount of suspended sediment reaching Ralston Afterbay is currently estimated to be deposited in the reservoir (Ayres Associates 1997). Consequently, the amount of sediment affected by the proposed project is a relatively small amount of the total amount transported in the river. Additionally, not all of the sediment stored in Ralston Afterbay or placed at Indian Bar will be transported in any 1 year, so the potential for project-related effects will most likely be further reduced relative to the existing annual sediment transport rates in the river.

The MFAR downstream of Ralston Afterbay is characterized by a steep, canyon-bound channel that is inherently stable and therefore relatively insensitive to changes in discharge and sediment supply (Harvey pers. comm.). In general, the channel form and processes of such rivers are related to infrequent flood events (50-year or greater recurrence interval), structural controls, landslides, human-induced impacts (e.g., hydraulic and placer mining), and discharges that occurred under different climatic regimes. The MFAR exhibits significant bedrock control of channel position, geometry, and gradient. Landslides, rock falls, and tributary-derived debris flows have placed materials with a wide range of sizes in the channel. In addition, mining practices and failure of Hell Hole Dam on the Rubicon River in 1964 (Resource Consultants and Engineers 1993) have modified the terraces and high-elevation boulder bars between Ralston Dam and the North Fork American River (NFAR) confluence.

The MFAR has a step-pool morphology composed of steep, coarse-grained (predominantly bedrock and boulder) reaches interspersed with lower-gradient, alluvial reaches associated with tributary alluvial fans, landslide debris, and bedrock outcrops. These features form localized constrictions that create upstream zones of sediment deposition during flood events. The steeper reaches act as conduits that convey most of the supplied sediment to downstream reaches during floods while the lower-gradient reaches act to temporarily store sediments between flood events. These lower-gradient, alluvial reaches generally exhibit a pool-riffle morphology (alternating pools, riffles, and bars) formed by fine- to coarse-grained alluvial deposits.

Monitoring Approach

The proposed monitoring approach is based on general principles and design of environmental impact studies (e.g., Bernstein and Zalinski 1983, Green 1979). Potential project effects are evaluated by collecting preproject and postproject water quality, aquatic habitat, and BMI data at monitoring sites located upstream and downstream of Ralston Afterbay. The downstream locations serve as treatment sites (areas potentially affected by the project) and the upstream locations serve as control sites (areas unaffected by the project). In this design, preproject (baseline) monitoring of the parameters of interest is conducted to characterize differences or relationships between these parameters in the treatment and control sites before the project begins. After the baseline monitoring period, the project is initiated and monitoring will continue to determine whether the differences or relationships between the treatment and control sites significantly change relative to those measured during the baseline period. Such a change will be evidence of a project effect. This is considered an effective design for detecting environmental impacts because it offers, with proper pairing of treatment and control reaches, a means of separating the effect of a given action from other extraneous sources of variation (e.g., climatic factors).

The monitoring plan proposes acquiring a minimum of 1 year of preproject water quality data and 1–2 years of preproject aquatic habitat and BMI data, followed by 2–3 years of postproject water quality, aquatic habitat, and BMI data. The potential effects of SPT operations and Indian Bar sediment disposal will be monitored concurrently, although the sequence of project activities may permit independent evaluations of these project components. The schedule for postproject monitoring will be subject to the occurrence of SPT operations, significant entrainment of sediment from the Indian Bar disposal site, and an appropriate range of flows for evaluating the performance of sediment disposal relative to model predictions. Accordingly, the target flows for postproject monitoring are 3,500 cfs, 5,000 cfs, and 8,000 cfs. These flows are expected to occur within a reasonable time frame (statistically, every 1 to 3 years), are sufficient to meet the flow threshold for SPT operations (3,500 cfs), and correspond to the flows used to model sediment entrainment from Indian Bar. Because hydrologic conditions needed to achieve these flows cannot be predicted or controlled from year to year, the minimum requirement for postproject monitoring will be the occurrence of at least one year in which flows reach or exceed 3,500 cfs (and SPT operations occur) and at least one year in which flows reach or exceed 8,000 cfs (and SPT operations occur). No post-project habitat or BMI monitoring will be conducted in years following runoff seasons when such events do not occur (e.g., dry years or extended droughts).

The decision to conduct postproject aquatic habitat and BMI monitoring in any given year will also be based on the magnitude of sediment entrainment (i.e., volume of entrained sediment) from Indian Bar following flow events large enough to cause spills over Ralston Dam. Using ground-based surveying techniques, PCWA will survey the Indian Bar sediment disposal site after initial sediment placement (fall 2002) and after each subsequent flow event capable of mobilizing significant quantities of sediment from the site (or after re-grading or moving sediment into the entrainment zone following such an event). The magnitude of sediment entrainment will be determined by PCWA and DFG based on comparisons of photographs of the Indian Bar disposal site (taken at a fixed location) before and after major spill events. If it is concluded that significant entrainment has occurred, the disposal site will be surveyed to document changes in area and cross-section of the site, and to estimate the volume of entrained sediment. Pebble counts (following the methods described in Section 4.1.1 of Bunte and Abt [2001]) will be conducted at the Indian Bar disposal site at the time of surveys to monitor particle size distributions over time.

Monitoring will be terminated after 2–3 sampling events (triggered by the occurrence of the target flows [as described above] necessary to evaluate the performance of sediment disposal relative to model predictions, and following the occurrence of SPT operations and significant entrainment of sediment from Indian Bar) if no significant adverse project effects on water quality, aquatic habitat, and BMI are detected. If such effects are detected, monitoring will be continued for a period of time mutually agreed to by PCWA and DFG to evaluate corrective measures to be implemented by PCWA.

An adaptive monitoring strategy is proposed to address the uncertainties related to the complex behavior of natural river systems. Factors that increase uncertainty and affect the ability of the monitoring program to detect project effects include:

- large natural variability (both spatial and temporal) in water quality, aquatic habitat, and BMI populations and communities;
- lack of sufficient baseline data and limited time frame in which to characterize preproject variability in the monitoring parameters; and

- local variation in flows, sediment loads, and sediment transport capacity that may differentially affect the monitoring parameters in the treatment and control areas.

Detecting the effect of a given management activity on water quality and aquatic habitat requires a demonstration that the change lies outside the normal range of the variable and that the change is attributable to the management activity. Thus, sufficient preproject data are required to adequately characterize preproject conditions and provide a meaningful basis for detecting project effects. In addition, because habitat monitoring sites will be located downstream of the project area and will be influenced by other sediment sources (North Fork MFAR and smaller tributaries), establishing a link between observed changes and the project may be difficult. Accordingly, monitoring data will be analyzed regularly to evaluate the monitoring program and determine whether any modifications can be made to improve its overall effectiveness.

A primary objective in developing the monitoring approach was to maximize the ability of the monitoring program to detect project effects. Accordingly, knowledge of hydraulic, sediment transport, and channel characteristics of the MFAR watershed will be used to select monitoring sites that are most sensitive to changes in sediment loads. Concurrent monitoring of several key water quality, aquatic habitat, and BMI parameters will also provide a more comprehensive and reliable indicator of overall trends in sediment and habitat conditions than 1 or 2 parameters alone. To further address uncertainty, the relative effects of the sediment management program will be evaluated in the context of other management activities or disturbances in the watershed. This task will involve continued coordination with federal, state, and local resource agencies to gather and update information on land management activities and watershed events (e.g., fires, landslides) that may significantly affect sediment loads in the MFAR, North Fork MFAR, and Rubicon Rivers.

After project activities begin, evidence for project effects will consist of significant changes (adverse or beneficial) in the relationships or differences between key water quality and aquatic habitat parameters established between treatment and control sites before project activities begin. If these changes constitute an adverse effect on water quality and aquatic habitat conditions downstream of Ralston Dam, the magnitude of these changes will be compared with established water quality and habitat thresholds to evaluate project performance and determine whether corrective actions are warranted. The need for corrective actions will also be based on the results of BMI monitoring, which will serve as a key indicator of the biological effects of observed water quality and habitat changes. In addition, these changes will continue to be evaluated in light of other watershed events and trends that may influence the monitoring results and conclusions.

A current limitation in determining an optimum sampling design and appropriate statistical model for detecting project effects is the lack of sufficient baseline data to adequately characterize natural variability in water quality, aquatic habitat, and BMI communities in the project area. Therefore, as more data become available, the monitoring program will continue to be evaluated to determine whether any changes in the sampling design or methods are warranted to improve the program's ability to achieve the objectives.

Water Quality and Aquatic Resources Monitoring Plan

Water Quality Monitoring

Objectives

The water quality monitoring program is designed to monitor project compliance with the water quality objectives established by the RWQCB in the Basin Plan (Regional Water Quality Control Board 1998). The Basin Plan objectives constitute allowable changes in water quality from project-related disturbances. Therefore, the main objectives of the monitoring program include quantifying water quality differences between sampling stations located upstream and downstream of Ralston Afterbay and ensuring that project-related changes in TSS and turbidity do not exceed the applicable Basin Plan water quality objectives. The water quality monitoring program will be most useful for evaluating project-related effects from SPT operations. SPT operations have a greater likelihood of affecting fine sediment transport that travels as suspended material because coarse material settles out at the upper end of the reservoir. Placement of reservoir sediments at Indian Bar is presumed to have little effect on background concentrations of suspended sediment because excavated reservoir sediments will consist mostly of coarse material that will be transported as bedload. The effects of the project on the coarser material traveling as bedload sediment will be addressed by the habitat monitoring program.

The RWQCB Basin Plan includes numerical water quality objectives for turbidity; however, there are no numerical standards for TSS. The narrative water quality objective for suspended sediment states that the load and discharge rate shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses. The turbidity water quality objectives vary in relation to the background levels as follows:

- where natural turbidity is between 5 and 50 nephelometric turbidity units (NTUs), increases shall not exceed 20%;
- where natural turbidity is between 50 and 100 NTUs, increases shall not exceed 10 NTUs; and
- where natural turbidity is greater than 100 NTUs, increases shall not exceed 10%.

These objectives will serve as thresholds for evaluating project performance. Accordingly, the water quality monitoring results will be used to test the following null hypotheses.

- **H_0:** During SPT operations, increases in turbidity downstream of Ralston Dam do not exceed 20% of ambient levels when natural turbidity is between 5 and 50 NTUs.
- **H_0:** During SPT operations, increases in turbidity downstream of Ralston Dam do not exceed 10 NTUs of ambient levels when natural turbidity is between 50 and 100 NTUs.
- **H_0:** During SPT operations, increases in turbidity downstream of Ralston Dam do not exceed 10% of ambient levels when natural turbidity is greater than 100 NTUs.

Based on limited TSS data available for the MFAR, background conditions may vary considerably during storm events and all 3 ranges of the numerical turbidity objectives may apply to the proposed project. Preproject monitoring will be conducted to establish this range and determine the relationship between turbidity and TSS at stations upstream and downstream of Ralston Afterbay.

Monitoring Parameters

Turbidity levels are generally correlated to the TSS concentrations, typically accounting for roughly 80% of the variability observed in simultaneous TSS measurements (Environmental Protection Agency 1991). The relationship between turbidity and TSS values is not typically linear and must be determined on a site-specific basis because the relationship can vary as a result of storm size, water color, organic matter, and algae growth. Collecting TSS samples that accurately represent average river conditions depends on hydraulic characteristics such as current patterns, flow velocity, and eddies. A composite sample collected over vertical and lateral intervals in the channel will typically provide a better representation of the average river TSS concentration than a single sample (Environmental Protection Agency 1985).

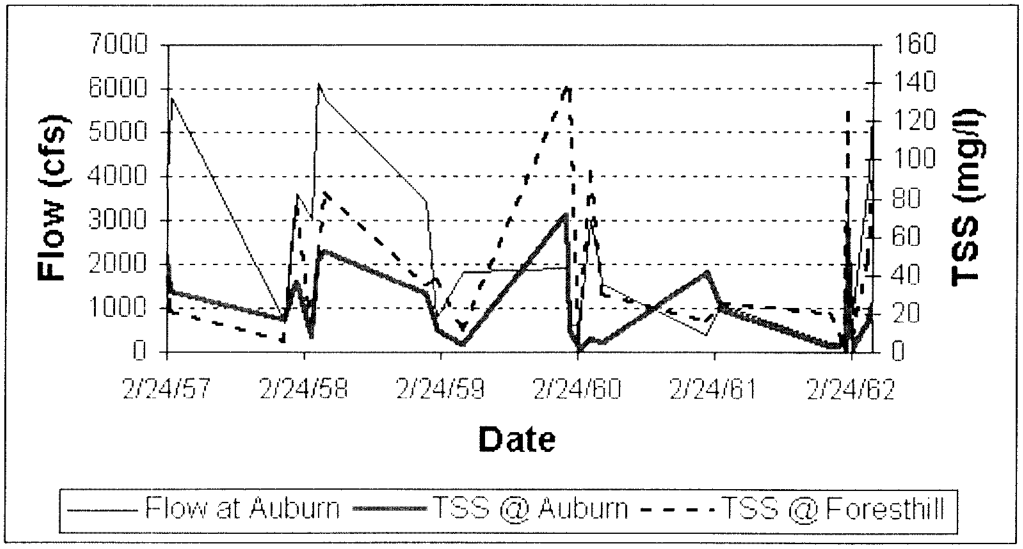
Turbidity measurements are less sensitive to the sampling location because turbidity is primarily a function of finer materials (silt and clay) that are more readily held in suspension and evenly distributed throughout the water. The time required to transport samples to a lab and conduct the analytical procedures for TSS effectively precludes its use as a real-time monitoring tool. Given the practical limitations of TSS sampling methods, need for correlation analysis with turbidity, and lack of regulatory objectives, this monitoring program will be focused on intensive automated turbidity monitoring; TSS data will be collected on a supplemental basis. The site-specific relationship between turbidity and TSS will be determined after sufficient monitoring data have been collected.

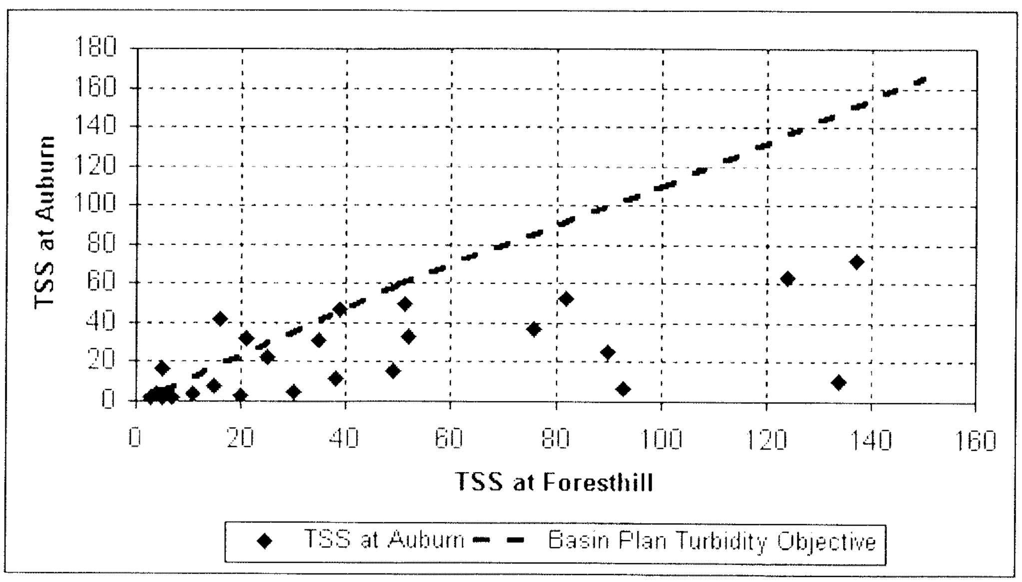
Few water quality data are available for the MFAR downstream of Ralston Dam. Simultaneous grab sample data for TSS are available from the MFAR at Foresthill and Auburn (47 miles downstream) for 25 scattered dates, collected during high flow periods between the years 1956 and 1962 (EarthInfo 1993). Other scattered grab samples are available up to 1985. Given that flow and TSS data are available for a variety of years with differing precipitation patterns, the available data may provide a reasonable estimate of the range of conditions that will be observed under current conditions and when the proposed project is implemented. The data represent sediment transport that is affected by several primary watersheds within the project area, including the Rubicon River (315 square miles), MFAR above Ralston Afterbay (94 square miles), and NMFAR (92 square miles) watersheds. Streamflow and TSS values at Foresthill and Auburn are reasonably correlated with each other (Figure 2). TSS values range up to a maximum of about 120 milligrams per liter (mg/l), and values at Auburn are generally lower than at Foresthill. Table 1 presents descriptive statistics for TSS data from all MFAR sample dates. The maximum value recorded at Foresthill and Auburn of 397 mg/l and 537 mg/l, respectively, are considerably larger than the paired data in Figure 2. The coefficient of variation (i.e., standard deviation/mean) is large and indicates that variability in the values is high.

Table 1. Summary Descriptive Statistics for TSS Data in MFAR

Statistic	MFAR at Foresthill (mg/l)	MFAR at Auburn (mg/l)
Mean	54.6	45.6
Median	30.0	12.0
Standard deviation	71.3	85.5
Minimum	2	1
Maximum	367	537
95% confidence interval of mean	± 25.3	± 19.7
Sample Size	33	75

Real-time automated turbidity monitoring data will serve as the primary tool for evaluating water quality conditions during SPT operations. Appropriate numerical turbidity objectives for long-term evaluation of water quality conditions during SPT were estimated from the variability in existing TSS data for the MFAR. Numerical data quality objectives are generally stated in terms of a specific level of precision and confidence that is desired in the collected data. Based on the Basin Plan objectives for allowable project-related increases in turbidity and lack of existing turbidity values for the MFAR, the monitoring program may need to be able to detect differences between upstream and downstream samples as low as 5 NTUs. Consequently, turbidity monitoring is designed to produce data capable of detecting differences of 5 NTUs with a 95% confidence level. Data will be collected that are sufficient to identify differences in TSS with a precision of 30 mg/l at a 95% confidence interval. Approximately 70–100 samples per year for the range of flows shown in table 1 may be needed to detect significant annual differences between upstream and downstream samples at this recommended level of precision.





Source: Earth Info Inc. 1993

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Figure 2
Flow and TSS in the Middle Fork of the American River

Sampling Design

Table 2 presents sampling locations and protocols for the water quality monitoring program, including collection schedule and sampling methods. Figure 3 shows the location of the water quality monitoring stations. It is hypothesized that during SPT operations, water quality conditions will not differ appreciably between upstream and downstream monitoring stations. Therefore, this monitoring program is designed to evaluate the proposed sediment management activities and ensure that adverse water quality effects do not occur. An initial 3-year monitoring period is recommended, consisting of 1 year of preproject monitoring followed by 2 years of monitoring to evaluate the water quality effects of SPT operations. The need for follow-on monitoring after year 3 will be evaluated after the initial data are collected and evaluated. Preproject monitoring data will be used to develop relationships between turbidity and TSS concentrations at stations upstream and downstream of Ralston Afterbay.

To obtain as many data values as possible during storm events and SPT operations, turbidity will be monitored on a real-time basis with automated sensors that can collect data at any desired time interval and relay the data by telemetry to the Ralston Powerhouse and PCWA's Foresthill office. Two sampling locations were selected for installation of automated turbidity monitoring probes to provide the primary compliance monitoring data. The Rubicon River, approximately 200 feet upstream from the Ralston Powerhouse (which is generally discharging about 1,000 cfs to the river), will serve as the primary upstream sample site. The Rubicon River has the largest contributing watershed and generates most of the sediment input to the reservoir (Bechtel Corporation 1997). PCWA's river-gaging station immediately upstream of Horseshoe Bar will serve as the principal downstream compliance monitoring location. The Horseshoe Bar gaging station records river stage and has a telemetry unit with radio link to Ralston Powerhouse. The gage can also be monitored from PCWA's Foresthill office.

Supplemental grab samples will be collected for both turbidity and TSS in the MFAR upstream of Ralston Afterbay at the bridge crossing, MFAR bridge crossing, and in the MFAR between Ralston Dam and the Oxbow Powerhouse tailrace. Samples for TSS will be collected manually by field personnel. Grab sample locations will serve as additional indicators of water quality conditions during the initial years of monitoring and allow site-specific correlation between turbidity and TSS values.

Table 2. Summary of Water Quality Monitoring Locations, Schedule, and Methods

Monitoring Locations	Schedule of Sampling Activities	Constituents Monitored & Frequency of Activity		
		Total Suspended Solids (Grab Samples Only[1])	Turbidity	
			Grab Samples[1]	Automated[2]
Rubicon River	Year 1 preproject monitoring	X		X
Upstream from Ralston Powerhouse	Years 2 & 3 monitoring	X		X
	After year 3 follow-on monitoring	X (as needed)		X (as needed)
MFAR Upstream from reservoir at bridge	Year 1 preproject monitoring	X	X	
	Years 2 & 3 monitoring	X (as needed)	X (as needed)	
MFAR Upstream from Oxbow Powerhouse tailrace	Year 1 preproject monitoring	X	X	
	Years 2 & 3 monitoring	X (as needed)	X (as needed)	
North Fork of the MFAR at bridge	Year 1 preproject monitoring	X		X
	Years 2 & 3 monitoring	X (as needed)		X (as needed)
MFAR at Downstream gage house	Year 1 preproject monitoring	X		X
	Years 2 & 3 monitoring	X		X
	After year 3 follow-on monitoring	X (as needed)		X (as needed)

Notes:

1 Grab samples for turbidity and total suspended solids (TSS) will be collected at a minimum of 4-hour intervals during storm events when water level is rising and starting when streamflow is 3,000 cfs or greater. Sampling should be targeted to include sufficient storm events that provide data from as wide a range of high streamflows as possible. Sampling in successive years should be targeted at storm events that generate flow conditions similar to those sampled during the pre-project monitoring.

2 Automated turbidity probe and telemetry system can be adjusted as needed based on available battery power. Data will be monitored during storm events and downloaded by telemetry at a minimum of 4-hour intervals. Turbidity recorders need be used only during storm events and at a frequency sufficient to generate at least 70 samples per year. Sampling should be targeted to include sufficient storm events that provide data from as wide a range of streamflows in excess of 3,000 cfs as possible. Sampling in successive years should be targeted at storm events that generate similar flow conditions similar to those sampled during the pre-project monitoring.

If the initial monitoring data indicate that turbidity and TSS data are closely correlated and turbidity measurements are effective for monitoring compliance of SPT operations, compliance monitoring for TSS will be discontinued and the real-time turbidity data will be used as the primary indicator for SPT operations

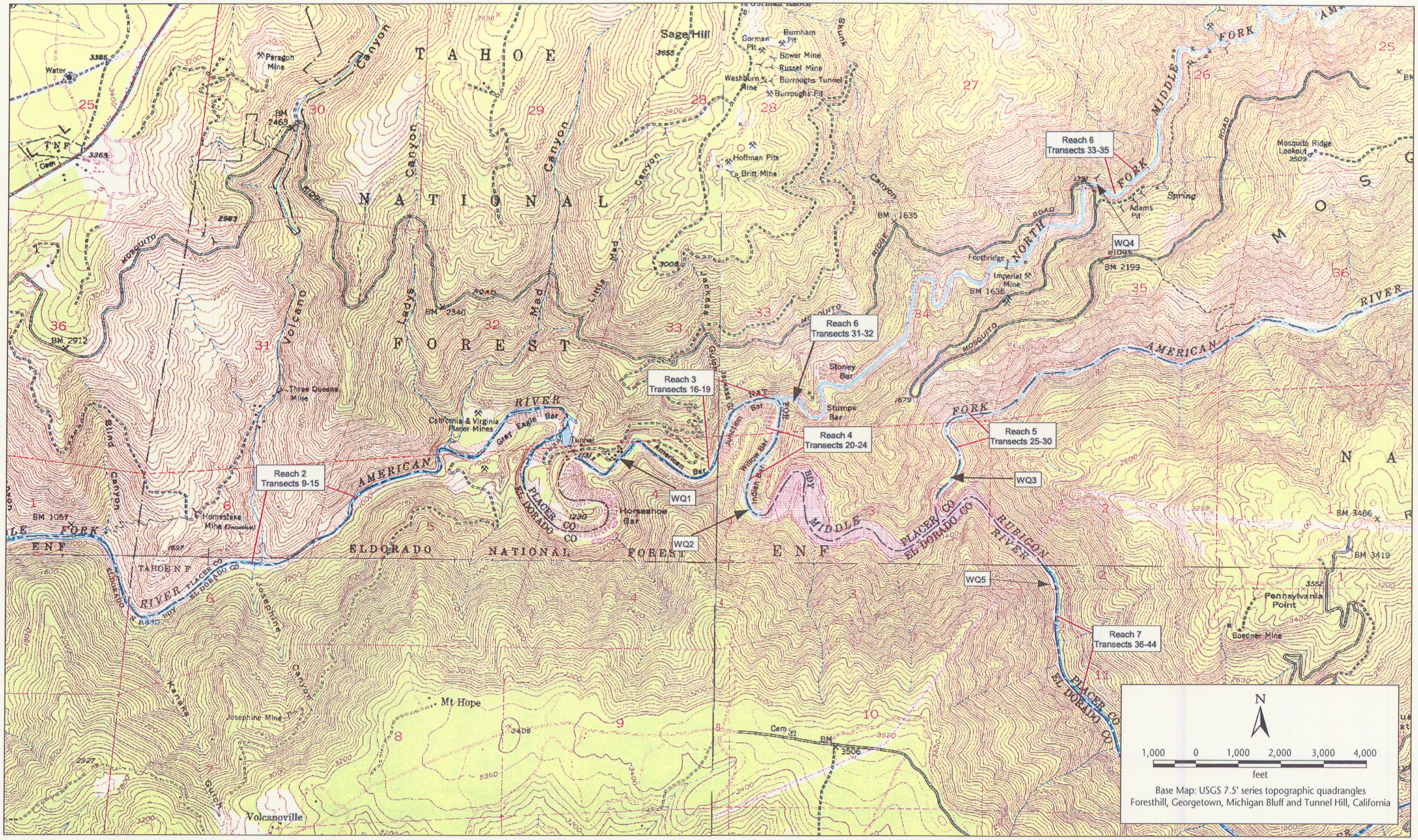

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Figure 3 (continued)
Aquatic Habitat/Benthic Macroinvertebrate (Reaches 1-7) and
Water Quality (WQ1-5) Monitoring Sites

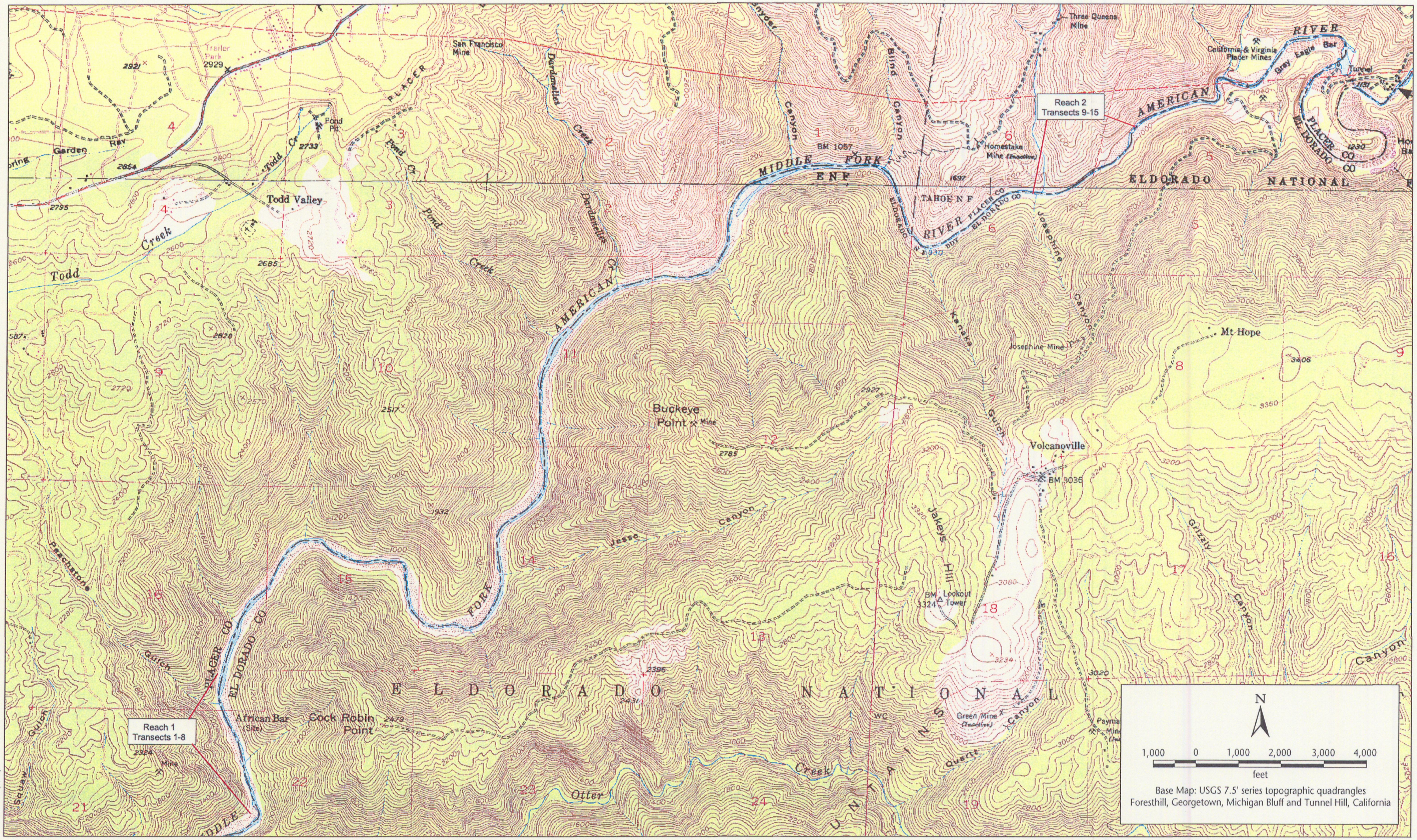

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Figure 3
Aquatic Habitat/Benthic Macroinvertebrate (Reaches 1-7)
Water Quality (WQ1-5)Monitoring Sites in Reaches 1 and 2

compliance. The TSS data will be used primarily for long-term evaluation of SPT operations and for additional confirmation of real-time water quality conditions as indicated with the automated turbidity sensors.

SPT operations will commence when river flows exceed 3,500 cfs. Therefore, preproject monitoring of turbidity and TSS will be conducted when storms generate river flow rates that exceed 3,000 cfs. Preproject data for low flow events will not be conducted because natural variability in TSS and turbidity will be much lower and not representative of conditions during SPT operations. Both automated turbidity and grab sample data will be collected at a minimum of 4-hour intervals during storm events commencing when streamflows begin to rise and ceasing when the hydrograph has begun to recede or SPT operations are discontinued, whichever occurs first. The trigger for commencing sample collection can be water level in the reservoir or flow at the Horseshoe Bar gage. An additional automated water level recorder is recommended for the Rubicon River site to determine when streamflow starts to increase during storm events and provide time to prepare for the necessary manual sampling activities. This gage does not have to be an approved USGS-type stilling well. The system can be a simple enclosure with a pressure transducer for monitoring water level. A flow-rating curve does not need to be calculated. For monitored storm-flow events, sampling should be targeted to include data from as wide a range of streamflows as possible that exceed 3,000 cfs. Sampling in successive years should be targeted to storm events that generate flow conditions similar to those sampled during the preproject monitoring.

During SPT operations, PCWA staff will monitor the real-time upstream and downstream turbidity monitoring data to evaluate compliance of operations with Basin Plan water quality objectives. All grab sample data collected at field sites will be recorded on a field data form. TSS and turbidity samples will be collected by hand using an appropriate bottle sampling device (e.g., Van Dorn, Kemmerer). Sample bottles will be specified by the laboratory performing the analyses. Samples will be analyzed to provide the lowest practical detection limit for TSS (less than or equal to 5 mg/l) and turbidity (less than or equal to 1 NTU). Field samples will be refrigerated for sample preservation and shipped to a commercial laboratory after each sampling event. A field blank of deionized water and field duplicate samples should be collected once for every 20 samples, with a minimum of 1 replicate per storm event. Automated turbidity probes installed at the Rubicon River and Horseshoe Bar sites will have a minimum detection limit of 1% of full-scale reading. The probe should be capable of measuring a range of turbidity measurements up to 500 NTU.

Data Analysis

Standard data control charting methods will be used to identify the rate and direction of change in real-time turbidity concentrations in the river and detect significant excursions from the Basin Plan water quality objectives. Supplemental information regarding TSS concentration conditions will be evaluated from the grab sample data. The long-term performance of SPT operations with respect to water quality objectives will be evaluated with standard statistical testing of the mean differences between preproject and postproject conditions. Linear regression analysis will also be used for year-to-year evaluations of project-related effects on water quality based on the relationship between values collected at the primary upstream and downstream sample sites. If routine patterns of turbidity and TSS in the tributary streams are constant over the duration of the monitoring program, regression analysis will allow the detection of changes between the Rubicon and the Horseshoe Bar gaging site attributable to the project without explicitly evaluating changes in the tributaries. Consequently, until the initial data collected from the tributaries prove otherwise, it is assumed that the automated turbidity data will be sufficient to establish a statistically significant relationship reflecting differences in water quality conditions between the upstream and downstream sites.

Following collection of the first year of pre-project data, results will be evaluated for statistical variability in turbidity and TSS concentrations. Descriptive and exploratory analysis of the data will be necessary to ensure that the proper statistical tools are applied to the analyses. Issues that may need to be addressed include transformation of data to approximate a normal data distribution and evaluation for autocorrelation among the data points. The estimated number of samples necessary to achieve the desired data quality objectives will be confirmed. Following the second and third years of data collection, means testing and linear regression analysis of turbidity and TSS data will be conducted to identify the differences between preproject and postproject data and the statistical significance of the differences. Adjustments to the data based on related variables such as background TSS and turbidity concentrations or streamflow may be used to improve the sensitivity of the data analyses.

The procedures for determining water quality conditions necessitating corrective actions will be defined in advance in coordination with RWQCB and California Department of Fish and Game (DFG). When the data indicate that downstream turbidity values exceed the water quality objectives, possible corrective actions may include immediately taking additional samples for both turbidity and TSS to provide additional data on the water quality conditions. If SPT operations are presumed to be causing a water quality compliance problem, other possible corrective actions may include reducing the flow through the gates, increasing flow through the spillway gates, or both. As a final action, the low level outlet gate may be closed to cease SPT until more favorable conditions occur. The procedure for ceasing and restarting SPT operations will also be defined before starting SPT.

Two issues described below merit consideration when interpreting project-related water quality monitoring data for SPT operations and to avoid taking corrective actions when they are not necessarily warranted: (a) evaluating effects of water residence time in the reservoir at varying levels of streamflow; and, (b) evaluating the direction of change in turbidity and TSS concentrations.

- **Hydraulic residence time:** Based on the volume of the reservoir, the residence time of a slug of water passing from the upper end of the reservoir to the downstream end will be short at high flows (approximately 40 minutes at 50,000 cfs) and samples collected simultaneously at upstream and downstream locations will presumably be adequately comparable to each other. When SPT operations first begin at a flow of 3,500 cfs, however, the residence time will be approximately 10 hours. TSS values typically rise and fall in correlation with streamflow. Therefore, it is likely that when upstream turbidity concentrations start to decrease as the stormflows recede, simultaneous measurement made downstream may indicate continued increasing concentrations and regulatory exceedances because of the time delay of previously high turbidity water moving downstream. In order to account for water residence time in the reservoir, data charting procedures should account for the time delay at varying flow rates to establish whether an exceedance in the thresholds is truly occurring. The transport time can be reasonably predicted with empirical calculations from bathymetric profile data of the reservoir. In addition, dye tracer tests can be conducted to more accurately characterize flow through the reservoir. The need for dye tracing will be evaluated after the first year of monitoring to determine whether such precision is necessary for the program.

- **Direction of changes in monitored constituents:** As noted above, TSS will typically rise and fall with the streamflow pattern. Following the passage of peak flows and corresponding TSS and turbidity transport during storm events, high variability in upstream and downstream TSS and turbidity may continue despite an overall decreasing trend in their values. Consequently, the absolute differences between upstream and downstream values during the receding period of a storm event may exceed the numerical water quality objectives. Compliance evaluations should account for whether the concentrations at upstream and downstream locations are rising or falling when interpreting the data with respect to this criteria. If concentrations are decreasing overall, yet downstream values are higher, it will indicate that the flush of sediment resulting from initial mobilization and transport is nearing completion. Concentrations at this point in the storm may be relatively low compared to the higher peak values occurring earlier in the storm and should not constitute a violation of the water quality objectives.

Aquatic Habitat Monitoring

Objectives

The primary objective of aquatic habitat monitoring is to quantitatively evaluate project effects on aquatic habitat based on changes or trends in key substrate and BMI parameters upstream and downstream of Ralston Afterbay. The results will be used to test the following null hypothesis:

- **Ho:** Differences between mean substrate size in the treatment reaches and that in the control reaches during preproject years do not change during postproject years.

This hypothesis also may be stated as follows:

- **Ho:** The relationship between mean substrate size in the treatment reaches and that in the control reaches during preproject years does not change during postproject years.

Rejection of either hypothesis will be evidence of significant project effects (adverse or beneficial). The biological significance of these changes will be evaluated based on the general trout- and BMI-substrate relationships and observed changes in BMI population or community attributes measured in the treatment and control reaches.

Stream and laboratory studies have shown that excessive amounts of fine sediments can adversely affect aquatic habitat and the capacity of that habitat to support trout and aquatic invertebrates. Although the results vary with species, life stage, and season, significant declines in fish and aquatic invertebrates were generally associated with riffles in which 50% or more of the coarse particles (gravels and larger materials) were covered or surrounded by fine sediment (embeddedness). This level will serve as a preliminary threshold for evaluating habitat quality during the preproject monitoring period. Additional years of preproject data will be necessary to adequately characterize annual variation in substrate conditions and establish an impact threshold (i.e., change in substrate conditions) that would trigger the need for corrective actions. This impact threshold will also be based on the results of BMI monitoring and any observed relationships between the BMI parameters and substrate conditions during the preproject monitoring period.

The BMI monitoring data will indicate seasonal and annual patterns of abundance, composition, and diversity associated with the ecology and natural history of BMI communities. These patterns will be compared from year to year to detect any change or shift that would indicate a response to an environmental change. More importantly, BMI monitoring will be useful in evaluating the biological effects (beneficial or adverse) of any changes in water quality and substrate conditions observed during the monitoring program.

In addition to monitoring the size composition of riffle substrates, the U.S. Forest Service and DFG requested monitoring of channel cross sections downstream of Ralston Afterbay to detect potential deposition of sediment in pools during the postproject monitoring period. The U.S. Forest Service also requested that water temperature loggers be installed upstream and downstream of Ralston Afterbay.

Monitoring Parameters

Substrate size composition and embeddedness will be used as key monitoring parameters for assessing project effects on aquatic habitat. These parameters were selected because they are sensitive indicators of changes in sediment loads, can be rapidly measured in the field, and provide a direct or indirect measure of factors known to affect the abundance and production of fish and invertebrates in streams.

Substrate Size Composition

The size composition of streambed substrates is a major factor determining the quality of stream habitat for trout and aquatic invertebrates. Changes in substrate size can affect the productive capacity of trout streams by affecting the suitability of substrate for spawning, the availability of suitable cover and shelter for juvenile and adult trout, and the amount of living space for aquatic invertebrates (Waters 1995, Bjornn and Reiser 1991).

Substrate Embeddedness

Embeddedness is the percentage to which coarse sediments (gravel and larger particles) are surrounded or covered by fine sediment (silt/clay and sand). This parameter provides a measure of the amount of interstitial space between coarse sediments and thus reflects the suitability of the streambed for incubation, emergence, and overwintering of trout, and the amount of living space for BMI. Excessive amounts of fine sediments and embeddedness have been shown to affect the abundance of juvenile salmonids and aquatic invertebrates in laboratory and natural streams (Hillman et al. 1987, Bustard and Narver 1975, Bjornn et al. 1977). Although the results vary depending on species, life stage, and season, a general observation was that significant declines in fish and invertebrate abundance were generally associated with embeddedness levels of 50% or more.

Sampling Design

Because of the high degree of spatial and temporal variability in habitat conditions in natural river systems, several criteria were developed to guide selection of monitoring sites. These criteria were based on the need to minimize differences between treatment and control sites, increase sampling efficiency, and maximize the ability of the monitoring program to detect potential project effects. Foremost among these criteria is the need for all monitoring sites, especially those that serve as primary treatment and control reaches, to be equally sensitive to changes in sediment loads and respond similarly to these changes. Second, monitoring sites should have similar channel and substrate characteristics that provide important aquatic habitat for trout and aquatic invertebrates. Third, monitoring sites should be located as close as possible to Ralston Afterbay to reduce the confounding effects of other sediment sources (e.g., tributaries). Finally, as a practical consideration, all sites should be accessible and provide safe conditions for field measurements.

Based on the hydraulic and sediment transport characteristics of the river, these criteria appear to best be met by localized alluvial portions of the river where sediment deposition occurs in response to local channel and valley constrictions that include tributary alluvial fans, landslide debris, and bedrock constrictions (Mussetter Engineering 2001). Mussetter Engineering identified 5 such reaches between the Ralston Dam and the North Fork of the American River confluence (Table 3).

Before selecting monitoring sites, a Jones & Stokes fisheries biologist will conduct an aerial survey of the MFAR by helicopter to examine the 5 reaches identified by Mussetter Engineering and identify other potential treatment and control reaches upstream and downstream of Ralston Afterbay. The aerial survey will include the first 5 miles of the MFAR and Rubicon River upstream of Ralston Afterbay, the MFAR from Ralston Dam to Louisiana Bar, and the lowermost 5 miles of the North Fork MFAR. The goal of this initial survey is to evaluate the suitability of potential treatment and control reaches based on the criteria presented above. Preference will be given to those reaches that are closest to the project area and are reasonably accessible by foot. All potential monitoring reaches will be delineated on 7.5-minute topographic maps. Photographs will be taken of representative portions of the potential monitoring reaches.

Table 3. Locations and Characteristics of Hydraulic Controls for Sediment Transport in the Middle Fork of the American River

Location	River Mile	Comments
Louisiana Bar	50.4	Pool and riffle upstream of bedrock control; road accessible
Mammoth Bar	52.4	Pool and riffle upstream of bedrock constriction at Murderer's Gulch; road accessible
Cherokee Bar	59.0	Head of alluvial reach that extends from Greenwood Bridge to Mammoth Bar; pools and riffles; road accessible
Canyon Creek	61.44	Pool formed by alluvial fan constriction and backwater from Ruck-A-Chucky landslide; not road accessible but can be reached by track in about 20 minutes
Other sites:		
Otter Creek	64.65	Pools and riffles upstream of alluvial fan-induced contractions; neither site is readily accessible but they are closer to Ralston Dam.
Volcano Creek	71.4	

Note: River mile 50.37 is the confluence with the North Fork of the American River.

Table 4 presents the proposed locations and schedule for aquatic habitat and BMI monitoring. Two reaches will be established immediately downstream of Ralston Afterbay between the dam and the confluence of the North Fork MFAR and between the confluence of the North Form MFAR and Horseshoe Bar. These reaches will be used primarily to evaluate changes in substrate composition associated with coarse sediment input from the Indian Bar disposal site. One or more treatment reaches will be established on the MFAR downstream of Horseshoe Bar to evaluate potential changes in fine and coarse sediment associated with SPT operations and Indian Bar sediment disposal. One or more control areas will be established on the Rubicon River upstream of Ralston Afterbay, the MFAR upstream of the reservoir, and on the North Fork MFAR.

Table 4. Summary of Aquatic Habitat and BMI Monitoring Locations, Activities, and Schedules

<table>
<tr><th>Monitoring Reach</th><th>Purpose</th><th>Aerial Survey and Monitoring Reach Selection</th><th>Monitoring Site Selection</th><th>Field Measurements</th></tr>
<tr><td>Rubicon River upstream of Ralston Powerhouse</td><td>Control for SPT operations</td><td rowspan="6">Conduct in first year of preproject monitoring period and in subsequent years only if warranted</td><td rowspan="6">Conduct in first year of preproject monitoring period and in subsequent years only if warranted</td><td rowspan="6">Sample in 2–3 preproject years and 2–3 postproject years following each occurrence of SPT operations. Schedule subject to change depending on project schedule, the occurrence of SPT-triggering flows, and the occurrence of significant sediment entrainment from Indian Bar.</td></tr>
<tr><td>MFAR upstream of Ralston Afterbay</td><td>Control for SPT operations</td></tr>
<tr><td>MFAR between Ralston Dam and North Fork of the MFAR</td><td>Treatment for Indian Bar sediment disposal</td></tr>
<tr><td>MFAR between North Fork of the MFAR and Horseshoe Bar</td><td>Treatment for SPT operations and Indian Bar sediment disposal</td></tr>
<tr><td>North Fork of the MFAR</td><td>Control for SPT operations and Indian Bar sediment disposal</td></tr>
<tr><td>MFAR downstream of Horseshoe Bar</td><td>Treatment for SPT operations and Indian Bar sediment disposal</td></tr>
</table>

Following selection of monitoring reaches, ground surveys will be conducted to more closely examine the reaches and identify specific habitats that meet the selection criteria above. Riffles will likely be key habitats because they are considered relatively sensitive indicators of bed conditions, provide important habitat for trout and invertebrates, and allow safe conditions for collecting substrate data across the entire channel.

Aerial surveys and monitoring site selection will be conducted in the first year of preproject monitoring. Substrate sampling will be conducted in the first year of preproject monitoring and in subsequent preproject and postproject years. Because substrate conditions are not expected to change significantly after winter and spring storm events, substrate sampling will be conducted once a year during the summer or fall when flows are low enough to permit sampling. Sampling will be conducted at the same time each year to minimize the effects of possible seasonal changes in fine sediments.

Preproject monitoring should begin as soon as possible and be conducted in selected years during the preproject monitoring period to characterize baseline variation in substrate conditions among and within reaches. Ideally, preproject data should include measurements of streambed conditions following flow events equal in magnitude and duration to those that will trigger SPT operations. A minimum of 2–3 years of preproject monitoring may be necessary to provide a meaningful basis for evaluating potential changes in substrate conditions during postproject years.

Monitoring of project effects will be conducted in 2–3 sampling events triggered by the occurrence of the target flows necessary to evaluate the performance of sediment disposal relative to model predictions, and following the occurrence of SPT operations and significant entrainment of sediment from Indian Bar (see Monitoring Approach).

Substrate Composition and Embeddedness

Five to 10 riffles will be established as monitoring sites in each reach. All riffles or a random sample of riffles in each reach will be selected for monitoring. Two transects will be established at each riffle. One transect will be established at a random location in the upstream third of the riffle, and the other transect will be established in the riffle crest or pool tail (immediately upstream of the head of the riffle) in an area equal in length to one-third the riffle length.

Field measurements of substrate composition and embeddedness will follow the methods described by Bain (1999). The location of each transect will be marked with paint and flagging above the high-water mark. Cloth or metal measuring tapes will be suspended above the wetted channel (perpendicular to the channel) between 2 metal stakes secured at the edge of the low-flow channel. Substrate composition will be measured with a 1-meter (m) metal ruler, divided into ten 10-centimeter (cm) sections painted contrasting colors. The first sampling location along each transect will be selected randomly and subsequent locations selected at regular intervals from the first. Sampling locations will be separated by at least 1 m. A maximum of 15 sampling locations will be evenly distributed across the transect, depending on channel width.

At each sampling location, the ruler will be lowered across the stream substrate (perpendicular to the current) and the dominant substrate class under each 10-cm segment will be recorded using the modified Wentworth scale (Table 5).

Table 5. Modified Wentworth Classification of Substrate Types by Size

Substrate Type	Particle Size Range (millimeters)	Code
Silt and clay	<0.059	0
Sand	0.06–1	1
Gravel	2–15	2
Pebble	16–63	3
Cobble	64–256	4
Boulder	>256	5

Embeddedness will be visually determined at each transect by examining the coarse sediments (gravel, pebble, cobble, boulder) in the deepest portion of the channel and recording the dominant level of embeddedness (Table 6).

Table 6. Embeddedness Rating for Stream Channel Materials*

Level of Embeddedness	Description	Code
Negligible	Gravel, pebble, cobble, and boulder particles have <5% of their surface covered by sediment.	0
Low	Gravel, pebble, cobble, and boulder particles have 5–25% of their surface covered by sediment.	1
Moderate	Gravel, pebble, cobble, and boulder particles have 25–35% of their surface covered by sediment.	2
High	Gravel, cobble, and boulder particles have 50–75% of their surface covered by sediment.	3
Very High	Gravel, pebble, cobble, and boulder particles have >75% of their surface covered by sediment.	4

* Fine sediment includes materials less than 2 mm in diameter: sand, silt, and clay.

As requested by DFG, pebble counts will be evaluated as an alternative method for assessing the size composition of riffle substrates. In fall 2002, pebble counts (following the methods described in Section 4.1.1 of Bunte and Abt [2001]) will be conducted at existing transects in addition to the Bain method. A squareholed template will be used to measure substrate particles based on the standard Wentworth scale (rather than the modified scale used in 2001). The embeddedness of gravel and larger material will be measured as the percentage of the total vertical extent of a particle below the bed surface. Following data collection, Jones & Stokes and DFG will compare the particle size distributions resulting from the two methods. If the particle size distributions produced by the Bain method are reasonably consistent with those produced by the pebble count method, the Bain method will continue to be used to characterize riffle substrates.

Otherwise, the pebble count method will be used for the remainder of the monitoring program.

Channel Cross-Sections

Standard surveying techniques will be used to measure channel cross-sections at several pools upstream and downstream of Ralston Afterbay during pre- and postproject monitoring years to detect potential changes in pool habitat that may occur following project activities. Pool cross-sections will be measured at three representative pools downstream of Ralston Dam (in Reaches 1 and 2) and three representative pools above Ralston Afterbay in the Rubicon River (Reach 7). Two to three transect locations will be established in each pool depending on the variability in channel profile along the length of the pool. All transect locations will be marked in the field with permanent markers and recorded with global positioning system unit. Channel cross sections will be measured in October when flows are at minimum levels (100 cfs, approximately).

Water Temperature

Automated water temperature loggers will be installed above and below Ralston Afterbay near the proposed water quality monitoring stations (MFAR at Horseshoe Bar gage, MFAR above Ralston Afterbay, North Fork MFAR, and Rubicon River. The loggers will be programmed to continuously record water temperatures at hourly intervals. The loggers will be installed in July 2002 and the data will be downloaded in the field every three months.

Data Analysis

Substrate composition and embeddedness data will be analyzed quantitatively using statistical techniques developed for control-treatment designs (e.g., Bernstein and Zalinski 1983). As discussed earlier, the applicability of the proposed design depends on proper pairing of the treatment and control reaches and sufficient preproject data to characterize the differences or relationship between streambed conditions in these reaches. Alternatively, the data can be analyzed graphically using descriptive statistics (e.g., means, confidence intervals) and/or regression techniques to characterize trends in streambed parameters over time (e.g., Adams and Beschta 1980).

Because the sampling design may not be able to effectively discern project effects from those of other sediment sources in the MFAR watershed, it will be necessary to complement the monitoring program with additional information to assess the relative magnitude of effects related to SPT and other sources. For example, bathymetric surveys of Ralston Afterbay before and after SPT operations will provide valuable information on the preproject and postproject quantities of fine sediment in the reservoir. In the event that a large amount of sedimentation is detected downstream of Ralston Dam, bathymetric surveys will provide a measure of net changes in reservoir sediment conditions, which will help assess the extent to which SPT operations contributed to the supply of fine sediment. The data then may help in the assessment of whether any net contribution to fine sediment supply in the river is attributable to the reservoir. Other sources of information include ongoing watershed monitoring programs and assessments being conducted by the U.S. Forest Service (Forest Service), U.S. Geological Survey, and other federal and state agencies responsible for resource and land management in the MFAR, Rubicon, and North Fork MFAR watersheds.

In addition, annual reports, maps, and interviews with resource managers will be used to monitor the occurrences of major events (e.g., fires, landslides, intense land use activities) that could influence erosion and sedimentation processes in these watersheds. This information will be used to further evaluate the relative effects of these sediment sources on habitat conditions in the monitoring reaches. The interpretation of monitoring results will also include an analysis of hydrologic parameters that may differentially affect geomorphic conditions in the monitoring reaches from year to year.

Benthic Macroinvertebrate Monitoring

Objectives

The primary objective of BMI monitoring is to provide biological indicators of aquatic habitat health and functionality to be used in conjunction with the water quality and substrate data to evaluate potential project effects on aquatic habitat. Quantitative bioassessment based on BMI was developed by the Environmental Protection Agency (EPA) as a tool for monitoring and assessing the impacts of watershed management activities on water quality, fish, and stream productivity. Quantitative bioassessment has become the legal standard in most states for mitigation and restoration projects. Justifications for the use of BMI as indicators of water and habitat quality have been described by Hutchinson (1993), Resh and Jackson (1993), Rosenburg and Resh (1993), and others. Additional advantages of BMI-based biological assessment include long storage life for preserved samples and the establishment of BMI voucher collections. Voucher collections may be evaluated by other investigators and serve as a source of information for taxonomists and resource managers.

Monitoring Parameters

The following parameters will be used to monitor the overall health and functionality of aquatic habitat in the treatment and control reaches during preproject and postproject periods.

Invertebrate Density

Invertebrate density is the number of individual invertebrates per square meter. This is a measure of overall habitat utilization by BMI, as well as a measure of forage available to fish. Typically, BMI density remains fairly stable. Sudden BMI density fluctuations are indicative of impacts on habitats and water quality. Disturbed systems also may exhibit high BMI densities attributed mainly to opportunistic species. Some opportunistic species include Philippine clam, some crawdad species, chironomid midges (e.g., Chironomus), culicids, and some worms.

Taxa Richness

Taxa richness is the total number of individual taxa and is used as a means of determining the overall health of an aquatic habitat (Plafkin et al. 1989). In general, the higher the water quality, habitat suitability, and variety, the higher the taxa richness. Similarly, sudden drops in taxa richness will indicate a negative impact within the system.

BMI Productivity

BMI productivity is defined as the grams of living invertebrates per square meter within the study area. This measurement yields the biomass per unit area that the habitat is able to support. Diverse, highly functional habitats typically produce higher biomass than is produced by impaired systems. Alternately, disturbed systems that are overrun by opportunistic species may have abnormally high biomass.

Ephemeroptera, Plecoptera, Trichoptera Ratios

By measuring the abundance of invertebrate families most sensitive to changes in water quality and habitat suitability, the relative habitat health can be examined. The Ephemeroptera, Plecoptera, Trichoptera (EPT) index examines nymphal Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), which as a group are generally considered to be pollution sensitive. The abundance index of these families increases with increasing water quality (Plafkin et al. 1989).

Jaccard Coefficient of Community Similarity

Jaccard Coefficient of Community Similarity and Community Loss indices (Barbour et. al. 1999) will be used to determine similarities between the treatment and control reaches and between preproject and postproject years.

$$\text{Jaccard Coefficient of Community Similarity} = \frac{\text{\# of taxa common to both samples}}{\text{\# of taxa in both samples}}$$

The Jaccard Coefficient of Community Similarity estimates the degree of similarity between samples, based on presence or absence of taxa. The coefficient values range from 0 to 1.0. The higher the coefficient, the greater the similarity between the samples.

Community Loss Index

The Community Loss index estimates the loss of taxa between comparison samples and reference samples.

$$\text{Community Loss} = \frac{[\text{\# of taxa in reference sample}] - [\text{\# of taxa common to both samples}]}{\text{\# of taxa in comparative sample}}$$

The index identifies the differences in sample composition. The higher the index value, the greater the dissimilarity between the comparison sample and the reference sample.

Sampling Design

The sampling design for BMI monitoring was based on EPA's quanititative bioassessment protocols for streams and wadeable rivers (Barbour et al. 1999). BMI populations will be sampled in the same pre- and postproject years as substrate monitoring and in 3 of the same riffle transects used for substrate sampling in each monitoring reach. (Table 4). Samples will be collected in the late spring (June), midsummer (August), and fall (October). Sampling 3 times per year is a standard protocol to adequately characterize seasonal changes and assess potential seasonal impacts on species and life stage composition of BMI communities. Littoral sampling from Ralston Afterbay will not be necessary because the water in the reservoir fluctuates sufficiently during normal yearly maintenance practices to limit colonization of the littoral zone by BMI.

A standard kick seine will be used to sample BMI at 3 locations along selected transects. These locations were selected to provide samples from a representative range of velocities along each transect. A kick is accomplished by placing the kick net in a stationary position and disturbing 0.33 square meter of substrate immediately upstream of the net. Large cobble and boulders will be dislodged and cleaned by hand to remove attached organisms. Sand, gravel, and pebble substrates will be disturbed by hand and with the toe or heel of a boot and the current will carry dislodged organisms into the net. Sample material from each kick will be combined into a single composite sample, which represents one square meter of substrate area. The material will be placed in an airtight container and preserved immediately in 95% ethanol. All samples will be labeled with the collection number, station, date, and collector. The samples will then be transported to the Jones & Stokes laboratory for analysis. After 24 hours, the ethanol in each sample will be replaced with fresh 95% ethanol.

In the laboratory, chain of custody forms will be used to track the samples. The contents of each sample will be placed into a 300-micrometer (μm) sieve, gently rinsed, and then placed in a Pyrex pan with 30% ethanol. The sample contents will then be examined for BMI by a technician using illuminated magnifying glasses. All BMI will be removed from debris with forceps and placed in containers filled with 70% ethanol. Once a sample presumably has all BMI removed, a second technician will then review the sample to ensure that all BMI are removed. After 2 technicians have searched the sample and found no more BMI, all debris will be discarded. If the second technician finds 4 or more BMI remaining in the sample, the original sorter will repeat the search of the entire sample.

Invertebrate biomass will be estimated using volumetric displacement. BMI specimens from all samples will be dried at room temperature for 15 minutes on size 613 qualitative filter paper and then placed in a 25 ml graduated cylinder with 15 ml of 15°C deionized water. The volumetric displacement will then be determined and recorded.

Specimens collected from each sample will be identified by taxonomists to the lowest justifiable taxon using an Olympus SZ-ST40 zoom stereo scope and the appropriate taxonomic references (Arnett 1968; Edmunds et al. 1976; McAlpine et al. 1981; Merritt and Cummins 1984; Pennak 1978; Usinger 1956; Wiggins 1977) in order to establish diversity, EPT ratios, opportunistic taxa ratios, taxa richness, and abundance, and to develop community indexes.

Starting in 2002, modifications and additions will be made to BMI sampling protocols to ensure consistency with the California Stream Bioassessment Procedure (www.dfg.ca.gov). These modifications include subsampling 300 organisms from each sample for identification purposes and complete counts of the remaining organisms, sending at least 10% of the samples to an independent quality assurance taxonomist to ensure taxonomic accuracy and enumeration, and using the California Bioassessment Worksheet.

Data Analysis

All data analyses will be conducted following the protocols for quantitative bioassessment established by EPA and the scientific community (Plafkin et al. 1989; Resh and Rosenberg 1984; Merritt and Cummins 1984; Hutchinson 1993; Resh and Jackson 1993; Rosenburg and Resh 1993).

Data Management and Reporting

Successful implementation of the water quality and aquatic resource monitoring program requires proper data reduction and analysis procedures, routine quality control checks during sampling and data processing, and annual reporting of results for permit compliance, impact assessment, and performance evaluation. The chain of custody for data handling, storage, and processing will be clearly established. It is best to have a single person responsible for the monitoring program to ensure that all field and laboratory techniques, data entry, quality control and assurance methods, and analytical methods are coordinated and follow established protocols.

Standard field and laboratory data forms will be prepared for each monitoring component. All completed field and laboratory data forms will be kept in a central location or logbook. Duplicates will be made and stored in a separate location. The lead technician will proof all data forms at the end of each day of field or laboratory work. All data will be entered into Microsoft Excel spreadsheets (or equivalent) and maintained in a central database. The original spreadsheets will be checked for errors by comparing all entries in the electronic spreadsheets with the raw field and laboratory entries. The central database will be write-protected and maintained on a main computer server. Working copies of the spreadsheets will be used for data reduction, analysis, and reporting. The results of the preproject and project operation monitoring will be presented in annual reports prepared at the end of each annual monitoring period. The reports will summarize the methods and results of the current and previous years' monitoring activities. Data and statistical analyses will be presented in summary graphs and tables. The reports will present and update conclusions regarding permit compliance, impact assessment, and monitoring performance and will include recommendations for modifications of sampling design and other program elements, if warranted.

References Cited

Printed References

Adams, J.N., and R.L. Beschta. 1980. Gravel bed composition in Oregon coastal streams. *Canadian Journal of Fisheries and Aquatic Sciences* 37:1514-1521.

Arnett, R.H. 1968. *The beetles of the United States (a manual for identification).* Ann Arbor, MI: The American Entomological Institute. 1,112 pp.

Ayres Associates. 1997. *American and Sacramento River, California project, geomorphic, sediment engineering, and channel stability analyses, final report.* Prepared for U.S. Army Corps of Engineers, Sacramento District, DACW05-93-C-0045. Sacramento, CA.

Bain, M.B. 1999. Substrate. Pages 95–103 in Bain, M.B. and N.J. Stevenson, editors. 1999. *Aquatic habitat assessment: common methods*. Bethesda, MD: American Fisheries Society.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish*, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agnecy; Office of Water; Washington, D.C.

Bechtel Corporation. 1997. *Sediment study of Ralston Afterbay Reservoir*. Final Report. Submitted to Placer County Water Agency. San Francisco, CA.

Bernstein, B.B. and J. Zalinski. 1983. *An optimum sampling design and power tests for environmental biologists*. Journal of Environmental Management 16:35–43.

Bjornn, T.C., M.A. Brusven, M.P. Molnau, J.H. Milligan, R.A. Klamt, E. Chacho, and C. Schaye. 1977. *Transport of granitic sediment in streams and its effects on insects and fish*. University of Idaho, Forest, Wildlife and Range Experiment Station Bulletin 17, Moscow.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83–138 in Meehan, W.R., editor. *Influences of forest and rangeland management on salmonid fishes and their habitats*. American Fisheries Society Special Publication 19. Bethesda, MD.

Bustard, D.R., and D.W. Narver. 1975. *Aspects o the winter ecology of juvenile coho salmon* (Oncorhynchus kisutch) *and steelhead trout* (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 32:667–680.

California Department of Conservation, Division of Mines and Geology. 1981. Geologic Map of the Sacramento Quadrangle, 1:250,000. Sacramento, CA.

__________. 1982. Geologic Map of the Sacramento Quadrangle, 1:250,000. Sacramento, CA.

__________. 1992. Geologic Map of the Chico Quadrangle, 1:250,000. Sacramento, CA.

Crouse, M.R., C.A. Callahan, K.W. Malueg, and S.E. Dominguez. 1981. Effects of fine sediments on growth of juvenile coho salmon in laboratory streams. *Transactions of the American Fisheries Society*. 110:281–286.

Cushman, R.M. 1985. *Review of Ecological Effects of Rapidly Varying Flows Downstream from Hydroelectric Facilities*. Environmental Sciences Division Oak Ridge National Laboratory, Oak Ridge, TN. 5:330–339.

Dailey, S. 2001. ENF star fire salvage slope stability investigation summary of initial findings. Adaptive Management Services.

U.S. Department of Fish and Game. 1979. *Rubicon River wild trout management plan*. Inland Fisheries Branch.

EA Engineering, Science, and Technology. 1990. *Preliminary feasibility analysis of alternative sediment management options for Ralston Afterbay Reservoir*. Prepared for Placer County Water Agency. Lafayette, CA.

EarthInfo Inc. 1993. USGS Quality of Water, West 1 Surface Water. Boulder, CO.

Edmunds, G.F., Jr., S.L. Jensen and L. Bemer. 1976. *The Mayflies of north and central America*. Minneapolis, MN: University of Minnesota Press. 330 pp.

El Dorado National Forest. 2001a. *Cumulative Watershed Effects Analysis for Middle Fork American River Watershed*. Prepared by Cynthia Podsialdo, Hydrologic Technician, El Dorado National Forest, December 2001.

__________. 2001b. *Cumulative Watershed Effects Analysis for Chipmunk Creek Watershed*. Prepared by Cynthia Podsialdo, Hydrologic Technician, El Dorado National Forest, December 2001.

__________. 2001c. *Cumulative Watershed Effects Analysis for North Fork Long Canyon Creek Watershed*. Prepared by Cynthia Podsialdo, Hydrologic Technician, El Dorado National Forest, December 2001.

Environmental Protection Agency. 1985. *A Screening procedure for toxic and conventional pollutants in surface and groundwater—part 1*. EPA/600/6-85/002a, Environmental Research Laboratory. Athens, GA.

__________. 1991. *Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska*. Water Division, Region 10, EPA/910/9-91-001. Seattle, WA.

Gislason, J.C. 1985. *Aquatic insect abundance in a regulated stream under fluctuating and stable diel flow patterns*. Fisheries Research Institute, University of Washington, Seattle, WA. 5:39–46.

Green, R.H. 1979. *Sampling Design and Statistical Method for Environmental Biologists*. Toronto: John Wiley & Sons, Inc.

Hillman. T.W., J.S. Griffith, and W.S. Platts. 1987. *Summer and winter habitat selection by juvenile chinook salmon in a highly sedimented Idaho stream*. Transactions of the American Fisheries Society 116:185–195.

Hutchinson, G.E. 1993. *A treatise on limnology. vol. iv, the zoobenthos*. (Ed.) Y.H. Edmondson. New York: John Wiley & Sons, Inc. 944 pp.

Hydrosphere Data Products, Inc. 2000. *Hydro data 2000*. Boulder, CO.

Jones & Stokes. 2002. *Ralston Afterbay Sediment Management Project Indian Bar Pilot Project*. (J&S 00-297.) February. Sacramento, CA. Placer County Water Agency. Foothill, CA.

Kondolf, G.M. 2000. *Assessing salmoid spawning gravel quality*. Department of Landscape Architecture and Environmental Planning and Department of Geography, University of California, Berkeley, CA.

Kondolf, G.M., and M.G. Matthews. 1993. The sizes of salmonoid spawning gravels. *Water Resource Research*, 29:2275-2285; in "Assessment of Potential for Flushing Sediments Released from South Fork Long Canyon Diversion Dam", report submitted to PCWA August 15, 1996.

Ligon, F.K., W.E. Dietrich, and W.J. Trush. 1995. *Downstream Ecological Effects of Dams: a geomorphic perspective*. BioScience. Volume 45, No. 3. March 1995. 183-192 pp.

McAlpine, J.F., (coordinator). 1981. *Manual of neararctic diptera, vol. I–III*. Research Branch, Agriculture Canada Monograph 27. Ottawa, CN. 3,587 pp.

Merritt, R.W., and K.W. Cummins (editors). 1984. *An introduction to the aquatic insects of North America*. Second Edition. Dubuque, IA: Dendall/Hunt Publishing Co.

Minshall, G.W. 1984. *The ecology of aquatic insects*. Praeger, NY: Praeger Publishers. Chapter 12, 358–400 pp.

Mussetter Engineering. 2001. *Technical memorandum, Indian Bar sediment disposal site study*. Prepared for Placer County Water Agency. Fort Collins, CO.

Parfitt, D., and K. Buer. 1980. *Upper Sacramento River Spawning Gravel Study*. California Department of Water Resources, Northern Division, Red Bluff, CA.

Pennak, R.W. 1978. *Fresh-water invertebrates of the United States*. New York: John Wiley and Sons. 628 pp.

Placer County Water Agency. 2001. *Ralston Afterbay reservoir sediment management project: sediment sampling and testing program*, October 2001. Foresthill, CA.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid bioassessment protocols for use in streams and rivers*. U.S. Environmental Protection Agency Publication EPA/440/4- 89/001. 189 pp.

Regional Water Quality Control Board. 1998. *Water quality control plan (basin plan) for the Central Valley region, Sacramento River and San Joaquin River basins*. Sacramento, CA.

Resh, V.H. and J.K. Jackson. 1993. *Rapid assessment approaches to biomonitoring and benthic macroinvertebrates*. New York: Chapman and Hall. Resh, V. and D. Rosenberg. 1984. *The ecology of aquatic insects*. Praeger, NY: Praeger Publishers. 625 pp.

Resource Consultants and Engineers. 1993. *American and Sacramento River California Project: Geomorphic, Sediment Engineering and Channel Stability Analyses*. Fort Collins, CO.

Rosenburg, D.M., and V.H. Resh (eds). 1993. *Freshwater biomonitoring and benthic macroinvertebrates*. New York: Chapman and Hall.

Usinger, R.L. (editor). 1956. *Aquatic insects of California, with keys to North American genera and California species*. Berkeley, CA: University of California Press. 508 pp.

Ward, J.V. 1992. *Aquatic insect ecology, v.1: biology and habitat*. John Wiley & Sons, Inc. New York.

Ward, J.V. and J.A. Stanford. 1982. *Thermal responses in the evolutionary ecology of aquatic insects*. Annual Review of Entomology 27:97–117.

Waters, T.F. 1995. *Sediment in streams: sources, biological effects, and control*. American Fisheries Society Monograph 7. Bethesda, MD.

Wiggins, G.B. 1977. *Larvae of North American caddisfly genera*. Toronto, CA: University of Toronto Press. 401 pp.

Personal Communications

Harvey, M. Hydraulic engineer. Mussetter Engineering, Inc., Fort Collins, CO—memorandum, 2001.

Harvey, M. Hydraulic engineer. Mussetter Engineering, Inc. Fort Collins, CO. March 9, 2001—email.

Jue, Jon. Resource officer. Eldorado National Forest. Georgetown, CA. March 5, 2002—email.

Mai, Christine. Hydrologist. Eldorado National Forest. Placerville, CA. February 13, 2002—email.

Smith, Dennis. Minerals officer. Eldorado National Forest. Georgetown, CA. April 24, 2002—telephone conversation.

Stiehr, P.E., P.L., Watermark Engineering, Inc. Technical memorandum. *Scour Evaluation at Middle Fork American River below Ralston Afterbay*. November 17, 1999.