Lower Clear Creek Floodway Rehabilitation Project
Proposal
Phase 3B

Presented to
The California Bay-Delta Authority
650 Capital Avenue
Sacramento California 95814

Prepared By:
Western Shasta Resource Conservation District
6270 Parallel Road
Anderson CA 96007

July 2005

Lower Clear Creek Floodway Rehabilitation Project

TABLE OF CONTENTS

LOWER CLEAR CREEK FLOODWAY REHABILITATION PROJECT

A Proposal Submitted by: **Western Shasta Resource Conservation District 6270 Parallel Road**
Anderson, CA 96007-4833

Local government/district
Tax ID number:

In collaboration with: **Lower Clear Creek Coordinated Resource Management and Planning Group and Lower Clear Creek Restoration Team**

Executive Summary:

This proposal requests funding to complete the next phase (Phase 3B) of the Lower Clear Creek Floodway Rehabilitation Project, and, in doing so, addresses a headcut that is threatening previous successful phases of the Project. This Project was initiated in 1998 to address impaired geomorphic, riparian, and salmonid habitat conditions on Clear Creek along the 1.8 mile reach degraded by historic gravel mining. Mining destroyed the natural channel and floodplain morphology, removed large volumes of sediment, exposed the underlying clay hardpan, and created ponds that strand adult and juvenile salmonids. The restoration approach developed by the multi-agency Clear Creek Restoration Team focuses on using local and imported alluvial materials to refill the floodway and restore bankfull channel dimensions, re-create floodplains, and revegetate floodplains with native riparian vegetation. The first two phases of the Project (Phases 1 and 2A) used a rather unique approach to salmonid habitat restoration by utilizing reclaimed dredge materials from upstream borrow locations to simultaneously rehabilitate riparian and wetland habitat. This lowered the cost significantly rather than using aggregate purchased from commercial suppliers. With the use of mercury during historic gold extraction practices on Clear Creek, concerns were raised in 2001 regarding use of potentially contaminated dredger tailings. Therefore, subsequent restoration phases (Phases 2B and 3A) were implemented with on-site borrow sources that were determined to have no history of gold dredging. Phase 3B will continue this approach, as local alluvial borrow sites have been located which will provide sufficient material and also allow creation of additional functional floodplain and 25 acres of riparian habitat through revegetation.

Previous phases of the project, implemented with CALFED Ecosystem Restoration Program and Central Valley Project Improvement Act (CVPIA) funding, imported or moved a total of 275,000 cubic yards of aggregate to fill ponds and restored 90.8 acres of floodplain. In one construction season, Phase 3B will reconstruct the bankfull channel for this next phase of the restoration project, contiguous with floodplain surfaces restored in previous phases. It will also stabilize a headcut that is migrating into previous project areas and is threatening to undo or damage the investments to date. The Project is supported by the Lower Clear Creek Coordinated Resource Management Group; CALFED through previous funding and objectives to recover Priority Group I Salmonid Species; the US Bureau of Reclamation and the U.S. Fish and Wildlife Service through previous funding and Section 3406 of the CVPIA; the U.S. Bureau of Land Management through cost sharing and property acquisition; the Anadromous Fish Restoration Program (AFRP); and multiple agencies involved with project design, engineering and restoration (Lower Clear Creek Restoration Team). The design of Phase 3B was funded by the US Bureau of Reclamation earlier this year which will enable construction to being in 2006 with CALF ED funding. Completion of Phase 3B will not only significantly improve salmonid/aquatic habitat, riparian and wildlife habitat, and fluvial geomorphic processes in Clear Creek, it will also protect previous investments and provide CALFED with monitoring programs detailing the success of the project, numerous project-related experiments, and a model Demonstration Stream available for immediate and continued adaptive management opportunities.

A. Project description: Project Goals and Scope of Work

1. Problems, Goal and Objectives

a. Background:
Since 1996, a unique partnership between local, state, and federal agencies, and local stakeholders has resulted in a step by step reduction of the large-scale disruption that occurred in the Clear Creek drainage system as a result of gold mining, gravel mining, dams and water diversion. These historical alterations in natural stream flow resulted in impaired fluvial geomorphic processes, a damaged channel and devastated salmonid populations. Through this unique multi-agency partnership and the commitment of over 21 million dollars to date from multiple agencies and programs, the stream and its salmonid populations are being restored. The project has expanded suitable spawning habitat and created new, functional channel segments, introduced coarse sediments to the new channel segments, and restored large sections of the channel and floodways to their natural state.

b. Problem:
Clear Creek originates near 6,000 ft elevation in the Trinity Mountains, and flows south between the Trinity River basin to the west and the Sacramento River basin to the east. Upper Clear Creek flows into Whiskeytown Lake (Elevation 1,210 ft) at Oak Bottom, 11 miles west of Redding (Figure 1). The lower section of Clear Creek (lower Clear Creek) flows south from Whiskeytown Dam for approximately 8 miles, then east for 8 miles before joining the Sacramento River five miles south of Redding. Until 2000, Saeltzer Dam blocked most of the spawning habitat between the Sacramento River and Whiskeytown Dam.

Major Pierson B. Reading discovered gold at the present-day Clear Creek Road Bridge in 1848. Following this historic discovery, the lower Clear Creek watershed was extensively altered, beginning with placer mining and dredger mining for gold up through the 1940's. Floodplains and terraces along the corridor were "turned upside down" by the dredging process, removing all riparian and upland vegetation, and converting finer grained substrates to piles of cobbles unsuitable for revegetation. These dredger tailings confined Clear Creek in some locations, and in other locations, discouraged the natural recovery of riparian and upland plant species. Commercial instream aggregate mining was prevalent through the mid-1980's (Figure 2). Aggregate mining is now conducted well outside of the floodway on old terraces north of Clear Creek Road. Instream mining destroyed the natural channel and floodplain morphology, removed most of the gravel within a 3-mile reach, exposed the channel bed surface to the underlying clay hardpan (Figure 3), and left large pits separated from the stream by small gravel berms (Figure 4). High flows in 1983 and 1986 permanently breached these pits, creating poorly draining areas that stranded both adult and juvenile salmonids.

Additional ecological degradation occurred in the Lower Clear Creek Watershed when Whiskeytown Dam was completed in 1963 at river mile 18 as part of the Trinity River Division of the Central Valley Project. Water releases into Clear Creek below the dam have reduced stream flow by 60% of unimpaired conditions. The magnitude of common floods (2-5 year recurrence) has been reduced by approximately 60%, and all coarse and fine sediment from the upper watershed is now trapped by the reservoir. Large floods (10-20 year recurrence) still occur occasionally, but are less frequent than under the natural flow regime. The channel morphology below the dam changed in the following ways: gravel bars became less pronounced, the bed surface coarsened, salmonid spawning habitat became degraded, and riparian vegetation encroached along the channel margins. Essential geomorphic processes such as sediment transport, channelbed scour and deposition, and channel migration have been severely impaired by the management of the flow from Whiskeytown Dam. These processes are critical components in creating and maintaining dynamic channel morphology, high quality salmonid habitat and riparian vegetation.

Research on the drainage system supports both the historical origins of the problem and the solutions identified by the Lower Clear Creek Floodway Rehabilitation Project. Support documentation includes the Lower Clear Creek Watershed Analysis (WSRCD, 1996) California Department of Fish and Game (CDFG) memorandum (Coots, 1971), the Clear Creek Fishery Study (CDWR, 1986), the Lower Clear Creek Floodway Rehabilitation Project, Channel Reconstruction, Riparian Vegetation and Wetland Creation Design (McBain and Trush, 2000) and the Final Geomorphic Evaluation of Lower Clear Creek Downstream of Whiskeytown Dam, California (McBain and Trush, 2001).

Beginning in 1998, multiple agencies concerned about Clear Creek formed the Clear Creek Restoration Team (Restoration Team) to plan and implement channel rehabilitation activities in the low-gradient alluvial reach to reverse the impacts of instream gravel mining, dredge mining, and Whiskeytown Dam. The Restoration Team is comprised of representatives from federal, state, and local agencies, who serve as technical advisors on creek restoration planning, design and monitoring. This project, named the Lower Clear Creek Floodway Rehabilitation Project (Project), was designed in 1999 by McBain and Trush, an environmental engineering consulting firm. A three phase project, with phase 3 broken into three components, phases 1, 2A, 2B, and 3A have been funded through multiple agencies and completed. This proposal requests funding to complete the next, and most critical phase, Phase 3B. The timing for this phase is important as a channel incision through an old gravel pit below previously implemented restoration phases (Phase 2 and 3A) has led to the creation of a significant headcut that is threatening those investments. The removal of Saeltzer Dam and extensive gravel injections at numerous sites upstream from the floodplain restoration project are recreating sediment transport processes that will ultimately lead to stability of the lower reaches, once the headcut threatening Phase 2 is eliminated, and an appropriately sized channel is created.

Several phases of project design and construction have been completed with CVPIA and CALFED ERP funding. Phase 1, funded by CVPIA, was completed in October 1998 and began removing material from the Reading Bar dredger tailing borrow site to isolate a large salmonid-stranding mining pit at the Mining Reach south pond complex. Phase 2A, completed in 2000, continued the extraction of borrow material at the Reading Bar site to fill 18.4 acres of off-channel north bank mining pits, re-create floodplains, and revegetate floodplains. Extensive revegetation occurred at both the Reading Bar site and the Mining Reach site. Phase 2B, completed in 2001, continued the floodplain restoration along the south bank and a portion of the downstream north bank, filling 59.5 acres of mining pits to eliminate the worst stranding sites. On-site borrow material was used, and floodplains were revegetated with native flora. Phase 3A, completed in 2002, was the first project phase that involved relocation of the channel itself, which was moved from a channel lined with claypan into an area with deeper alluvium. Only limited structural measures were installed (to prevent recapture of the original channel), and geomorphic monitoring has shown that the channel is now dynamic, functioning as designed (with flows over 3,000 cfs overtopping the constructed floodplain), has even more in-channel anadromous fish habitat than was originally anticipated, a 342% increase in spawning habitat use within constructed reaches (Phase 3A), and reduced stranding of juveniles on floodplains. Phase 3A included 12.9 acres of riparian revegetation on the newly constructed floodplains. To date, revegetation of constructed floodplains has increased habitat for riparian-dependent avian fauna including five California Partners in Flight Riparian Focal Species, and two California Department of Fish and Game Species of Special Concern (CDF&G and PRBO 2003). In 2004 proportional nest success for riparian focal species was higher on restoration plots than on reference sites in the watershed (Burnett and Harley, 2004).

c. Goals and Objectives: This proposal requests funding to complete Phase 3B of the Lower Clear Creek Floodway Rehabilitation Project. This phase will reconstruct the bankfull channel and portions of floodplain along 0.9 miles in the center of the restoration project area in one construction season, as well as monitor project implementation for three years. The reconstructed bankfull channel is designed to function geomorphically within newly constructed floodplain surfaces completed in Phases 2A and 2B of the Floodway Project (2000-01), which are immediately adjacent to Phase 3B. Most importantly, the work will address a headcut that has continued to migrate and is now threatening the successful channel and riparian habitat created in previous project phases. This headcut was documented and taken into account with the original design, however, it was anticipated that funding to complete the project would occur in a more timely manner given the identified importance of restoring Clear Creek. The downstream edge of the headcut has now migrated 700 feet upstream since 1998, and the low flow water surface elevation (WSE) in the upstream areas has already been dropped some 2.5 feet in the period. Current drop through the headcut is about 5.5 feet over 650 feet.

The overarching goal for Lower Clear Creek is to re-establish critical ecological functions, processes, and characteristics, within contemporary regulated flow and sediment conditions, that best promote recovery and maintenance of resilient, naturally reproducing salmonid populations and the river's natural animal and plant communities (See Conceptual Plan in Appendix I). This goal was developed by the Restoration Team, and is supported by the Lower Clear Creek Coordinated Resource Management Planning Group (CRMP), the U.S. Bureau of Reclamation (USBR), the U.S. Fish and Wildlife Service (USFWS) and the U.S. Bureau of Land Management (BLM), and is consistent with goals of the CALFED Bay-Delta Ecosystem Restoration Program (ERP), Central Valley Project Improvement Act (CVPIA), and the Anadromous Fish Restoration Program (AFRP). The Restoration Team, comprised of representatives of the USBR, BLM, USFWS, National Marine Fisheries Service (NMFS), Natural Resources Conservation Service (NRCS), CDFG, CRMP, California Department of Water Resources (CDWR), and the Western Shasta Resource Conservation District (WSRCD), have cooperatively developed this Project to improve conditions for salmonids and restore ecological processes and functions degraded by decades of land use, mineral extraction, aggregate extraction, and, the impacts of Whiskeytown Dam.

Objectives of the Lower Clear Creek Floodway Rehabilitation Project are:

- Rehabilitate the channel degraded by historic aggregate extraction in the Mining Reach by reconstructing the bankfull channel and floodplains.
- Restore sediment transport processes, including coarse bedload transport continuity and fine sediment deposition on floodplain surfaces.
- Restore native riparian vegetation on floodplain and terrace surfaces by focusing on species that provide a diverse canopy structure and removing competing exotic species.
- Reduce salmonid stranding and mortality in floodplain gravel extraction pits.
- Improve habitat conditions for native fish and wildlife species, including priority salmonid species of central concern to CALFED, CVPIA, and AFRP programs.

Phase 3B Objectives:
Specifically, Phase 3B of the Project will target the following objectives:

- Re-establish an alternate bar morphology in the Mining Reach, including riffles, exposed gravel bars, and deep pools.
- Design the channel dimensions to transport the channel bed particles at flows slightly less than the anticipated future channel forming discharge (design discharge is 3,000 cfs), allowing coarse sediment to route through the reach.
- Design floodplains to begin to inundate at flows slightly less than the design discharge (3,000 cfs), allowing fine sediments transported in suspension to deposit on floodplain surfaces.
- Promote natural channel migration across the floodway during flows equal to or larger than the design discharge (3,000 cfs flow event). Lateral channel movement is considered a success, not a failure.

- Raise the bankfull channel thalweg at least three feet above clay hardpan to convert most of channelbed back to a gravel and cobble surface.
- Create floodplain micro-topography that simulates observed pre-dam high flow scour channels or abandoned primary channels. Revegetate many of these channels with native riparian vegetation, while leaving some unvegetated to experimentally evaluate whether natural riparian revegetation can occur (seed beds).
- Reduce the particle size in the design bankfull channel to optimize fish habitat by using appropriately-sized borrow materials.

2. Project Justification, Models, and Hypotheses

a. Justification: The Clear Creek project will provide model implementation of the Adaptive Management Process (AMP) by testing the hypothesis that streamflow and sediment can be managed for ecosystem health and function on a highly-regulated river. The careful evaluation of project data and the revisions made as a result of this evaluation will assist CALFED in its work with similar highly regulated Central Valley streams. Using the AMP, the project will provide essential information for balancing continued resource use with the restoration of river ecosystem health.

Historically Clear Creek supported populations of spring-run, fall-run, and late fall-run chinook salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss*). Spring-run chinook salmon and steelhead were extirpated from Clear Creek as a result of habitat destruction from mining and blocked access by Whiskeytown and Saeltzer dams (Saeltzer Dam was removed in 2000). Clear Creek is now managed for fall, late fall- and spring run chinook salmon, and steelhead. These species are all listed as CALFED "Priority Group I Species", whose management "will require substantial manipulations of the ecosystem" and for which CALFED "takes major responsibility for recovery…" (CALFED ERP Vol. I p. 32). With the removal of Saeltzer Dam in 2000 and subsequent restored access to the upper canyon reaches of Lower Clear Creek, as well as recent re-allocation of higher minimum baseflows, it is a timely opportunity to improve conditions for spring-run chinook salmon and steelhead. To achieve this goal will require (1) improving spawning habitat conditions and rearing conditions in the lower Clear Creek alluvial reaches and (2) reducing juvenile mortality associated with off-channel stranding.

The Project also qualifies as restoration action under Section 3406 of the CVPIA and will complement future restoration actions funded under CVPIA. Additional justification is provided in the Revised Draft Restoration Plan for the AFRP, which places 'High' priority on Action Item 2: "Halt further habitat degradations and restore channel conditions from the effects of past gravel mining."

As mentioned above, the Restoration Team developed the Project to improve the river ecosystem health and anadromous fish production of Lower Clear Creek. The WSRCD and the Lower Clear Creek CRMP developed the Lower Clear Creek Watershed Management Plan, (WSRCD 1998), which identified numerous actions to restore native anadromous fisheries within Clear Creek. The Project is consistent with the vision and goals for restoration established by the CRMP process. Finally, support for the project is also provided by Central Valley Project Water Association, Western Area Power Administration, NORCAL Fishing Guides and Sportsman's Association, Pacific Coast Federation of Fishermen's Associations, Horsetown Clear Creek Preserve, Shasta County, Shasta Tehama Bioregional Council and Shasta College.

Not only is there strong local and statewide impetus for restoring ecosystem elements (channel morphology, sediment transport processes, riparian community) to aid in the recovery of four Priority I salmonid species, but there is also an exceptional scientific and adaptive management opportunity in Clear Creek to test the hypothesis that streamflow and sediment can be managed on a highly regulated river to successfully restore and maintain channel morphology and fluvial processes, albeit at a smaller scale than existed historically. Evaluating this hypothesis on Lower Clear Creek will help CALFED determine whether this approach to river restoration and management can be successfully implemented on other highly regulated Central Valley streams. This approach, if successful, could provide an ideal balance between continued resource use (for irrigation, power generation, municipal uses) and restoring river ecosystem health. Clear Creek is perhaps one of the best locations to test this hypothesis because of the following exceptional opportunities:

Low Risk of Damage to Human Infrastructure. The entire floodway is essentially free of structural developments that would be negatively impacted by high flow releases, channel migration, sediment transport processes, sediment deposition, and riparian growth. The experimental value of managed high flow releases, large-scale channel reconstruction, and spawning gravel replenishment is therefore quite high.
Government Ownership of Floodway. The BLM and National Park Service own almost the entire floodway, and the BLM is working toward acquiring the few remaining parcels in coming years. Moreover, these lands contain large deposits of dredger tailings, which can serve as a long-term gravel source for mitigating the impacts of Whiskeytown Dam on coarse sediment supply, as well as provide opportunities to widen riparian and associated upland habitat corridors and reduce fragmentation effects.
Restoration can be accomplished quickly. Full restoration of the stream (restoring gravel supply, completing the Mining Reach Floodway Rehabilitation Project) can be accomplished within the next two to three years;
Saeltzer Dam Removal. The removal of Saeltzer Dam in 2000 has facilitated coarse sediment routing through the system and encouraged re-introduction of steelhead and spring-run chinook salmon to the stream.
"Low" overall cost. No water "cost" to the Bay-Delta system is provided, because flow releases into the stream would still be delivered to the Bay-Delta.
Experimental Control. Lower Clear Creek is unique since the reach downstream of Whiskeytown Dam is short (17 miles), has few tributaries, relatively good access, and long-term USGS gauging records, and provides good experimental control during managed flow releases from the dam. Additionally, the upper half of Lower Clear Creek is in a confined canyon reach, and the lower half is a low gradient alluvial reach, thereby enabling researchers to evaluate two types of channel morphologies. Considerable geomorphic monitoring of the stream bas been conducted since 1998.

Completing Phase 3B is a critical component of testing the hypothesis that streamflow and sediment can be managed on a highly regulated river to successfully restore and maintain channel morphology and fluvial processes because it will reverse the extensive downcutting to the clay hardpan and eliminate the coarse sediment trapping characteristics of the Mining Reach due to a lack of natural channel confinement.

Finally if allowed to continue, the relatively rapid upstream migration (about 700' since 1998) of a headcut in the Phase 3B area is now beginning to damage existing restoration investments in the project area and has the potential to substantially damage a significant proportion of the phases that have already been implemented. The headcut area, also known as "Backbuster", is documented in Figures 5 through 12, taken from a presentation to the CALFED Project Amendments Committee in October, 2004.

b. Conceptual Models: The Restoration Team is currently in the process of updating the Ecological Monitoring Plan (monitoring plan) for the Project and has developed new conceptual models (Appendix II) based on prior models, recent CALFED Environmental Water Program (EWP) models, and the results of monitoring data collected to date as part of the adaptive management process on Lower Clear Creek. The models illustrate the current understanding of the Lower Clear Creek system. These models illustrate how changes in resource inputs to the current system through restoration actions enable natural processes to restore structure and induce positive habitat responses that lead to increases in the diversity and productivity of biotic communities.

The monitoring plan assesses the effectiveness of the Project by evaluating: (1) changes in the structure of the physical channel and floodplains through geomorphic monitoring, (2) the response of anadromous salmonid species to changes in the channel and floodplain, (3) changes in terrestrial habitat through riparian revegetation monitoring including an evaluation of the functional ability of constructed features to naturally recruit vegetation and key physical factors that drive vegetation response and wetland habitat creation, and (4) the response of avian species to changes in terrestrial habitat.

Additional resources used to define the structure of the restoration project has been provided by the conceptual model entitled "Attributes of Alluvial River Integrity" (Appendix II), first introduced for the Trinity River Maintenance Flow Study (McBain and Trush 1997), and later incorporated in the Trinity River Flow Evaluation Study (USFWS and HVT, 1999) and the Habitat Restoration Plan for the Lower Tuolumne River Corridor (McBain and Trush 2000). This model was finally published in the Proceedings of the National Academy of Sciences (PNAS) (Trush et al. 2000). This conceptual model is based on the critical geomorphic and ecological processes that form and maintain alluvial rivers, and can be used to: 1) propose a set of hypotheses (the Attributes) that may be used to improve our understanding of how rivers function; 2) illustrate how human alterations to the environment may have affected the fundamental geomorphic processes of a particular alluvial river; and 3) develop quantitative and measurable restoration objectives.

Based on the Attributes and our current understanding of alluvial rivers, the linkages can be described between physical inputs (e.g. woody debris, streamflow, sediment), physical processes (e.g., sediment transport, bank erosion, fine sediment deposition), habitat structure (e.g., shallow-gradient riffles, well-sorted and clean spawning gravels, riparian vegetation recruitment), habitat responses (habitat connectivity, increased rearing habitat) and biotic responses (e.g., avian nest success, salmonid density-dependent mortality) as shown in the Conceptual Models. Then the effects of dams, streamflow and coarse sediment regulation, mining, and other human alterations can be related to these linkages. In Clear Creek, Whiskeytown Dam has severely reduced woody debris and coarse and fine sediment supply; reduced the magnitude, duration, and frequency of peak flows; and altered seasonal flow patterns. In addition, aggregate mining and gold dredging have reduced coarse sediment supply to the river by removing stored sediment from the channel and floodplain and trapping coarse sediment that is in transport on the streambed. These reductions/alterations in key inputs to the system (i.e., sediment, coarse woody debris and water) have reduced sediment transport, channel migration and avulsion, and floodplain inundation and have resulted in channel incision, bed armoring, channel narrowing (through riparian vegetation encroachment), and the abandonment of pre-dam floodplains. The result of these structural changes is a decrease in the quantity and quality of aquatic and terrestrial habitats, which causes a direct negative response of the populations and species richness of flora and fauna that are adapted and dependent upon a functional alluvial system.

The ecosystem-based approach to restoration stemming from these conceptual models centers on re-establishing the critical geomorphic and hydrologic processes that sustain alluvial rivers. The ERP and Strategic Plan support this by "proposing an integrated-systems approach that attempts to protect and recover multiple species by restoring or mimicking the natural physical processes that create and maintain diverse and healthy habitats" (CALFED Strategic Plan pg 2-6). The Attributes identified above provide a framework of critical processes required to meet this goal, but also provide essential information to management, to be used in an adaptive management framework.

The conceptual models for Lower Clear Creek have several key uncertainties including:

Will a reduced channel and floodplain geometry with smaller particle size and reduced flow regime re-create a dynamic alluvial channel with functional, inundating floodplains?
Will riparian vegetation encroachment within the active channel be scoured by periodic, moderately high events or will periodic mechanical manipulation or a combination of flows and mechanical manipulation be required?
Can high-value wildlife habitat associated with riparian restoration and natural recruitment be recreated off-channel?
Are all aquatic habitat types (e.g. high value wetlands) adequately represented throughout the restoration project?

The Restoration Team, with funding from the CVPIA, is also continuing to develop and refine the Clear Creek Decision Analysis and Adaptive Management Model (CCDAM). This model, developed by ESSA Technologies, is a predictive model that evaluates the effects of restoration activities system-wide. The CCDAM, which includes the development of specific testable hypotheses, will aid in adaptive management experimentation for future phases of restoration and guide management decisions. Monitoring data collected as part of the Project and other phases will increase the model's accuracy and strengthen the validity of its predictions.

c. Hypotheses: Two forms of hypothesis testing will occur: First, evaluate the overall project hypotheses illustrated in the matrix in Appendix II; and second, develop implementation experiments that will maximize learning for similar implementation projects in the CALFED program/study area.

Specific to this restoration project, an overarching hypothesis is: Reconstructing the channel morphology and restoring geomorphic processes will increase the quantity and quality of salmonid (chinook salmon and steelhead trout) habitat within the project study area. The USFWS Instream Flow Branch, under the supervision of Mark Gard, has applied the "2d" Physical Habitat Simulation Model in 2004 to the (implemented) channel relocation phase (Phase 3A) of the Mining Reach, both before and after Phase 3A was complete. This has allowed an evaluation of changes in available salmonid habitat and then track the habitat through time. Field observations of juvenile salmonid habitat use on Clear Creek, as well as recent scientific literature, suggests that complex channel morphology (backwater alcoves, side channels, high flow scour channels, and small ephemeral tributary confluences) provide large amounts of habitat for fry and juveniles. Evaluation of Phase 3A by the USFWS demonstrates how this project has created these types of habitat features and significantly increased the amount and quality of habitat over pre-project conditions. Furthermore, the WSRCD has implemented 3 years of detailed geomorphic monitoring on Phase 3A, which has demonstrated that the project has generally met all design objectives. An updated monitoring plan (originally submitted to CALFED in 2000), and being revised in 2005, (Appendix III) will be testing project-related hypotheses. Additionally the monitoring has been refined as a result of participation in the CALFED Adaptive Management Forum (CALFED, 2003) to include quantified objectives. Tables for each monitoring program are included in Appendix III.

The Restoration Team developed the following broad hypotheses on which project design, monitoring, and evaluation efforts are based. General project-related hypotheses include:
(H1) Reconstructing the channel morphology and restoring geomorphic processes will increase the quality and quantity of salmonid (chinook salmon and steelhead) habitat within the project study area.
(H2) Filling mining pits and restoring bankfull channel geometry will decrease stranding-induced mortality of adult and juvenile salmonids within the project reach, and reduce predation mortality.
(H3) Filling mining pits and restoring bankfull channel geometry will improve upstream migratory passage and survival through the project reach for adult salmon and steelhead.
(H4) Revegetation of reconstructed floodplains will increase the quantity and diversity of native riparian vegetation, as well as terrestrial fauna.

(H5) Reconstructing the bankfull channel and floodplain surfaces at a scale consistent with the post-dam flow regime will increase natural regeneration of riparian species on reconstructed floodplain surfaces.
(H6) Filling mining pits, creating floodplains, and restoring bankfull channel geometry will improve the geomorphic processes responsible for creating and maintaining high quality aquatic and terrestrial habitats.
(H7) Filling mining pits, creating floodplains, and restoring bankfull channel geometry can be implemented in a way that minimized effects to existing wetlands and does not preclude the creation of new wetlands.

There are many sub-hypotheses associated with these fundamental ones, which are listed in Appendix III. The project hypotheses form an important component of a broader hypothesis that restoration is possible on a scaled down dynamic alluvial river under a highly regulated setting. This hypothesis has tremendous implications for all highly regulated alluvial rivers in the CALFED study area and other watershed areas, and Clear Creek provides an excellent location to test this hypothesis.

3. Approach and Scope of Work

a. Approach: The overall project approach to reverse the impact of instream gravel mining and flow/sediment regulation by upstream dams is as follows:

1) Remove dredger tailings (1999-2000) or unmined alluvium (2001-2006) at "borrow" sites in upstream reaches to create functional floodplains;
2) Transport borrow material to instream mining reach to fill pits, create floodplains, and restore channel morphology; and
3) Revegetate both the borrow site and mining reach floodplains and wetlands with native riparian vegetation.

The Project can be subdivided into two components: (1) Floodplain creation where a majority of earthwork is conducted (Phase 1 and 2, completed in 2001), and (2) the channel relocation where the bankfull channel is either relocated or reconstructed (Phase 3). Phase 3 will complete the project by relocating and reconstructing the bankfull channel. The complexity of channel relocation work resulted in Phase 3 being broken into three components:

- Phase 3A (completed in 2002) which restored the channel in the upper quarter of the project area;
- Phase 3B (current funding request) which will relocate the channel in the middle of the project site, and
- Phase 3C(potentially to be completed after 3B) will relocate the channel at the downstream end of the site.

As implemented in Phase 2, Phase 3B will use borrow material from unmined areas within, and upstream of, the original project area (Figure 14) in order to expand restoration in the project area, without the need to expend substantial resources in processing historic dredger tailings to remove potential mercury. Restoration activities, including revegetation, for the original dredger tailings borrow site used for Phase 1 and 2A (Reading Bar), was completed in 2002. Revegetation of native riparian vegetation will again occur during Phase 3, with continued co-reliance on designing the project to maximize natural regeneration.

b. Scope of Work: As portions of the Project have been implemented, peer review, monitoring observations, and new design ideas (hypotheses) are incorporated into the latest Phase to be implemented through an adaptive management process. For example, the Phase 2B and 3A revegetation designs incorporated several design improvements based on collaboration with Point Reyes Bird Observatory (PRBO) to address the needs of avian species (including some that are MSCS species), while additional backwater elements were added into Phase 3A after input from CDFG and members of the Adaptive Management Forum panel. These subtle design improvements could continue to occur during Phase 3B implementation and will serve as experiments for adaptive management.

The components of the Phase 3B scope of work will include:

1) Relocate and raise bankfull channel in the middle of the mining reach, obtaining material from on-site, unmined borrow areas (unmined status as determined by a certified geologist), and
2) Revegetate floodplains and wetlands at both the borrow and channel relocation portions of the site (earthwork implemented in Summer 2006, riparian revegetation implemented in Fall 2007)

Specific implementation tasks include:

1) Project management. The WSRCD will provide overall project management for all components of the project.
2) Collect additional topographic and clay hardpan data. Identify the location and elevation of clay hardpan throughout the project area in greater detail, and conduct ground topographic surveys to generate more accurate earthwork computations.
3) Refine the Phase 3B earthwork design. Incorporate information and experiments developed from monitoring Phase 2A, 2B, and 3A implementation into Phase 3B designs. Document design revisions and experiments to be conducted as part of the design.
4) Obtain necessary permits and conduct ESA consultations. The 'Final CEQA/NEPA Mitigated Negative Declaration and Finding of No Significant Impact' and the Reclamation Board permit were prepared for the entire project and provide compliance for the entire Phase 3 and will be amended. Other permits will be obtained from appropriate agencies for Phase 3B, and ESA consultations will be conducted with NMFS and USFWS, as appropriate.
5) Develop final grading plans, construction specifications, construction plan, and water quality control plan. Based on the design revisions above, grading plans and construction specifications for Phase 3B will be prepared.
6) Prepare bid package, solicit bids, award contract, and implement earthwork design. Floodplains will be constructed from a combination of un-mined, on-site borrow material and on-site topsoil sources; the bankfull channel will be constructed from cleaned and sorted gravels (1/4-inch to 6-inch diameter) imported to the project site.
7) Revegetation design. A site assessment will be conducted of the constructed floodplains including excavation of soil pits to characterize textural stratification and subsurface hydrologic conditions. Monitoring wells will be installed in a subset of the pits and monitored for one growing season to characterize hydrologic fluctuations. Revegetation design plans will be prepared along with planting specifications.
8) Prepare bid package, solicit bids, award contract, and implement riparian design. Riparian revegetation plantings will include locally-obtained cuttings (willows, cottonwoods, mulefat, etc.), locally-obtained seeds (valley oak, native grasses, etc.), and nursery stock grown from locally-obtained seed (white alder, Oregon ash, sedges, mulefat, etc.).
9) Construction management and supervision. The WSRCD will conduct construction management and supervision on a daily basis for both the earthwork and riparian revegetation component of Phase 3B implementation.
10) Implement monitoring. The monitoring plan for the Project was developed for all phases of the project. It was originally submitted to CALFED in 2000 as part of the ERP Funding Requirements and is currently undergoing revision (2005). The monitoring plan has been implemented as part of Phases 2A, 2B, and 3A and includes elements for geomorphology, fisheries, riparian vegetation and avian species. Monitoring will also include mercury and wetlands, components that are being developed as part of the revision of the current monitoring plan.

11) <u>Irrigation and Maintenance</u>. The WSRCD will irrigate and do maintenance on selected sections of the riparian revegetation component of the project for three years after completion of the riparian revegation section of the Project.

Survey and designs, which are presented as Tasks 1, 2 and 4 (See also figures 13 through 21), are being funded by USBR and will be completed by late summer, 2005.

4. Feasibility

The project approach, as presented in the previous sections and supported by the Conceptual Models for Lower Clear Creek, was developed by local stakeholders, resource agencies, and the Restoration Team as the most feasible and appropriate restoration approach available. Large-scale reconstruction of the Lower Clear Creek floodway has the highest probability of achieving the project goals of re-establishing the critical ecosystem components within contemporary regulated conditions, and it is essentially the only approach that is self-sustaining in the long-term.

Designs for the entire Project were completed under contract with USBR in 1999 to ensure a comprehensive design prior to implementing any single phase. This design is presented in the Lower Clear Creek Floodway Rehabilitation Project; Channel Reconstruction, Riparian Vegetation, and Wetland Creation Design Document (McBain & Trush, et al. 1999) (Appendix IV.). This document was peer reviewed, and Phases 2A, 2B, and 3A have been successfully implemented. WSRCD, the Restoration Team, the Project Consultant Team (Graham Matthews & Associates, Souza Environmental Solutions and PRBO), and the USBR have demonstrated the ability to successfully plan, design, implement and monitor large-scale restoration projects, both in a timely manner and within budget.

If awarded the requested directed action funding, the Restoration Team and the WSRCD will implement Phase 3B construction in 2006 and riparian revegetation in 2007, with 3 years of post-construction monitoring following implementation. This timeline is consistent with other phases and from recommendations of previous Project monitoring. Additionally all work for the Project is on lands managed by the BLM, one of the lead Federal agencies for this project, and is consistent with their management plans for Lower Clear Creek.

5. Environmental Compliance and Permitting

The Project is subject to all local, state, and federal environmental regulatory requirements. The USBR, BLM, and WSRCD, as Co-Lead Agencies, submitted for public review a Joint Proposed Mitigated Negative Declaration/Finding of No Significant Impact and Initial Study/Environmental Assessment for the Lower Clear Creek Floodway Rehabilitation Project (IS/EA) in September 1999. The IS/EA encompassed all project boundaries and identified all potentially significant impacts associated with the proposed Phase 3 Project with the exception of the 3A borrow area. An updated and expanded wetlands delineation of the project area is being completed and a biological assessment will be completed by federal lead agencies to meet the requirements of the federal Endangered Species Act (ESA).

Implementation of each successive phase is dependent on the production and review of final designs. Final geomorphic design review is provided by the Restoration Team, as well as an independent engineering entity. Final geomorphic designs are prepared by Graham Matthews & Associates under a separate contract with the USBR. Final revegetation designs will be prepared by Souza Environmental Solutions and reviewed by the Restoration Team.

In addition to environmental compliance documents, numerous permits are required for the Project. CEQA/NEPA compliance will be amended and the Reclamation Board permit were completed prior to Phase 2 for the entire project and do not need to be repeated for Phase 3. Permits required for Phase 3B are listed below:

Temporary Entry Permits from landowners
RWQCB 401 Waiver
NEPA Document
CEQA Document
Endangered Species Act Consultation (NMFS)
Endangered Species Act Consultation (USFWS)
California Endangered Species Act (CESA) (DFG)
Army Corps of Engineers Nationwide Permit

The WSRCD has successfully obtained permits for all previous phases of the Project (Phase 2A, 2B, and 3A). Phase 3B is very similar in design and construction techniques to phase 3A , therefore it is unlikely that any difficulties will be encountered in obtaining permits for the next phase of the Project.

6. Performance Measures

In response to requirements of the CALFED 1998 Proposal Solicitation Package, a comprehensive monitoring plan was prepared by the USBR and WSRCD in 2000. The monitoring plan was originally submitted to CALFED, and is currently being updated for CALFED review. The monitoring plan (Appendix III.) presents project goals and objectives, and specific monitoring objectives for avian, fisheries, geomorphic, and riparian vegetation components that are intended to address those stated project objectives. Project performance monitoring efforts will include several local, state, and federal resource agencies, non-profit organizations and consulting firms, academic institutions, and resource volunteers working cooperatively under the guidance of the WSRCD, USBR, USFWS, BLM, and CDFG. Fishery resource monitoring elements will be conducted by USFWS offices in Red Bluff and Sacramento. The WSRCD will be responsible for implementing monitoring elements for the remaining three elements through identified and qualified subcontractors. A mercury monitoring component has also been developed with assistance from CBDA staff, information from the Draft Mercury Synthesis and Data Summary Report for Lower Clear Creek (Tetra Tech, 2005), and the Environmental Mercury Laboratory at UC Davis. Monitoring will assess potential project impacts and provide adaptive management feedback for both the Project and the Bay Delta. Mercury sampling is divided into 2 separable components: total mercury load and biosentinel mercury monitoring.

The purpose of the total mercury load monitoring is to determine whether restoration activities on Lower Clear Creek are contributing to downstream loads of mercury and to estimate loads to downstream waterbodies. To accomplish this, Tetra Tech, Inc. will monitor storm events to capture mercury and particle transport when the majority of the sediment transport occurs for three years after completion of instream channel work. Low flow events will be sampled to assess baseline transport of mercury. One floating event will be used to collect data during dam overflow spills or planned pulse flows. Tetra Tech has over 30 years experience in the development of innovative and scientifically accurate approaches to assess complex environmental issues, has led the City of San Jose technical team for the TMDL for copper and Nickel in the in the South San Francisco Bay and is conducting technical studies that will provide the basis for the development of a mercury TMDL for the Guadalupe River Watershed. A monitoring approach is presented in Appendix III.

The biosentinel approach to mercury monitoring has been recommended to the California Bay-Delta Authority (CBDA) in the Mercury Strategy (Weiner et al, 2003) as the optimal approach for measuring the key parameter of concern: relative methylmercury exposure. Young-of-year fish and certain invertebrates can provide accurate measures of this exposure through their bioaccumulation of methylmercury. Sampled carefully, these “biosentinels” can provide precise, statistically differentiable measures over time and between locations. In the

Clear Creek restoration work, as in most aquatic restorations in California, there is a need to measure the potential change in the production of methylmercury stemming from restoration actions. Monitoring of appropriate biological indicators will track the trend in relative methylmercury exposure and bioaccumulation in and around these sites.

Meythlmercury bioaccumulation will be studied by the Environmental Mercury Laboratory at UC Davis, who has specialized, since 1991, in the research and monitoring of food chain methylmercury bioaccumulation. Over the years Environmental Mercury laboratory has refined the use of these "biosentinel" organisms such that they can provide fine-scale, statistically based measures of spatial and temporal variation. In research funded by the State, they have demonstrated strong statistical linkages between mercury levels in these test organisms and (1) mean methylmercury concentrations in the water and (2) mercury concentrations in corresponding large sport fish of human health concern. So, appropriate biosentinels sampled carefully can provide an integrated measure of local, recent aqueous exposure that also corresponds to sport fish mercury bioaccumulation. US Fish and Wildlife Service has already determined that two small fish species are present across all or nearly all of the regions of focus: mosquitofish (*Gambusia affinis*) and California roach (*Hesperoleucas symmetricus*). Both can be useful biosentinels, based on prior work, particularly the California roach. Well developed techniques (Appendix III) will be used to monitor methylmercury exposure in relation to current and ongoing restoration efforts in the Clear Creek watershed.

Annual monitoring reports summarizing the results of all sampling conducted during the previous year will be provided by both elements. Annual reports will provide data tables and the results of statistical analyses to assess impact of the restoration project. Recommendations for any changes in the monitoring program will also be provided that will feed directly back into the adaptive management feedback loop for Lower Clear Creek. Additionally, information from this monitoring can be utilized in other Bay Delta watersheds where mercury is a concern, particularly when associated with restoration efforts.

The proposed mercury monitoring for Phase 3B is directly in line with the core components of the Bay Delta Mercury Strategy and addresses multiple management goals within the core components. Further, findings and recommendations from in the monitoring programs will guide future restoration on Clear Creek by developing adaptive management opportunities that will feed directly back into future restoration planning and design. Additionally, information from this monitoring can be utilized in other watersheds within the Bay Delta where historical mining has made mercury a concern during watershed management and restoration.

In addition to the overall monitoring plan, a more detailed Channel Monitoring Methods for the Lower Clear Creek Floodway Rehabilitation Project was prepared in 2001 as part of the geomorphic valuation of Lower Clear Creek report, which (1) increases the monitoring specificity and details presented in the monitoring plan, (2) provides a detailed description of the methods required to complete the geomorphic, hydrologic, and streambed monitoring tasks for Phases 2 and 3, and (3) provides a detailed description of materials and techniques to be used as a guide for implementing field monitoring programs described in the monitoring plan.

The monitoring activities outlined in these documents will be used to evaluate design performance (e.g., are the floodplains designed at the proper elevations such that they are inundated by 3,000 cfs?) and project performance (did the stream stay at grade and not downcut back down to the clay hardpan?). The details in how these performance measures will be measured are in the monitoring plans, and will be evaluated by a combination of monitoring during high flow events (mostly targeting design performance), as well as long-term monitoring of channel morphology, riparian revegetation, fish habitat and use, and bird use (targeting project performance).

Monitoring of the project is essential to assess the success of the project and strengthen the future implementation of projects through the adaptive management feedback loop. Additionally, monitoring data can contribute to CALFED ERP's goals, milestones, and objectives and benefit other restoration projects in the Bay Delta system.

7. Data Handling and Storage

Because of the size and complexity of the various phases of restoration (planning, design, implementation, monitoring), a large volume of data and project-related information is being generated. Quality Control/Quality Assurance and information availability are important components of the data handling and storage. Data handling and storage is being coordinated by WSRCD with data components located at the appropriate agency office. All data from earlier phases of the Project have been stored in Microsoft Word, Microsoft Excel, and AutoCad Land Development Desktop 2 software. All design documents produced to date have also been saved in PDF format for ease of viewing and sharing. The USFWS collects and stores monitoring data on items such as fish counts, spawning habitat, and fish passage. WSRCD compiles monitoring data on project design, riparian revegetation and monitoring, and geomorphic components, including coarse sediment mobilization, channel morphology, fine sediment deposition, channel profiles, channel dimension evolution, mapping vegetation success, and restored floodplain cross sections. WSRCD will be the central clearinghouse for reports and data, although most reports are accessible in the Watershed Information Model (WIM) developed by the WSRCD with funding from the Department of Water Resources. WIM is an interactive website that provides maps, information and documents in an easy to access and use format (http://wim.shastacollege.edu).

8. Expected Products/Outcomes

With the significant investments being made on Lower Clear Creek by CALFED and CVPIA, it will continue to be, the focus of field tours, seminars, and informational brochures. Lower Clear Creek h will continue to be, the focus of extensive scientific monitoring and experimentation, seminars, and informational brochures.

Five monitoring components will release reports (avian, geomorphic, riparian, fisheries and mercury) will be reviewed and released to guide future restoration actions on Lower Clear Creek and within the Bay Delta system. A total of 15 individual annual monitoring reports and one comprehensive report will be generated and published on the web through The Watershed Information Model (http://wim.shastacollege.edu/).

A comprehensive workshop will be held each year to inform restoration teams working on other projects in the Bay Delta of the progress at meeting the goals and objectives of the project, and will include the solicitation of their recommendations, and as well as a detailed discussion of the issues faced by project staff. Each monitoring team may also provide presentations at CALFED conferences and through other scientific venues, such as professional conferences and journals.

9. Work Schedule

Project implementation will begin as soon as funding is awarded and continue for five years, until December 2010. A timeline in calendar years that represents the beginning and ending of work for each task per year is included in Appendix VIII. Each component is separable by task, as indicated in the graphics. Channel designs for the project will be completed by July 2005 and coordination for NEPA/CEQA compliance has begun. Construction would begin in the summer of 2006. Riparian revegetation would be completed in fall of 2007 to allow time for proper design of riparian revegetation based on a site assessment of the newly created floodplains. Geomorphic and fisheries monitoring would begin in the summer and winter of 2006 and continue for three years. Avian and riparian revegetation monitoring would begin in spring/fall of 2008 and continue for three years.

B. Applicability to CALFED Bay-Delta Program ERP Goals, the ERP Draft Stage 1 Implementation Plan, and CVPIA Priorities.

1. ERP and CVPIA Priorities

This proposal directly addresses ERP goals, ERP Draft Stage 1 implementation Plan, CVPIA priorities. Draft Stage 1 priorities addressed by the Lower Clear Creek Floodway Rehabilitation Project fall within the 'Restoration Priorities for the Sacramento Region' of the Draft Stage 1 Implementation Plan, and includes several of the Stage 1 priorities:

Restoration Priority 1: *Develop and implement habitat management and restoration actions in collaboration with local groups, such as the Sacramento River Conservation Area Non-Profit Organization.* This Project has been conducted in collaboration with the Lower Clear Creek Coordinated Resource Management Planning (CRMP) Group, the Shasta-Tehama Bioregional Council, Shasta Fly Fishers, NorCal Fishing Guides & Sportsman's Assn., Shasta Sportsman, Shasta College, Horsetown Clear Creek Preserve, Shasta Historical Society, Whiskeytown Environmental Education Camp, Shasta Paddlers, Native Plant Society, Shasta County Farm Bureau, Shasta Wildlife Rescue, Redding Mountain Bikers, Black Powder, and the Redding Rancheria.

Restoration Priority 2: *Restore fish habitat and fish passage particularly for spring-run chinook salmon and steelhead trout and conduct passage studies.* CALFED, CVPIA and other government agencies have invested heavily in the return of spring-run salmon and steelhead access in Clear Creek, including funding for removal of Saeltzer Dam in 2000. With this migration barrier removed, spring-run salmon can over-summer in deep, cold-water pools in the Clear Creek canyon reaches below Whiskeytown Dam. Gravel augmentation is providing needed spawning habitat for these species. The potential increase in spring-run chinook salmon and steelhead fry production in reaches upstream of Saeltzer Dam could be limited by rearing habitat in those reaches. The Project may provide additional rearing habitat for all species and potential spawning habitat for steelhead, by restoring the pool-riffle morphology in the 1.8-mile project reach. In addition, floodplain restoration and scour channel construction should greatly reduce juvenile mortality caused by stranding in off-channel pits during high flows. Collectively, these project objectives could benefit spring-run chinook salmon and steelhead production from the Clear Creek watershed.

Restoration Priority 3: *Conduct adaptive management experiments in regard to natural and modified flow regimes to promote ecosystem functions or otherwise support restoration actions*. While the Project does not target experiments with different flow regimes, it is conducive to monitoring the effects of high flows that result from natural floods as well as dam releases. Additionally there is the potential for CALFED EWP flows to be released on Clear Creek, which would be captured as part of the monitoring efforts. The project is testing whether fluvial processes can be restored in a highly regulated river such as Clear Creek at a smaller scale than existed naturally, as a strategy to restore and maintain channel morphology, riparian vegetation, and salmonid populations.

Restoration Priority 4: *Restore geomorphic processes in stream and riparian corridors.* The Clear Creek Floodway Rehabilitation Project is founded fundamentally on the goal of re-establishing ecological processes as the most effective way to maintain the river ecosystem. Additionally, gravel augmentation may help restore sediment transport in Lower Clear Creek.

Restoration Priority 5: *Implement actions to prevent, control and reduce impacts of non-native invasive species in the region.* This proposed project will monitor non-native invasive plant species in order to provide information necessary to implement measures to control existing populations and prevent colonization in the restored areas. The Floodway Rehabilitation Project has restored native riparian vegetation to approximately 47 acres of floodplain that was highly degraded by aggregate and dredger mining. Portions of the restored floodway contain Tree of Heaven (*Ailanthus altissima*), black locust (*Robinia pseudoacacia*), scarlet wisteria (*Sebania punicia*) and Himalayan Blackberry (*Rubus discolor*) that are monitored with funding from BLM. Replanting soon after construction with native riparian canopy and understory species increases the opportunity for native vegetation to become established and reduces the opportunity for non-native invasive species to spread within the Clear Creek floodway.

CVPIA Priorities: The general purposes of the CVPIA are identified by Congress in Section 3402(a) to "protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California." Section 3406 (b) 12 describes specific actions to be implemented in Clear Creek, including the development of a comprehensive program to provide flows to restore salmon and steelhead habitat below Whiskeytown Dam. The Lower Clear Creek Floodway Rehabilitation Project, in part, will allow the development and implementation of this program by completing channel restoration.

MSCS Big R Species: This project will monitor actions taken to promote the ecosystem recovery of three Multi Species Conservation Strategy Recovery species, Central Valley spring run chinook salmon (Oncorhynchus tshawytscha), Central Valley fall/late-fall-run chinook salmon (Oncorhynchus tshawytscha) and Central Valley steelhead (Oncorhynchus mykiss).

ERP Restoration Program Milestones for the Sacramento River Basin: This proposal measures progress toward ERP milestones in ecological processes, habitats and stressor reductions, including coarse sediment supply through the implementation of gravel augmentation and the assessment of natural sediment transport processes linked to stream channel maintenance, erosion and deposition, maintenance of fish spawning areas and regeneration of riparian revegetation. Two separate milestones for riparian habitat are measured with this project: first, the development of a program to establish, restore and maintain riparian habitat, improve floodplain habitat, salmonid shaded riverine habitat, and, second, the restoration of a portion of the two miles target of riparian restoration along the lower reaches of Clear Creek. Both of these expected habitat milestones can be directly measured by monitoring of the Lower Clear Creek Project. ERP stressor milestones of unimpeded upstream passage and stranding are directly addressed by monitoring of this project being completed by the USFWS.

2. Relationship to Other Ecosystem Restoration Actions, Monitoring Programs, or System-wide Ecosystem Benefits:

Lower Clear Creek is the upstream-most major tributary to the Sacramento River and is situated in an ideal location for adaptively managed restoration. With ample streamflow available from the Trinity Mountains and from the Trinity River Division of the CVP, the opportunity to experiment and learn from the Clear Creek restoration program is tremendous. With Saeltzer Dam now removed, an experienced stakeholder group in place, spawning gravel augmentation and other rehabilitation efforts established, and with relatively low risks due to public ownership and the general lack of development within the floodway, Lower Clear Creek has potential to be a model restoration river for CALFED and CVPIA programs.

The highest priority action for Lower Clear Creek is, therefore, to complete the Project, in a manner that both maximizes the opportunity to gain valuable information, but achieves the goal expediently. As emphasized throughout this proposal, information gathered from this project and the Clear Creek restoration program in general can be extrapolated to restoration efforts throughout the Central Valley. The Project addresses those components. For example, Clear Creek has excellent remnant riparian forest and the potential for high quality, non-fragmented riparian and upland habitat for riparian obligate species. While it has managed flows, it still experiences high flow events that affect the floodplain and allow for some level of natural successional processes to take place (such as floodplain inundation). It provides all components of the life history of anadromous fish populations (3 chinook runs and steelhead) with the potential to improve that even further. While Non-native Species (NIS) are present, these are not at a magnitude found on other streams (such as Stony Creek), so there is high potential to control the level of negative impacts from those species. It provides a valuable resource for environmental education to locals, including children/students. There are some localized potential impacts caused by development, however, and the ongoing issue of how to most effectively deal with mercury is being actively addressed.

Clear Creek also was a major supplier of coarse sediment to important spawning reaches in the upper Sacramento River mainstem, estimated to be 5,000 tons/yr (CALFED ERP Vol. II). Finally, Lower Clear Creek supports the only known breeding populations of Yellow Warblers (*Dendroica petechia)* and Song Sparrows (*Melospiza melodia)* in proximity of the Sacramento River to function as a source population. Increasing habitat for these species along Clear Creek is a high riparian restoration priority for the revegetation design and for the California Partners in Flight and The Riparian Habitat Joint Venture (RHJV 2000).

As with most large restoration programs, prioritizing the activities to implement in a logical method is a challenging task. The Floodway Rehabilitation Project, however, is perhaps the highest priority action necessary to improve ecological functions and salmonid populations in Clear Creek. With removal of Saeltzer Dam complete, migratory access to the upper canyon reaches in Lower Clear Creek is restored. Additionally, the USBR and WSRCD have also been implementing a program to place large volumes of spawning gravel in the channel, both below Whiskeytown Dam, and in downstream alluvial sections below the former Saeltzer Dam site. These projects are improving stream corridor conditions in Clear Creek. The next priority is the completion of restoration of the bankfull channel and floodway within the Project area reach, particularly as headcut migration in the current channel at Phase 3B is threatening restoration investments made to date.

3. Request for Next-Phase Funding

This proposal requests next-phase funding to complete Phase 3B of the Lower Clear Creek Floodway Rehabilitation Project. Phase 1 constructed a large berm to isolate salmon from a pond on the south side of Clear Creek that was identified as the largest stranding problem, and was completed in 1998 based on designs developed by McBain & Trush, Graham Matthews & Associates, and North State Resources under a contract with the USBR. The original CALFED funding proposal for the project was submitted by the WSRCD. Substantial funding ($3,559,596, managed by USFWS) was awarded to complete the preliminary design of the entire project and to implement Phase 2 of the project. Phase 2 was split into 2A and 2B. Phase 2A filled one large gravel extraction pit to recreate/rehabilitate 18.4 acres of floodplain, and construction was completed in 1999. Revegetation was completed in 2000. Pits were re-filled with gravel obtained from the Reading Bar borrow site. Phase 2B, implemented during summer 2001, continued floodplain rehabilitation by filling an additional two ponds to recreate/rehabilitate 57.3 acres of floodplain, primarily on the south side of the stream. Revegetation followed construction in 2002, in a manner similar to Phase 2A.

Phase 3 completes the channel and floodplain rehabilitation effort by relocating and reconstructing the bankfull channel. Phase 3 is broken into three components: Phase 3A was completed in 2002 with remaining funds from Phase 2 ERP funding (due to cost effective implementation) and relocated the channel in the uppermost 1,500 ft of the project site; Phase 3B will relocate the channel in the middle of the project site; and Phase 3C would relocate the channel at the downstream end of the site.

4. Previous Recipients of CALFED Program or CVPIA Funding

The WSRCD has successfully completed and/or is completing the following restoration efforts in Lower Clear Creek and Shasta County.

a. CALFED No. 98-F15 for Phase 2 and Phase 3A of the Lower Clear Creek Floodway Rehabilitation Project. Total funding: $3,559,596. All construction for this project has been completed in 2003, the grant has been increased to $4,003,239.58 and extended for additional monitoring of project performance.

b. CALFED No. 99-N16 Clear Creek Prescription. Total $256,260. Grant Completed on 2003
c. CVPIA No. 6-FG-20-14240l for Lower Clear Creek CRMP Organization. Total $55,700. Grant completed in 2001.
d. CVPIA No. 7-FG-20-14560 for LCC Erosion Inventory. Total $197,752. Grant Completed in 2001.
e. CVPIA No. 7-FG-20-15290 for LCC Spawning Gravel $408,000. Grant completed in 2000
f. CVPIA No. 7-FG-20-14610 for LCC Fuel Inventory $15,111. Grant completed in 1998.
g. CVPIA No. 7-FG-20-14720 for LCC Photogrammetry Survey $39,087. Grant completed in 1997.
h. CVPIA No. 00-FG-200079 for LCC Spawning Gravel $325,000. Grant completed in 2003.
i. CVPIA No. 00-FG-230718 for LCC Spawning Gravel $98,851. Grant completed in 2001.
j. CVPIA No. 01-FG-230725 for LCC DVD $7,395.00 Grant completed in 2002.
k. CVPIA No. 01-FG-200131 For LCC Phase 3 and 4 Design $115,000. Grant completed in 2002.
l. CVPIA No. 02-FG-230736 For LCC CRMP $19,744. Grant completed in 2003.
m. CVPIA No. 03-FG-200008 For LCC Spawning Gravel $75,000. Grant completed in 2003.
n. CVPIA No. 03-FG-200008 For LCC Spawning Gravel $140,000 Grant completed in 2004.
o. CALFED No. 03-075-555-0 For LCC Spawning Gravel $335,489. Grant 75% completed
p. CALFED No. 04-162-555-0 For County ecosystem improvements $821,727.00 Grant 25% complete
q. CALFED No. 46-0000-1797 Shasta West Watershed Assessment $131,600. Completed in 2005.
r. CALFED No. 03-074-555-0 Bear Creek Watershed Assessment $140,806. 75 percent complete.
s. CALFED No. 03-106-555-0 Cow Creek Water Quality $67160. Grant 50% complete.
t. CALFED No. 46-0000-1798 Watershed Information Model $378,899. Grant completed in 2005.

5. Additional information for land acquisition

All of the property contained within the project area is owned by the BLM, and no properties are proposed for purchase as part of this proposal.

6. Qualifications

a. Principal Participants

Western Shasta Resource Conservation District

Mary Schroeder, District Manager, received a B.S. degree in Forest Industries Management from The Ohio State University, Columbus, Ohio. She has over 25-years business management experience in natural resource and wood products industries. As chief administrative officer of the District, Mary is responsible for directing the District's business and field operations consistent with the strategic plan.

Michael Harris, Projects Manager for watershed restoration, fisheries, and wildlife. He has a B.S. in Biology from California State University-Sacramento, and a B.A. in Economics from the University of California-Davis, and is completing his Master of Science in Biological Conservation from the California State University-Sacramento. Michael's experience includes habitat sampling; scheduling and data management; vertebrate sampling of mammals, reptiles and amphibians; monitoring of avian species. His publications include 2001 and 2002 California Department of Transportation –Carmel River Mitigation Bank Report. Michael's thesis will be titled "Small Mammal Microhabitat Analysis of a Restoration Site."

Agency Team Representatives

Francis Berg, Assistant Field Manager, Bureau of Land Management, has graduate courses in Environmental Administration and Archaeology from the University of California-Riverside; a B.A. in Anthropology (Highest

Honors, Phi Beta Kappa) from Riverside City College, Riverside, CA; and an Associate of Arts (Greatest Distinction) Francis has been the Assistant Field Manager at the Redding Field Office since 1991. He supervises a team in wildlife, fisheries, botany, range conservation, forestry, archaeology, geology, recreation management and planning, and leads the implementation of the restoration of Lower Clear Creek and sections of the Sacramento River in Tehama and Shasta Counties.

Jim DeStaso, Fisheries Biologist, US Bureau of Reclamation, has a Master's Degree in Zoology and Physiology from the University of Wyoming and a B. S. in Biology from William Paterson University. Jim has worked for the Bureau of Reclamation since 1995 and his responsibilities include project implementation of multi-agency river ecosystem restoration projects, including channel improvements, budget oversight of restoration projects, contract administration and environmental compliance. Jim is a member of the Restoration Team and is a BOR Program and CVPIA Manager for Clear Creek.

Matthew Brown, Fisheries Biologist, US Fish and Wildlife Service, has a M.S. in Biology from Arizona State University and a B.A. in Biology from the University of California-Santa Cruz. His work is focused on Chinook salmon with a concentration on habitat restoration under the CVPIA and evaluating the impacts of water development. Matthew is a member of the Restoration Team and oversees all fisheries monitoring on Clear Creek.

Mike Berry, Senior Fisheries Biologist Specialist for the California Department of Fish and Game. A graduate from the Humboldt State University with a B.S. in Fisheries, Mike worked in Washington State as a fisheries biologist, and for 10 years with California's Wild Trout Program. He is currently working on the recovery of listed anadromous salmonids in the Central Valley including a lead biologist for Lower Clear Creek Floodway Rehabilitation project and CVPIA restorations. He is a member of the Cow Creek Watershed Management Group and the Restoration Team for Clear Creek. His current work focues on management issues for anadromous fisheries and water quality.

Patricia Bratcher, Staff Environmental Scientist, California Department of Fish and Game: Ms. Bratcher is the Habitat Restoration Coordinator for the California Department of Fish and Game on the upper Sacramento River. Her primary responsibilities include: Coordination of the Anadromous Fish Restoration Program; planning for restoration activities on the upper Sacramento River and its tributaries, as well as coordinating efforts with the rest of the Central Valley; interagency and intra-agency coordination; and representing the Department on interagency teams involved with watershed restoration efforts. Ms. Bratcher is also a technical representative with several watershed groups in the upper Sacramento Valley, which includes assisting watershed groups in preparing proposals for funding through CVPIA and CALFED, as well as other funding sources. She has been working within the natural resource field since 1985 and obtained a Bachelor's degree (Magna Cum Laude) in Environmental Biology from California State University, Fresno in 1988.

Consultants

The consultants identified for this project have a proven track record and are the same consultants that have worked on this project in the past.

Graham Matthews, Principal of Graham Matthews and Associates (GMA), has 24 years experience in hydrology and fluvial geomorphology, and 22 years of experience in the design and construction of stream and riparian restoration projects. Graham received a B.A. in Geology from Pomona College (1981) and a M.S. in Earth Sciences from U.C. Santa Cruz in 1990. GMA is a small, diverse consulting firm established in 1990, and consists of hydrologists, engineers, geomorphologists and fish biologists. GMA specializes in: (1) stream restoration design, implementation and monitoring; (2) hydrologic and hydraulic data collection and analysis; (3) geomorphic data collection and analysis; and (4) hydraulic and hydrologic modeling. The firm has worked on hydrologic/geomorphic issues and stream restoration designs in California Oregon, and Idaho. Recent projects include: 2.5 miles of the Wood River Channel and Wetland Restoration Project (awarded the Grand Environmental Achievement Award by IECA in 2002); Year 2000 Projects for the Williamson River Restoration Project, in the Upper Klamath Basin, OR; Clear Creek Channel Restoration Project Phase 1, 2, and 3A, 3B; the Agency Creek Dam Removal and Channel Restoration Project near Chiloquin, OR, the Angora Creek SEZ Restoration Project in South Lake Tahoe, and a variety of projects on the Carmel River, CA. Many of these projects included the full-range of surveying, design, construction specifications, permits, and construction management. Following implementation, GMA has conducted hydrologic and geomorphic monitoring for many of these projects, including topographic and bathymetric mapping for volume change detection, substrate characterization through surface counts, bulk samples, and permeability, streamflow measurement and gage operation, and sediment transport measurements.

Greg Treber, Principal of Terrestrial Connections, has both a M.S. in Agriculture-Plant Ecology with Natural Resource Management emphasis and a B.S. in Agriculture with a Botany minor from California State University-Chico. He has worked as a Botanist for the U.S. Forest Service and the Bureau of Land Management and has planned, designed and implemented several large scale riparian and wetland restoration project on the Sacramento and San Joaquin Rivers. Mr. Treber has been involved in the annual riparian revegetation monitoring of the Lower Clear Creek Rehabilitation Project since 2002.

Jeff Souza, Principal of Souza Environmental Solutions, has a M.S. in Agriculture with an emphasis on Plant and Soil Science from California State University-Chico, and a B.S. in Environmental and Systematic Biology with a concentration in Fish and Wildlife Biology from California Polytechnic State University in San Luis Obispo. He has over 18 years professional experience in the assessment, restoration, monitoring and project permitting of terrestrial and aquatic habitats associated with stream, riparian, and wetland systems. Jeff has been involved in the restoration of Clear Creek since 1995 and has conducted the annual riparian revegetation monitoring of the Lower Clear Creek Rehabilitation Project since 2002.

Dr. Neil Schwertman, Professor Emeritus, Department of Mathematics and Statistics, California State University, Chico, has a B.S in Mathematics from the U.S. Naval Academy and a Ph.D. in Applied Statistics from the University of Kentucky. He was a Professor in Mathematics and Statistics at CSU, Chico for 28 years and has provided statistical consulting for a wide range of disciplines including Biology, Agriculture, English, Anthropology, Social Welfare and Corrections, and Education. Dr. Schwertman has been providing statistical assistance for the annual riparian revegetation monitoring of the Lower Clear Creek Rehabilitation Project since 2003.

Ryan Burnett, PRBO Conservation Science's Regional Biologist for the Northern Sacramento Valley and Northern Sierra Nevada. Ryan holds a B.S. in Wildlife, Fish, and Conservation Biology from the University of California, Davis. He has over eight years experience designing and implementing avian monitoring projects including working with federal, state, and NGO's to implement riparian, oak woodland, and coniferous forest avian adaptive conservation plans. Ryan is the project leader for PRBO's Songbird monitoring of the Lower Clear Creek Floodway Restoration Project and authored a recently published paper entitled, "Using Songbird Monitoring to Guide and Evaluate Riparian Restoration in Salmonid Focused Stream Rehabilitation Projects**.**

Dr. Darell G. Slotton, (U.C. Davis) has directed applied research projects addressing heavy metal contamination and bioaccumulation issues in California aquatic ecosystems for over 15 years, with a primary focus on mercury.

He has led investigations of copper, zinc, and cadmium contamination at Iron Mountain Mine, Keswick Reservoir, and Camanche Reservoir, where sediment resuspension and metals transport, solubility, and bioavailability were studied. Since 1985, he has run a mercury monitoring and research program at Davis Creek Reservoir and a mercury analytical laboratory at UC Davis. In the 1990s, Dr. Slotton led a research program throughout the gold mining region of the Sierra Nevada, focusing on benthic invertebrates and fish as sentinels of relative bioavailable mercury exposure. He conducted an intensive study of mercury mass loading, bioaccumulation, and remedial options at the Mt. Diablo Mercury Mine and Marsh Creek watershed. Slotton has led numerous mercury studies throughout the Cache Creek watershed and was a long-time participant in the Clear Lake Superfund Mercury Project. Other projects have included mercury bioassessment studies in both lower Putah Creek and its mine-impacted upper watershed. A current multi-year project is researching the mercury issue in the Truckee River and Pyramid Lake, Nevada. International projects include mercury bioaccumulation and source assessment studies in the Lake Titicaca watershed of Peru and the Ayeyarwady River system of Myanmar. Since 1998, Slotton's primary focus has been directing several regional projects funded by the CALFED Bay-Delta Agency (now CBDA). One was a San Francisco Bay-Delta study of mercury source detection, bioaccumulation, and methylation, and the implications for wetlands restoration projects. A second focused on the Cache Creek watershed, determining the trophic relationships in localized mercury bioaccumulation, and the relationship to aqueous mercury chemistry. Another recently investigated the mercury bioaccumulation implications of a potential large dam removal project on the Yuba River. His most recent CBDA project involves the development and implementation of a biosentinel component for the new Bay-Delta watershed-wide fish mercury monitoring program.

Dr. Ted Donn, (Tetra Tech) is a broadly trained ecologist with over 20 years of post-doctoral experience. Dr. Donn managed projects involving evaluation of impacts to water and sediment quality, terrestrial and marine communities, ecological risk assessment, endangered species surveys, and GIS and database development ranging in value from $10,000 to over $750,000. Dr. Donn has extensive experience with water and sediment quality issues in both freshwater and marine systems, mercury behavior in aquatic environments, and restoration of salmonid habitat. He has contributed to the development of TMDLs for nutrients and metals for water bodies in California, Arizona, Colorado, and Florida. Dr. Donn has conducted evaluation of the effects of mercury and other contaminants on benthic organisms and fish in the Gulf of Thailand, in Colorado streams and reservoirs, and in the Everglades. Dr. Donn managed the preparation of a summary report on mercury issues associated with ongoing restoration activities designed to improve habitat for anadromous salmonids in Lower Clear Creek. This project includes the compilation and synthesis of data available in peer-reviewed literature, published reports, and unpublished data sets. Dr. Donn has reviewed marine monitoring data submitted in support of NPDES permits applications (Section 301(h) of the CWA), developed management and monitoring objectives for POTW monitoring programs, and has reviewed the intercompatibility of discharge-related monitoring programs in the Southern California Bight. Dr. Donn was a contributing author to an EPA guidance document on marine and estuarine monitoring methods for the National Estuary Program.

b. Scientific Contributors

The Restoration Team is comprised of representatives of various federal, state and local resource agencies. Although over thirty representatives attend the meetings at various times, the key participants are:

- Jim DeStaso, Bureau of Reclamation
- Matt Brown, U.S. Fish & Wildlife Service
- Howard Brown, NOAA Fisheries
- Aric Lester, California Dept. of Water Resources
- Francis Berg, U.S. Bureau of Land Management
- Graham Matthews, Graham Matthews and Assoc.
- Jeff Souza, Souza Environmental Solutions
- Jess Newton, U.S. Fish and Wildlife Service
- Patricia Bratcher, California Dept. of Fish and Game
- Mike Berry, California Department of Fish and Game
- Ron Rogers, U.S. Bureau of Land Management
- Michael Harris, Western Shasta RCD
- Ryan Burnett, PRBO Conservation Science

Geomorphic designs underwent review by the Restoration Team, as well as agency engineering staff as needed. Project designs for Phases 1 & 2 were prepared by McBain & Trush, North State Resources, Graham Matthews & Associates, and Stetson Engineers. Phase 3B geomorphic designs have been prepared by Graham Matthews & Associates. Riparian revegetation designs will be prepared by Souza Environmental Solutions. Construction implementation will be completed by the WSRCD, monitoring and evaluation will be implemented by WSRCD, USFWS, Graham Matthews & Associates, Souza Environmental Services, and PRBO. Adaptive Management will be continued through both the WSRCD and the Restoration Team.

c. Planning Organizations
The WSRCD has been implementing wildlife and fisheries restoration projects, erosion control projects, fuels reduction projects, and coordinated resource planning projects in Shasta County since 1957. In 1999 the WSRCD was named "District of the Year" by the California Association of RCDs. Since 1997, WSRCD has implemented numerous projects on Lower Clear Creek, including spawning gravel introduction, a watershed analysis, and erosion control projects, including all previous phases of the Lower Clear Creek Floodplain Restoration Project. The WSRCD will coordinate the project with the Lower Clear Creek CRMP group and the Restoration Team.

d. Other Collaborators
Other groups who have been contributing to the success of the project, reviewing documents and providing input include the Horsetown Clear Creek Preserve Board of Directors, the Shasta County Office of Education – Whiskeytown Environmental School, French Gulch School and the Shasta-Tehama Bioregional Council. In addition numerous schools collaborate with the Restoration Team by using the project as a learning lab. This includes Chrysalis Charter School which has adopted the project and has integrated restoration into its curriculum.

e. Conflicts of Interest.
No potential conflicts of interest are anticipated.

7. Costs
a. Budget
The total cost for this project is 4,774.622.00 for completion of all tasks. A budget by task and a detailed budget by year is in Appendix VII.

b. Cost-Sharing

COST SHARING COMMITMENTS: The total CALFED project funding commitment to the WSRCD has been 4,003,239.58. Over $1,391,912 cost sharing has been obtained for previous phases of the project and will continue through the end of the total project. To date Phase 3B has the following Cost share commitments in place.

BLM	Invasive Weed Surveys and Treatment	$45,000
BLM	Elderberry Surveys for Phase 3B	$10,000
BLM	Wetlands Delineation for Phase 3B	$25,000
BOR	Biological Evaluation for Phase 3B	$40,000 (Includes NEPA)
CVPIA	Phase 3B Survey and Design	$86,000
CVPIA	LCCFRP Stream Gage	$20,000.
		$226,000

Additional cost share will come from meeting attendance by agency personnel, additional grant sources through the WSRCD, as well as BLM and CVPIA yearly funding allotments for lower Clear Creek.

8. Local Involvement

This project has been presented by the Restoration Team to the Lower Clear Creek CRMP Group, which provides a mechanism for private stakeholder participation and fully supports this proposal. The Shasta County Board of Supervisors has been an avid supporter of the work being done in the Clear Creek Watershed. Periodic reports will continue to be made to the board, and a letter of support is attached. The Shasta-Tehama Bioregional Council, a 12-year old organization of state/federal/local agencies, industry, businesses, conservation organizations, local elected officials, labor, the academic community, and the general public, continues to avidly support the restoration of Lower Clear Creek.

Stakeholder groups continue to be brought into the process through quarterly meetings of the Lower Clear Creek CRMP Group (involving landowners, residents, and any stakeholders interested in activities in the watershed) including Shasta Fly Fishers, NorCal Fishing Guides & Sportsman's Assn., Shasta Sportsman, Shasta College, Horsetown Clear Creek Preserve, Shasta Historical Society, Whiskeytown Environmental Education Camp, Shasta Paddlers, Native Plant Society, Shasta County Farm Bureau, Shasta Wildlife Rescue, Redding Sunset Rotary, Redding Mountain Bikers, Black Powder, Redding Rancheria. Businesses in the CRMP Group include: J. F. Shea Sand and Gravel, Salix Applied Earthcare, Schmitt Equipment Sales, and Sunrise Excavation, Osprey Excursions, and Bob's Guide Service.

9. Compliance with Standard Terms and Conditions

The WSRCD will comply with the state and federal standard terms.

10. Figures and Appendices

A. Figures
B. Appendix
  - I. Conceptual Plan for Restoration of the Lower Clear Creek Floodway.
  - II. Conceptual Models
  - III. CALFED Monitoring Plans and Tables
  - IV. Channel Construction Document
  - V. Channel Monitoring Methods
  - VI. Timeline for Implementation
  - VII. Detailed Budget
  - VIII. Letters of Support

Literature Cited:

Burnett, R.D. and J. Harley. 2004. Songbird Monitoring of the Lower Clear Creek Floodway Rehabilitation Project.1999-2003 Comprehensive Report. PRBO Report # 1174.

CALFED Bay Delta Program. 2003. Lower Clear Creek Adaptive Management Forum Report.

CALFED Bay Delta Program. 1999. CALFED Bay Delta Program, Ecosystem Restoration Program Plan, Revised Draft VOL I and II, February 1999.

CALFED Bay Delta Program. 1998. CALFED Bay Delta Program Strategic Plan for the Ecosystem Restoration Program.

California Department of Water Resources. 1986. Clear Creek Fishery Study. Northern District, Sacramento, CA.

Coots, Millard. 1971. Unpublished California Department of Fish and Game data, Redding, CA.

McBain and Trush. 1997. Trinity River Channel Maintenance Flow Study Final Report. Prepared for the Hoopa Valley Tribe, Trinity River Task Force.

McBain and Trush. 2000. Habitat Restoration Plan for the Lower Tuolumne River Corridor. Prepared for the Tuolumne River Technical Advisory Committee .

McBain and Trush, Graham Matthews and Associates, North State Resources. 1999. Lower Clear Creek Floodway Rehabilitation Project Channel Reconstruction, Riparian Vegetation, and Wetland Creation Design Document. Prepared for the Clear Creek Restoration Team.

McBain and Trush. 2001. Final Geomorphic Evaluation for Lower Clear Creek Downstream of Whiskeytown Dam, California. Prepared for the Bureau of Reclamation

RHJV (Riparian Habitat Joint Venture). 2000. Version 1.0. The riparian bird conservation plan: a strategy for reversing the decline of riparian associated birds in California. California Partners in Flight. http://www.prbo.org/CPIF/Riparian/Riparian.html.

Trush, W.J., S.M. McBain, and L.B. Leopold. Attributes of an alluvial river and their relation to water policy and management. Proceedings of the National Academy of Science, 97(22): 11858-63.

US Bureau of Reclamation, Bureau of Land Management, and Western Shasta Resource Conservation District. 1999. Lower Clear Creek Floodway Rehabilitation Project Final Mitigated Negative Declaration/Finding of No Significant Impact Joint CEQA Initial Study/NEPA Environmental Assessment.

USBR and WSRCD. 2000. Ecological Monitoring Plan for the Lower Clear Creek Floodway Rehabilitation Project. Prepared for CALFED Bay Delta Program.

USFWS and Hoopa Valley Tribe. 1999. Trinity River Flow Evaluation Final Report. Prepared for the Secretary of the Interior.

WSRCD. 1996. Lower Clear Creek Watershed Analysis. Prepared for the Bureau of Land Management.

WSRCD. 1998. Lower Clear Creek Watershed Management Plan. Prepared for Lower Clear Creek CRMP.

A. Figures

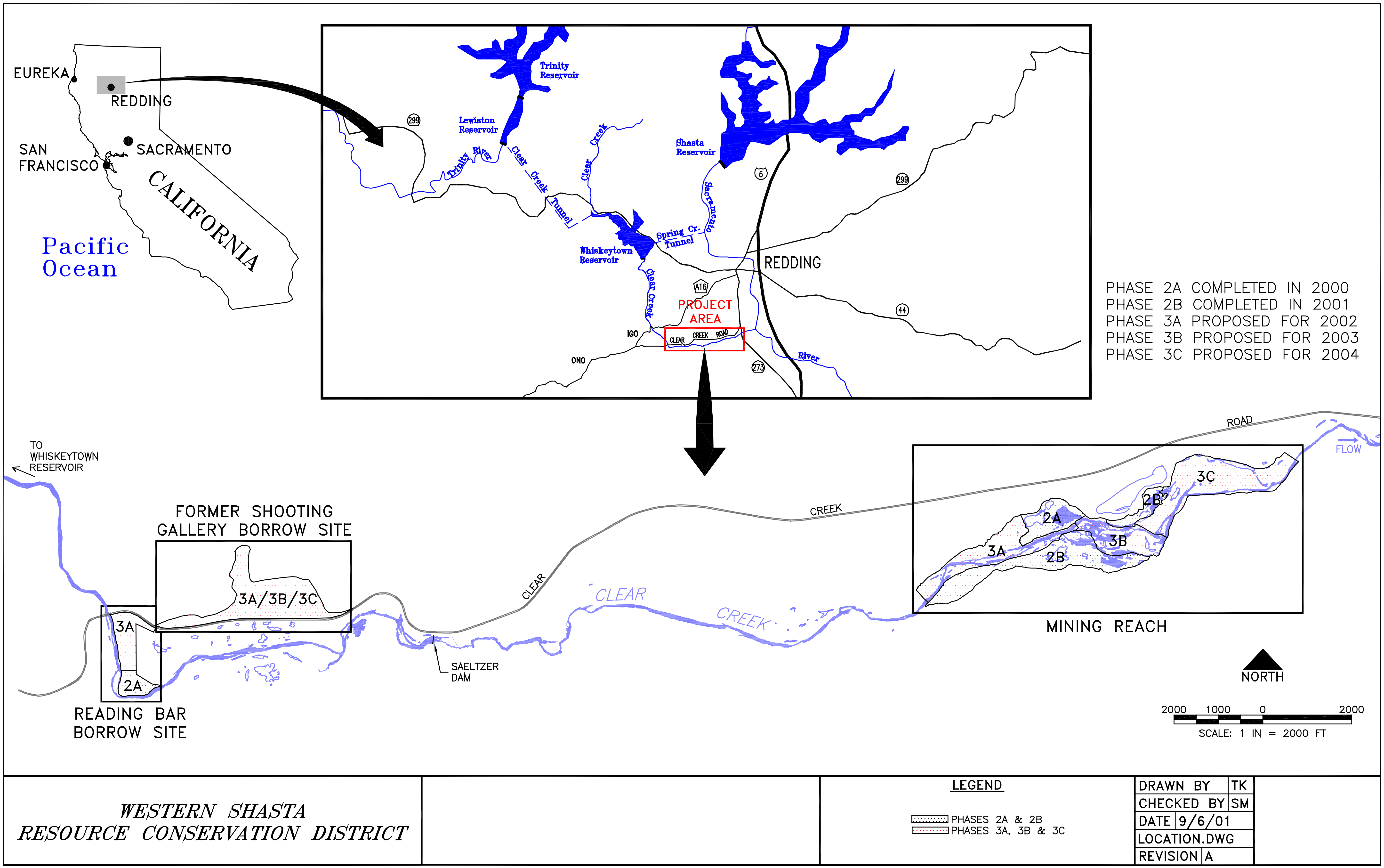
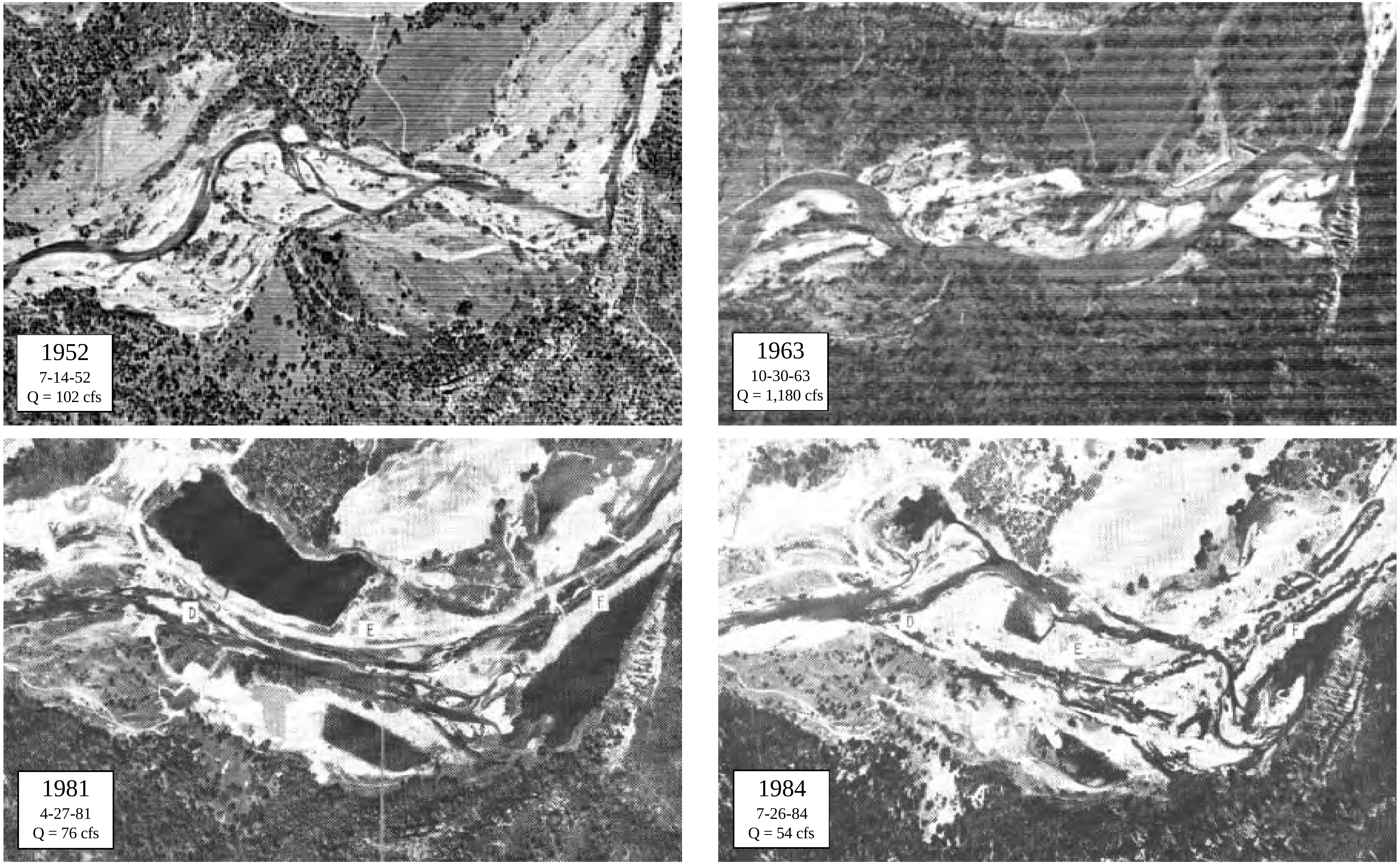


Figure 1. Lower Clear Creek Floodway Rehabilitation Project mining reach



WESTERN SHASTA
RESOURCE CONSERVATION DISTRICT

Scale approximately 1” = 500’

Figure 2. Sequential aerial photographs of the downstream project area.

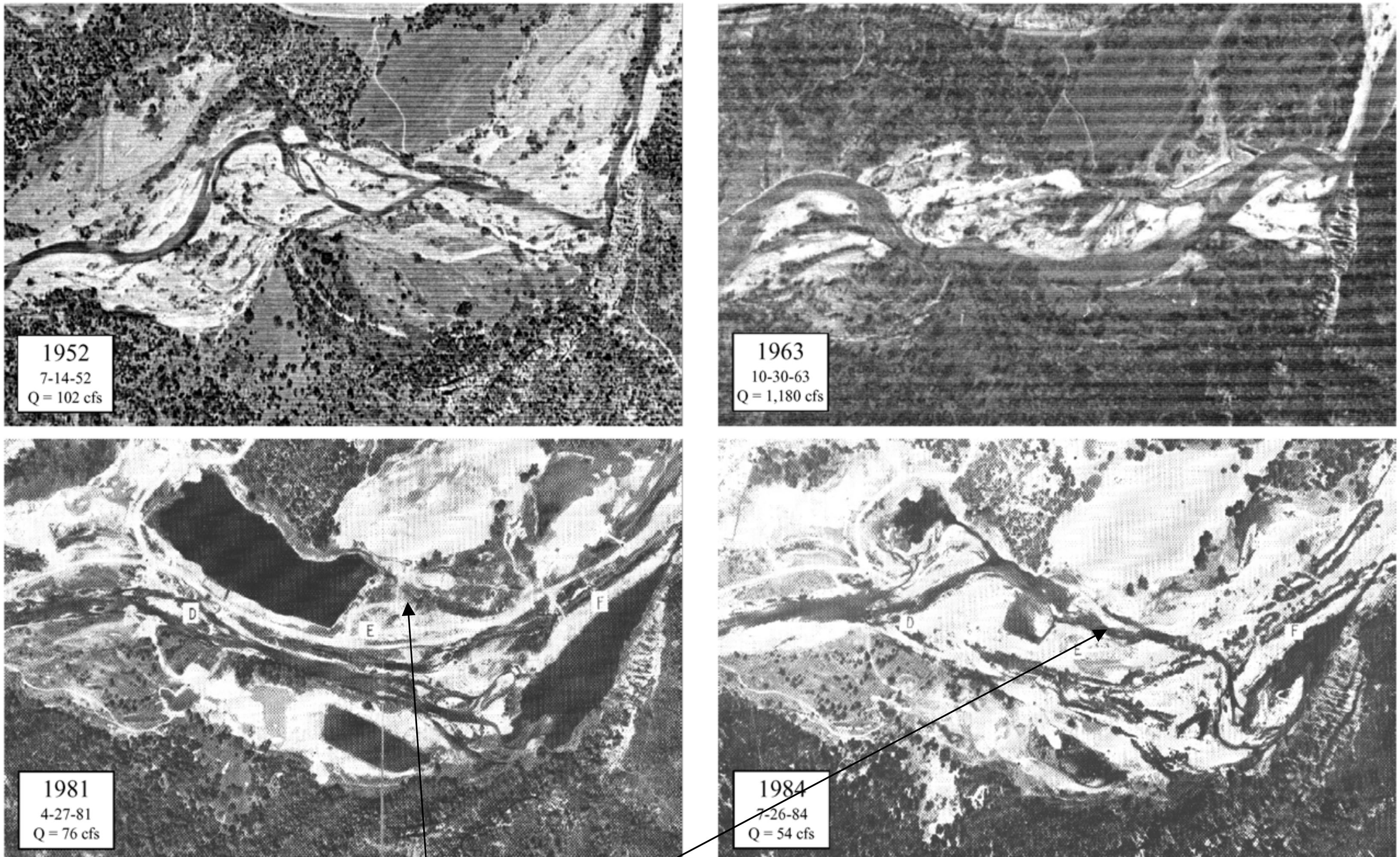
Figure 3 - Photo of Clear Creek along the project reach, showing most of the channel bed surface is exposed clay hardpan.

Figure 4 - Oblique photo of Clear Creek Floodway Rehabilitation Project site prior to construction in 1997. Photo is looking north, with primary Clear Creek channel running diagonally across the photo (flow from left to right).

CLEAR CREEK FLOODPLAIN RESTORATION PROJECT – Phase 2A, 1999 top, 2001 bottom)

Fig. 5

Fig. 6



McBain & Trush | GMA GRAHAM MATTHEWS & ASSOCIATES | North State Resources

Sequential Aerial Photographs of the DOWNSTREAM Project Area
Scale approximately 1" = 500'

FIGURE 6
25 May 99

Backbuster Area

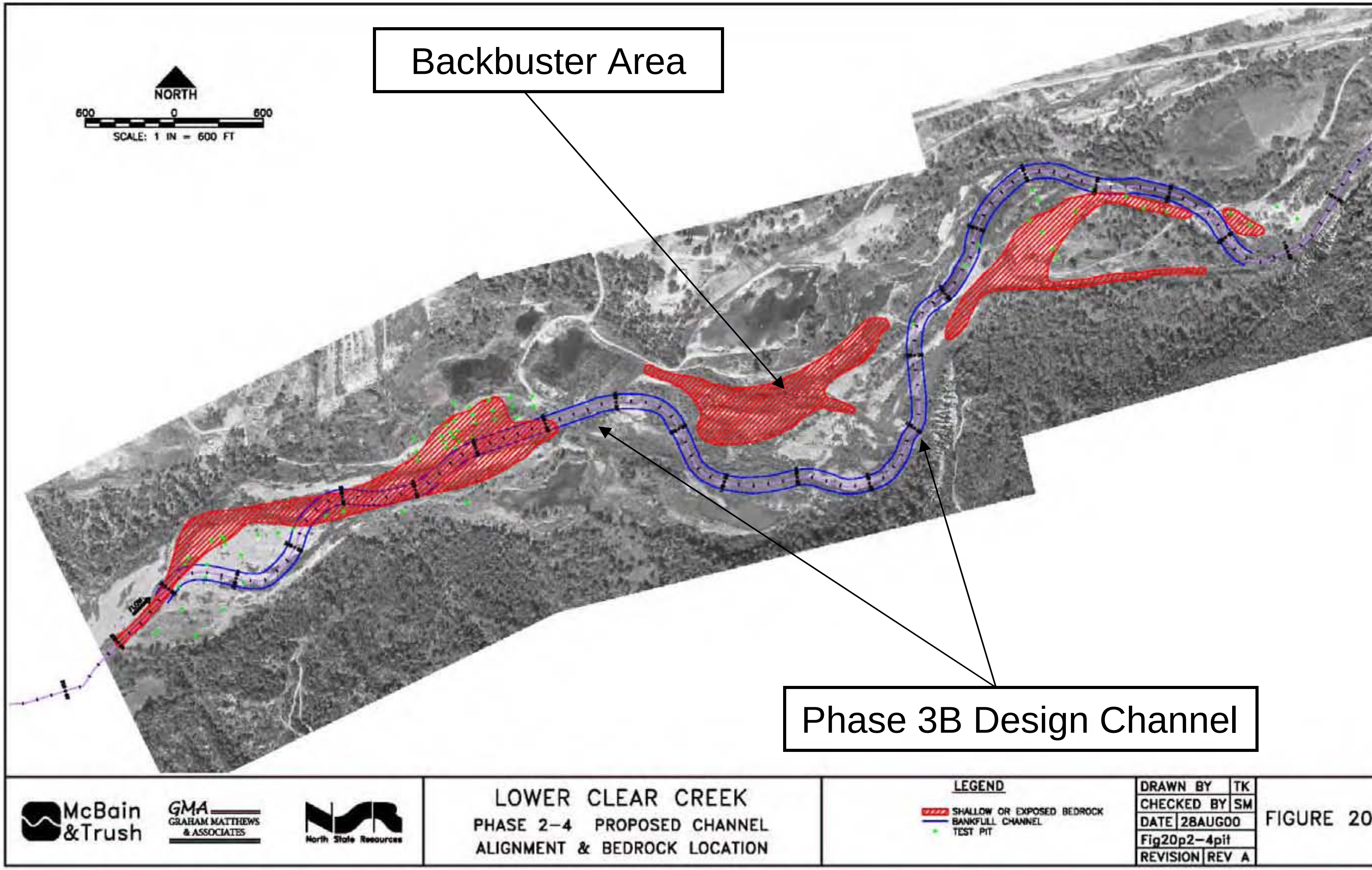
Fig. 7

Backbuster Area

FIGURE 17. LOWER CLEAR CREEK IN REACH 4
AT THE FLOODWAY REHABILITATION PROJECT SITE (1997),
SHOWING LOW GRADIENT CHANNEL AND IMPACTS OF INSTREAM AGGREGATE MINING

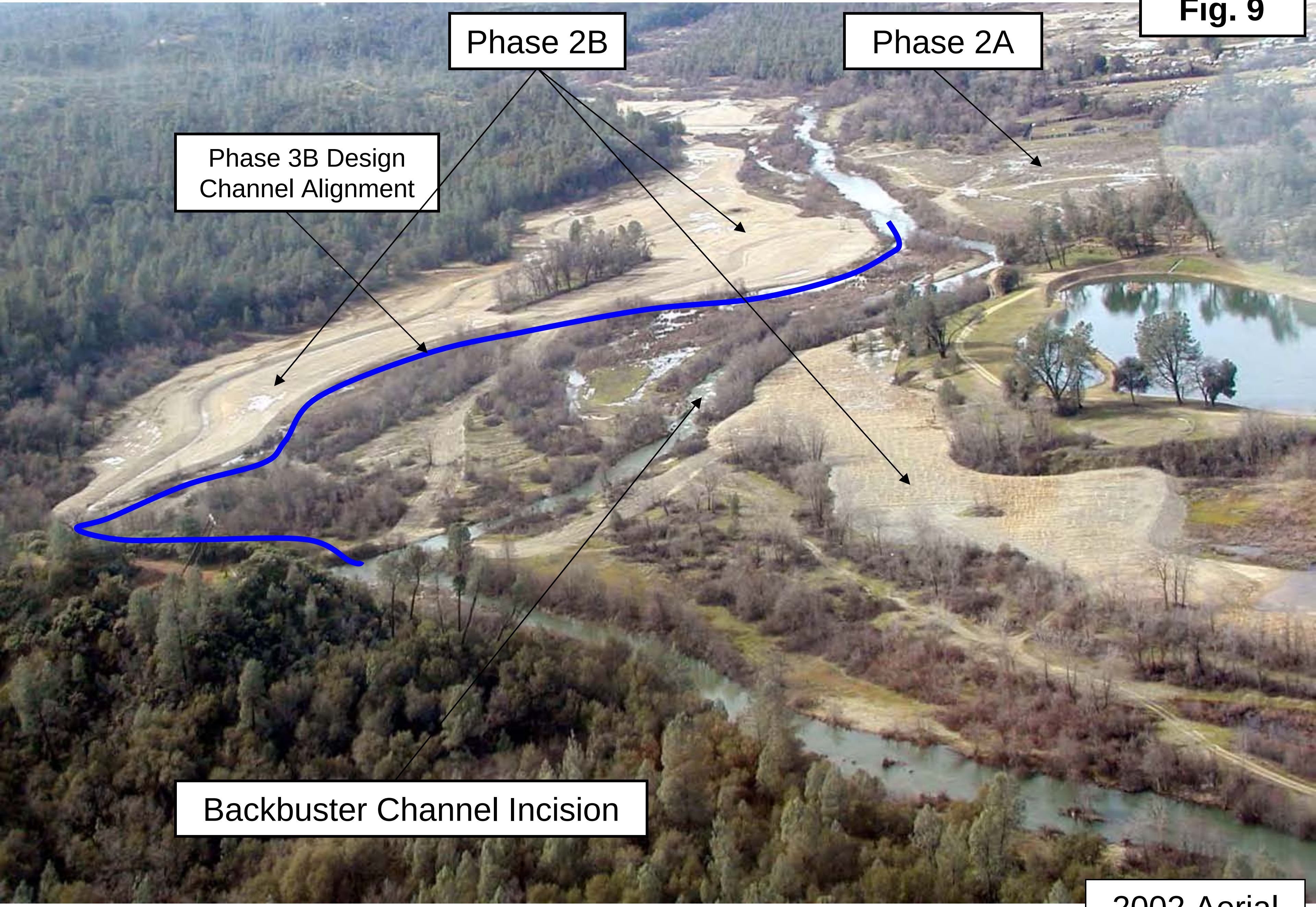
12/6/01

Fig. 8



Backbuster Area
Phase 3B Design Channel
NORTH
600 0 600
SCALE: 1 IN = 600 FT
McBain & Trush
GMA GRAHAM MATTHEWS & ASSOCIATES
North State Resources
LOWER CLEAR CREEK
PHASE 2-4 PROPOSED CHANNEL
ALIGNMENT & BEDROCK LOCATION
LEGEND
SHALLOW OR EXPOSED BEDROCK
BANKFULL CHANNEL
TEST PIT
DRAWN BY TK
CHECKED BY SM
DATE 28AUG00
Fig20p2-4pit
REVISION REV A
FIGURE 20

Fig. 9


Phase 2B
Phase 2A
Phase 3B Design
Channel Alignment
Backbuster Channel Incision
2002 Aerial

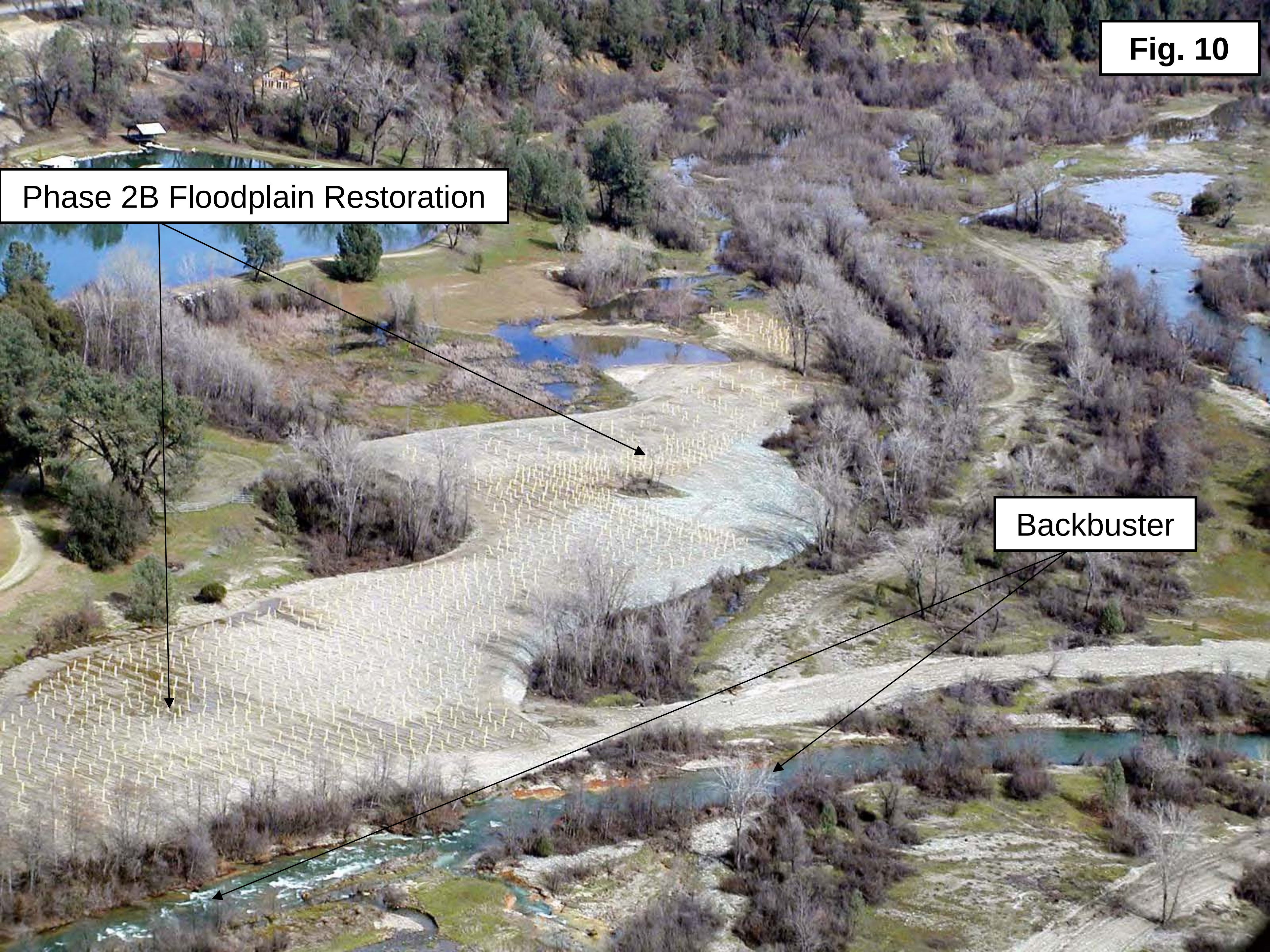


Fig. 10
Phase 2B Floodplain Restoration
Backbuster

Fig. 11

1995

2004

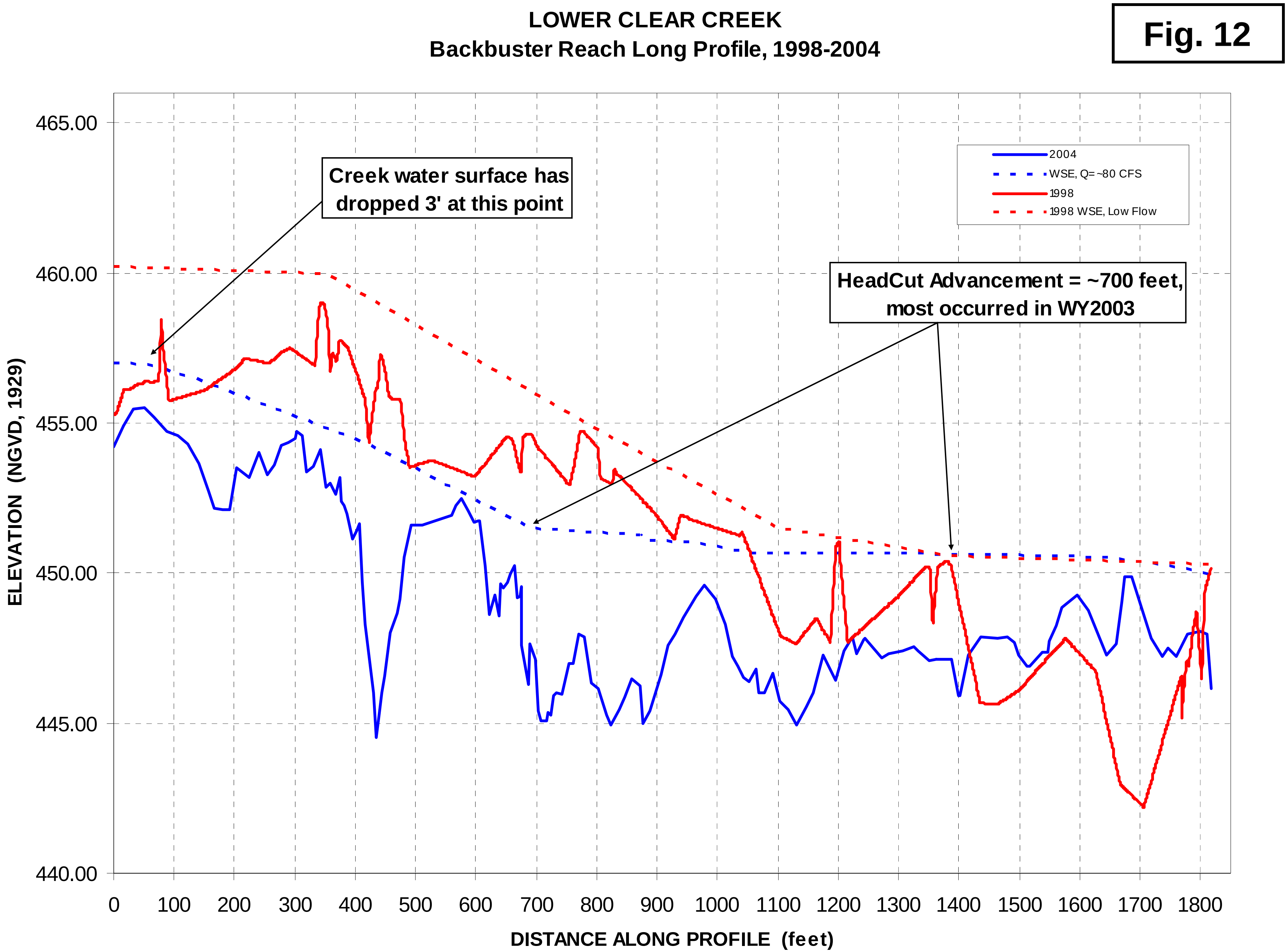
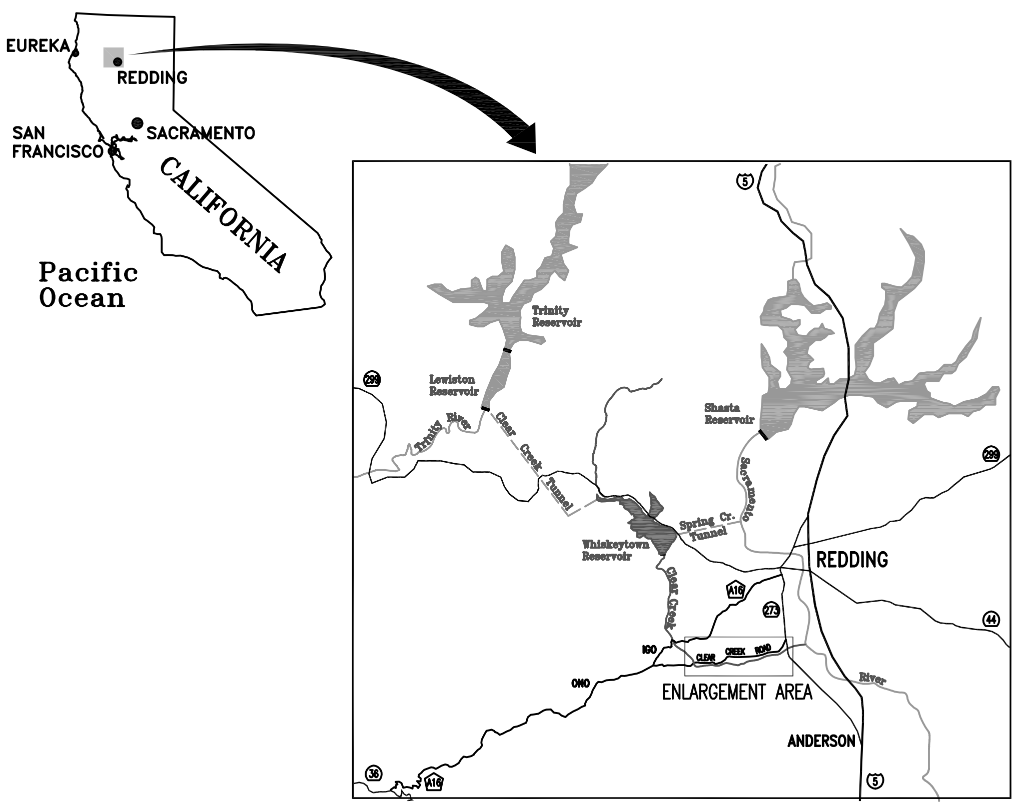
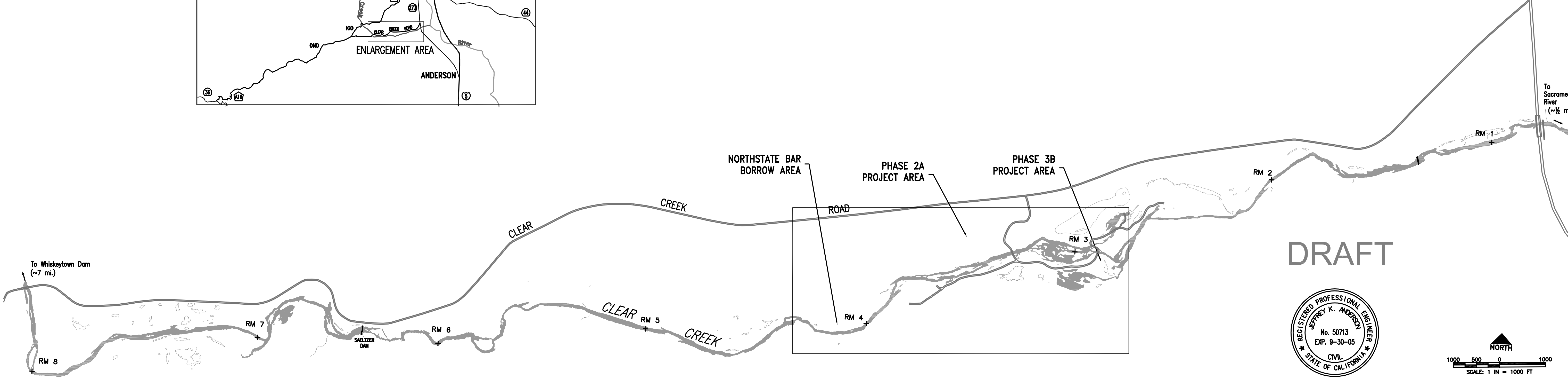


Fig. 12
LOWER CLEAR CREEK
Backbuster Reach Long Profile, 1998-2004
Creek water surface has dropped 3' at this point
HeadCut Advancement = ~700 feet, most occurred in WY2003
2004
WSE, Q= ~80 CFS
1998
1998 WSE, Low Flow
ELEVATION (NGVD, 1929)
465.00
460.00
455.00
450.00
445.00
440.00
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
DISTANCE ALONG PROFILE (feet)

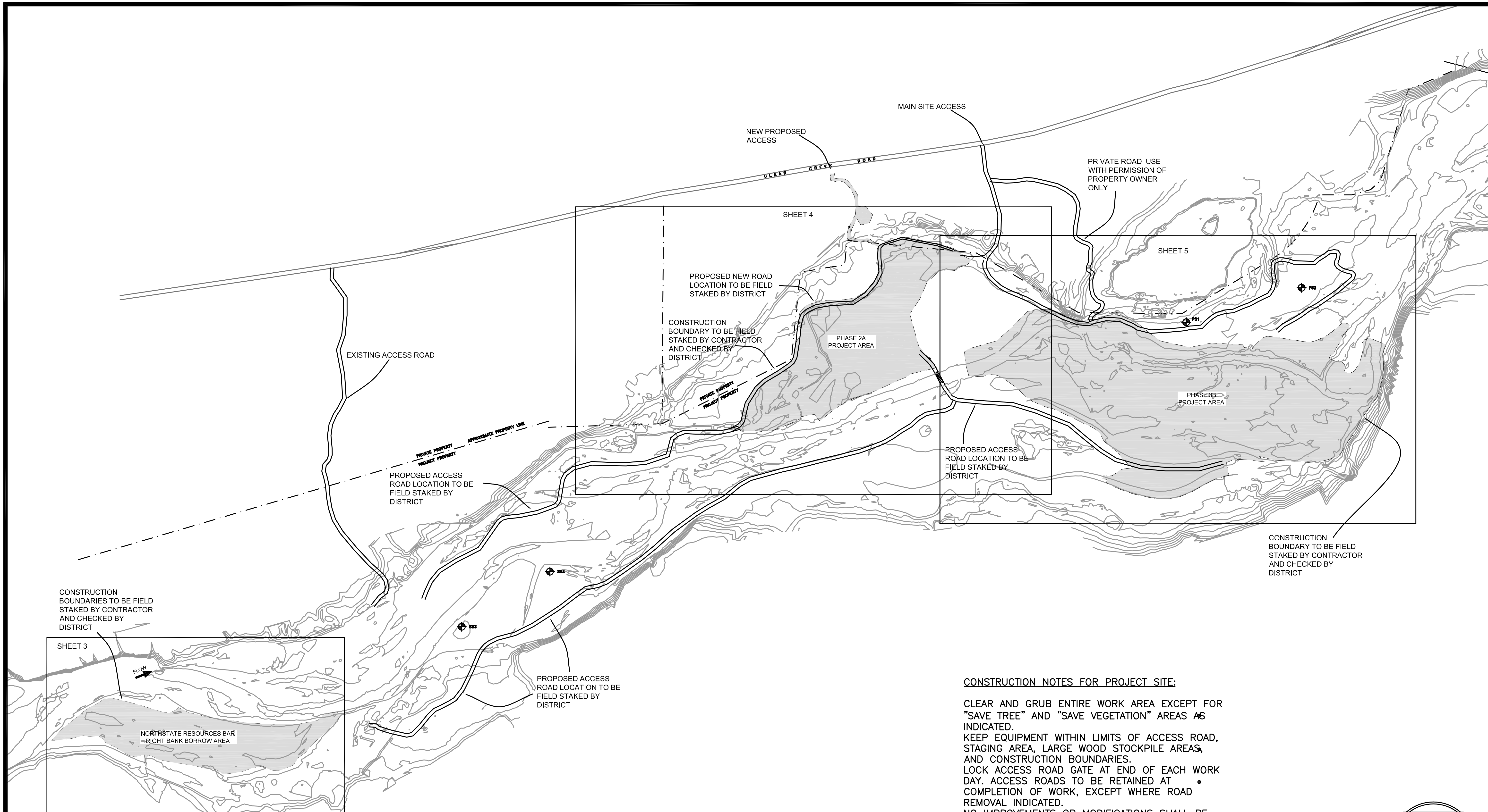
LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT
SHASTA COUNTY, CALIFORNIA



INDEX TO SHEETS



PREPARED BY	KB	DATE 6/05	REV. DATE	PREPARED FOR	LOWER CLEAR CREEK FLOODWAY REHABILITATION PROJECT PHASE 3B	GMA GRAHAM MATTHEWS & ASSOCIATES	N	SCALE VARIES	SHEET 1/9
REVIEWED BY	GM JKA	6/05 6/05		WESTERN SHASTA RESOURCE CONSERVATION DISTRICT 6270 PARALLEL ROAD ANDERSON, CA 96007		Hydrology · Geomorphology · Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax graham@gmahydrology.com			



CONSTRUCTION NOTES FOR PROJECT SITE:

CLEAR AND GRUB ENTIRE WORK AREA EXCEPT FOR "SAVE TREE" AND "SAVE VEGETATION" AREAS AS INDICATED.
KEEP EQUIPMENT WITHIN LIMITS OF ACCESS ROAD, STAGING AREA, LARGE WOOD STOCKPILE AREAS, AND CONSTRUCTION BOUNDARIES.
LOCK ACCESS ROAD GATE AT END OF EACH WORK DAY. ACCESS ROADS TO BE RETAINED AT COMPLETION OF WORK, EXCEPT WHERE ROAD REMOVAL INDICATED.
NO IMPROVEMENTS OR MODIFICATIONS SHALL BE MADE TO THE STAGING AREA WITHOUT PRIOR APPROVAL OF THE DISTRICT.
ALL EQUIPMENT MAINTENANCE AND REFUELING TO OCCUR IN DESIGNATED EQUIPMENT STAGING AREA.

No. 50713
EXP. 9-30-05
CIVIL

DRAFT

		DATE	REV. DATE
PREPARED BY	KB	6/05	
REVIEWED BY	GM JKA	6/05 6/05	

PREPARED FOR
WESTERN SHASTA RESOURCE CONSERVATION DISTRICT
6270 PARALLEL ROAD
ANDERSON, CA 96007

LEGEND
CONSTRUCTION BOUNDARY
EXISTING 5' CONTOURS
ACCESS ROADS
SURVEY CONTROL POINTS

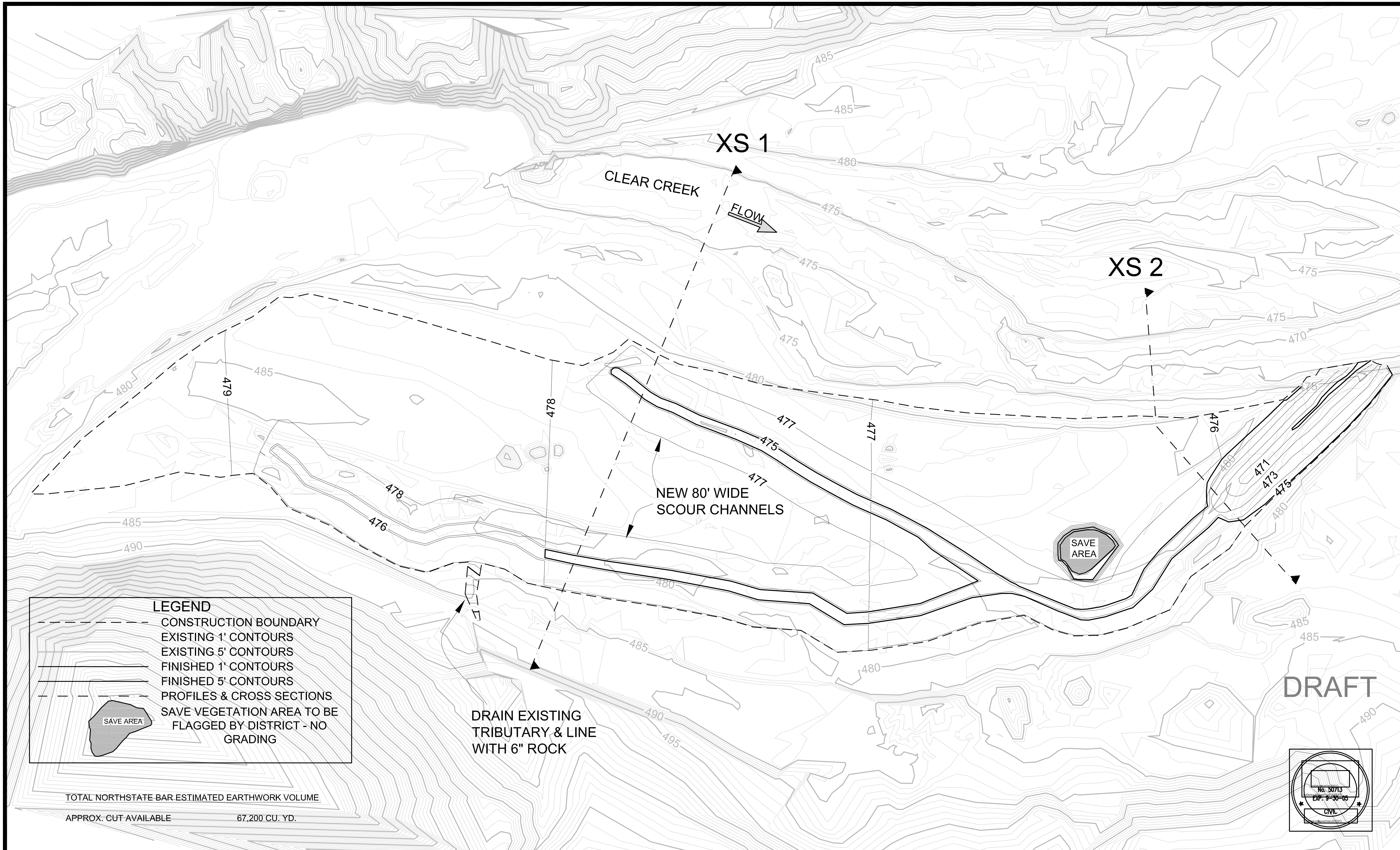
LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT
PHASE 3B
PROJECT SITE ACCESS, WORK AREAS, AND SHEET LAYOUT WITH 2004 AERIAL PHOTO

GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

N

SCALE
0 250

SHEET
2/9



		DATE	REV. DATE
PREPARED BY	KB	6/05	
REVIEWED BY	GM JKA	6/05 6/05	

PREPARED FOR
WESTERN SHASTA RESOURCE CONSERVATION DISTRICT
6270 PARALLEL ROAD
ANDERSON, CA 96007

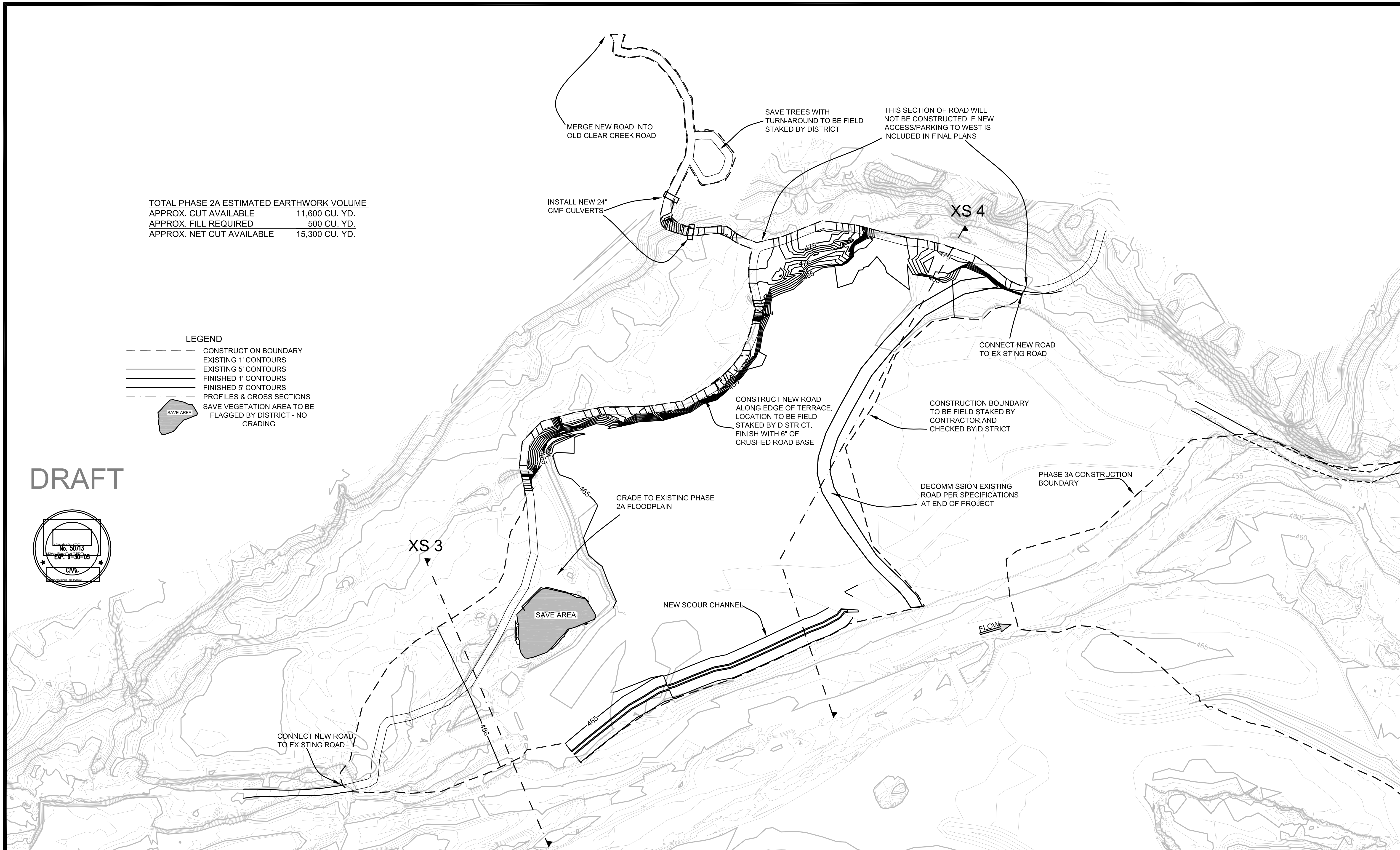
LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT
NORTHSTATE BAR BORROW AREA
GRADING PLAN

GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

N

SCALE
0 50

SHEET
3/9



PREPARED BY	KB	DATE 6/05	REV. DATE
REVIEWED BY	GM JKA	6/05 6/05	

PREPARED FOR
WESTERN SHASTA RESOURCE CONSERVATION DISTRICT
6270 PARALLEL ROAD
ANDERSON, CA 96007

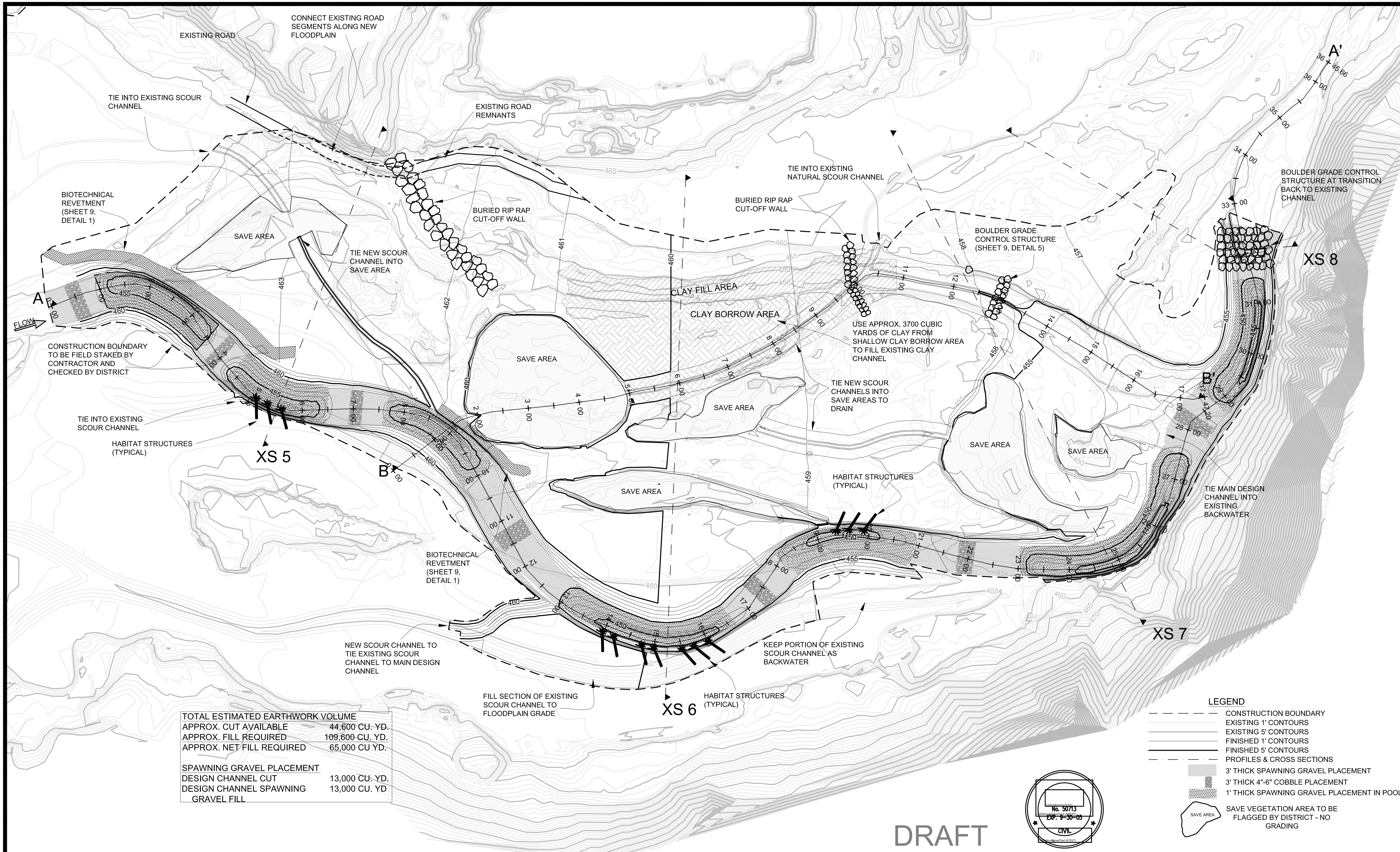
LOWER CLEAR CREEK FLOODWAY REHABILITATION PROJECT
PHASE 2A GRADING AND NEW ACCESS ROAD

GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

N

SCALE 0 80

SHEET 4/9



TOTAL ESTIMATED EARTHWORK VOLUME	
APPROX. CUT AVAILABLE	44,600 CU. YD.
APPROX. FILL REQUIRED	109,600 CU. YD.
APPROX. NET FILL REQUIRED	65,000 CU YD.
SPAWNING GRAVEL PLACEMENT	
DESIGN CHANNEL CUT	13,000 CU. YD.
DESIGN CHANNEL SPAWNING GRAVEL FILL	13,000 CU. YD

LEGEND

- CONSTRUCTION BOUNDARY
- EXISTING 1' CONTOURS
- EXISTING 5' CONTOURS
- FINISHED 1' CONTOURS
- FINISHED 5' CONTOURS
- PROFILES & CROSS SECTIONS
- 3' THICK SPAWNING GRAVEL PLACEMENT
- 3' THICK 4"-6" COBBLE PLACEMENT
- 1' THICK SPAWNING GRAVEL PLACEMENT IN POOLS
- SAVE AREA — SAVE VEGETATION AREA TO BE FLAGGED BY DISTRICT - NO GRADING

		DATE	REV. DATE
PREPARED BY	KB	6/05	
REVIEWED BY	GM JKA	6/05 6/05	

PREPARED FOR
WESTERN SHASTA RESOURCE CONSERVATION DISTRICT
6270 PARALLEL ROAD
ANDERSON, CA 96007

LOWER CLEAR CREEK FLOODWAY REHABILITATION PROJECT
PHASE 3B
GRADING PLAN

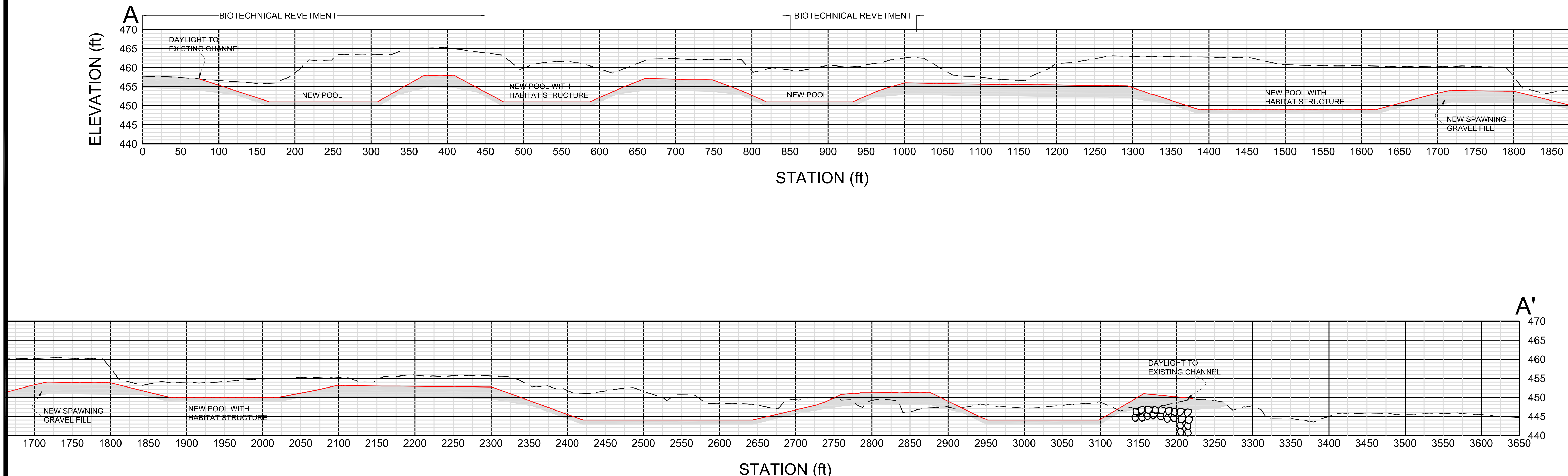
GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

N

SCALE 0 80

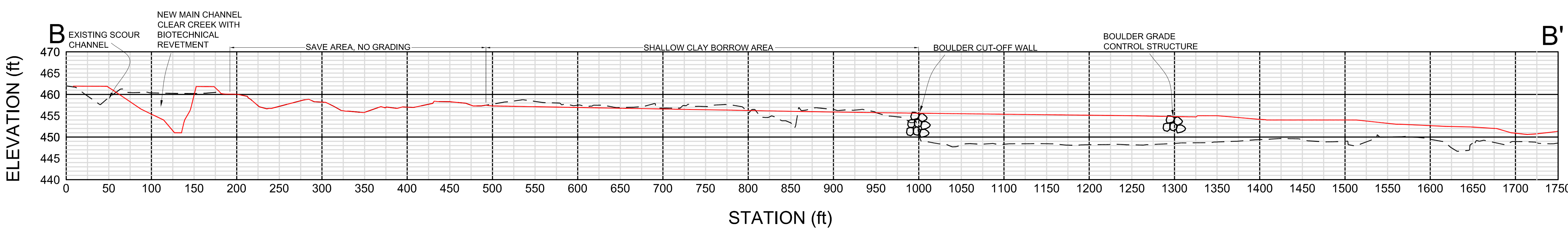
SHEET 5/9

LONGITUDINAL PROFILE A - A'



HORIZONTAL SCALE: 1"=60'
5X VERTICAL EXAGGERATION

LONGITUDINAL PROFILE B - B'



HORIZONTAL SCALE: 1"=60'
5X VERTICAL EXAGGERATION

DRAFT

No. 50713
EXP. 9-30-05
CIVIL

		DATE	REV. DATE
PREPARED BY	KB	6/05	
REVIEWED BY	GM JKA	6/05 6/05	

PREPARED FOR
WESTERN SHASTA RESOURCE CONSERVATION DISTRICT
6270 PARALLEL ROAD
ANDERSON, CA 96007

LEGEND
EXISTING GROUND SURFACE
FINISHED GROUND SURFACE

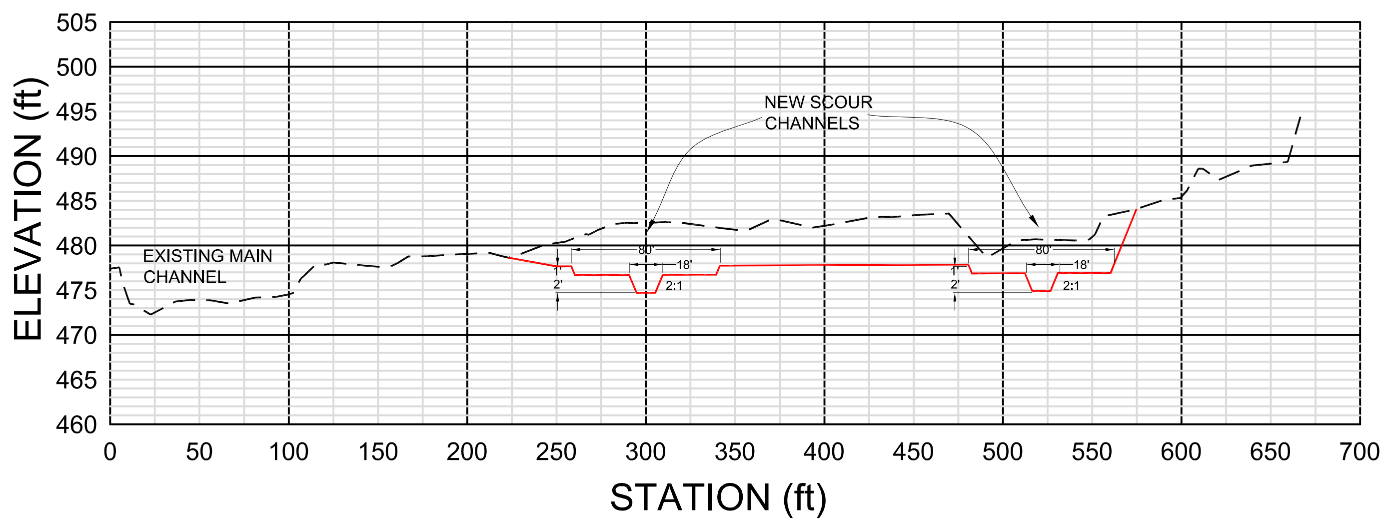
LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT
PHASE 3B PROFILES

GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

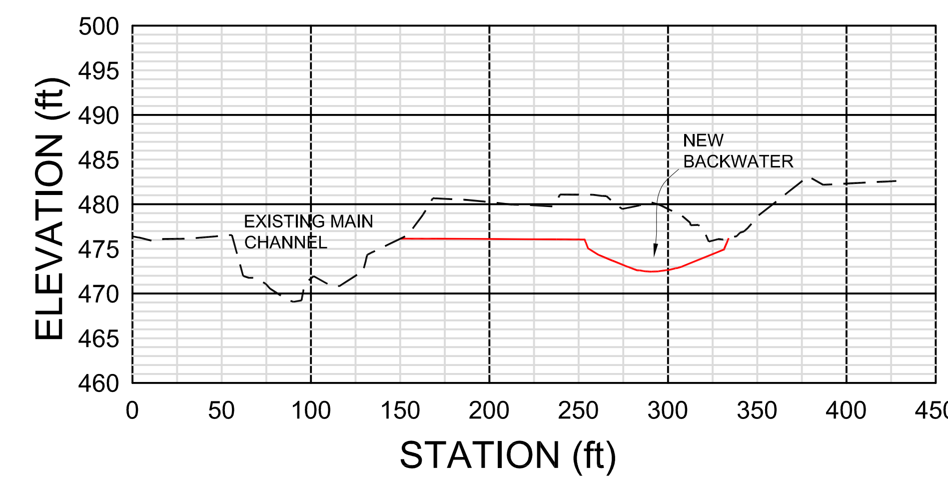
SHEET
6/9

NORTHSTATE BAR BORROW AREA

CROSS SECTION 1



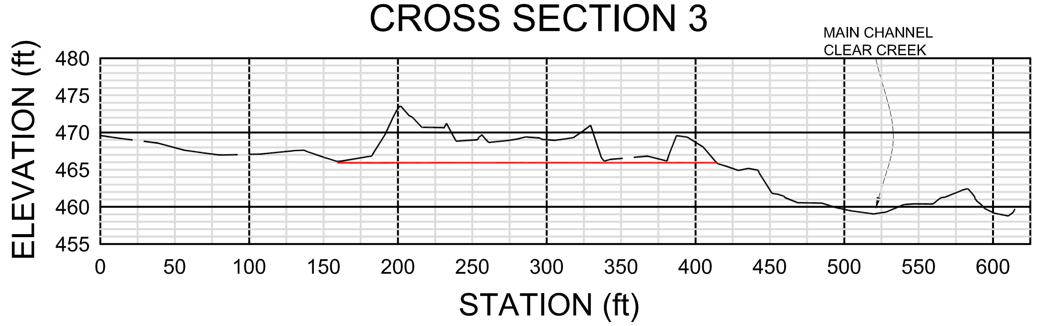
CROSS SECTION 2



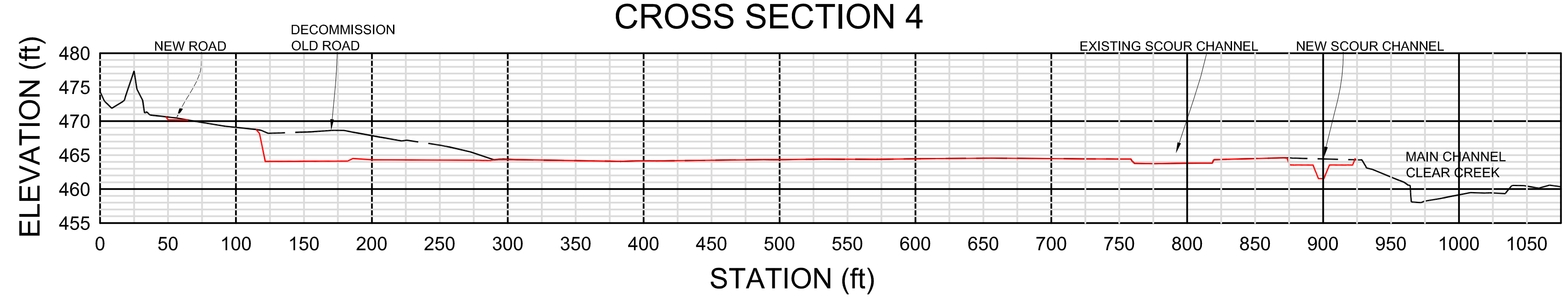
HORIZONTAL SCALE: 1"=50'
5X VERTICAL EXAGGERATION

PHASE 2A GRADING AND ACCESS ROAD

CROSS SECTION 3

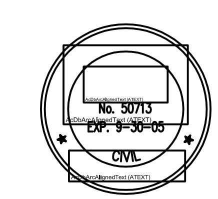


CROSS SECTION 4



HORIZONTAL SCALE: 1"=60'
5X VERTICAL EXAGGERATION

DRAFT



		DATE	REV. DATE
PREPARED BY	KB	6/05	
REVIEWED BY	GM JKA	6/05 6/05	

PREPARED FOR
WESTERN SHASTA RESOURCE CONSERVATION DISTRICT
6270 PARALLEL ROAD
ANDERSON, CA 96007

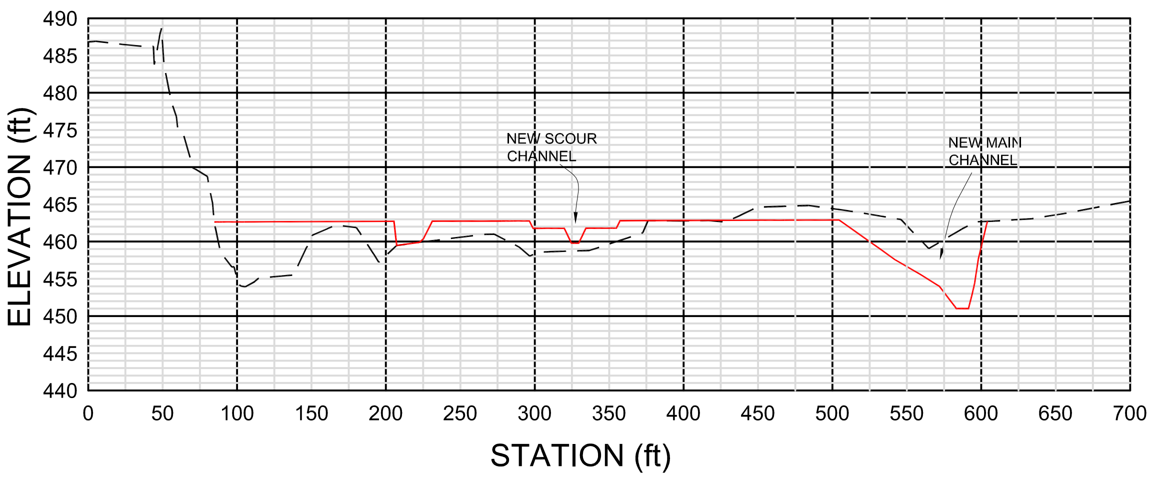
LEGEND
— — — EXISTING GROUND SURFACE
——— FINISHED GROUND SURFACE

LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT
CROSS SECTIONS
NORTHSTATE BAR AND PHASE 2A

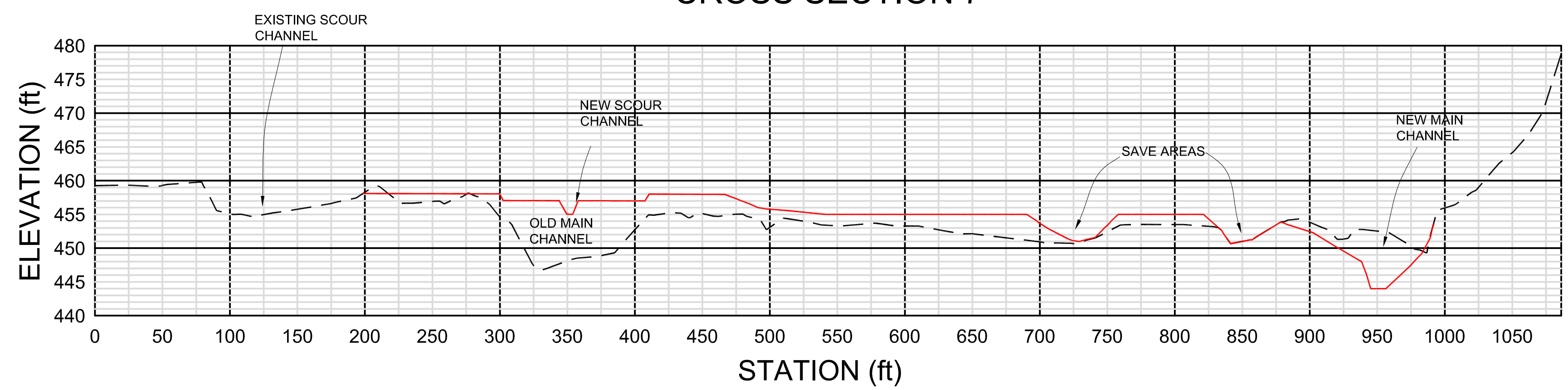
GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

SHEET
7/9

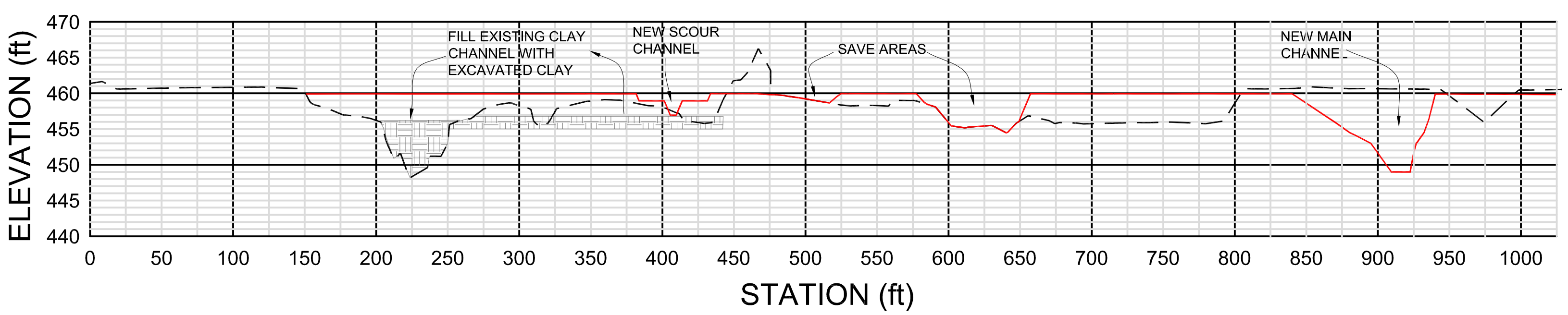
CROSS SECTION 5



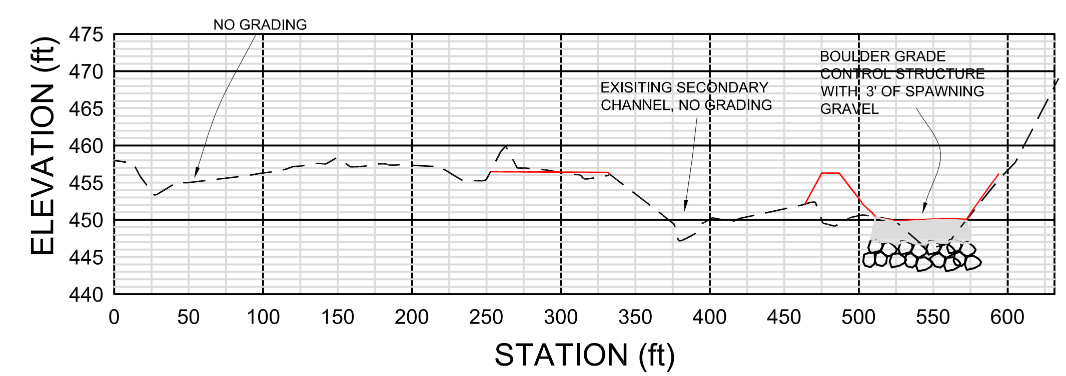
CROSS SECTION 7



CROSS SECTION 6



CROSS SECTION 8



HORIZONTAL SCALE: 1"=60'
5X VERTICAL EXAGGERATION

DRAFT

No. 50713
EXP. 9-30-05
CIVIL

		DATE	REV. DATE
PREPARED BY	KB	6/05	
REVIEWED BY	GM JKA	6/05 6/05	

PREPARED FOR
WESTERN SHASTA RESOURCE CONSERVATION DISTRICT
6270 PARALLEL ROAD
ANDERSON, CA 96007

LEGEND
EXISTING GROUND SURFACE
FINISHED GROUND SURFACE

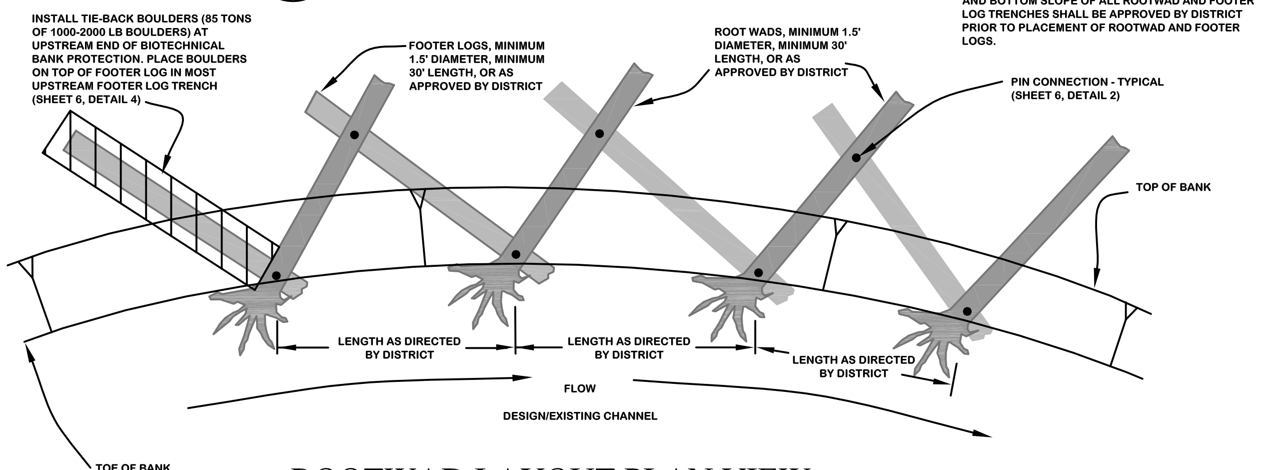
LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT
CROSS SECTIONS
PHASE 3B

GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

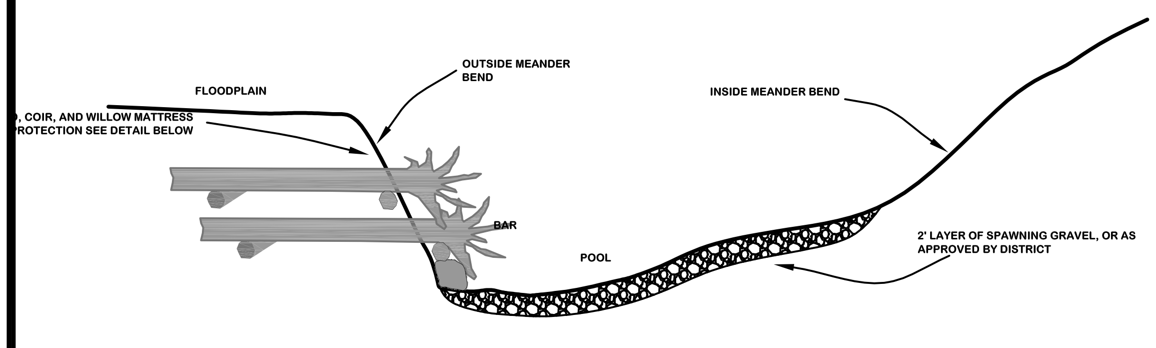
SHEET
8/9

1 BIOTECHNICAL BANK PROTECTION

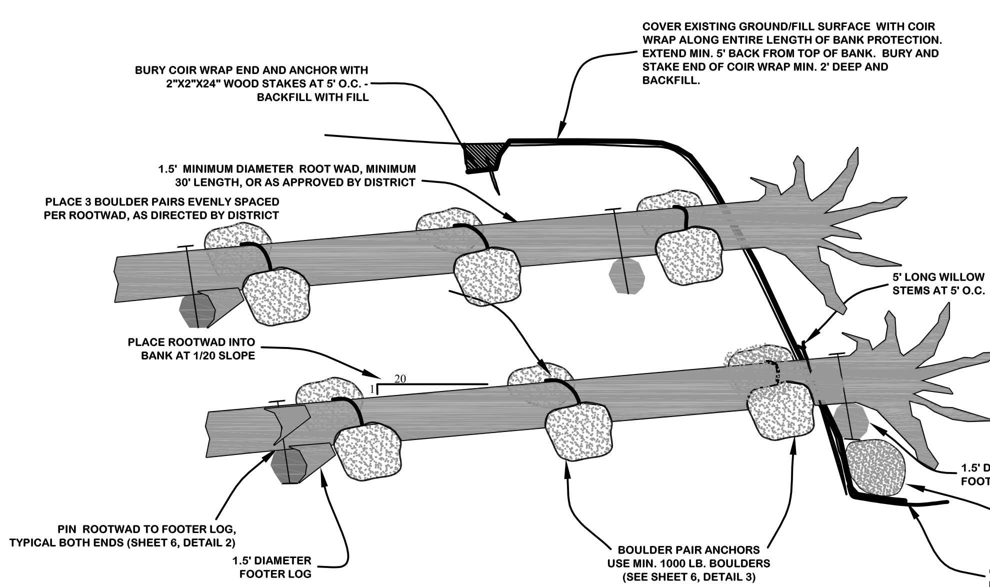
NOTE: BIOTECHNICAL BANK PROTECTION SHALL CONSIST OF 20 ROOTWADS AND 20 FOOTER LOGS TOTAL OVER LENGTH OF BANK PROTECTION. SPACING OF ROOTWADS SHALL BE ADJUSTED IN FIELD AS DIRECTED BY DISTRICT. THE LOCATION, WIDTH, DEPTH, AND BOTTOM SLOPE OF ALL ROOTWAD AND FOOTER LOG TRENCHES SHALL BE APPROVED BY DISTRICT PRIOR TO PLACEMENT OF ROOTWAD AND FOOTER LOGS.

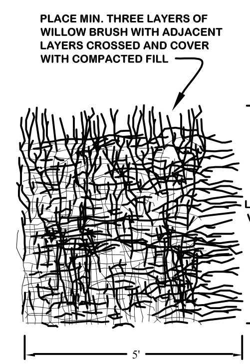


ROOTWAD LAYOUT PLAN VIEW



SECTION VIEW

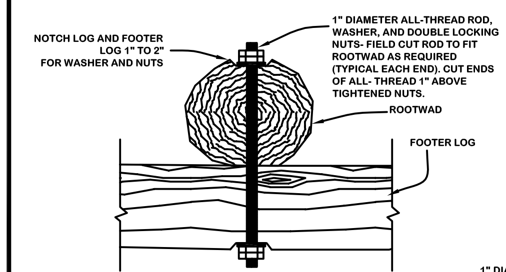




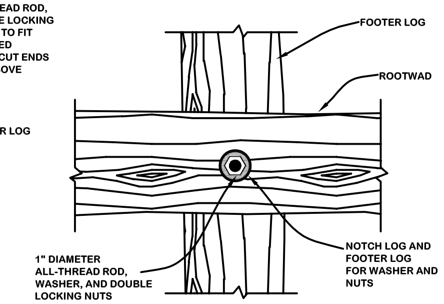
PLAN VIEW OF WILLOW BRUSH LAYERS

SECTION VIEW DETAIL

2 PIN CONNECTION DETAIL

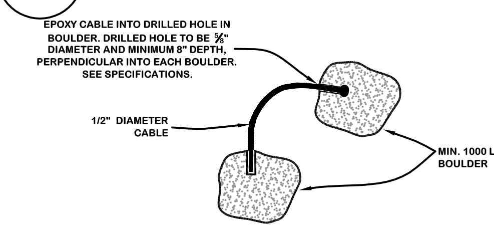


SECTION VIEW

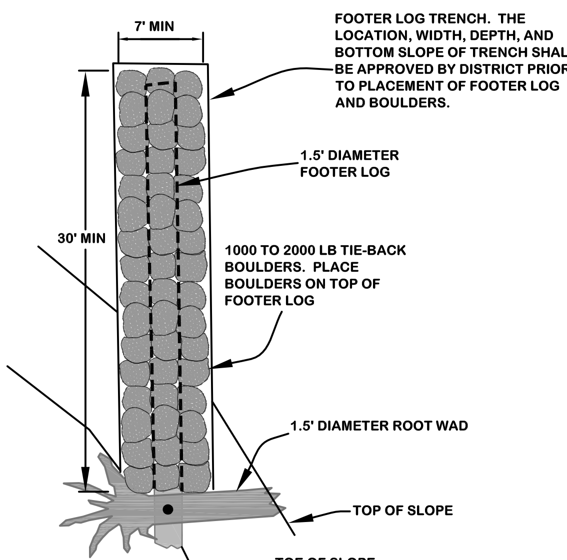


PLAN VIEW

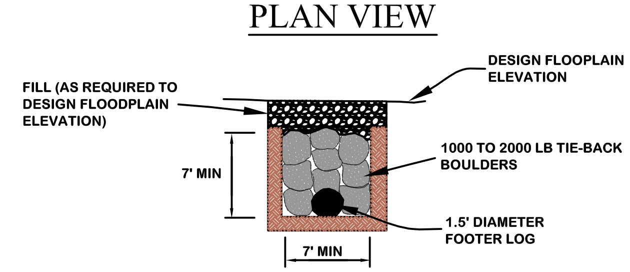
3 BOULDER DETAIL



4 TIE-BACK BOULDER DETAIL

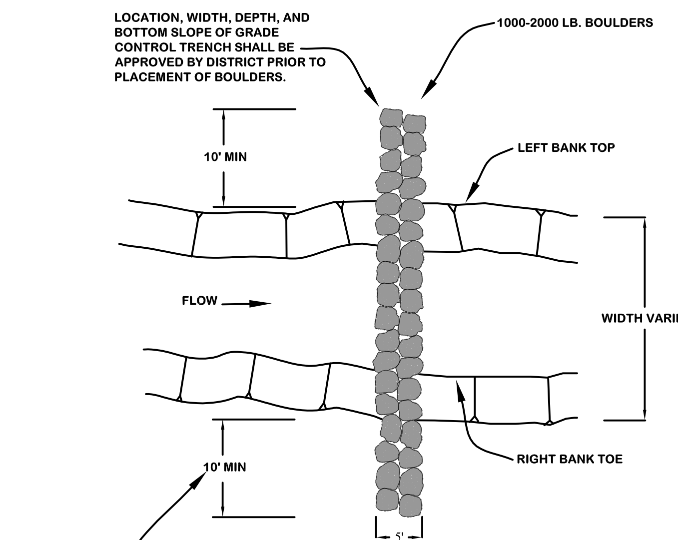


PLAN VIEW

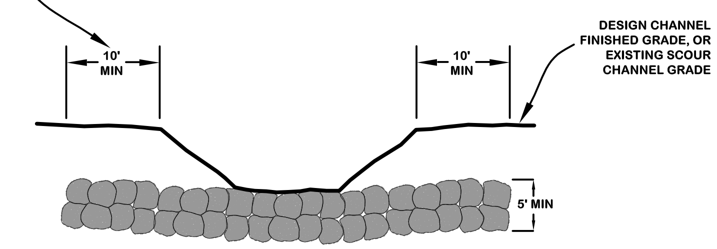


SIDE SECTION VIEW

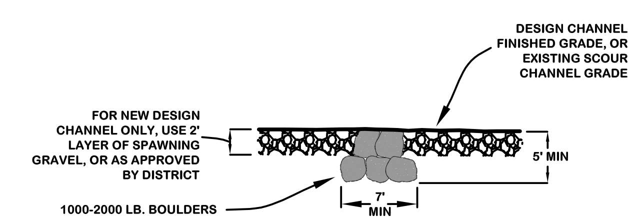
5 GRADE CONTROL STRUCTURE - TYPE 1



PLAN VIEW



FRONT SECTION VIEW



SIDE SECTION VIEW

DRAFT

REGISTERED PROFESSIONAL ENGINEER JEFFREY K. ANDERSON No. 50713 EXP. 9-30-05 CIVIL STATE OF CALIFORNIA

		DATE	REV. DATE	PREPARED FOR
PREPARED BY	KB	6/05		WESTERN SHASTA RESOURCE CONSERVATION DISTRICT 6270 PARALLEL ROAD ANDERSON, CA 96007
REVIEWED BY	GM JKA	6/05 6/05		

LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT
PHASE 3B DETAILS

GMA
GRAHAM MATTHEWS & ASSOCIATES
Hydrology · Geomorphology · Stream Restoration
P.O. Box 1516 Weaverville, CA 96093-1516
(530) 623-5327 ph (530) 623-5328 fax
graham@gmahydrology.com

SCALE VARIES

SHEET 9/9

Appendix I.
Lower Clear Creek Conceptual Plan

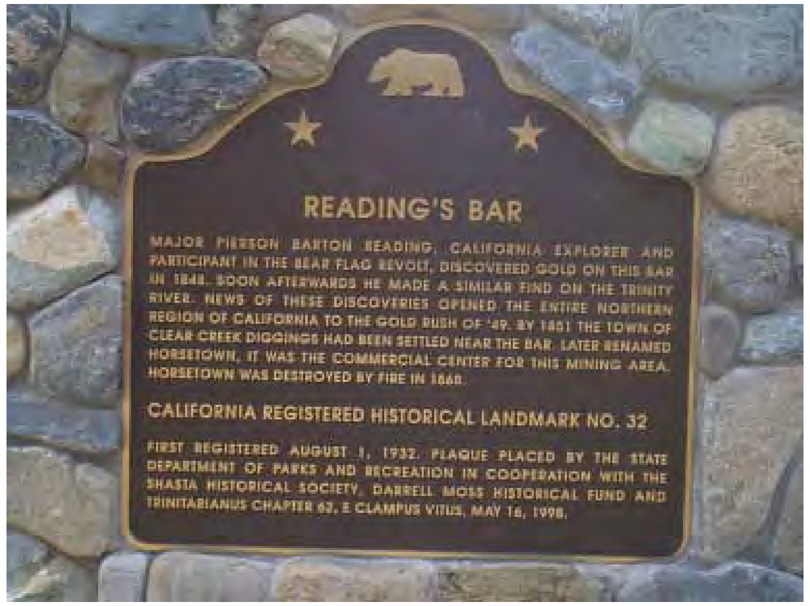
CONCEPTUAL PLAN FOR RESTORATION OF THE LOWER CLEAR CREEK FLOODWAY

PREPARED FOR:
THE LOWER CLEAR CREEK TECHNICAL WORK GROUP

JUNE 1999

BACKGROUND

Land use, beginning with the discovery of gold at Reading Bar in 1848, and continuing today with gravel mining and flow/sediment regulation at Whiskeytown Dam, has profoundly changed the landscape of the lower Clear Creek watershed. These land uses, while providing tremendous benefits to society, have unfortunately caused severe damage to biological habitats provided by the creek. Recent and continuing restoration efforts are attempting to reverse these negative impacts on the creek by restoring the Clear Creek watershed. Restoration activities include adding spawning gravel, removing fish barriers, controlling erosion, reducing fuel loads and improving streamflows. The following summary describes focused efforts that will be undertaken in the next several years to restore two large sections of the lower Clear Creek floodway. The Proposed Action will complement future restoration actions that are necessary to recreate a natural stream channel and floodplain throughout the lower sections of the Creek



RESTORATION FUNDING SOURCES

In response to declining fishery populations Congress passed the Central Valley Project Improvement Act (CVPIA). One of the primary purposes of the CVPIA is to protect, restore and enhance fish, wildlife and associated habitats in the Central Valley and Trinity River Basins of California. CVPIA targets actions necessary to improve salmonid populations in Clear Creek and provided funding to develop plans and conduct environmental evaluations necessary to implement this restoration effort.

The mission of the CALFED Bay-Delta Program, which is providing most of the funding for this project, is to develop a long-term comprehensive plan that will restore ecosystem health and improve water management for beneficial uses on the Bay-Delta system. The Lower Clear Creek Floodway Restoration Project is consistent with the ecological process objectives of the CALFED Bay-Delta Program and, in 1998, the Western Shasta County Resource Conservation District was awarded a CALFED grant to initiate construction actions necessary to restore the lower Clear Creek floodway as described in this conceptual plan.

BLM's Redding Resource Area Office is also funding restoration efforts with in the lower Clear Creek Floodway. BLM funds target acquisition of important parcels in the floodway and restoration of lands degraded by mining activities through creation of additional wetlands.

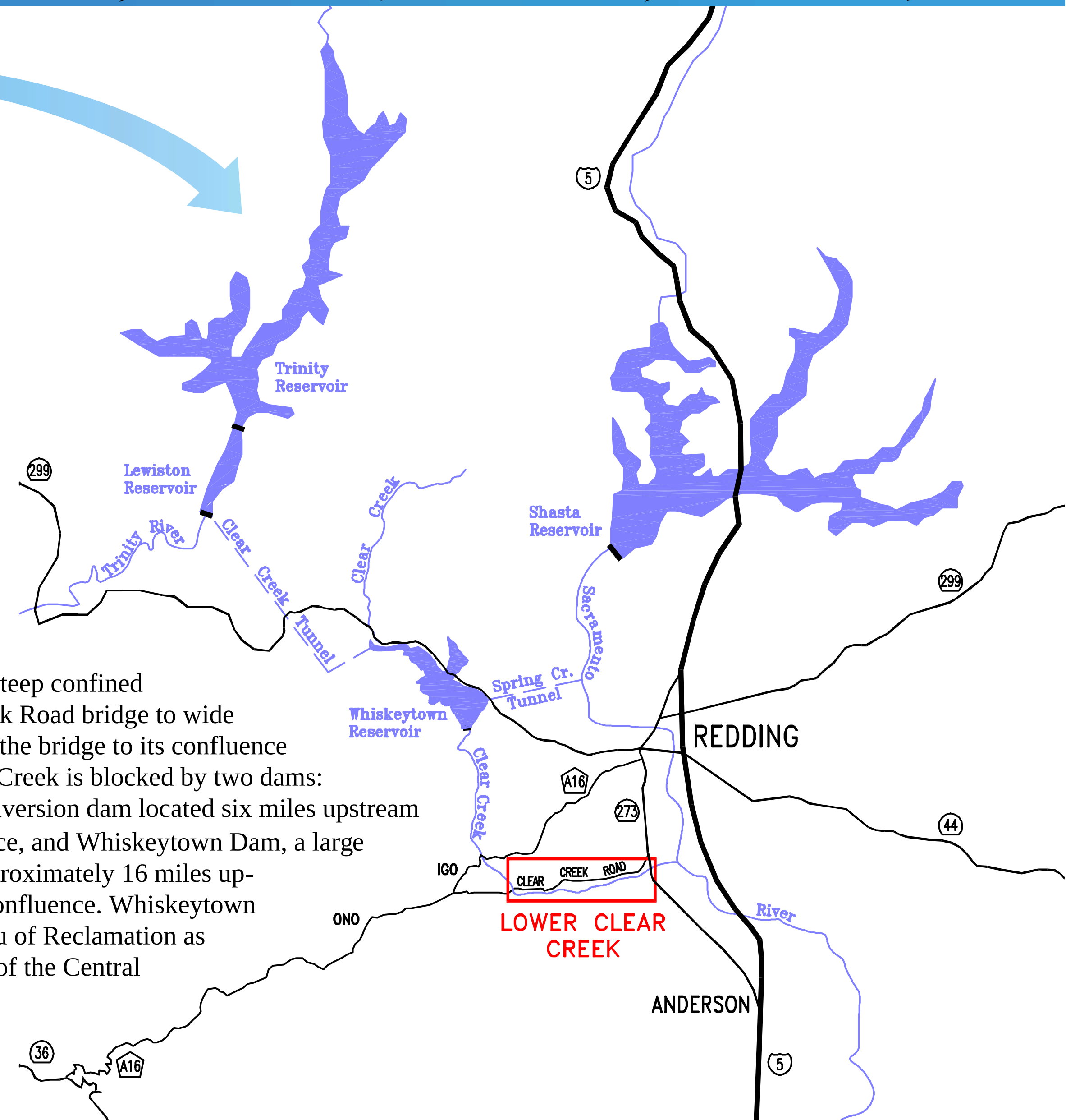
AGENCY AND STAKEHOLDER PARTICIPATION

The Lower Clear Creek Channel Restoration Team is:
Western Shasta Resource Conservation District (WSRCD)
California Department of Fish and Game (CDFG)
California Department of Water Resources (DWR)
U.S. Bureau of Reclamation (USBR)
U.S. Fish and Wildlife Service (USFWS)
Bureau of Land Management (BLM)
Natural Resources Conservation Service (NRCS)
National Park Service (NPS)
Wester Area Power Administration (WAPA)
Northern California Power Administration (NCPA)

Support for the project is also provided by:
Central Valley Water Users Association
Shasta County
Shasta College
Clear Creek Coordinated Resource Management and Planning Group
Horsetown Clear Creek Preserve.

GEOGRAPHY OF CLEAR CREEK

Clear Creek originates on the eastern side of the Trinity Alps and flows south to its eventual confluence with the Sacramento River. Clear Creek channel morphology varies from steep confined bedrock reaches above Clear Creek Road bridge to wide meandering alluvial reaches from the bridge to its confluence with the Sacramento River. Clear Creek is blocked by two dams: Saeltzer Dam, a small irrigation diversion dam located six miles upstream of the Sacramento River confluence, and Whiskeytown Dam, a large storage/diversion dam located approximately 16 miles upstream of the Sacramento River confluence. Whiskeytown Dam is operated by the US Bureau of Reclamation as part of the Trinity River Division of the Central Valley Project, and is responsible for regulating streamflows to lower Clear Creek.



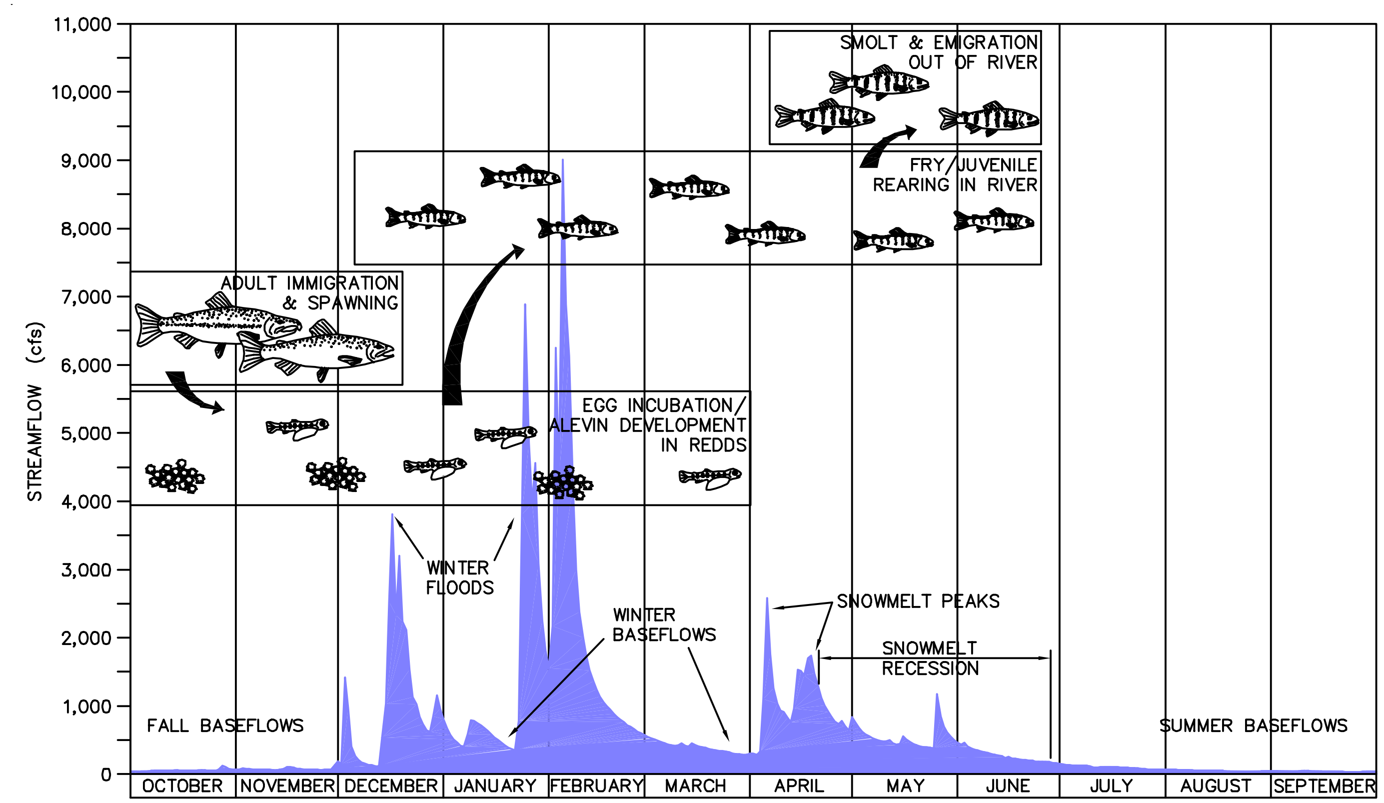
HISTORICAL NATURAL CONDITIONS ON CLEAR CREEK

The lower eight miles of Clear Creek, after it exits the canyon, are predominately alluvial, meaning that the bed and banks of the channel are formed of sand and gravel rather than bedrock. Alluvial channels similar to Clear Creek were historically very dynamic, due in large part to highly variable streamflows. Using pre-Whiskeytown Dam streamflows as an indicator of historic unimpaired flows, some key stream characteristics can be highlighted:

- **Summer baseflows**: Flows in lower Clear Creek were typically less than 50 ft^3/sec, and resulting high water temperatures forced remaining salmonids to seek refuge in colder tributary streams and headwater sections located further up the creek. Most juvenile chinook salmon migrated downstream to the delta and ocean environment in the spring before higher water temperatures and summer low flows occur.

- **Fall/winter floods**: Small to extremely large floods resulting from rainfall or rain-on-snow events provided flows for adult salmonids to migrate into and up Clear Creek. Fall/winter baseflows between storm events provided flows for adult spawning and fry rearing. The moderate and large fall/winter storm events (4,000 to 10,000 ft^3/sec) were responsible for mobilizing gravels, depositing gravels, creating floodplains, and causing the channel to migrate across the valley bottom. During extremely large flood events (10,000 to 30,000 ft^3/sec), the channel often jumped across the valley bottom, usually reshaping the channel and stands of riparian vegetation within the valley walls.

- **Snowmelt peak**: Because most of the Clear Creek watershed is below the typical snowline elevation (4,000 ft), snowmelt peaks were less than 2,000 ft^3/sec. These flows provided adequate flows and water temperatures for juvenile salmonid rearing habitat. Juvenile outmigration to the ocean also coincided with snowmelt runoff in Clear Creek and the Sacramento River.

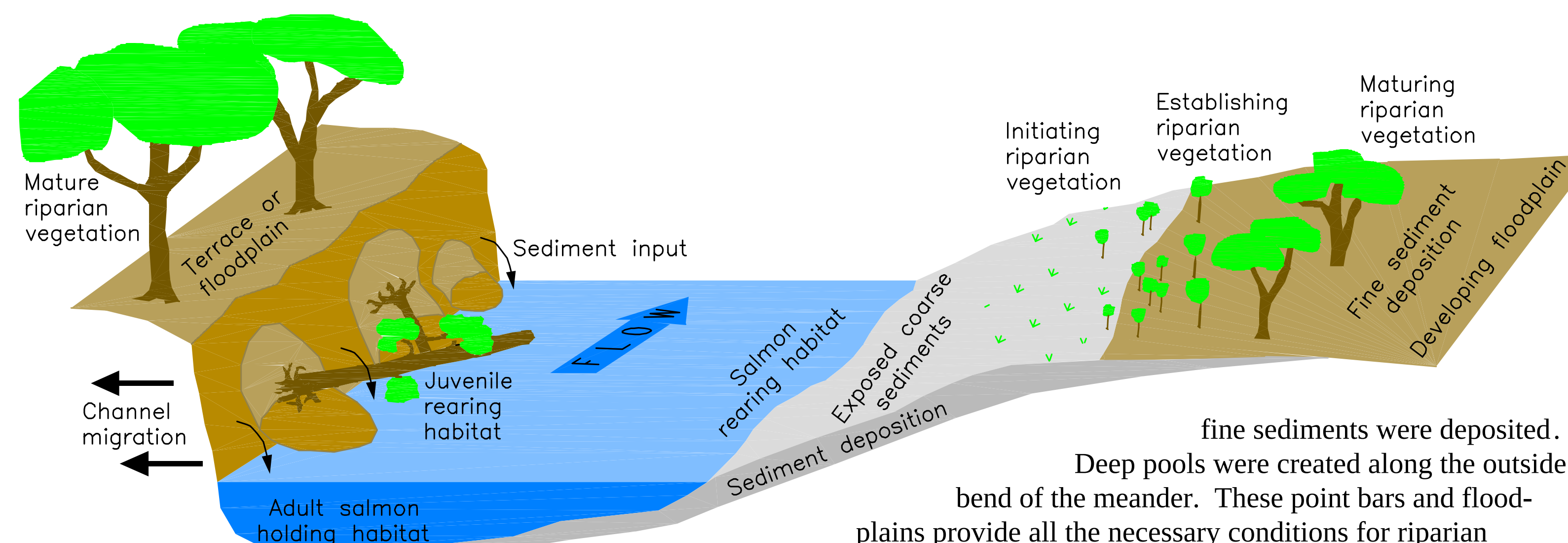


IMPORTANCE OF CLEAR CREEK TO SALMON AND STEELHEAD TROUT

Clear Creek is the first large tributary downstream of Shasta Dam, making it an important stream for salmon and steelhead production. Historically, several distinct runs of chinook salmon and steelhead trout inhabited Clear Creek. These species are anadromous, meaning they spawn in fresh water, migrate to the sea as juveniles, grow large and mature at sea before returning to their natal streams to spawn. Chinook salmon typically spawn in the fall, depositing eggs in gravel substrates in run and riffle habitats. The female digs a pit (redd) in the gravel, and as she deposits her eggs, the male fertilizes them. The eggs incubate and develop into fry under the gravel, and emerge in the late winter and spring. Young salmon rear in slow edgewater and backwater habitats during the spring, then migrate downstream with snow melt runoff to the sea in late spring. Steelhead differ from chinook salmon in that they typically spawn in winter and spring and young steelhead spend between one to four years rearing in freshwater before migrating downstream to the sea usually in the early spring. The proposed channel restoration project described in this summary acknowledges the importance of these natural environmental conditions to salmonid production and incorporates these conditions into restoration efforts.

RIPARIAN WILDLIFE COMMUNITIES

Restoration of functional, frequently flooded riparian habitats along lower Clear Creek will provide a greater diversity of riparian habitat types and stages. Conversion of marginal upland habitats that are currently dominated by tailing piles to large diverse wetland habitats will greatly enhance wildlife habitat values. Increased habitat diversity will in turn provide additional micro-habitats that are used by many wildlife species for all, or portions of their life stages.



Winter storms were very important for creating and maintaining a healthy Clear Creek floodway. These flows transported sediments (cobbles, gravel, sand, silts) from the upper watershed downstream, much of which was deposited in the valley reaches downstream of Clear Creek Road bridge. This pattern of sediment transport and deposition created alternating bars and floodplains. The creation of gravel and cobble bars forced the creek channel to meander back and forth across the valley floor. During high flows the creek eroded banks on the outside bends of the meander and deposited sediments on the inside curve of the creek forming bars. Over time these point bars slowly evolved into floodplains as fine sediments were deposited. Deep pools were created along the outside bend of the meander. These point bars and floodplains provide all the necessary conditions for riparian vegetation to germinate and grow. Periodic high flows would scour and kill some patches of riparian vegetation, while enhancing others by placing new soil deposits along the floodplain. This pattern of damage and regrowth resulted in diverse stands of riparian vegetation, and created a wide range of terrestrial and aquatic habitats important for native fish and wildlife species.

In short, the natural pattern of high flows, low flows, and sediment supply combined to create a dynamic and diverse lower Clear Creek floodway, which in turn supported substantial populations of salmon, steelhead and other native wildlife species. Human induced changes to Clear Creek, beginning in 1848 with the discovery of gold at Reading Bar, initiated substantial changes to the floodway, leading to our present need to restore degraded reaches.

HISTORIC USE IMPACTS

Recalling that the interaction of streamflows and sediment create and maintain a healthy Clear Creek floodway, any changes to the balance of streamflow and sediment induce a change to the floodway, and many of the native species that inhabit it. Some of the more important changes are described below.

1848 Gold Discovery

Gold was discovered along the banks of Clear Creek in 1848, and was the first of many actions that lead to the decline of salmon and steelhead populations. Placer mining altered the stream channel and increased erosion of sediments into the channel degrading salmon and steelhead habitats. Once placer miners exhausted surface gold deposits, several hydraulic cannons were brought into the watershed to gain access to subsurface gold deposits along the stream banks and hillsides. The devastation caused on by these hydraulic cannons on the landscape prompted passage of California's Anti-Debris Act in 1883 outlawing the use of hydraulic cannons.

Large Dredging in the Early 1900's

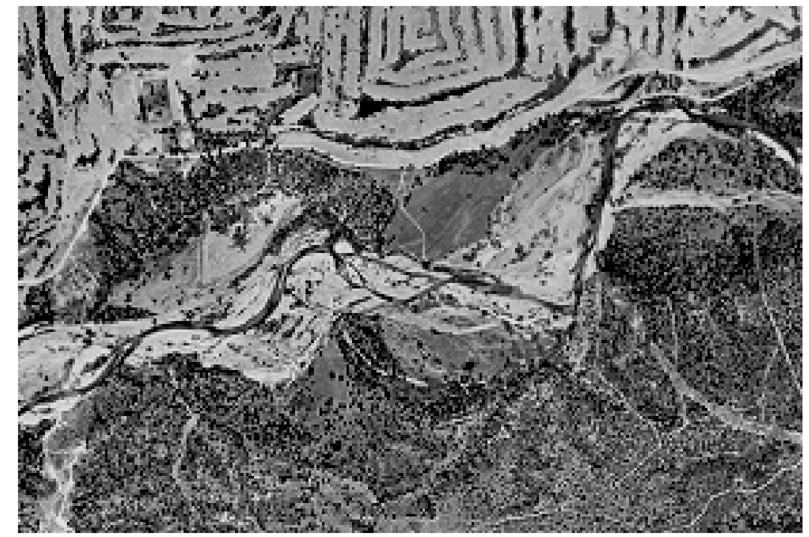
Large floating dredges began working the lower reaches of the creek channel and tributary streams during the early years of the twentieth century. Operation of these dredges throughout the lower reaches of the creek caused massive alterations to the natural morphology of the stream channel and ecosystem further degrading salmon and steelhead habitats.

Saeltzer Dam, 1903 to Present

Saeltzer Dam was first constructed in 1903 by the Townsend Flat Water Ditch Company to provide water for agriculture, livestock, and land development businesses in the area. The dam, located about 6 miles upstream of the Sacramento River creates a migration barrier for salmon and steelhead eliminating access to valuable spawning and rearing habitat. Several attempts have been made to provide fish passage over the dam without success. In response, both the Central Valley Project Improvement Act and the CALFED Bay-Delta Program have recognized the need to remedy the fish passage problem and efforts are underway to provide a fish friendly solution.

Gravel Extraction, 1950s through 1978

Gravel extraction operations began removing tailing piles and gravel accumulations within the lower Clear Creek floodway during the 1950's. Removal of large quantities of alluvial material (gravel, cobble and sand) has seriously degraded the natural functioning condition of the stream channel and floodplain. The combination of sediment reduction from upstream dams and instream gravel extraction has lowered the elevation of the creek to the point where much of the channel bottom rests on clay hardpan or bedrock. Gravel extraction also removed floodplains, created braided channels, and left several large open pits within the channel and floodway. Fry and juvenile salmon become trapped in these open off channel pits during periods of fluctuating flow which are common during the late winter and spring rearing period. The conversion of the bed from gravel to clay hardpan also reduced the quality and area of spawning and food producing habitats within the stream channel. The area most impacted by these activities is located three miles downstream of Saeltzer Dam and the intent of this restoration project is to remedy the impacts of gravel extraction. Moreover, this restoration project is designed to remediate many of the other human land-use impacts.



Project Site 1952

Project Site 1980

Whiskeytown Unit of the Trinity River Division, 1963 to Present

The Trinity River Division (TRD) of the Central Valley Project was authorized in 1955 to increase water supplies available for irrigation and other beneficial uses in the Central Valley. Whiskeytown Dam serves to capture Clear Creek flows and water diversions from the Trinity River through the Clear Creek Tunnel. Inflows to Whiskeytown Dam are diverted to the Sacramento River at Keswick Dam through the Spring Creek Tunnel. Regulated flow releases combined with the elimination of sediment sources upstream further impacted available fishery habitat in lower Clear Creek by altering the natural fluvial processes that are critical to maintaining favorable habitat conditions. In recent years the Bureau of Reclamation, working cooperatively with the U.S. Fish and Wildlife Service, National Marine Fisheries Service and California Department of Fish and Game, has provided additional flow releases to improve habitat conditions for salmon and steelhead.

LOWER CLEAR CREEK FLOODWAY RESTORATION

PROJECT OBJECTIVES

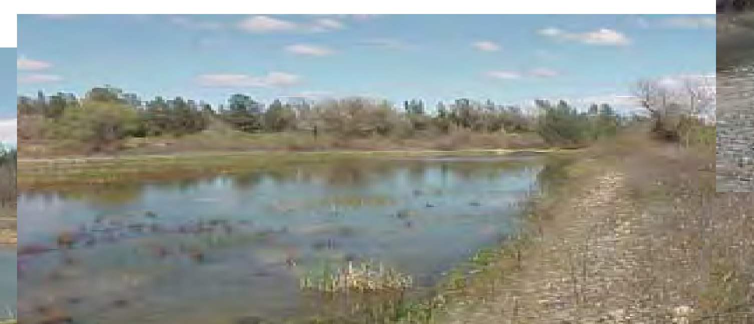
The goal of the Lower Clear Creek Floodway Restoration Project is to restore floodway function and morphology to two reaches of stream that have been severely degraded by gravel extraction and gold dredger mining. At the gravel extraction site (Project site), this will be accomplished by filling old mining pits, whereas at the gold dredger mining sites (Borrow sites) this will be accomplished by removing dredger tailings for use at the Project site. At both sites, these activities will restore a properly sized bankfull channel, reconstruct functional floodplains, increase gravel supply, plant native riparian vegetation, and construct floodplain surfaces to encourage natural riparian regeneration. Because both sites are on public lands, this project will accomplish the restoration goal and reduce project costs by restoring two sites for the price of one. These borrow areas also provide opportunities to restore other floodplain surfaces and enhance upland habitats through creation of new wetlands. Our specific objectives for restoration are:

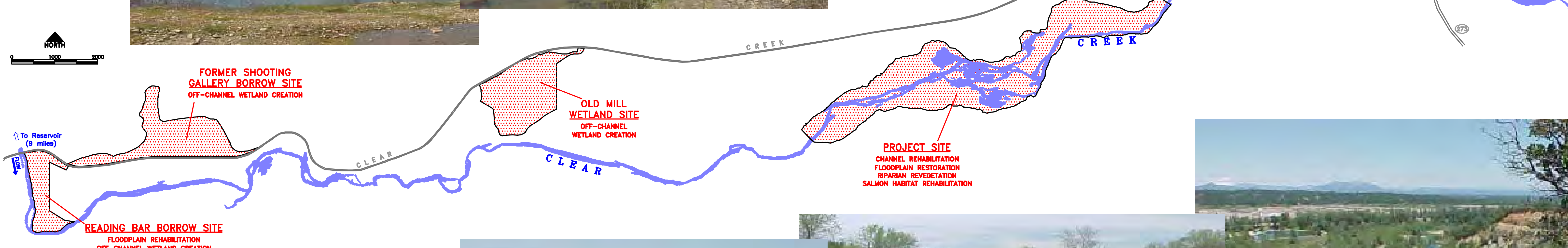
- ***Reverse channel damage caused by historic gravel extraction at the Project site by reconstructing a properly sized bankfull channel and floodplain.***
- ***Restore the ability of the channel to route coarse sediment downstream and deposit fine sediment on floodplain surfaces.***
- ***Restore native riparian vegetation on floodplain surfaces by focusing on species that provide a diverse canopy structure and removing competing exotic plant species.***
- ***Reduce salmonid stranding and mortality in floodplain gravel mining pits.***
- ***Provide improved habitat conditions for native fish and wildlife including priority salmonid species of central concern to CALFED and CVPIA restoration programs.***
- ***Create diverse off channel wetland habitats in marginal upland habitats that are currently degraded by dredger tailings and in other uplands locations as opportunities arise.***

ECOSYSTEM RESTORATION VISION

River ecosystem health is dependent to a large degree on the physical processes that occur within the watershed. In aquatic systems, fish and wildlife species are even more dependent on the physical condition of their environment for survival, growth and reproduction. Native fish, wildlife, and plant species have evolved over the millennia to best survive under those natural physical conditions. Restoration of the lower Clear Creek floodway is based on the premise that salmon and trout habitat is best restored and maintained by recreating those natural conditions, flow and sediment transport, within the current physical and operational constraints that exist within Clear Creek today. Given these conceptual ideas the Lower Clear Creek Channel Restoration Team developed the following vision statement to guide development of future restoration actions within lower Clear Creek:

Utilize an integrated approach to re-establish critical ecological functions, processes, and characteristics, within contemporary regulated flow and sediment conditions, that best promote recovery and maintenance of resilient wild salmon populations and the river's natural animal and plant communities.





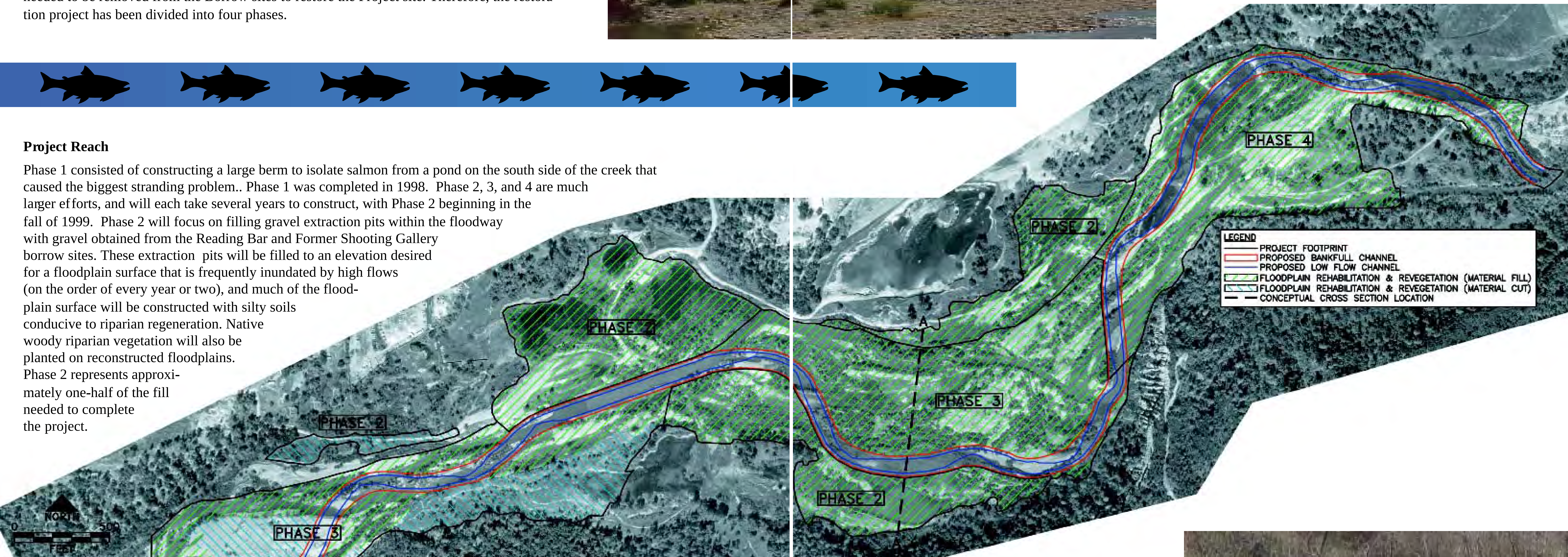
MAJOR PROJECT FEATURES

Extensive gravel mining at the Project site left a series of pits and reaches of channel with exposed clay hardpan, and in some locations, diverted the channel from its natural location into artificial bypass channels. Destruction of a defined channel resulted in many multi-channeled reaches that caused significant stranding mortality to both adult and juvenile salmon. Restoring this site requires that much of the gravel removed during mining activities be replaced to redefine a primary channel and floodplain. The scale of restoring these sites is largely due to the extensive volume of gravel removed from the Project site, and the large volume of gravel needed to be removed from the Borrow sites to restore the Project site. Therefore, the restoration project has been divided into four phases.

Phase 4 will restore Clear Creek to its pre-gravel mining location in the downstream end of the project site. Presently, Clear Creek flows through an artificially constructed bypass channel through clay and bedrock, bisecting its natural meandering channel. In addition to moving the channel back to its historic location, floodplains will be reconstructed, and native woody riparian vegetation will be replanted.

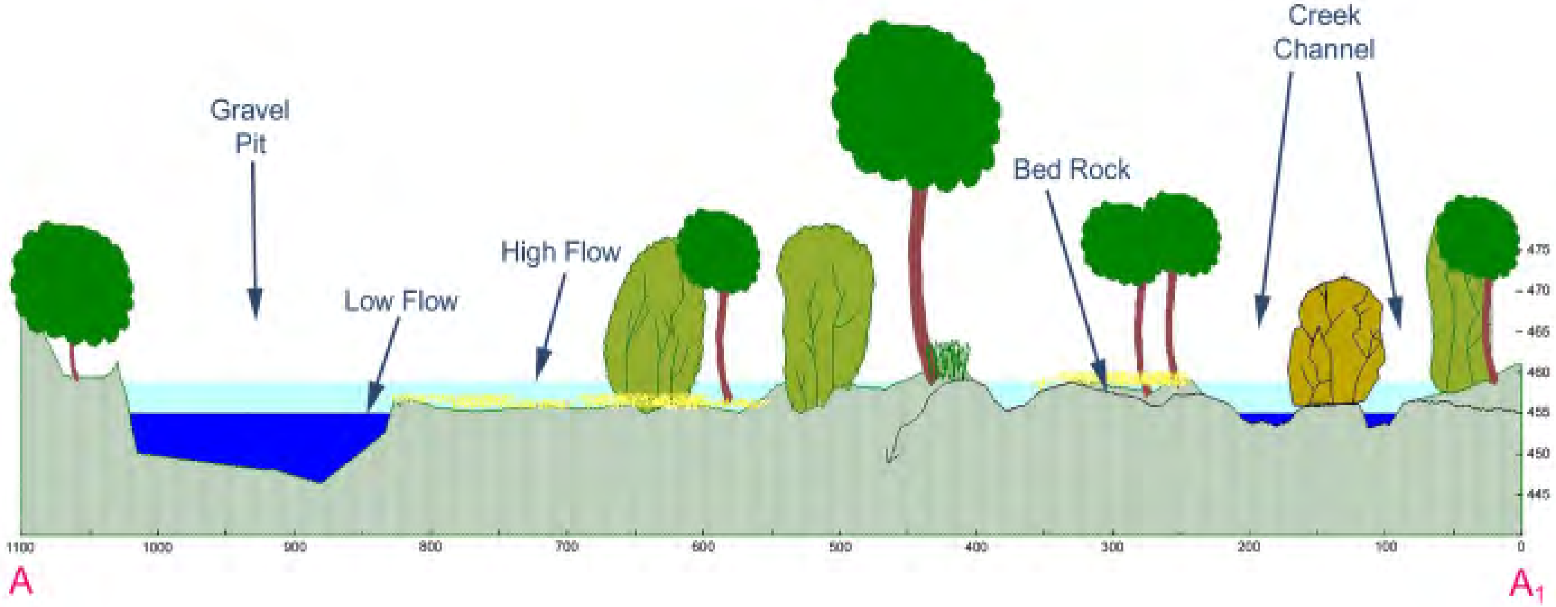
Project Reach

Phase 1 consisted of constructing a large berm to isolate salmon from a pond on the south side of the creek that caused the biggest stranding problem.. Phase 1 was completed in 1998. Phase 2, 3, and 4 are much larger efforts, and will each take several years to construct, with Phase 2 beginning in the fall of 1999. Phase 2 will focus on filling gravel extraction pits within the floodway with gravel obtained from the Reading Bar and Former Shooting Gallery borrow sites. These extraction pits will be filled to an elevation desired for a floodplain surface that is frequently inundated by high flows (on the order of every year or two), and much of the floodplain surface will be constructed with silty soils conducive to riparian regeneration. Native woody riparian vegetation will also be planted on reconstructed floodplains. Phase 2 represents approximately one-half of the fill needed to complete the project.



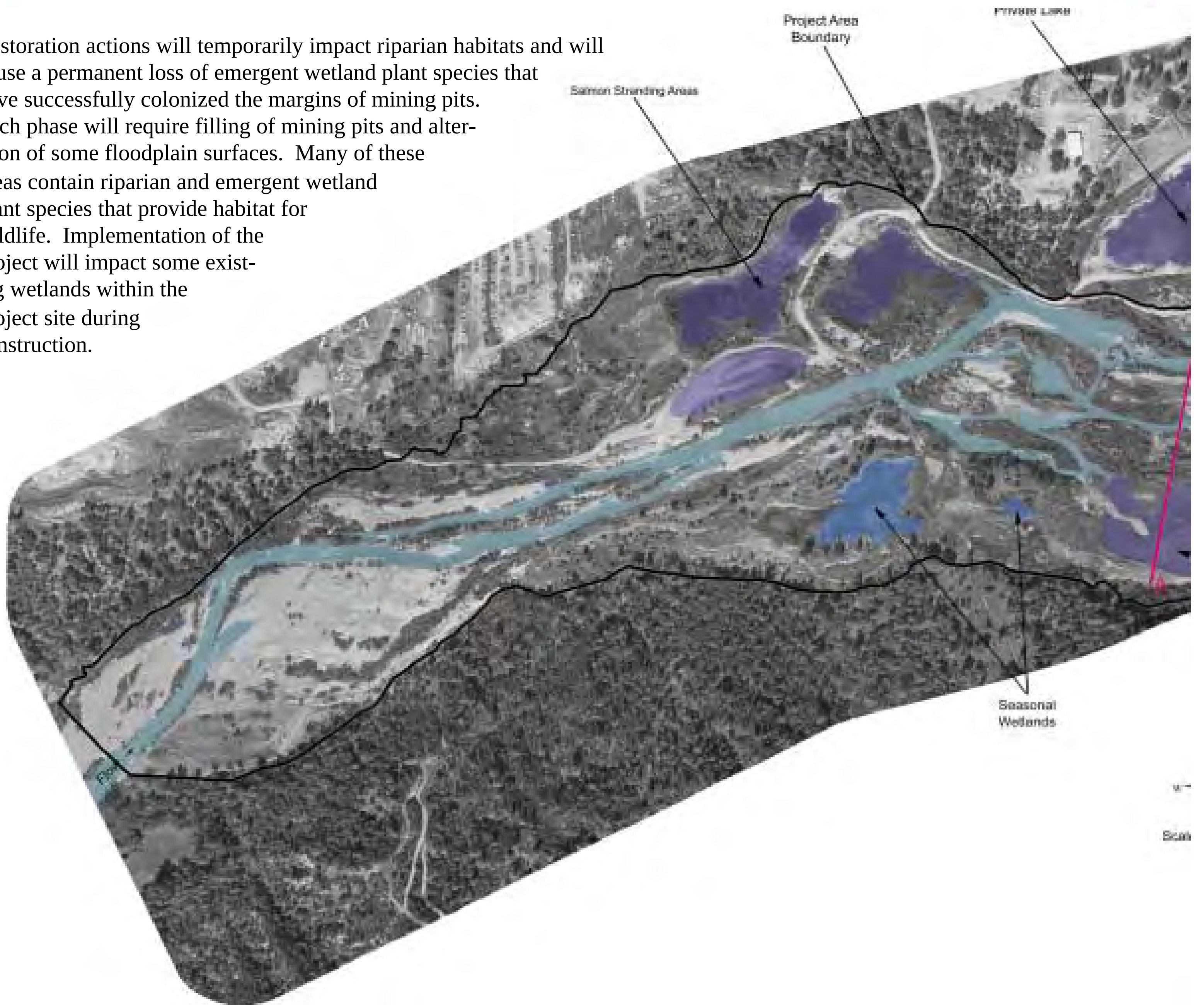
Phase 3 will focus on redefining a primary channel through the upper two-thirds of the reach, as well as recreating floodplain surfaces and riparian revegetation. A critical component of Phase 3 requires moving the new channel away from bedrock areas, and raising it's bed above bedrock surfaces by adding gravels and cobbles. Converting the channel from a predominately bedrock bottomed stream back to a gravel and cobble bedded stream will allow the channel to create bars and move across the floodway By adding gravel and cobbles back to the channel, most of the instream habitat (salmon spawning and rearing habitat) will be created during Phase 3 of the project. Most of Phase 3 will recreate a meandering channel with a series of pools and riffles, and these meanders are intended to move and readjust during high flows.

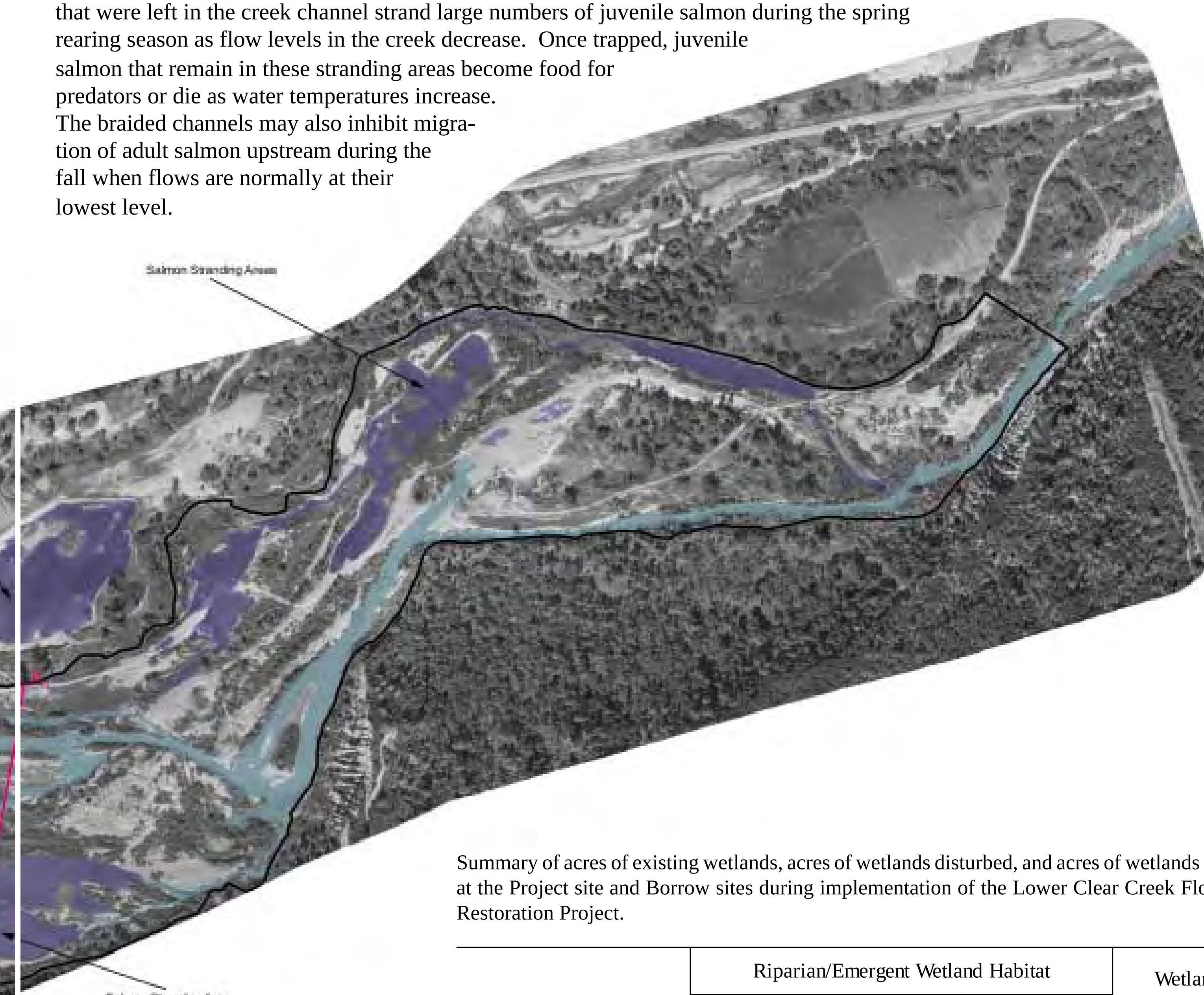
EXISTING CONDITIONS AT THE PROJECT SITE



Years of gravel extraction within the Project Reach have removed vast quantities of alluvial gravel deposits that are critical to maintaining healthy habitat for salmon and steelhead. Riffle habitats that once contained abundant spawning gravels have been replaced by clay and bedrock surfaces that are unsuitable for spawning. Remnant gravel mining pits that were left in the creek channel strand large numbers of juvenile salmon during the spring rearing season as flow levels in the creek decrease. Once trapped, juvenile salmon that remain in these stranding areas become food for predators or die as water temperatures increase. The braided channels may also inhibit migration of adult salmon upstream during the fall when flows are normally at their lowest level.

Restoration actions will temporarily impact riparian habitats and will cause a permanent loss of emergent wetland plant species that have successfully colonized the margins of mining pits. Each phase will require filling of mining pits and alteration of some floodplain surfaces. Many of these areas contain riparian and emergent wetland plant species that provide habitat for wildlife. Implementation of the project will impact some existing wetlands within the project site during construction.





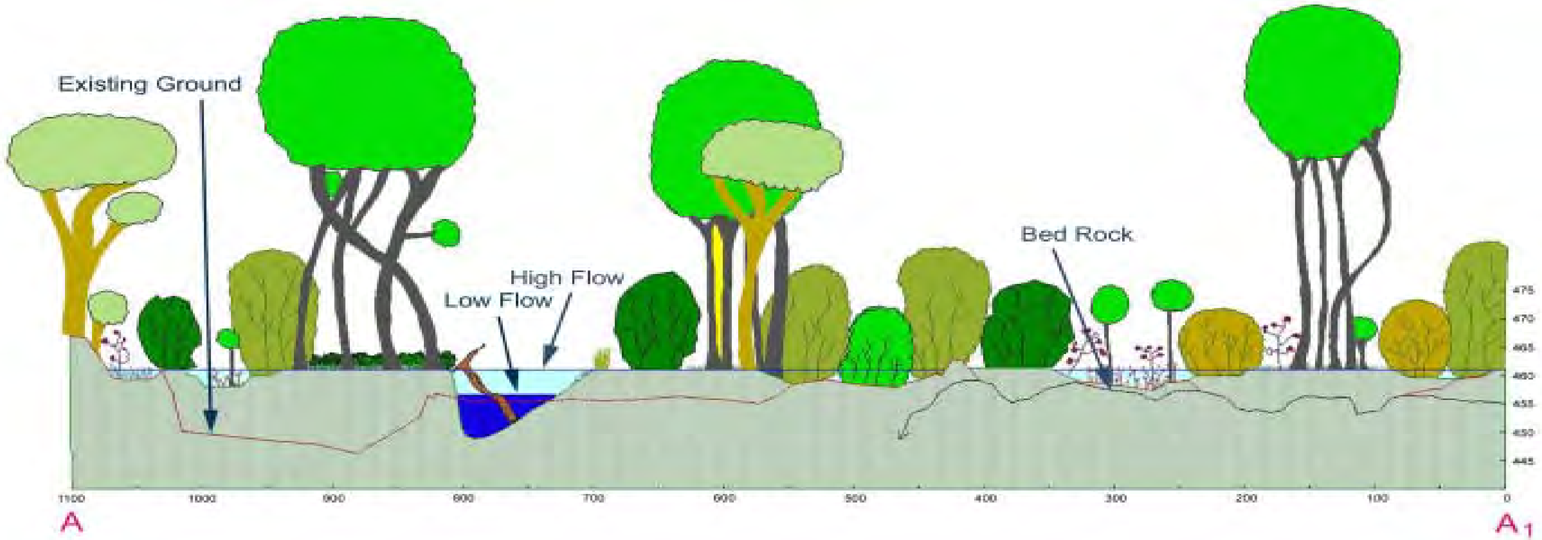
Summary of acres of existing wetlands, acres of wetlands disturbed, and acres of wetlands created at the Project site and Borrow sites during implementation of the Lower Clear Creek Floodway Restoration Project.

Location	Riparian/Emergent Wetland Habitat			Wetland Increase (acres)
	Existing (acres)	Disturb (acres)	Created (acres)	
Project Site (Phase 2-4)	88.6	52.2	77.2	25.0
Borrow Sites				
Reading Bar	4.3	0.9	7.9	7.0
Former Shooting Gallery	6.8	4.4	13.6	9.2
Old Mill[1]	6.9	5.0	32.4	27.4
Total	106.6	59.1	125.7	65.6

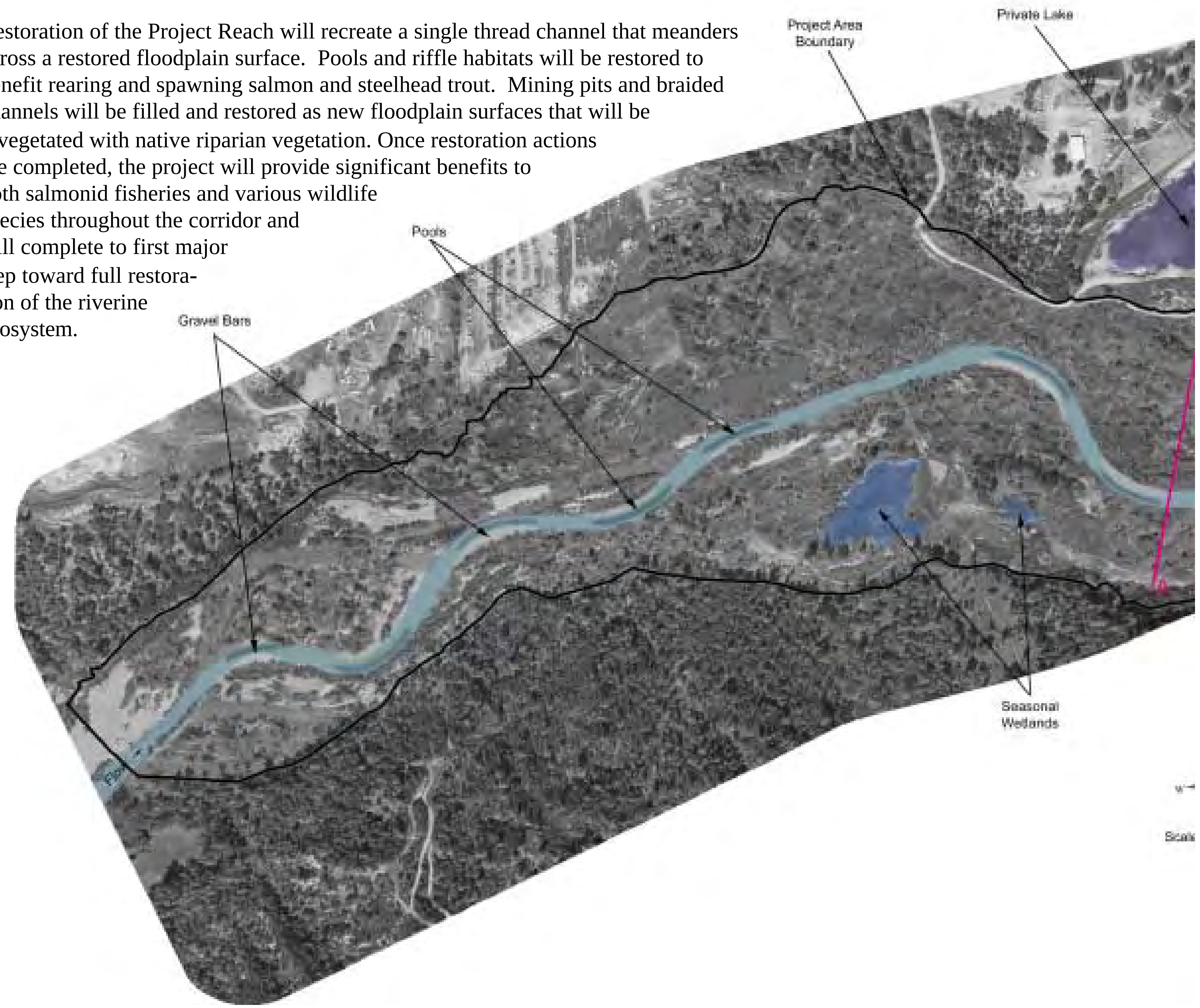
[1] Wetland estimates include 6 acres Phase 1 mitigation and Abandoned Mines Restoration effort by BLM.

The project will create additional riparian wetlands on newly created floodplains in the project site and will create additional riparian and emergent wetlands in each of the three borrow sites upstream. Vegetation communities to be restored include Arroyo willow, black willow, mixed willow, white alder, Fremont cottonwood, bulrush, buttonbush, elderberry, mulefat, and sedges. Planting various vegetation communities will insure creation of diverse wildlife habitats and will restore floodplain surfaces to historic conditions.

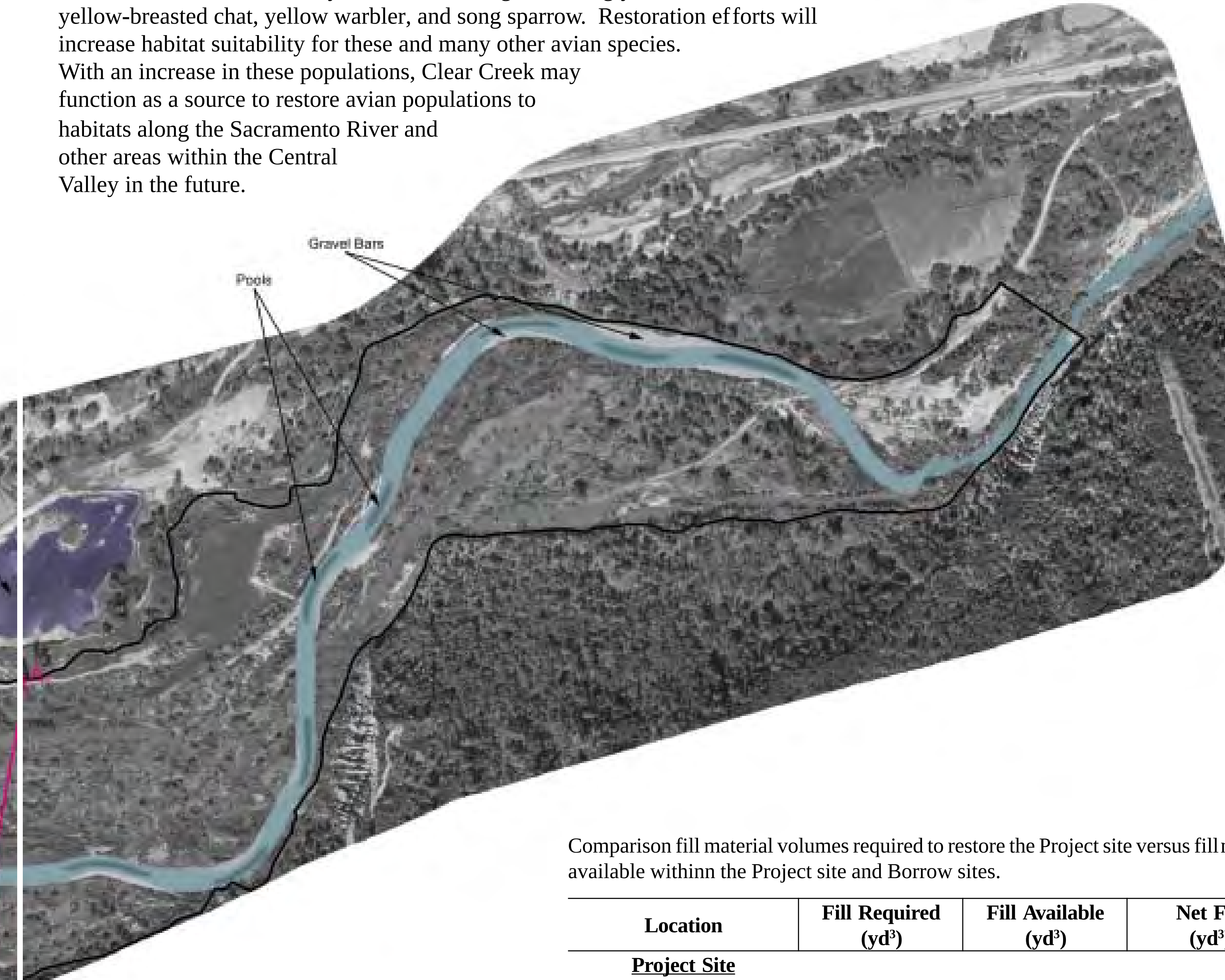
RESTORED CONDITIONS AT THE PROJECT SITE



Restoration of the Project Reach will recreate a single thread channel that meanders across a restored floodplain surface. Pools and riffle habitats will be restored to benefit rearing and spawning salmon and steelhead trout. Mining pits and braided channels will be filled and restored as new floodplain surfaces that will be revegetated with native riparian vegetation. Once restoration actions are completed, the project will provide significant benefits to both salmonid fisheries and various wildlife species throughout the corridor and will complete to first major step toward full restoration of the riverine ecosystem.



Clear Creek currently supports breeding populations of several migratory bird species that were once common in the Central Valley, but are becoming increasingly rare. These include the yellow-breasted chat, yellow warbler, and song sparrow. Restoration efforts will increase habitat suitability for these and many other avian species. With an increase in these populations, Clear Creek may function as a source to restore avian populations to habitats along the Sacramento River and other areas within the Central Valley in the future.



Comparison fill material volumes required to restore the Project site versus fill material available withinn the Project site and Borrow sites.

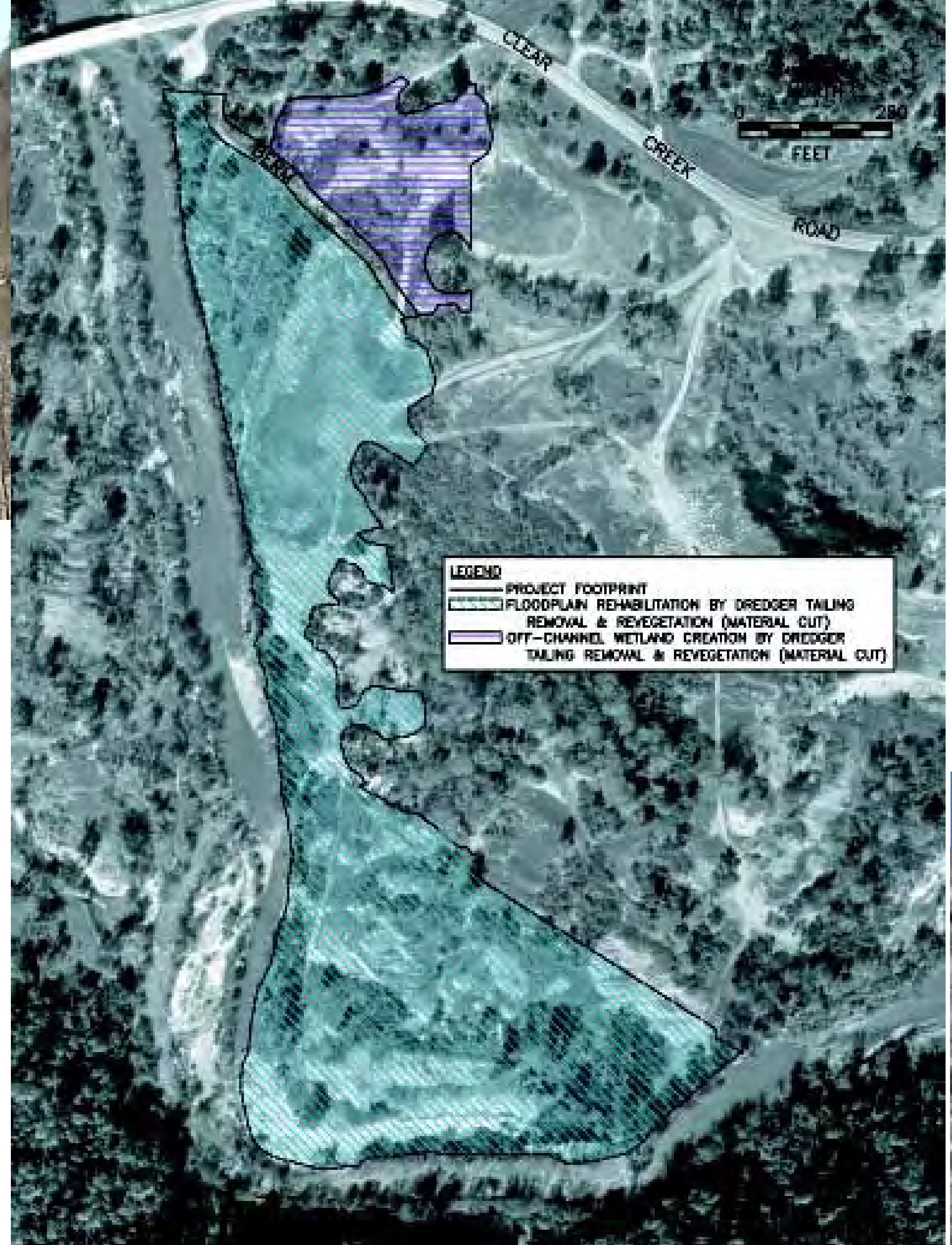
Location	Fill Required (yd^3)	Fill Available (yd^3)	Net Fill (yd^3)
Project Site			
Phase 2	173,000	25,000	148,000
Phase 3	242,051	132,095	110,000
Phase 4	156,000	41,000	114,000
Subtotal	571,000	198,000	372,000
Borrow Sites			
Reading Bar		120,000	252,000
Former Shooting Gallery		310,000	(58,000)
Old Mill[1]			
Subtotal		430,000	
Total Surplus			+58,000

[1] Materials from Old Mill site are not required for phase 2-4 implementation

Construction of the project will require movement of large volumes of material (dredger tailing and existing floodplain surfaces) to fill pits and create a new stream channel and floodplain surfaces. Construction of the entire project will require approximately 571,000 yd^3. Approximately 198,000 yd^3 of material is available within the project site in historic flood terraces and 430,000 yd^3 of material are available at the Reading Bar and Former Shooting Gallery Borrow Sites leaving a surplus of approximately 58,000 yd^3 of material.

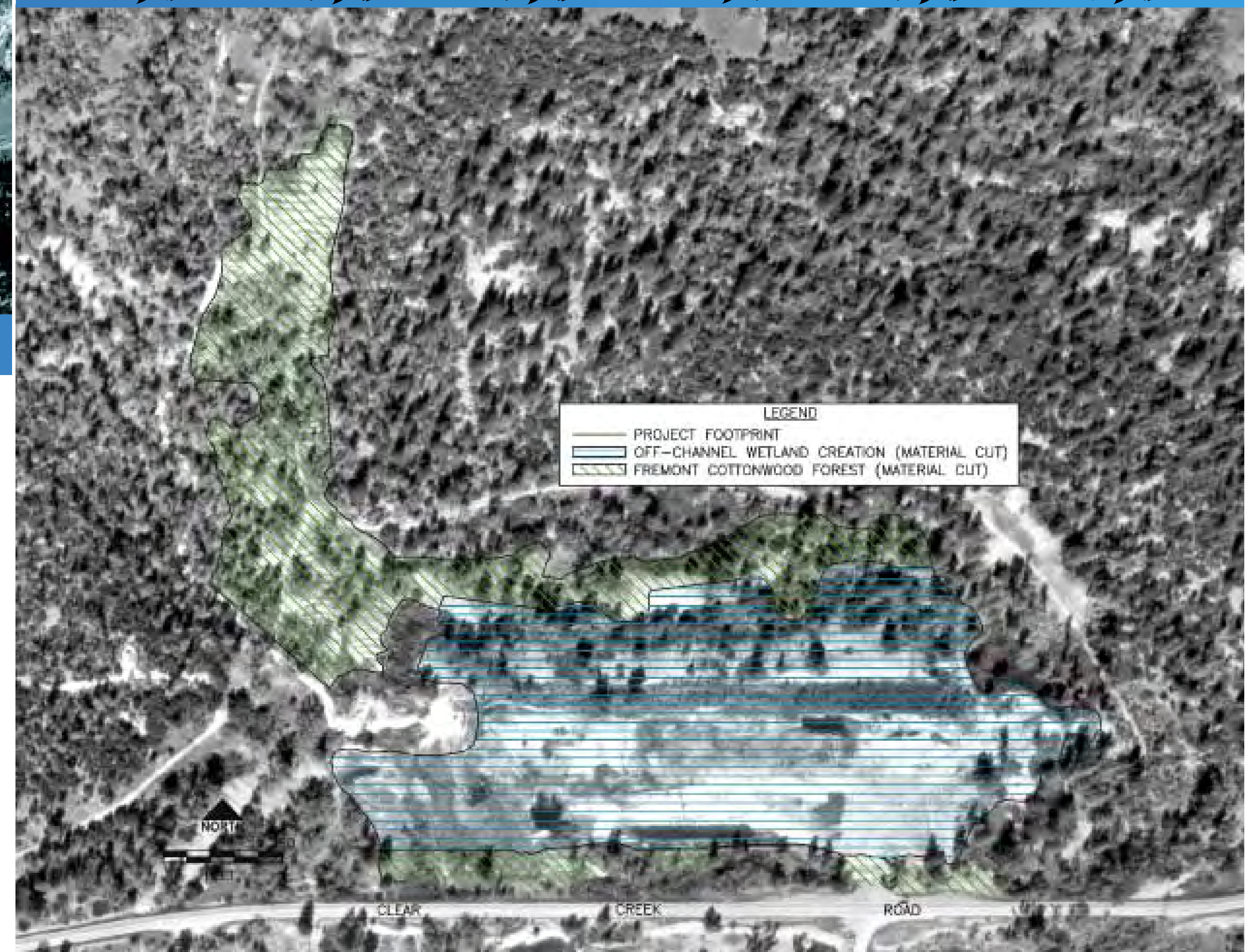
Borrow Sites

Constructing Phase 2-4 will require large volumes of cobble and gravel. Two sites with extensive dredger tailings on public land have been identified as the best sources of cobbles and gravels: Reading Bar and the Former Shooting Gallery. A third site, Old Mill, was identified as a good location to create and enhance upland habitats through creation of off channel wetlands. These sites are all within a few miles of the Project site, and using these borrow sites will provide economical sources of gravel and cobbles. Fill material will be obtained by excavating dredger tailings. Because the Reading Bar site is adjacent to Clear Creek, dredger tailings will be removed to an elevation that creates a new floodplain surface over most of the site, and off-channel wetlands will be created further away from the channel.



The Former Shooting Gallery is isolated from Clear Creek, thus dredger tailings and surface fill material at these sites will be excavated to create off-channel wetlands. Off-channel wetlands will be designed and constructed to provide a diversity of habitat types which include shallow fresh water emergent vegetation, wet meadows, woody riparian communities and open water areas.

The Old Mill Site provides a good location for creation of additional wetland habitats and six acres of riparian emergent wetlands will be created on this site as mitigation for wetland losses incurred at the Project Site during implementation of Phase 1 in 1998. The Bureau of Land Management has also selected this site for creation of up to an additional 20 acres of wetlands using funds obtained through their Abandoned Mines Restoration Program.

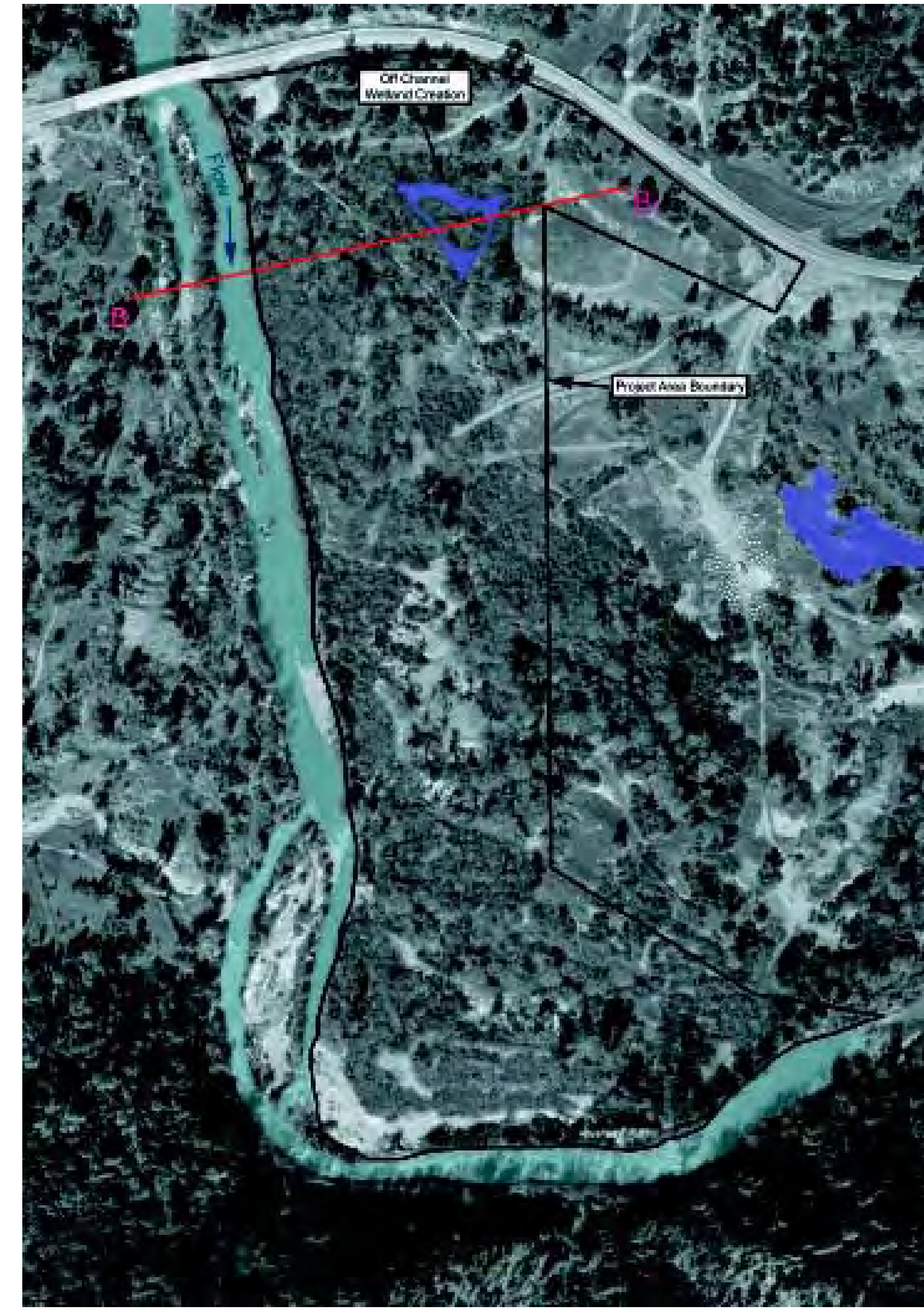


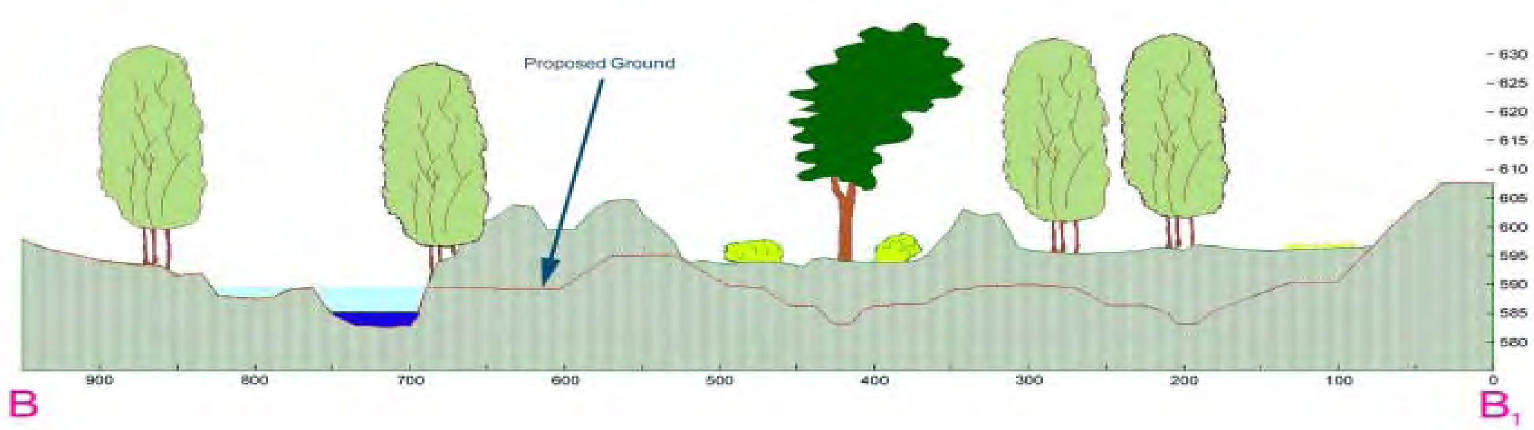
EXISTING CONDITIONS AT THE READING BAR SITE

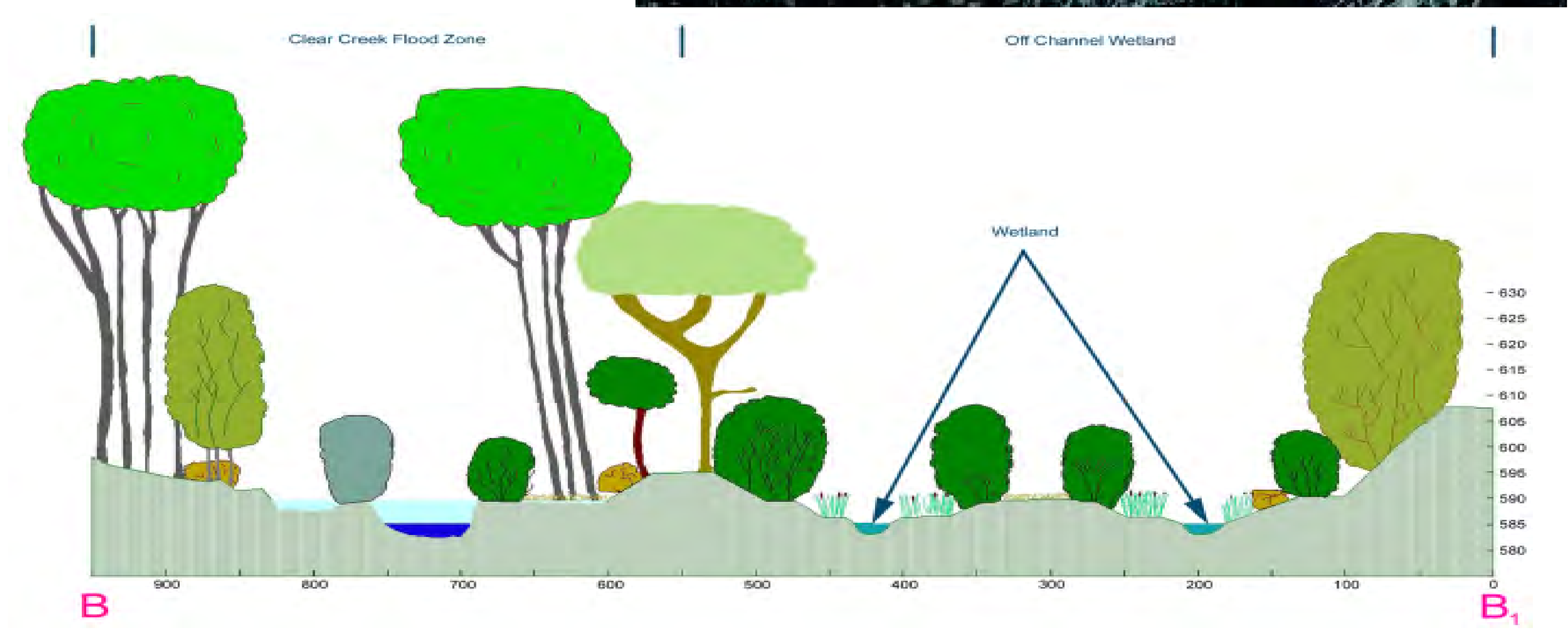
RESTORED CONDITIONS AT THE READING BAR SITE

The Reading Bar Site has been altered by both gold miners and gravel mining operators and provides a good source of borrow material needed for restoration of the Project Site downstream. Because the Reading Bar site is adjacent to Clear Creek, dredger tailings will be removed to an elevation that creates a new floodplain surface over most of the site.

Off-channel wetlands will be created further away from the channel in an area that currently provides little wildlife habitat value. Restored floodplain surfaces and off-channel wetlands will be revegetated with native riparian and wetland species which will provide greater benefits to wildlife species. By integrating the removal of borrow materials with restoration actions, the project will reduce costs and accomplish restoration goals at the Borrow Sites and Project Site simultaneously.







CONCEPTUAL PLAN FOR RESTORATION OF THE LOWER CLEAR CREEK FLOODWAY

PREPARED FOR:
THE LOWER CLEAR CREEK TECHNICAL WORK GROUP

PREPARED BY:

McBain & Trush

McBain & Trush
P.O. Box 663
Arcata, CA 95518
(707) 826-7794

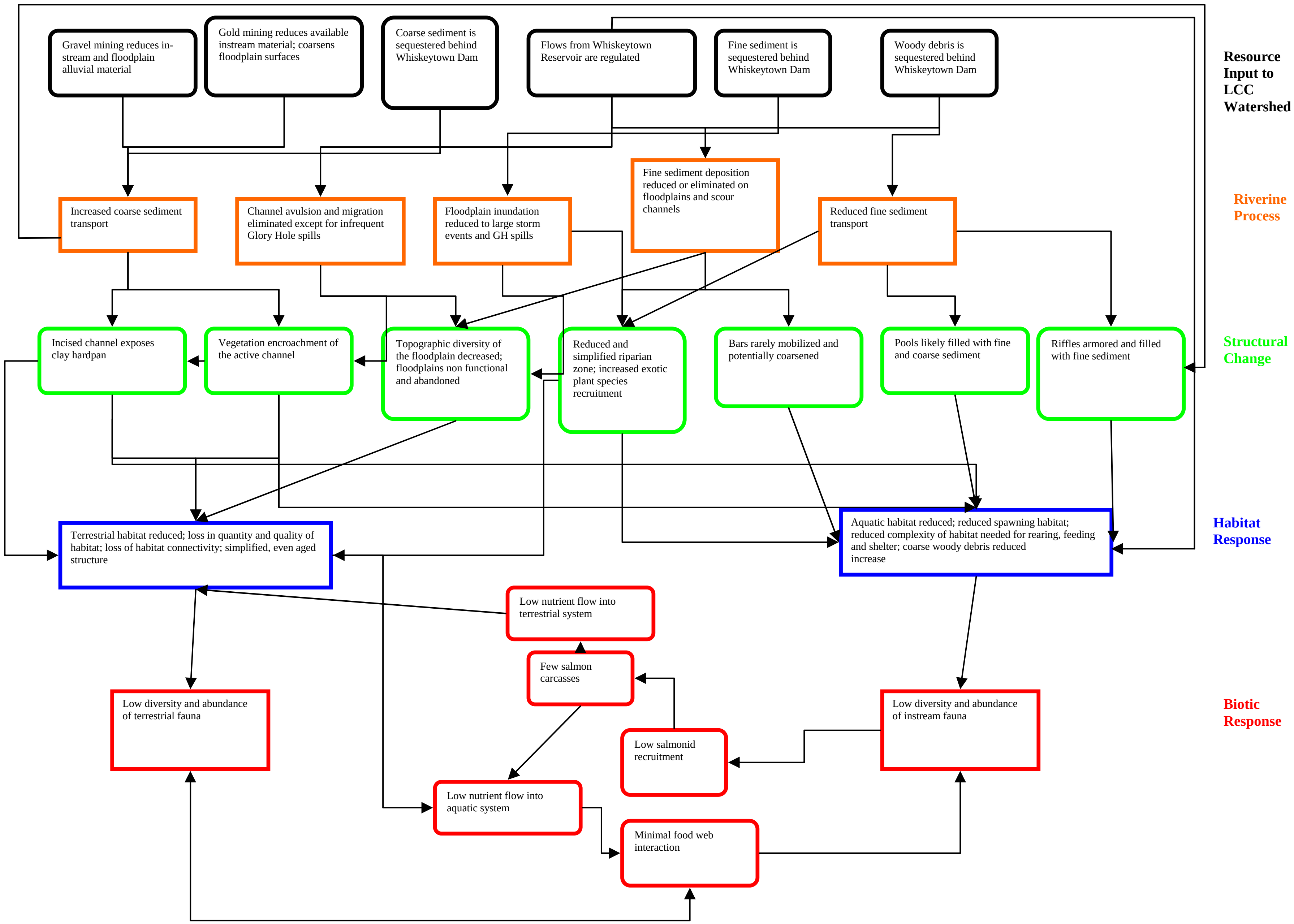
North State Resources

Northstate Reources
5000 Bechelli, Suite 203
Redding, CA 96002
(530) 222-5347

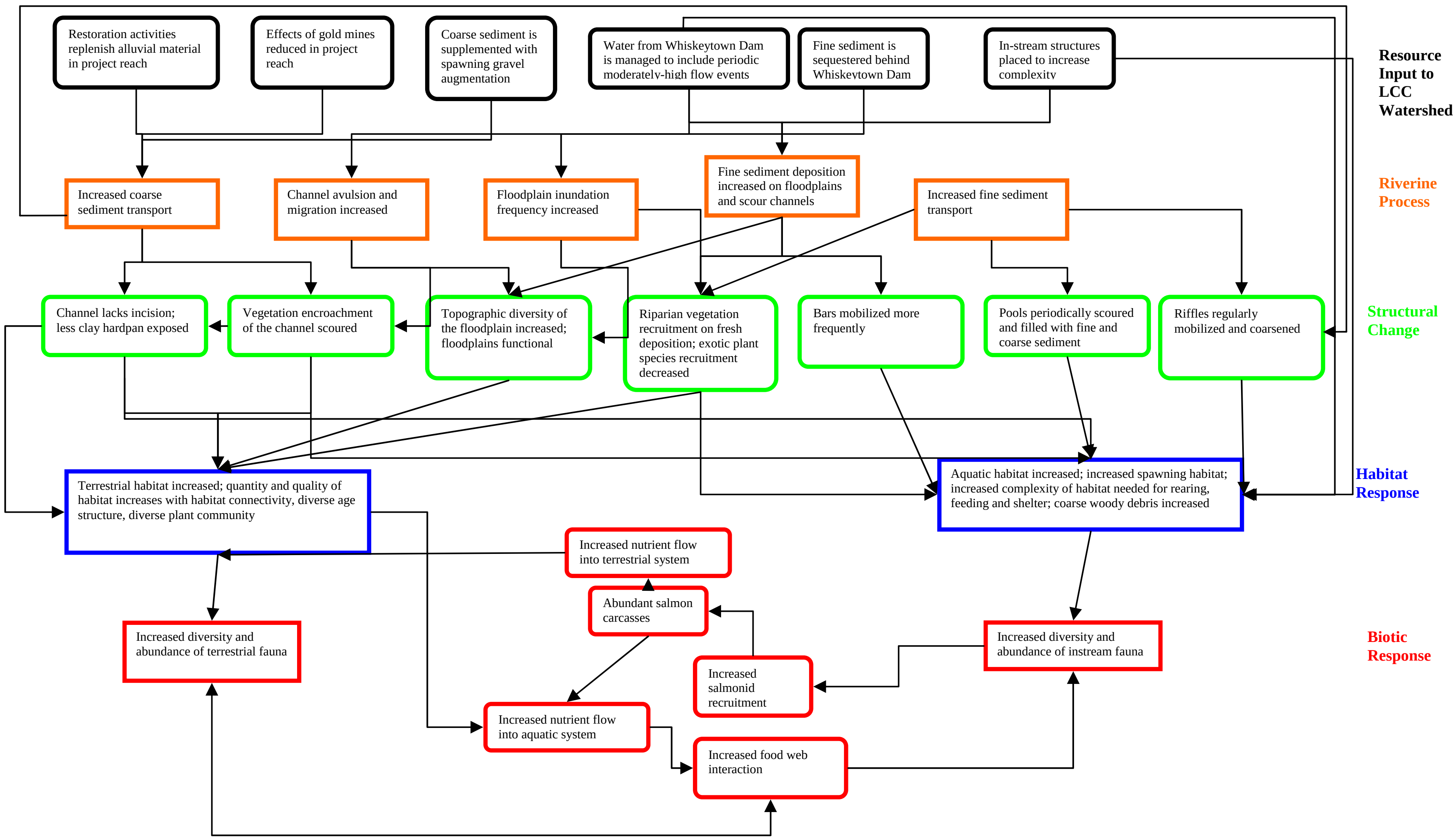
JUNE 1999

Appendix II.
Conceptual Models

Contents:



Overarching conceptual model linking the impacts of dams and gravel mining to physical processes, habitat structure, and biotic response on lower Clear Creek



Overarching conceptual model linking the impacts of restoration activities to physical processes, habitat structure,and biotic response on lower Clear Creek

Hypothesis **Sub-hypothesis**

H1: Reconstructing the channel morphology and restoring geomorphic processes will increase the quality and quantity of salmonid (chinook salmon and steelhead) habitat within the project study area

Raising the channelbed above the clay hardpan and restoring an equilibrium grade through reach by adding large volumes of gravel will increase spawning gravel quantity

Constructing the bankfull channel with sorted (clean) cobbles and gravels will greatly increase spawning gravel quality and egg-to-emergence success

Raising the channelbed above the clay hardpan and restoring an equilibrium grade through reach by adding large volumes of gravel will maintain gravel storage in the reach, providing long-term habitat value

H2: Filling mining pits and restoring bankfull channel geometry will decrease stranding-induced mortality of juvenile salmonids within the project reach, and reduce predation mortality

Filling mining pits will eliminate predatory piscivores, increasing smolt production from lower Clear Creek

Filling mining pits will reduce fry and juvenile stranding, increasing smolt production from lower Clear Creek

Creating sideslopes greater than 3% on terrace surfaces, scour channels to assist juvenile travel from floodplains back to primary channels, and a defined thalweg in the scour channels will reduce fry and juvenile stranding on floodplains during high flow releases.

H3: Filling mining pits and restoring bankfull channel geometry will improve upstream migratory passage and survival through the project reach for adult salmon and steelhead

Recreating one to two primary channels will reduce adult stranding mortality, increasing spawning success and fry production

H4: Revegetation of reconstructed floodplains will increase the quantity and diversity of native riparian vegetation, as well as terrestrial and avian fauna

Planting vegetation in large dense patches with some open cobble bar will reduce cowbird predation, increase migratory songbird habitat, and as the canopy species mature, will create habitats for cavity nesters and raptors.

Planting vegetation in large patches with some open cobble bar will provide habitat for killdeer, doves, and other species dependent on open gravel bar habitats

A combination of riparian plantings and natural regeneration will result in additional species and age diversity than if the entire site were planted.

Planting cuttings in the late winter to the depth of the winter groundwater table elevation will encourage cutting roots to follow the declining water table into the summer, increasing the cuttings ability to survive the hot and dry summer months, increasing planting success

Planting container stock in topsoil will increase the ability of the soil to hold moisture, increase the capillary fringe, and require less frequent irrigation, all increasing planting success

Drip irrigation on container stock will provide more substantial and deeper watering than water truck application, resulting in greater container stock survival

H5: Reconstructing the bankfull channel and floodplain surfaces at a scale consistent with the post-dam flow regime will increase natural regeneration of native riparian species on reconstructed floodplain surfaces

Reconstructing floodplains to begin inundating during the contemporary 1.5 year flood will result in natural riparian regeneration to occur

Reconstructing floodplains to begin inundating during the contemporary 1.5 year flood will result in fine sediment deposition during larger floods, creating new seedbeds and encouraging riparian regeneration

Reconstructing floodplains will allow larger floods to cause channel migration, avulsion, and scour channel creation, creating new seedbeds and encouraging riparian regeneration and channel complexity

Creating scour channels that are 1-3 feet deeper than the floodplain will create moist seedbeds in all years during the cottonwood and willow seed dispersal period, allowing natural regeneration to occur during most water years

Allowing and encouraging channel migration and avulsion will greatly increase the riparian regeneration process on new floodplains and scour channels

H6: Filling mining pits, creating floodplains, and restoring bankfull channel geometry will improve the geomorphic processes responsible for creating and maintaining high quality aquatic and terrestrial habitats

Recreating the bankfull channel using substrates finer than 128 mm (5-inch) diameter will allow these particles to be mobilized by 2.0-year flood (3,000 cfs)

Recreating the bankfull channel and floodplain by refilling the valley bottom with alluvium will allow channel migration and avulsion to occur during moderate to large floods, rather than remaining in a stable location incised within clay hardpan.

Recreating the bankfull channel and floodplain by refilling the valley bottom with alluvium will reduce or eliminate channel degradation in upstream and downstream reaches.

Channel migration and avulsion during moderate to large floods will create a complex alternate bar channel morphology with one to three primary channels, increasing salmonid spawning and rearing habitat

Figure 6. Summary of primary hypotheses and subhypotheses

Attributes of an alluvial river and their relation to water policy and management

William J. Trush*[†], Scott M. McBain[‡], and Luna B. Leopold[§]

*Institute for River Ecosystems, Fisheries Department, Humboldt State University, Arcata, CA 95521; [‡]McBain and Trush, P.O. Box 663, Arcata, CA 95518; and [§]Department of Geology and Geophysics, University of California Berkeley, 400 Vermont Avenue, Berkeley, CA 94707

Contributed by Luna B. Leopold, August 15, 2000

Rivers around the world are being regulated by dams to accommodate the needs of a rapidly growing global population. These regulatory efforts usually oppose the natural tendency of rivers to flood, move sediment, and migrate. Although an economic benefit, river regulation has come at unforeseen and unevaluated cumulative ecological costs. Historic and contemporary approaches to remedy environmental losses have largely ignored hydrologic, geomorphic, and biotic processes that form and maintain healthy alluvial river ecosystems. Several commonly known concepts that govern how alluvial channels work have been compiled into a set of ''attributes'' for alluvial river integrity. These attributes provide a minimum checklist of critical geomorphic and ecological processes derived from field observation and experimentation, a set of hypotheses to chart and evaluate strategies for restoring and preserving alluvial river ecosystems. They can guide how to (*i*) restore alluvial processes below an existing dam without necessarily resorting to extreme measures such as demolishing one, and (*ii*) preserve alluvial river integrity below proposed dams. Once altered by dam construction, a regulated alluvial river will never function as before. But a scaled-down morphology could retain much of a river's original integrity if key processes addressed in the attributes are explicitly provided. Although such a restoration strategy is an experiment, it may be the most practical solution for recovering regulated alluvial river ecosystems and the species that inhabit them. Preservation or restoration of the alluvial river attributes is a logical policy direction for river management in the future.

Since the 1990s, the physical and environmental consequences of river alteration and management have been openly questioned. Continued increases in flood losses, both financial and human, and the unanticipated and unwanted results of dams and channel straightening, invite reevaluation of river management. Reevaluation has even led to removing existing dams (e.g., Butte and Clear creeks in California, Elwha River in Washington), as well as implementing experimental releases of high flows (1, 2).

Historically, river policymakers and resource managers have been less attentive to a growing body of experience, experiment, and theory concerning geomorphic processes that form and maintain alluvial river ecosystems. There are several commonly known concepts that govern how healthy alluvial channels work that we have compiled as attributes of alluvial river integrity. These attributes can guide how to (*i*) restore alluvial processes downstream of an existing dam without necessarily resorting to extreme measures such as demolishing one, and (*ii*) preserve alluvial river integrity below proposed dams. This set of attributes is not a classification system or a substitute for individual study and observation on a river. It provides a minimum checklist of critical geomorphic and ecological processes derived from field observation and experimentation, a set of hypotheses to chart and evaluate strategies for restoring and preserving alluvial river ecosystems. At the ever-present risk of oversimplification, the attributes also can help policymakers appreciate many of the complex requirements of alluvial river ecosystems.

Alluvial river ecosystems persist through a complex, interacting array of physical and biological processes. For any impetus imposed on the river ecosystem (e.g., a recommended flow release), we should expect a response (e.g., scouring sand from a pool). The significance of an impetus will depend on an appropriate threshold beyond which a specific response is expected. A process, therefore, is comprised of an impetus and an expected response. To use the alluvial river attributes as guidelines for recovering or preserving critical processes, one must consider how the magnitude, duration, frequency, and timing of an impetus will exceed a threshold to produce a desired response. Rarely, however, is a single impetus imposed on a river ecosystem associated with a single response.

Floods are primary impetuses for all alluvial river morphology. An increase in discharge may initiate bed surface movement and bank erosion, once the force exerted by the flood event (the impetus) has passed some threshold for movement or erosion. This threshold may require a specific flow magnitude and duration before producing a significant morphological response. The timing and frequency of the flood also may have profound effects on a species or a population. Mobilizing sand from a pool in January may smother salmon eggs incubating in the downstream riffle. The impetus, therefore, cannot be prescribed as a simple measure of force, nor can the total reaction be as succinctly quantified or even fully anticipated. It is with this backdrop of uncertainty that the attributes were compiled.

The Alluvial River Attributes

The alluvial river attributes (3) can help river managers identify desired processes, then help prescribe necessary impetuses based on useful empirical relationships and thresholds developed by river geomorphologists and ecologists. All of the concepts deriving the alluvial attributes have been described among a wide range of professional journals, technical books, and agency reports (reviewed in ref. 2), but their compilation has not been previously published. They may not apply equally to all alluvial river ecosystems. Some rivers may not be capable of achieving certain attributes because of overriding constraints, e.g., a river passing through an urbanized corridor often is not free to migrate. These constraints do not eliminate the attributes' usefulness; knowing what might remain broken should influence what can be repaired.

Attribute No. 1. ***The primary geomorphic and ecological unit of an alluvial river is the alternate bar sequence.*** *Dynamic alternating bar sequences are the basic structural underpinnings for aquatic and riparian communities in healthy alluvial river ecosystems.*

The fundamental building block of an alluvial river is the alternate bar unit, composed of an aggradational lobe or point bar, and a scour hole or pool (Fig. 1). A submerged transverse bar, commonly called a riffle, connects alternating point bars. An alternate bar sequence, comprised of two alternate bar units, is a meander wavelength; each wavelength is between 9 and 11 bankfull widths (4). The idealized alternate bar sequence is

[†]To whom reprint requests should be addressed. E-mail: bill@mcbaintrush.com.

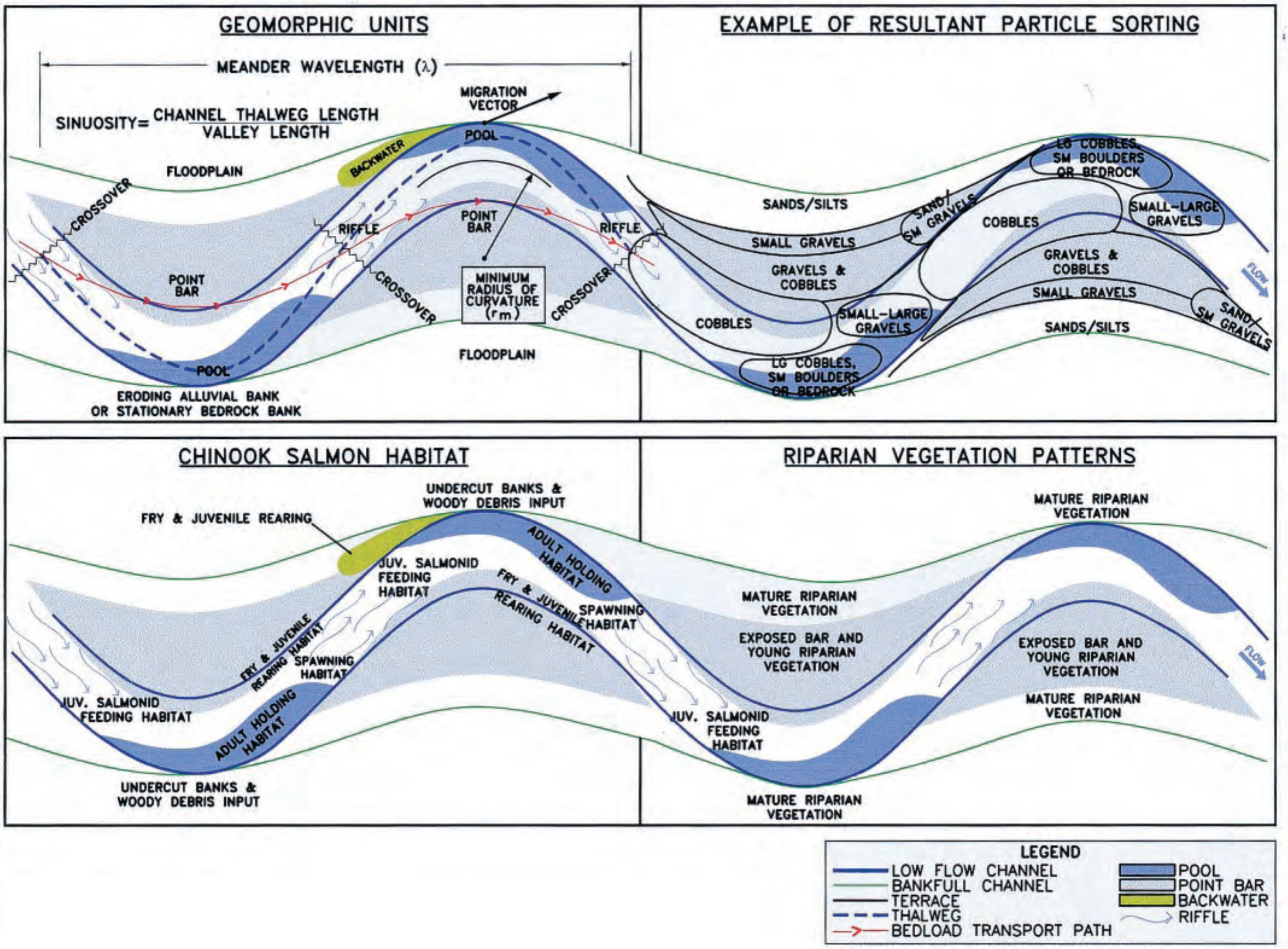


Fig. 1. An idealized alternate bar sequence showing geomorphic units, particle-sorting trends, typical salmonid habitats, and riparian vegetation succession patterns.

rarely found in nature, because natural geomorphic variability (e.g., valley width contractions, bedrock exposures, etc.) perturbs the idealized channel form shown in Fig. 1. Floods flowing through alternating bar sequences frequently rearrange the bar topography, producing diverse, high-quality aquatic and terrestrial habitat.

Attribute No. 2. ***Each annual hydrograph component accomplishes specific geomorphic and ecological functions.*** *Annual hydrograph components (including winter storm events, baseflows, snowmelt peaks, and snowmelt recession limbs) collectively provide the impetus for processes that shape and sustain alluvial river ecosystems. These components are uniquely characterized by year-to-year variation in flow magnitude, duration, frequency, and timing.*

Hydrograph components are seasonal patterns of daily average flow that recur from year to year. For many rivers in the western U.S., these hydrograph components include summer baseflows, rainfall- and rain-on-snow-generated floods, winter baseflows, snowmelt peak runoff, and snowmelt recession (Fig. 2). Each annual hydrograph component can be characterized by its interannual variability in flow magnitude, duration, frequency, and timing. A subset of all processes needed to create and sustain alluvial river ecosystems is provided by each hydrograph component. Eliminate or alter the interannual variability of the hydrograph components, and the ecosystem is invariably altered.

Attribute No. 3. ***The channelbed surface is frequently mobilized.*** *Coarse alluvial channelbed surfaces are significantly mobilized by bankfull or greater floods that generally occur every 1–2 years.*

As streamflow rises throughout a winter storm and during peak snowmelt, a geomorphic threshold for mobilizing the channelbed surface is eventually exceeded. This flow threshold typically occurs over a narrow range of streamflow and varies spatially, depending on the morphology, grain size, and location of sediment deposits (Fig. 3). In general, grains on the channelbed surface are mobilized many times a year, but sometimes not at all in other years, such that, over the long-term, the streambed is mobilized on the order of once a year. The duration of channelbed mobilization is a function of the duration of the high flow, which is typically on the order of days.

Attribute No. 4. ***Alternate bars must be periodically scoured deeper than their coarse surface layers.*** *Floods that exceed the threshold for scouring bed material are needed to mobilize and rejuvenate alternate bars. Alternate bars are periodically scoured deeper than their coarse surface layer, typically by floods exceeding 5- to 10-year annual maximum flood recurrences. Scour is generally followed by redeposition, often with minimal net change in the alternating bar topography.*

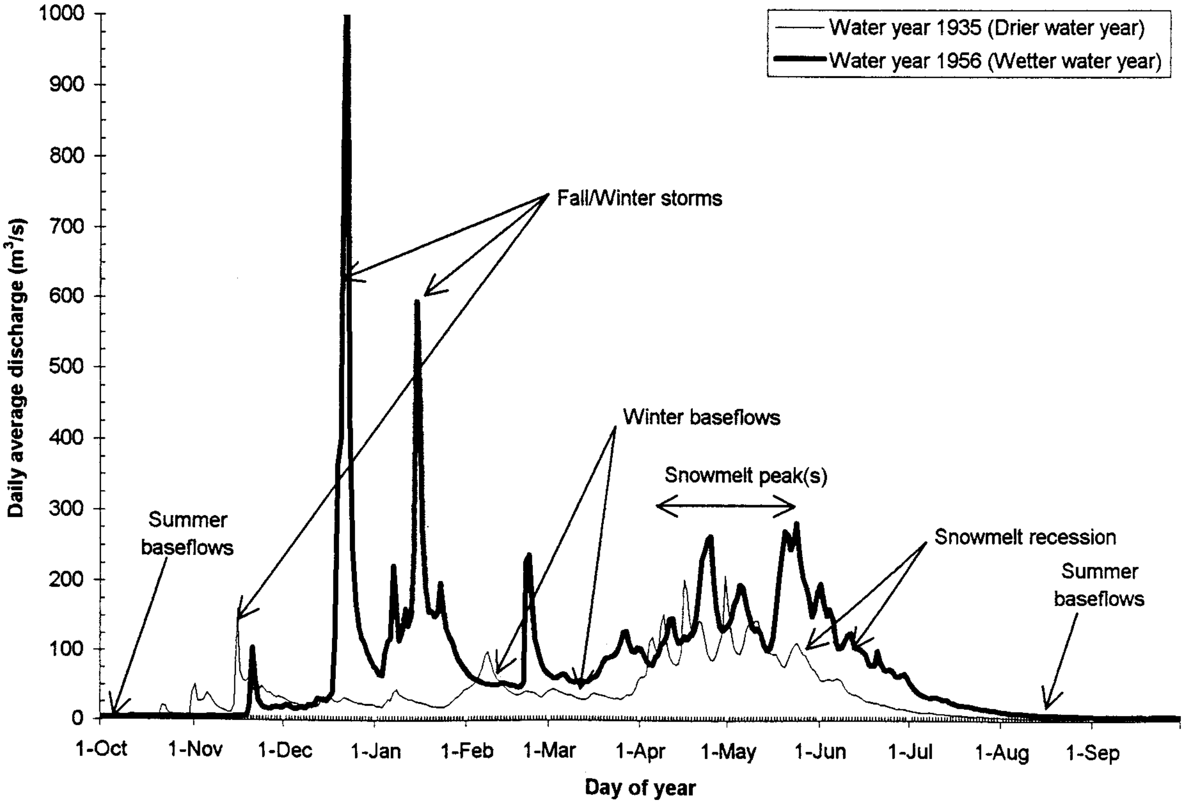


Fig. 2. Hydrograph components of an annual hydrograph by using 1956 (wetter year) and 1935 (drier year) unimpaired flows on the Trinity River in California.

Complex alternating bar sequences are partly created and maintained by providing the natural frequency and intensity of bed scour dependent on discharges that vary in magnitude and duration. During the rising limb of a hydrograph, after the bed surface begins to move, the rate of gravel transport rapidly increases and the bed surface begins to scour. The degree of scour can be significant, up to several feet deep. Infrequent, wet years typically generate storms with a high magnitude and long duration; scour depth will be substantial. On the receding limb of a flood hydrograph, gravel and cobbles redeposit, often resulting in no net change in channelbed elevation after the flood.

Attribute No. 5. ***Fine and coarse sediment budgets are balanced.*** *River reaches export fine and coarse sediment at rates approximately equal to sediment input rates.*

Although the amount and mode of sediment stored may fluctuate within a given river reach, channel-wide morphology is sustained in dynamic quasiequilibrium when averaged over many years. The magnitude and duration of high flows surpassing a flow threshold for channelbed mobility are critical for balancing the sediment budget. Chronic channelbed aggradation and/or degradation are indicators of sediment budget imbalances. A balanced coarse sediment budget implies bedload continuity; that is, the coarser particle sizes comprising the channel bed must be transported through alternate bar sequences.

Attribute No. 6. ***Alluvial channels are free to migrate.*** *During lateral migration, the channel erodes older flood plain and terrace deposits on the outside bend whereas it deposits sediment on the bar and flood plain of the inside bend. Although outer and inner bend processes may be caused by different hydrograph components, the long-term result is maintenance of channel width.*

Channel migration is one of the most important processes creating diverse aquatic and terrestrial habitats: Sediment and woody debris are delivered into the river and flood plains are rebuilt on the inside of the meander. That the stream has occupied numerous locations in its valley is evidenced by direct observations of its movement over time, and by indirect evidence obtained if one digs deeply enough into the flood plain. Gravel and cobbles laid down by the river many years before will be found. The channel does not typically migrate during periods of low flow, but migrates during flows approaching and exceeding bankfull discharge. Shear stress on the outside of bends exceeds that necessary to erode the materials on the outside of the bank. In lower gradient reaches of alluvial rivers, migration tends to be more gradual.

Attribute No. 7. ***Flood plains are frequently inundated.*** *Flood plain inundation typically occurs every 1–2 years. Flood plain inundation attenuates flood peaks, moderates alternate bar scour, and promotes nutrient cycling.*

As flows increase beyond that which can be contained by the bankfull channel, water spreads across the flatter flood plain surface. The threshold for this process is the bankfull discharge. This first threshold allows flow simply to spill out of the bankfull channel and wet the flood plain surface; a slightly larger discharge is required to transport and deposit the fine sediments that are in suspension. Flood plain inundation also moderates alternate bar scour in the mainstem channel by limiting flow depth increases within the bankfull channel during floods. As water covers the flood plain, flow velocity decreases. Sediment begins to settle, causing fresh deposits of fine sands and silts on the flood plain. This deposition promotes riparian vegetation regeneration and growth.

Attribute No. 8. ***Large floods create and sustain a complex mainstem and flood plain morphology.*** *Large floods—those exceeding 10- to*

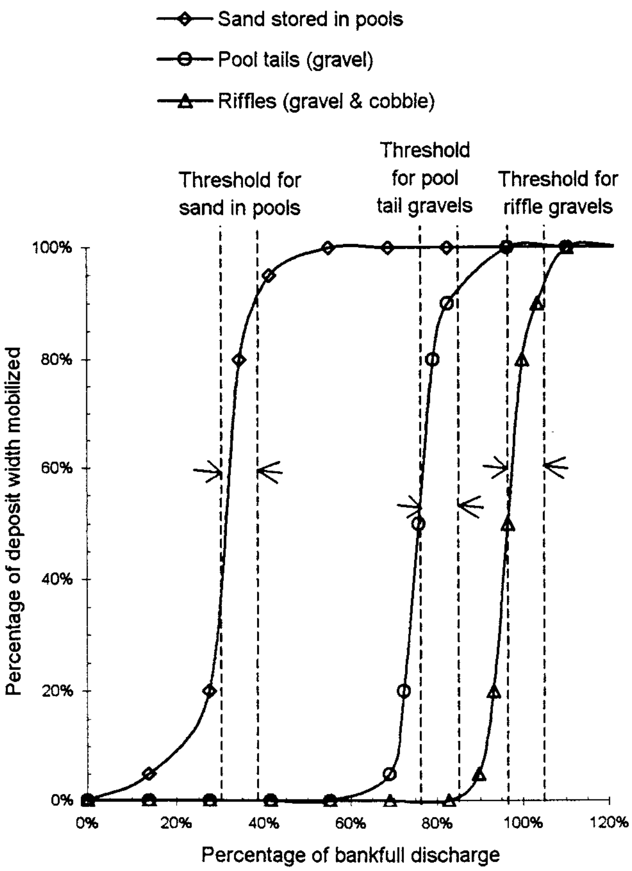


Fig. 3. Conceptual bed mobility thresholds, showing the narrow range in discharge that initially mobilizes the surfaces of selected alluvial features.

20-year recurrence events—reshape and/or redirect entire meander sequences, avulse mainstem channels, rejuvenate mature riparian stands to early successional stages, form and maintain side channels, scour flood plains, and perpetuate off-channel wetlands, including oxbows.

A still larger flow threshold than floodplain inundation is one that scours the flood plain. The streamflow necessary to surpass this threshold is typically many times the bankfull flow because shear stress on the vegetated flood plain surface must be high enough to cause scour. Infrequent large floods are critical for sustaining channel complexity because they change river location and morphology on a large scale and prevent riparian vegetation from dominating the river corridor.

Attribute No. 9. ***Diverse riparian plant communities are sustained by the natural occurrence of annual hydrograph components.*** *Natural, interannual variability of hydrograph components is necessary for woody riparian plant life history strategies to perpetuate early and late successional stand structures.*

Native riparian plant communities characteristic of alluvial river ecosystems are adapted to, and thus sustained by, a constantly changing fluvial environment. The magnitude and duration of annual hydrograph components needed for alternate bar scour, channel migration, floodplain inundation and scour, and channel avulsion provide necessary substrate conditions for successful seedling establishment and stand development. The timing and frequency of annual hydrograph components must coincide with seasonally dependent life history requirements, such as the short window of time when riparian plants are dispersing seeds. A sustainable supply of large woody debris from the riparian zone ultimately depends on variable age classes of woody riparian vegetation and a migrating channel.

Attribute No. 10. ***Groundwater in the valley bottomlands is hydraulically connected to the mainstem channel.*** *When flood plains are inundated, a portion of surface runoff from the watershed is retained as groundwater recharge in the valley bottomlands.*

The river corridor is hydraulically interconnected. Groundwater in the floodplain is closely connected to mainstem flows (5) and can be periodically recharged by mainstem flooding. Avulsed meander bends often create oxbow wetlands, which retain direct hydraulic connectivity to mainstem surface flows.

The alluvial river attributes can be used to recommend flow releases and other management activities below an existing dam. Although this strategy is being considered in other locations, we will use the Trinity River in Northern California as an example, where the recovery of Pacific salmon and steelhead trout is being linked with the overall goal of restoring an alluvial river ecosystem.

The Trinity River at Lewiston

The mainstem Trinity River in northern California was once an alluvial river capable of constantly reshaping its channelbed and banks. In 1963, the U.S. Bureau of Reclamation constructed a large storage reservoir and diversion tunnel to store and divert up to 90% of the natural streamflow from the Trinity River into the Sacramento River for power generation and agricultural/municipal water supply (6). Historically, Trinity River daily flows varied from less than 2.8 m^3/s baseflows in dry summers to near 2,800 m^3/s floods in wet winters. Snowmelt peak runoff and its recession limb were two critical annual hydrograph components generated upstream of Lewiston (Fig. 2). In wet years, snowmelt runoff typically peaked at 340 m^3/s or higher in late June or July, whereas in dry years the peak would only be 110 m^3/s or lower in mid-May through mid-June (7). Together they provided the magnitude and duration of flows needed to balance the sediment budget and accomplish a wide range of physical and biological processes. Both hydrograph components theoretically could have occurred at any time of the year and still have balanced the sediment budget. But seasonal timing of snowmelt runoff was critical to ecological processes.

Peak snowmelt runoff was an important environmental cue for juvenile salmonids to begin their migration to the Pacific Ocean (2). Amphibians needed snowmelt runoff to keep oxbow wetlands inundated. If the snowmelt recession limb did not extend into early June, the wetland might have dried out before amphibians could complete their aquatic life history stage. Interannual variability of timing, magnitude, and duration of snowmelt recession limbs determined whether a particular oxbow wetland could sustain an amphibian population. Successful cottonwood regeneration on freshly deposited floodplains also required specific snowmelt peaks and recession limbs to create favorable moisture conditions for seedling germination, as well as the absence of extreme winter storm events the following year to prevent seedling loss.

After the dam was completed, flows were kept nearly constant at 4.2 m^3/s; river managers thought that 4.2 m^3/s would provide ideal hydraulic conditions for chinook salmon spawning. What river managers did not foresee was that by eliminating hydrograph components they would set in motion a chain of predictable events. Seedlings, no longer scoured away by frequent winter and snowmelt floods, rapidly encroached onto the alternate bars. Prominent berms of freshly deposited sand and silt accumulated along the channel margins within the maturing dense riparian vegetation (Fig. 4), effectively isolating the floodplain from the mainstem river. High shear stresses of infrequent high flow events were then concentrated in the channel's center.

APPLIED PHYSICAL SCIENCES

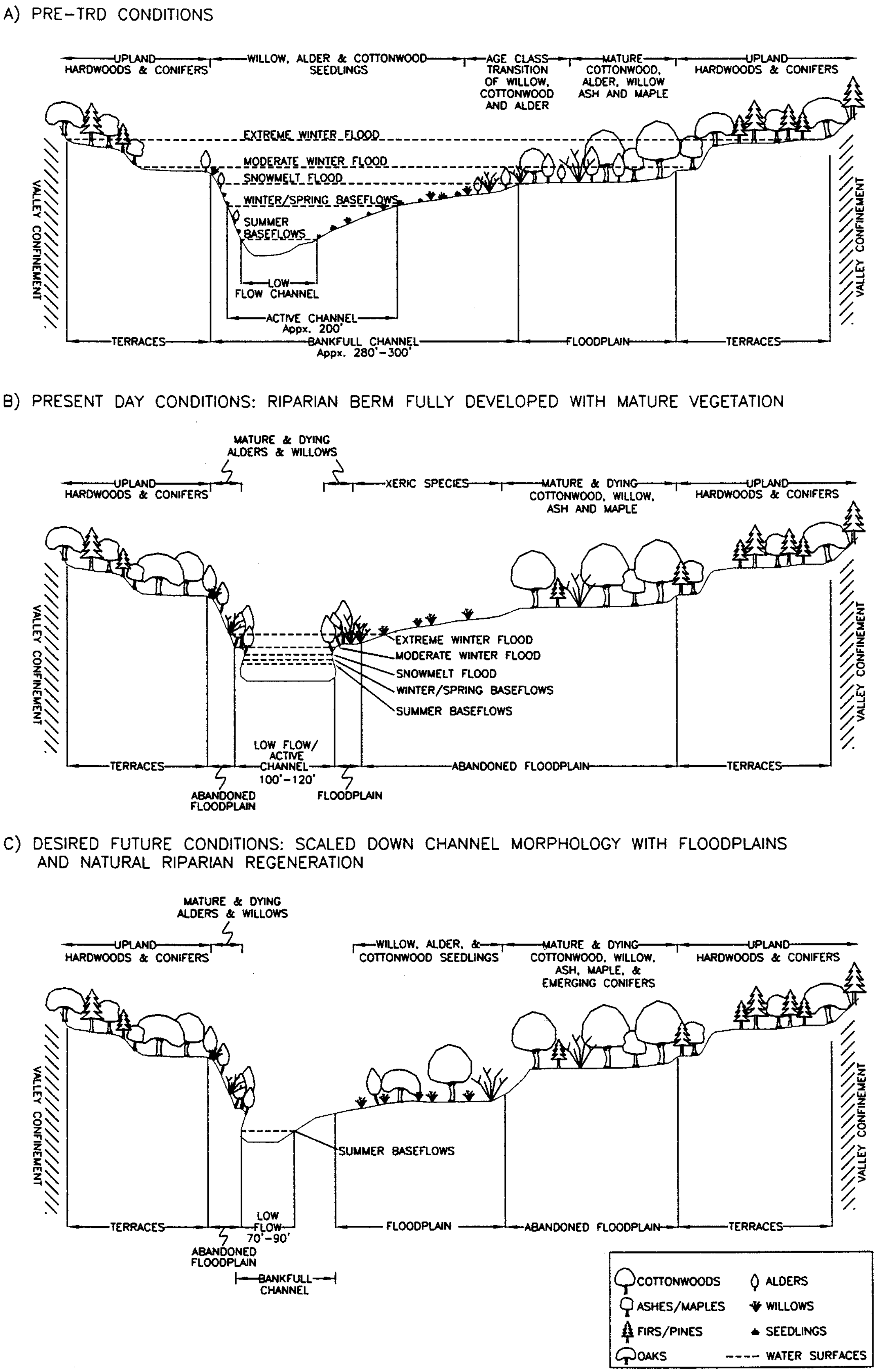


Fig. 4. Evolution of channel geometry and riparian vegetation in response to flow and sediment regulation from the Trinity River Division of the Central Valley Project in California, 1963–1999.

The river's complex alternate bar morphology was quickly transformed into a smaller, confined rectangular channel (Fig. 4) now unable to meander. Floodplains were abandoned. Cumulatively, this flume-like morphology and floodplain isolation greatly reduced habitat quantity and complexity important to numerous aquatic and riparian species.

Salmon populations were immediately and significantly affected. With most of their primary spawning and rearing habitat upstream of an impassable dam, the mainstem channel below Lewiston became the primary habitat provider. When young salmon emerge from spawning gravels as fry, their immediate habitat preference is for gently sloped, low velocity, exposed cobble areas typically found along predam alternate bar margins. In contrast, the vertical banks of the postdam channel allow excessive velocities to extend up to the banks' edges. Although the constant 4.2 m^3/s dam release temporarily accommodated spawning habitat needs, fry rearing habitat became a limiting factor to salmon production because of this rapid change in channel shape.

Was the widespread habitat loss in the Trinity River predictable? Managers who expected that spawning habitat would be preserved below the dams ignored the sediment budget (*Attribute No. 5*). Trinity and Lewiston dams prevent all bed material from passing downstream; the only sources for spawning gravels are downstream tributary inputs, minor flood plain scour, and occasional gravel introductions. The snowmelt peak and recession hydrograph components were completely eliminated (*Attribute No. 2*), even though this river ecosystem had been dominated by snowmelt runoff. Of the planned flow releases greater than 4.2 m^3/s, all were well below the threshold for mobilizing the channelbed (*Attributes Nos. 3* and *4*), routing bed load (*Attribute No. 5*), or inundating the floodplain (*Attributes Nos*. *7*, *8*, and *10*). Consequently, seedlings escaped being scoured and encroached onto the predam alternating bars (*Attribute No. 9*). Loss of the alternate bar morphology (*Attribute No. 1*) was inevitable; so was the loss of habitat created by it.

Was the widespread habitat loss on the Trinity River preventable? Anadromous salmonids cannot pass upstream of Lewiston Dam, therefore their habitat will never be completely replaced unless both dams are removed. The mainstem Trinity River below Lewiston Dam cannot be brought back to its original dimension. But a scaled-down alluvial channel morphology in equilibrium with its constrained sediment budget, reduced hydrograph components, and occasional bed material introductions could greatly restore habitat abundance and quality.

A new restoration approach for the Trinity River that is guided by the alluvial attributes is in its final planning stages. An environmental impact statement/report (6) includes this new restoration strategy, developed by the U.S. Fish and Wildlife Service and Hoopa Valley Tribe (2), as one fishery restoration alternative. The management goal would be to rebuild and maintain a self-sustaining alternate bar morphology and riparian community by using the attributes as a blueprint. Planned releases from Lewiston Dam would provide snowmelt peak and snowmelt recession hydrograph components (*Attribute No. 2*) to recreate physical processes that will recover an alluvial channel morphology (*Attributes Nos. 1*, *3*, *4*, and *6–8*) and sustain off-channel wetlands (*Attribute No. 10*). The sediment budget would be balanced by releasing appropriate hydrograph components with sediment transport capacities commensurate with sediment inputs (*Attribute No. 5*). If transport capacities exceed supply, as might occur during large flood releases in wet years, bed material would be introduced into the mainstem to compensate. Riparian berms on segments of fossilized alternating bars (in the upper 64 km) would be mechanically cleared as a precursor to reestablishing dynamic alternating bars (*Attribute No. 9*).

Conclusion

Society is embarking on a grand experiment. Recent dam removals are merely forerunners of a much larger task ahead. Many more dams will remain than are removed. In practice, we must rely on the crucial assumption that native species have evolved with the natural flow regime. Violating this assumption often results in consequences that can be highly significant and difficult to reverse. The intent to recover alluvial river ecosystems below dams, as proposed for the Trinity River in northern California, will be controversial. To obtain the societal benefits of water diversion, flood control, and hydropower generation, rivers will continue to receive less flow and sediment than under unimpaired conditions. But if important attributes are provided to the greatest extent possible, alluvial river integrity can be substantially recovered. The compromise will be a smaller alluvial river; it may not recover its predam dimensions, but it would exhibit the dynamic alternate bar and floodplain morphology of the predam channel. Although a restoration strategy guided by the alluvial attributes is an experiment, it may be the most practical direction toward recovering regulated alluvial river ecosystems and the species that inhabit them.

1. U.S. Bureau of Reclamation. (1995) *Operation of Glen Canyon Dam, Final Environmental Impact Statement.* (U.S. Bureau of Reclamation, Washington, D.C.)
2. U.S. Fish and Wildlife Service & Hoopa Valley Tribe (1999) *Trinity River Flow Evaluation Final Report.* (U.S. Fish and Wildlife Service, Sacramento, CA).
3. Trush, W. J. & McBain, S. M. (2000) in *Stream Notes*, ed. Rocky Mountain Research Station (U.S. Forest Service, Fort Collins, CO).
4. Leopold, L. B., Wolman, M. G. & Miller, J. P. (1964) *Fluvial Processes in Geomorphology* (Freeman, San Francisco).
5. Hurr, R. T. (1983) *U.S. Geological Survey Professional Paper* 1277-H (U.S. Geological Survey, Reston, VA).
6. U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Hoopa Valley Tribe & Trinity County (1999) *Trinity River Mainstem Fishery Restoration Environmental Impact Statement/Report* (U.S. Fish and Wildlife Service, Sacramento, CA).
7. McBain, S. M. & Trush, W. J. (1997) *Trinity River Maintenance Flow Study Final Report* (Hoopa Valley Tribe, Hoopa, CA).

Appendix III.

Lower Clear Creek Monitoring Plan and Tables

Contents:

ECOLOGICAL MONITORING PLAN
FOR
LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT

***Presented To*:**

CALFED Bay Delta Program
1416 Ninth Street, Suite 1155
Sacramento, California 95814

Contract Number: 114209J022

***Prepared By*:**

Bureau of Reclamation
Northern California Area Office
16349 Shasta Dam Blvd.
Shasta Lake City, CA 96019
&
Western Shasta
Resource Conservation District
3294 Bechelli Lane
Redding, CA 96002

January 2000

TABLE OF CONTENTS

INTRODUCTION

On behalf of the Lower Clear Creek Restoration Team (Restoration Team) the Western Shasta Resource Conservation District (WSRCD) applied for a grant to CALFED in May of 1998 to begin restoration of the lower Clear Creek stream channel and floodplain. The Restoration Team is comprised of representatives from various federal, state and local resource agencies as follows:

Bureau of Reclamation	Natural Resources Conservation Service
U.S. Fish and Wildlife Service	California Department of Fish and Game
National Marine Fisheries Service	California Department of Water Resources
Bureau of Land Management	Western Shasta Resource Conservation District
National Park Service	Central Valley Water Users Association
Clear Creek CRMP Group	Central Valley Hydro-power users
	Horsetown Clear Creek Preserve

The grant application proposed to restore a severely degraded reach of lower Clear Creek impacted by extensive gold and gravel mining activities. The project was logically divided into four phases and includes restoration of floodplains and upland habitats upstream of the project where borrow activities are planned. Phase 1 of the project was completed in 1998 with funds provided through the Central Valley Project Improvement Act (CVPIA) and included construction of a natural bar (plug) to reduce stranding of juvenile salmon and improve passage conditions for adult salmon migrating upstream. Phase 2 will initiate restoration of floodplains and further reduce stranding of juvenile salmonids by filling aggregate extraction pits within the stream channel and floodplain. Phase 3 will focus on rehabilitating the active stream channel, improving floodplain connectivity, and revegetation of natural riparian communities. Phase 4 will restore flow into a section of historic stream channel diverted by aggregate extraction. The grant proposal submitted to CALFED requested funds to implement Phases 2 through 4 however, only Phase 2 of the project was funded during the 1998 solicitation process. A second CALFED grant application was submitted in the Spring of 1999 for funding of Phases 3 and 4. This monitoring plan encompasses monitoring activities for all phases under the assumption that all four phases of the project will be implemented.

CALFED MONITORING PLAN REQUIREMENTS

CALFED requires successful grant applicants to complete ecological and biological monitoring plans where appropriate. For the *Lower Clear Creek Floodway Rehabilitation Project* a monitoring plan must be submitted, reviewed and approved by CALFED. The CALFED Proposal Solicitation Package under which Phase 2 of the *Lower Clear Creek Floodway Rehabilitation Project* was selected states that at a minimum the monitoring plan shall include:

- objectives of the monitoring;
- questions to be addressed through monitoring (hypothesis);
- personnel conducting the monitoring and their related experience;
- duration of monitoring;
- constituents to be monitored;
- sampling methods;
- locations and frequencies of measurement; and
- reporting formats.

The monitoring plan must also incorporate a Quality Assurance Project Plan (QAPP) and annual monitoring reports must be submitted to CALFED presenting findings and a determination as to whether monitoring objectives have been achieved. This monitoring plan was prepared on behalf of the WSRCD by the U.S. Bureau of Reclamation (BR) to comply with CALFED monitoring requirements.

PROJECT MONITORING OBJECTIVES

The primary objective of the *Lower Clear Creek Floodway Rehabilitation Project* is to initiate rehabilitation by restoring a natural channel and floodplain morphology, and native riparian vegetation. Restoration of a natural channel and floodplain in combination with appropriate flow releases will initiate and sustain natural sediment transport processes and channel migration; restore aquatic, wetland, and riparian habitats; improve floodplain connectivity and riparian regenerative processes; and ecological function to the riverine ecosystem. Successful achievement of this objective is anticipated to provide several ecological benefits within the lower Clear Creek Floodway. These ecological benefits are expected to:

- Reduce juvenile stranding mortality and improve adult salmonid passage conditions;
- Increase salmonid spawning habitat;
- Improve geomorphic processes that create and maintain habitat for salmonids and other aquatic species;
- Improve channel-to-floodplain connectivity, improving nutrient and fine sediment cycling throughout the floodway;

- Increase native riparian vegetation, particularly canopy species (cottonwood) important for avian habitat;
- Reduce exotic vegetation through active removal and replacement with native species, and;
- Improve wetland values.

To evaluate project success relative to the ecological benefits stated above specific monitoring objectives were developed and logically divided into three categories for evaluation (Table 1). The three categories developed include fishery resources, geomorphology, and riparian communities.

FISHERIES MONITORING OBJECTIVES

Under current conditions fishery habitat within the project reach has been degraded by removal of alluvial material from the channel and floodplain. Clay and bedrock surfaces have become exposed within the channel reducing the quality and quantity of spawning habitat. The occurrence of shallow braided channels may hinder adult salmon migration upstream during low flow periods that persist during the fall. Several remnant aggregate excavation pits and lowered floodplain surfaces strand fry and juvenile salmonids during periods of fluctuating flow, which are common during the late winter and spring rearing periods. Creation of a restored naturally functioning stream channel and floodplain are anticipated to improve salmon spawning and rearing habitat, reduce the juvenile salmonid stranding, and improve adult passage conditions through the reach.

To evaluate project success in restoring degraded fishery habitat the Restoration Team developed three primary objectives to monitor and evaluate. The objectives were developed to answer specific questions relative to salmonid habitat and survival. The three specific monitoring objectives are:

F1. Improve salmonid rearing and spawning habitat within the project reach.

F2. Reduce juvenile salmonid stranding mortality.

F3. Improve adult passage conditions through the project reach upstream.

Table 1. Ecological objectives, hypotheses, and study parameters for Lower Clear Creek Floodplain Rehabilitation Project.

I) Biological/Ecological Project Objectives For Fishery Resources.

Objective/Hypothesis	Monitoring Parameter (s) and Data Collection Approach	Data Evaluation Approach	Monitoring Agent, Comments, Study Priority	Funding
Objective F1: Improve salmonid rearing and spawning habitat within the project reach. Hypothesis F1. Implementation of channel restoration project will increase the quality and quantity of salmonid (chinook salmon and steelhead trout) habitat within the project study area.	Map meso-habitats and conduct habitat transect measurements for meso-habitats throughout the project study area. Monitor meso-habitat use by rearing juvenile and spawning adult salmonids using direct observation methods, bank observations and snorkel divers, within project site.	Use established IFIM-PHABSIM methodologies to describe habitat availabilities for rearing and spawning salmonids prior to and after habitat restoration. Compare total habitat area and weighted usable area (WUA) for each life stage before and after channel restoration. Compare habitat use in meso-habitats prior to and after habitat restoration.	USFWS Spawning use has been monitored over a three year period and some baseline data is available. High Priority.	CVPIA 3406(b)(12).
ObjectiveF2: Reduce juvenile salmonid stranding mortalities Hypothesis F2. Implementation of channel restoration project will decrease stranding induced mortality of adult and juvenile salmonids within the project reach.	Survey stream channel and floodplain locations using direct observation, electrofishing and seining techniques throughout project study area immediately following flood events to determine extent of juvenile stranding.	Compare stranding survey data before and after channel and floodplain restoration efforts are complete.	USFWS Stranding of juvenile salmonids is recognized as a serious problem by resource agencies. High Priority.	CVPIA 3406(b)(12)
ObjectiveF3: Improve adult passage conditions through the project reach upstream. Hypothesis F3. Implementation of channel restoration project will improve passage conditions for adult salmon and steelhead trout through the project reach upstream.	Visually assess adult salmon passage during upstream migration through the project over critical riffles to determine if current conditions inhibit adult passage upstream. If passage problems occur, map problem areas and establish transects across critical riffles to quantify hydraulic parameters, water depth and velocity, during the migration period.	If passage problems are identified, describe existing passage conditions and compare hydraulic conditions over critical riffles prior to and after habitat restoration.	USFWS Implementation of Phase 1 during 1998 corrected the most serious adult passage concern. Other areas within the project site are not considered to be significant passage problems. Moderate Priority.	CVPIA 3406(b)(12)

Table 1. Ecological objectives, hypotheses, and study parameters for Lower Clear Creek Floodplain Rehabilitation Project. Continued.

II) Biological/Ecological Project Objectives for Geomorphology.

Objective/Hypothesis	Monitoring Parameter (s) and Data Collection Approach	Data Evaluation Approach	Monitoring Agent, Comments, Study Priority	Funding
Objective G1: Recreate a properly sized alluvial channel morphology. Hypothesis G1: Coarse sediment will be mobilized by design bankfull flow (the bed moves)	The monitoring parameter will be percentage of tracer rocks mobilized for different alluvial features (point bars, riffles, pool tails, etc). Tracer rocks will be installed on at least two point bars and two riffles within the project reach, and monitored for mobilization and distance after each discrete high flow event sufficient to cause mobilization.	Tracer rocks will be evaluated by: 1) whether they moved, and 2) how far they moved. The former will allow us to evaluate whether the bed is mobilized by design bankfull discharge, and the latter will provide information on particle travel distance as a function of flow and duration of flow.	WSRCD Will allow designers to improve bankfull channel design for later projects. Moderate priority	Currently CVPIA, CALFED is anticipated future source.
Objective G2: Recreate a properly sized alluvial channel morphology. Hypothesis G2: The bankfull channel will migrate or avulse during flows approaching bankfull discharge and larger (the channel migrates)	The monitoring parameter will be bankfull channel location within the valley-wide cross section, and planform location over time. Cross sections will be installed throughout two alternate bar sequences (targeting meander bends). Post-construction aerial photographs will be rubber-sheeted and channel location digitized and overlain on previous channel locations.	Migration or avulsion of the bankfull channel will be evaluated by comparing channel response (feet moved, rate of movement) with the magnitude and duration of flow that caused the channel to migrate.	WSRCD Much of this will be collateral information gathered with other geomorphic monitoring activities. Moderate priority	Currently CVPIA, CALFED is anticipated future source
Objective G3: Recreate a properly sized alluvial channel morphology. Hypothesis G3: Flows exceeding design bankfull discharge will begin inundating constructed floodplains.	The monitoring parameter will be water surface elevation within the bankfull channel, and flow discharge for that water surface elevation. At one site assessable during high flows at the project site and borrow site water surface elevations will be predicted during the design phases, and elevations will be measured during high flow events after construction.	Measured water surface elevations will be compared to constructed floodplain elevations, and hydraulic parameters will also be collected to refine hydraulic model.	WSRCD Will allow designers to improve bankfull channel design for later projects. Moderate priority	Anticipated CALFED Grant

Table 1. Ecological objectives, hypotheses, and study parameters for Lower Clear Creek Floodplain Rehabilitation Project. Continued.

II) Biological/Ecological Project Objectives for Geomorphology.

OBJECTIVE/HYPOTHESIS	MONITORING PARAMETER (S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH	MONITORING AGENT, COMMENTS, STUDY PRIORITY	FUNDING
Objective G4: Recreate a properly sized alluvial channel morphology. Hypothesis G4: Flows exceeding design bankfull discharge will begin depositing fine sediments (sand and silt) on constructed floodplains	The monitoring parameter will be water surface elevation within the bankfull channel, flow discharge for that water surface elevation, and fine sediment deposition on floodplains At one site accessible during high flows at the Borrow Site and Project Site water surface elevations will be measured during high flow events after construction, and a depth flow threshold for fine sediment deposition will be sought.	Water surface elevations will be compared to constructed floodplain elevations (to get water depths); then, fine sediment deposition will be measured by cross sections and scour nails, and sediment composition will be documented by bulk substrate sampling. The source of the high flow (tributary derived vs dam spill) will be considered and when feasible (safe), depth integrated suspended sediment samples will be collected and analyzed for particle size distribution.	WSRCD Fine sediment deposition on floodplains is critical for natural riparian regeneration. There may also be significant depositional differences between tributary generated flood events and dam generated flood events. Moderate priority	Anticipated CALFED Grant
Objective G5: Raise channel above bedrock hardpan, increasing alluvial storage within the bankfull channel. Hypothesis G5: Subsequent high flows and reductions in sediment supply upstream available upstream of the project will cause bankfull channel to begin incision.	Longitudinal thalweg surveys. Bedrock contacts along the proposed channel centerline will be surveyed as part of the design phase, as-built channel thalweg will be surveyed to document elevation above bedrock contacts, and subsequent surveys will track whether (and how much) incision occurs after specific high flow events that exceed bed mobility thresholds	Compare longitudinal profiles and cross sections prior to and after high flow events to determine patterns of aggredation and deposition.	WSRCD Without removing Saeltzer Dam and/or manually adding coarse sediment, reconstructed channel not controlled by bedrock will again begin to incise during high flow events large enough to transport coarse bed material. This monitoring will document where incision occurs and how much. Moderate priority	Anticipated CALFED Grant

Table 1. Ecological objectives, hypotheses, and study parameters for Lower Clear Creek Floodplain Restoration Project, Continued.

II) Biological/Ecological Project Objectives for Geomorphology.				
OBJECTIVE/HYPOTHESIS	MONITORING PARAMETER (S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH	MONITORING AGENT, COMMENTS, STUDY PRIORITY	FUNDING
Objective G6: Recreate a properly sized alluvial channel morphology with adequate coarse sediment supply. Hypothesis G6: As the bankfull channel migrates, coarse and fine sediments will deposit on the inside of meander bend, creating a new functional floodplain.	The monitoring parameter will be bankfull channel width, bankfull channel depth, and perhaps estimates of bankfull channel boundary shear stress. These parameters will be obtained from cross sections installed throughout two alternate bar sequences (targeting meander bends.)	Evolution of cross section shape, dimensions, and perhaps boundary shear stress will be documented before and after discrete high flow events. Channel adjustment will also be considered in light of changing sediment loads, high flow magnitude, and high flow duration.	WSRCD Much of this will be collateral information gathered with other geomorphic monitoring activities. Channel dimension evolution will be used to improve future channel designs. Moderate priority.	Currently CVPIA, CALFED is anticipated future source.

Table 1. **Ecological objectives, hypotheses, and study parameters for Lower Clear Creek Floodplain Restoration Project, Continued.**

III) Biological/Ecological Project Objectives for Riparian Communities.				
OBJECTIVE/HYPOTHESIS	MONITORING PARAMETER (S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH	MONITORING AGENT, COMMENTS, STUDY PRIORITY	FUNDING
Objective R1: Restore native riparian vegetation on newly created floodplain surfaces. Hypothesis R1. The revegetation phase of channel restoration activities will increase the quantity and diversity of native riparian vegetation on reconstructed floodplain surfaces.	Map and describe the composition of riparian vegetation within the project study area prior to and after stream channel and floodplain restoration activities. Continue to monitor project site for a minimum five year period following the completion of restoration activities.	Planform Mapping: Construct maps of riparian vegetation coverage and compare riparian vegetation communities before and after restoration efforts. Cross Section: Establish cross sections and sample plots to monitor planting success, natural recruitment, species composition, distribution and density. Duplicate data collection efforts (cross sections, plots, mapping) at control sites located outside of project study area, monitor over time and compare results.	WSRCD Moderate Priority	CALFED funding is anticipated
Objective R2: Create favorable physical conditions for regeneration of native riparian species on restored floodplains. Hypothesis R2. Implementation of channel and floodplain restoration activities, combined with favorable hydrologic conditions during seed dispersal period, will increase natural regeneration of native riparian species on constructed floodplain surfaces.	Monitor natural recruitment of riparian species on newly created floodplain surfaces for a minimum of five years following completion of restoration activities.	Establish cross sections and sample plots on newly restored floodplains. Monitor natural recruitment of riparian vegetation. Compare recruitment, density, distribution and species composition to that observed at control sites.	WSRCD Moderate Priority	CALFED funding is anticipated

GEOMORPHIC MONITORING OBJECTIVES

Construction of Whiskeytown Dam, Saeltzer Dam and gravel extraction have significantly reduced the magnitude and frequency of natural fluvial geomorphic processes that are necessary to maintain healthy ecological functions in lower Clear Creek. Gravel excavation removed point bars, floodplains, and riparian vegetation, leaving an unconfined stream channel with multiple channels and numerous open extraction pits. In addition, gold dredging at the Reading Bar borrow site destroyed the floodplain and presently confines the low flow channel between dredger tailings.

The overall geomorphic objective at both the project site and borrow site is to create a single thread channel morphology that is properly sized to the anticipated future sediment transport and flow release regimes. To achieve this desired condition, the Restoration Team developed two basic questions to be addressed by geomorphic monitoring: (1) Are natural geomorphic processes being restored by the project (Restoration of Processes), and (2) how is the channel location and morphology adjusting during high flow events (Project Performance)? The first question addresses project performance as it relates to ecological and geomorphic restoration objectives, while the second addresses how well the channel was built by targeting critical channel locations most susceptible to undesired channel adjustment. For monitoring purposes these two basic geomorphic questions were further broken down into more specific process related objectives that can be readily quantified and evaluated.

Specific geomorphic restoration objectives include:

G1. Riffle matrix particles (D_{84}) are mobilized by design bankfull discharge (3,000 cfs)

G2. Bankfull channel migrates across floodway

G3. Bankfull channel capacity is 3,000 cfs; as flow exceeds 3,000 cfs, flow begins to spread across constructed floodplains

G4. Flows inundating floodplain to a depth > 1 ft causes fine sediments to deposit on floodplain.

G5. Introducing gravel via the restoration project will reduce bedrock exposure in the channel and upstream gravel augmentation will help maintain this condition.

G6. As bankfull channel migrates across floodway, point bars and new floodplains are formed as it migrates

Recall that two sites are being restored adjacent to the creek; the gravel mining reach project site, and the Reading Bar borrow site. All six geomorphic process objectives are adopted for the gravel mining reach project site; however, because the Reading Bar site will be strictly a floodplain and bank rehabilitation project, only Objectives 2, 3, 4, and 6 apply.

RIPARIAN MONITORING OBJECTIVES

Understanding that the overall goal of the project is to rehabilitate natural form and function of the stream channel and floodplain, the first step is to re-create the physical form of the channel and floodplain. Following completion if the initial step, riparian restoration objectives to help achieve the project goal include revegetation of reconstructed floodplains, promotion of natural regeneration/recruitment by creating favorable physical conditions for natural riparian regeneration, minimizing disturbance of existing riparian vegetation, and removal of exotic plant species within the project area.

The riparian revegetation component is as important to project success as proper geomorphic channel design. Riparian vegetation provides much of the terrestrial and aquatic habitat in healthy river ecosystems, while stabilizing riverbanks, dissipating floodwaters, trapping fine sediment, and creating hydrologic complexity that creates channel diversity. The long-term goal of the riparian revegetation component is to restore the extent, morphology, and dynamics of riparian vegetation within the floodway that can be maintained by the current flow regime. An additional short-term goal is to provide floodplain stability for the floodway rehabilitation project.

Wetland revegetation will include a combination of natural plant colonization (i.e., passive revegetation) and artificial planting (i.e., active revegetation). Natural plant colonization will be conducted by creating favorable physical conditions for natural regeneration, while artificial planting will occur on the emergent bench habitats by planting native emergent wetland plant species. Following removal of borrow material, the primary goal of creating off-channel wetlands is creation of higher quality wetland habitats than those currently existing on-site and throughout the lower Clear Creek corridor that resulted from historic gold and gravel mining disturbances.

Restoration areas occur along portions of the project site and at each borrow site. These areas include locations for both natural colonization and active planting efforts. The Project Site consists of approximately 70 acres of riparian planting areas, 23 acres that will be part of the restored active Clear Creek stream channel, and approximately 100 acres of frequently flooded floodplain surfaces left for natural riparian plant recolonization. The Reading Bar borrow site consists of approximately eight acres of riparian planting areas, a 0.30 acre emergent wetland, and approximately15 acres that will be part of the restored active Clear Creek stream channel and/or open areas left for natural plant recolonization. The Former Shooting Gallery borrow site will consist of approximately 11 acres of riparian planting areas, approximately three acres of emergent wetland, approximately seven acres of open water wetlands, and 36 acres for natural plant recolonization.

The revegetation goal is to encourage natural regeneration wherever possible, while revegetating where necessary, to restore riparian vegetation coverage and complexity on lower Clear Creek. Monitoring efforts will focus not only on the revegetation success, but also on how revegetation develops into a multiage, structurally diverse and species rich riparian forest. Specific objectives related to riparian stand function and recovery are:

R1. Restore native riparian vegetation on newly created floodplain surfaces by planting patches of native riparian hardwoods on surfaces that are inundated at a frequency appropriate for each species life history requirements. The hydraulic roughness on the outside bends of the floodplain will be elevated at critical locations to reduce the potential of catastrophic channel avulsion immediately following construction.

R2. Promote natural regeneration/recruitment on reconstructed floodplains, by creating areas where favorable physical conditions for natural riparian hardwood regeneration can evolve.

MONITORING ENTITIES AND EXPERIENCE

Monitoring efforts are anticipated to include multiple agencies, environmental consulting firms, academia, and resource volunteers working cooperatively under the guidance of the WSRCD, BR, USFWS, Bureau of Land Management (BLM), and California Department of Fish and Game (CDFG). Fishery resource monitoring elements will be conducted by USFWS offices in Red Bluff and Sacramento. The WSRCD will be responsible for implementation of monitoring elements identified for the riparian and geomorphic monitoring parameters. McBain and Trush, fluvial geomorphologists, and North State Resources, Inc., consulting environmental scientists, assisted the WSRCD in the development of specific monitoring plans for riparian and geomorphology. A more thorough description of monitoring entities relative to fishery resources, geomorphology, and riparian habitats are discussed below.

FISHERY RESOURCES

The U.S. Fish & Wildlife Service’s Ecological Services Division Instream Flow Branch in Sacramento and the Northern Central Valley Fish and Wildlife Office in Red Bluff will work cooperatively to conduct the fishery resources monitoring effort.

Mark Gard PhD, is the Instream Flow Branch Chief for the U.S. Fish and Wildlife Service and will supervise data collection and habitat modeling efforts described under element F1 of the monitoring plan. Mark is a recognized expert in the use of IFIM and has over 10 years of experience in fisheries research.

Mr. Matt Brown received a Bachelors of Arts Degree in Biology from the University of California at Santa Cruz in 1986 and a Master of Science Degree from Arizona State University in 1990. He worked as a non-game fish biologist for the Arizona Game and Fish Department from 1990 to 1991. He worked for the Fish and Wildlife Service on threatened and endangered fish in New Mexico from 1991 to 1993. Matt began work on chinook salmon at the Northern Central Valley Fish and Wildlife Office in January 1994. His current work focuses on habitat restoration under the Central Valley Project Improvement Act and evaluating the impacts of water development. Matt Brown will assist and coordinate with Mark Gard's habitat modeling efforts and will supervise monitoring of juvenile stranding and adult passage.

GEOMORPHOLOGY AND RIPARIAN VEGETATION

The WSRCD will be responsible for implementation, coordination and management of project monitoring efforts for the riparian and geomorphology elements of the Monitoring Plan. Mr. Jeff Souza is currently the Projects Manager for the Western Shasta Resource Conservation District (RCD) in Redding and has been with the RCD for the last four years. He has a Bachelor of Science degree in Environmental Biology from California Polytechnic State University, San Luis Obispo and a Masters degree in Agriculture from California State University at Chico. Jeff is a native of the northern Sacramento Valley and has been working in the fields of resource management and restoration for over ten years. As Projects Manager for the RCD, Jeff has successfully managed over two dozen projects in the areas of wildlife and fisheries restoration, erosion control, fuels reduction, and coordinated resource planning.

MONITORING DURATION, CONSTITUENTS, AND METHODS

FISHERY RESOURCES

Objective F1- Improve salmonid rearing and spawning habitat within the project reach.
Modeling of spawning and rearing habitat will occur in the restoration site prior to and after restoration actions are completed. Restoration actions are currently scheduled to begin in the summer and fall of 1999 with the initiation of Phase 2. Completion of Phase 4, which is the final Phase, is planned to occur in the summer of 2001. Prior to implementation of restoration activities (Spring of 1999) USFWS will conduct a field reconnaissance survey to determine specific study site boundaries, transect locations and develop meso-habitat maps. Hydraulic data on water surface elevations, bed topography, cover and substrate will be collected for input into a 2-dimensional hydraulic and habitat model. Following construction and calibration of hydraulic data sets the 2-dimensional model will be used to predict water velocities and depths present in

the study site over a range of discharges that are likely to occur within study site under future flow release conditions. This output, along with the substrate and cover distribution in the site and Habitat Suitability Criteria previously developed on Clear Creek or other streams, will be used to predict the amount of spawning and rearing habitat present over a range of discharges in the restoration site prior to restoration actions.

Implementation of restoration actions will create a new channel alignment and floodplain throughout the project site. Therefore, a second survey (2002) will be required to map habitat conditions and identify new transect locations. Hydraulic data on water surface elevations, bed topography, cover, and substrate will be collected for the restored channel configuration for input into a 2-dimensional hydraulic and habitat model. Data sets will then be assembled for input and calibration of the 2-dimensional hydraulic model. Following model calibration, the 2-dimensional model will be used to predict water velocities and depths over a range of expected flows. This hydraulic output will then be used with cover and substrate distribution data and Habitat Suitability Criteria to predict the amount of salmonid spawning and rearing habitat present within the study site under restored conditions.

A Final Report will be completed at the end of the study comparing the amount of rearing and spawning habitat for a range of discharges present in the study site before and after restoration actions. Habitat comparisons will be conducted for fry, juvenile and spawning life stages of chinook salmon and steelhead trout. Information developed from this study may result in additional restoration recommendations and may assist in development of flow release patterns.

Objective F2- Reduce juvenile salmonid stranding mortality.
The current degraded conditions of the lower Clear Creek channel create favorable conditions for stranding juvenile salmonids. USFWS and CDFG have documented stranding of juvenile salmonids in several locations within the Project Site. Implementation of channel and floodplain restoration actions is expected to reduce stranding mortality. To evaluate the success of the restoration effort the USFWS will continue existing surveys of the project site through implementation of the project. A description of survey methods follows.

The USFWS's Northern Central Valley Fish and Wildlife office currently conducts surveys to document the occurrence of salmonid stranding throughout the Project site. The entire Project site topography has been mapped and digitized aerial photographs are used to depict locations of all potential stranding sites. Each potential stranding site has been described based on location, physical characteristics and hydrology (isolated pond, inundated at high flow, or connected to main channel).
Pedestrian surveys are conducted of the entire Project site by qualified biologists throughout the rearing season. Data recorded for each survey include date, time, Clear Creek Flow, and weather conditions. Observations recorded during each survey for each location include: 1) presence of juvenile chinook salmon at each location; 2) qualitative estimate of the number of juvenile

chinook salmon observed; 3) description of current hydrologic characteristics; and, 4) water temperature.

New project topographic maps and aerial photographs will be developed following completion of the restoration project. USFWS biologists will survey the project site during periods of high flow and throughout the juvenile rearing season to identify and map potential stranding locations that may exist under restored conditions. Should potential stranding locations exist, USFWS will continue surveys, quantify the magnitude of the stranding problem and develop potential solutions for recommendation to the Lower Clear Creek Restoration Team.

Because restoration efforts are designed to restore natural fluvial processes through creation of a dynamic channel morphology, channel migration is expected to occur over time. However, if the restored channel is not in balance with future flow and sediment transport rates there is a potential that major channel migration could occur during flood events. Should large scale shifts in the location of the channel be observed USFWS will again survey the project area and document potential stranding locations.

Annual progress reports will be submitted to the Restoration Team and CALFED describing survey methods, frequency of surveys, and results. A final report will be submitted to the Lower Clear Creek Restoration Team one year after construction of the restoration project. The final report will describe survey methods, summarize annual survey results, and compare stranding conditions prior to and after restoration.

Objective F3- Improve adult passage conditions through the project reach upstream.
The existence of braided channels and gravel extraction pits in and adjacent to the creek channel may hinder passage of adult salmon upstream during low flow. To document impacts to adult passage the Northern Central Valley Fish and Wildlife office will visual assess adult salmon passage conditions during upstream migration over critical riffles within the project site prior to implementation of restoration efforts. If passage problems are observed, problem areas will be mapped and evaluated in more detail as follows. Transects will be established across critical riffles to collect hydraulic data (water depth, velocity, water surface elevation and discharge) to fully describe existing passage conditions.

After restoration of the project site is completed USFWS biologists will again visually assess adult passage conditions through the site. Should passage problems be observed transects will be established at each location and hydraulic data collection efforts will be repeated. Additional hydraulic data will then be collected under different flow release conditions for development of hydraulic models to describe the relationship between passage conditions and stream discharge for each critical riffle within the restored channel. Results of hydraulic modeling, will provide information to assist development of recommendations to correct passage conditions through implementation of mechanical restoration actions or improved flow releases. Hydraulic modeling efforts for fish passage will be coordinated with hydraulic and habitat modeling efforts described under Objective F1.

A final report will be submitted to the Restoration Team and CALFED describing the effectiveness of restoration actions to improve fish passage conditions. The report will include detailed descriptions of methods used, results, and recommendations for corrective measures if necessary.

GEOMORPHOLOGY

Objective G1-Riffle matrix particles (D_{84}) is mobilized by design bankfull discharge (3,000 cfs). The bankfull channel morphology was designed so that the D_{84} particle size in riffles would be just mobilized by the design bankfull discharge (3,000 cfs). Bed mobility models were used to predict the channel dimensions necessary for a 3,000 cfs flow to mobilize the D_{84} particle size. In the two long-straight riffles shown on Plate 1, tracer rocks representing the local D_{84} particle size (and other particle sizes) will be used to evaluate whether bed mobility objectives are being met in the design channel. Cross sections will also be established through two alternate bar sequences, which will include cross sections and marked rocks through point bars, pool tails, and riffle crests to document bed mobility on other geomorphic features. Surface pebble counts will be collected for as-built conditions, and marked rocks inserted at many cross sections shown on Plate 1. After each peak flow larger than 2,000 cfs, the marked rocks will be monitored. We expect changes in particle size as the constructed bed surface adjusts during high flows, therefore, after the first water year, we will re-document particle size with repeat pebble counts, and set out new sets of tracer rocks. Tracer rocks in subsequent years will be monitored after each peak flow greater than 2,000 cfs. The objective is to determine if D_{84} tracer particles are being mobilized by flows up to and exceeding the design bankfull discharge (3,000 cfs).

Objective G2-Bankfull channel migrates across floodway.
As-built topographical surveys will be conducted as part of construction implementation verification; cross section pins established at the end of construction will serve as long-term cross section monitoring endpoints. Ground level photographs will be taken of each cross section and aerial photographs will be flown after construction to document as-built conditions at both the project site and Reading Bar borrow site. Using the tracer rocks as an indicator of bed movement and potential for channel migration, cross sections will be resurveyed after flows that mobilize the tracer rocks. Subtle channel migration will be documented by these repeat cross sections, while repeat aerial photographs will be used to document more dramatic shifts in channel location. Ground level photographs and aerial photographs will be re-taken every three years or after a high flow that causes dramatic changes to channel morphology, whichever is sooner.

Objective G3-Bankfull channel capacity is 3,000 cfs; as flow exceeds 3,000 cfs, flow begins to spread across constructed floodplains.

The bankfull channel morphology was also designed to convey the design bankfull discharge (3,000 cfs); flows larger than 3,000 cfs should begin to spill onto the floodplains. The HEC-2 hydraulic model was used to develop the channel dimensions at the gravel mining reach project site to achieve this objective, while at the Reading Bar site, we were fortunate to have monitored water surface profiles during a 2,900 cfs flow, so design floodplain elevations should be very accurate. Monitoring water surface elevations on cross sections through both the project reach and Reading Bar reach during 3,000 cfs magnitude flows will evaluate whether this conveyance objective is being met. This will be conducted at all sampling sites shown on Plate 1. At the Reading Bar borrow site, eleven cross sections were established in 1998 to monitor Phase 1 reclamation (these are not shown on Plate 1). These cross sections will continue to be monitored and ground level photographs taken to evaluate final reclamation of the Reading Bar site as Phase 2 is implemented.

Objective G4-Flows inundating floodplain to a depth > 1 ft causes fine sediments to deposit on floodplain.

Streams typically transport most of their sediment load (up to 95 percent) as finer sediments suspended in the water column during high flows. Under natural conditions, a large proportion of this fine sediment may deposit on floodplain surfaces, which creates seed-beds for riparian regeneration and reduces fine sediment deposition within the bankfull channel. Stream reaches downstream of a large storage reservoir (e.g., Whiskeytown Dam) often have very little fine sediment transported in suspension because the reservoir traps sediments derived from the upstream watershed. We are concerned that the finer components of the suspended sediment load (<0.1 mm) in Clear Creek is small due to Whiskeytown Dam, which will reduce fine sediment deposition on floodplain surfaces. We will monitor fine sediment deposition on floodplains by taking detailed elevation measurements and photographs at a subset of the cross sections shown on Plate 1. Surveys will be conducted before and after high flow events that inundate the floodplains, and water surface elevations will be monitored to evaluate whether there is a depth threshold for fine sediment deposition. Detailed elevation measurements will also be conducted at selected permanent vegetation plots shown in Plate 2. This information will be used in conjunction with the riparian monitoring to evaluate potential correlations between natural riparian regeneration and areas of fine sediment deposition.

Objective G5-Introducing gravel via the restoration project will reduce bedrock exposure in the channel and upstream gravel augmentation will help maintain this condition.

Gravel mining and the impact of upstream dams in reducing coarse sediment supply have cumulatively caused channel downcutting in the reach, and increased exposure of clay hardpan bedrock in the low flow channel. Because salmon cannot spawn in bedrock, and aquatic insect production in bedrock is low, raising the channelbed above the bedrock by massive gravel introduction will greatly improve aquatic habitat conditions. Our primary concern is, because Whiskeytown Dam will continue to trap coarse sediment from the upstream watershed into the future, the restoration site will begin downcutting a short time after project completion. Removal of Saeltzer Dam and continuing the gravel introduction program will reduce the risk or degree of downcutting, but it still may occur. The primary method of monitoring channel grade through the reach will be collective cross sections, thalweg profiles through the entire reach, and substrate mapping at the alternate bar monitoring sites supported with photographs of each site (Plate 1). Monitoring will again be triggered by flows that exceed bed mobility thresholds, as described under other objectives. In addition, we will continue measuring coarse sediment transport in Lower Clear Creek, but move the sampling site to a reach immediately upstream of the gravel mining reach project site (Plate 1). This sampling will provide empirical sediment transport input for applying a HEC-6 bedload transport model for predicting scour and fill at the project site, and evaluating how well the model predicts scour and fill compared to actual channel response.

Objective G6-As bankfull channel migrates across floodway, point bars and new floodplains are formed as it migrates.
As a stream migrates across the floodway, they build bars and floodplains on the inside of the migrating meander bend. This floodplain formation is not solely dependent on the channel migrating; an upstream sediment supply is needed to physically construct the point bar and floodplain on the inside of the bend. Restoration efforts on lower Clear Creek (including this project) will continue to add coarse sediment to the stream corridor to help create and maintain point bars and floodplains. Cross sections will again be the foundation for monitoring whether this objective is being met. At the two alternate bar monitoring sites and Reading Bar borrow site, cross sections will be established/monitored at certain locations where migration is expected to occur: at the outside of meander bends. In addition photo monitoring sites will established at each cross section. This monitoring will repeat the methods used to evaluate Objective 3, except that it will focus on the inside of the bend (in the depositional area) rather than the outside of the bend (erosional area).

Project Performance Objectives

There are two primary project performance objectives:

1. Provide short-term stability at two critical meander bends to prevent immediate channel recapture into old location

2. Design channel should convey bankfull discharge (3,000) cfs before spilling onto floodplain.

Evaluating these two objectives, the six geomorphic process objectives, and riparian vegetation objectives described in later sections, requires an accurate measure of streamflow to establish cause and effect relationships between stream response and discharge. Therefore, streamflow monitoring is also described below.

Short-Term Stable Meander Bends

The overarching geomorphic objective of the project is to restore the ability of the channel to move sediment, adjust its dimensions, and migrate across the floodway. However, we would prefer, at least for the first five years while the riparian vegetation grows, that the channel remain relatively stable in two locations within the project reach where the stream is susceptible to re-occupy its pre-restoration channel. These locations are at Stations 214+00 and 180+00 on Plate 1. In these two locations, cross sections will be established through the apex of the meanders to monitor lateral migration, bank undercutting, and adjustments in channel morphology.

Hydraulic Conveyance

Channel geometry to convey the design bankfull discharge is a primary design objective. As flows begin to exceed 3,000 cfs, flow should begin to inundate floodplain surfaces and deposit fine sediments being transported in suspension. If flows exceeding 3,000 cfs are still contained within the bankfull channel, then higher than designed for shear stresses could occur, causing larger bedload transport rate, increased risk of channel downcutting, and increased risk of habitat loss. A HEC-2 water surface profile model was used to help design the bankfull channel dimensions to convey the design bankfull discharge; it will also be used to evaluate hydraulic conveyance performance. At all cross sections shown on Plate 1, water surface elevations for distinct high flow events will be monitored and compared to floodplain elevations. These cross sections will also be included in the HEC-2 model, and the roughness values in the HEC-2 model can be calibrated to improve the predictive capability of future designs.

Streamflow Gaging

Evaluating the response of the channel to a given flow requires two additional measures in addition to measuring the response itself: the magnitude of the flow that caused the channel response, and the flood frequency of that flood for perspective. For example, we would not expect the channel to avulse across the floodway during a 1.5 year flood, but would expect the bed surface to be mobilized. Long-term streamflow gaging has been conducted by USGS at the Igo gaging station a few miles upstream, and this gage will provide the primary flow measurement point for evaluating the project. We have installed a second continuous recording gaging station at the downstream end of the project site (see Plate 1) to provide more local flow data and serve as a backup to the USGS gaging station. In addition, we have installed and will continue to monitor four staff plates installed throughout both the gravel mining restoration site and Reading Bar borrow site to document local water surface elevations for a given discharge.

Monitoring Schedule and Reports

All data and reports will be available in electronic format, and will be archived on CDROM for distribution to interested parties. Cross section, longitudinal profile, and most other field data will be entered and archived in Microsoft Excel spreadsheets. Planform maps will be digitized into and archived in AutoCAD using NAD 1927 horizontal and vertical datum.

Because geomorphic processes occur during high flow events in the fall and winter, progress reports will be prepared at the end of the fall/winter high flow season (June). Monitoring at the Reading Bar borrow site will begin in the winter of 1999/2000, while monitoring at the project site will not occur until Phase 3 is completed in the fall of 2001. Therefore, progress reports will be produced as follows:

June 2000: Reading Bar borrow site year 1 progress report.
June 2001: Reading Bar borrow site year 2 progress report.
June 2002: Reading Bar borrow site year 3 progress report, Phase 3 project site year 1 progress report.
June 2003: Phase 3 project site year 2 progress report, Phase 4 project site year 1 progress report.
June 2004: Phase 3 project site year 3 progress report, Phase 4 project site year 2 progress report.

A final report of geomorphic monitoring at the project site and Reading Bar borrow site will be completed by December 2004 provided project implementation occurs on schedule. Should delays in the implementation schedule occur the geomorphic monitoring schedule will be adjusted accordingly.

RIPARIAN VEGETATION

Objective R1-Restore native riparian vegetation on newly created floodplain surfaces by planting patches of native riparian hardwoods on surfaces that are inundated at a frequency appropriate for each species life history requirements. The hydraulic roughness on the outside bends of the floodplain will be elevated at critical locations to reduce the potential of catastrophic channel avulsion immediately following construction.

Some riparian plant species are sensitive to inundation (Fremont cottonwood, Oregon ash, etc.) while others are more sensitive to deposition (white alder). These sensitivities, combined with seed dispersal times are often the major physiologic factors driving vegetation patterns adjacent to streams; in regulated rivers these relationships lead to riparian vegetation encroachment. Plant success after revegetation will be determined by whether planted riparian hardwoods were thriving in their planted environments. Riparian plant recruitment into revegetated floodplains should be similar in composition to revegetated stands in the same inundation regime. A thriving riparian stand will have an increasing canopy cover and understory that is increasing in species richness, while riparian encroachment into the low water channel should be nonexistent.

To evaluate revegetation development, 10 meter radius circular plots will be established within each patch type planted, and band transects will be used (Bonham 1989, Kent and Coker 1992). Circular plots shall be randomly placed within any of the patches of a specific patch type using CAD software. The number of randomly sampled circular plots is determined by the total area of each patch type planted within a construction phase divided by 2 acres (Figure 2). Because plot number is determined by the *total area* of a patch type, some patches do not have circular plots. For example, if a singular patch is smaller than the radius of the circular plot it will not sampled, or if the total acreage of a patch type is less than 2 acres only one circular plot will be used. Within each circular plot, plant species, each species estimated percent cover, maximum and average height, youngest, and oldest hardwood age, stem number (for hardwoods < 7.5cm) and diameter at breast height and stem number (for plants > 7.5 cm) will be measured. Photo monitoring will also occur at each circular plot to help document conditions. Additionally, permanent 2 meter wide band transects will be sampled along valley wide cross sections established in alternate bar reaches during geomorphic sampling, and along cross sections where piezometers have been established (Figure 2). Plant species, estimated plant species cover, hardwood age class, average and maximum canopy height, substrate transitions, and visible soil moisture will be quantified during band transect sampling. Photo monitoring stations will also be established across each cross section to help describe changing conditions to riparian vegetation through the monitoring period.

Fine sediment deposition during floods is a response to elevated hydraulic roughness over floodplains caused by maturing riparian vegetation. Fine sediment accumulation is an important ecosystem process on floodplains because it promotes the development of seed beds where regeneration can occur and provides richer soils for the needs of plants that can not live closer to the channel where substrate is coarser and where groundwater is more responsive to rapid drops in river stage. As fine sediment continues to deposit channel confinement increases, which leads to greater pool depths and fish habitat complexity.

Sediment deposition and channel confinement related to vegetation will be monitored using a combination of square permanent plots and previously established band transects. Permanent 10 x 10 meter plots will be established on floodplains and in scour channels to evaluate sediment deposition (Plate 2). Substrate composition, stem density within the plot and upstream from the plot (or in the direction of flood flow), plant growth habits, plant species, and substrate size will be evaluated.

Objective R2-Promote natural regeneration/recruitment on reconstructed floodplains, by creating areas where favorable physical conditions for natural riparian hardwood regeneration can evolve.

Riparian hardwood recruitment is vital to the perpetuation and structural diversity within riparian vegetation. Riparian rehabilitation success could be easily gauged in an ecosystem context by the presence or absence of willow and cottonwood seedlings, and the reduction of riparian vegetation encroachment. Not only is fine sediment deposition important for seedling recruitment, but hydrologic conditions in the year of germination and subsequent years must provide the water that developing seedlings need without scouring or in some other way killing them. If recruited plants cannot be semi-annually scoured from within the active channel riparian vegetation will begin to encroach in the rehabilitated channel. While the project has some control over the physical conditions leading to successful hardwood recruitment on floodplains and reducing riparian encroachment, the project has no control over where and how much fine sediment will deposit, and over what annual flood magnitudes/timing and flow recession rates sedimentation occurs.

Data collected while monitoring objective R1 will be used to evaluate hardwood recruitment and encroachment. Groundwater elevations in piezometers will be monitored and related to changes in river stage, which will complement band transect based vegetation data. Evaluating the groundwater river stage relationship will help in understanding the physical variables that relate to the presence (or absence) of naturally recruited hardwoods.

Exotic plants pose the greatest threat to riparian rehabilitation success. Exotic plants could potentially out compete plantings and colonize open areas where natural recruitment could occur. If post project conditions favor exotic plant species over native hardwoods, than the environmental conditions that promote exotic species over natives will be evaluated. Micro-climatic measurements of relative humidity and air temperature will be taken within all monitoring plots using a sling psychrometer. Trends in species composition will be evaluated in context to geomorphology, distance from the active channel, and microclimate. Additionally, data collected while monitoring objective R1 will be used to evaluate exotic plant species success, recruitment, and inter/intra specific competition that could lead to the exclusion of native hardwood species.

Monitoring Schedule and Reports

Monitoring will begin immediately following the revegetation of each construction phase. Monitoring will occur again towards the end of each growing season in October for a period of five years. Progress reports will be produced as follows:

June 2000: Reading Bar and Phase 2a site as-built report
January 2001: Reading Bar and Phase 2a 1-year progress report, and 2b site as-built report
January 2002: Reading Bar and Phase 2a 2-year progress report, Phase 2b 1-year progress report, and Phase 3 as-built report
January 2003: Reading Bar and Phase 2a 3-year progress report, Phase 2b 2-year progress report, Phase 3 1-year progress report, and Phase 4 as-built report
January 2004: Reading Bar and Phase 2a 4-year progress report, Phase 2b 3-year progress report, Phase 3 2-year progress report, and Phase 4 1-year progress report

A final report of riparian monitoring at the project site and Reading Bar borrow site will be completed by December 2004 provided that implementation occurs on schedule. Should delays in the implementation schedule occur, the riparian monitoring schedule will be adjusted accordingly.

QUALITY ASSURANCE PROJECT PLAN

All field data collection will occur under the supervision of qualified resource professionals, i.e. fish and wildlife biologists, geomorphologists, botanists, and/or engineers where appropriate. All work conducted on this design to date has used State Plane Coordinate System and NAD 1927 datum; future monitoring will continue this standard. Because this base control has been established by licensed surveyors, vertical and horizontal accuracy should continue to be excellent. Cross sections and longitudinal profiles will be collected by skilled technicians with an engineers level, which provide excellent vertical accuracy. Data will be recorded in hardbound water-resistant transit books, and study site setup, survey, and field note recording will follow standard stream monitoring protocols published by Harrelson et al., 1994. Field data will be entered into Excel spreadsheets by a member of the survey crew, and independently reviewed by a senior member of the survey crew for quality control.

REFERENCES

Harrelson, C.C., Rawlins, C.L., and Potyondy, J.P. 1994. *Stream channel reference sites:an illustrated guide to field technique.* Gen. Tech. Rep. RM-245. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

MONITORING OF MERCURY LOAD FROM RESTORATION ACTIVITIES

APPROACH – MERCURY SAMPLING AND INTERPRETATION

Tetra Tech will conduct mercury sampling, data reduction, and data interpretation for the Western Shasta Resource Conservation District's three (3) year mercury monitoring program on Lower Clear Creek. The specified objective of this monitoring program is to determine whether the stream restoration activities undertaken by WSRCD and its' partners in Lower Clear Creek have affected the load of mercury discharged. The proposed Tetra Tech project manager is Dr. Ted Donn.

Field Sampling

Surface water sampling will be conducted at two stations, one above, and one below the restoration project area. These sampling locations will be collocated with existing (GMA gage CC3A), or soon to be installed (Phase 4), Graham Matthews Associates geomorphology stations (Figure 5). These stations will be sampled during six flow events each year for a period of three years. The six events each year will consist of:

- Three storm events. These events are designed to capture mercury and particle transport during those conditions during which the bulk of the sediment transport occurs (Pittman and Matthews 2004). The high flow (storm) sampling events will be coordinated with the sediment sampling conducted by Graham Matthews Associates to ensure comparability of data, and safety of the sampling crews..
- Two low flow events, including one late spring event and one fall (September) event. It is anticipated that the late spring event would occur before the thermocline has become established in Whiskeytown Reservoir. The fall sampling event would occur shortly before the reservoir turns over in the late summer or fall, and during the period when Chinook salmon have entered the system to spawn and flows are increased. Discharges from below the thermocline are expected to have the highest methylmercury concentrations likely to be encountered from reservoir releases at this time.
- One floating event. This event will be used to collect data during unusual conditions such as a glory hole spill or release of flushing flows.

Seven (7) surface water samples will be collected will be collected from areas in the stream where flow is greatest, generally in the thalweg at about 2/3 maximum water depth. This region typically has the highest suspended sediment load. Depending on stream conditions, samples may be collected at intervals across the stream at each sampling station using "ultra-clean" sampling techniques by experienced Tetra Tech staff. Based on available data, the average total unfiltered mercury concentration in Lower Clear Creek is low, approximately 1.4 ng/L in low flow and 5 ng/L in high flow conditions (Ashley unpublished data from 2001 to 2003). These data were used to estimate the required sample size. A sample size of 7 is expected to allow detection of a difference in the mean values between the upstream and downstream stations of 50 to 60 percent of the mean with a power of 70 percent at a confidence level of 0.05, for a single sampling event (Tetra Tech 1986; Tetra Tech, Ross & Associates, and EOA, Inc. 2000).

As the number of sampling events increases, the power to detect differences will increase. After the first year of sampling, the sampling design will be re-evaluated and the number of samples adjusted as necessary.

Laboratory Analysis
Each sample will be analyzed for total mercury (filtered and unfiltered) and total suspended solids. These data will be correlated with data on flow and turbidity concurrently collected by Graham Matthews Associates. In addition, methylmercury determinations will be conducted on two (2) samples from each station to determine the relationship between total mercury, methylmercury, and particulates. In conjunction with the hydrologic and geomorphic data generated by Graham Matthews Associates, these data could be used to calculate mercury loads entering and exiting the restoration area.

Data Evaluation and Reporting
Analytical data reports, with minimal interpretation, will be provided to WSRCD after each sampling event. The associated report would consist of basic statistical analyses of the data from the sampling event and a short summary. Tetra Tech will prepare an annual report summarizing the results of all sampling conducted during the previous year. This report will provide data tables and the results of statistical analyses to assess impact of the restoration project. Recommendations for any changes in the monitoring program will also be provided. The Tetra Tech project manager will attend three (3) TAC meetings each year to present the results of the monitoring program and address any comments or proposed changes.

Costing Assumptions
The estimated costs for the three year monitoring period are $230,000. A breakdown of costs is provided in the attached table. These costs are based on the following assumptions:

1. Three year study.
2. Six sampling events per year.
3. Each sampling event takes 2 days for a field crew of 2 persons.
4. The project manager will attend 3 TAC meeting per year to report results..
5. The cost proposal does not include annual escalation in salaries or analytical costs.

Analytical costs are based on use of laboratories that have previously conducted low level mercury analyses for Tetra Tech projects. Some cost savings may be achieved by leveraging WSRCD’s status as a governmental entity to obtain better analytical costs through an alternative CalFed approved laboratory. Tetra Tech will investigate costs from alternative laboratories.

References

Ashley, R. Unpublished data. 2001 to 2003 surface water sampling results from Lower Clear Creek. USGS, unpublished data.

Pittman, S. and G. Matthews. 2004. *Clear Creek Floodplain Rehabilitation Project, Shasta County, California: WY2004 Geomorphic Monitoring Report*. Prepared for: Western Shasta Resource Conservation District, Anderson CA. Prepared by: Graham Matthews & Associates, Weaverville, CA. June 2004.

Tetra Tech. 1986. T*echnical Support Document for ODES Statistical Power Analysis*. Prepared for: Marine Operations Division, Office of Marine and Estuarine Protection, U.S. Environmental Protection Agency.

Tetra Tech, Ross & Associates, and EOA, Inc. 2000. *Task 10, Copper Action Plan*. Sponsored by: City of San Jose, and Copper Development Association.

Western Shasta Resource Conservation District
MERCURY SAMPLING IN LOWER CLEAR CREEK; SHASTA COUNTY, CA

Field Sampling

Labor Category	Fully Burdened Rate		Hours		Cost
Project Manager	$125.00		72		$9,000.00
Principal	$120.00		0		$0.00
Senior Engineer/Scientist	$100.00		360		$36,000.00
Staff Engineer/Scientist	$75.00		432		$32,400.00
Associate Engineer/Scientist	$60.00		0		$0.00
Project Administration	$80.00		36		$2,880.00
Clerical/graphics	$55.00		0		$0.00
	Labor Subtotal:		900		$80,280.00
Other Direct Costs:					
Computer Usage	$1.16	/hour			$1,044.00
Hotel and per diem	$85.00	/day	36	days	$3,060.00
Mileage and tolls (6 events)	$0.375	/mile	7056	miles	$2,664.00
Courier services	$0	/event	18	events	$0.00
		Subtotal:			$6,768.00
	G&A at	11.94%			$808.09
Total ODCs					$7576.09
		Task Total			**$87,856.09**

Laboratory Analyses

Labor Category	Fully Burdened Rate		Hours		Cost
Project Manager	$125.00		18		$2,250.00
Principal	$120.00		0		$0.00
Senior Engineer/Scientist	$100.00		0		$0.00
Staff Engineer/Scientist	$75.00		36		$2,700.00
Associate Engineer/Scientist	$60.00		0		$0.00
Project Administration	$80.00		0		$0.00
Clerical/graphics	$55.00		18		$990.00
	Labor Subtotal:		72		$5,940.00
Other Direct Costs:					
Computer Usage	$1.16	/hour			$83.52
Laboratory analyses	$ 26,760.00	/year	3	years	$80,280.00
		Subtotal:			$80,363.52
	G&A at	11.94%			$9,595.40
Total ODCs					$89,958.92
		Task Total			**$95,898.92**

Data Evaluation and Reporting					
Labor Category	**Fully Burdened Rate**		**Hours**		**Cost**
Project Manager	$125.00		192		$24,000.00
Principal	$120.00		0		$0.00
Senior Engineer/Scientist	$100.00		0		$0.00
Staff Engineer/Scientist	$75.00		120		$9,000.00
Associate Engineer/Scientist	$60.00		0		$0.00
Project Administration	$80.00		12		$960.00
Clerical/graphics	$55.00		24		$1,320.00
	Labor Subtotal:		396		$35,000.00
Other Direct Costs:					
Computer Usage	$1.16	/hour			$459.36
Hotel and per diem (conference)	$100.00	/day	6	days	$600.00
Mileage and tolls	$0.375	/mile	3828	miles	$1,468.50
Courier services	$0.00	/report	3	reports	$0.00
Copying	$0.06	/page	240	pages	$14.40
		Subtotal:			$2544.26
	G&A at	11.94%			$303.43
Total ODCs					$2847.69
		Task Total			**$37,847.69**

PROJECT TOTAL:	**$221,602.70**

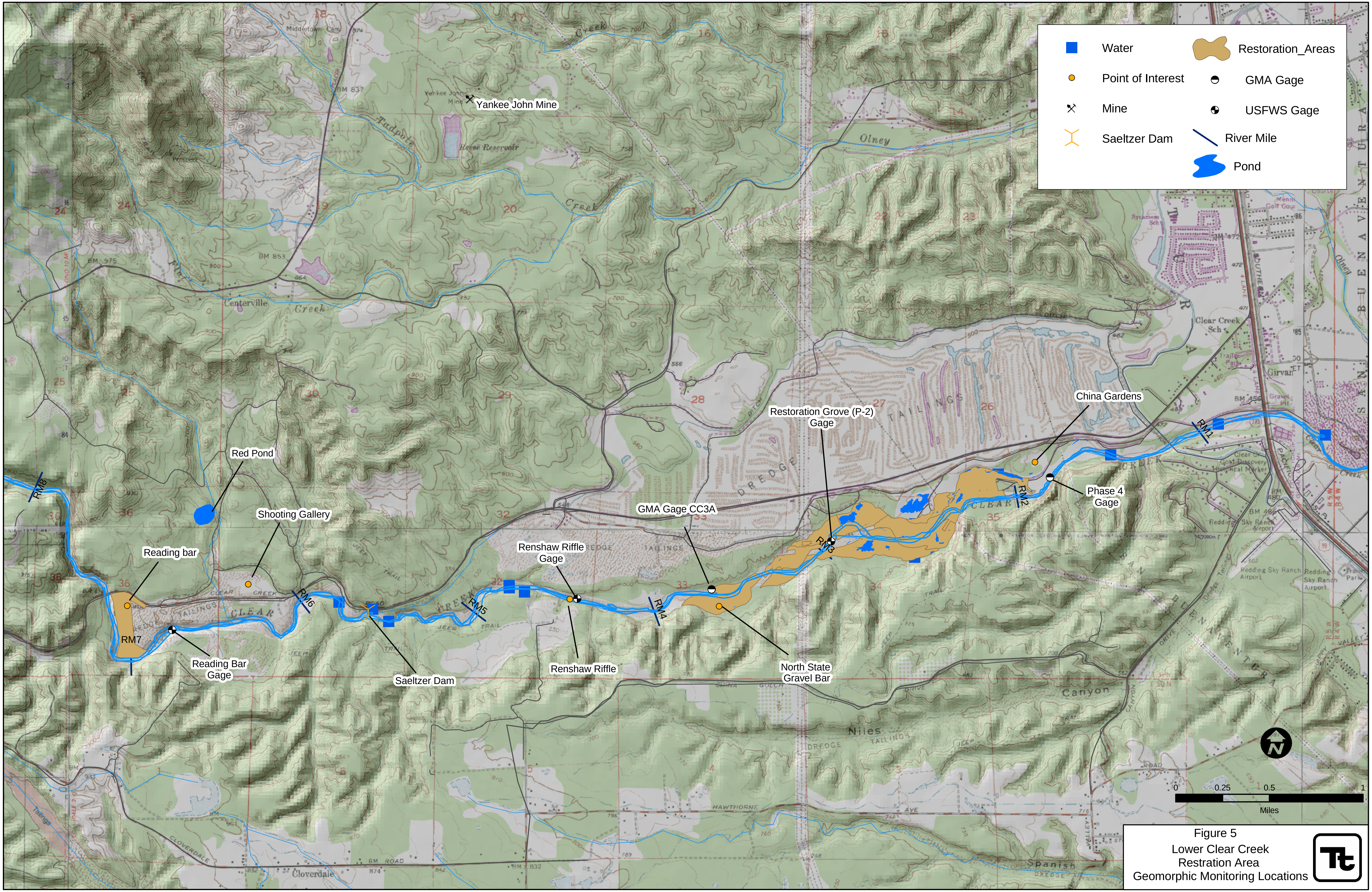


Figure 5
Lower Clear Creek
Restration Area
Geomorphic Monitoring Locations

SUMMARY SCOPE OF WORK FOR CLEAR CREEK BIOSENTINEL MERCURY MONITORING

Darell Slotton
Dept. of Environmental Science and Policy
University of California, Davis

The biosentinel approach to mercury monitoring has been recommended to the California Bay-Delta Authority (CBDA) in the Mercury Strategy as the optimal approach for measuring the key parameter of concern: relative methylmercury exposure. Young-of-year fish and certain invertebrates can provide accurate measures of this exposure through their bioaccumulation of methylmercury. Sampled carefully, these "biosentinels" can provide precise, statistically differentiable measures over time and between locations.

In the Clear Creek restoration work, as in most aquatic restorations in California, there is a need to measure the potential change in the production of methylmercury stemming from restoration actions. Monitoring of appropriate biological indicators will track the trend in relative methylmercury exposure and bioaccumulation in and around these sites.

The Environmental Mercury Laboratory at UC Davis has specialized, since 1991, in the research and monitoring of food chain methylmercury bioaccumulation. Projects have included the study of water, sediment, microbial methylmercury production, and a wide assortment of biota. Lower trophic level biota, particularly certain young-of-year fish and invertebrates, have proven to give the most useful measures of relative methylmercury exposure levels and uptake. Over the years we have refined the use of these biosentinel organisms such that we now can provide fine-scale, statistically differentiable measures of spatial and temporal variation. In research funded by CBDA, we have demonstrated strong statistical linkages between mercury levels in these test organisms and (1) mean methylmercury concentrations in the water and (2) mercury concentrations in corresponding large sport fish of human health concern. So, appropriate biosentinels sampled carefully can provide an integrated measure of local, recent aqueous exposure that also corresponds to sport fish mercury bioaccumulation. CBDA is relying on the biosentinel approach to monitor large new restoration projects throughout the Delta region. The UC Davis Slotton laboratory is developing and implementing that work. We propose to use these same techniques to monitor methylmercury exposure in relation to current and ongoing restoration efforts in the Clear Creek watershed.

US Fish and Wildlife Service has already determined that two small fish species are present across all or nearly all of the regions of focus: mosquitofish (*Gambusia affinis*) and California roach (*Hesperoleucas symmetricus*). Both can be useful biosentinels, based on prior work, particularly the California roach. These fish will be sampled at strategically located sites in and around the restoration areas. Each site sampling for each species will consist of numerous individuals to be analyzed individually and/or multiple composites, each composed of multiple individuals. This will provide extensive, tight replication sufficient to generate statistical confidence intervals around each mean mercury value. Biosentinel mercury can then be statistically compared both spatially among the carefully distributed sites, and within individual sites over time. Collections are proposed for twice each year: once toward the end of the cool season in the spring and again toward the end of the warm season in the summer or fall. Small fish biosentinels have been shown to integrate their exposure from the previous 1-6 months.

FIELD SAMPLING AND PRESERVATION TECHNIQUES

Fish will be collected with a variety of techniques including backpack electroshocker, seines, and, hand nets. Samples will be cleaned, separated by species, and frozen directly in the field in sealed Ziplock bags with water surrounding, using dry ice in field packs. With this preservation technique, virtually fresh condition has been demonstrated in samples thawed for analysis after up to at least 12 months. Small/juvenile fish samples will be analyzed whole body, either individually or in multiple composites, each containing multiple individuals. Whole body samples will be analyzed for total mercury, with methylmercury and the methyl:total mercury ratio additionally analyzed for each overall sample, using a composite prepared from equal portions of each individual or composite.

Riffle insects, if utilized, will be taken primarily with research kick screens. A variety of nets may also be used. Aquatic insect samples will be separated to the level of functional feeding group, which normally corresponds to the genus level. Each insect type will be separated into consistent multi-individual composites of whole individuals ($n \geq 30$ for small insects, $n \geq 10$ for larger insects), ideally collected in 3-4 unique replicates. The principal researchers will perform all separation of aquatic insects, ensuring proper taxonomic identification. Aquatic insect samples will be carefully cleaned of any surficial sediment directly at the collection site, using a technique of multiple transfers, with shaking, into successively cleaner water baths. Size range (length) will be determined and individual insects will be counted into pre-weighed, clean vials, one for each composite. Continuing at streamside, excess water will be consistently removed by inverting the vials over laboratory tissues. Average fresh/wet weight of the insects can then be later determined in the laboratory through weighing. All aquatic insect composite samples will be analyzed for methylmercury in addition to total mercury. Biotic samples of all types will be transported frozen on dry ice to the UC Davis Environmental Mercury Laboratory for analytical work

ANALYTICAL METHODOLOGY

Biological samples will be prepared and analyzed for total and methyl mercury at the UC Davis Environmental Mercury Laboratory. Small/juvenile fish samples will be analyzed whole body, individually or as multi-individual, whole body composites. Aquatic insects will be analyzed as multi-individual, whole body composites. The invertebrate multi-individual composites and whole small fish samples will be analyzed as dry powders for consistency. Moisture percentage will be carefully determined, through sequential weighings, to allow conversion to fresh/wet weight concentrations. Samples will be dried to constant weight at 55 °C and ground to a fine powder with either a modified coffee grinder (small fish) or Teflon-coated tools (invertebrates). Dry powder samples have proven ideal for reproducibility, sample archiving, and availability for ancillary analyses such as carbon and nitrogen stable isotopes.

Samples will be analyzed for total mercury by UC Davis with standard cold vapor atomic absorption (CVAA) spectrophotometry, using a Perkin Elmer Flow Injection Mercury System (FIMS) with an AS-90 autosampler, following digestion under pressure at 90 °C in a mixture of concentrated nitric and sulfuric acids with potassium permanganate. The detection limit for this method is typically 0.005 µg/g. The methyl:total mercury ratio will also be assessed for whole small fish and aquatic insect composite samples.
Methylmercury will be analyzed by UC Davis by complexation with bromide in a copper sulfate / sodium bromide solution, followed by organic extraction into methylene chloride / hexane, and then acid digestion and FIMS CVAA analysis as for total mercury. The detection limit for this method is typically 0.005 µg/g.

Moisture percentages will be determined using standard drying and sequential weighing technique.

QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

A rigorous program of QA/QC will be utilized throughout the project to ensure that accurate data are being generated. Standard field, preparatory, and analytical QA/QC will include the collection of numerous field replicate samples, careful preservation and assessment of actual moisture percentages of biotic samples, and extensive analytical split samples, spikes, spike replicates, calibration samples, blanks, laboratory control samples, and a range of standard reference materials with certified total mercury and methylmercury contents. Individuals of the same type and length, or replicate multi-individual composites function as field replicate samples for the analysis of sample organism variability at each sampling site. QA/QC samples are primarily tracked through the use of control charts, with warning limits set at two standard deviations away from the mean and control limits set at three standard deviations away from the mean. Samples will be preserved prior to analysis in carefully monitored laboratory freezers and refrigerators. Archived dry powdered samples will be maintained in individually labeled and tracked vials.

DATA REDUCTION

Following QA/QC verification, replicate sample data (individual small fish, replicate multi-individual fish composites, and replicate multi-individual insect composites) will be analyzed statistically by determining mean concentrations and 95% statistical confidence intervals for each type from each site-sampling. These shall be compared between corresponding samples from the different sites to assess statistical separation or similarity.

UC DAVIS BUDGET
CLEAR CREEK MERCURY MONITORING

Year	Salary	Benefits	Travel	Supplies	Service Contracts	Equipment	Total Direct	Indirect	TOTAL
1	$17,099	$5,985	$500	$1,500	$2,500		$27,584	$6,896	$34,480
2	$17,612	$6,164	$500	$1,500	$2,600		$28,376	$7,094	$35,470
3	$18,140	$6,349	$500	$1,500	$2,700		$29,189	$7,297	$36,487

Total 3 year budget: $106,437

LABOR	Labor costs = 0.35 FTE each year. Positions are 1) Principal Investigator (0.1 FTE); 2) Lab/Field/Data Manager (0.1 FTE); 3) Chemist(s) (0.15 FTE). Benefits are included at 35% of salaries.
TRAVEL	Travel costs include mileage reimbursements for use of personal vehicles for sampling, reconaissance, coordination, and presentations.
SUPPLIES	Includes supplies for field collections, sample handling and preparation, laboratory analytical work, computer and office work, publications, and presentations.
SERV. CONTRACTS	Primarily charges to accomplish 5% QA/QC split sample analyses by outside laboratory.
INDIRECT COSTS	CBDA indirect rate has been negotiated at 25%. Substantially higher indirect rate if not through CBDA.

I) Biological/Ecological Project Objectives For Avian Resources.

OBJECTIVE/HYPOTHESIS	MONITORING PARAMETER (S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH	MONITORING AGENT, COMMENTS, STUDY PRIORITY	FUNDING
Objective A1: Create a functional riparian system during stream channel and floodplain restoration that supports highly productive populations of native avian species. Hypothesis A1: The revegetation phase and riparian floodplain dynamics created during channel and floodplain restoration will increase the productivity of a suite of riparian focal species above reference site levels.	Locate and monitor nests of a suite of riparian breeding bird species using established nationally standardized protocols. Vegetation data will be collected around each nest in order to link habitat features influencing nest success. Both restoration and reference sites will be monitored for 5 to 10 years post restoration.	The number of young produced per territory and/or Mayfield estimates of nest success at restoration and reference sites will be compared to determine productivity. Logistic regression will be used to evaluate the influence of habitat conditions on productivity and associate age of restoration with productivity.	PRBO High Priority	CALFED Monitoring PSP will fund all of the avian monitoring.
Objective A2: Create a functional riparian system during stream channel and floodplain restoration that supports higher densities of a suite of riparian breeding species than reference sites. Hypothesis A2: The revegetation phase of channel and floodplain restoration will increase the breeding densities of a suite of avian focal species on restoration sites over those of reference sites.	Map the breeding territories of a suite of focal bird species using established protocols at restoration and reference sites for 5 to 10 years post restoration.	Using standardized data of number of territories per 10 hectares we will compare the breeding densities on restoration sites to adjacent reference sites. Additionally, the change in densities and rate of change will be compared between restoration sites with different restoration design and features.	PRBO High Priority	

Objective A3: Create a functional riparian system during stream channel and floodplain restoration that supports high annual adult survival of a suite of riparian breeding species. Hypothesis A3: The creation of a functional riparian system will result in higher adult survival of a suite of riparian focal species.	Constant-effort mist netting following nationally standardized protocols will be conducted over a 5 to 10 year time frame to estimate adult annual survival for a suite of riparian breeding bird species at two sites at Clear Creek (conducted for 5 years through 2005).	Using the program MARK we will use Akaike's Information Criteria (AIC) to select the most appropriate model to estimate adult annual survival. Survival estimates will help refine objectives for nest success and provided a key component necessary for determining if breeding bird populations are sustainable at Clear Creek.	PRBO High Priority	
Objective A4: Create a functional riparian system during stream channel and floodplain restoration that supports a high diversity of riparian breeding bird species. Hypothesis A4: Restoration activities will result in restored sites combined supporting avian species richness equal to or above those levels of reference sites combined.	Using a nationally standardized point count protocol collect point count data throughout the project area at restoration and reference sites that have been monitored since 1999.	Using point count indices of species richness and/or ecological diversity we will compare treated sites and reference sites using one of several potential comparative statistical methods. We will also use linear regression to associate year since restoration with avian species richness.	PRBO High Priority	

II) Biological/Ecological Project Objectives for Geomorphology.				
OBJECTIVE/HYPOTHESIS	MONITORING PARAMETER (S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH	MONITORING AGENT, COMMENTS, STUDY PRIORITY	FUNDING
Objective G1: Recreate a properly sized alluvial channel morphology. Hypothesis G1: Coarse sediment will be mobilized by design bankfull flow (the bed moves)	The monitoring parameter will be percentage of tracer rocks mobilized for different alluvial features (point bars, riffles, pool tails, etc). Tracer rocks will be installed on at least two point bars and two riffles within the project reach, and monitored for mobilization and distance after each discrete high flow event sufficient to cause mobilization.	Tracer rocks will be evaluated by: 1) whether they moved, and 2) how far they moved. The former will allow us to evaluate whether the bed is mobilized by design bankfull discharge, and the latter will provide information on particle travel distance as a function of flow and duration of flow.	WSRCD Will allow designers to improve bankfull channel design for later projects. Moderate priority	Currently CVPIA, CALFED is anticipated future source.
Objective G2: Recreate a properly sized alluvial channel morphology. Hypothesis G2: The bankfull channel will migrate or avulse during flows approaching bankfull discharge and larger (the channel migrates)	The monitoring parameter will be bankfull channel location within the valley-wide cross section, and planform location over time. Cross sections will be installed throughout two alternate bar sequences (targeting meander bends). Post-construction aerial photographs will be rubber-sheeted and channel location digitized and overlain on previous channel locations.	Migration or avulsion of the bankfull channel will be evaluated by comparing channel response (feet moved, rate of movement) with the magnitude and duration of flow that caused the channel to migrate.	WSRCD Much of this will be collateral information gathered with other geomorphic monitoring activities. Moderate priority	Currently CVPIA, CALFED is anticipated future source
Objective G3: Recreate a properly sized alluvial channel morphology. Hypothesis G3: Flows exceeding design bankfull discharge will begin inundating constructed floodplains.	The monitoring parameter will be water surface elevation within the bankfull channel, and flow discharge for that water surface elevation. At one site assessable during high flows at the project site and borrow site water surface elevations will be predicted during the design phases, and elevations will be measured	Measured water surface elevations will be compared to constructed floodplain elevations, and hydraulic parameters will also be collected to refine hydraulic model.	WSRCD Will allow designers to improve bankfull channel design for later projects. Moderate priority	Anticipated CALFED Grant

II) Biological/Ecological Project Objectives for Geomorphology.				
OBJECTIVE/HYPOTHESIS	MONITORING PARAMETER (S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH	MONITORING AGENT, COMMENTS, STUDY PRIORITY	FUNDING
	during high flow events after construction.			
Objective G4: Recreate a properly sized alluvial channel morphology. Hypothesis G4: Flows exceeding design bankfull discharge will begin depositing fine sediments (sand and silt) on constructed floodplains	The monitoring parameter will be water surface elevation within the bankfull channel, flow discharge for that water surface elevation, and fine sediment deposition on floodplains At one site accessible during high flows at the Borrow Site and Project Site water surface elevations will be measured during high flow events after construction, and a depth flow threshold for fine sediment deposition will be sought.	Water surface elevations will be compared to constructed floodplain elevations (to get water depths); then, fine sediment deposition will be measured by cross sections and scour nails, and sediment composition will be documented by bulk substrate sampling. The source of the high flow (tributary derived vs dam spill) will be considered and when feasible (safe), depth integrated suspended sediment samples will be collected and analyzed for particle size distribution.	WSRCD Fine sediment deposition on floodplains is critical for natural riparian regeneration. There may also be significant depositional differences between tributary generated flood events and dam generated flood events. Moderate priority	Anticipated CALFED Grant
Objective G5: Raise channel above bedrock hardpan, increasing alluvial storage within the bankfull channel. Hypothesis G5: Subsequent high flows and reductions in sediment supply upstream available upstream of the project will cause bankfull channel to begin incision.	Longitudinal thalweg surveys. Bedrock contacts along the proposed channel centerline will be surveyed as part of the design phase, as-built channel thalweg will be surveyed to document elevation above bedrock contacts, and subsequent surveys will track whether (and how much) incision occurs after specific high flow events that exceed bed mobility thresholds	Compare longitudinal profiles and cross sections prior to and after high flow events to determine patterns of aggregation and deposition.	WSRCD Without removing Saeltzer Dam and/or manually adding coarse sediment, reconstructed channel not controlled by bedrock will again begin to incise during high flow events large enough to transport coarse bed material. This monitoring will document where incision occurs and how much. Moderate priority	Anticipated CALFED Grant

II) Biological/Ecological Project Objectives for Geomorphology.				
OBJECTIVE/HYPOTHESIS	MONITORING PARAMETER (S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH	MONITORING AGENT, COMMENTS, STUDY PRIORITY	FUNDING
Objective G6: Recreate a properly sized alluvial channel morphology with adequate coarse sediment supply. Hypothesis G6: As the bankfull channel migrates, coarse and fine sediments will deposit on the inside of meander bend, creating a new functional floodplain.	The monitoring parameter will be bankfull channel width, bankfull channel depth, and perhaps estimates of bankfull channel boundary shear stress. These parameters will be obtained from cross sections installed throughout two alternate bar sequences (targeting meander bends.)	Evolution of cross section shape, dimensions, and perhaps boundary shear stress will be documented before and after discrete high flow events. Channel adjustment will also be considered in light of changing sediment loads, high flow magnitude, and high flow duration.	WSRCD Much of this will be collateral information gathered with other geomorphic monitoring activities. Channel dimension evolution will be used to improve future channel designs. Moderate priority.	Currently CVPIA, CALFED is anticipated future source.

Lower Clear Creek Floodway Rehabilitation Project
Riparian Revegetation Goals and Objectives Monitoring Table

OBJECTIVE/HYPOTHESIS	QUANTIFIED OBJECTIVES	MONITORING PARAMETER(S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH
Objective R1: Restore native woody riparian vegetation on newly created floodplain surfaces.	Attain a minimum survival rate of 50% of the plantings (defined as a planting space) after 3 growing seasons. Attain an average woody riparian planting height of 3 meters after 5 growing seasons. Produce an average woody riparian planting canopy cover of 20% in 5 years. Produce an average canopy cover of 100% in ten years on the floodplains for woody riparian plantings combined with native woody recruits.	Monitor the survival and productivity of the primary succession species for the first 5 years. Monitor survival and productivity of the secondary succession species for the next five years Monitor productivity of the primary succession species again at 10 years.	<u>Row Transects:</u> Establish and map fixed belt transects along randomly selected planting rows on the constructed floodplains. Monitor planting survival, canopy cover and height.
Objective R2: Create favorable physical conditions for regeneration of native woody riparian plant species on restored floodplains.	Produce an average canopy cover of 50% after 5 years in the scour channels of natural recruitment of native woody riparian plant species (**including non-native blackberry**). Produce an average canopy cover of 100% in ten years for woody riparian plantings combined with native woody recruits (**including non-native blackberry**) on the floodplains.	Monitor the number and canopy cover of woody plant species recruitment on the floodplains for 5 years. Monitor canopy again at 10 years. Monitor the canopy cover of woody plant species recruitment in the scour channels for 5 years. Monitor canopy again at 10 years.	<u>Row Transects:</u> Establish and map fixed belt transects along randomly selected planting rows on the constructed floodplains. Monitor number, height and canopy cover of woody recruited plants. <u>Scour Channel Transects:</u> Establish fixed linear transects at regular intervals along the scour channels. Monitor cover of woody recruited plants using a line-intercept method.

Lower Clear Creek Floodway Rehabilitation Project
Riparian Revegetation Goals and Objectives Monitoring Table

OBJECTIVE/HYPOTHESIS	QUANTIFIED OBJECTIVES	MONITORING PARAMETER(S) AND DATA COLLECTION APPROACH	DATA EVALUATION APPROACH
Objective R3: Restore native perennial herbaceous vegetation on newly created floodplain surfaces.	Attain a frequency ratio of 3:1 of native:non-native plants on the constructed floodplains after 10 years (5 years after herbaceous planting).	Monitor the frequency of native to non-native herbaceous plant species on the floodplains for 5 years following the initiation of an herbaceous planting program.	<u>Row Transects:</u> Establish fixed location quadrats along row transects on the constructed floodplains. Monitor frequency of herbaceous plant species occurrence.
Objective R4: Create favorable physical conditions for regeneration of native herbaceous plant species on restored floodplains.	Attain a frequency ratio of 3:1 of native:non-native plants in the scour channels after 5 years.	Monitor the frequency of native to non-native herbaceous plant species in the scour channels for 5 years. Monitor frequency again at 10 years.	<u>Scour Channel Transects:</u> Establish fixed location quadrats along scour channel transects. Monitor frequency of herbaceous plant species occurrence.
Objective R5: Reduce non-native species encroachment on rehabilitated floodplains	Eliminate colonies of target non native invasive weeds	Survey project footprint and surrounding areas for the presence of non native invasive weeds.	<u>Conduct Invasive Weed Surveys:</u> Complete weed surveys every three years and monitor established colonies
Objective R6; Create favorable conditions for the regeneration of native wetland species in areas to promote no loss of total wetland	Attain a replacement ratio of 1:1 for wetland losses as a result of floodplain restoration	Measure the total wetlands created through restoration of floodplains and channel rehabilitation	Delineation of waters of the U.S., including wetlands will be conducted in accordance with the 1987 *Corps of Engineers Wetlands Delineation Manual*

Biological/Ecological Project Objectives For Fisheries Monitoring

RESTORATION ACTION	GOAL	QUANTITATIVE OBJECTIVE	HYPOTHESES	PERFORMANCE MEASURE(S) & MONITORING METHOD	LINKS TO OTHER PROGRAMS
3a: Stream channel reconstruction (Lower Clear Creek Floodway Restoration Project) SCALE = 1-10 & 10-10^2 channel widths	**F5**:Improve the quantity and quality of salmonid spawning habitat. **F6**: Improve the quantity and quality of juvenile rearing habitat.	**F5-A**: Attain at least a 200% increase in spawning habitat use, over baseline period. **F5-B**: Attain egg survival-to-emergence (STE) equal to or greater than outside the project reach. **F6-A**: Channel features designed to provide juvenile habitat will be retained for >5 years and will be utilized at levels >100% above average densities in control reaches. **F6-B**: Attain average juvenile densities in the reconstructed channel that equal or exceed levels in control reaches.	**F5-A**: Channel reconstruction will increase spawning habitat use by Chinook. **F5-B**: Channel reconstruction will result in above average STE. **F6-A**: Channel features designed as rearing habitat will contain relatively high densities of juvenile Chinook. **F6-B**: Mean juvenile densities in the reconstructed channel	**F5-A**: Spawning habitat use (surface area of redds/redd aggregates) as measured by redd mapping (over a 10 year period). [TASK 2.2] **F5-A:** Weighted Usable Area as predicted by "River2D" hydraulic modeling. Use redd mapping to validate model. [TASK 9, 10] **F5-B**: STE rates for Chinook eggs hydraulicly placed in artificial redds and gravel quality parameters (e.g. temperature, bed scour, permeability, DO, Nitrogenous waste, and % fines). [TASK 6] **F6-A&B** : Density of juvenile Chinook as measure by direct observation (habitat use) surveys. [TASK 5] **F6-B**: Weighted Usable Area as predicted by "River2D" hydraulic modeling. [TASK 9, 10]	**F5-A**: EWP (Goal 2, Obj' a) **F5-B**: CCDAM (5.2.3) **F5-B:** EWP (Goal 2, Obj' e)

Biological/Ecological Project Objectives For Fisheries Monitoring

RESTORATION ACTION	GOAL	QUANTITATIVE OBJECTIVE	HYPOTHESES	PERFORMANCE MEASURE(S) & MONITORING METHOD	LINKS TO OTHER PROGRAMS
		F6-C: Attain aquatic macro-invertebrate prey densities in the reconstructed channel at 1) levels >100% above densities in clay hard-pan channel areas and 2) levels greater than densities in natural riffles.	will be greater than in control reaches. **F6-C**: Spawning gravel lining reconstructed channel reaches will increase the production & diversity of macro-invertebrate food sources for juvenile Chinook.	**F6-C**: Invertebrate production, density & diversity and ratio of predation susceptible to unsusceptible inverts. Measured by standard sampling methods. [TASK 7] **F6-C**: Analyze stomach contents of juvenile Chinook to confirm which invertebrates are prey species. [TASK 7]	**F6-C**: EWP (Goal 2, Obj' e) **F6-C**: CC AMF rpt
RESTORATION ACTION	**GOAL**	**QUANTITATIVE OBJECTIVE**	**HYPOTHESES**	**PERFORMANCE MEASURE(S) & MONITORING METHOD**	**LINKS TO OTHER PROGRAMS**
3b: Floodplain reconstruction (Lower Clear Creek Floodway Restoration Project)	**F6**: Improve the quantity and quality of juvenile rearing habitat.	**F6-A**: Designed floodplain scour channels will provide seasonal juvenile rearing habitat. **F6-B**: Determine which of 3 scour channel designs provides the most	**F6-A**: Scour channels, during the wet season, will provide suitable habitat for and be used by juvenile salmonids.	**F6-A&B**: Fish density, water temperature/depth/velocity, stranding/isolation (connectivity), presence of predators, duration and quantity of wetted area, and dissolved O_2 as measured during electrofishing & seining surveys. [TASK 12]	CVPIA CBDA CBDP milestone 59

Biological/Ecological Project Objectives For Fisheries Monitoring

RESTORATION ACTION	GOAL	QUANTITATIVE OBJECTIVE	HYPOTHESES	PERFORMANCE MEASURE(S) & MONITORING METHOD	LINKS TO OTHER PROGRAMS
SCALE = 1-10 & 10-10^2 channel widths	**F7**: Reduce juvenile salmonid stranding on floodplains. **F8**: Improve adult upstream passage conditions through the project reach.	suitable habitat for juvenile salmonids based on fish density and environmental conditions. **F7**: Reconstructed floodplains will reduce juvenile stranding to levels at or below levels found on nearby floodplains. **F8**: Eliminate stranding and passage hindrances for adult Chinook in the project reach.	**F6-B**: The 3 scour channel designs are not equally suitable for juvenile salmonids. **F7**: Juvenile stranding rates on constructed floodplains will be lower than on nearby floodplains. **F8**: Filling of gravel mining pits in the floodplain will eliminate passage problems for adult salmon through the project reach.	**F7**: Stranding rate (fish/m^2) as measured by floodplain stranding surveys. [TASK 11] **F8**: Objective met. No stranding or passage problems remain. No monitoring needed.	**F7**:CBDP milestone 71 **F8**:CBDP milestone 67

Appendix IV

Channel Construction Design Document

LOWER CLEAR CREEK
FLOODWAY REHABILITATION PROJECT

Channel Reconstruction, Riparian Vegetation, and Wetland Creation Design Document

Prepared for:

Clear Creek Restoration Team

Contemporary peer reviewers

Future project evaluators

Prepared by:

McBain and Trush
P.O. Box 663
Arcata, CA 95518

Graham Matthews
P.O. Box 1516
Weaverville, CA 96093

North State Resources
5000 Bechelli Lane, Suite 203
Redding, CA 96002

30 August 2000

This page intentionally left blank

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The Lower Clear Creek Floodway Rehabilitation Project will rehabilitate two degraded reaches of Clear Creek (Figures 1 and 2): a 1.9 mile reach (Project Reach) extensively mined for aggregate and a 1.0 mile reach (Reading Bar Reach) containing dredger tailings to be used as borrow materials at the Project Reach. In addition, two off-channel sites (Gallery and Old Mill borrow sites) will be restored as wetland/riparian habitat following removal of borrow materials for the Project Reach. This document will present quantitative rehabilitation objectives, an approach to achieve these objectives, and design procedures for Phases 2-4 of the lower Clear Creek rehabilitation project.

At the Project Reach, extensive in-channel and floodplain aggregate extraction removed natural channel confinement, natural point bars, floodplains, and riparian vegetation, leaving an unconfined floodway with multiple low-flow channels and numerous large pits. The pits and lack of a defined channel strand adult salmonids returning from the ocean to spawn and juvenile salmonids emigrating to the ocean. The Reading Bar Reach, also placer mined and dredged for gold in the 19th and early 20th century, has a severely damaged channel morphology.

The Project Reach is the only section of lower Clear Creek that has been extensively mined for instream aggregates. The resulting degraded channel morphology is a significant stressor to anadromous salmonid production in lower Clear Creek, including spring-run, fall-run, and late fall-run chinook salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss*). This high priority rehabilitation activity has been identified in numerous restoration documents, including the Lower Clear Creek Watershed Analysis (BLM/RCD 1995), AFRP Working Paper (USFWS 1995), and CALFED Strategic Plan (1999).

This project will not only benefit salmonids; the project will rehabilitate form, function, and structure for the Clear Creek channel and the adjoining floodplain, native flora and fauna should benefit as well. For example, as restored patches of cottonwoods mature, cavity nesting birds will begin utilizing these patches. A variety of native species will utilize early successional willow patches created within a dynamic channel morphology. The floodway design presented below is a work in progress; the channel location and dimensions are based on our current understanding of how the system works. As we gain more geomorphic information and improve our revegetation implementation methods, we expect the channel design to evolve as we incorporate these improvements.

2. BACKGROUND

River channel restoration is a relatively recent and rapidly expanding field. The recent literature documents many ecologically-based channel and wetland restoration projects, almost all completed since the early 1980s. Many of these projects, particularly those in Europe, have involved restoration of natural meanders in a channelized reach (Binder et al. 1983, Brookes 1987, Jungwirth et al. 1995, Toth 1996, Brookes and Shields 1996, Olsen 1996). Recent projects in the United States that attempt to restore natural function include the Blanco River in Colorado, Greenhorn Creek in Plumas County, California, the Wood River in Klamath County, Oregon, the Kissimmee and St. Johns Rivers in Florida, and many others.

Many of these restoration projects are in lowland areas with low stream gradients, where historical information indicates a sinuous, meandering channel existed prior to straightening and channelization. Some projects have been implemented after catastrophic floods, where restoration actions were intended to jumpstart the natural recovery process. Other projects attempt to either stabilize the stream (bank protection, grade control structures) or assume that it is a static system. These projects often fail to accommodate the naturally dynamic nature of the river. Lower Clear Creek is blessed because most of the lower corridor is under public ownership, therefore the need to protect structures (homes, bridges) from flood damage is virtually non-existent. This project offers the rare opportunity to design and encourage a dynamic channel, one that not only transports coarse sediment, but one that can freely migrate between valley walls. This ability is incorporated into our rehabilitation approach and objectives.

3. HISTORICAL EVOLUTION OF LOWER CLEAR CREEK

Beginning with the discovery of gold at Reading Bar in 1848, lower Clear Creek has undergone significant changes due to land use. Various forms of gold mining transformed the natural landscape into piles of placer, hydraulic, and dredger tailings. In most locations, the entire floodway was "turned upside down" in the search for gold. Gold mining also brought secondary impacts to the creek, including roadbuilding, deforestation, and urban development. Dredger tailings adjacent to the creek between Saeltzer Dam and Clear Creek Bridge are the most pronounced relics of historic gold mining activity, with the tailings confining the river and providing very little value as floodplain or riparian habitat. Saeltzer Dam was constructed in the early 1900's for diverting irrigation water, which also blocked upstream access by migrating salmonids and trapped coarse sediment from upstream sources.

The next significant impact to lower Clear Creek was the Trinity River Division of the Central Valley Project. Completed in 1963, Whiskeytown Dam and reservoir trapped coarse sediment, but more importantly, greatly reduced the volume and magnitude of historic flows. Reducing the magnitude and frequency of high flow events responsible for creating and maintaining lower Clear Creek allowed fine sediment to accumulate in the channel and allowed riparian vegetation to establish and mature along the low flow channel. As the vegetation matured, the combined root strength of the riparian band "fossilized" gravel deposits and reduced the quantity and quality of aquatic habitat. Salmonids, aquatic invertebrates, and other aquatic species are more productive if gravel deposits have fewer fine sediments (e.g., fine sediment in salmon spawning gravels reduces egg-to-emergence survival by reducing oxygen delivery and metabolic waste removal).

The last significant impact to lower Clear Creek was instream and off-channel gravel mining, occurring from 1950 to 1978. In the short reach where instream mining occurred (from river mile 2.2 to 3.8), several hundred thousand cubic yards were removed from the floodway. Impacts to channel morphology and salmonid habitat were significant; the bankfull channel was destroyed and floodplains removed, leaving wide shallow channels and interspersed deep pits. Destroyed channel morphology reduced sediment routing through the reach. Excessive gravel removal exposed a clay hardpan over much of the channel bottom, directly removing salmonid spawning and fry rearing habitat. Salmon and steelhead spawn in gravel and cannot spawn on clay hardpan. Equally important was the lost channel confinement, allowing both adult and juvenile salmonids to stray into adjacent pits and be stranded.

The cumulative impacts of these land uses are summarized as follows:

1. <u>Simplification of channel morphology.</u> Comparing 1937 and 1997 channel locations shows a distinct trend of channel straightening, which has resulted in fewer and shallower pools, and longer riffles (Figure 3).
2. <u>Downcutting of channel.</u> Gravel extraction and upstream blockage of coarse sediment supply has caused Clear Creek to downcut to the clay hardpan in many locations, particularly at the proposed rehabilitation site. Low flow water surface profiles in 1937 and 1997 show local downcutting over 5 feet (Figure 4). This process has converted much of the channelbed surface from gravels and cobbles to exposed clay hardpan. Exposed cobbles and gravels characteristic of a low gradient alluvial channel provides high quality aquatic habitat; loss of gravels and cobbles, and conversion to exposed clay hardpan, greatly reduces salmonid spawning and fry rearing habitat.
3. <u>Loss of a defined bankfull channel and floodplain.</u> Gravel extraction physically removed any semblance of a defined bankfull channel and floodplain, leaving the stream with deep pits and multiple low-flow channels. Figure 5 and 6 shows sequential aerial photographs for (a) the upstream end of the project reach and (b) the middle of the project reach for the years 1952, 1963, 1981, and 1984. Similar views in 1997 are shown in Figure 7. Photos from 1952 and 1963 document a significantly different channel from the post-dam and instream mining time period. The 1963 photo shows a channel recently exposed to the Dec 1955 and Feb 1958 floods (about 40-year and 15-year events, respectively). These historical photos show wide expanses of exposed gravels and cobbles, with riparian vegetation as patches associated with high flow scour channels and floodplains. The 1981 and 1984 photos illustrate the impact of gravel extraction in the project reach, and the response of the 1983 flood to the gravel extraction reach. The 1997 photo shows pre-rehabilitation project conditions; the only difference between the 1997 photo and current conditions is implementation of Phase 1 of this project in the fall of 1998, isolating the southern pond in the upper image of Figure 7.

This project seeks to reverse these negative impacts by reconstructing a properly sized channel morphology in lower Clear Creek, as well as improving habitat in adjacent sites that will provide construction materials for the instream portion of the project. Proper design of the instream portion of the project requires a more thorough evaluation of primary factors that create and maintain channel morphology. Much of this evaluation has been performed in several technical memoranda previously prepared by the design team, as well as substantial new analyses. These reports include:

(1) Lower Clear Creek hydrologic evaluation technical memorandum (April 1998)
(2) Lower Clear Creek bedload transport measurements-technical memorandum for WY 1998 (May 1999)
(3) Lower Clear Creek Floodway Rehabilitation Project – Specifications package for Phase One design(May 1998)
(4) Lower Clear Creek Floodway Rehabilitation Project – CALFED Grant Application for Phase 2-4 (July 1998)
(5) Lower Clear Creek Floodway Rehabilitation Project – Conceptual rehabilitation plan (May 1999)

Information contained in these reports and documents is only summarized as necessary rather than repeated. If the reader wishes to obtain these documents from the Clear Creek Restoration Team, please contact Mr. Jim Destaso, US Bureau of Reclamation, 16349 Shasta Dam Blvd, Shasta Lake, CA 96019.

4. SITE DESCRIPTION

Clear Creek originates in the Trinity Mountains, and flows south between the Trinity River basin to the west and the Sacramento River basin to the east, and ranges from over 6,000 ft elevation at Shasta Bally to 400 ft elevation as it joins the Sacramento River. The lower section of Clear Creek flows south from Whiskeytown Dam for approximately 8 miles, then flows east for 8 miles before joining the Sacramento River five miles south of Redding. The primary gaging station on Clear Creek is 8 miles downstream of Whiskeytown Dam (Clear Creek near Igo), with a drainage area of 228 mi^2. The unregulated drainage area between Whiskeytown Dam and the confluence with the Sacramento River is 48.9 mi^2.

Clear Creek is part of the Trinity River Division of the Central Valley Project, and streamflows have been regulated by Whiskeytown Dam since May 1963. Trans-basin diversion from the Trinity River through Judge Francis Carr power plant to Whiskeytown Lake began in April 1963. Diversions from Whiskeytown Lake to the Sacramento River via Spring Creek tunnel into Keswick Reservoir began in December 1963.

The climate in the Clear Creek watershed is Mediterranean, with most precipitation occurring in the winter months (November through April) and dry summers with temperatures exceeding 100 degrees Fahrenheit. Average annual precipitation in the Clear Creek watershed varies from 20 inches near the confluence with the Sacramento River to over 60 inches in the upper watershed. Precipitation is primarily rainfall, with snow occurring at the highest elevations of the watershed.

As introduced in the previous section, there are several damaged reaches of lower Clear Creek, the primary being the instream gravel mining reach from river mile 2.2 to 3.8. Instream gravel mining removed much of the gravel from the floodway in this reach, leaving large instream pits and a wide, shallow floodway. Rehabilitation will require substantial fill to recreate a defined channel and floodplain. Fill material will be borrowed from two upstream sites: Reading Bar and the Former Shooting Gallery (Gallery), (Figure 2). The benefit of using local borrow sites is that fill can be removed in a way to restore borrow sites as well as the project site; in effect, restoring four sites for the price of one. Each site has unique project components and rehabilitation objectives, which are listed below:

Project site: Rehabilitate 1.5 miles of Lower Clear Creek from river mile 2.2 to 3.8, including reconstructing the bankfull channel, reconstructing the floodplain by filling in mining pits, and planting riparian vegetation on reconstructed floodplain surfaces. Primary design issues are channel geometry, planform geometry, riparian revegetation, integrating riparian revegetation into topographic design, and integrating aquatic habitat needs into topographic design. Four phases are identified, with Phase 1 completed in Fall 1998, Phase 2 commencing in Fall 1999, and Phase 3 and 4 completed after 2001. Phase 1 and 2 focus on filling mining pits and recreating floodplains, while Phase 3 and 4 focus on channel relocation and reconstruction.

Reading Bar: Primary borrow site to implement Phase 2 at the Project Reach. As dredger tailings are removed, the left bank of lower Clear Creek will be returned a functional floodplain from river mile 7.8 to 8.4, and a small wetland outside of the contemporary floodway will be created. The floodplain will be planted with native riparian vegetation, and the off-channel wetland will be planted with native emergent vegetation.

Former Shooting Gallery (Gallery): Primary borrow site to implement Phase 3 and 4 at the Project Reach. As dredger tailings are removed, the former shooting range will be converted to a complex off-channel wetland complex. Portions of the off-channel wetland will be planted with native emergent wetland vegetation to evaluate natural vegetation recruitment success versus planted wetland vegetation efforts. Dredger tailings in the gulch area will be removed down to an elevation near the winter groundwater table and replanted with native riparian vegetation.

5. REHABILITATION APPROACH AND OBJECTIVES

The goal of the Lower Clear Creek Floodway Rehabilitation Project is to rehabilitate the natural form and function of the channel and floodplain, which includes increasing riparian vegetation, increasing the quantity and quality of salmonid habitat, and increasing the quantity and quality of terrestrial riparian habitats. To achieve these goals, the project will reconstruct selected reaches of the lower Clear Creek channel, improve fish passage, spawning, and rearing habitat, extensively plant riparian vegetation, and create off-channel wetlands for waterfowl and other wetland species. This project is being planned within the context of watershed-level rehabilitation and management planning under the Lower Clear Creek Coordinated Resource Management Program (CRMP). Other significant CRMP projects include removing or modifying Saeltzer Dam, introducing spawning gravels into lower Clear Creek, implementing erosion control programs, and reducing fuels within the watershed. Funding for the project comes from several sources, and the objectives of those funding sources are described below.

and bareroot plant stock will require irrigation for the first three years to allow roots to grow down to the water table. A drip irrigation system should be installed to the plant series with container stock. Each plant should have two emitters, emitting a half-gallon of water an hour. Once installed, container stock should be watered for an entire day once every other week from June to October. Irrigation times will gradually be decreased over the three-year period to wean plants from irrigation. If needed, drip irrigation systems will be installed at both the project and borrow sites.

7.4.5. Plant protection

Newly planted riparian vegetation provides a succulent food source for many herbivores so revegetated areas may have to be protected, primarily from deer and beaver browsing. Other small mammals and insects may browse some plants, but the habitats that are being rehabilitated will eventually attract their predators. Our primary concern is beaver browsing. Beavers are known for their voracious appetite and their preference for willows and cottonwoods. Research has shown that "beavers appear to be restricted in the distance they can safely range away from open water – about 200 feet" (Nature Conservancy, 1998). The project will be reducing beaver habitat along the river by filling in mining pits, but wetland areas on terraces will remain, so beaver habitat will be reduced but not eliminated. Therefore, protection may require temporary depredation permits from CDFG, installing protective "cages" around individual plants, fencing off an entire revegetated area, installing plant quantities in excess of the numbers that we expect to ultimately survive, or treating a percentage of plantings with a mammal repellent (e.g., ROPEL). The decision on which protective measure to use will be based on cost, chance for success, ease of implementation and maintenance.

7.4.6. Long-term expectations

If 100 percent of planted riparian vegetation survives, nearly complete canopy coverage of the floodway will occur. Obviously, we do not expect 100 percent survival, so natural die-off of a portion of revegetated floodplains is expected. We also expect that future floods will cause channel migration and floodplain scour, destroying planted riparian vegetation in some areas, but also creating new seedbeds for natural riparian regeneration in the future. Planting will provide initial species variation, but only time, floods, and droughts will provide age class and structural diversity that is desired (Figure 23).

7.5. BIOTECHNICAL BANK REINFORCEMENT

As mentioned in Section 5, there are three meander bends within the project reach where channel migration into its old channel is undesirable for the first five years or so. Therefore, biotechnical bank reinforcement should be considered for these locations (Figure 24). Biotechinical bank reinforcement is a complement of more traditional bank protection (rock), and, softer biotechnical engineering (vegetation). Small boulders placed along the toe of the low water channel are combined with sod mats and brush mattresses to providing immediate structural reinforcement and longer-term vegetation benefits.

The outside bank of channel bends where biotechnical bank reinforcement will be constructed should have at least 3:1 slopes (H:V), with rock placed at the slope's toe. Slopes need to be shallower than 1:1 to facilitate sod mat and brush mattress placement. Two feet diameter (or smaller) boulders should be placed along the bank toe from the thalweg to the height of average summer low water (Figure 28). Boulder placement should start 100 feet upstream from the beginning of the corner and end 100 feet downstream. Boulder could be obtained from the north end of the Reading Bar borrow site.

Sedges (*Carex aquatilis*) provide substantial cohesive strength to substrates, making them ideal for bioengineering applications. Two approaches to sedge application are being considered, both require that the edges of the treated area be trenched and keyed into the bank to prevent it from being flanked and removed during floods. The first approach consists of placing living sedge sod along the average summer low water up the bank two feet (Figure 28). Sedge mats will need to be grown for one to two years in natural fiber netting (coir, jute, bog mat, or other comparable product). If possible, Clear Creek seed stock should be used for growing sedge mats, and mats should be installed using conventional sod installation techniques. After the sedge sod is installed a wider mesh coir fabric will be placed over the sod mats, "tying" them to the bank. The coir mesh fabric placed over the sod mats provides extra assurance that the sod mats will be able to withstand water velocities up 15 feet per second immediately after construction.

The second method being considered installs jute/coir mesh on the bank starting at the summer low water surface going up the bank three feet, and planting individual sedge "plugs" through the mesh. The advantage of the first method is that the structural integrity of a sedge mat is higher, potentially being able to withstand velocities greater than 15 feet per second, however the cost and pre-project preparation is higher. The second method is attractive because of lower costs; however, the immediate bank strength after construction is much lower and it will take two years (probably more) to achieve the same root strength as the sod mats.

Willows grow higher on the bank than sedges, are structurally strong, and can significantly reduce local water velocities along the bank as they mature. Willow brush mattressing will be installed from where sedges end to the break in slope where floodplain begins (Figure 28). While brush mattressing is material and labor intensive, it provides considerable strength immediately after installation. Brush mattressing consists of weaving live willow branches together to form a tight interlocking mattress. The mattress is attached to the bank using live willow stakes, and then cable (or jute string) is used to tie the mattress structure down. Because the primary structure is composed of living material, once the willows have rooted, the structure continues to grow stronger with time. As a dense willow thicket develops, water velocities will slow, inducing fine sediment deposition making these corners less prone to channel migration and channel recapture in these three critical meander bends.

8. OFF-CHANNEL WETLAND DESIGN

A small portion of the Reading Bar and approximately one-half of the Former Shooting Gallery borrow sites will be reclaimed as off-channel wetlands. Reclamation will include site grading and soil preparation to create favorable hydrology and soil conditions to achieve desired wetland function objectives. The borrow sites currently have small wetlands on-site; material excavation will enlarge and improve these wetlands. Vegetation within these existing wetlands is a complex of seasonal emergent herbaceous and woody riparian vegetation. Existing wetland plant species recolonized these sites following disturbances from historical gold and gravel mining activities and have low to moderate wildlife value. Currently wetland vegetation at these sites varies from sparsely vegetated to dense thickets, much more variable than the wetlands occurring within the project area.

8.1. OBJECTIVES

After borrow material is removed, the primary goal of creating off-channel wetlands is to create higher quality wetland habitats than those currently existing on-site and throughout the lower Clear Creek corridor.

Constructed wetlands at the Reading Bar and Former Shooting Gallery sites will target wetland dependent wildlife including aquatic amphibians (aquatic garter snake, western toad), waterfowl (mallard, wood duck), wading birds (great blue heron, great egret), and shorebirds (killdeer, spotted sandpiper). These habitats will also attract species that use wetlands for portions of their life history requirements such as riparian and upland birds (Black-headed grosbeak, Spotted towhee), upland reptiles and amphibians (western fence lizard, gopher snake), and various mammals (raccoons, deer).

General wetland objectives are:

- Design wetland areas that are seasonal and perennial. The lowest surfaces in the perennial wetland must be below the minimum groundwater table elevation to remain wet year-round.

- Create variable planform morphology to maximize edge effect, water depths and habitat diversity. The design will incorporate variable shapes, islands, peninsulas, and other topographic features to provide a physically diverse wetland.

- Design variable bench elevations to provide diverse microhabitats for emergent wetland and riparian vegetation. Benches will be constructed to provide variable water depths, leaving different “zones” for plant species colonization.

- Revegetate seasonal and perennial wetland habitats by planting native herbaceous and hardwood species within sites appropriate for each species life history requirements. Existing wetland habitats within the lower Clear Creek corridor are dominated by exotic and/or weedy hydrophytic vegetation resulting from random plant colonization following gravel-mining activities. Planting native wetland plants will create habitats with greater wildlife value and structural diversity than those currently occupying wetlands left from gravel and gold mining.

- Promote natural regeneration/recruitment of hydrophytic vegetation in constructed wetland areas by providing topographic contours and other suitable microsites with variable inundation regimes, creating favorable conditions for plant regeneration.

- Remove invasive exotic plant species and discourage future re-establishment

8.2. WETLAND TOPOGRAPHIC DESIGN

8.2.1. Reading Bar site

The Reading Bar site will consist of a 0.6-acre emergent wetland roughly circular in shape (Figure 25). The water table at this location is connected to Clear Creek, therefore, water elevations are expected to vary with flow, and the minimum expected water surface elevation will be at the summer low flow elevation (585 ft). Obligate wetland plant species are controlled and/or limited by the hydrologic regime in which they live. The species of plant that will survive in a given location depends on soil conditions, inundation period(s), and depth of inundation. Therefore, the constructed wetlands will incorporate various design depths to create different elevation zones, providing a variety of inundation regimes.

The off-channel wetland at the Reading Bar site will be isolated from Clear Creek by an earthen dike for flood flows up to 15,000 cfs. The “deep water” that isolates the island is designed to be 2 ft deep during summer low flow and up to 7 ft during a design bankfull discharge on Clear Creek. Benches will also be constructed to provide riparian vegetation surfaces on the perimeter of the wetland (Figure 25). Wetland side-slopes will be a minimum 3:1 to allow riparian vegetation to establish.

8.2.2. Former Shooting Gallery

Unlike the Reading Bar wetland, the water table at the Former Shooting Gallery site is not connected to Clear Creek; water levels will vary with groundwater elevation rather than streamflow. The maximum expected water surface elevation is 575 feet, as defined by the lowermost culvert outlet draining the site under Clear Creek Road. The minimum expected water surface elevation is currently unknown (although we do have piezometers installed to monitor water levels this summer). Until additional summer water table elevations are measured, we will assume a minimum water surface elevation of 571 feet. Islands within the wetland site are designed to be 9 ft above summer minimum water elevation and 5 ft above maximum water levels (Figure 26). Deep-water habitat is designed to be 4 feet deep during summer low water levels and 8 feet deep during maximum water levels. Wetland slopes should be at least minimum 3:1 to allow vegetation to establish. If practicable, fine materials will be placed over the wetland site to provide substrate suitable for emergent wetland plant growth.

Benches will be planted with wetland emergent vegetation, while islands, peninsulas, and higher benches planted with woody riparian vegetation (Figure 26). For example, at the former shooting gallery the bench located on the north side of the wetland will be revegetated as a Fremont cottonwood series, eventually providing additional wildlife habitats. The bench on the south side of the same wetland adjacent to Clear Creek Road also will be revegetated to provide visual and noise buffers. On the eastern edge of the wetland, a low patch of cottonwoods will be retained, with two peninsulas designed to radiate from it. Another peninsula is designed to radiate from the existing riparian bench on the southern side of the wetland. The peninsulas will be designed to be zero to four feet above the water surface (depending on time of year). A small creek draining into the wetland site from the northwest will provide flow and fine sediment to help maintain the wetland and improve function.

8.3. WETLAND REVEGETATION DESIGN

The topography, hydrology, and soils will be provided as part of the topographic design described above. There are two competing hypotheses on how these off-channel wetlands should be revegetated. The design team hypothesizes that strategic but limited planting of target native emergent wetland vegetation will give those preferred species a jump-start to invasive exotic species. We want to prevent the sites from being overrun with aggressive species that exclude other, wetland plant species; such as cattail marshes, which are typical of the lower Clear Creek corridor. Others hypothesize that natural recolonization will achieve the same revegetation goals in a less costly manner. Therefore, we recommend a combination of natural colonization and artificial planting of native wetland vegetation to provide the vegetative component of the wetland design. This will allow us to evaluate which method provides superior results.

The emergent portion of constructed off-channel wetlands will provide water depths up to approximately eight feet during the wet portion of the year, and as low as two feet during the summer. Emergent vegetation that provides high-value habitat, such as bulrush (*Scirpus* sp.), will be planted on shallower inundated benches and is uncommon locally. The constructed wetland habitats will also include islands and peninsulas for nesting, loafing, and other wildlife use. Slopes in the constructed wetlands will range from 3:1 in steep areas to between 8:1 and 10:1 in emergent bench areas. As previously discussed, existing vegetation will be incorporated into these areas to provide cover, habitat continuity, and additional vegetative structure.

Currently, borrow sites have hydrologic conditions suitable for wetland construction (as evident by the existing wetlands). Wetland construction will use existing surface and subsurface hydrology to create higher quality wetland habitats. We have installed piezometers at the Former Shooting Gallery borrow site, monitored groundwater table elevations through 2000, and used results to design the wetland depth (Figure 26). The created wetland habitats are characterized as seasonal emergent wetlands (perennial in wet years) much like the existing wetland features. However, the created wetlands will include additional microsites for natural plant colonization, maintain a longer inundation period, and through planting efforts, include plant species that are high quality to wildlife.

Designed wetland topography will create a variety of surfaces at different elevations, encouraging greater plant species diversity than current conditions (Table 6).

Surface	Hydrology	Target habitat	Vegetation series
Deep water	Perennial, 2-8 ft deep	Deep water, emergent	pondweed (floating and submerged) water lily
Emergent, emergent bench	Mostly perennial, some seasonal	Emergent	Bulrush, buttonbush
Riparian bench, peninsula	Infrequently inundated, 0 to 4 ft above water surface	Riparian emergent, riparian	Cottonwood, Arroyo willow, black willow, buttonbush
Island	Infrequently inundated, 0 to 9 ft above water surface	Riparian emergent, riparian, mesic at Former Shooting Gallery	Cottonwood, Arroyo willow, black willow, buttonbush, sedge

Table 6. Relationship of proposed emergent and riparian vegetation planting to constructed surfaces and expected hydrology.

9. REFERENCES

Andrews, E. D., 1994. Marginal bedload transport in a gravel stream, Sagehen Creek, California, *Water Resources Research*, Vol. 30, No. 7, pp. 2241-2250.

Binder, W., P. Jurging, and J. Karl, 1983. *Natural river engineering: characteristics and limitations*. Garten + Landschaft. 93:91-94.

Brookes, A., 1987. Restoring the sinuosity of artificially straightened stream channels, *Environmental Geology and Water Science*, 10:33-41.

Brookes, A. and F.D. Shields, Jr., 1996. *River Channel Restoration, Guiding Principles for Sustainable Projects*. John Wiley & Sons, Chichester, United Kingdom.

California Partners in Flight and Riparian Habitat Joint Venture, 1998. *The draft riparian bird conservation plan: a strategy for reversing the decline of birds and associated riparian species in California*. Sacramento, California.

Dunne, T. and L. B. Leopold, 1978. *Water in Environmental Planning*. W.H. Freeman and Company, New York.

Dury, G.H., 1976. Discharge prediction, present and former, from channel dimensions, *Journal of Hydrology*, Vol. 30, pp. 219-245.

Jungwirth, M., S. Muhar, and S. Schmutz, 1995. The effects of recreated instream and ecotone structures on the fish fauna of an epipotamal river. *Hydrobiologia*. 303:195-206.

Kondolf, G. M. and W. V. G. Matthews, 1993. *Management of coarse sediment on regulated rivers*, University of California: Water Resources Center.

Kondolf, G. M. and M. G. Wolman, 1993. The sizes of salmonid spawning gravels, Water Resources Bulletin, Vol. 29, No.7, pp. 2275-2285.

Leopold, L.B. and M.G. Wolman, 1957. River Channel Patterns: Braided, Meandering, and Straight, *USGS Professional Paper 282-B*, pp. 39-85.

Ligon, F.K., W.E. Dietrich, and W.J. Trush, 1995. Downstream ecological effects of dams, *Bioscience,* Vol. 45, No. 3., pp. 183-192.

McBain and Trush, 1997. *Trinity River Maintenance Flow Study - Final Report*, Arcata, California.

M.G. Wolman and L.B. Leopold, 1957. River Flood Plains: Some observations on their formation, *USGS Professional Paper 282-C*, pp. 87-107.

Olsen, H.O. (ed) 1996. River Restoration -- Danish experience and examples. National Environmental Research Institute. Silkeborg, Denmark.

Parker, G., P. C. Klingeman, et al., 1982. Bedload and size distribution in paved gravel-bed streams, *Journal of the Hydraulics Division*, Vol. 108, No. HY4, pp. 544-571.

Parker, G., 1990. Surface-based bedload transport relation for gravel rivers, *Journal of Hydraulic Research*, Vol. 28, No. 4, pp. 417-436.

Toth, L.A., 1996. Restoring the hydrogeomorphology of the channelized Kissimmee River. In: Brookes, A. and Shields, F.D., Jr. *River Channel Restoration, Guiding Principles for Sustainable Projects*, John Wiley & Sons, Chichester, United Kingdom, pp. 369-383.

Pelzman, R. J., 1973. *Causes and Possible Prevention of Riparian Plant Encroachment on Anadromous Fish Habitat.* Environmental Services Branch, California Department of Fish and Game**:** 26 pp.

Sawyer, J. O. and T. Keeler-Wolf, 1995. *A Manual of California Vegetation.* California Native Plant Society, Sacramento.

The Nature Conservancy, 1998. *Sacramento River project: Riparian forest restoration manual*. Sacramento, California.

Williams, G. P., and M.G. Wolman, 1984. Downstream effects of dams on alluvial rivers, *USGS Professional Paper 1286*, 83p.

Williams, G.P., 1986. River Meanders and Channel Size, *Journal of Hydrology*, Vol. 88, p. 147-164.

Appendix V.

Channel Monitoring Methods

CHANNEL GEOMORPHOLOGY MONITORING METHODS

PHASES 2 AND 3 OF THE LOWER CLEAR CREEK FLOODWAY REHABILITATION PROJECT

LIST OF FIGURES AND ATTACHMENTS

Figures

Attachments (on CD provided with this appendix)

a. Bed scour template.xls - Scour core installation and monitoring data form
b. Pebble Ct V2.xls - Pebble count analysis template
c. Photomonitoring Example.pdf - Completed photopoint data sheet for a Trinity River location
d. Photopoint Data Sheet.doc - Sample photopoint data sheet
e. Piezomonitor TemplateV3.xls - Filed data form for reading piezometers
f. Sieve Template-1phi.xls - Particle size analysis template
g. TRACERS.xls - Marked rocks inventory data form
h. XS-templ.xls - Survey data entry and graphical plotting template

INTRODUCTION

The monitoring component of a functional adaptive management program requires field monitoring, data compilation and analysis, and interpretation of results in order to improve designs and implementation. This appendix provides a detailed description of the methods required to complete the field monitoring tasks for Phases 2 through 4 of the Ecological Monitoring Plan for the Lower Clear Creek Floodway Rehabilitation Project. It is intended to provide enough detailed discussion and description of technique so that monitoring personnel can use it as a guide for developing field monitoring programs to satisfy the Fisheries Resources and Geomorphology monitoring objectives. These objectives are described in the Ecological Monitoring Plan and the reader should be familiar with them.

Please note that many of the methods and techniques presented in this appendix are also presented in the U. S. Forest Service General Technical Report RM-245, *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et al. 1994). This guide is periodically referenced herein as RM-245. Monitoring personnel are encouraged to obtain and read RM-245 as many of the following topics are discussed in greater detail than presented in this appendix. In addition, other fundamental techniques not discussed in this appendix are presented in RM-245 that may prove beneficial for monitoring personnel (e.g., surveying, measuring discharge, characterizing bed and bank material). Copies of RM-245 can be obtained From the U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80526.

In addition to describing monitoring procedures for Clear Creek, this appendix provides materials lists to complete the installation of monitoring stations. Most of the materials that are listed can be purchased at a conventional hardware store, however others (e.g., aluminum tags, field notebooks, surveying gear) must be purchased from survey supply houses. One such supply house is Forestry Suppliers, Inc., a company specializing in tools, instruments, and equipment for natural resource sciences. Where applicable, the Forestry Suppliers catalog number will follow an item in parentheses, for example: (FS #49217). Forestry Suppliers usually offers several brands or types of the same general item; the catalog number provided is merely an example of the type of equipment recommended for the monitoring task. Forestry Suppliers, Inc. can be contacted at (800) 360-7788, or via the Internet at: http://www.forestry-suppliers.com.

MONITORING METHODS

1.0 FIELD NOTEBOOKS

A field notebook may very well be the most important piece of equipment used for any project. Most, if not all site observations, sketches, and measurements will be recorded in the field notebook. As described in RM-245, most hydrologists use bound field notebooks that are about 5” x 7”, with alternate graph pages, ledger pages, and various tables and equations at the back for reference. Laid flat, they photocopy onto standard 8 ½” x 11” sheets for standard filing. Each field book should be assigned its own unique number (e.g., Clear Creek Monitoring Field book No. 1). If field notebooks contain weatherproof paper, (e.g., “Rite in the Rain” brand (FS #49326)), then a harder #4 lead pencil is recommended as #2 lead tends to smudge on weatherproof paper.

Field notes should always be written clearly and legibly. It is likely that numerous field personnel will use the same notebook before it is completely filled, therefore, it is imperative that all notes and sketches be written with the intent that others will need to interpret them (possibly years in the future). Always begin notes for a new site visit on a fresh page, and include the names of all field crew members, date, time, and weather conditions. All notes and sketches should be made dark enough so that they photocopy well, and should always be written in pencil. Notes should never be erased (particularly survey notes); they should be lined out and any corrections should be noted and initialed.

Clearly label the inside front cover or first page of the field notebook with a name, address, and phone number in case the book is lost. Including a written offer for a reward is also a good idea. Leave the first two or three pages blank to list the book’s contents and any other special notes (e.g., symbols, abbreviations, etc.). After returning to the office from the field, always photocopy the day’s field notes and archive them in an off-site location (in case of fire, theft, or some other unfortunate catastrophe). When finished, store all field notebooks in the office so they are available for reference and for the next field session.

2.0 AERIAL PHOTOGRAPHS

Aerial photographs provide a planform view of project sites and serve as a basis for documenting changes in site conditions over time. Careful analysis of the aerial photos can be used to interpret changes in channel location, channel morphology, vegetation, or other variables.

Monitoring

Aerial photographs should be flown after construction to document as-built conditions at both the project site and Reading Bar borrow site. While there can not be a set rule for the frequency of taking aerial photographs, we suggest they be re-taken as each phase of the restoration project is completed, every three years, or after a high flow that causes dramatic changes to channel morphology, whichever is sooner. All aerial photos should be taken at a 1” = 350’ (1:4,200) scale, because this scale provides excellent visibility of the floodway, excellent image quality of enlargements (scale can be increased by 10x to 1” = 35’ without losing much photographic resolution), and is consistency with previous aerial photo scale.

Stereoscopic aerial photos are those that can be overlapped and viewed through a stereoscope, which renders a three-dimensional image by adding topographic relief to the viewer's field of vision. This technique is very useful in interpreting landforms and other features that can otherwise be indistinguishable, especially at sites such as river channels and floodplains that have little topographic relief. Because individual aerial photographs must be overlapped to view in stereo, the total number of photos taken to cover one site is greater than non-stereo coverage (and therefore cost more). However, the resolution offered by stereo pairs, particularly along a channel and over a floodplain, is superior to non-stereo coverage, and allows the photos to be orthorectified if desired. In addition, color aerial photos will provide further resolution to a site and aid in interpreting certain features that may appear different in black-and-white.

Based on June, 2001 price estimates from Hedges Aerial Surveys of Redding, CA (the same contractor who provided 1997 and 2000 photo coverage for the Clear Creek project), the cost for various types of aerial photographic coverage is presented in the following table:

	Non-stereo black and white	Non-stereo color	Stereo black and white	Stereo color
1"=350' scale prints of restoration project only	$900	$1,300	$1,000	$1,500
1"=350' scale prints from Sacramento River to Clear Creek Bridge	$1,200	$1,500	$1,800	$2,300
1"=350' scale prints from Sacramento River to Whiskeytown Dam	$1,700	$2,750	$3,400	$5,500

The above listed costs are provided for budget purposes only, and the actual cost may vary.

A conventional aerial photograph contains image displacements caused by the tilting of the camera and the terrain relief. The stated scale is approximate and is not uniform across the photo; therefore, measurements made from the photograph may not be accurate. Orthorectification is a process that corrects photo distortion. Once an aerial photograph has been orthorectified, it becomes a photographic map that contains a uniform scale across the photo. The 1997 digitally orthorectified photos produced by ENPLAN has served as the base map photo for the work done on lower Clear Creek. At minimum, we recommend that color stereo pairs be taken from the Sacramento River to Clear Creek bridge, but not be orthorectified due to significant cost. We also recommend that once all construction activities and revegetation are completed, that the next photo set be digitally orthorectified to serve as the next base map (replacing the 1997 photo base map).

3.0 PHOTO POINT MONITORING

Photomonitoring is the process of taking landscape or feature photographs repeatedly over time from the same location (i.e., the photopoint), perspective, and frame so that differences between years can be compared (Elzinga et al. 1998). In general, a photomonitoring program consists of: selecting, and installing photopoints; developing a standardized protocol for photopoint relocation and photography; taking photographs at all photopoints and taking standardized notes, and; documenting and archiving all photographs taken during photomonitoring.

Materials

Quality and consistent photomonitoring equipment are the basis of good, standardized photographs. The pieces of equipment used for a photomonitoring program include:

- camera, shutter release cable, tripod
- hand pruners, machete, and pruning saw for clearing vegetation
- blank photomonitoring data sheets, to be filled out after every photograph
- photomonitoring fieldbook, with photopoint location descriptions
- scale pole marked in 0.5 ft increments (FS #40046)
- plumb bob (or fishing weights and line for constructing a plumb bob)
- chalk board and chalk for writing relevant photopoint data
- flagging tape to mark photopoint location (FS #57905)
- compass for measuring the focal point bearing (FS #37182)
- clinometer for measuring the focal point angle (FS #43830)
- engineer's measuring tape (in 0.01 increments) for measuring the camera height above the observation monument (FS #71175)
- two 300-ft survey tapes for triangulating observation points (FS #39532 or #39851)

The camera used for photomonitoring should either be digital or 35mm. Digital cameras are attractive choices because the photographs can be easily archived and reproduced. No matter what camera is selected for the project, it is best if the same camera is used throughout the project history and the same settings (e.g., ASA or image quality) are used for successive photographs.

Methods

A photomonitoring program must take repeated photographs from the same location. To be able to effectively compare photographs taken at the same point on different dates, the photographs must be as equivalent to each other as possible. A photomonitoring program must consider the time of year that the lighting and vegetation will be in a similar condition as the first photograph at the photopoint. In addition, photomonitoring timing must consider river discharge and plant growth. Once a photomonitoring program is developed (locations selected, monitoring schedule developed), the actual benchmark for where photographs are to be taken, or photopoints, must be selected.

The first type of photopoint consists of two rebar pins, a line of site pin, and an observation pin (Figure 3.1). Rebar pins monument both the observation point and the line of sight, and are labeled with aluminum tags. The camera and tripod are setup over the observation pin and centered over it using a plumb bob. The line of sight pin is 25 ft away along a fixed compass bearing (the compass bearing is recorded on the photopoint data sheet which is in the fieldbook). The field of view and focal point (in the cameras viewfinder), is centered on the chalkboard sitting atop the scale pole. No declination compensation (to adjust for difference in true and magnetic north) is required to the bearing recorder on the data sheet.

The second type of photopoint consists of a nail with a washer (the observation point), and a fixed point demarcating the line of sight (Figure 3.2). This photopoint type is commonly used on hillsides. The camera and tripod are setup and centered (using a plumb bob) over the nail. The field of view is determined by a compass bearing and an inclination. In some cases a line of sight monument is described in for the photopoint, in other cases no line of sight monument was used. Therefore, the field of view is centered using the line of sight monument, compass bearing and inclination.

The third type of photopoint consists of two pins from which an observation point is triangulated, and a fixed point demarcating the line of sight (Figure 3.3). This photopoint type is typically used were the observation point occurs in the river. Two 300-ft surveying tapes are attached to triangulation points (usually rebar pins), and using distances from each triangulation point the observation point is relocated and the tripod and camera are setup at this point. The field of view is determined by a compass bearing and an inclination. It is especially important to use the most recent photograph taken from that photopoint to help reestablish the same field of view as the previous monitoring. In some cases a line of sight monument is described in for the photopoint. Therefore, the field of view is centered using the line of sight monument, compass bearing and inclination.

All photopoint monuments must be photographed at the time of installation and should be GPS surveyed by the Department of Water Resources to precisely locate the photopoint on the Clear Creek base map. The monument photographs are intended to capture the monument's immediate surroundings, the monument itself, and any other relevant information that could prove useful in relocating the monument. The monument photographs are included the photomonitoring fieldbook, with other location information.

The photomonitoring fieldbook is the result of the first year's photomonitoring effort. For each site, the photomonitoring fieldbook contains photopoint location descriptions, photographs and descriptions of monuments (both line of site and observation pin), the most recent photopoint data sheets, and the most recent photograph taken from each photopoint. A sample photopoint data sheet is included on the CD that accompanies this appendix.

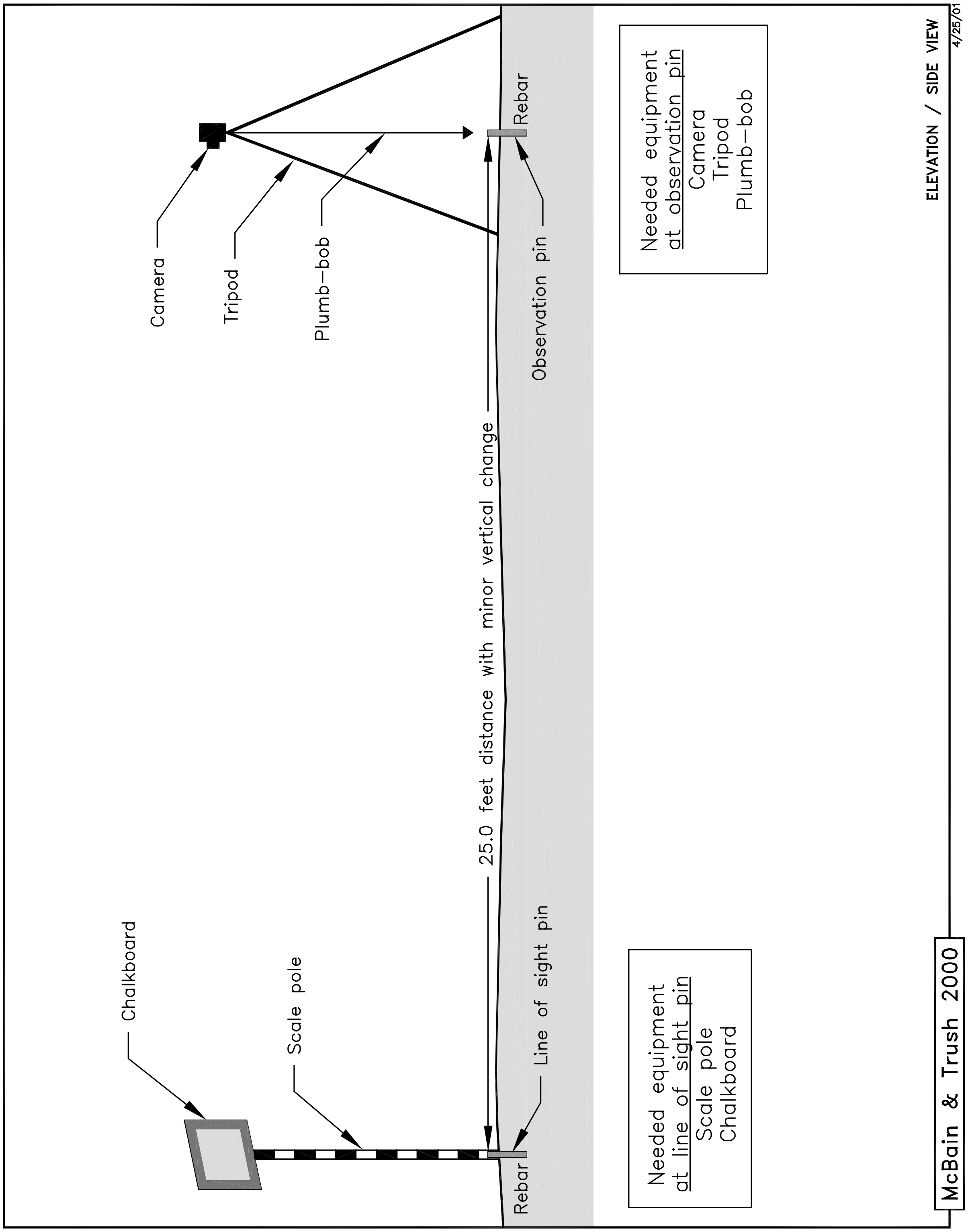


Figure 3.1: Photomonitoring point Type 1: where both observation pin and line of sight pin are established.

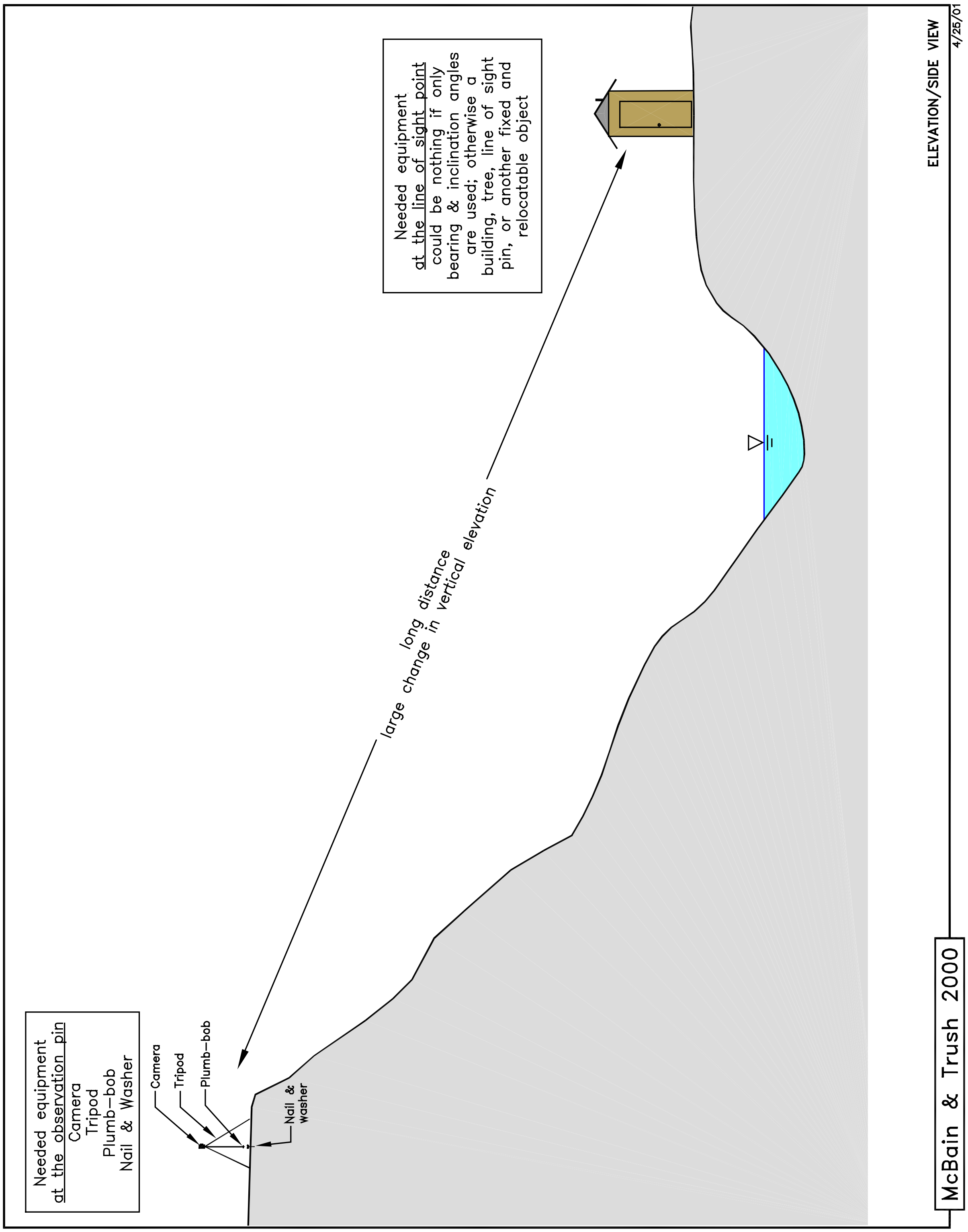


Figure 3.2: Photomonitoring point Type 2: photopoint where only the observation pin can be established.

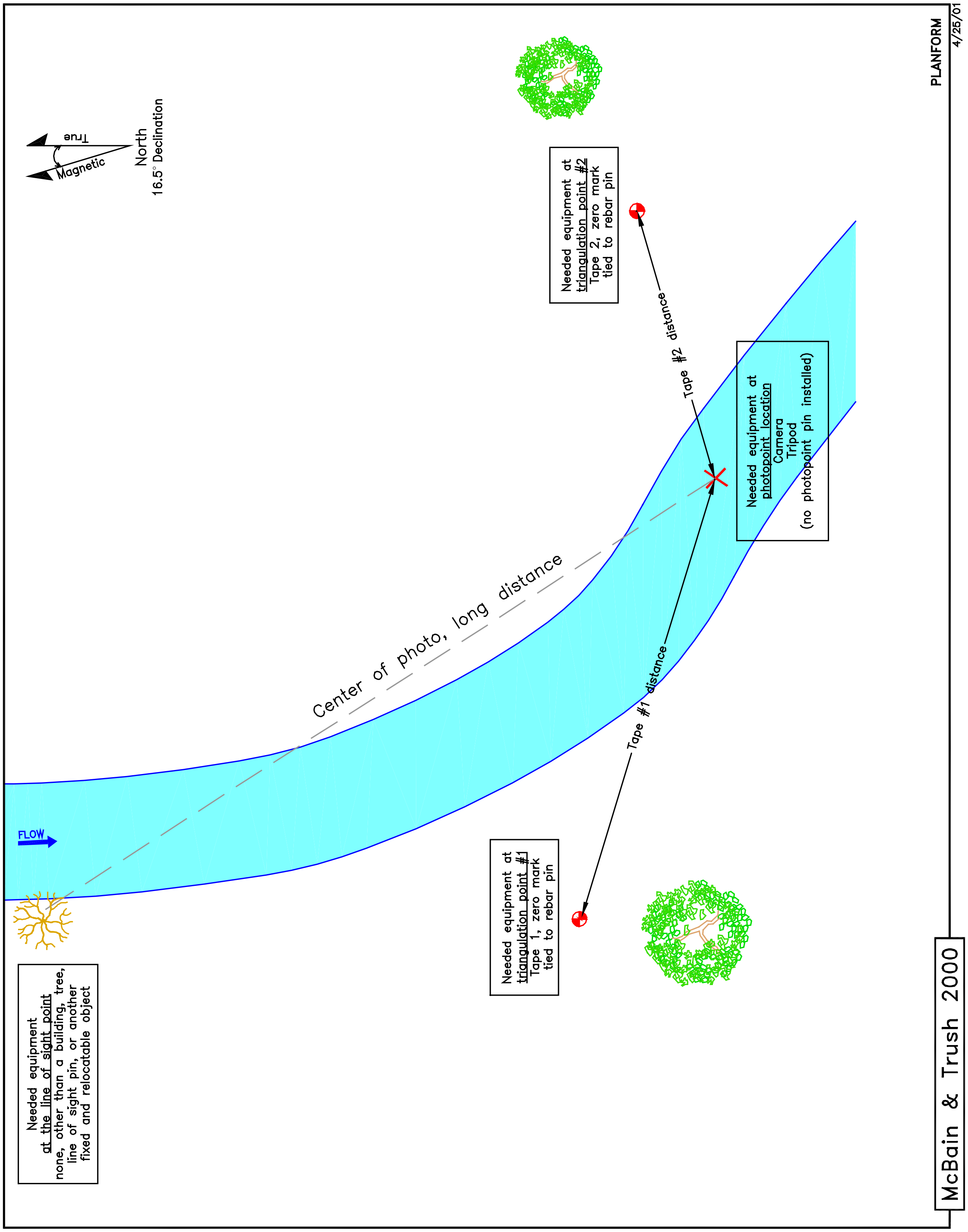


Figure 3.3: Photomonitoring point Type 3: photopoint where oberservation point monument can not be established (photopoint position triangulated from two fixed points).

Installation

The following table lists materials required to install photopoint monuments (note that this list includes materials for all three photopoint types). Where applicable, a Forestry Suppliers catalog number follows the item in parentheses.

- ½” rebar, for photopoint monuments, cut at 3’ to 5’ lengths
- 1” washers for photopoint monuments
- 12” galvanized spikes for photopoint monuments
- 1”-diameter (or similar size) aluminum tags for labeling photopoint monuments (FS #79360 or FS #79500)
- plastic tarp, to paint washers and monuments on
- wire, wire cutters and pliers for affixing the tags
- putty Epoxy, to affix monuments to bedrock or concrete if needed
- “PK” nails to for installing monuments into asphalt
- orange paint, for painting monuments (FS #57561)
- small sledge hammer for installing photopoints (FS #67244)
- stamp kit, for stamping the photopoint numbers on the tags or washers

Most of the above listed materials can be purchased at a conventional hardware store, however others (e.g., aluminum tags) can be purchased from Forestry Suppliers, Inc., a company specializing in tools, instruments, and equipment for natural resource sciences.

Monitoring

Several Photopoints may be clustered around a site, or one site may contain only a single photopoint. For each site, or where a single photopoint occurs, the specific site location is sketched in the photomonitoring program field book. After locating the photopoint monuments, the photomonitoring equipment can be set up and the photopoint (re)occupied. The camera and tripod are set directly over the observation monument at the predetermined height stated on the photopoint data sheet, and centered over the pin using a plumb-bob. The specific procedures are:

1. Using the site description and/or aerial photos, find the observation point/monument, and line of sight monument.
2. Set up the tripod over the observation point/monument.
3. Using a fishing line and lead weight plumb bob hanging from a central point on the tripod, center tripod over the observation monument.
4. Attach camera to tripod, on the chalkboard write the date, the discharge and the initials of the location where the discharge was measured, and the photopoint number.
5. Using an engineers tape (marked in increments of feet and tenths of feet) raise or lower the base of the camera such that the camera height is the specified distance above the observation monument (indicated on the photopoint data sheet).

6. Using a compass, determine the direction the camera's viewfinder will be aiming, specified as a bearing from magnetic north (indicated on the photopoint data sheet)
7. Center the camera's viewfinder on the chalkboard and scale pole or some other line of sight monument (indicated on the photopoint data sheet).
8. Using a clinometer, determine the angle that the camera's viewfinder will be tilted up or down, specified as inclination or angle
9. Using a line bubble level, check to ensure the horizon in the photograph framed in the viewfinder is level
10. Check the camera settings listed on the photopoint data sheet to ensure that the lens (wide angle or telephoto) settings are the same as the previous photo monitoring, and that the camera's image settings allow the photograph to be taken at full size, fine quality
11. Using the last photograph taken from the photopoint (included in the photomonitoring fieldbook), check to make sure the photographs are equivalent (with the exception of physical or vegetative changes), make any fine tuning adjustments necessary
12. Three photos should be taken at each photopoints to assure a quality photograph equivalent to the last monitoring (this setting is automatic if the camera has been properly checked before going into the field). Two photographs should be taken at different F-stops, bracketing the correct F stop (assure proper light balance in the photograph). One photograph should be taken at one F stop above the suggested F stop (as measured by a light meter), one photograph should be taken at the setting suggested by the light meter, and one photograph should be taken at one F stop below the suggested setting.
13. Fill out a new photopoint data sheet, noting any changes to the photopoint monuments, camera settings, physical disturbances etc.

Once photopoint monitoring begins, a database can be created. One way of creating a searchable database is through the use of accession numbers. This is accomplished by naming all photopoint monuments with a unique moniker according to river mile, site, photopoint number, and whether the pin is the observation or line of sight pin. This unique name is called the photopoint accession number and is also used as the database reference number for the photopoint. For example, the following accession number "PPT#816CC3LS" means:

PPT# = Photopoint number
816 = River mile 81.6
CC = Clear Creek
3 = third photopoint
LS = line of sight pin

The accession number can be looked up in the photomonitoring fieldbook to get specific details about the point and its location and can also be placed on an aluminum tag attached to the photopoint pin. By establishing this protocol, all photographs can be accessed by using the photopoint accession number.

4.0 CROSS SECTION INSTALLATION AND MONITORING

The monumented cross section serves as the location for measuring physical channel characteristics, such as channel form (e.g., location, grade, position), stream discharge, and particle size distributions. Because the cross section serves as the location from where hydraulic measurements and calculations are performed, its orientation is across the channel, perpendicular to the direction of flow.

Materials

The following materials are required to install monitoring cross sections at Clear Creek project sites (note that the following materials list is for a single cross section only).

- rebar: 4 pieces, 5/8”-diameter, cut at 3’ to 5’ lengths
- sledge hammer to install rebar (FS #67244)
- 1”-diameter (or similar size) aluminum tags (FS #79360)
- wire, wire cutters and pliers for affixing the tags
- stamp kit, for stamping the aluminum tags
- surveyor’s plastic rebar caps (FS #39496)

Installation

One of the primary purposes of establishing a cross section is to perform hydraulic calculations and document topographic change over time. To do this, set the rebar (often referred to as “pins”) along a transect that is perpendicular to flow. Drive each pin vertically into the ground to a depth where no more than 4” is exposed above the ground surface (for safety as well as to reduce risk of disturbance). Install at least two 5/8” rebar pins on each side of the stream, one that is 2-3 ft above the summer low flow water surface (preferably within 20 feet of the low flow water edge), and one at the base of the bluffs at the edge of the floodway. Pins are installed at the base of the bluffs so that the risk of them eroding in the future is minimal. Rebar on opposite sides of the channel should be set at similar elevations such that a tape stretched between pins is reasonably horizontal (Figure 4.1). Place a plastic surveyor’s rebar cap on each pin immediately after it is installed.

The exact location of each pin should be tied to the NAD83 California State Planes, Zone 1, US Foot coordinate system, as established by the Department of Water Resources. To locate the pins accurately, each pin should be initially surveyed with a survey-grade Global Positioning System (GPS). The elevation of all pins should reference the datum of the primary benchmark at each site (NAVD 88). Figures 4.2 and 4.3 show the location of primary benchmarks at each site. After the pins are installed, label them using the 1”-diameter aluminum tags. Tags are wire-attached to each pin, and the following information is stamped onto the tag: cross section name (based on longitudinal stationing established from the 1997 ENPLAN base map), date installed, and elevation of the top of the pin referenced to the primary site benchmark. The river location and longitudinal station from the 1997 ENPLAN base map is included as Figures 4.4 and 4.5 for the Restoration Grove project site and Reading Bar borrow site, respectively.

Monitoring

Monitoring is intended to document the changes along a transect either perpendicular to flow (cross section) or along the length of the channel (longitudinal and thalweg profile). In addition to the active channel, the technique described below also includes methods to monitor the scour channels.

All channel surveying, including new and existing cross sections, longitudinal profiles, and scour channels, should be re-surveyed on an annual basis and following high flow events capable of causing topographic (and therefore geomorphic) change. The channel cross section is measured by surveying the ground surface and channel topography along a tape stretched between the rebar pins. The following list includes the basic materials required to complete a topographic cross section survey:

- engineer's surveying level, tripod, and 25-foot stadia rod (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- long, flexible measuring tape (commonly 300' long) with clips or similar fasteners to affix tape to rebar pins (FS #39532 or #39851)
- "Rite in the Rain" brand field notebook (FS #49326)
- waders and wading boots
- hand pruners, machete, or pruning saw for clearing vegetation

The rebar pins at the base of the bluffs serve as survey endpoints. First, attach the zero end of the tape to the left bank (facing downstream) rebar pin. Stretch the tape tight and level across the channel, and attach it to the upper right bank rebar pin. Record the distance between pins.

After beginning the survey by establishing elevation from the primary benchmark, begin the cross section survey at the upper left bank rebar (station zero) by surveying both the top of the rebar pin and then the ground surface. From this point, the survey progresses along the tape by recording ground surface elevations at significant topographic (breaks-in-slope), geomorphic (particle size or vegetation changes), and hydrologic features (water surface elevations and high water marks). We do not recommend using a total station for cross section surveys as they do not provide the elevational precision of engineers levels, and this precision is needed to document subtle floodplain evolution. First-time surveys should record ground surface elevations at 2-foot intervals, then subsequent surveys can follow significant breaks caused by topographic changes, with spacing not exceeding 10 feet. Continue the survey across the channel to the right bank rebar pin. As with the left bank pin, survey both the ground surface at the base of the pin as well as the top of the pin. When finished, survey elevation of the primary benchmark to close the survey (do turning points if needed) and record closure error in the field notebook. If closure error is greater than 0.05 feet, repeat the turning point loop to locate and remove the survey error.

Next, survey the water surface slope (longitudinal profile) through the reach. Because water surface slope varies with discharge, slope should be surveyed each time the site is visited during different flows. In addition, water surface slope during peak flows can be reconstructed using debris lines or other high water indicators (also see Section 5.0). Water surface slope is measured by stretching the tape along the channel at the water's edge. Ideally, the length required to obtain a representative slope incorporates one complete riffle-pool sequence (Harrelson et al. 1994). For Clear Creek project sites, slopes should be

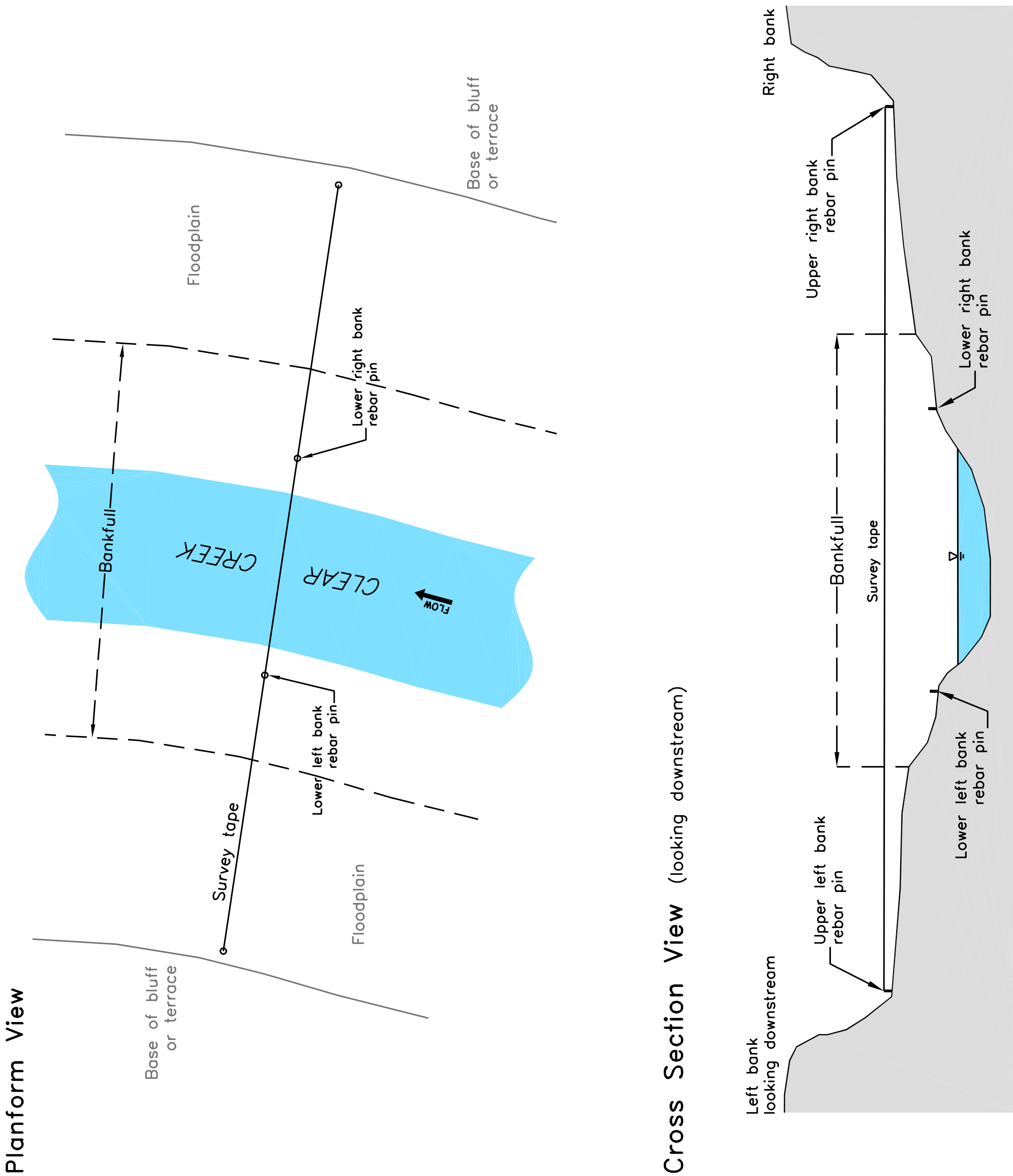


Figure 4.1: Schematic diagram of channel cross section.

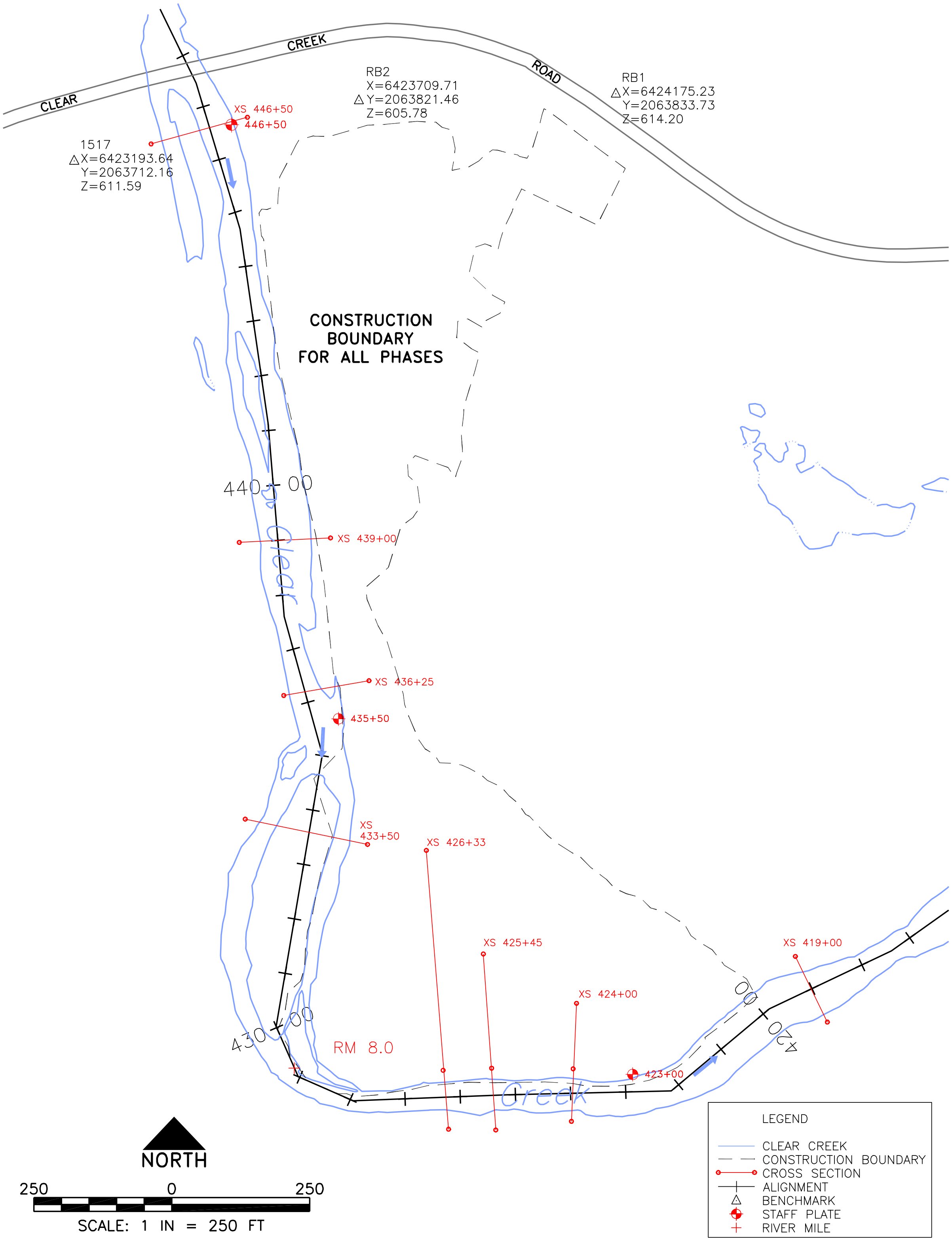


Figure 4.2: Reading Bar site map showing location and elevation of primary benchmarks, longitudinal stationing, and 1997 channel location.

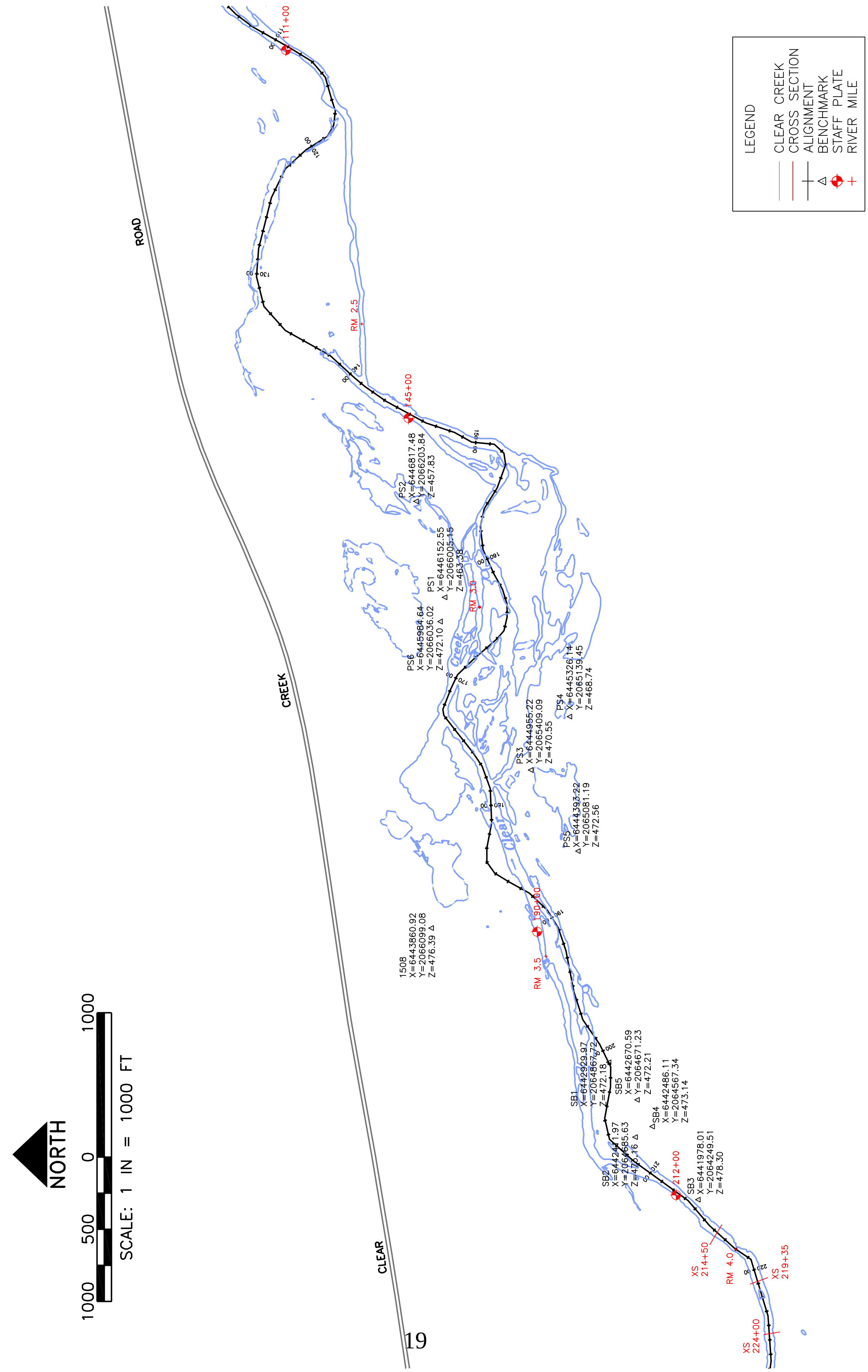


Figure 4.3: Restoration Grove site map showing location and elevation of primary benchmarks, longitudinal stationing, and 1997 channel location.

surveyed over a 300 to 400 foot length centered on the cross section (e.g., 150 feet upstream and downstream). After the tape is laid out, elevations are surveyed at approximately 20- to 50-foot intervals for the entire length of tape, concentrating on topographic changes in the water surface (i.e., breaks-in-slope) rather than equally spaced points. When the end of the tape is reached, close the survey by returning to and surveying the primary benchmark, taking turning points if needed and recording the survey error in the field notes.

After fieldwork is complete, photocopy the field notes. Then enter the survey data into an Excel workbook and plot the results. An Excel worksheet should be created for each cross section survey, such that all surveys for a given cross section are contained within a single workbook file. A survey data entry template and graphical plotting template are included with the CD that accompanies this appendix.

5.0 THALWEG PROFILE AND WATER SURFACE SURVEYS

The thalweg is the deepest portion of the channel at any given longitudinal station. Thalweg profile surveys are similar to water surface slope surveys (Section 4.0); however, in addition to surveying water surface elevations, channel topography is surveyed along its deepest portion. Similar to cross section surveys, thalweg profile surveys document the topographic changes through a given reach.

Materials

The following materials are required to conduct thalweg profile and water surface surveys at Lower Clear Creek project sites:

- Total Station (optional)
- engineer's surveying level, tripod, and 25-foot stadia rod (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- long, flexible measuring tape (commonly 300' long) with clips or similar fasteners to affix tape to rebar pins (FS #39532 or #39851)
- 5/8" rebar cut at 5-foot lengths
- sledge hammer to install rebar (FS #67244)
- "Rite in the Rain" brand field notebook (FS #49326)
- flagging (FS #57905)
- waders and wading boots
- hand pruners, machete, or pruning saw for clearing vegetation

Monitoring

Thalweg profiles are measured by surveying the channel bed surface along the deepest portion of the channel during periods of low flow. Thalweg profiles should always begin and end at the same upstream and downstream location (based on longitudinal stationing established from the 1997 ENPLAN base map). Endpoints can also be referenced to permanent features on the bank or floodplain, such as a large tree or channel cross section, provided they are spatially documented within the site coordinate system per survey-grade GPS or Total Station.

The water surface is also surveyed at the same time as the thalweg, thereby providing longitudinal channel topography and a corresponding water surface elevation with the same survey. Moreover, debris lines may be present especially following a flood event. It is important to survey these "high water mark" elevations if they are present, because they will provide water surface elevations and a slope of the flood discharge that deposited them.

To survey the thalweg and water surface, first walk the length of the channel to be surveyed and set temporary rebar vertically along the banks, beginning at the upstream end of the profile. Depending on the sinuosity of the reach, space the rebar at intervals so that a tape strung between rebar remains along the channel (slightly less than 300 ft if a 300 ft survey tape is used). Install each piece of rebar so that at least one foot is exposed above the water surface, and tie flagging to the rebar so it doesn't produce a boating hazard during the survey. The length of channel to be surveyed should extend through the particular study reach. Next, affix the zero end of the tape to the upstream channel rebar (upstream endpoint) and connect the tape to the next downstream rebar.

After beginning the survey by establishing elevation from the primary benchmark, begin surveying the thalweg and water surface at the upstream endpoint. If using a level, assume a longitudinal station of "zero" at this point, with stationing increasing in the downstream direction. Again if using a level, survey the thalweg elevation, and document the water depth at the thalweg elevation to get the water surface elevation (thalweg elevation + water depth = water surface elevation). Water surface elevations are easiest to survey at the water's edge if using a total station, rather than trying to survey this surface at the thalweg. Continue downstream along the tape, carefully surveying important topographic features such as the boundaries of riffles and pools. Surveying should focus on the topographic features that define the reach and how these features change with time and/or discharge; therefore, survey points should not be spaced at even intervals. When the last rebar is reached, close the survey by returning to and surveying the elevation of the primary benchmark. Record closure error in the field notebook. If closure error is greater than 0.05 feet, repeat the turning point loop to remove the error. Finally, remove the temporary rebar used to string the tape.

As mentioned above, a total station is an alternative to the level surveying method. In contrast to an engineer's surveying level, total station surveys topographic data electronically in three dimensions with respect to the established site coordinate system. Data can therefore be plotted on a planform map and are very illustrated. The total station data logger records coordinates and elevations as individual topographic points are surveyed. Because of this, total station surveys are recommended for the thalweg profile surveys because precision is not as important as the cross section surveys, the thalweg surveys can be performed faster with a total station than an engineer's surveying level, and thalweg location changes can be shown on a map.

Although water surface slopes can be surveyed under most flow conditions, thalweg profiles should only be surveyed during low flows when the channel is safe to wade and the flow is generally clear enough to see the channel bed. Profiles should be re-surveyed on an annual basis, and if possible, following high flow events capable of causing topographic (geomorphic) change. Keep in mind that flood debris should be present following a high flow event and this slope should be surveyed as well.

As with the cross sections, thalweg and water surface profile surveys should be transferred upon returning to the office. Photocopy the field notes and then transfer the survey data to a computer and plot the results. An Excel workbook should be created for each given profile such that the results of each field survey is contained on a worksheet within that workbook.

If a total station is used rather than an engineers level, then the "distance and elevation" data should be exported into an ASCII file that can be imported by Excel. The cross section survey data entry template and graphical plotting template on the attached CD can also be used for the thalweg profiles.

6.0 PIEZOMETERS

A piezometer is a small-diameter well constructed to measure the height of groundwater. Piezometer design for Clear Creek project sites consists of a PVC pipe that is set vertically into the ground that allows water to flow into the lower portion of the casing through a well screen. "Piezometer" and "well" are used interchangeably in this section.

Materials

The following materials are required to construct a piezometer for floodplain groundwater monitoring at lower Clear Creek monitoring sites:

- backhoe
- solid casing: 2"-diameter schedule 40 PVC pipe, threaded to accept well screen and cap
- well screen: 2"-diameter schedule 40 PVC pipe, factory slotted at 0.01" or 0.02" openings, threaded to accept solid casing and plug
- breathable cap for the top of the casing (to prevent rain or foreign materials from entering the well), and a plug for the bottom
- a pump or hand bailer to "develop" the well
- survey equipment (engineer's level, tripod, stadia rod, field notebook) (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- 3 clear glass jars (4oz. or larger)
- a roll of string
- plastic 5-gallon bucket
- "Rite in the Rain" brand field notebook (FS #49326)

The piezometer materials (casing, screen, cap, plug, and bailers) can be purchased from manufacturers specializing in groundwater development and sampling products, such as Boart-Longyear. Boart-Longyear can be contacted at (800) 241-9468 or via the Internet at: http://www.boartlongyear.com/usregion/.

Because of the simple piezometer design proposed for this project, piezometers should be located in areas that are not subjected to ponding surface water as this water can infiltrate vertically and give a false water table elevation. If this setting cannot be avoided, an impervious material (e.g., bentonite or concrete grout) should be backfilled around the uppermost few feet of the well casing. The reader is encouraged to consult an appropriate technical reference such as Groundwater and Wells by F. G. Driscoll (1986) for these installation techniques.

Installation

The following procedure installs piezometers at the Lower Clear Creek site using a backhoe and is illustrated in Figure 6.1. The procedure assumes pits will be excavated on the floodplain by a backhoe, that the piezometers will be set in these pits, and the pits will be backfilled by the backhoe with the same excavated materials. Because the lowest groundwater elevations occur during the late summer months, the piezometers should be installed during this time to ensure the groundwater elevation does not drop below the depth of the piezometer (resulting in a dry well).

Instruct the backhoe contractor to excavate a pit in the desired monitoring location. The pit should extend below the summer groundwater table, which is located where water begins to flow freely into the bottom of the excavation. Stop the excavation when the depth of the pit is at least two feet below the surface of the late summer water table.

Next, assemble the PVC pipe according to the depth of the pit and the depth to groundwater. Thread the solid casing into the well screen (slotted casing), thread (or cap) the plug into the bottom of the screen, and stand the assembly vertically in the pit, alongside one of the pit walls (it does not necessarily need to be placed directly in the center of the pit). Set the assembled well in the pit such that approximately 2 to 3 feet of well screen sits *below* the lowest expected groundwater table elevation. In addition, no more than 1 foot of solid casing should remain sticking up above the ground surface. Once the well is sitting in the pit and meets this criteria, have the backhoe operator carefully backfill the pit so that large gravels and cobbles do not damage the screen or solid casing. It will be necessary to hold the piezometer vertically in place with a rod as the pit is backfilled. Continue to backfill until the original ground surface is reached.

Well development

After the well is installed, it needs to be “developed”. This process is necessary because excavating and backfilling the pit disturbs the native ground and sets fine sediments into suspension, which can enter the well and/or clog the screen. Developing the well consists of removing water from the well immediately after it is set to draw the turbid water and surrounding fine sediments into the well so that they can be removed. To do this, use either a portable pump or a hand bailer. A hand bailer is an instrument used to collect groundwater from a well. The hand bailer is usually a cylinder, 1 to 2 feet long with a diameter that allows it to slide inside the monitoring well, and contains a check valve at its base.

Development for drinking water wells is considered complete when the water being removed from the well clears of turbidity (Driscoll, 1986). However, clear water may not be an achievable condition following the backhoe installation method (i.e., a large area of disturbance relative to the diameter of the well). Because of this, and because these wells will not serve as a drinking water source, the following well development method is suggested.

To develop the well with a bailer, tie string to the top of the bailer and lower it into the well. As the bailer sinks, it will fill with water. After it fills, remove the bailer from the well (the check valve will keep the water from flowing out). Empty the first bailer into a glass jar, cap the jar, and set it aside, then proceed with developing the well by removing 3 well volumes of water (approximately 5 gallons for a 10 foot deep, 2 inch-diameter well). When the final bailer of water is removed, empty it into a second glass jar. Compare the sediment content of both jars. If the water is significantly less turbid than the initial sample, development can be considered complete. If there is no appreciable decrease in turbidity, repeat the process by

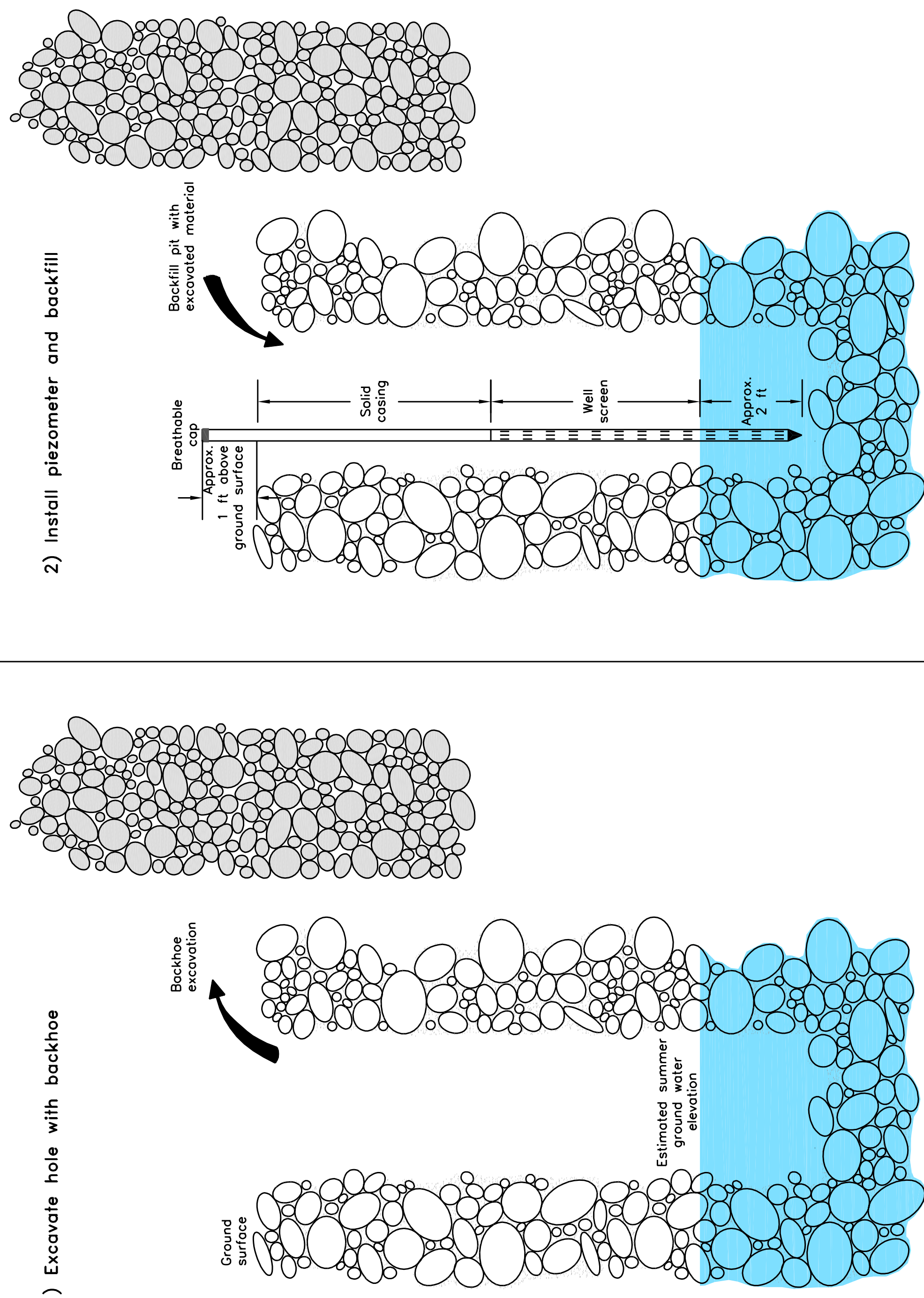


Figure 6.1: Piezometer installation procedure.

removing an additional 3 well volumes of water. If there is still no change, then the sediment concentration present in the samples is likely representative of the sediment concentration of groundwater in the vicinity of the well, and the well can be considered developed (to develop the well with a portable pump, follow the same instructions). Record all measurements and observations in the field notebook.

After development is complete, measure the depth of the inside of the well from the top of the casing. Some sediment will unavoidably be present in the bottom of the well, and this depth to the top of the sediment should be recorded. Next, make a notch on the top of the well casing on its north side. Using a hacksaw or similar device, cut a small (0.5 cm) “v” notch into the well casing, and survey the casing elevation at the notch. This notch will represent a measuring reference point that will serve as the location from which all water level measurements are read and groundwater elevations calculated. To avoid any confusion by other monitoring personnel, label the well with a sharpie, both on the inside rim of the well casing and on the inside of the well cap.

Monitoring

All wells should be measured (or “read”) every month to document the temporal groundwater fluctuations at each site. To do this, measure the depth to water in each well using either an electronic water meter, a tape measure, or a stadia rod. If using a tape measure or stadia rod, it is helpful to shine a flashlight down the well to note exactly when the water surface is contacted. The depth to water in each well should always be measured from its “v” notch. Water depths are recorded either in the field notebook or on a special field data form that converts depth-to-water measurements to true elevations. A field data form for recording and converting these measurements is included with the CD that accompanies this appendix. The advantage of using the field form is that true groundwater elevations are instantly available on-site.

In addition, one well per site should be selected for continuous monitoring. To do this, install a “down hole” pressure transducer and data logger to record groundwater elevations on a daily basis. The data collected by the data logger will provide an accurate account of groundwater fluctuations at the site and will supplement the measurements taken at the other wells. The data logger and monitoring assembly should be weatherproof, and a locking well cap should be used to prevent tampering with the equipment. There are several manufacturers of monitoring equipment, such as Global Water Instrumentation, Inc (http://www.globalw.com), who specialize in equipment made for these applications (e.g., Global Water model WL15).

Periodically, the total depth of the inside of each well should be re-measured to determine if there is any significant sedimentation inside the well. Because the piezometer is set in the ground without a filter pack[1], sediment may accumulate in the well over time and the well may need to be re-developed to remove excess fine sediment and clear the well screen.

A filter pack consists of sand or gravel that is smooth, uniform, clean, well-rounded, and siliceous. It is placed in the annulus of a well between the borehole wall and the well screen to prevent formation material from entering the screen (Driscoll 1986).

7.0 SURFACE SEDIMENTS MAPPING AND SAMPLING

To quantify surface particle size at a monitoring site, a sample of the streambed or floodplain substrate is collected and the distribution of particle size measured by number (e.g., pebble count) or by weight (e.g., sieve analysis). The pebble count technique is best suited for documenting particle size distributions of gravels and cobble substrates typically found within the bankfull channel, and is one of the most common due to its relative simplicity. The pebble count technique is discussed in detail in RM-245. Monitoring personnel should be familiar with the pebble count technique to document size parameters of surface sediment populations.

The channelbed surface within the bankfull channel often contains a mosaic of coarse substrates. For example, a Clear Creek meander bend may contain large cobbles in the riffles, and gravels and cobbles on point bars. Outside the bankfull channel, the floodplain would likely eventually be composed of sand and silt deposited by high flows. In this case, the channel and floodplains may each have separate distinct textural populations, or facies. Because each facies will yield its own unique particle size distribution, each must be sampled separately in order to document representative particle size information.

Materials

The following materials are required to delineate and document textural facies at lower Clear Creek monitoring sites:

- large-scale map or aerial photographs of the monitoring site; for example, a 1" = 25' scale map is recommended for in-channel mapping and a 1" = 50' scale map is recommended for floodplain mapping
- clipboard or map board (FS #51035)
- pencils and erasers
- long, flexible measuring tape (commonly 300' long) with clips or similar fasteners to affix tape to rebar pins (FS #39532 or #39851)
- "Rite in the Rain" brand field notebook (FS #49326)
- ruler (metric scale) (FS #47450)
- Total Station (optional)

Technique

To collect representative particle size information at a monitoring site, textural facies must be first delineated and then mapped. Following this task, each facies can be sampled and its particle sizes measured.

To delineate the textural facies at a site, Lisle and Madej (1992) suggest stratifying the bed into recognizable areas whose bed surface grain size composition falls into certain predetermined grain size ranges. Develop the grain size ranges to represent those that make up the bed surface at the site, then delineate facies boundaries based on a visual estimate of a large size parameter. For example, Lisle and Madej (1992) used the D_{75} (particle size in a cumulative distribution for which 75 percent is finer) as a large size parameter to delineate four facies:

Size Range	Facies Description
D_{75} > 64 mm	Cobble
64 mm > D_{75} > 22 mm	Coarse pebble
D_{75} < 22 mm	Fine pebble
Surface covered with > 25% sand	Sand

The above table shows an example of how facies can be delineated at a site, and can be used for in-channel and floodplain mapping. In addition to the above-listed size ranges, a silt size range is recommended for Clear Creek project sites (e.g., surface covered with > 25% silt = silt facies). Because particle size distributions are site-specific, facies size ranges and reference size parameters should be developed for each site.

Once facies are delineated, they should be mapped. Depending on the particular objectives at each site, mapping can rage from a hand-drawn sketch map to a Total Station survey. Hand-drawn sketch maps are typically sufficient to document facies locations, and should be constructed by drawing facies borders on a scaled topographic map, survey-controlled base map, or enlarged orthorectified aerial photograph of the site. A tape strung across a cross section is helpful for locating position on a bar or floodplain, and mapping should focus on plotting facies contacts (with facies labeled). Figure 7.1 presents a sample facies map.

Monitoring

In addition to aiding in the collection of representative bed samples due to textural variation at a site, surface sediments mapping provides a means to document textural evolution at that site (e.g., bed coarsening or fining, silt deposition on floodplains). Moreover, repeated mapping compliments other work performed and can aid in interpreting geomorphic processes at that site. A specific pebble count technique is presented in RM-245 on page 49, and a particle size analysis template for both pebble counts and volumetric bulk samples is included on the CD that accompanies this appendix.

Surface sediments mapping should follow any high flow event capable of causing geomorphic change at a site, or at least on an annual basis. In the case of in-channel monitoring, a monitoring trigger may be a flow exceeding a bed mobility threshold (perhaps 2,000 to 3,000 cfs), whereas on a floodplain, a monitoring threshold may be overbank flows (exceeding 3,000 cfs). Because each facies has its own unique particle size distribution, facies should be recognized (and mapped) prior to conducting pebble counts so that representative areas will be sampled and correct particle size parameters documented.

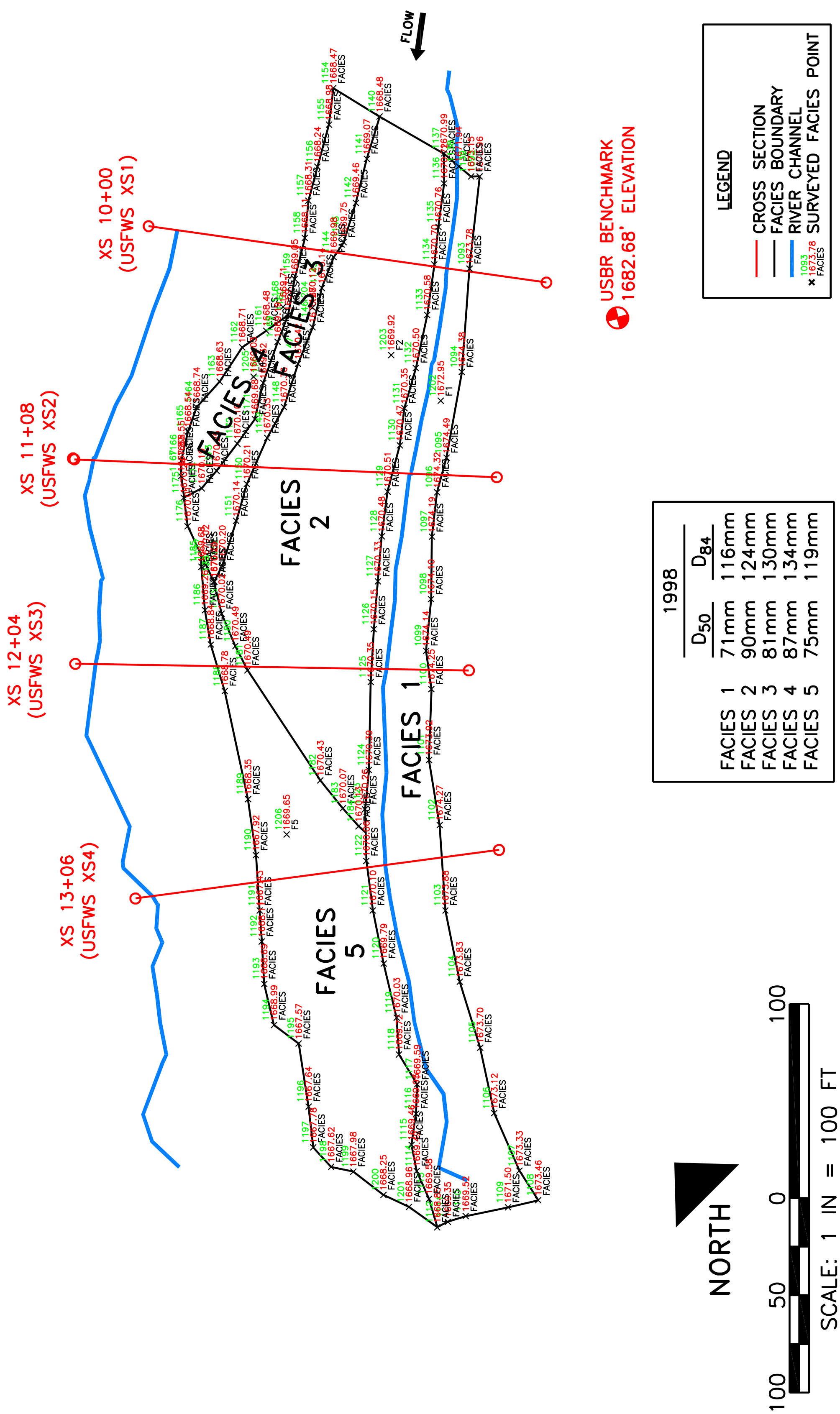


Figure 7.1: Sample textural facies map from the Trinity River, created by a total station survey.

8.0 MARKED ROCKS

Marked rocks, or tracer rocks, are used to document channelbed surface mobility on alluvial features (e.g., point bars, medial bars, pool tails, etc.). Specific particle size classes representative of the area to be monitored are painted a bright color, such as fluorescent orange, and placed at discrete locations in the channel along a monitoring cross section. Following a discrete high flow, the cross section is revisited to document whether mobility of the marked rocks occurred, and if so, how far they moved. The marked rocks are then re-set or replaced as initially installed for the next high flow event. In addition, marked rocks should be also set at a "control" cross section, located upstream of a restoration site, to compare and contrast bed mobility thresholds between unrestored channel areas and restoration sites.

Materials

The following materials are required to set and monitor marked rocks for channelbed surface mobility on alluvial features:

- bright paint, at least 3 cans of spray paint (e.g., Krylon brand "invert-a-can" or 1 quart of canned paint per cross section
- disposable paint brushes (if using canned paint)
- "sharpie" brand waterproof marker for labeling rocks
- tarp for painting rocks
- long, flexible measuring tape with clips or similar fasteners to affix tape to cross section rebar pins (FS #39532 or #39851)
- "Rite in the Rain" brand field notebook (FS #49326)
- particle size distributions from a pebble count or sieve analysis at the monitoring cross section
- waders and wading boots

Installation

Marked rocks should be grouped into "sets", with each set consisting of a D_{84}, D_{50}, and D_{31} (particle sizes in a cumulative distribution for which 84, 50, and 31 percent is finer, respectively). The size of the D_{84}, D_{50}, and D_{31} for each facies are based on the results of a pebble count or other sediment sampling technique as described in Section 7.0. First, collect rocks from a nearby exposed bar that represent each size class. Collect enough rocks so that sets can be placed on a cross section at three-foot intervals along the bankfull width (i.e., if the width of an exposed point bar on the cross section is 60 feet, collect 20 rocks each of the D_{84}, D_{50}, and D_{31} size class).

It is common for the monitoring cross section to pass through more than one facies due to particle sorting during high flows. If these conditions exist, it is best to split the marked rock sets into no more than two separate populations according to the major facies changes.

Once the rocks are collected, group them by size class and place them on the tarp to air dry (if needed), making sure their surfaces are clean and free of any fine sediment. This procedure works best when performed on a hot summer day. After the rocks have dried, paint one side, allow to dry, flip the rocks over, and paint the other side. After the paint has dried, use a thick "sharpie" brand waterproof marker to label each rock set. Label each rock set with a sequential letter or number, identify which lateral tape station on the cross section upon which it was originally placed, and record this data in the field notebook or data form. Each cross section should have its own unique marked rock-labeling scheme, such as numbers, letters, and/or paint color (see Figure 8.1).

Next, string the long tape tight across the cross section in the same manner as if the cross section was to be surveyed (affix the zero end of the tape to the left bank rebar pin and pull the tape tight across the stream). Begin placing rock sets by starting at one end of the bankfull channel, placing rock sets at two-foot intervals: place the D_{84} on the cross section, the D_{50} one foot upstream of the D_{84}, and the D_{31} one foot upstream of the D_{50} (Figure 8.1). This placement scheme prevents artificial shielding of smaller tracers by larger tracers. Each marked rock should rest on the bed surface so that its exposure mimics that of the surrounding rocks. To do this, place each marked rock on the bed surface by removing a similar sized rock from the bed and setting the marked rock in its place. This allows marked rock placements to reasonably maintain natural bed surface conditions and avoid unnaturally over-exposing or under-exposing the marked rocks. Record the precise station each mark rock set is located in the fieldbook.

Monitoring

The primary monitoring objectives are to determine at what streamflow discharge the marked rocks move, which alluvial features are mobilized, where rocks move on each feature, and how far the rocks move. Because the D_{84} at the Clear Creek project sites is designed to move at flows slightly less than the bankfull discharge (3,000 cfs), marked rocks should be checked for movement following flows greater than 2,000 cfs. Past studies using marked rocks suggest that after its initial placement, the rock sometimes reorients itself to a more hydraulically stable location rather than being truly mobilized (McBain and Trush 1997). Therefore, a marked rock should not be considered “mobilized” if its travel distance does not exceed two feet from its initial set position.

To record movement after a high flow, string the tape between cross section rebar pins and note whether each marked rock set was mobilized, and measure how far downstream they traveled. Next, inventory which rocks are missing. If they can be found downstream and have adequate paint and labeling, replace them on the cross section for the next monitoring event. However, many marked rocks that move downstream cannot be recovered due to substantial distance mobilized downstream, burial, and/or paint abrasion. New rocks of the appropriate size class must be gathered, dried, re-painted and labeled, and set on the cross section to await the next transporting flow. Record in the field book which rocks moved from the cross section and which were replaced. A marked rock data form is included on the CD that accompanies this appendix.

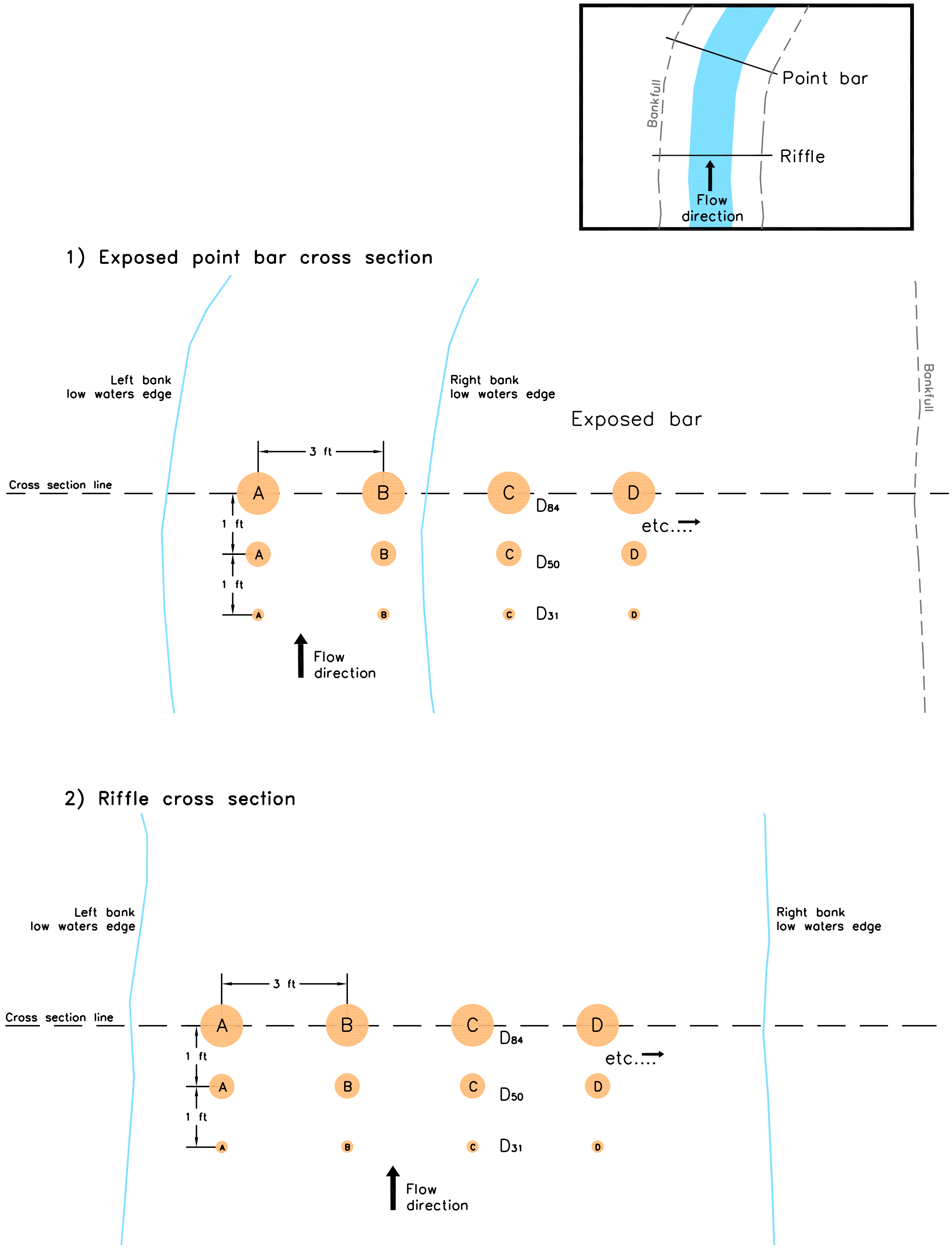


Figure 8.1. Typical tracer gravel placement along a cross section through hypothetical point bar(1) and riffle (2)

9.0 SCOUR CORES

Scour cores are used to document channelbed scour and redeposition on alluvial features (e.g., point bars, medial bars, riffles, pool tails). To measure this, a core of channel bed substrate is removed and backfilled with brightly painted, uniform size “tracer gravels” that are slightly smaller than the surrounding bed materials. When discharge increases and scours the surrounding bed, the tracer gravels also become entrained and are transported downstream. Following high flows capable of causing scour and redeposition, the scour core location is revisited to document scour and redeposition depths. Two to three scour cores are typically installed at a site where scour and redeposition is to be measured.

Materials

The following materials are required to install and monitor scour cores (note that the following materials list is for one scour core only):

- McNeil-type sampler, 6”, 8”, or 12” diameter (depending on size of substrate), 18” to 24” deep (see Figure 9.1)
- pre-painted tracer gravels approximating the D_{31} size class (enough to backfill the volume of the McNeil sampler); this size is required to ensure complete tracer gravel mobilization when the surrounding bed scours. For Clear Creek, small gravels finer than 1 inch should work.
- survey equipment (engineer’s level, tripod, stadia rod, field notebook) (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- long, flexible measuring tape with clips or similar fasteners to affix tape to cross section rebar pins (FS #39532 or #39851)
- waders and wading boots
- neoprene gloves
- small hand tools (e.g., gardening trowel) to excavate the substrate
- plastic 5-gallon bucket
- “Rite in the Rain” brand field notebook (FS #49326)

Installation

Choose a location to measure scour. Scour cores are commonly placed on a cross section to provide precise stationing and easiest to install on exposed bars. Survey the elevation of the bed surface (referenced to the site primary benchmark) and record this elevation in the field notes. Next, manually work the McNeil sampler approximately 1.5 feet into the bed, and place the excavated substrate in the 5-gallon bucket for disposal away from the scour core. This process can be tedious; best results are obtained by iterations of working the sampler a few inches into the bed, excavating some substrate, and repeating the process until the excavation is roughly 1.5 feet deep. Once the target depth is reached, survey the elevation of the bottom of the core, then backfill the core to roughly the original bed elevation with the tracer gravels. After backfilling the core, remove the McNeil sampler, smooth the surface of the tracer gravels with your hand, and survey the elevation of the top of the tracer gravels (see Figure 9.1, steps 1 through 5, and Figure 9.2).

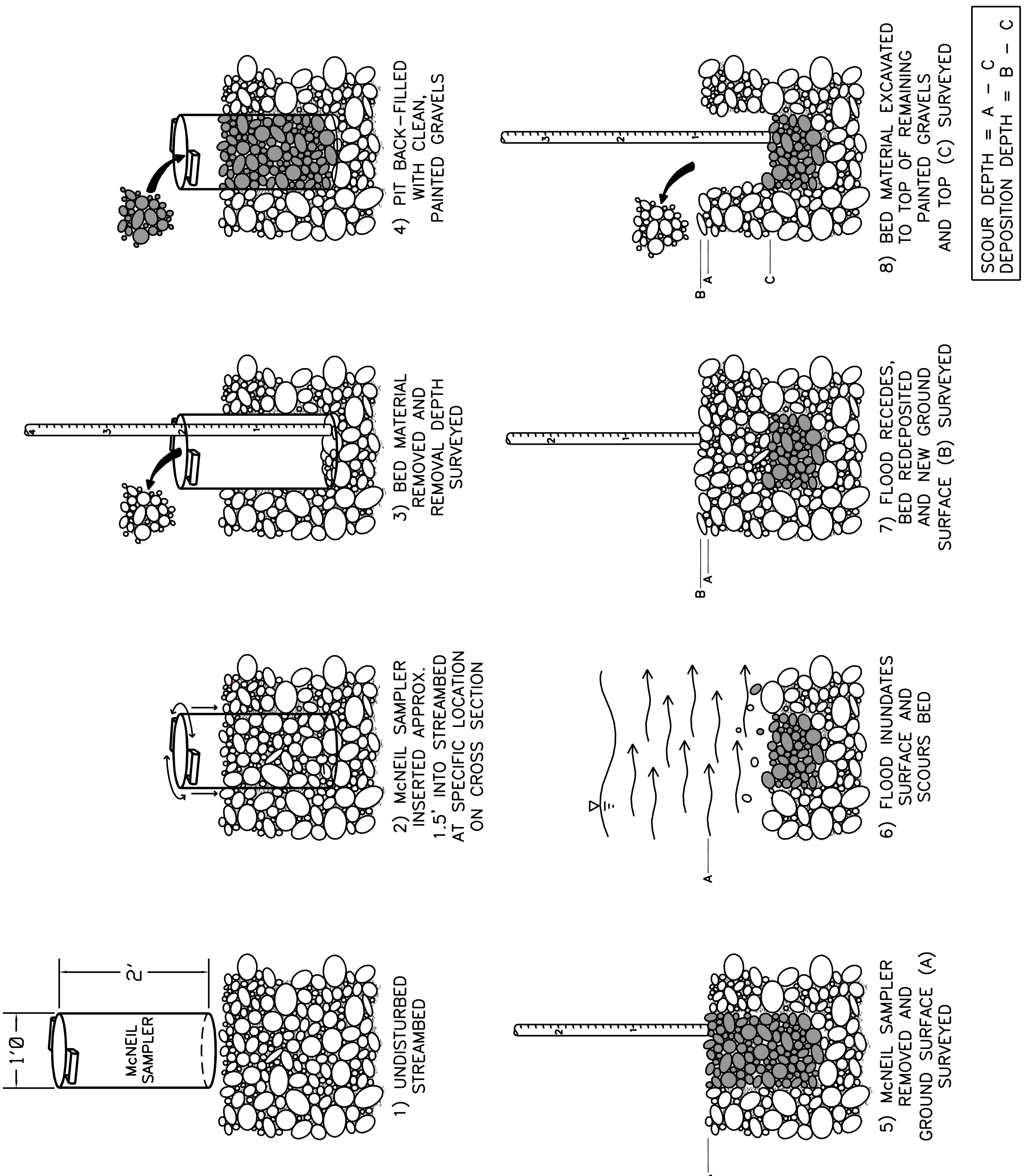


Figure 9.1: Scour core installation and monitoring procedure.

Figure 9.2: Photograph of freshly installed scour cores (yellow tracer gravels are exposed on the bed surface) on the Trinity River. A long tape is stretched perpendicular across the channel, and blue flagging is tied to the tape delineating precise scour core stationing. Note that there are 5 scour cores visible in the photograph; Clear Creek sites should only contain 2 or 3 on each cross section due to its smaller channel dimension.

<u>*Monitoring*</u>

During a high flow event that scours the bed, the tracer gravels will became entrained and transported away from the scour core. To document scour and redeposition depths following a scouring event, reoccupy the scour core location by stringing the tape across the cross section. Once the tape is strung, locate the precise station the core was installed, and survey the bed surface elevation. Using the McNeil sampler, carefully re-excavate the core until the tops of the tracer gravels are found It is important to re-excavate slowly, so the surface of the tracer gravels is not disturbed; if the excavation extends into the tracer gravels, an inaccurately large scour and redeposition depth will be recorded. Once the surface of the tracer gravels is exposed, survey the elevation of the top of the tracer gravels. Differences in surveyed bed elevations and surface tracer gravel elevations document scour and redeposition depths (Figure 9.1, steps 6 through 8). A scour core installation and excavation form is included on the CD that accompanies this appendix.

10.0 STAFF GAGE

Staff gages are used to measure the river's water surface elevation (stage) and are commonly associated with stream gaging stations to establishing stage-discharge relationships. However, staff plates can be installed independent of gaging stations for visual stage observations (to correlate to discharge) at any location of interest.

Materials

The following materials are required to install a single staff gage:

- enameled steel staff plate, marked in feet and tenths (FS #39732)
- 3 inch "channel iron", 7 feet long, with one end cut at a 45° angle (see Figure 10.1)
- custom-made 3-inch channel iron pounder (similar in design to a standard metal fence post pounder)
- economy heartwood redwood 2x4, ripped to fit snugly into channel iron and provide a flush surface to mount the staff plate (see Figure 10.1)
- survey equipment (engineer's level, tripod, stadia rod) (e.g., FS #37748, FS #37677, and FS #43259, respectively)
- "Rite in the Rain" brand field notebook (FS #49326)
- stainless steel carriage bolts and wood screws
- drill with 3/8" bit for mounting holes in channel iron and redwood

Installation

Choose a location to install the staff gage. The staff gage should be located in low-velocity water and out of the path of debris, and should also be located in a position that can record the lowest anticipated stage in the channel (Harrelson et al. 1994). If possible, the staff gage should also be installed in a location where the riffle crest that controls the low flow water surface elevation is fairly stable.

After a suitable location is selected, install the channel iron approximately 3 feet vertically into the substrate such that the wood and staff plate can be affixed after the iron is set into the bed, keeping in mind that the staff gage will be read from the bank (i.e., be sure that the staff plate will face the bank from which stage will be observed and recorded). Next, drill four 3/8" diameter holes in the upper 3-½' of channel iron and redwood, and use stainless steel carriage bolts to attach the wood to the channel iron. Then use stainless steel wood screws to attach the staff plates to the redwood (see Figure 10.1). When affixing the staff plates to the wood, be sure that the plates are positioned low enough so that they will record stage at the lowest anticipated flow in the channel.

After the staff gage is set, survey the elevation of the top of the staff plate (the 3.33' or 6.66' elevation) to establish the real elevation of the staff plate by surveying from the primary site benchmark. This will establish a real elevation of the staff plate and thereby establishing a datum to convert all stage readings to real elevation if needed. Establishing the elevation of the staff gage also provides control in case the staff gage is damaged or disturbed. In addition, it may be necessary to set more than one staff gage in order to cover the expected range of flows at the site (i.e., if stage varies more than 3.33' over the range of flows of

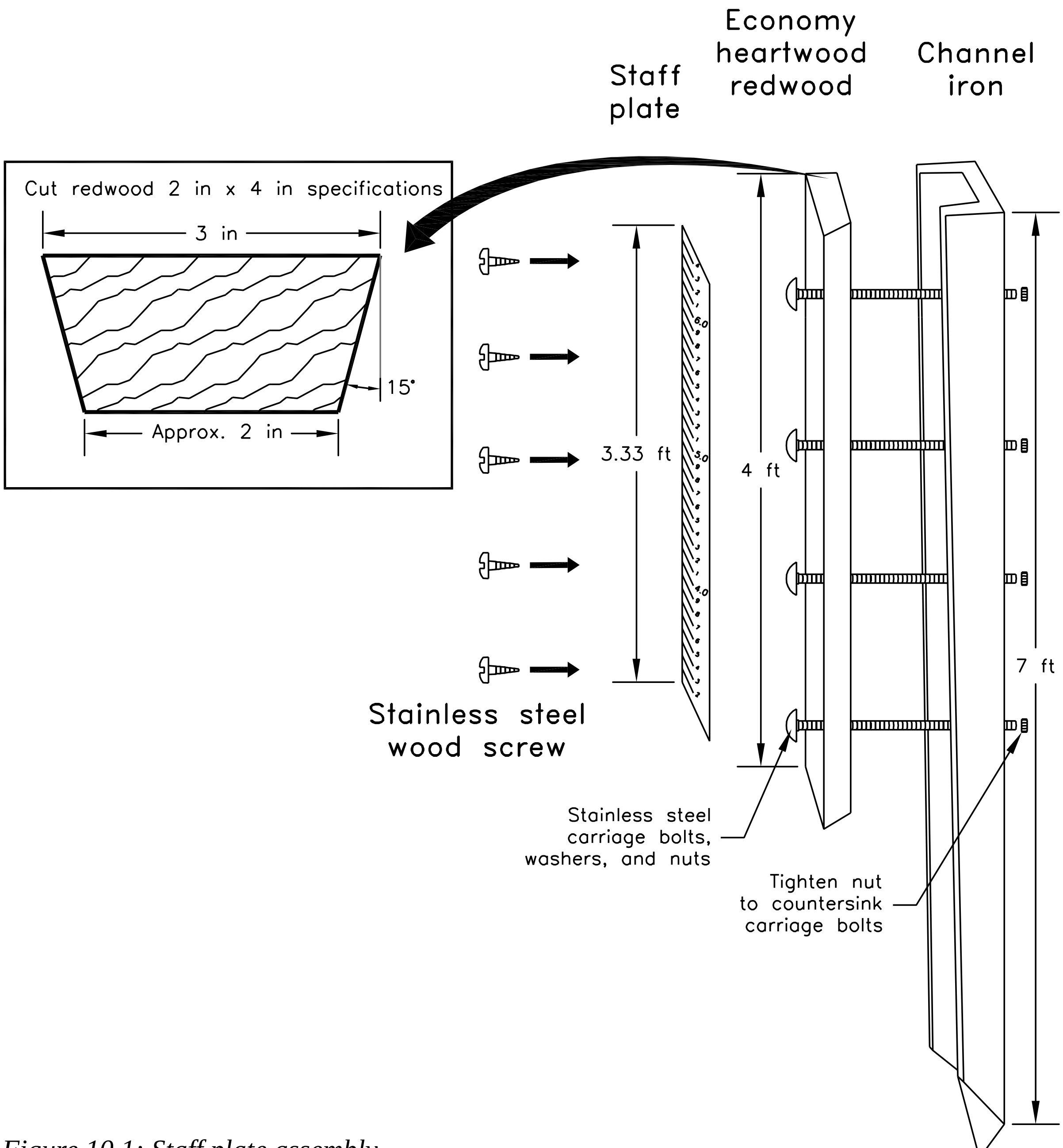


Figure 10.1: Staff plate assembly

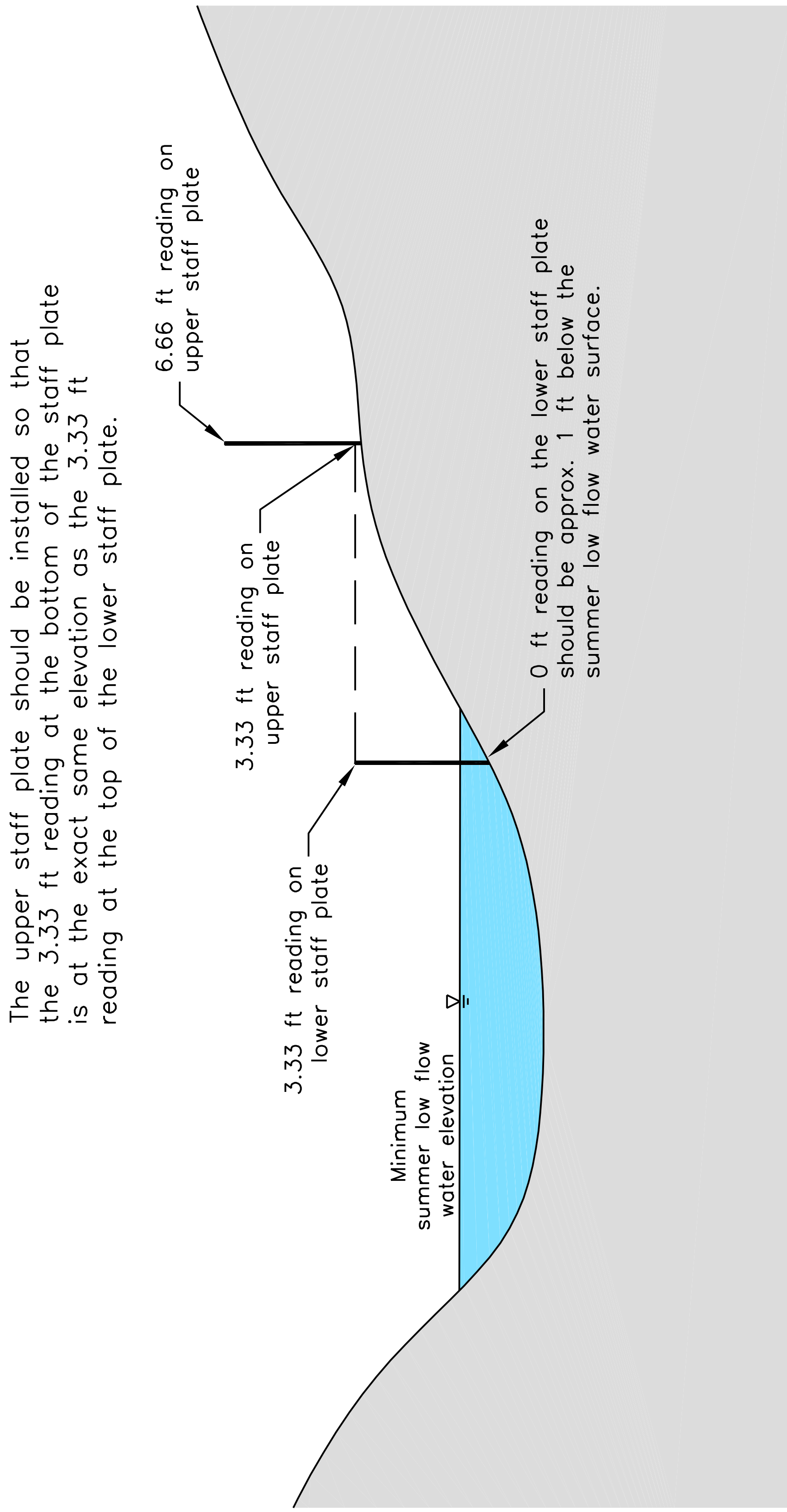


Figure 10.2: Multiple staff plate placement schematic

interest). In this case, it is important to set the second staff plate using survey control so that the elevation of the 3.33' line on the top of the lower staff plate is the same elevation as the 3.33' line on the bottom of the upper staff plate (see Figure 10.2).

Monitoring

The water surface should be read from the staff gage whenever the site is visited. This reading is commonly referred to as "gage height". Gage height and time of the reading should be recorded in the field notes.

Because the fundamental purpose of the staff gage is to correlate stage to discharge, should be measured at the time the staff gage is installed and at later times during various stages. Moreover, discharge must always be measured near the staff gage, whether at the location of the staff gage or at a location up- or downstream (as long as discharge is neither gained or lost between where discharge is measured and the staff gage). Generally, the closer the discharge is measured to the observed stage, the better.

When total discharge for a cross section is computed, its value is plotted against the gage height. Successive measurements of stage and discharge are plotted on what is called a discharge rating curve (Leopold 1994). On log-log graph paper, plot the gage height on the ordinate (Y-axis) and the discharge on the abscissa (X-axis) (Harrelson et al. 1994). An example rating curve is presented as Figure 10.3.

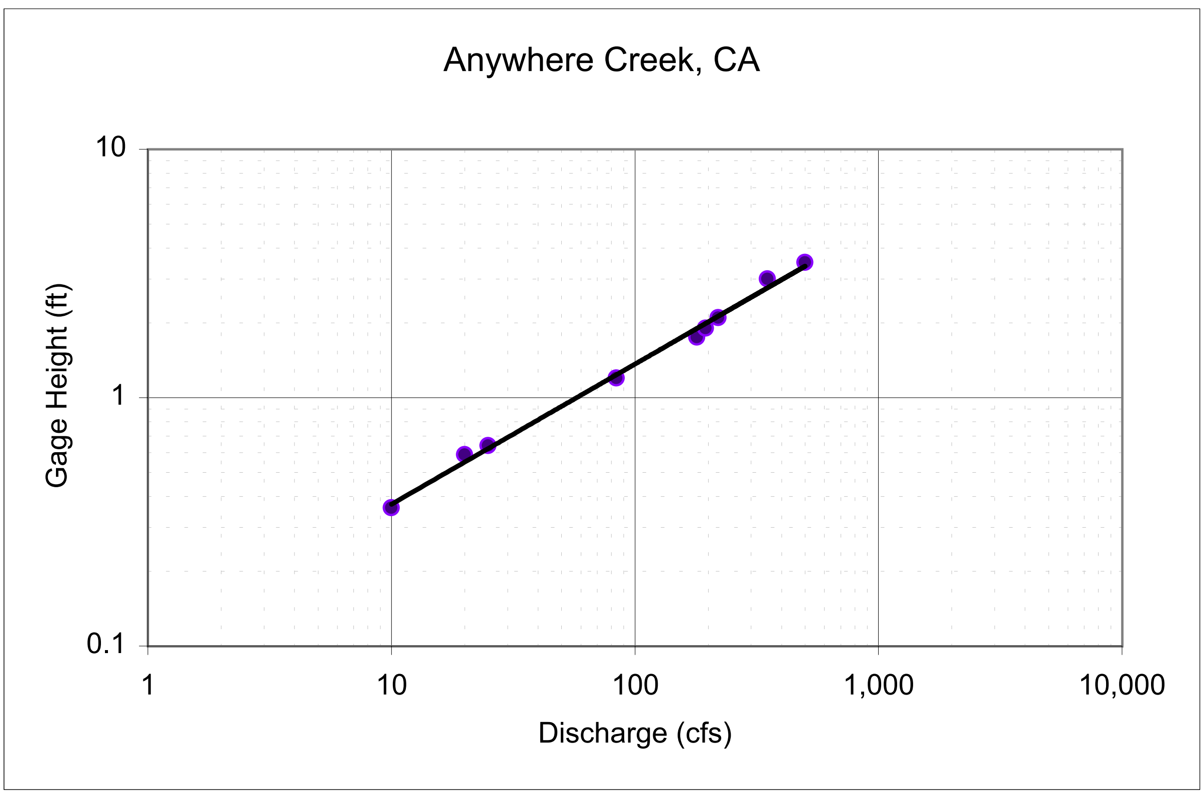


Figure 10.4. Example rating curve showing a power function fit of measured gage heights and discharges.

The goal of placing staff plates is to develop a stage-discharge rating curve for the location where the plate is set, upon which we can evaluate flow-stage relationships important for project performance (i.e., do the constructed flood plains inundate at 3000 cfs?). Because several staff gages have already been installed at Clear Creek project sites, (see figures 4.2 and 4.3) it would be impractical to take a discharge measurement at every staff gage to develop the rating curves. Instead, a single discharge measurement approximately halfway between the two Clear Creek project sites (Reading Bar and Restoration Grove) is sufficient to plot against stage recorded at all staff gages. The recommended location for this discharge measurement location is at Renshaw Riffle (river mile 5.3) and assumes that this measurement at Renshaw Riffle accurately depicts discharge at both project sites.

To accurately document stage-discharge relationships for a measured discharge at Renshaw Riffle to water stage recorded at each staff gage, we recommend first taking a discharge measurement, then immediately collecting staff plate readings at all staff gages. Alternatively, if discharge cannot be measured at Renshaw Riffle, discharge can be obtained from the U.S. Geological Survey Clear creek near Igo, CA gage (Gage ID# 11372000). However, because the Igo gage is located further from the project sites than the Renshaw Riffle, stage-discharge relationships will not be as representative of local site conditions if there is a tributary derived runoff event occurring. In addition, the discharge recorded at Igo will be different than discharge measured at Renshaw Riffle. If discharge data is used from both sources (Renshaw Riffle and Igo), the stage-discharge data can be plotted on the same graph, but each discharge source should have its own data point symbol. The Igo data points should be closely scrutinized to see if they can be reasonably used in developing rating curves at staff plates in the project reach.

Because the channel geometry can change where discharge is measured (thereby affecting the area-velocity relationship for discharge computation), the relationship between stage and discharge can change. Changes in the stage-discharge relationship will cause subsequent stage-discharge points to deviate from the rating curve. This is called a “shift” in the rating. After such a change takes place, such as after a large flood, a new rating curve will have to be constructed via a new series of discharge measurements and staff gage readings.

REFERENCES

Driscoll, F. G. 1986. *Groundwater and Wells*. Johnson Division, St. Paul, Minnesota. 1089 p.

Elzinga, C. L., D. W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. Denver, Colorado, US Bureau of Land Management.

Harrelson, C.C., C. L. Rawlins, and J. P. Potyondy. 1994. *Stream channel reference sites:an illustrated guide to field technique.* Gen. Tech. Rep. RM-245. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

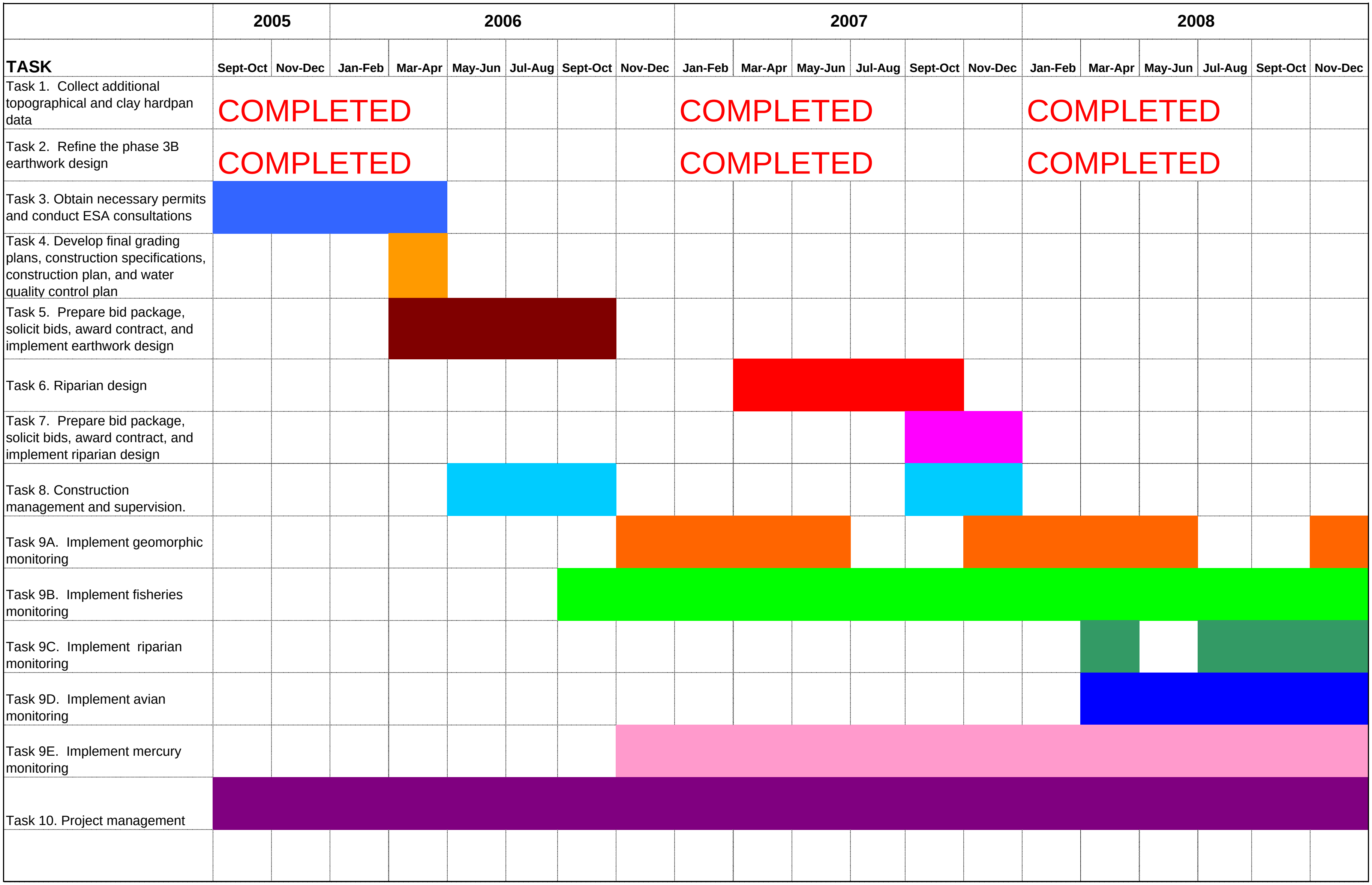
Leopold, L. B. 1994. *A View of the River*. Harvard University Press. Cambridge, MA. 298 p.

Lisle, T. E., and M. A. Madej. 1992. Spatial variation in armouring in a channel with high sediment supply. In, Billi, P., R. D. Hey, C. R. Thorne, and P. Tacconi (eds.). Dynamics of Gravel Bed Rivers. John Wiley and Sons, Ltd. pp. 277-291.

McBain and Trush. 1997. Trinity River maintenance flow study - Final Report. Arcata, CA. 316p.

Appendix VI.
Timeline

Lower Clear Creek Floodway Rehabilitation Project Timeline



Lower Clear Creek Floodway Rehabilitation Project Timeline

	2009						2010					
TASK	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sept-Oct	Nov-Dec	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sept-Oct	Nov-Dec
Task 1. Collect additional topographical and clay hardpan data	COMPLETED						COMPLETED					
Task 2. Refine the phase 3B earthwork design	COMPLETED						COMPLETED					
Task 3. Obtain necessary permits and conduct ESA consultations												
Task 4. final grading plans, construction specifications, construction plan, and water quality control plan												
Task 5. Prepare bid package, solicit bids, award contract, and implement earthwork design.												
Task 6. Riparian design.												
Task 7. Prepare bid package, solicit bids, award contract, and implement riparian design												
Task 8. 8. Construction management and supervision.												
Task 9A. Implement geomorphic monitoring												
Task 9B. Implement fisheries monitoring												
Task 9C. Implement riparian monitoring												
Task 9D. Implement avian monitoring												
Task 9E. Implement mercury monitoring												
Task 10. Project management												

Appendix VII.

Detailed Budget

Task Budget for The Lower Clear Creek Floodway Rehabilitation Project

Project management	**$117,128.00**
Collect additional topographic and clay hardpan data	**$0**
Refine the Phase 3B earthwork design.	**$0**
Obtain necessary permits and conduct ESA consultations	**$30,000.00**
Develop final grading plans, construction specifications, construction plan, and water quality control plan	**$25,000.00**
Prepare bid package, solicit bids, award contract, and implement earthwork design	**$1,781,500.00**
Revegetation design	**$50,000.00**
Prepare bid package, solicit bids, award contract, and implement riparian design	**$390,766.00**
Construction management and supervision	**$73,535.00**
Implement monitoring.	**$1,170,198.00**
Irrigation and Maintenance	**$40,319.00**
Contingency	**$367,845.00**
Indirect	**$728,332.00**
Project Total	**$4,774,622.00**

.

Task 1. Project Management	Year 1				Year 2				Year 3				Year 4				Year 5			
	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total
District Manager: Attend meetings, oversee contracting, project implementation, district affairs= 50 hours per year	28	50	Hour	1,400	29	50	Hour	1,450	30	50	Hour	1,500	31	50	Hour	1,550	32	50	Hour	1600.00
benefits @ 30%				420				435				450				465				480.00
Project Manager: Oversee implementation of the project 100hr/year year 12 meetings @ 5 hours plus monitoring contracts 50 hours plus tours and misc 40 hours	26	250	Hour	6,500	27	250	Hour	6,750	28	250	Hour	7,000	29	250	Hour	7,250	30	250	Hour	7500.00
benefits @ 30%				1,950				2,025				2,100				2,175				2250.00
Project Coordinator: Year 3, 4and 5 100 hours irrigation and maintenance plus 25 hours misc									22	125	Hour	2,750	23	125	Hour	2,868	23	125	Hour	2867.50
benefits @ 30%												825				860				860.25
Secretary: General support 70 hours per year	15	70	Hour	1,050	15.5	70	Hour	1,085	16	70	Hour	1,120	16.6	70	Hour	1,162	17.2	70	Hour	1200.50
benefits @ 30%				315				326				336				349				360.15
Education and Outreach Materials			Lump Sum	4,000			Lump Sum	4,000			Lump Sum	4,000			Lump Sum	4,000			Lump Sum	4000.00
Copies and office supplies	1	1,550	Lump Sum	1,550	1	Lump Sum	500	500	1	Lump Sum	520	520	1	Lump Sum	540	540	1	Lump Sum	560	560.00
Meeting supplies	1	2,000	Lump Sum	2,000	1	Lump Sum	207	207	1	Lump Sum	2,143	2,143	1	Lump Sum	2,218	2,218	1	Lump Sum	2,300	2300.00
Postage	1	700	Lump Sum	700	1	Lump Sum	200	200	1	Lump Sum	210	210	1	Lump Sum	220	220	1	Lump Sum	225	225.00
Misc. offic equipment	1	500	Lump Sum	500	1	Lump Sum	200	200	1	Lump Sum	210	210	1	Lump Sum	220	220	1	Lump Sum	222	222.00
Transportation and Travel	0.50	3,000	Miles	1,500	0.52	3,000	Miles	1,560	0.54	3,000	Miles	1,620	0.56	3,000	miles	1,680	0.58	3,000	1,721	1740.00
Total				**21,885**				**18,738**				**24,784**				**25,556**				**26165.40**

Task 2 and 3. Refine the Phase 3B earthwork design and Collect additional topographic and clay hardpan data	Year 1				Year 2				Year 3				Year 4				Year 5			
	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total	Rate	Quantity	Unit	Total
Pre-construction surveys			Lump Sum	***41,400***																
Pre-design field data gathering and meetings with Restoration Team			Lump Sum	***31,050***																
Total				-																

Task 4. Obtain necessary permits and conduct ESA consultations	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
	Rate	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Elderberry surveys for Phase 3B			Lump Sum	***10,000***																
Wetlands Delineation			Lump Sum	***25,000***																
Biological Evaluation and NEPA			Lump Sum	***40,000***																
CEQA			Lump Sum	10,000																
Permit fees and preparation of permit documents			Lump Sum	20,000																
Total				**30,000**																
	Year 1				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
Task 5. Develop final grading plans, construction specifications, construction plan, and water quality control plan	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Earthwork designs, grading plans, and specifications				***51,750***																
Water Pollution Control Plan				25,000																
Total				**25,000**																
	Year 1				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
Task 6. Prepare bid package, solicit bids, award contract, and implement earthwork design	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Construction Staking	$25,000	1	Lump Sum	25000																
Mobilization	$50,000	1	Lump Sum	50000																
Clearing and Grubbing	$1,000	40.00	Acres	40000																
Instream Imported Clean Gravel	$22	13,000	Cubic Yard	286000																
Imported Mass Fill from Local Borrow	$6	65,000	Cubic Yard	390000																
Haul and Stockpile for 3C from Local Borrow	$7	30,000	Cubic Yard	210000																
Onsite Cut/Fill topsoil, stockpile	$4	44,000	Cubic Yard	176000																
Biotechnical Revetment	$350	650	Linear Foot	227500																
Clay backfill and Compaction in Existing Incised Channel	$10	4,000	Cubic Yard	40000																
Habitat Structures	$5,000	5	Each	25000																
Heavy Rock Weir	$20,000	3	Each	60000																
Transition Grade Control Structure	$50,000	1	Lump Sum	50000																
Install/Remove three railroad bridge crossings	$10,000	3	Each	30000																

Over-excavate new channel	$5	13,000	Cubic Yard	65000																
Insert clean gravel into stream channel (includes wet placement and dry grading)	$4	13,000	Cubic Yard	52000																
Dewatering and re-watering	$25,000	1	Lump Sum	25000																
Silt Fence and other miscellaneous materials	$10,000	1	Lump Sum	10000																
As-built surveys	$20,000	1	Lump Sum	20000																
Total				**1,781,500**																
	Year 1				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
Task 7. Revegetation design	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Site Assessment/Data Analysis					20,000		Lump Sum	20,000												
Riparian Revegetation Design					30,000		Lump Sum	30,000												
Total								**50,000**												
	Year 1				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
Task 8. Prepare bid package, solicit bids, award contract, and implement riparian design	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Lead Technician Year 2 lead cutting procurement 700,					12	700	Hour	8,652												
benefits @ 30%								2,596												
Field Technician (3) Year 2 cuttings and revegetation 2100 hrs,					10	2,100	hour	21,630												
benefits @ 30%								6,489												
Mobilization							Lump Sum	9,000												
Purchase container stock					5	5,356	Plant	24,102												
Herbaceous Plantings					1	4,000	Plant	4,400												
Install herbaceous Plantings							Lump Sum	6,000												
Purchase and spread native seeds					19	600	total cost	11,400												
Install cuttings and container stock					7,900	25	acre	197,500												
Topsoil insertion at container stock locations					3	5,356	Planting	13,390												
Irrigation purchase and installation							Lump Sum	18,000												
Cold Storage Facilities (trailer and storage							Lump Sum	15,000												
Field Supplies for gathering of cuttings							Lump Sum	6,500												
Mileage					0	2,700	Mileage	1,107												
Fertilizer, rebar, misc materials					2	30,000	Planting	45,000												
Total								**390,766**												

Task 9. Construction management and supervision.	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
	Rate	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Project Manager: oversee implementation of the construction 600 hrs first year, Oversee implementation of revegetation project year 2 150 hours	26	600	Hour	15,600	27	150	Hour	4,050												
benefits @ 30%				4,680				1,215												
Project Coordinator (700 hours first year supervising construction and revegetation, 2 Year supervising construction and revegetation	22	700	Hour	15,400	23	300	Hour	6,900												
benefits @ 30%				4,620				2,070												
Field Supplies			Lump Sum	12,500			Lump Sum	5,000												
Mileage	1	1,500	Mileage	750	1	1,500	Mileage	750												
Total				**53,550**				**19,985**												
Task 10. Implement Monitoring	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
	Rate	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Fisheries Monitoring			Lump Sum	150,000			Lump Sum	150,000			Lump Sum	150,000								
Geomorphic Monitoring			Lump Sum	45,000			Lump Sum	45,000			Lump Sum	45,000								
Mercury Monitoring (total load)			Lump Sum	73,000			Lump Sum	73,000			Lump Sum	73,000								
Biosentinel Mercury Monitoring			Lum Sum	34,480			Lum Sum	35,470			Lum Sum	36,487								
Avian Monitoring											Lump Sum	22,000			Lump Sum	25,000			Lump Sum	27000.00
Revegetation Monitoring											Lump Sum	64,000			Lump Sum	45,548			Lump Sum	76213.00
Total				**302,480**				**303,470**				**390,487**				**70,548**				**103213.00**
Task 11. Irrigation and Maintenance	**Year 1**				**Year 2**				**Year 3**				**Year 4**				**Year 5**			
	Rate	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**	**Rate**	**Quantity**	**Unit**	**Total**
Lead Technician Year 3 through 5 supervise irrigation and maintenance with field technicians 300 hrs									12.73	300	Hour	3,819	13.11	300	Hour	3,933	13.5	300	Hour	4053.00
benefits @ 30%												1,146				1,180				1215.90
Field Technician (3) year 3 through 5 480 hours irrigation and maintenance									11	480	Hour	5,093	11	480	hour	5,266	11	480	Hour	5265.60
Field supplies											Lump Sum	4,500			Lump Sum	1,500			Lump Sum	1500.00
Mileage									0.54	1,100	miles	594	0.56	1,100	miles	616	0.58	1,100	miles	638.00
NIS treatments and monitoring											Lump Sum	***11,650***			Lump Sum	***11,650***			Lump Sum	***11650.00***
Total												**15,152**				**12,495**				**12672.50**

	Year 1		Year 2	Year 3	Year 4	Year 5
Subtotal Per Year		**2,214,415**	**782,958**	**430,423**	**108,599**	**142050.90**
Total (five years)	**3,678,445**					
10% Contingency	**367,845**	**Cost Share**	**234,150**			
Indirect	**728,332**					
Total Project Cost	**4,774,622**					

Please note cost share in red Italics

Appendix VIII.

Letters of Support

Shasta County
BOARD OF SUPERVISORS

Mark Cibula, District 2

1450 Court Street, Suite 308B
Redding, CA 96001-1680
(530) 225-5557
(800) 479-8009
(530) 225-5189-FAX

July 14, 2005

California Bay-Delta Authority
650 Capitol Mall, 5th Floor
Sacramento, Ca. 95814

To Whom It May Concern:

I am writing to express my strong support for The Western Shasta Resource Conservation District (WSRCD) proposal to the CALFED Ecosystem Restoration Program. This important project will benefit the fish and wildlife, geography, economy, and recreation of Shasta County.

This proposal requests funding to complete the next phase (Phase 3B) of the Lower Clear Creek Floodway Rehabilitation Project and, in doing so, addresses a headcut that is threatening previous successful phases of the Project. This Project was initiated in 1998 to address impaired geomorphic, riparian, and salmonid habitat conditions on Clear Creek along the 1.8-mile reach degraded by historic gravel mining.

Previous phases of the project, implemented with CALFED Ecosystem Restoration Program and Central Valley Project Improvement Act (CVPIA) funding, restored 90.8 acres of floodplain. This proposed Phase 3B (Project) will reconstruct the bankfull channel for this next phase of the restoration project contiguous with floodplain surfaces restored in previous phases. It will also stabilize a headcut that is migrating into previous project areas and threatening to undo or damage the investments to date.

The Project is supported by the Lower Clear Creek Coordinate Resource Management Program, by CALFED through previous funding and objectives to recover Priority Group I Salmonid Species, by the U.S. Bureau of Reclamation through previous funding and Section 3406 of the CVPIA, by the Bureau of Land Management (BLM) through cost sharing and property ownership, by the Anadromous Fish Restoration Program (AFRP), and by agencies involved with project design and restoration (Lower Clear Creek Restoration Team). Completion of this next phase of the Project will not only significantly improve salmonids/aquatic habitat, riparian and avian habitat, and fluvial geomorphic processes in Clear Creek, but it will also protect previous investments.

The timing of this proposal is particularly important as there have been a number of recent successes in increasing the fish and wildlife in the area. The recent acquisition of land by BLM on Clear Creek and the new formation of a Clear Creek Watershed citizens group make for the perfect combination of resources for a tremendously positive impact in an area with great potential for enjoyment by citizens of the entire region.

Please feel free to contact me if you need further information.

Thank you for your consideration of this important project.

Sincerely,

MARK CIBULA
Supervisor, District 2
County of Shasta

Horsetown-Clear Creek Preserve

P.O. Box 107 • Igo, CA • 96047

July 13, 2005

California Bay-Delta Authority
650 Capitol Mall, 5th Floor
Sacramento, CA 95814

RE: Clear Creek Restoration Project

We enthusiastically support the work of the Western Shasta Resource Conservation District (WSRCD) to restore the Lower Clear Creek Watershed. A great deal of successful rehabilitation work has been done in the Clear Creek Watershed since 1998. Horsetown-Clear Creek Preserve (HCCP) would very much like to see the next phase of the rehabilitation project completed.

The area of Clear Creek where this work is being done has been the focus of our organization since 1988. It was our vision to reclaim this portion of Clear Creek, which was the site of the second major gold discovery in California in 1849. Gold mining, and later gravel mining, were very destructive to the creek and the fisheries there. Also, in 1988 there was considerable crime in the area.

HCCP's vision to reclaim this creek is being accomplished in a grand way through the WSRCD's efforts with the Floodway Rehabilitation Project. The 90 acres of floodplain restored to date has made a tremendous impact. The next phase of the Project not only reclaims additional acres of the floodplain, it addresses a headcut that is threatening previous successful work. This is a particularly important phase where time delays may have a negative impact.

Each spring and fall HCCP invites members of the public to educational walks in the watershed. Salmon viewing and tours of the restoration project have become popular events, along with fly fishing demonstrations (trout), aquatic insects, banding of songbirds by Point Reyes Bird Observatory, and general birding events. The public visiting our watershed is excited to see the success here in improving the salmonids/aquatic habitat and the riparian and avian habitat. Throughout the year more and more people are enjoying the beauty of Clear Creek along with greater numbers of fish, bird, and wildlife populations.

It is with great pleasure that we endorse and cooperate to support the Western Shasta Resource Conservation District in the Lower Clear Creek Watershed and Horsetown-Clear Creek Preserve. We respectfully request that the California Bay-Delta Authority support these efforts with funding to complete the next phase of this successful project.

Cathy Scott

Cathy Scott, President, Horsetown-Clear Creek Preserve

Lower Clear Creek
Watershed / Coordinated Resource Management & Planning Group
Private landowners, stakeholders, concerned citizens, federal, state and local agencies working together to restore the lower Clear Creek watershed

6270 Parallel Road, Anderson, CA 96007 • Phone: (530) 365-7332 Fax: (530) 365-7371

July 12, 2005

California Bay-Delta Authority
650 Capitol Mall, 5th Floor
Sacramento, CA 95814

RE: Lower Clear Creek Floodway Rehabilitation Project, Phase 3B

Dear Authority Committee,

Since 1996, landowners, residents and agencies have met together under the auspices of the Clear Creek CRMP Group, thanks to the efforts of the RCD. The active CRMP participants and the 800+ people on the mailing list have been kept informed, asked for input and enjoyed many educational meetings and tours in the Lower Clear Creek watershed.

Following the progress that has been made to date on the Lower Clear Creek Rehabilitation Project, we continue to be impressed by the scale of the work being done, the efforts to include community members and school children in the process, and, of course, the improvement in the numbers of fish returning to Clear Creek already.

On behalf of the Lower Clear Creek Watershed/CRMP Group, I would like to express that the goals of Phase 3 of the Lower Channel project are extremely valuable and fully support efforts to obtain CALFED funding for this work. If there is anything further we can do in this regard, please let me know.

Sincerely,

Leslie Bryan
Clear Creek Watershed Coordinator

United States Department of the Interior

BUREAU OF RECLAMATION
Northern California Area Office
16349 Shasta Dam Boulevard
Shasta Lake, California 96019-8400

IN REPLY REFER TO:

JUL 14 2005

NC-311
ENV-7.00

California Bay-Delta Authority
650 Capitol Mall, 5th Floor
Sacramento, CA 95814

Subject: Lower Clear Creek Floodway Rehabilitation Project Phase 3B

As the lead Federal agency for the restoration of Clear Creek under the Central Valley Project Improvement Act, the Bureau of Reclamation strongly supports and encourages the California Bay-Delta Authority to fund Phase 3B of the Lower Clear Creek Floodway Rehabilitation Project (Project). Furthermore, Reclamation endorses the Western Shasta Resource Conservation District (WSRCD) as implementer of Phase 3B.

The Project is designed to improve anadromous fish habitat by rehabilitating 2 miles of the Clear Creek floodplain and channel that was degraded by in-stream gold and aggregate mining. Since 1998, Reclamation has provided cost-share funding for design and implementation of Phases 1, 2A, 2B, and 3A. Reclamation is fully committed to completing the Project and has funded a consulting firm to design and prepare a construction-ready bid package for Phase 3B.

Since 1998, Reclamation has worked closely with the WSRCD on design and implementation of the Project. As the implementer of the Project, the WSRCD has shown an unparalleled degree of expertise in coordinating design, permitting, and construction of the Project. The WSRCD has the proven ability to work closely with contractors during construction of all previous Project phases. The WSRCD has implemented all previous phases on time, under budget, and to design specifications.

If you have any questions or would like to discuss further, please contact me at 530-276-2046.

Sincerely,

James De Staso III
Fishery Biologist

State of California | The Resources Agency

Memorandum

To: Mr. Tim Ramirez
California Bay Delta Authority
Ecosystem Restoration Program
650 Capitol Mall, 5th Floor
Sacramento, CA 95814

Date: July 14, 2005

From: **DONALD B. KOCH, Regional Manager**
Northern California-North Coast Region
Department of Fish and Game
601 Locust Street
Redding, CA 96001

Subject: Directed Action Funding Submission for Phase 3B, Clear Creek Floodway Rehabilitation Project

For several years the California Department of Fish and Game (DFG) has been a technical advisor to the Western Shasta Resource Conservation District (RCD) in the arena of watershed restoration for the benefit of threatened and endangered anadromous fish and other natural resources. The focus of RCD's work has been primarily in the lower Clear Creek watershed. Efforts have been underway to restore the most degraded 1.8 mile section of creek, utilizing the principles of ecosystem management.

Restoration of Clear Creek is identified in the Central Valley Project Improvement Act (CVPIA) and the CALFED Bay-Delta Program Ecosystem Restoration Program, Draft Stage 1 Implementation Plan. The partnership between the RCD and multiple local, State, and Federal agency technical advisors (which includes DFG) to restore Clear Creek has received wide support, as evidenced by several State and Federal grants. To date roughly two-thirds of the planned restoration work has been completed; Phase 3B of the Clear Creek Floodway Rehabilitation Project (Project) is one of the final steps in completing the original restoration plan.

The proposal requests funding to implement Phase 3B and, in doing so, addresses a head-cut that is threatening previous successful phases of the Project. A solution to the head-cutting problem is necessary to protect existing restoration sites on Clear Creek, to provide the opportunity for future restoration, and to avoid a stranded investment of between $13 million and $14 million in the lower Clear Creek drainage. If left untreated, the head-cut problem at the unstable reach poses several threats to the lower Clear Creek restoration project which include:

1. the loss of existing spawning and rearing habitat that was recreated at the restoration site;
2. the loss of the most suitable location for diverting the channel in future phases of the project. From a geomorphic perspective, the head-cut will create difficult design challenges for future channel alignment. If the redirection has to be relocated further upstream, it will cut through a revegetated area which has already been restored; and

3. a potential for lowering the depth to the water table which would negatively affect existing riparian restoration and make future riparian revegetation more difficult.

Completion of this next phase of the Project will improve salmonid/aquatic habitat, riparian and avian habitat, and fluvial geomorphic processes in Clear Creek. It will also protect previous investments and provide CALFED with valuable project implementation information, project-related experimental results, and a model demonstration stream available for immediate and continued adaptive management opportunities. On a similar note, DFG supports necessary monitoring on the project to lend worthwhile data and improve to lend CALFED ERP knowledge on projects of this nature.

We look forward to continuing our relationship with the RCD as a technical advisor to help ecosystem restoration, environmental education, and watershed stewardship within our areas of influence.

cc: Messrs. Ken Moore, Neil Manji
Steve Turek, Randal C. Benthin
and Mike Berry
Ms. Patricia Bratcher
Department of Fish and Game
601 Locust Street
Redding, CA 96001

Ms. Diana Jacobs
Department of Fish and Game
1416 Ninth Street
Sacramento, CA 95814

5.1. FUNDING SOURCES AND THEIR OBJECTIVES

Project planning and implementation are being funded by the Central Valley Project Improvement Act (CVPIA) and the CALFED Bay Delta Ecosystem Restoration Program. Funding for off-channel wetland creation is also being provided by the BLM Abandoned Mines program. Total funding for this project will require approximately $14,000,000. Clear Creek is a specific line item restoration stream in the CVPIA, with a primary purpose to protect, restore and enhance fish, wildlife and associated habitats in the Central Valley and Trinity River Basins of California. The largest funding contributor to this project is the CALFED Bay Delta Ecosystem Restoration Program. CALFED's primary ecosystem restoration objective is to:

"Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species"

The objective to "improve ecological function" is difficult to quantify. We attempt to better describe this goal as "attributes of alluvial river integrity" that help guide rehabilitation goals and objectives of this project.

5.2. ALLUVIAL RIVER ATTRIBUTES AS A GUIDE TO REHABILITATION

Our approach to channel rehabilitation design is based on a series of alluvial attributes that have been found to effectively define the geomorphic characteristics of a healthy, fully functioning river system (McBain & Trush 1997). The term "alluvial" exceeds simply having the channel composed of cobbles and gravels (alluvium); the river must also be able to form and adjust its bed and banks. We define these alluvial attributes for each system based on site-specific characteristics, and then develop the linkages between these attributes that will encourage a dynamic, self-sustaining river ecosystem to the greatest extent possible within contemporary constraints (dams, structures in the floodway). In the following sections, we review the attributes, explain relationships between existing site conditions and the desired attribute, and finally describe changes that must occur to re-create these functional attributes.

5.2.1. Attribute 1: A spatially complex channel morphology

The historical channel morphology of lower Clear Creek was highly dynamic, with exposed gravel/cobble point bars, high flow scour channels, abandoned main channels, and vegetated floodplains (Figure 8). Historically, the reach of Clear Creek through the project site is between meandering and braided morphology (Figures 5, 6, and 9). Through series landscape perturbations (gold mining, gravel extraction, and dam building), this historical channel morphology was drastically altered. The existing channel morphology of lower Clear Creek within the project area is highly disturbed through a combination of years of gravel extraction and a lack of upstream sediment supply due to upstream dams. These activities resulted in an entrenched channel, confined by dense riparian berms, with a streambed incised to clay hardpan at many locations. The channel has straightened as a result of the incision and developed a rectangular channel geometry typical of highly regulated gravel bedded rivers in California (Kondolf and Matthews, 1993, Williams and Wolman, 1984). The channel morphology has little planform or cross section complexity, and pools are separated by steep, clay hardpan controlled riffles. Where the channel was gravel mined, the bankfull channel and floodplain confinement was eliminated by extraction (Figure 10). In these areas, the channel is multi-channeled, making adult and juvenile salmonid migration difficult. In areas not mined for gravel, channel incision and entrenchment has also greatly reduced the extent of floodplains accessible by contemporary floods, limiting overbank flow and therefore concentrating stream power in the active channel. Lack of functional floodplains and reduced flows have also reduced riparian regeneration on elevated surfaces.

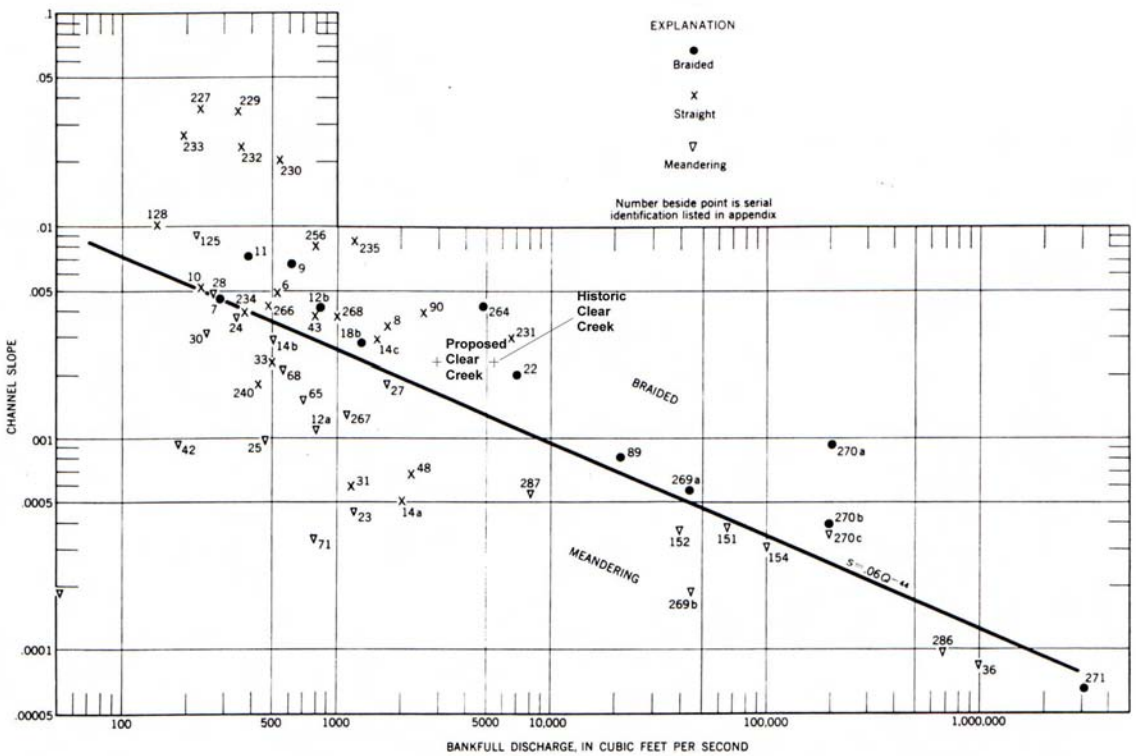


Figure 9. Relationship between braided and meandering channel form, predicting Clear Creek in the transition between meandering and braided channel morphology.

To recreate a spatially complex channel morphology, the streambed must be raised above the clay hardpan horizon, the pits filled as part of reconstructing a bankfull channel and floodplains scaled to the anticipated future high flow regime, and the high flow regime improved to recreate a dynamic, meandering pattern.

5.2.2. Attribute 2: A variable streamflow regime

Long-term success of rehabilitation efforts on lower Clear Creek to restore a dynamic stream channel and floodplain will depend on the nature of the streamflow regime and the amount of coarse sediment added to the system. Unregulated streamflows on Clear Creek were highly variable, with summer baseflows less than 50 cfs and winter peak floods sometimes over 24,000 cfs (Figure 11). Whiskeytown Dam maintained a nearly constant flow of 50 cfs over most of the year, with the exception of small runoff events from the watershed downstream of the dam (Figure 11). Maintaining constant low flows typical of regulated streams tends to cause riparian encroachment and gravel bar fossilization, followed by channel incision and development of a relatively uniform rectangular channel form. This type of channel lacks the complexity needed for high quality aquatic habitat. This pattern is well established on a variety of river channels, including the Trinity River (McBain & Trush, 1997) and is pronounced on Clear Creek as well (Pelzman, 1973). Increasing flow variability via increasing the frequency of high flows greater than 3,000 cfs will be an important factor for the success of this rehabilitation design, as these high flows will discourage future riparian encroachment and encourage a dynamic channel. Presently, Reclamation is evaluating structural and operational alternatives to increase the magnitude and frequency of high flows from Whiskeytown Dam, which should be incorporated into the final design.

5.2.3. Attribute 3: A frequently mobilized channelbed surface

A frequently mobilized bed surface is an important threshold that defines a “dynamic” stream channel. Bed mobilization begins gravel transport, ensures significant fine sediment transport, creates alluvial deposits (riffles and bars) that shape aquatic and terrestrial habitat, and discourages fossilization of exposed bars by riparian vegetation. In healthy rivers, the bed surface is mobilized by flows at or slightly smaller than bankfull discharge, such that the size of the bed surface is indicative of flows that dominate channel dimensions.

The project has two inter-related design approaches to incorporate this attribute: (1) channelbed mobility analysis to design the bankfull channel morphology such that the bed is mobilized by the anticipated bankfull discharge, and (2) decrease the size of the fill material substrate size distribution to ensure mobilization following project channel reconstruction (scale substrate to anticipated future bankfull discharge). Design of the channel substrate will incorporate a particle size distribution that is anticipated to be mobilized by the future 1.5 to 2.0 year flood.

5.2.4. Attribute 4: Periodic scour and redeposition of the channelbed subsurface

Alternate bars, pool tails, and other deposits are scoured deeper than their coarse surface layers by floods exceeding 3-yr to 5-yr annual maximum flood recurrences, followed by re-deposition during the receding limb of the flood hydrograph, such that net change in topography is usually small. Prior to Whiskeytown Dam, periodic high flow events, capable of inducing considerable scour and re-deposition within a single storm hydrograph, maintained a dynamic alternate bar morphology. Bed scour maintained open and exposed gravel bar surfaces by scouring riparian seedlings established during the previous spring/summer. Bed scour greater than the depth of one D_{84} of the coarse surface layer was usually caused by floods exceeding a 3-yr to 5-yr recurrence interval.

Improving this attribute requires two factors: adequate flood flows, and adequately sized channelbed material in sufficient quantities. The relatively small storage of Whiskeytown Dam allows larger spillway events to occur (up to 15,000 cfs). This causes bed scour, but coarse sediment lost behind Whiskeytown and Saeltzer Dams reduces redeposition of scoured bars, such that they are gradually lost. This project, by adding considerable volumes of coarse sediment and creating functional floodplains, in addition to continued gravel introduction upstream, will allow moderate depths of bed scour to occur on bars and reduce the risk of losing these bars.

5.2.5. Attribute 5: Balanced fine and coarse sediment supply, and routing of those sediments downstream.

A properly functioning river reach should transport sediment at approximately the same rate as that supplied from the upstream watershed. A balanced sediment budget also implies bedload transport continuity, meaning that most particles, over time, will be moved downstream through the reach during high flow events. "Sediment" can be broadly classified as coarse (gravels and cobbles) and fine (sands and silts). An adequate coarse sediment supply is critical for the river to create and adjust its channel dimensions, form bars, and transport sediment. Whiskeytown Dam, Saeltzer Dam, and instream gravel mining have significantly reduced coarse sediment supply in the project reach. Additionally, reduced flows from Whiskeytown Dam have allowed fine sediments delivered by the lower watershed to accumulate within the low-flow channel. The proposed project will fill pits that impede bedload routing, redefine a properly sized bankfull channel to improve bedload transport and routing, and recreate a functional floodplain that will encourage fine sediment deposition.

5.2.6. Attribute 6: A migrating or avulsing channel

Another important threshold that defines a "dynamic" stream channel is a migrating or avulsing channel. Dynamic alluvial channels episodically migrate through their floodplains between valley walls. Channel migration occurs at variable rates depending upon flow magnitude/duration, sediment supply, and influence of riparian vegetation. In large, relatively infrequent storm events (greater than 10-yr storm), the channel may avulse, completely changing its channel location. Channel migration creates and maintains channel and floodplain complexity by adjusting width and bank slope, by providing input of large woody debris from eroding banks, by creating new floodplain surfaces on the inside of meander bends, and by creating new seedbeds on these floodplains that encourage riparian vegetation colonization.

Because nearly all the Clear Creek floodway is under Federal or State ownership (with no structures in the floodway), Clear Creek is one of few regulated Central Valley rivers where channel migration can be encouraged. However, channel migration immediately after construction could potentially negate much of the riparian vegetation plantings. The channel rehabilitation project involves substantial earthmoving activity, which exposes the project to greater risk of adjustment in the first few years before vegetation growth provides some bank stability. There is a trade-off between using structural and/or bio-technical bank protection to provide some stability in the first few seasons, while allowing channel migration and avulsion in the future. In addition, there are several locations where channel change is not desirable in the first 5 years, because the channel could relocate into its previous location before the floodplain riparian forests become well established. These locations are typically where the design channel diverges greatly from the existing channel, and the risk of channel recapture is sufficient to warrant use of bio-technical bank protection. At most other locations, much smaller scale bio-technical bank protection is proposed, and many sites would only receive vegetation treatments. This will, over time and combined with episodic high flows, encourage channel migration.

Increasing the frequency and rate of channel migration in the future will be critical to discourage a new riparian berm forming at the project site. Unless flood flow releases from Whiskeytown Dam are improved, it is likely that a new riparian berm will become established within the design channel. Such a riparian berm typically prevents channel migration, except in larger events (greater than 10 to 20-yr magnitude floods), and would prevent many of these alluvial attributes to occur properly. This project encourages channel migration by rebuilding alluvial banks on the outside of meander bends and adding considerable volumes of coarse sediment into the channel, although a few sections of the design channel will have some bioengineering to reduce channel migration for the first few years.

5.2.7. Attribute 7: A functional floodplain

A functional floodplain is defined as a flat surface outside the bankfull channel that is frequently flooded, induces fine sediment deposition, and supports naturally regenerating riparian vegetation. Functional floodplains, typically inundated once annually on average, provide water storage during floods that attenuates flood peaks, and provides suitable locations for riparian vegetation establishment. A properly sized bankfull channel and floodplain provide sufficient channel confinement to maintain important geomorphic processes (bed mobility and sediment transport), yet allows floodplain overflow during larger flows. This process reduces the rate of increasing shear stress in the bankfull channel, provides floodplain scour and deposition to encourage riparian vegetation complexity, and encourages fine sediment deposition. Presently, there are very few functional floodplains in lower Clear Creek. Pre-Whiskeytown Dam floodplains are now either perched at a level which is only rarely inundated (functionally a terrace now), or have been excavated so that the surface is inundated for extended periods every year and does not provide the confinement necessary for coarse sediment transport.

A primary goal of this project is to re-create functional floodplains. This will be accomplished by raising (filling in pits) and/or lowering (cutting down pre-Whiskeytown Dam floodplains) existing surfaces to flood during discharges exceeding bankfull discharge (Figure 12). Newly constructed floodplains will not be flat and homogenous; complex floodplain micro-topography will be constructed to simulate high flow scour channels, and because these scour channels will be closer to the water table, natural riparian regeneration will be encouraged. These channels will be no more than 1-2 feet deep, and 30-70 feet wide. Grading in other floodplain areas will create a series of swales and low mounds, not hydraulically connected to overbank flows, although all these surfaces would be inundated in 3 to 5-yr events. Substrate variation, such as silts and fine sands, will be placed on floodplains to add complexity. Rapid vegetation growth will add roughness to floodplains, inducing fine sediment deposition during overbank flood events within a few years after construction.

5.2.8. Attribute 8: Self-sustaining, dynamic riparian vegetation.

Creating self-sustaining, dynamic riparian vegetation is directly linked to dynamic channel behavior and to functional floodplains. Historical aerial photographs of lower Clear Creek do not show large continuous riparian forests found in lower reaches of other Central Valley Rivers. Instead, due to the moderate gradient and channel avulsions, riparian vegetation occurred in a mosaic of strips and patches, usually associated with abandoned primary channels and high flow scour channels on floodplains. The process of channel migration, channel avulsion, and local removal of riparian vegetation during large floods created a diverse riparian vegetation, both in species and age class. Riparian vegetation also likely consisted of a diverse under and over-story species, and diverse structure, age, species, and composition provided maximum habitat value to birds and terrestrial species. A complex patch structure also increases the edge effect and increases biodiversity.

This project will address this attribute through a variety of methods: (1) preserving as much of the existing riparian vegetation as possible, (2) planting of a wide variety of species in a complex arrangement of vegetation series, which are based on those associations found in undisturbed riparian communities in a similar setting to Clear Creek, and (3) creating “seed beds” to encourage natural riparian regeneration. Saving existing vegetation stands within 2-3 feet of design topography will provide immediate channel stability in certain areas, and provide some greenery immediately after construction. Riparian planting will be extensive, occurring on most new surfaces, but as a patchwork that mimics riparian vegetation patterns in existing high flow scour channels. Seed beds will be sowed in constructed high flow scour channels, but will be dressed with deeper topsoil and not manually revegetated. These seed beds will be experiments to test whether natural riparian regeneration can assume a more substantial role in future revegetation efforts.

5.3. CLEAR CREEK REHABILITATION OBJECTIVES

Objectives of the Lower Clear Creek Floodway Rehabilitation Project are:

- Reverse channel degradation caused by historic aggregate extraction in the Mined Reach by reconstructing a properly sized bankfull channel and floodplain;
- Restore the ability of the channel to route coarse sediment downstream and deposit fine sediment on floodplain surfaces;
- Restore native riparian vegetation on floodplain and terrace surfaces by focusing on species that provide canopy structure and removing competing exotic species;
- Reduce salmonid stranding and mortality in floodplain extraction pits;
- Provide improved habitat conditions for native fish and wildlife species including priority salmonid species of central concern to CALFED, CVPIA, and AFRP programs;

These objectives will be met using the healthy river attributes as a guide. The following section provides a detailed discussion of the project design and the basis for evaluating the project.

6. CHANNEL DESIGN

There are three primary disciplines to integrate into an overall project design: channel morphology, riparian revegetation, and wetland design and revegetation. This section describes design concepts, processes, and results for channel morphology. Later sections discuss the design concepts, processes, and guidelines for riparian vegetation and off-channel wetland design.

6.1. CHANNEL DESIGN OVERVIEW

The goal of the channel and floodplain design for the Project Reach and the Reading Bar site is to restore a dynamic, properly sized alluvial channel morphology. More specifically, design objectives include:

- Re-establish an alternate bar morphology, with riffles, exposed bars, and deep pools.
- Channel will transport D_{84} particle size at flows slightly less than the anticipated future channel forming discharge (3,000 cfs), and coarse sediment can route through the reach.
- Floodplain will begin to inundate at flows slightly less than the anticipated future channel forming discharge (3,000 cfs), and fine sediments transported in suspension will deposit on floodplain surface.
- Channel can migrate across floodway during flows equal to or larger than the anticipated future channel forming discharge (3,000 cfs). Lateral channel movement is a desired outcome, not a failure.
- Raise bankfull channel at least three feet above clay hardpan to convert most of channelbed back to a gravel and cobble surface.
- Create floodplain micro-topography that simulates observed pre-dam high flow scour channels or abandoned primary channels. Revegetate many of these channels with native riparian vegetation, while leaving some unvegetated to experimentally evaluate whether natural riparian revegetation can occur (seed beds).
- Reduce the particle size in the design bankfull channel (Phase 3 and 4) by using borrow materials from the Former Shooting Gallery Site, of which 98% of the materials are finer than 6 inches.
- Evaluate whether we can cost-effectively screen out particles finer than ¼-inch to construct the design bankfull channel and create high quality aquatic habitat.

To achieve these channel design objectives, our pre-design development process required the following geomorphic evaluation:

1. Evaluate changes in the Project Reach due to gold mining, gravel mining, and flow and sediment regulation from upstream dams.
2. Evaluate historic and existing channel forming flow regime.

3. Evaluate contemporary sediment transport conditions.
4. Assume future bankfull discharge based on anticipated future hydrologic regime, and evaluate whether this discharge is sufficient to transport coarse sediment.
5. Measure local channel geometry in pseudo-reference reaches, evaluate regional channel geometry relationships from the literature, and evaluate whether the bankfull discharge in the design channel geometry is capable of transporting coarse sediment.
6. Identify clay hardpan location and depth in project site to identify constraints on channel alignment.

6.2. SUMMARY OF GEOMORPHIC AND HYDROLOGIC EVALUATION

Steps 1-7 are described in the following sub-sections for the Project Reach. These results will be applied to the Project Site channel design and the Reading Bar floodplain design.

6.2.1. Geomorphic Analysis

Many channel restoration projects have failed because designers have not considered the natural channel form of the channel. Practitioners often attempt to redesign a meandering channel morphology in settings where the natural trend for the stream is to be braided (e.g., “restoring” channels in alluvial fans). If a meandering channel is designed for a stream that has a natural tendency to be braided, the project will eventually fail as the stream evolves back into a braided system. Historical conditions suggest that the morphology of Clear Creek was in the transition between meandering and braided (Figure 9), which is supported by pre-Whiskeytown Dam aerial photos (Figures 5 and 6). Human manipulations to the flow and sediment regime through dams and land use practices will often shift this natural tendency in channel form and size. Whiskeytown Dam has reduced the bankfull discharge of Clear Creek, and Figure 9 predicts that this will move the Clear Creek channel morphology towards the meandering form.

Longitudinally, comparison of historical and recent profile surveys has shown that bed elevations in the project reach had been lowered by 3-7 feet or more as a result of instream gravel mining and reduced coarse sediment supply (Figure 4). The existing thalweg profile is typified as a step-pool profile, with clay hardpan horizons forming the steep steps, and long relatively flat run/pools between (Figure 13). Pit excavation and bar skimming, when followed by subsequent floods, caused rapid and extensive local channel down-cutting, which then caused head-cutting that migrated upstream. These processes continued until constrained by clay hardpan exposures, such that much of the present-day channelbed surface is exposed clay rather than alluvium. The proposed project will attempt to reverse this process by raising the bankfull channelbed surface above the clay hardpan with ¼-inch to 6-inch diameter gravel fill, and recreating floodplains by filling remaining instream pits and skimmed bars.

6.2.2. Hydrologic Analysis

The magnitude and frequency of channel-forming floods have been significantly reduced. Using the 1.5 and 2.0-year flood as representative descriptors of a channel-forming flood, pre-Whiskeytown Dam 1.5 to 2.0-year flood was 5,800 cfs and 7,500 cfs respectively, and the present-day 1.5 to 2.0-year flood is 2,260 cfs and 3,180 cfs respectively. The impact of both gravel mining and upstream flow and sediment regulation has virtually eliminated the ability of the 1.5 to 2.0-year flood to transport coarse sediment, let alone create and adjust channel dimensions. Additionally, a 2,260 to 3,180 cfs "channel forming" discharge does not transport coarse sediment at the downstream end of the Clear Creek canyon (as measured at the USGS gaging station near Igo), and only begins to mobilize a few D_{84} particles at an alternate bar sequence at Reading Bar.

Evaluating flood frequency of the 1-day and 3-day maximum daily average flows is another approach to consider for estimating channel-forming flow. The present-day 1.5 and 2.0 year flood for the 1-day maximum daily average flow is 930 cfs and 1,450 cfs, while the same flood indices for the 3-day maximum daily average flow is 650 cfs and 990 cfs. As with the instantaneous peak flood frequency indices, these flows are not large enough to do any significant geomorphic work, and are thus inadequate to maintain healthy channel morphology.

The draft channel designs assume a future design channel forming flood of 3,000 cfs; however, we are concerned that 3,000 cfs is insufficient to maintain the integrity of the rehabilitation project (i.e., prevent riparian encroachment) and satisfy important ecological goals (channel migration, bed mobility). The US Bureau of Reclamation is presently evaluating options for improving the magnitude of future channel forming flows, which will significantly improve project performance.

6.2.3. Sediment Transport

The design channel morphology should be able to adequately route coarse sediment supplied by upstream reaches, preferably avoiding significant (i.e., feet) aggradation or degradation of the channel. One of the difficulties of designing the Clear Creek channel to convey upstream coarse sediments is that the upstream supply is currently small due to Whiskeytown and Saeltzer dams, and that the supply will change once Saeltzer Dam is removed (estimated to occur in fall 2000). Saeltzer Dam most likely passes coarse sediment during higher flows (~10,000 cfs range), while Whiskeytown Dam does not allow any sediment to pass.

Future rates of coarse sediment supply are also expected to be small, based on coarse sediment transport samples collected in 1998 at the Igo gaging station (Figure 14). This site was chose to help evaluate "if Saeltzer Dam is removed, how much gravel is being supplied from the watershed downstream of Whiskeytown Dam, and is that volume sufficient to maintain alluvial storage in the project reach?" Samples were collected during flows of 2,600 cfs and 3,200 cfs, both of which were below a threshold of significant gravel movement, again indicating that larger channel forming flows are needed. Marginal tracer rock movement at a downstream alternate bar sequence corroborated this observation. Although transport of gravel at this site may be partly constrained by availability (supply-limited), so gravel transport would most likely increase if gravel were artificially introduced upstream. Small volumes of spawning gravel has been introduced immediately downstream of Saeltzer Dam to partially mitigate for the upstream dams, and to improve the quantity and quality of spawning habitat downstream. The primary channel design issue related to future sediment transport regimes is: a) when Saeltzer Dam is removed, how much, if any, of the sediment stored behind it be removed, and b) what rates of gravel augmentation will be needed to maintain alluvial storage in the project reach.

6.2.4. Bankfull Discharge

There are a variety of methods typically used to estimate bankfull discharge (assumed synonymous with channel-forming discharge) for a given river, including:

1. Assume bankfull discharge is approximated by the 1.5 to 2.0-year flood.
2. Estimate bankfull discharge by estimating the flow that begins to inundate a floodplain formed under the contemporary flow regime. On highly regulated rivers similar to Clear Creek, reduced peak flows impair or eliminate the ability to form a bankfull channel and floodplain. On Clear Creek, we have not seen classic floodplain indicators, just riparian sand berms along the channel margins that are typical of highly regulated rivers. Channel width at the top of riparian berms is 90 ft at the USGS gaging station near Igo (RM 10), 105 ft at the alternate bar downstream of Reading Bar (RM 7.7), and 130 ft at the Renshaw Riffle (RM 5.2), each of which is approximately 2,000 cfs to 3,000 cfs based on WY 1998 observations. The Renshaw Riffle is half the slope of the other sites; thus, the channel is appropriately 30 ft wider.
3. Estimate discharge by meander wavelength forming under the contemporary flow regime. A subtle alternate bar sequence immediately downstream of Reading Bar is the only location where a post-Whiskeytown Dam era meander has formed. The meander wavelength is 1,100 ft, and using $Q_{bf}=0.00747\lambda^{1.818}$ (Dury 1976), the predicted bankfull discharge for that meander wavelength is 2,500 cfs.
4. Estimate discharge from regional relationships of drainage area and channel dimensions. Dunne and Leopold (1978) relationship for SF area and Puget Sound area gives an equation of : $Q_{bkf} = 53D_A^{0.93}$ using a drainage area of 48.9 mi^2 below the dam which yields Q_{bkf} = 2,000 cfs. Adding 250 cfs for dam releases during the winter period results in a Q_{bkf} estimate of 2,250 cfs.
5. Estimate discharge that begins to mobilize the bed surface. Marked rocks at an alternate bar surface just began to mobilize in the center of the channel during a peak flow of 2,900 cfs (D_{84} = 130 mm versus a design D_{84} of 128 mm), while 3 miles upstream at the USGS gaging station, bedload sizes were all smaller than 32 mm during a peak flow of 3,200 cfs. We have recently added more bed mobility experiment sites to better understand bed mobility thresholds, but these sites will not provide any data until this coming high flow year (WY 2000).

The preliminary results of sediment sampling has led us to assume a design bankfull discharge for the project be a minimum of 3,000 cfs, and preferably higher. Flows of less than 3,000 cfs do not fully mobilize channelbed particles and are therefore incapable of performing the geomorphic functions necessary to rehabilitate the dynamic alluvial function of this reach. Channel geometry, planform geometry, and substrate size will be scaled to this discharge; however, the design bankfull discharge may need to be increased in the near future if it is insufficient to achieve geomorphic restoration objectives.

6.2.5. Meander geometry

Pre-dam meander wavelengths, based on 1952 air photos (Figures 5 and 6) and 1936 planform map (Figure 3), range between 1,200 ft and 2,300 ft, with a best value pre-dam prediction in the project reach of 1,600 ft. With the exception of one alternate bar sequence at the Reading Bar site, present-day meanders are merely remnants of pre-dam meanders, fossilized by riparian berms. This single alternate bar sequence formed because one bank was a talus slope of dredger tailings (no riparian berm could form), thus Clear Creek was provided a local source of coarse sediment to form alternate bars that we hypothesize are reasonably scaled to the post-dam flow regime. These incipient alternate bars have a meander wavelength of 1,050 ft. No other sites have been located that appear to provide dynamic alluvial features, unconstrained by vegetation encroachment or clay hardpan/valley wall confinement.

This field observation was compared to a number of regime equations published in the literature. We used three relationships to estimate meander wavelength. A bankfull discharge to meander wavelength relationship compiled by Dury (1976):

$$\lambda=15.18Q_{bf}^{0.55} \qquad (1)$$

A bankfull width to meander wavelength relationship compiled by Leopold and Wolman (1957):

$$\lambda=6.5W_{bf}^{1.1} \qquad (2)$$

A bankfull width to meander wavelength relationship compiled by Williams (1986):

$$\lambda=7.5W_{bf}^{1.12} \qquad (3)$$

The bankfull discharge to meander wavelength relationship published by Dury (1976) contains considerable scatter, likely a result of combining streams with differing geologic controls (slope, valley confinement, particle size, etc). We used Equation 1 with the design bankfull discharge (3,000 cfs), and also tried another technique that may provide more site-specific applicability from this relationship. We first plotted the pre-dam estimated bankfull discharge (5,700) and pre-dam meander wavelength (1,600 ft), which plotted below Dury's regression line. We then "adjusted" the regression line by retaining the slope, but moving the line down so that it intersected the pre-dam values for Clear Creek. The resulting equation is:

$$\lambda=13.75Q_{bf}^{0.55} \qquad (4)$$

Then, using the design bankfull discharge (3,000 cfs) in Equation 4, a meander wavelength is estimated from this locally adjusted meander wavelength relationship. Table 1 presents the results of these meander wavelength estimates. Based on results from Table 1, we are targeting design meander wavelengths at 1,200 ft. However, on-site constraints, including clay hardpan location, valley wall intrusions, and space within the floodway, prevents this wavelength applied to every meander. Furthermore, while a perfect 1,200 ft wavelength sinusoidal channel may be aesthetically pleasing from an airplane, it is rarely seen in nature. We use 1,200 ft as a target, but some wavelengths are longer and shorter, depending on local site conditions, radius of curvature, and clay hardpan location.

Method	Discharge (cfs)	Width (ft)	Predicted l (ft)
Reading Bar alternate bars	2,260 (post-dam 1.5 year flood)	105	1,100
Dury (Equation 1)	3,000	n/a	1,250
Dury (Equation 4)	3,000	n/a	1,120
Leopold and Wolman (Equation 2)	n/a	100	1,030
Williams (Equation 3)	n/a	100	1,300

Table 1. Summary of meander wavelength estimates

6.2.6. Preliminary Channel Geometry

Channel geometry was estimated iteratively as follows:

(1) Assuming a design maximum particle size of 6-inches, a D_{84} of 5 inches, and a high flow slope of 0.0023, apply bed mobility model to predict average depth needed to mobilize D_{84} particle size in a riffle.
(2) Setting that depth and slope constant, estimate Mannings roughness coefficient (0.028 for as-built conditions) for bankfull channel, and iteratively adjust channel width until bankfull discharge is conveyed by bankfull channel.
(3) Compare resultant width and depth with literature predictions and nearby reference reaches.

Bed mobility can be estimated for a simple channel geometry using Shields equation (Equation 5) if: 1) particle size, energy slope, water density, and sediment density is known, and 2) if dimensionless critical shear stress (τ^*_c) is estimated.

$$\text{Critical depth} = \frac{(\rho_s - \rho_w)(\tau^*_c)(D_{84})}{\rho_w (Slope)} \tag{5}$$

Dimensionless critical shear stress values can be predicted from models (e.g., Parker et al., 1982; Andrews, 1994), as well as by back-calculating from marked rock experiments. For D_{84} particle size, a critical shear stress value of 0.02 is reasonable based on our back-calculations on the Trinity River and predictions in Andrews (1994). Using this value and D_{84}=128 mm, Slope of 0.00232, and water (ρ_w) and sediment density (ρ_s) of 1,000 kg/m^3 and 2,650 kg/m^3, respectively, the predicted depth where the D_{84} is mobilized is 6.0 ft. Increasing the depth to 6.1 ft and increasing channel width to 100 ft results in the channel able to convey 3,000 cfs using a Manning's *n* of 0.028, and begins to spill onto the floodplain when Manning's *n* increases to 0.035. The results of steps 1 and 2 is shown on an idealized riffle cross section (Figure 15) with a maximum depth of 6.1 ft and average depth of 4.7 ft. Using San Francisco Bay regional drainage area-bankfull channel relationships (Dunne and Leopold, 1978) predict an average channel depth of 4.5 ft and channel width of 70 ft using an unregulated drainage area of 48.9 mi^2. Hydraulic geometry relationships presented in Dury (1976) predict average bankfull channel depth of at a 3,000 cfs bankfull discharge predict average channel depth of 7 ft and channel width of 110 ft (Dury, 1976).

Finally, field indicators of bankfull channel were poor at best. Channel width at the top of the riparian berms are 90 ft at the USGS gaging station near Igo (Figure 16, river mile 10), 105 ft at the alternate bar downstream of Reading Bar (Figure 17, river mile 7), and 130 ft at the Renshaw Riffle (Figure 18, river mile 5). Average channel depths are 4.8 ft, 5.6 ft, and 6.1 ft, respectively. Corresponding water surface slopes at flows near 3,000 cfs are 0.0033 at the USGS site, 0.00314 at the Reading Bar site, and 0.00061 at the Renshaw Riffle. The expected channel gradient at the Project site (0.0023) is slightly less than the USGS site and Reading Bar site, but much steeper than the Renshaw Riffle. Therefore, channel dimensions at the USGS site and Reading Bar site may be slightly smaller than that expected at the Project site, and dimensions at the Renshaw riffle would be larger than that expected at the Project site. The significantly lower slope at the Renshaw Riffle explains why the channel width and depth are larger than at the other sites. Based on these observations and estimates, we targeted a design bankfull discharge of 3,000 cfs, bankfull width of between 100-110 feet, a maximum bankfull depth of 6 feet, and a bankfull cross sectional area of 450-550 ft^2.

An idealized pool cross section template was also developed using existing pool/point bar morphology observed on-site (Figure 19). Bankfull channel width and average depth values are approximately the same as the riffle cross section templates, but maximum depth is significantly larger (10 ft). Additionally, point bar face slopes were set at 8:1 (horizontal:vertical) based on field observations.

The channel design was only evaluated for coarse sediment transport thresholds, not for its ability to route a presently unknown coarse sediment supply from the upper watershed. We are currently applying a modified version of Parker (1990) surface based coarse sediment transport model to evaluate a variety of coarse sediment supply rates to bracket Saeltzer Dam sediment removal options, as well as help develop gravel introduction rate recommendations to help maintain the restoration project. This effort will be completed in the fall of 2000.

6.2.7. Clay hardpan constraints

Reducing the amount of existing clay hardpan exposure within the bankfull channel is a priority rehabilitation objective. The clay hardpan surface undulates throughout the project reach, sometimes at a depth of 20 ft below the water table to being exposed on the banks. Therefore, the location and elevation of the clay hardpan surface is a significant constraint on the channel design. Presently, the clay hardpan provides most of the riffle control. With the exception of the upstream grade control, riffle control should be converted back to gravel and cobbles because the clay hardpan severely limits channel function and available habitat. Excavation of channel segments into clay hardpan would lock the channel into place, preclude the dynamic channel behavior we are targeting.

To evaluate the extent of clay hardpan constraints along potential channel alignments, we undertook an extensive test pit program. We mapped surface exposures of clay hardpan and excavated over 70 test pits at the Project site to define alluvial depths to clay hardpan (Figure 20). This investigation confirmed the extent of clay hardpan in certain key areas, which when combined with profile and fill volume considerations, led us to propose a new channel alignment that avoided the main clay hardpan locations. Clay hardpan location and elevation has become the critical factor in channel alignment because the general floodway surface has been lowered from instream mining. Therefore, the solution is twofold: raise the floodway surface above the clay hardpan by filling with gravel and cobbles from borrow sites, and re-aligning the channel to locations where the clay hardpan is at a lower elevation. Filling the floodway will also reduce the knickpoints shown on Figure 13, which reduces the risk of additional knickpoints developing and migrating upstream.

6.2.8. Borrow material constraints

Borrow materials are very different between Reading Bar and the Former Shooting Gallery borrow sites. Reading Bar was formed when sediment transported through the confined Clear Creek canyon deposited when the valley walls widened just beyond the present-day Clear Creek Bridge. Because this area is the first depositional area out of the canyon, much of the bar contains large cobbles and small boulders, in addition to gravel and sand. In contrast, the alluvial material to be borrowed from the Former Shooting Gallery appears to have come from the small gulch entering from the north (Figure 26), such that the particle size is much smaller (gravels and cobbles). Materials testing at the Former Shooting Gallery borrow site suggest that 98 percent of the material is finer than 6 inches and 84 percent finer than 3 inches. Therefore, for Phase 2, we recommend using the coarsest materials (boulders) at the Reading Bar site to fill the deep pits, and cap the pits (new floodplains) with gravels and cobbles from Reading Bar.

Because Phase 3 focuses on reconstructing the bankfull channel and near-channel floodplains, construction materials should be sized small enough to be frequently mobilized by the design bankfull discharge. In addition, these size classes should be within the range of particle sizes preferred by spawning salmon and steelhead. If the finer sediments less than 4 mm are removed (via screening) from the Former Shooting Gallery borrow materials, the D_{84} increases to 5.3 inches (135 mm) and the D_{50} increases to 1.6 inches (40 mm), which are within the range of preferred substrate sizes of chinook salmon (Kondolf and Wolman, 1993). Therefore, materials obtained from the Former Shooting Gallery should better satisfy particle size requirements than those obtained from coarser portions of the Reading Bar borrow site.

6.3. PHASE 2-4 CHANNEL DESIGN PARAMETERS

The preceding geomorphic evaluation resulted in the draft channel design parameters summarized in Table 2. We emphasize that these dimensions are targets, not absolutes; dimensions of most natural channels are extremely variable, and channel relationships found in the literature usually provide only the likely tendency of channel dimensions. Additionally, we expect these dimensions to naturally adjust as floods occur in the future.

Channel parameter	**Dimension**
Target channel morphology	**Meandering with scour channels**
Existing channel alignment gradient	**0.0032**
Design channel alignment gradient	**0.0023**
Increase in design channel length	**1,100 ft**
Target design meander wavelength	**1,100 ft**
Design bankfull discharge (channel forming flood)	**3,000 cfs**
Design maximum (D_{98}) particle size	**6 inches (152 mm)**
Design maximum (D_{84}) particle size	**5 inches (128 mm)**
Design bankfull channel width	**100 ft**
Design low flow (100 cfs) channel width	**50 ft**
Design bankfull channel average depth in riffles	**4.9 ft**
Design bankfull channel maximum depth in riffles	**6.1 ft**
Design low flow (100 cfs) channel depth in riffles	**1.5 ft**
Design low flow (100 cfs) channel depth in pools	**8 ft**

Table 2. Summary of proposed channel dimensions for Project Reach channel design.

As stated in previous sections, the existing 2.0-year flood (3,100 cfs) does not provide the channel forming function expected of it. Therefore, there is considerable risk that the infrequency of bedload transport and channel migration will allow riparian vegetation to re-fossilize the reconstructed channel. If this occurs, many of the important objectives of the project would not be realized. Additionally, there was considerable uncertainty as to when and if Saeltzer Dam would be removed, and the resulting change in coarse sediment transport into the project reach. It appears that Saeltzer Dam will be removed in fall 2000, with at least 50% of the sediment removed, although this estimate has not been finalized. Sediment Transport modeling is now underway that will provide some predictive capability to expected outcomes of Saeltzer Dam removal, and additional modeling is underway to refine Phase 3 and 4 channel morphology to accommodate the expected coarse sediment supply. No effective discharge analysis was performed at the project reach because the future sediment supply was dependent upon Saeltzer Dam removal; this analysis will provide useful design information once Saeltzer Dam removal is complete.

The phasing of the project was set up so that the channel reconstruction phases (Phase 3 and 4) would occur in year 2001 and 2002, allowing time for Reclamation to evaluate alternative ways to increase the magnitude of the channel forming flood, finalize Saeltzer Dam removal plans, and for the design team to collect additional geomorphic information to better document geomorphic response to flows exceeding 3,000 cfs. Therefore, the channel dimensions listed in Table 2 may be adjusted in the future if the anticipated channel-forming flood can be improved.

6.4. TOPOGRAPHIC DESIGN

The design parameters developed in Section 6.3 now need to be converted into a three-dimensional channel design. This is developed from the following two dimensional templates: cross sections showing typical riffle and pool geometry, planform alignment showing meander pattern and pool/riffle sequences, and vertical profile showing elevational control of the thalweg and floodplains.

6.4.1. Planform alignment

Using a target meander wavelength of 1,100 ft, a planform alignment was developed that avoided shallow clay hardpan exposures (Figure 20). The selected alignment abandons the existing channel at three locations: 1) upstream end of the project (proposed station 192+00 to 215+00) through the exposed gravel bar with deep alluvium, 2) middle of project (proposed station 155+00 to 181+00) to avoid the knickpoint shown in Figure 13, and 3) the downstream end of the project to abandon the chute and restore the historic channel location on the north side of the valley (proposed station 117+00 to 153+00). This proposed alignment increases channel length by 1,100 ft, and decrease channel gradient during bankfull discharge from 0.0030 to 0.0023. This alignment also reduces fill volume needed to construct floodplains in the vicinity of the knickpoint. Test pits indicate that depths to clay hardpan are a minimum of 5 feet along this alignment, providing a significant amount of alluvial cover.

While a primary objective of this project is a dynamic channel morphology, there are three locations where we would prefer that the realigned channel not recapture its old location for 3 to 5 years after construction:

- Proposed alignment station 214+00, the first diversion point at the upstream end of the project.
- Proposed alignment station 181+00, the diversion point to avoid the most pronounced clay hardpan knickpoint at the project.
- Proposed alignment station 153+00, the diversion point of the proposed channel into its historic northern location, avoiding the chute.

Bioengineering protection should be installed at the outside of the meander bends at these locations to reduce the risk of channel recapture. The bioengineering plan is described in Section 5.10.

6.4.2. Channel Profile at Project Reach

After selecting a channel alignment, we examined the profile throughout the project reach and for some distance upstream and downstream of the project area. We first identified upstream and downstream grade control, and determined the elevation of that control. We then drew a straight-line between these channel grade controls as an initial target for design riffle crests to intersect this line. Based on the alignment and specific sub-reach objectives, this linear profile was then adjusted as follows. Two short, relatively straight reaches that are lower gradient than the overall channel gradient were designed to be low gradient spawning riffles (similar to the Renshaw Riffle and the downstream end of the Chute channel in Phase 4). Decreasing the thalweg and floodplain slopes in these two reaches required the remaining reaches to become slightly steeper to maintain the overall design channel gradient. The design thalweg profile at this point was a series of straight lines that riffle crests were to intersect.

The next step was to superimpose a more detailed thalweg design profile onto the existing ground surface along the design channel alignment (Figure 21). The design channel alignment defined where pools and riffles were located: pools coincided with meander bends, and riffles connected pools as transverse bars. Where pools in the design alignment coincided with existing pools, the existing pool profile was retained. Pool depths ranged from 4 to 10 feet depending on the radius of curvature of the meander bend (smaller radius = greater flow convergence = deeper pool). Riffle and pool boundaries and elevations, identified on the design channel alignment, were transferred to the design thalweg profile.

After refinement of the profile, we determined floodplain elevations based on a uniform offset of 6.0 feet above the riffle crest elevations. These new floodplain elevations were then extended across the floodplain to an intersection with the valley edge or other higher ground feature (e.g., existing riparian stand, etc.). We then evaluated the difference between existing surface elevation and design floodplain elevation to determine which existing vegetation could be saved from disturbance.

Within the design channel we developed detailed pool geometry typically based on expected low-flow pool depths of 6-8 feet. These pool geometries reflect the characteristics of pools in less disturbed channels, including location of maximum pool depth relative to meander bend geometry, shape of the associated point bar, pool tail geometry and transition into riffle crest. While we are designing the channel with quantitative design criteria, our intent is for the constructed channel to self-adjust in the future. We cannot design and construct a perfect reflection of what would be created by natural processes in the future because the channel we are designing for has no set stable endpoint. It simply continues adjusting.

Refinement of the typical floodplain elevations was then made to this target channel morphology to add complexity to the constructed surface. A pattern of high flow overbank channels was delineated to mimic natural floodplain complexity and provide for a greater variety of geomorphic settings for riparian plantings.

The design channel was then subjected to hydraulic modeling using HEC-RAS to verify hydraulic performance, including channel and floodplain velocities and shear stress, overbank flow locations and quantities, and other hydraulic parameters.

The final step in the design process involved refinement of floodplain topography to daylight design topography to existing ground, in order to refine cut/fill areas, vegetation preservation areas, and clearly define the limits of the construction zone.

6.4.3. Slope

Existing bed elevations at the upstream end of the project reach are 468.0 feet at station 214+50. At this location, however, a clay ridge controls the entrance to the design channel. We propose excavating through the clay ridge approximately two feet to match the existing channel thalweg elevation, thus providing an initial thalweg elevation of 466.0 feet. The exit elevation at the downstream end of Phase 4 is 443.7 feet at station

118+00. Total drop, therefore, is 22.3 feet. Overall length of existing channel is 9,650 feet, for a design riffle crest slope of 0.0023 ft/ft.

Implementing Phase 3 and Phase 4 channel relocation and reconstruction will increase the total channel length in the project reach by 1,100 ft total. Assuming the beginning and end invert elevation would remain the same, channel slope through the reach would be reduced from 0.0030 ft/ft to 0.0023 ft/ft.

6.4.4. Floodplain Width and Elevation

Historical evidence suggests that most of the valley floor was readily accessed by flood flows, which is no longer true due to channel incision and gravel mining impacts. Surfaces that were clearly functional floodplains in 1952 are now terraces, most of which were not even accessed in the 1997 and 1998 high flows (13,000 cfs to 16,000 cfs, 10-20 year recurrence interval events). The current design will re-establish floodplains to the base of most valley walls, recreating valley-wide functional floodplains (Figure 24). Scour channels that drain back to the main channel have been designed 1 to 3 feet lower than the general floodplain elevation to provide topographic diversity on the floodplain, help reduce juvenile salmonid stranding, and provide natural riparian regeneration seedbeds. Piezometers have been installed at many locations at the project site and borrow sites to document seasonal variations in water table elevations, which have assisted greatly in designing scour channel elevations, estimating riparian cutting installation depths, and designing off-channel wetlands.

6.5. HYDRAULIC MODEL EVALUATION OF BANKFULL CHANNEL

After selection of a channel alignment, we developed a hydraulic model of the proposed channel to assess hydraulic variables and verify the design assumptions regarding slope, depths, velocities, and channel/floodplain conveyance. The modeling is based on the Corps of Engineers HEC-RAS Water Surface Profile Model. Boss RMS for AutoCAD software was used to define the geometric parameters of the hydraulic model for the proposed Project site design. We created 51 cross sections extending from proposed alignment station 118+00 to 218+00. Cross section data was generated from the proposed design channel topographic model (Figure 22). In general, the cross sections were spaced approximately 200 feet apart, with the only minor divergence from the design channel stationing to reflect anticipated channel flow paths.

Two runs were performed: estimating “as-built” conditions with main channel Manning’s *n* values of 0.028, and one with future conditions (with additional vegetative and form roughness) using Manning’s *n* values of 0.035. The as-built Manning’s *n* value is based on recent back-calculations on a channel rehabilitation project on the lower Tuolumne River, which has slightly smaller particle size and half the slope as Clear Creek. Therefore, the 0.028 roughness value applied to Clear Creek may be slightly low. The purpose of the model is to evaluate whether the design bankfull channel is just overtopped by the assumed bankfull discharge (3,000 cfs). Results of the modeling suggest that the proposed bankfull discharge is approximately 0.5 ft below the design floodplain elevation under as-built conditions (n=0.028), but is slightly higher than the design floodplain elevation under future conditions (Table 3). Average channel velocities at bankfull discharge are on the upper end of the rule of thumb (4-6 ft/s).

At the Reading Bar borrow site, we were fortunate to be able to observe water surface elevations during a 2,900 cfs runoff event that occurred on February 7, 1999. This water surface elevation was surveyed from Clear Creek bridge downstream past the lowermost extent of the Reading Bar Borrow Site, and used to design the floodplain elevation rather than modeling water surfaces with a HEC-RAS model.

While some adjustments could be made to the channel design to inundate the floodplain under as-built conditions (i.e., lower the floodplain), we feel that the present design is adequate because channel roughness will increase soon and we wish to preserve the confinement to transport sediment through the reach.

6.6. DESIGN UNCERTAINTIES AND RISK

There are five significant uncertainties in the project design and performance that require discussion.

6.6.1. Radius of curvature and meander wavelength at upstream end of project

The fossilized pre-dam channel morphology upstream of the project site has a longer meander wavelength and larger radius of curvature than that of the post-dam dimensions used in this channel design. Because large floods still occur, there is some risk that the first meander wavelength should be elongated and radius of curvature increased to provide a better transition between the two morphologies. This should also reduce some of the risk associated with the design channel avulsing back into the existing channel on the first meander. If Phase 3 is funded, we will re-evaluate this important first meander bend geometry.

6.6.2. Aggradation caused by channel slope breaks

As the design channel transitions into the existing channel at the far upstream end of the project (Figure 24), the design channel cuts into a clay hardpan ridge to connect to the existing channel. The proposed channel thalweg at this cut is approximately one foot higher than the thalweg in the existing channel, resulting in a local decrease in slope at design channel entrance. This can cause local sediment deposition, creating a medial bar near the entrance, which can induce recapture into the existing channel or general channel instability at the very beginning of the project. We extended the thalweg profile 1,500 ft upstream of the project site to evaluate whether this potential local slope break was exacerbated by a larger change in slope (Figure 21). This section of channel was historically gravel mined (Figure 5), and is now predominately exposed clay hardpan. The slope of the clay hardpan is slightly steeper than the design reach, suggesting that deposition at the upstream end may indeed be a potential problem. A mitigating factor is the riparian berm along the existing channel, which partially offsets the impact of lower slope by focusing stream energy in the center of the channel and increasing sediment

transport capacity (McBain and Trush, 1997). Regardless, this transition is the most critical component of the project, and may require some maintenance (sediment removal) in the first few years after project completion.

Other significant breaks in slope in the project reach is at the upstream end of each of the spawning riffles (Figure 21), where the slope drops from 0.0023 to 0.0015 to create preferential depths and velocities for chinook salmon spawning. In both cases, existing riparian vegetation along the channel margins will be retained, which should assist in routing sediment through the reach and reduce bank erosion. If deposition occurs at the heads of these riffles, then we need to evaluate whether maintenance needs to occur; recall that a primary objective of the project is to be dynamic and self-adjust, and we need to divorce ourselves from maintenance at some point after the project is completed.

6.6.3. Future channel contact with clay hardpan

The proposed channel alignment attempts to avoid most of the exposed clay hardpan within the project reach, and in those areas where the channel crosses clay hardpan, the channel will be raised off the hardpan by filling with gravels and cobbles. Obviously, if the channel design performs properly, the channel will migrate into areas of exposed clay again. The channel remaining on the clay hardpan for long periods of time is generally undesirable; we anticipate that these clay contacts are transitory, and the channel will eventually migrate back across the channel through alluvium. The risk of channel capture by clay exposures by lateral migration is unknown. A potentially more likely scenario is channel downcutting to the clay hardpan by inadequate coarse sediment supply from upstream sources. Removal of Saeltzer Dam and continued input of coarse sediment will reduce this risk (another component of the geomorphic evaluation phase of this project will be to recommend coarse sediment management downstream of Saeltzer Dam).

6.6.4. Impact to reaches downstream of the project

A typical byproduct of constructing a channel restoration project is an immediate increase in sediment supply as unconsolidated gravels, cobbles, and sands are made available to transport during floods, particularly in the first few years after project completion. Typically, during the first few sediment transport events, sediment transport is high and deposition can occur both in the project reach and the reach downstream of the project. Sediment transport will eventually decrease as an armor layer develops on the bed surface and riparian vegetation begins to increase channel stability. Aggradation may occur at the downstream end of the project (Figure 21), but because the channel is on exposed bedrock there, aggradation will actually improve conditions downstream of the project. The extensive riparian encroachment downstream of the project will minimize risk of lateral migration or riparian vegetation loss.

6.6.5. Braided versus meandering planform

Historically, Clear Creek was on the transition between a meandering and braided channel morphology (Figures 5 and 6). The 0.0030 channel slope and the proposed 0.0023 slope plot along the transition between braided and meandering channel morphology (Figure 9). Streams that are braided or near this transition are often converted to meandering streams due to flow and sediment regulation upstream (Ligon et al., 1995 and others). The effect of Whiskeytown and Saeltzer dams lowering flow and sediment supply, combined with the rehabilitation project lowering the channel slope and increasing riparian vegetation should move the stream morphology towards a more meandering morphology than braided morphology.

6.7. LONG TERM EXPECTATIONS

Future project reviewers may be unsure or not understand the performance expectations of the project by the designers. We have stated numerous times in this document that one of the goals of the project is to allow the channel to be dynamic; we expect it to move. In fact, if the channel is not dynamic, then our objectives have not been met. Channel movement is perhaps the most commonly perceived source of restoration project failure, followed by coarse sediment aggradation or degradation; therefore, we discuss some our expected performance of the project upon which future evaluators can put actual channel response into perspective.

6.7.1. Channel migration

Our conceptual model of how Clear Creek used to move across its valley floor is one of gradual movement during moderate to high flow years, and wholesale channel avulsion during rare large flood events exceeding 10-year flood recurrence. The risk of rapid migration or avulsion during moderate floods decreases with time after construction and revegetation is completed as vegetation helps stabilize the channel and floodplains. Acknowledging this risk immediately after project completion, our desire for future channel movement is similar to our conceptual model of pre-dam conditions: small migration rates during moderate flow years, and avulsion during larger flood years (Figure 23).

6.7.2. Coarse sediment scour and deposition

While most channel restoration projects tend to fail due to sediment burial, we feel the greatest risk to failure is downcutting back down to bedrock, even after sediment routing is restored through the Saeltzer Dam reach. We expect and encourage the bed surface to move, coarse sediments to be transported, and local areas of aggradation and degradation. Local aggradation and/or degradation of up to two feet may be normal for this type of stream. Larger degrees of aggradation and/or degradation would be much less desirable.

6.7.3. Floodplain performance

Natural functioning channels tend to deposit a portion of their fine sediment load onto floodplains during overbank flow events. It is our desire to re-establish this process by recreating functional floodplains. However, this process requires frequent overbank flows large enough to suspend sediment grains up to 2 mm in diameter in order for those grains to access and deposit on floodplains. While these flows still periodically occur, the magnitude and frequency of them has been greatly reduced, such that fine sediment is usually transported as bedload in the low flow channel rather than in suspension out of the low flow channel to be deposited onto floodplains. Therefore, we do not expect large volumes of fine sediment to deposit on constructed floodplains by flows less than 6,000 cfs.

We have attempted to design the simulated high flow scour channels to intersect the shallow groundwater table during the springtime when native woody riparian vegetation is casting its seed. These moist areas on the floodplain should provide excellent seedbed locations, and should produce large amounts of natural riparian regeneration. If Saeltzer Dam is removed and Townsend Ditch is decommissioned, water availability to north bank floodplains may decrease slightly due to the loss of seepage from the ditch (which probably elevated shallow groundwater table when diversions were occurring).

7. RIPARIAN REVEGETATION

Riparian revegetation is as important to project success as proper geomorphic channel design. Riparian vegetation provides much of the terrestrial and aquatic habitat in healthy river ecosystems. Riparian vegetation also stabilizes the riverbanks, slows floodwaters, stores fine sediment and creates hydraulic complexity that causes topographic channel. As will be discussed in the next section, historic riparian vegetation was typically patchy, separated by extensive open gravel bars. Revegetation efforts will mimic this pattern, but because of the changes to Clear Creek hydrology and loss of riparian forests throughout the California, the revegetation plan should create more extensive riparian vegetation than historically occurred. The long-term goal of riparian revegetation is to restore the extent, morphology, and dynamics of riparian vegetation within the floodway that can be maintained by the future flow regime, and the short-term goal is to provide additional stability for the floodway rehabilitation project.

7.1. HISTORICAL EVOLUTION

Describing historical conditions as a means to develop desired future conditions (reference conditions) is a common restoration approach. However, the cumulative impacts of historic land use and current flow and sediment regulation often make historic site descriptions impossible. While we may not achieve these reference conditions soon, they can still be rehabilitation goals. Unfortunately, extensive disturbance to channel morphology and riparian vegetation began in 1848 with the discovery of gold at Reading Bar, too early for settlers to document conditions in Clear Creek before this disturbance. Therefore, we must rely on old aerial photographs, conditions on nearby surrogate streams, and descriptions provided by scientific literature to describe desired riparian conditions and processes. The following sections attempt to paint the historical evolution of lower Clear Creek riparian vegetation, including the present-day initial condition that rehabilitation activities will build upon.

7.1.1. Project site

We are unsure whether placer or dredger gold mining occurred within the floodway near the project site; no remnant tailings are found along the stream channel. However, extensive dredger tailings on adjacent terraces suggests that the channel suffered the same fate as the terraces. Later floods most likely converted the mining tailings back to gravel bars and floodplains. The most significant impact to the reach (which this project is addressing) was instream gravel mining, and to a lesser extent, flow and sediment regulation by Whiskeytown Dam. Therefore, much of the historical context will be between pre- and post-gravel mining.

Riparian vegetation patterns before the dam and gravel mining generally occurred as two patterns:
1) stringer patches within the bankfull channel that established in high flow scour channels and abandoned main channels,
2) larger patches on floodplains and low terraces (Figures 5 and 6).

Pre- mining channel morphology at the Project Reach and Reading Bar was near the transition between a meandering and braided stream (Figures 5 and 6). Distinct riparian plant species are associated with different geomorphic surfaces and hydrologic indices (i.e., flood frequency). For example, Fremont cottonwoods tended to grow in high flow scour channels that were lower to the groundwater table, had fine sediments deposited there during floods (providing seedbeds), and were periodically cleared of herbaceous vegetation, allowing seedlings to initiate and establish. Different riparian vegetation cover types, called plant series (Sawyer and Keeler-Wolf, 1995) within the Clear Creek corridor are summarized in Appendix B Table 1. Fundamental associations between dominant plant series and geomorphic surfaces are shown in Table 4.

Plant Series	Recurrence Interval range	Pre-dam flood magnitudes (cfs)	Geomorphic surface
Narrowleaf willow	Summer baseflow to 1.5 year flood	25 to 6,000	Within bankfull channel, in scour channels on floodplains
White alder	Summer baseflow to winter baseflow (those outside the bankfull channel are not dependent on streamflow)	100 to 500 (those within the bankfull channel)	Within bankfull channel on outsides of bends, base of valley walls near shallow groundwater
Fremont Cottonwood, Black willow	1.5 year to 20 year flood	6,000 to 20,000	On floodplains and along scour channels on floodplains
Valley Oak	> 10 year flood	>10,000	On upper floodplain surfaces, terraces, and hillsides

Table 4. Common plant series along Clear Creek, the associated range of discharges that the series falls within and the recurrence intervals of the discharges pre and post flow impairment.

This semi-natural riparian setting was first altered by reduced frequency, magnitude, and duration of high flows caused by Whiskeytown Dam. The natural regeneration process was for riparian plants that seed in the summer during low water to be highly successful at initiating, but less successful at establishing and maturing. The high flow regime was historically responsible for periodically scouring away most vegetation initiating along the low water surface, but the dam reduced high flows to the point where the plants were no longer scoured. As the plants matured, their roots immobilized the low flow channel to the point where only large floods >15,000 cfs could begin to remove them. This was evident soon after Whiskeytown Dam was completed (Pelzman, 1973). Narrowleaf willow (a summer seeder) and white alder are the dominant plant species growing along the low flow channel (Figure 10). Additionally, reducing the high flow regime negatively impacted Fremont cottonwood regeneration, they require disturbance to create favorable seeding conditions.

The more direct impact occurred in the 1970's and 1980's as instream gravel mining removed riparian vegetation when excavating bars and floodplains. Mining eliminated the natural geomorphic surfaces that riparian vegetation grew on, leaving a wide channel with numerous pits within the floodway. Various wetland and riparian plant species took advantage of the perennial and seasonal wetlands created by the off channel and in-channel gravel pits. Narrowleaf willow thickets and bands of white alder surround these wetlands.

7.1.2. Reading Bar and Former Shooting Gallery borrow sites

Both the Reading Bar and Former Shooting Gallery borrow sites were placer mined for gold in the 1850's, then later dredged. These actions "turned the ground over," removing all vegetation and leaving hummocks of dredger tailings. Small pockets of wetland vegetation surrounded by cottonwood stands remain between the dredger tailings and in lower areas mined for gravel. These borrow sites also contain numerous exotic plant species, particularly the aggressive tree of heaven (*Ailanthus altissma*), Himalaya blackberry (*Rubus discolor*) and star thistle (*Centaurea solstitialis*). Again, white alder and narrowleaf willow have encroached along the low flow channel at the Reading Bar site, immobilizing the channel.

7.2. REGULATORY AGENCY REVEGETATION GUIDELINES

The Design Team has contacted federal and state agencies (BLM, COE, USFWS, CDF&G) participating on the restoration team to obtain specific guidelines for riparian rehabilitation. Each agency has established wetland mitigation policies and personnel with vast experience in wetland rehabilitation projects however, specific restoration guidelines for species composition and planting designs were not available. The Design Team also contacted the Audubon Society and the Nature Conservancy and both of these two non-profit agencies had a considerable amount of revegetation information. COE has mitigation monitoring guidelines targeting compliance with Section 404 of the Clean Water Act. These guidelines do not identify specific restoration measures. Development of specific mitigation measures is the responsibility of the project proponent. The revegetation guidelines for this project were developed based on prior experience of the Design Team, discussions with resource agency experts and information provided in the literature.

7.3. GOALS AND OBJECTIVES

Recalling that the overall goal of the project is to rehabilitate the natural form and function of the channel and floodplain, the first step is to recreate the physical form of the channel and floodplain. This is described in Section 5. Revegetation objectives to achieve the project goal include:

1) Site planting --Revegetate reconstructed floodplains by planting patches of native riparian hardwoods at inundation frequencies appropriate for each species life history requirements.

Constructed floodplains and wetlands will be revegetated in a way that reflects natural interactions between vegetation, hydrology, and channel morphology (planting species in their hydrologic niches). Riparian plant recruitment is episodic and patchy. Certain geomorphic surfaces are successfully colonized in some years, then as vegetation matures, high flows scour away patches of riparian vegetation. Integrating the establishing patches with scoured patches results in a historically diverse vegetation pattern along Clear Creek (Figure 5 and 6). To recreate this diversity, floodplains will be revegetated in a mosaic of patches. Planting patches will replace riparian vegetation on some surfaces, while leaving others exposed for natural plant recruitment (see next objective).

2) Promote natural regeneration/recruitment by spreading topsoil over some areas of reconstructed floodplains, creating favorable physical conditions for natural riparian hardwood regeneration.

Replanting will speed riparian dependent wildlife habitat recovery at wetlands and floodplains; however, this only creates even age patches of riparian vegetation, which is not representative of regionally undisturbed systems. Natural recruitment of most riparian species requires proper soil conditions (exposed fine sediments), correct timing of seed dispersal to coincide with wet soil conditions, and sufficiently wet soil for the plant to survive as a seedling. Constructing areas that provide favorable seed germination conditions when herbaceous and hardwood species are dispersing seeds will encourage natural recruitment. These areas will not be manually planted. If this approach appears successful, this type of natural revegetation effort should be contemplated in other areas to encourage multiage riparian stands and long-term habitat rehabilitation.

3) Minimize disturbance of existing riparian vegetation

Rehabilitation activities will not disturb any valley oaks in the reach; however, other upland associated species of oak may be removed, including Mexican Elderberry (*Sambucus mexicana*). Existing valley oaks will provide acorns for the revegetation effort, as well as contributing to future oak recruitment. Fremont cottonwoods will be preserved wherever possible because they are in low numbers along the creek. Cottonwoods that do need to be removed during construction will be cut up and used for cuttings. In some cases we will prune older trees a year prior to replanting so that these trees can supply one-year-old branches for planting.

4) Remove invasive exotic plant species and discourage future re-establishment.

Many exotic plant species within project and borrow sites will be removed during material excavation and floodplain regrading. Two hardwood species will be specifically targeted because of their aggressive colonization: tree of heaven (*Ailanthus altissma*) and black locust (*Robinia pseudoacacia*). Two herbaceous species will be targeted for removal: star thistle (*Centaurea solstitialis*) and Himalaya berry (*Rubus discolor*). The above ground portion and the stump/root wads of exotic plants will be removed. After initial removal, a maintenance program may be needed to discourage exotic species from displacing native riparian species established by this project.

7.4. FLOODPLAIN REVEGETATION DESIGN

Based on the objectives listed above, a riparian planting scheme was developed for restored geomorphic surfaces at the Project reach (Figure 24) and Reading Bar borrow site (Figure 25). The design mimics vegetation patterns found on the different geomorphic surfaces of less disturbed regional streams, and targets the following revegetation strategies for each geomorphic surface:

Point bars- Pre-dam point bars were exposed gravel and cobbles, with sporadic patches of narrow leaf willows. Where point bars still remain, flow regulation allowed them to be colonized by white alder and narrow leaf willows. Reconstructed point bars will not be revegetated, and riparian berms on un-mined point bars will be removed. Natural revegetation will occur on point bar surfaces.

High flow scour channels- High flow scour channels will be constructed to simulate those observed in pre-dam aerial photographs. These channels are closer to the groundwater table than the floodplains, are moist during spring seed dispersal due to positive groundwater gradient from the adjacent hillsides, and tend to trap fine sediment during high flows. When combined with coinciding hydrology and riparian seed dispersal, these areas encourage patches of riparian hardwood seeds to germinate. Some of these constructed high flow scour channels will be revegetated; others will remain unplanted to become potential seedbeds for future natural riparian regeneration. In the future, natural riparian regeneration of these surfaces should increase both structural and age class diversity of riparian vegetation within lower Clear Creek.

Floodplains- Floodplains will be constructed at an elevation where they are frequently inundated by anticipated future high flows (>3,000 cfs). Much of the revegetation will occur on these surfaces. Target species include Fremont cottonwood, black willow, mixed willow, arroyo willow, white alder, mulefat, and Mexican elderberry. Patch type series planting will also be implemented on floodplain surfaces.

Terraces- Terraces will not be constructed because they require larger volumes of fill to construct, and do not provide as much riparian habitat potential as floodplain surfaces. Existing terraces (many of them pre-dam floodplains) will not be revegetated, with existing senescent riparian or upland vegetation retained as seed sources.

7.4.1. Plant palette and revegetation strategy

There are two approaches to riparian revegetation. The first includes planting a full complement of plant species, canopy, mid-story, and under-story plants. While this is a more complete planting scheme, it is often cost prohibitive because the understory components. Furthermore, if the understory species are planted before a canopy has developed, the sun intolerant understory plants will have low survival. The second approach is focuses on planting the dominant tree and shrub species to provide cover and shade, which will eventually create the micro climatic conditions favorable for natural mid-story and under-story plant recruitment. We recommend the latter approach for revegetating lower Clear Creek.

Final riparian vegetation coverage combines revegetation on constructed surfaces and vegetation retained during project construction. Currently 20 plant series (or cover types) are found within the Clear Creek corridor, although not all are riparian or native to Clear Creek. Proposed revegetation will focus on 10 plant series (Appendix B, Table 2). Many of these plant series have identical species, but the composition varies by plant dominance (e.g., a Fremont cottonwood series has black willow, arroyo willow, and others, but the dominant species is Fremont cottonwood). This strategy limits the number of individual riparian plant species included to 12, and wetland emergent species to 4.

Construction activities will require some Mexican elderberry plants to be removed. Mexican elderberry is the host for the endangered Valley Elderberry Longhorn Beetle, and removal of elderberry plants will require consultation with USFWS under the federal Endangered Species Act (ESA) Typical mitigation for elderberry disturbance ranges from 3:1 to 5:1 for stems 1 inch in diameter or greater. Mexican elderberry is a component of many of the proposed planting series, and will planted along with other species (Figure 24). Consultation with the USFWS will ultimately determine specific mitigation requirements for impacts to elderberry that will occur during project implementation.

7.4.2. Patch planting

Figures 24, 25, and 26 show patches of riparian vegetation series to be planted (each patch is based on a unique plant series). Planting procedure, density, species within a patch, and planting arrangement need description for a contractor to be able to implement the riparian design. Each proposed patch shown in Figures 24, 25 and 26 could be planted by digging trenches perpendicular to stream flow for efficient implementation. Each patch would be planted with a unique assemblage of woody plant species, dominated by a certain species (Figure 27). Ideally, only 50% of the overall constructed floodplain area would be planted, with the remaining floodplain area unplanted to allow planted riparian canopies to grow and develop, to allow natural regeneration to occur, and to provide patchiness by leaving open areas.

The number of plants in a patch is based on the growth habits of a specific plant species. For example, mixed willow patches have a higher stem density than Fremont cottonwood patches. Planting densities in each patch are high for several reasons. The ideal outcome of revegetation is a patchy mosaic of Fremont cottonwood forests and shrubby willow thickets; mortality in planted patches is an ideal way to achieve this patchiness. The revegetation design relies on cuttings being planted into a shallow ground water table, The first year planting should have higher plant density to ensure revegetation success; if plant survival is too high to achieve a patchy morphology, subsequent revegetation efforts should increase the unplanted area and reduce planting density to create a desired vegetation patchiness.

Implementation of the revegetation effort should be done in a way to achieve the desired results (diversity of series, diversity of species, patchiness, open areas) in the most economical means possible. This can be accomplished by digging trenches perpendicular to streamflow to the winter groundwater table, and installing hardwood cuttings at the spacing indicated by the patch type (Table 5). Two cuttings could be planted at each planting location along the trench to increase plant survival. For example, in Fremont cottonwood patches, two cuttings are placed every 10 feet in the trench, contrasted to mixed willow patches where 2 cuttings are placed every 3 feet. Planting locations along trenches are randomized based on the starting location of the trench so that the revegetation does not appear as a row crop (cutting mortality within trenches will also help to alleviate the row crop appearance).

Patch/Series Type	**Stand Growth Habits**	**Spacing**
Fremont cottonwood	Forest	10 ft on center between trenches and 10 ft on center between plants, 2 cuttings per planting
Black willow	Forest	10 ft on center between trenches and 10 ft on center between plants, 2 cuttings per planting
White Alder	Forest	10 ft on center between trenches and 10 ft on center between plants, 2 cuttings or 1 container plant per planting
Mixed willow	Thicket	10 ft on center between trenches and 3 ft on center between plants, 2 cuttings per planting
Arroyo willow	Thicket	10 ft on center between trenches and 3 ft on center between plants, 2 cuttings per planting
Buttonbush	Shrub	5 ft on center between trenches and 5 ft on center between plants, 2 cuttings per planting
Mexican Elderberry	Shrub	5 ft on center between trenches and 5 ft on center between plants, 2 cuttings per planting
Mulefat	Shrub	5 ft on center between trenches and 5 ft on center between plants, 2 cuttings per planting
Bulrush	Rhizomatous	Wet planted, 2 ft on center between plants
Sedge	Rhizomatous	Rolled mats

Table 5. Proposed planting spacing for selected patch types based on different stand growth habits.

Within each series, the species composition is installed in the trench in the proportion of that series. For example, for the mulefat series, 80% should be mulefat, 10% should be red willow, and 10% should be arroyo willow (Appendix B, Table 2). These species would then be planted in the trench 5 ft apart in the following sequence:

MF – MF – MF – MF – RW - MF – MF – MF - MF – AW

Where MF= mulefat, RW=red willow, and AW=arroyo willow.

7.4.3. Exotic species control and weeding

Many exotic plant species within project and borrow sites should be removed during floodplain regrading, material excavation and wetland construction. Two hardwood species should be targeted for removal; tree of heaven (*Ailanthus altissma*) and black locust (*Robinia pseudoacacia*). Three herbaceous species should be targeted for removal where physically and economically possible, star thistle (*Centaurea solstitialis*), Johnson grass (*Sorghum halepense*), and Himalaya berry (*Rubus discolor*). The above-ground portion and the stump/root wads of exotic plants should be removed to discourage subsequent regeneration. However, a seed bank may still be present after construction, so an exotic plant removal program may be needed.

Clear Creek flows through an arid region of California, where plant establishment is often a function of not only seed availability, but also water. Revegetation projects that supply water in excess of that available through local precipitation (either through flood, sprinkler, or drip irrigation) often have problems with exotic weeds out-competing plantings that are irrigated. There may be a substantial exotic seed bank both in the soils that will be replanted, as well as those being imported. While there may not be a cost effective way to prevent annual herbaceous exotic plants from growing, exotic woody exotic plants should be removed annually. For a period of five years, the revegetated project including the borrow sites should be cleared of all sprouting exotic hardwoods. After five years, planted riparian vegetation should provide enough canopy cover to discourage the regeneration of exotic hardwoods.

7.4.4. Irrigation

Hardwood cuttings should not require irrigation because they will be planted to the depth of the winter groundwater table on floodplains, and we anticipate that the decline of this winter groundwater table should be at a rate less than the root growth rate of the cuttings (i.e., the roots can follow the declining groundwater table through the spring and summer). Soil moisture and groundwater will be the only water available to the hardwood cuttings; therefore it is imperative that cuttings be planted at the specified depths (Figure 27).

While we recommend that revegetation emphasize cuttings and natural regeneration, some plant series will require container and bareroot stock (e.g., white alder). Container