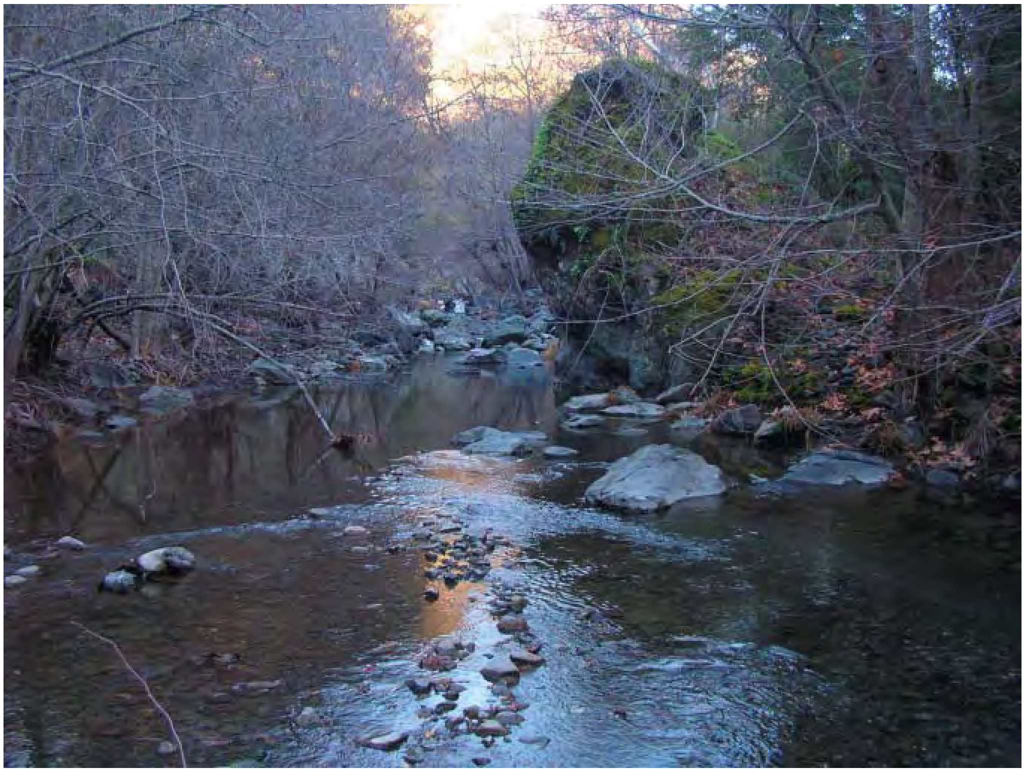
ALAMEDA CREEK POPULATION RECOVERY STRATEGIES AND INSTREAM FLOW ASSESSMENT FOR STEELHEAD TROUT

FINAL Study Plan



Prepared for:

Alameda Creek Fisheries Restoration Workgroup

Prepared by:

McBain & Trush, Inc.
980 7th Street
Arcata, CA 95521

Dr. William Trush (bill@mcbaintrush.com)
Scott McBain (scott@mcbaintrush.com)

With assistance from:

Alameda Creek Fisheries Restoration Workgroup Technical Participants
Andy Gunther, Center for Environmental Management and Restoration

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EXECUTIVE SUMMARY

The Alameda Creek Fisheries Restoration Workgroup (Workgroup) was organized in 1999 to restore steelhead to the Alameda Creek watershed. Initial Workgroup efforts focused on (1) building the collaborative relationships required for watershed-scale restoration, and (2) removing or modifying physical barriers that interfere with steelhead migration. The Workgroup recognized that additional instream flow releases also would be needed. This Study Plan, required by a 2006 Memorandum of Understanding, describes work needed for estimating the magnitude, timing, duration, frequency, and location of instream flow releases necessary to restore the steelhead fisheries (while also considering other native fishes and riparian communities) in the Alameda Creek watershed while minimizing potential impacts to water supply. This Study Plan first reviews steelhead (Oncorhynchus mykiss) life history characteristics and environmental requirements relevant to the Alameda Creek watershed. A conceptual recovery strategy emphasizing the need and utility of instream flow releases to support multiple life history tactics is then developed, followed by a description of key management issues that must be addressed for steelhead restoration. In the final section, ten Study Plan elements are presented as preliminary scopes of work.

Historic steelhead life history tactics within the Alameda Creek watershed likely occurred in two broad categories: (a) fry born in the upper tributaries reared for one or two years, then migrated rapidly to San Francisco Bay and (b) following emergence, the fry moved downstream and reared in the mainstem and/or Niles Cone before entering San Francisco Bay. Historically, headwater tributaries likely contributed large smolts directly to San Francisco Bay, especially during consecutive wetter years, but many additional large smolts were likely produced by slower migrating juveniles that grew on their way downstream through the mainstem channels, before smolting and entering Alameda Creek Estuary and then San Francisco Bay. Probable life history tactics are identified in the Study Plan; these were grouped into five population restoration strategies.

Restoration of a steelhead population in Alameda Creek will require attention to the entire watershed; instream flow releases will be a vital component of all steelhead population recovery strategies. The ultimate task for restoring the steelhead population is to establish conditions that allow a large number of smolts to develop that each grow as large as possible before entering San Francisco Bay. Instream flow releases (especially of colder water) will be expected to improve spawning success, significantly increase habitat abundance and quality (especially water temperature) for juvenile steelhead rearing, grow larger juveniles and smolts with significantly higher smolt-to-adult return rates, and encourage the transformation of juveniles to smolts. Instream flow releases were not evaluated in isolation from other factors affecting fisheries recovery, such as migration barriers and poor water quality, and thus required a watershed-wide perspective. While high-flow passage barriers have attracted the most attention in the watershed, the cumulative delay in upstream adult migration from multiple low flow barriers and water diversions may significantly impact future spawning success if not evaluated and remedied.

Key management issues in the Alameda Creek watershed addressed in the Study Plan included: (1) Can instream flow releases from San Antonio, Calaveras, and Del Valle reservoirs create a viable population recovery strategy as well as benefit other population recovery strategies farther downstream? (2) What additional fish barriers need removal or modification for adult steelhead to access all desirable headwater and mainstem spawning sites when successful spawning is likely? (3) Can the pools backwatered by the ACWD rubber dams in the Niles Cone region be managed to benefit downstream migrating juveniles and smolts? and (4) What will be future roles of the lowermost Alameda Creek mainstem channel (below the Bart Weir) and a restored estuary in recovering Alameda Creek's steelhead population? The Study Plan provides the relevance and analytical framework for solving these and six other prominent management issues critical to sustainable steelhead population recovery and overall health of the Alameda Creek ecosystem.

Management issues had to be transformed into tasks, called Study Plan Elements, to facilitate Study Plan implementation. Each Element addresses tasks (including a general purpose statement and methodologies), anticipated products, approximate costs using a 1-yr to 3-yr planning horizon, and potential entities responsible for doing the work. The Elements are not listed by priority; all should be considered in the first through third year of Study Plan implementation.

Restoration of a steelhead fishery in Alameda Creek is challenging given the many past and present human activities that have altered this ecosystem. However, all parties that must participate in this effort are working together. The resilient nature of steelhead, demonstrated in many watersheds around the state, suggests implementation of the Study Plan will succeed in restoring a self-sustaining steelhead population to the Alameda Creek watershed.

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CHAPTER 1

1 INTRODUCTION

The Alameda Creek Fisheries Restoration Workgroup (Workgroup) was organized in 1999 to recover the steelhead population in Alameda Creek watershed. Initial Workgroup efforts focused in part on identifying and removing or modifying physical barriers that prevent/delay steelhead migration. Key Workgroup participants signed a Memorandum of Understanding (MOU) in September of 2006 to cooperatively study and implement additional restoration actions in the Alameda Creek watershed. A key unresolved management action is whether, and to what extent, additional instream flow releases are needed to: (1) encourage adult steelhead upstream migration, (2) improve spawning success, (3) significantly increase habitat abundance and quality for juvenile steelhead rearing, (4) grow larger juveniles and smolts, and (5) facilitate downstream smolt migration and smoltification.

The MOU describes the purpose of preparing a Study Plan as a "*detailed work plan for the work necessary to estimate the range, magnitude, timing, duration, frequency, and location of flows to restore steelhead fisheries (while also considering other native fishes and riparian communities) in the Alameda Creek watershed while minimizing the potential impacts to water supply*." The Workgroup envisions three phases to recommend instream flow releases for restoring the steelhead fishery. Phase 1 is to prepare the study plan, Phase 2 is to collect necessary field data and perform preliminary analyses, and Phase 3 to synthesize the analyses the data and formulate instream flow alternatives. The primary work product of Phase 1 is this Study Plan for quantifying and evaluating instream flow releases necessary to restore steelhead to the Alameda Creek watershed, while minimizing impacts to water supply and considering other native fishes and riparian communities. Instream flow releases however cannot be evaluated in isolation of other factors affecting fisheries recovery, such as migration barriers and poor water quality. Therefore this study plan took a watershed-wide perspective within which natural streamflows and instream flow releases could be evaluated (Mobrand, Lichatowich, Lestelle, and Vogel 1997).

1.1 Study Plan Organization

This study plan first reviews steelhead (*Oncorhynchus mykiss*) life history characteristics and environmental requirements relevant to the Alameda Creek watershed. A conceptual recovery strategy emphasizing the need/utility of instream flow releases is then developed, followed by a description of ten key management issues. In the final section, ten study plan elements are presented as preliminary scopes of work. Each study plan element includes a rationale related back to the management issues and population recovery strategies, field data collection needs and proposed methodologies, anticipated analyses, products, and approximate costs. A timeline for task completion in each element uses a 1-yr to 3-yr planning horizon.

1.2 Basin Orientation and Reports/Data Reviewed for the Study Plan

Development of the study plan required considerable data collection and synthesis, review of many reports, and helpful discussions with Workgroup members. Appendix A lists information reviewed. A geographic overview of the Alameda Creek Basin is provided in Figure 1. A second basin map identifies streamflow and water temperature monitoring locations (Figure 2), and a third map delineates channel distances from San Francisco Bay that could be used to standardize historic and future monitoring locations (Figure 3).

CHAPTER 2

2 STEELHEAD LIFE HISTORY

Steelhead are challenging to manage because they never stay in one place very long. Eggs are deposited in one place, the juveniles rear in others, the smolts grow and migrate even farther downstream, and the adults will often range across the open Pacific Ocean close to Japan before returning to spawn one to several years later. Therefore, planning steelhead recovery fundamentally is a routing puzzle in space and time.

Steelhead prosper over a wide range of watershed sizes and climatic conditions in California. NOAA (NOAA-NWFSC Tech Memo-27: Status Review of West Coast Steelhead) notes that steelhead exhibit the most complex suite of life history traits of any Pacific salmonid. Winter steelhead adults can begin their spawning run in November, but generally do not begin in earnest until mid-December. Depending on winter flows, migration can last through April. The athletic steelhead adults generally seek out spawning habitat in the watershed's headwaters, though spawning in the mainstem channel is not unusual. Spawned-out adults can return to the ocean (usually females), though typically less than 10% survive to do so. Steelhead eggs require 50 days to 80 days before the fry swim free of the gravel bed (Spence et al. 1996). Juvenile fish may remain in the watershed more than 2 years. Those residing in freshwater and/or an estuary less than a full year from the time of egg deposition are considered '0+ juveniles'. Juveniles that spend one complete winter in freshwater and/or an estuary are called '1+ juveniles' and those remaining two complete winters in freshwater and/or an estuary are considered '2+ juveniles'. Prior to entering the Pacific Ocean, all juveniles physiologically transform into ocean-tolerant smolts. Smolts mature into adults and may remain in the Pacific Ocean from 1 to 3 years (or more) before returning to their natal streams to spawn. In California, most adult steelhead returning to spawn have spent at least one full winter rearing as juveniles (i.e., as 1+ juveniles) in their natal watershed.

Often each unique period of juvenile freshwater residency (i.e., staying less than a year, more than one full year, and slightly more than two full years in the watershed) is considered a separate life history strategy. While helpful, these strategies do not sufficiently differentiate patterns of watershed use. For example, a juvenile steelhead spending one winter in Alameda Creek (a '1+ juvenile') might reside high in the headwaters then migrate rapidly to San Francisco Bay, or it might move far downstream shortly following emergence to spend the entire winter in Niles Canyon before migrating to San Francisco Bay in late-spring. Both would enter San Francisco Bay as 1+ smolts, but their tactics for utilizing the watershed would have been fundamentally different. To reduce confusion, the term 'life history tactic' rather than 'life history strategy' may better characterize the many different ways juvenile steelhead once utilized, and could again utilize, the Alameda Creek watershed.

2.1 Steelhead Life History Tactics

Alameda Creek likely favored several life history tactics, in large part attributable to extreme annual streamflow patterns and a varied, geomorphically-active stream channel network. As Alameda Creek Basin was urbanized, its streamflows regulated, and dams/barriers constructed, fewer life history tactics continued to be viable. The diversity of steelhead life history tactics that likely occurred in the Alameda Creek watershed includes the following (Figure 4):

Tactic 1A and Tactic 1B. Steelhead fry emerge from headwater tributaries in Tactic 1A or the upper mainstem in Tactic 1B (e.g., just below Little Yosemite Canyon). The fry then migrate into Niles Canyon within a few months and rear in Niles Canyon throughout their first summer and autumn. Over-wintering in Niles Canyon is followed by pre-smolt out-migration in spring (now as 1+ fish) and eventually entering San Francisco Bay in late-spring or very early-summer as 1+ smolts. Tactic 1A may be prevalent in Wet years when adult access is best, while Tactic 1B may be prevalent in Dry years when adult access into smaller tributaries is restricted and the window for successful spawning is very narrow.

Tactic 2A and Tactic 2B. Steelhead fry emerge from headwater tributaries in Tactic 2A or the upper mainstem in Tactic 2B. The fry then migrate through Niles Canyon by early-summer and spend the remaining summer and autumn in Niles Cone, either in the backwater pools or farther downstream. Over-wintering in Niles Cone is followed by rapid pre-smolt movement farther downstream in Niles Cone by mid-spring, then entry into San Francisco Bay by late-spring as 1+ smolts.

Tactic 3A and Tactic 3B. Steelhead fry emerge from headwater tributaries in Tactic 3A or the upper mainstem in Tactic 3B. Fry from the headwaters in Tactic 3A soon travel downstream and spend the summer and autumn with fry from Tactic 3B in an upper mainstem channel. Over-wintering in the upper mainstem channel is followed by rapid pre-smolt movement farther downstream, perhaps spending some time in Niles Canyon, before entering San Francisco Bay by late-spring as 1+ smolts.

Tactic 4. Steelhead fry emerge from a headwater tributary and remain in the tributary (though likely moving downstream) through their first winter, then migrate downstream in early spring or late-winter and enter San Francisco Bay by mid-spring as 1+ smolts. This tactic might rely on back-to-back Wet years for adult access, high spawning success, tolerable summer rearing, and downstream access the following spring.

Tactic 5. Steelhead fry emerge from a headwater tributary and remain in the tributary (though likely moving somewhat downstream) through their first winter, then migrate downstream in early spring or late-winter to Niles Canyon where they spend their second summer and autumn. In early-spring they would continue downstream as pre-smolts, entering San Francisco Bay in early- or mid-spring as 2+ smolts.

Tactic 6. Steelhead fry emerge from a headwater tributary and remain in the tributary (though likely moving downstream) through their first winter, then migrate downstream in early spring or mid-spring eventually to Niles Cone where they spend their second summer and autumn. In the following early-spring they would enter San Francisco Bay in early- or mid-spring as 2+ smolts. This tactic might apply to later downstream migrating 1+ pre-smolts, that experience a temperature threshold preventing smoltification and forcing them to ‘wait-out’ a second winter before smolting.

Tactic 7. Steelhead fry emerge from a headwater tributary and remain in the tributary (though likely moving somewhat downstream) through their second winter, then migrate downstream in early spring or late-winter and enter San Francisco Bay by mid-spring as 2+ smolts. This tactic might rely on a Wet year (for adult access and spawning success), followed by a Dry year and then a Normal/Wet year (the Dry year preventing downstream migration as 1+ juveniles and forcing a second summer and winter).

Tactic 8A and Tactic 8B. Steelhead fry emerge from headwater tributaries in Tactic 8A or the upper mainstem in Tactic 8B. The fry then migrate through Niles Canyon and Niles Cone by early-summer and enter San Francisco Bay as 0+ smolts. This tactic would rely on wetter years with good growth potential. These 0+ smolts could have spent the summer in the estuary, and then have migrated to the ocean in fall.

These diverse life history tactics allowed steelhead, as a species, to persist and thrive under widely ranging geomorphic and hydrologic conditions across the watershed. The resiliency derived from this diversity cannot be overstated, even if difficult to quantify.

2.2 Smolt-to-Adult Return

Fork length (FL) at smolting clearly matters to steelhead survival. Big smolts are much more likely to return as spawning adults than small smolts. The threshold for a smolt length with even a modest 0.5% chance of success (returning as a spawning adult) is approximately 150 mm FL (fork length). A smolt-to-adult return curve (SAR curve) was developed from experimental CDFG hatchery data on the Eel River (Figure 5) (Kabel and German 1967). Data collected closer to Alameda Creek might be used to adjust this curve, and should be considered an important study plan item. Downstream juvenile migrant and upstream adult trapping data are available from Shapovalov and Taft (1954) for Waddell Creek and Scott Creek (Bond 2006), both near Santa Cruz. Though these watersheds are much smaller than the Alameda Creek watershed, they nevertheless should be consulted. The Shapovalov and Taft (1954) sampling effort still ranks as the most intensive steelhead field study in California, but may not provide sufficient resolution for computing an SAR curve (though it has been attempted).

Additional growth downstream can be a highly successful mechanism for improving adult steelhead return. To illustrate, we fit a slightly asymmetrical bell-shaped size class distribution to all downstream migrating 2+ juveniles captured (total of 345 captured) in San Antonio Creek, Arroyo Hondo, and Indian Creek during spring 2003 (SFPUC 2004)(Figure 6). Although these migrants are not swimming to San Francisco Bay and were spawned by rainbow trout adults, the data provide insight into how important these tributaries might have been prior to the dams. Applying the SAR curve provided in Figure 5 to this size class distribution (multiplying the number of individuals in each size class by their probability of returning in the SAR curve), the estimated number of returning adult steelhead was 2.8. This calculation functionally requires these three tributaries to empty directly into San Francisco Bay with no opportunity for the parr and smolts to grow while migrating down mainstem Alameda Creek. Estimates for returning adults were also made assuming a very healthy specific daily growth rate of 0.2%FL/day for 50 days and 100 days migration down Alameda Creek's mainstem channel to the San Francisco Bay. The predicted adult return, 7.5 steelhead adults for 50 days growth and 15.6 adults for 100 days growth, highlights the significance of addressing habitat quality and quantity in mainstem Alameda Creek and estuary. Note that even doubling the capacity of rearing parr and smolt habitat within these tributaries (if all three were not behind dams) might not compensate for poor growth during migration downstream. This may set the stage for competing/complimenting restoration plan strategies: increasing the miles of habitat opened/improved versus encouraging a higher growth rate. Instream flow releases will be instrumental in creating more habitat (when it might be most needed) and encouraging higher growth rates (by creating favorable water temperatures and abundant benthic macroinvertebrate habitat).

Given the impact of SARs, a fishery recovery program in Alameda Creek must consider which life history tactics could produce 150 mm smolts/pre-smolts and larger. The Waddell Creek study by Shapovalov and Taft (1954) and recent studies in Scott Creek (Bond 2006) show that the estuary plays a key role in growing juvenile steelhead past the 150 mm threshold. An important life history constraint in Alameda watershed is whether 1+ juvenile steelhead can grow sufficiently large and become smolts, before entering San Francisco Bay, without the aid of Niles Cone or an estuary. This could occur either in the headwater tributaries (persevering one stressful summer rather than two), immediately downstream of the three major dams with sufficient instream flow releases, or farther downstream in the Arroyo de la Laguna mainstem and Alameda Creek mainstem (from the base of Little Yosemite Canyon to the bottom of Niles Canyon).

2.3 Water Temperature Thresholds for Steelhead Life History Stages

Water temperature thresholds will be central to strategizing recovery and recommending instream flow releases (e.g., Santa Ynez River Technical Advisory Committee 2000). Cooler waters are more likely to favor high juvenile growth rates. Instream flow releases can generate physical juvenile rearing habitat, but abundant habitat that is too warm is not acceptable habitat. However greater streamflow generally produces cooler water temperatures, especially instream flows released from the hypolimnion of reservoirs. The Workgroup will need to agree on appropriate water temperature criteria and thresholds for each steelhead life stage. Water temperature plots in Appendix B, with temperature thresholds of 72º (22.2º C) as stressful and 68º F (20.0º C) considered marginal for juvenile growth, show warm water temperatures can be stressful by late-May. Instream flow releases will be an important management tool for extending favorable water temperatures into spring and summer.

Smolting temperature thresholds may influence which life history tactics will be recoverable. A 1+ juvenile steelhead leaving Welch Creek in mid-May would experience water temperatures well above 55º F (12.8º C) in Alameda Creek mainstem that would prevent/impair smoltification. Juvenile growth could still happen, even vigorously in the mainstem, but smoltification would be delayed until the following spring. This delay would require rearing another winter somewhere along mainstem Alameda Creek or possibly by swimming into a lower tributary such as Stonybrook Creek.

A longitudinal water temperature profile from the confluence of Calaveras Creek downstream to San Francisco Bay was constructed from multi-agency monitoring in WY2002 for spring and summer (Figure 7). Upper daily average water temperature thresholds of 68º F (20.0º C) for favorable juvenile/smolt growth and 55º F (12.8º C) for high smolting success reveal water temperatures by mid-June exceeded juvenile growth threshold in Niles Canyon and farther downstream. Mid-April already had water temperatures exceeding the smoltification success threshold. Water temperature profiles for other years (Dry and Wet) will be needed to help determine which life history tactics could be sustained, given contemporary temperature constraints, and which will be aided by instream flow releases.

2.4 Water Quality and Juvenile Steelhead Rearing

Stream turbidities in mainstem Alameda Creek below the Arroyo de la Laguna confluence are high. Several biologically-relevant threshold NTUs developed from the scientific literature (Bash and Berman (2001); Bisson and Bilby (1982); Cummins (2004); Rosetta 2004 ODEQ (2004)) and overlaid onto the WY2006 annual turbidigraph (Figure 13) show that stream turbidity could reduce smolt size, and therefore reduce adult return. However, this was a high runoff year and likely not representative of most annual turbidigraphs.

Juvenile 1+ and 2+ steelhead could migrate from headwater tributaries down Alameda Creek mainstem and pass the Arroyo de la Laguna confluence from mid-February through May. They would rely on good habitat conditions, including favorable water quality, within Niles Canyon to grow and consequently improve their chance of returning as spawning adults. Under good conditions in clear water, a 150 mm steelhead juvenile growing its way through Niles Canyon between February 15 and May 25 in 2006 (i.e., 100 days) could reach 186 mm (using a daily specific growth rate of 0.2% FL/day). Using the 2006 annual turbidigraph, as measured by the USGS at the Niles Canyon gage, we modeled a smolt size increase to only 157 mm. Referring to the SAR curve (Figure 5), a 186 mm smolt has a 4.5% chance of returning as an adult, whereas a 157 mm smolt has a considerably smaller chance of 0.5%. Managing fine sediment sources upstream, therefore, could significantly affect which life history tactics have the best capabilities for producing large steelhead smolts.

CHAPTER 3

3 STEELHEAD POPULATION RECOVERY IN ALAMEDA CREEK BASIN

Adult steelhead swimming up the contemporary Alameda Creek Basin will be missing most of their spawning habitat in southern tributaries, now blocked by dams, and missing their northern tributaries now isolated by multiple partial migration barriers and lower baseflows in an urbanized landscape. Streamflows in Niles Canyon have changed relative to the historic hydrograph: lower baseflows from April 1 through late-May and higher baseflows in the summer (Figure 9 and Figure 10). These changes generate less juvenile rearing habitat in the springtime, but only marginally cooler water temperatures for rearing in the summer. The broad mainstem meanders in Niles Cone are gone, while the backwater pools behind the rubber dams likely impair juvenile out-migration and growth. The Alameda Creek estuary is functionally, relative to benefiting juvenile steelhead, gone as well.

The ultimate recovery task is to produce a size class distribution of out-migrating smolts capable of restoring a steelhead fishery in Alameda Creek. The diversity of life history tactics (Figure 4) is a testament of, and strategy for, contingency planning in a highly variable environment approaching the steelhead's southern limit. The study plan must consider the role of instream flow releases in recovering many life history tactics; the most promising tactics for future recovery may not have been prominent historically. The management goal is to grow annual smolt size class distributions entering San Francisco Bay that are (1) as high/large as possible (i.e., as many smolts possible), (2) positioned as far to the right in the distribution as possible (i.e., bigger smolts), and (3) a sum product of multiple life history tactics. Any recommended management action in the study plan, especially instream flow releases, should be quantitatively traceable to improving smolt number and/or size.

Chapter 3 provides the conceptual framework for recovery. In Section 3.1, similar steelhead life history tactics (summarized in Chapter 2 and illustrated in Figure 4) are assigned to one of several pathways to recovery. Each was considered a potential population recovery strategy that must cope with contemporary changes to the Alameda Creek watershed. Each will have a different capacity for improving smolt number and size once common impediments have been removed, i.e., elimination of the Bart Weir as an adult passage barrier. Section 3.2 anticipates the potential benefits of releasing instream flows to each population recovery strategy. No one recovery strategy will outperform all others in all water years. Thus the recovery of more than one strategy was considered essential. Section 3.3 forecasts those recovery strategies most likely to contribute to a sustainable steelhead fishery in the near future as well as those strategies most likely to profit from instream flow releases.

3.1 Description of Steelhead Population Recovery Strategies

Historic steelhead life history tactics (Figure 4) in Alameda Creek likely fell into two broad categories: (a) fry were born and reared high in the watershed for one or two years, then migrated rapidly to San Francisco Bay and (b) following emergence, the fry moved downstream and reared in the mainstem and/or Niles Cone before entering San Francisco Bay. The circumstance that likely prevailed historically was that headwater tributaries supplied large smolts and older juveniles, especially during sets of wetter years, but many more large smolts were produced by slower migrating juveniles that grew their way downstream through the lower mainstem, before smolting and entering Alameda Creek Estuary and then San Francisco Bay.

The eight life history tactics in Figure 4 were grouped into five population strategies to keep discussion and analyses manageable. Each can be considered a potential recovery strategy, based on a set of life history tactics, for producing adult steelhead in Alameda Creek watershed.

3.1.1 Headwater Population Recovery Strategy

Tactic 3A, Tactic 4, and Tactic 7 have steelhead rear in the headwaters as 1+ or 2+ juveniles then migrate down the mainstem channels for 1 to 3 months, while still growing, before entering San Francisco Bay as 1+ or 2+ smolts. Tactic 3A and Tactic 4 will likely produce many more 1+ smolts, than 2+ smolts produced by Tactic 7. However the considerably higher smolt-to-adult return of large 2+ smolts, relative to smaller 1+ smolts, may favor Tactic 7 as best of the three for producing returning adults. The sizes of 1+ and 2+ smolts upon entering San Francisco Bay likely were considerably bigger than when they had left their natal headwaters 1 to 3 months earlier.

The Headwater Population Strategy likely was the prime producer of the watershed’s adult steelhead; most smolts leaving Alameda Creek watershed could trace their 1+ juvenile origin back to the headwaters. Not all Alameda Creek watershed’s headwaters contributed equally. Tributaries with greater annual rainfall had the better potential, and offered less risk for sustaining 0+ juveniles through the summer to become 1+ pre-smolts the next spring. The southern half of Alameda Creek watershed above Niles Canyon had the mountainous terrain to generate higher annual rainfall, especially Arroyo Hondo, Calaveras Creek, and the uppermost Alameda Creek mainstem (Figure 1). The northern and more inland half of the watershed, above the Arroyo del Valle confluence with Arroyo de la Laguna, was considerably drier and variable (inter- and intra-annually). Over-summering in these headwater tributaries under very low flows and warm air temperatures required thermally stratified pools. The temporal windows for spawning success would have been much wider and more frequent (inter- and intra-annually) for adult steelhead migrating into the southern Alameda Creek watershed, than into the northern watershed.

The Headwater Population Strategy could not support the historical adult run with headwater tributaries alone. The 1+ (and some 2+) juveniles embarking on their downstream migration in late-winter and spring needed additional growth before entering San Francisco Bay as smolts. A 10% increase in length during this part of their journey would have greatly improved their chance of returning to spawn (Figure 5). Arroyo de la Laguna, mainstem Alameda Creek above Arroyo de la Laguna, and the mainstem through Niles Canyon had the capability to grow migrating juvenile steelhead. Annual hydrographs from the USGS Niles gage from WY1891 to WY1901 (Figure 9) in Niles Canyon show daily average streamflows from April 01 (and earlier) into late-May were typically above 40 cfs to 60 cfs and would have had favorable water temperatures (Figure 7) for benthic macroinvertebrate production and juvenile steelhead growth. However, by the end of May and into early-June baseflows declined steeply. While diversions had already begun by the 1890’s this drop in baseflow was likely natural. At low baseflows, some pools may have thermally stratified to provide limited summer refuge, but overall the mainstem channel through Niles Canyon would not have been a most desirable place for 1+ or 2+ juvenile steelhead to reside over the last half of summer and early-fall.

Dependency of the Headwater Population Strategy on the lower watershed may have been even greater than juvenile steelhead accruing additional size while migrating through Niles Canyon in springtime. Once emerging from Niles Canyon and onto the Niles Cone, 1+ and 2+ juveniles might have encountered highly favorable conditions for late-springtime growth in the deep alluvial meander bends (even better than in Niles Canyon) and/or in the Alameda Creek estuary. We do not know how good, historically, the meandering mainstem channel and estuary really were at growing juvenile steelhead. If conditions were good, the potential for added growth would have been a primary factor influencing annual run size for the entire watershed.

In summary, for the Headwater Strategy to have sustained a sizable steelhead run (e.g., 1000 adults) historically, the entire Alameda Creek watershed had to contribute. If San Francisco Bay historically lapped at the bottom of Niles Canyon, thus eliminating Niles Cone and estuary, adult run size would have been considerably smaller without changing anything upstream. If San Francisco Bay historically lapped at the confluence of Alameda Creek with Arroyo de la Laguna, with no estuary, the effect would have been even greater.

3.1.2 Dam Population Recovery Strategy

Tactic 3B is a promising new strategy that requires good summer rearing conditions for 0+ juveniles below a dam releasing cool summer and fall flows. Depending on reservoir stratification dynamics, the Dam Population Strategy may steadily produce 1+ smolts the following spring. In effect, this population strategy would minimize many uncertainties of the Headwater Population Strategy. Given that the dams have isolated most headwater habitat, the Dam Population Strategy could be considered a modern-day replacement for much of the Headwater Population Strategy. However, the amount of habitat eliminated by the dams will not likely be replaced downstream. The condition of the mainstem channels, particularly Niles Canyon and Niles Cone, would still be of concern, as juveniles and pre-smolts reared below the dams would need to grow during their downstream migration through the mainstem reaches. Tactic 3B should be considered below dams on San Antonio Creek, Arroyo del Valle, and Calaveras Creek.

3.1.3 Mainstem Population Recovery Strategy

Historically, Tactic 1A, Tactic 1B, and Tactic 5 were likely not as important as the Headwater Strategy. However Niles Canyon was/is a central location, where essentially all juvenile steelhead must pass through. Other mainstem segments farther upstream, Arroyo de la Laguna up to the Arroyo del Valle confluence and Alameda Creek from the San Antonio Creek confluence upstream to the base of Little Yosemite Canyon, did not have as much habitat potential. Niles Canyon has the size and physical complexity to grow many migrating 1+ and 2+ juvenile steelhead, and should be a prominent component of a steelhead fisheries restoration program. However as seasonal water temperatures warmed, the number of 1+ and 2+ steelhead surviving the summer and early-fall may have been small in drier water years.

3.1.4 Niles Cone Population Recovery Strategy

Tactic 2A, Tactic 2B, and Tactic 6 may have been highly successful historically. A sinuous, narrow alluvial channel from the base of Niles Canyon to San Francisco Bay could have provided highly complex and thermally-stratified juvenile steelhead rearing habitat. Today, the importance of this strategy seems highly diminished. Juvenile steelhead actively migrating downstream, but not soon enough for smolting, may find themselves forced to endure another summer before smolting and heading to San Francisco Bay. Thermal stratification of the backwater pools during summer may not be sufficient to improve a juvenile steelhead's chance of returning as an adult. The mainstem channel from the Bart Weir down to San Francisco Bay also may not provide sufficient thermal refuge, or abundant habitat, for over-summering juvenile steelhead that must wait until fall before smolting. The primary objective for Niles Cone may be to keep it neutral relative to the other strategies: don't help, but also don't hurt. This will apply to potential delays in adult upstream migration and downstream smolt migration.

3.1.5 Basinwide Fry Population Recovery Strategy

Tactic 8A and 8B were likely annual boom-or-bust possibilities, even if they did occur historically. However, the unknown status of the historic Alameda Creek estuary keeps this strategy a distinct possibility. A healthy estuary that encouraged 0+ juvenile growth for 3 to 5 months before the 0+ smolts entered San Francisco Bay could have produced smolts.

3.2 Steelhead Population Recovery Strategies and Instream Flows

Identification of promising strategies for recovery in Alameda Creek watershed is an important step tackled in Section 3.1. But an evaluation of which strategies hold the greatest near-term and long-term promise is equally important. Instream flow releases from existing reservoirs in Alameda Creek watershed will be a pivotal restoration tool. This section identifies how instream flow releases might help each population recovery strategy to succeed in significantly contributing smolts to San Francisco Bay.

3.2.1 Headwater Population Recovery Strategy

The historic Headwater Population Recovery Strategy required three primary functions from its headwater tributaries. The first was to provide sufficient streamflows - from mid-November or mid-December to the end of March - for adult steelhead to navigate the basin and to arrive and spawn successfully in the headwater tributaries. The second was to contribute sufficient streamflow downstream, cumulatively, to create good growth, ample food, and easy passage for those juveniles soon to become smolts, from the beginning of their journey in March or April until entering SF Bay or Alameda Creek estuary by mid-June. The third function was to provide good growth and ample food for fry and 1+ juveniles not leaving the tributaries, but residing the summer and into the following spring. As summer progressed, good habitat and ample food naturally deteriorated, but conditions remained bearable/survivable at least in the wetter years.

Today, the same requirements apply, though the miles of headwater tributaries have been greatly reduced. Arroyo Mocho and Arroyo Las Positas are the two large headwater tributaries remaining. Mainstem Alameda Creek upstream of Little Yosemite Canyon (though now affected by the Diversion Dam) also can be considered part of the Headwater

Population Strategy. Smaller tributaries include Sinbad Creek, Welch Creek, Stonybrook, Pirate Creek, and Vallecitos Creek. The large tributaries, by virtue of being large, have more unregulated streamflow and deeper, bigger pools to sustain over-summering 0+ and 1+ juvenile habitat.

Juvenile steelhead rearing habitat abundance and quality (e.g., water temperature) in headwater tributaries are impacted cumulatively by many small surface and shallow groundwater withdrawals. Instream flows released from dams/diversions will improve adult access and spawning success in the headwaters, as well as encourage juvenile growth/survival during downstream migration. An important aspect of the Study Plan will be estimating how much of improvement might be expected from different instream flow releases. A direct implication of instream flow releases on the viability of the Headwater Population Recovery Strategy will be whether streamflows interacting with the many partial stream passage barriers diminish spawning success significantly. A successful Headwater Population Recovery Strategy will need to provide: (1) unimpeded adult access past large barriers downstream and many small tributary barriers and (2) good growth conditions for juveniles smolting and migrating downstream.

3.2.2 Dam Population Recovery Strategy

The Dam Population Strategy is a contemporary strategy that attempts to mimic these three primary headwater functions within a much shorter segment of tributary channel below each of the three existing dams. Capacity for 1+ steelhead juvenile production below dams on San Antonio Creek, Arroyo del Valle, and Calaveras Creek will depend almost entirely on instream flow releases. Because cold hypolimnial dam releases rapidly warm downstream, much of the habitat created will hinge as much, or more, on avoiding thermal thresholds and their timing, than on the abundance of physical habitat created (i.e., creating lots of warm habitat is not recovery). Instream flows will need to sustain over-summer juvenile rearing to implement the Dam Population Recovery Strategy.

Instream flow releases can be unseasonably cold in spring through fall because of their hypolimnial origin in the reservoirs. Mimicking the third headwater function is relatively straightforward. A small release can make a big temperature difference downstream. Opportunities for sustaining high quality over-summering habitat for 0+, 1+, and 2+ juvenile steelhead are encouraging, though the volume of hypolimnial water available as instream releases will be a primary determinant of how much summer habitat can be sustained below the dams. Assessing the second headwater function will be harder. This will require prescribing instream flow releases for achieving goals downstream. While a 10 cfs instream flow release may create high quality rearing habitat in early-April near the dam, a 10 cfs ‘contribution’ toward creating good growth, ample food, and easy passage for those juveniles already on their migration route to Niles Cone may not be sufficient for the Dam Population Strategy to succeed. The first function also may require specific instream flow releases, rather than relying on natural runoff from other portions of the basin, particularly for Arroyo del Valle. A successful Dam Population Recovery Strategy will need to provide: (1) unimpeded adult access past the large barriers downstream and small tributary barriers (in Arroyo del Valle) that may require instream flow releases, (2) the magnitude and duration of instream flow releases necessary to sustain juvenile summer rearing below the reservoirs, and

(3) the magnitude, duration, and timing of instream flow releases significantly improving downstream rearing conditions for smolting/migrating juvenile steelhead.

Managing a Dam Population Recovery Strategy directly relies on managing the Mainstem Population Recovery Strategy. Many 0+ and 1+ juveniles had to migrate out of headwater tributaries because of rapidly deteriorating habitat conditions (including over-crowding) by mid- or late-spring, and into the mainstem channels of Arroyo de la Laguna and Alameda Creek (extending up to the base of Little Yosemite Canyon). The opportunity to smolt for these juveniles would have passed, thus requiring most of them to spend another winter in the basin (some may have smolted in the fall). Therefore, they needed a place to grow and to survive the summer. Mainstem Alameda Creek above the San Antonio confluence likely provided better habitat than Arroyo de la Laguna because the southern portion of Alameda Creek had higher more predictable runoff, but neither likely provided good over-summering habitat. Many juveniles that initially stayed in either mainstem segment probably moved farther downstream by mid-summer, though the deeper pools would have supported all juvenile age classes.

3.2.3 Mainstem Population Recovery Strategy

Niles Canyon and the mainstem channel segment from the Arroyo de la Laguna confluence upstream to the San Antonio Creek confluence offered good habitat for migrating juveniles and probably offered substantially better over-summer habitat than the mainstem segments upstream. Streamflows were much greater in Niles Canyon (a drainage area more than double that of the two mainstem segments above the Arroyo de la Laguna confluence) and the narrow, bedrock-boulder channel had bigger and deeper pools. While some adults likely spawned in the mainstem segments, most fry and 1+ juveniles probably originated from upstream. Many juveniles, once encountering Niles Canyon, could have grown substantially during part of the summer then survived the remainder (and maybe smolted in fall).

Niles Canyon figures prominently into the five steelhead population recovery strategies. Habitat - streamflow quantification should capture/quantify these multiple roles of providing ample habitat and food for: (1) downstream migrating pulses of juveniles/pre-smolts originating from the headwaters and upper mainstems, (2) steelhead juveniles having spent the winter in Niles Canyon, but also preparing to leave in spring, and (3) summer rearing juveniles, once the spring pulse of downstream migrating juveniles/pre-smolts has passed. The Mainstem Population Recovery Strategy will need mid-spring through early-autumn instream flow releases. Riffles in the mainstems can generate ample habitat for migrating juveniles and benthic macroinvertebrates under the proper streamflows in the springtime. Later when water temperatures warm, abundant pool habitat may supersede riffle habitat for juvenile steelhead surviving the summer. Therefore, separate habitat – streamflow relationships for pool and riffle habitat should be developed as part of the instream flow analysis for Niles Canyon mainstem.

A successful Mainstem Population Recovery Strategy will need to provide: (1) the magnitude, duration, and timing of instream flows collectively released from the three reservoirs and the ACWD Turnout to improve the habitat for juveniles actively migrating farther downstream (March through mid-June), (2) the magnitude, duration, and timing of instream flows collectively released from the three reservoirs and the ACWD Turnout to improve the habitat for juveniles residing the summer, and (3) connectivity to Alameda Creek mainstem for juvenile steelhead migrating downstream in the Sunol Quarry reach and past the confluence of San Antonio Creek.

3.2.4 Niles Cone Population Recovery Strategy

Niles Cone likely served the same functions as Niles Canyon: provide good habitat for migrating smolts and good habitat for over-summering juveniles. However, insufficient information exists on whether the large meander bends in upper Niles Cone actually did provide good or excellent summer rearing habitat. With the ACWD rubber dams positioned in upper Niles Cone and the remainder of the mainstem channelized and bracketed by rip-rapped levees, over-summering juvenile rearing habitat likely is now very limited. Growth conditions for migrating smolts might be substantially better, provided downstream migration past the ACWD rubber dams will not be a problem or predation in the backwatered pools a problem.

Niles Cone also will depend on dam releases but perhaps in more subtle ways than for Niles Canyon and other mainstem reaches farther upstream. Streamflows through Niles Canyon that keep water temperatures below roughly 73º F (22.8 C) could encourage juveniles to continue migrating downstream into Niles Cone, though not to smolt but to remain as juveniles another summer. As seasonal water temperatures further warm, these juveniles could find themselves extremely stressed physiologically and vulnerable to predators.

Success, at least initially, for the Niles Cone Population Recovery Strategy will be to minimize impacts to the migrating smolts and pre-smolts (i.e., be neutral) produced by the Headwater and Mainstem population recovery strategies. More information is needed for assessing the influence of the backwater pools (behind the ACWD rubber dams) to determine what management actions to recommend. For the Niles Cone Population Strategy to be better than neutral, the strategy will need to provide: (1) physical rearing habitat in the flood control channel during smolt migration to help grow smolts originating from Headwater, Dam, and Mainstem smolt populations, and (2) acceptable over-summer 0+ and 1+ rearing habitat, possibly to have these fish smolt in the fall after water temperatures drop. Operation of the ACWD rubber dams will have a significant influence on providing streamflows for smolt and juvenile rearing habitat.

3.2.5 Basinwide Fry Population Recovery Strategy

The last population recovery strategy, based on life history tactics, is the Basinwide Fry Population Recovery Strategy where 0+ juveniles become smolts without spending a winter in the watershed. Provisions for success in the other strategies all will aid this one. However, one component remains that has not been identified, but that nevertheless would benefit all the recovery strategies. The Alameda Creek estuary could have played a central role in steelhead population dynamics and annual run size. By providing accelerated growth rates, compared to growth rates in the mainstem, the estuary could have grown some 0+ juveniles into sufficiently large smolts and shifted the smolt size class distribution considerably farther to the right for older steelhead. A successful Basinwide Fry Population Strategy, that will benefit all other recovery strategies as well, will need to provide good juvenile rearing habitat in the Flood Control channel of Niles Cone and good smolt rearing habitat in a restored Alameda Creek Estuary.

3.3 Summary

Each of the five population strategies constitutes a pathway to recovery. The Headwater and Dam population recovery strategies appear the most promising for contributing to near-term recovery and the strategies most likely to profit from instream flow releases. If adult passage at the Bart Weir, the ACWD rubber dams, and PG&E and SFPUC crossings was remedied this year, but nothing else changed or managed differently, a small strongly fluctuating annual population of returning adult steelhead in the future is possible, but could not generate the larger, sustainable population size desired by the Workgroup. The Headwater strategy would provide these smolts, with additional growth provided by the mainstem channel in Niles Canyon as headwater juveniles migrated to San Francisco Bay. Additional instream flow releases would put the Dam population recovery strategy immediately into play, particularly in San Antonio Creek and Calaveras Creek below their respective reservoirs. These same instream flow releases could significantly improve mainstem rearing conditions for downstream migrating headwater juveniles depending on the magnitude, duration, and timing of those releases. Annual steelhead runs approaching 1000 adults, or even 500 adults, seem unlikely without providing good juvenile rearing conditions in Niles Canyon and Niles Cone, as well as in a future restored estuary. But recovery of good juvenile rearing conditions in the lower watershed will take considerably longer. Thus the Mainstem and Niles Cone recovery strategies will deserve longer-term perspectives, but should be considered no less important.

CHAPTER 4

4 ALAMEDA CREEK STUDY PLAN MANAGEMENT ISSUES

The population recovery strategies share common management issues in Alameda Creek watershed that will control their chances of significantly contributing steelhead smolts in the future. Chapter 4 provides the background characterization and analytical approaches for addressing ten important management issues ranging from watershed-wide adult passage assessment, habitat quantification as a function of streamflow, and the establishment of an adult steelhead population recovery goal for Alameda Creek watershed.

4.1 Management Issue No. 1.

Adult steelhead annually need to construct redds in the Alameda Creek Basin where their incubating eggs have a legitimate chance of collectively producing enough emergent fry to sustain available juvenile rearing habitat. All population recovery strategies need fry and therefore will require the assessment of spawning success relative to barriers, natural and man-made, and streamflow (including the potential benefits of instream flow releases).

4.1.1 Background

Adult steelhead need to arrive at favorable headwater spawning sites when streamflows will promote redd construction, egg incubation and hatching, and alevin/fry emergence, as well as limit redd super-positioning and minimize scour risks. The journey upstream for adult steelhead became increasingly difficult as development within Alameda Creek Basin progressed, culminating in complete blockage at the start of their journey by the BART Weir. While high flow passage barriers have attracted the most attention, the cumulative delay in upstream adult migration from multiple low flow barriers and water diversions may also significantly impact future spawning success if not evaluated and remedied. For example, if a 30 cfs baseflow is not passable at the BART Weir there will be long and frequent delays in upstream passage for adult steelhead between February 1 and March 15, 2004 (Figure 11). By the time steelhead reach headwater tributaries such as Welch Creek, streamflows may already be too low for farther migration and/or spawning.

Each identified obstruction should have a streamflow passage window accommodated in its engineering design. This passage window, within which the obstruction must be passable, can be modeled by routing steelhead and Chinook salmon adults to specified destinations over a wide range of water years. For example, if Welch Creek near the Sunol Water Treatment Plant can be accessed by steelhead at 5 cfs or greater, spawning could occur from February 27 through March 4 (Figure 11). For an adult to be poised at the mouth of Welch Creek when this storm event began (February 25), passage obstructions downstream had to have been negotiated. If an adult steelhead arrived just downstream of the BART Weir on February 8, could this adult have arrived at the mouth of Welch Creek on February 25? If it had arrived February 9? Or February 10? By modeling passage and delays at each obstruction encountered, a passage window for successful spawning can be constructed over 10 to 15 water years that span wet and dry years. The modeling will require estimates for daily migration rates. Adult migration routing can be done with available information, accompanied by a sensitivity analysis to determine if more field data collection (e.g., tracking radio tagged adults) would be warranted.

Each spawning site within the basin required unique environmental conditions to assure constructed redds produced many emergent fry. A steelhead swimming upstream past Union City needed sufficient days to navigate the channel network up to the headwaters then construct a redd and spawn. The buried eggs needed sufficient days inundated (depending on water temperature) to incubate, hatch, and eventually emerge from the channelbed before streamflows became too low or too warm. For many historic tributary spawning sites in the Arroyo de la Laguna watershed, dry and normal water years likely would not have offered successful spawning conditions (success defined as redds producing many fry). Therefore, the annual extent of potentially successful spawning habitat would have changed from one water year to the next, even with no human intervention.

The recovery plan must promote adult access to all desirable spawning sites throughout the Alameda Creek Basin when spawning habitat is abundant and constructed redds would have a high probability of producing fry (i.e., would be successful). Sustaining diverse population recovery strategies, by spawning emergent fry in many basin locations, will be important for fisheries recovery under variable water years.

4.1.2 Analytical Approach

Basinwide evaluation of subtle and not-so-subtle adult migration barriers, with the ultimate goal of achieving spawning success, must begin at desired headwater spawning locations and proceed downstream. The first step will be to select desired spawning reaches as destination points in Alameda Creek Basin for the passage analysis. Once these spawner destination points have been selected, the window for successful spawning opportunity (SSO) will be established for each destination point from WY1990 through WY2006. The SSO is the set of days in a given water year analyzed (i.e., specific dates) within which, if a redd were constructed, it would have a good chance of producing fry. The recovery plan goal would have adult steelhead arrive within the SSO for as many water years as possible, thus the SSOs become targets of the fish passage analysis. The spawner routes from SF Bay to all desired spawning destination points will be assessed by first identifying all potential barriers along each route then estimating the range of streamflows each barrier is passable. The passage analysis along each spawner route will investigate where in Alameda Creek Basin adult steelhead could have produced fry between WY1990 and WY2006 if specific migration barriers had been removed or modified. The collective investigation of all migration routes and spawner destinations will be used to recommend upper and lower streamflow passage criteria specific to each barrier for promoting successful steelhead spawning. The streamflow criteria serve as engineering design criteria, with the analysis linking (and justifying) design criteria to this specific recovery goal. The final issue for fish passage will be prioritizing and budgeting barrier fixes.

4.2 Management Issue No. 2.

Abundant and productive juvenile rearing habitat in Niles Canyon and upper mainstem channels, required by all population recovery strategies, can be significantly increased and improved (especially water temperatures) by instream flow releases.

4.2.1 Background

All promising steelhead population recovery strategies for Alameda Creek Basin will require abundant and productive 0+, 1+, and 2+ juvenile rearing habitats in the mainstem channels. Upper mainstem channels include Alameda Creek mainstem, from the confluence of Arroyo de la Laguna upstream to the base of Little Yosemite Canyon, and Arroyo de la Laguna mainstem up to the confluence of Arroyo del Valle. Each mainstem channel segment will be expected to provide ample habitat for juveniles actively migrating through the segment in spring and may be expected to provide adequate rearing habitat through the summer and early-fall. Good rearing conditions for juvenile steelhead, either migrating through or residing within, need: (1) ample available physical habitat, basically a function of unregulated streamflows and planned releases, (2) favorable and timely water temperatures also influenced by unregulated streamflows and planned releases, and (3) good water quality with turbidity a noteworthy variable. The Report of the Technical Committee (1989), *Establishment of a Steelhead Fishery in Alameda Creek*, concludes: "*The major requirements of the juvenile fish in freshwater consist of: 1) water temperatures that do not exceed 72º F for prolonged periods, 2) continuous surface water flows or sufficient intermittent stream flow conditions (isolated pools) throughout the year in portions of the stream to provide rearing habitat, and 3) adequate spring to early summer (February-May 15) continuous flows to allow "out-migration" of smolts to the ocean (access to San Francisco Bay in this case).*"

4.2.2 Analytical Approach

4.2.2.1 Juvenile Rearing Habitat Quantification: Habitat Rating Curves

A principal task for the study plan will be quantifying physical rearing habitat for discrete channel segments as a function of streamflows. Streamflow – habitat abundance rating curves, with streamflow (cfs) on the X-axis and habitat abundance (ft^2) on the Y-axis called 'habitat rating curves', are basic tools for instream flow investigations (Figure 12). Habitat rating curves will be developed for the following mainstem segments: (1) Niles Canyon up to Arroyo de la Laguna confluence, (2) mainstem Alameda Creek from Arroyo de la Laguna upstream to the Sunol Water Treatment Plant, (3) mainstem Alameda Creek from the Sunol Water Treatment Plant upstream to the Calaveras Creek confluence, (4) mainstem Arroyo de la Laguna upstream to the Arroyo del Valle confluence, and (5) mainstem Alameda Creek from the Calaveras Creek confluence upstream to the Diversion Dam. Streamflows in the habitat rating curves should range from low summer baseflows to high winter baseflows.

4.2.2.2 Quantify Water Temperature Relationships to Streamflow and Season

Good juvenile rearing habitat requires not only abundant habitat, but habitat with favorable water temperatures. Annual thermographs will be instrumental in evaluating habitat potential below the dams and consequently in developing instream flow recommendations. Water temperature thresholds must be established for steelhead egg incubation, fry and juvenile rearing, and smoltification.

4.2.2.3 Estimate Availability of Good Juvenile Rearing Habitat under Different Instream Flow Releases and Unregulated Annual Hydrographs

Habitat rating curves simply provide an estimate for how much physical habitat occurs at any given streamflow. The recovery plan must provide abundant, high-quality rearing habitat where and when it is needed in Alameda Creek Basin to sustain promising steelhead life history tactics. Abundant habitat, as quantified by the habitat rating curves, becomes available habitat if (a) present when the life stage needs it and (b) water temperatures are favorable. By combining annual hydrographs with habitat rating curves (i.e., multiplying daily average streamflow by the amount of habitat at that streamflow on the rating curve), the amount of habitat on any given day of a particular water year can be estimated. Annual habigraphs, with day of the water year on the X-axis and habitat abundance (ft^2) on the Y-axis, will differ by channel reach, water year, and species life stage. Annual habigraphs should be constructed for WY1990 through WY2006 for the channel reaches quantified to account for inter-annual hydrograph variability.

The next step is combining the annual habigraphs with stream temperature thresholds and life history periodicity (the time of year required for completing each life history stage, e.g., steelhead spawning from mid-December through March) to estimate annual habitat availability. An important analytical step takes the streamflow - habitat rating curves and applies them to annual hydrographs, computing total habitat for each daily average discharge of a water year. Similar to an annual hydrograph, the X-axis would be day of the water year while ft^2 of total habitat, rather than streamflow, would be the Y-axis. This simple conversion transforms annual hydrographs into annual habigraphs, taking us closer to something more real than imaginary. These annual habigraphs will be constructed for steelhead spawning, egg incubation, 0+ juvenile rearing, 1+ juvenile rearing, and 2+ juvenile rearing life stages.

Providing abundant available habitat in water years that are likely to sustain/grow juvenile steelhead, and produce healthy smolts, by promising population recovery strategies is the management target for prescribing instream flows. Instream baseflow releases will be assessed by modeling habitat abundance for juvenile rearing life stages from mid-winter through summer in all the mainstem channel segments and selected tributaries especially below dams (for the Dam Population Recovery Strategy). Two desirable outcomes will be expected from instream flow releases: (1) good smolt rearing conditions along the entire migration route for each population recovery strategy and (2) sufficient over-summer juvenile rearing conditions in the mainstems and tributaries below dams. Instream flow releases can accomplish both outcomes by extending juvenile rearing farther into late-spring or early–summer (by influencing water temperatures) and generating more juvenile rearing habitat.

Although we want to utilize the full capacity of the basin to sustain/grow juveniles and smolts, pre-diversion annual hydrographs varied considerably and therefore so would annual habitat capacity have historically varied. The WY1990 through WY2006 hydrographs can be gamed by changing (releasing) baseflows, modeling water temperature response, and re-computing habitat availability. Past and future can then be compared, to evaluate whether incremental instream flow releases modestly or significantly improve habitat availability.

4.3 Management Issue No. 3.

Manage instream flows from San Antonio, Calaveras, and Arroyo del Valle reservoirs to support the Dam Population Recovery Strategy as well as benefit all other population recovery strategies in Alameda Creek Basin by improving downstream juvenile rearing conditions.

4.3.1 Background

San Antonio Creek, Calaveras Creek, and Arroyo del Valle all have reservoirs/dams eliminating steelhead access into their headwaters. Although habitat has been eliminated upstream, these reservoirs could be managed to create downstream physical habitat and cooler water temperatures, by releasing instream flows, providing good 0+, 1+, and 2+ juvenile rearing habitat year-round. These instream flow releases also would benefit other population recovery strategies by improving the amount and timing of juvenile rearing habitat seasonally available in downstream mainstem reaches (e.g., in Niles Canyon). Given the extensive loss of headwater habitat and uncertain recovery potential of Niles Cone and the estuary, the Dam population recovery strategy may become the primary provider of 1+ and 2+ juveniles.

4.3.2 Analytical Approach

4.3.2.1 Quantify Juvenile Rearing Habitat - Streamflow Relationships: Habitat Rating Curves

Just as for the mainstem channel reaches, habitat rating curves must be developed for San Antonio Creek, Calaveras Creek, and Arroyo del Valle stream channels downstream of their respective dams. For Arroyo del Valle, two segments should be quantified: one immediately below the dam and another downstream of the Chain of Lakes.

4.3.2.2 Quantify and Model Water Temperature Relationships to Seasonal Instream Flow Releases

Good juvenile rearing habitat requires not only abundant habitat, but habitat with favorable water temperatures. Modeling annual thermographs under different instream flow scenarios will be instrumental in evaluating habitat potential below all the dams and consequently in developing instream flow recommendations. For Arroyo del Valle, a temperature model should be constructed from the dam downstream to Arroyo de la Laguna mainstem. Thermal stratification in pools also should be monitored, and possibly modeled.

4.3.2.3 Develop Annual Habigraphs under Different Instream Flow Scenarios

Once habitat rating curves and water temperature data/models are available, annual habigraphs will be constructed. The key population recovery factor will be whether instream flow releases can sustain good 0+, 1+, and 2+ juvenile rearing habitat through the summer and early-fall. As hypolimnial instream flow releases warm downstream, the extent of favorable summer habitat will contract upstream. Annual habigraphs, therefore, will be constructed at multiple locations along Arroyo del Valle (ending at the Arroyo de la Laguna confluence) and from Calaveras Dam downstream to Welch Creek confluence along mainstem Alameda Creek. The relatively short channel reach below San Antonio Reservoir may require a single habigraph for each water year and instream flow scenario modeled.

Annual habigraphs, for a given instream flow scenario, would be modeled over a period of water years (e.g., WY1990 through WY2006) that encompasses all water year types (i.e., Wet through Dry). Annual habigraph modeling can be accomplished only if daily water temperature at the dam release point is estimated for each of those water years. This will require an operational understanding of available stratified cold water in the reservoirs and the regulatory issues controlling dam operations.

4.3.2.4 Construct Longitudinal Available Habitat Profiles

Habigraphs for any single water year and instream flow scenario investigated will be used to create longitudinal profiles of good 1+ and 2+ juvenile habitat (i.e., X-axis = distance below the dam and Y-axis = abundance of good habitat (ft^2)) from late-winter through early-fall. These profiles will be instrumental in evaluating instream flow releases. Higher releases likely will generate more summer rearing habitat farther downstream by keeping the channel favorably cool. A goal must be established to determine how much summer habitat is enough. Two analytical approaches to estimating a goal can be explored. First, the annual longitudinal habitat availability curves may show a sharp drop in available good habitat downstream, and would require much higher additional instream flow releases to maintain abundant habitat even farther downstream. Second, estimate the amount of 1+ and 2+ habitat lost above the reservoirs and attempt to recover this amount of summer habitat downstream through instream flow releases.

4.4 Management Issue No. 4.

Can the pools backwatered by the rubber dams in Niles Cone be managed as a benefit or neutral influence on downstream migrating steelhead? Essentially all juveniles in Alameda Creek watershed must pass through these backwater pools, and therefore influences all population recovery strategies.

4.4.1 Background

The rubber dams have multiple influences on steelhead juveniles and smolts, but we simply do not know enough yet to determine which influence(s) will significantly affect steelhead recovery strategies. A quantitative understanding and prediction of how rubber dam operations influence mainstem water temperatures (including the influence of periodic pool drawdown on local and downstream water temperatures) during critical life stages (e.g., during smoltification) will be an important recovery tool.

Water temperature profiles in the backwatered pools (or ‘impoundments’) indicate that excessive temperatures > 72º F (22.2º C) can occur by late-May with minor thermal stratification (Figure 13). The greatest benefit of the present rubber dam impoundments would be to enhance growth for early migrating pre-smolts and smolts (March through mid-May over many years). A similar growth effect for juvenile steelhead, however, would be a mixed blessing. By mid-May (though generally much earlier) water temperatures are too warm for smoltification. Juveniles that have left Niles Canyon must spend the summer doldrums somewhere, because migration downstream into SF Bay would be certain death without undergoing smolt transformation. Instead, these juveniles must either (1) return upstream into Niles Canyon (which also will be warm, but perhaps not fatally), (2) find thermal refuge downstream in which to survive the summer and early-fall, or (3) survive in the depths of the backwater pools. Presently, the third option seems most likely, and needs to be investigated.

Instream flow releases to improve habitat conditions in Niles Canyon could degrade an already marginal backwater pool environment and exacerbate the problem. When daily maximum water temperatures begin to exceed 73º F to 75º F (approximately 22.8º C to 23.9º C), juvenile steelhead tend to cease migration and seek local thermal refuge. If instream flows through Niles Canyon are augmented, more juveniles could leave Niles Canyon late in the migration season and add to the backwater pools' burden of supporting even more juveniles through the summer. Higher streamflows exiting Niles Canyon also could impede thermal stratification in the backwater pools, and thus degrade or eliminate stratified cooler water. Both possibilities need investigation.

Downstream migrating steelhead smolts/juveniles, as well as downstream migrating steelhead adults, must freely pass the rubber dams. Sonoma County Water Agency's 5-yr study of its rubber dam operations on the lower Russian River can serve as a model and resource for assessing Alameda Creek's rubber dams. The Workgroup should meet with Sonoma County Water Agency Staff to determine whether similar fieldwork would be beneficial on Alameda Creek.

4.5 Management Issue No. 5.

Greater and timely availability of good juvenile steelhead rearing habitat in Lower Alameda Creek Flood Channel, from the BART weir to San Francisco Bay, could significantly improve smolt output and success for all population recovery strategies.

4.5.1 Background

Once steelhead smolts/juveniles leave the backwater pools to continue their downstream migration, Lower Alameda Creek assumes two important life history roles. If these migrants are smolts, this mainstem segment can promote growth while minimizing predation by offering complex habitat and cool water temperatures when smolts are actively migrating in spring.

Lower Alameda Creek mainstem is the last freshwater stop-over before encountering saline water. If juveniles leaving the backwater pools have not smoltified, and cannot until the next spring (e.g., temperatures are already too warm for smoltification), their fate rests in locating habitat that would allow them to survive the summer. This could be Lower Alameda Creek mainstem's second role. Historically, the mainstem's broad alluvial meanders likely had stratified pools that provided sufficient refuge. The present mainstem does not.

Field measurement of a habitat – streamflow rating curve, and subsequent construction of annual habigraphs, can be accomplished by habitat mapping using recent aerial photography to map juvenile habitat in late-spring through early-autumn. Detailed spatial water temperature monitoring, over seasonal baseflows and in potential thermal refugia, is needed; water temperature modeling for this reach may not be necessary. Field reconnaissance of present-day juvenile habitat abundance and diversity (possibly using minnow trapping to assess habitat preferences and spatial abundance patterns) should be considered. Evolution of freshwater marsh-like conditions should be documented and future changes forecasted.

Minnow traps and/or seine netting in discrete habitats can be used to identify preferences for different habitat types as well as estimate relative abundances. Seasonal, longitudinal salinity profiles need to be measured where the mainstem meets San Francisco Bay.

As fine sediment has deposited within the trapezoidal, rip-rapped flood control channel below the BART Weir, a defined low flow channel colonized with dense riparian vegetation has created physical juvenile steelhead rearing habitat. As more sediment deposits and seedlings mature into bushes and trees, the flood control channel could lose its ability to convey the design flood. Clearing and dredging would remedy the increased hydraulic roughness, but destroy the habitat. An important task is to investigate whether a compromise can be developed that allows some hydraulic roughness, but maintains flood transport capacity. Accurate measures of hydraulic roughness should be field-measured to assist the Alameda County Flood Control District and Army Corps of Engineers in evaluating whether dredging within the flood control channel in the near future is necessary.

4.6 Management Issue No. 6.

Plans for rebuilding the Alameda Creek estuary must consider life history requirements of anadromous salmonids.

4.6.1 Background

The potentially huge role of a functional estuary for anadromous salmonids often has been underappreciated, though all population recovery strategies would rely on the estuary to help produce large, healthy smolts. Unfortunately, not much information is available on historic habitat conditions of the Alameda Creek estuary. Many coastal estuaries seal-off in summer to offer freshwater residency, or only slightly brackish-water residency, resulting in very high growth rates (Bond 2006). But an estuary in San Francisco Bay seems unlikely to be sealed off annually. Therefore, steelhead entering the former Alameda Creek estuary may needed to have been smolts. Though contemporary water temperatures are high in the lower flood control channel, historically there may have been sufficiently cool water refugia through summer from stratified pools (under very low baseflows) and/or springs emerging in Niles Cone. Restoration of adjacent salt ponds should be closely coordinated with the steelhead recovery strategies. Unfortunately the first stage of this estuary restoration plan will be implemented at the historic entrance of Alameda Creek, north and disconnected from the present Alameda Creek mainstem.

4.7 Management Issue No. 7.

Other aquatic species should be considered during implementation of the steelhead recovery plan.

4.7.1 Background

Recovery of Chinook salmon populations in Alameda Creek might be less challenging than steelhead population recovery principally because Chinook juveniles do not over-summer in freshwater. Chinook salmon have recently been observed at the BART Weir. While these observed adults likely were not born in Alameda Creek, their presence strongly suggests that regardless of heritage they will migrate up Alameda Creek once the barriers have been fixed. Early peak runoff events in mid-November through larger storms in December were, and will be, crucial for migrating adult fall Chinook. These adults should be expected to migrate into and spawn in Niles Canyon, or pass through Niles Canyon then take a left turn and head up Arroyo de la Laguna to spawn, following the higher baseflows. The mainstem channel of Arroyo de la Laguna appears to provide abundant Chinook salmon spawning substrate, though no formal investigation has been made. Low baseflows in October for most water years, and even low November baseflows, must be considered in evaluating spawning habitat availability in Arroyo de la Laguna. Mainstem Alameda Creek above the Arroyo de la Laguna confluence also has considerable spawning gravel potential, but current baseflows in fall appear too low. Dam releases might provide the necessary baseflows.

Following spawning, several juvenile Chinook life history tactics would then be possible. Emerging fry, beginning February or March, could seek low velocity refuge while rapidly negotiating lower Arroyo de la Laguna mainstem and then temporarily reside in Niles Canyon. Alternatively, fry could remain in Arroyo de la Laguna through mid-spring before migrating downstream. Prior to urbanization and construction of the flood control channel in Niles Cone, older fry exiting Niles Canyon (or young fry brought downstream from Arroyo de la Laguna in one large winter flood) could have reared in the sinuous mainstem channel and/or in the estuary. Chinook smolts likely entered San Francisco Bay beginning mid-May to early-June depending on the life history tactic, and possibly continued through the summer and early-fall (if the historic estuary provided the habitat and favorable water temperatures). Today, this life history tactic would encounter the rubber dam impoundments and then the low flow but free-flowing portion of the flood control channel without an estuary. Chinook fry/parr migrating downstream early in spring might encounter conditions favorable for smolting and growth, while migration in late-spring and early-summer might encounter lethal conditions.

Non-salmon/steelhead fish species including Pacific lamprey, California roach, Sacramento sucker, Sacramento pike-minnow, and prickly sculpin should be considered as an ecosystem approach to recovery rather than a completely salmon-centric approach. Juvenile Pacific lamprey habitat and selected amphibian habitat in Niles Canyon, Sunol Valley, and possibly in Arroyo de la Laguna should be inventoried.

4.8 Management Issue No. 8.

Determine if Little Yosemite Canyon and farther upstream is, or can be, a viable contributor to the Headwater Population Recovery Strategy.

4.8.1 Background

Good physical rearing habitat exists above and below Little Yosemite Canyon and below Alameda Creek Diversion Dam on upper mainstem Alameda Creek. The upstream migration of adult steelhead past the cascades in Little Yosemite Canyon seems a possibility in wetter years (though not in dry or many normal years). Infrequent adult passage diminishes the importance of this reach for rearing juvenile steelhead and contributing smolts. Although not the preferred solution for anyone, trapping adult fish at the base of Diversion Dam then transporting them over the dam might be considered. However, CDFG would likely not consider trap-and-haul as a substitute for unassisted fish passage, either through dam removal or installation of fish ladders. Even without contemporary anadromous access, spawning rainbow trout above the Diversion Dam could be contributing juveniles that smolt farther downstream, provided these downstream migrants can successfully pass the Diversion Dam.

4.9 Management Issue No. 9.

The Sunol quarry mainstem of Alameda Creek and confluence at San Antonio Creek must be reconnected for steelhead migration in the Headwater and Dam population recovery strategies.

4.9.1 Background

Considerable attention and studies already have been directed at the loss of surface streamflows through the gravel quarry reach of mainstem Alameda Creek above the Arroyo de la Laguna confluence. The eventual engineering solution for the structures/barriers, groundwater seepage, and gravel mining activities must be coordinated with other recovery actions to prevent both these channel reaches from limiting recovery. The San Francisco Public Utilities Commission is beginning to address restoration of the gravel quarry reach as part of renewing gravel mining releases in the Sunol Valley.

4.10 Management Issue No. 10.

Establish an adult steelhead population recovery goal for Alameda Creek watershed.

4.10.1 Background

How many smolts and what size class distribution are needed to recover sustainable steelhead population in Alameda Creek watershed? Not an easy question, but a necessary one. A ‘successful’ journey is more than surviving the trip. Smolt health and size are important if a smolt is to have any realistic chance of returning to Alameda Creek as an adult. Successful re-establishment of a steelhead population to the Alameda Creek watershed requires many healthy and large smolts. How many would be enough and where would they originate within the watershed must be addressed. Inventorying present and potential miles of good steelhead rearing habitat above Niles Canyon is needed to estimate smolt production capacity. Rainbow trout sampling in streams upstream of Calaveras Reservoir and San Antonio Reservoir could be used to estimate potential 1+ and 2+ smolt production in streams downstream of both reservoirs with similar morphology. Downstream migrant growth also would be modeled to shift the size class distribution to the right, and thereby increase steelhead smolt survival. An estimate of the upper watershed’s potential (if San Francisco Bay lapped at the Arroyo de la Laguna confluence) minus the basinwide potential would quantify the importance of the lower mainstem and estuary. In this manner, the importance of each reach could be partially evaluated independently of other channel segments downstream.

CHAPTER 5

5 ALAMEDA CREEK STUDY PLAN ELEMENTS

The ten management issues must be transformed to tasks for the study plan to succeed. The Study Plan Elements presented in this chapter, each with specific tasks, can be used as preliminary scopes of work. Each Study Plan Element (SPE) addresses tasks (including a general purpose statement and methodologies), products, approximate costs using a 1-yr to 3-yr planning horizon, and likely entities responsible for doing the work. The Elements are not listed by priority; all will need consideration in the first through third year of Study Plan implementation. Linkages of the Elements to Management Issues are shown in Table 4, and interdependencies and sequencing of the Elements are shown in Figure 14. The Elements with their task descriptions still require additional detail, discussion, and refinement to be separate and complete scopes of work, but they should help move the study plan forward.

5.1 Study Plan Element #1: Quantification of Steelhead Habitat – Streamflow Relationships

The relationship between streamflow and habitat quantity is critical to assessing instream flow releases. A principal requirement for the Study Plan will be quantifying physical steelhead habitat for discrete channel segments as a function of streamflows. Streamflow – habitat relationships developed in this SPE and necessary data from other Study Plan Elements (e.g., water temperature in SPE#5) will be synthesized in SPE#10 to assess instream flow releases.

5.1.1 <u>Tasks</u>

5.1.1.1 Task No. 1: Select field methodology for quantifying habitat –streamflow relationships.

Streamflow – habitat abundance rating curves (habitat rating curves), with streamflow (cfs) on the X-axis and habitat abundance (ft^2) on the Y-axis, are basic tools for instream flow investigations. Several methodologies are available for either measuring habitat abundance as a function of streamflow directly (Expert Habitat Mapping) or modeling habitat abundance using preference criteria for water depth, velocity, cover, etc. (1-D PHABSIM and 2-D Hydrodynamic Modeling). With extensive fieldwork necessary, regardless of the method used, the cost of developing habitat rating curves will be high. As cost per unit of stream channel mapped increases, generally less of the stream channel can be directly sampled. We recommend using Expert Habitat Mapping (EHM) in all channel reaches because it: (1) catalogues spatial complexity by mapping habitat at specific streamflows onto a channel basemap generated by a low altitude aerial photograph or surveyed planmap, (2) can be applied to large portions of the total mainstem channel, and (3) is more cost-effective. EHM would create habitat rating curves for spawning and egg incubation, 0+, 1+, and 2+ juvenile steelhead rearing/migratory habitats in the mainstem and tributary reaches. While the Workgroup ultimately must agree on a preferred methodology, the following task descriptions assume EHM will be selected.

5.1.1.2 Task No. 2. Create basemaps for EHM.

In EHM, a habitat mapping team will identify in the field, then draw an accurate single boundary around each distinct area satisfying the team's habitat criteria onto a basemap. Basemaps will be created from fixed-wing or balloon aerial photography. Each distinct bounded habitat area is called a "polygon." Polygons will be drawn collectively by the mapping team, not individually, i.e., only one polygon will be drawn to represent a discrete area of habitat at a particular flow. Habitat polygons delineated on the basemaps at each experimental streamflow will be digitized for surface area. The basemap must: (1) be of appropriate scale for mapping, (2) be scaled accurately, (3) have substrate, boulders, large wood, and other prominent features included as a base layer. The basemap scale will be approximately 1 inch = 10 ft.

5.1.1.3 Task No. 3. Assemble and calibrate the mapping team.

In applying EHM there can be concern regarding potential bias and repeatability, such as the fish biologists doing the mapping will each have unique interpretations of what subset of physical variables constitutes habitat (i.e., where to delineate habitat on the basemaps). We recognize that the habitat mapping team must adhere to a mutual and repeatable standard for mapping habitat of selected species life stages. Salmonid habitat is too complex to have a few physical variables entirely dictate its quantification. Nonetheless, every precaution to reduce and/or document bias must be made. Bias will be minimized by: (1) establishing a range of values for key habitat variables (depth, velocity, and substrate) similar to habitat variable characterization required of the PHABSIM methodology, (2) assigning team members with extensive field experience to represent all stakeholders, (3) convening a preliminary field session to calibrate the habitat mapping team, (4) providing a complete photo archive of the mapped channel reaches at each experimental streamflow, (5) making the field habitat maps for each experimental streamflow readily available, (6) verifying field mapping by selectively measuring depths and velocities within mapped habitats, (7) documenting field decisions in writing, and (8) reporting strengths and weaknesses of the habitat mapping by team members following the experimental streamflows.

A two-person crew will assist the habitat mapping team. The habitat mapping team will first identify and flag areas considered significant habitat within each monitoring site. The two-person crew will then measure depths and velocities within, and just outside, the boundaries of selected rearing habitats. The two-person crew will mark the locations of measured depths and velocities directly onto the same basemap used by the field mapping team. The number of measurements will necessarily depend on the complexity of the habitat being mapped, however 4 to 5 velocity measurements per habitat selected for verification is anticipated.

The primary criteria for delineating habitat will be Habitat Suitability Curves (HSI curves) commonly used in 1-D PHABSIM and 2-D Hydrodynamic Modeling. However, application of the HSI curves alone will not be sufficient to delineate all habitats. Shear zones, proximity to cover, the quality of the cover, the hydraulic influence of large woody debris, and turbulence must be incorporated into the team's mapping criteria. HSI curves for the target species have been developed by many agencies as part of numerous FERC relicensing projects. A potential concern for some may be that habitat mapping is binary: a certain segment of channelbed is - or is not - habitat at a given streamflow. Rarely is habitat on or off. Habitat quality typically changes with streamflow. However, a binary approach to habitat mapping may be the best approach for distinguishing habitat changes with relatively small baseflow changes. By adopting tighter physical habitat criteria, using a suitability value of 0.6 or greater on the HSI curves as a guideline, field habitat mapping is more discriminating and thus capable of identifying rates of change and thresholds in habitat abundance relative to changes in streamflow.

5.1.1.4 Task No. 4: Construct habitat rating curves.

Approximately 50% of each mainstem channel segment could be habitat mapped. EHM will be performed at a minimum of 6 baseflows ranging from low summer baseflows to high winter baseflows. Habitat quantification over this experimental flow range should adequately capture potentially important habitat changes in the hydraulically complex areas and result in smooth habitat rating curves. Ground photographs will be taken at each flow to generate a photographic atlas of the mapping flows. Prior to the field habitat mapping, vantage points accessible at all flows will be selected to ensure an overlapping panoramic photo mosaic of each stream segment mapped.

Habitat rating curves will be developed for the following mainstem segments: (1) Niles Canyon up to Arroyo de la Laguna confluence, (2) mainstem Alameda Creek from Arroyo de la Laguna upstream to the Sunol Water Treatment Plant, (3) mainstem Alameda Creek from the Sunol Water Treatment Plant upstream to the Calaveras Creek confluence, (4) mainstem Alameda Creek from Calaveras Creek confluence upstream to the Diversion Dam, (5) mainstem Arroyo de la Laguna upstream to the Arroyo del Valle confluence, and (6) the flood control channel below BART Weir (Figure 1). These mainstem channel reaches provide critical habitat for the Headwaters, Dam, and Mainstem population recovery strategies. Steelhead habitat below reservoirs in San Antonio Creek, Calaveras Creek, and Arroyo del Valle also will be quantified for prescribing instream flows to help create the Dam Population Recovery Strategy.

To expand the results of an EHM habitat rating curve (derived from mapping 50% of the channel) to the entire stream channel segment (i.e., the 50% not mapped), several options would be available. First, habitat area can simply be doubled, relying on the 50% of channel mapped to represent the 50% not mapped. Second, individual habitat rating curves can be developed by mesohabitat types to develop a weighted estimate of total channel segment habitat. The 50% mapped channel would not be contiguous. Rather 2 to 3 segments (collectively comprising 50%) could be chosen, as well as unique channel reaches (such as tributary deltas) that could not be accurately represented by any other reach.

5.1.2 Product

A report with streamflow - habitat rating curves for each mainstem/tributary segment quantifying steelhead spawning, 0+ juvenile rearing, 1+ juvenile rearing, and 2+ juvenile rearing habitats ranging from low summer baseflows to high winter baseflows.

5.1.3 Dependency on Other Study Elements

No other study elements necessary, other than hydrologic data for identifying range of summer and winter baseflows in each study reach.

5.1.4 Approximate Cost and Technical Qualifications

Approximately $50,000 to $75,000 per study reach for producing the basemap, assembling and calibrating the mapping team, doing the Expert Habitat Mapping, and digitizing and constructing the habitat rating curves. For the four mainstems and three tributaries below dams, the total cost would be $350,000 to $525,000. EHM can be developed and performed by fisheries biologists from CDFG, SFPUC, ACWD, and other interested parties.

5.2 Study Plan Element #2: Adult Steelhead Passage Assessment

Most assessments of natural and artificial barriers focus on whether passage at a specific location can be obtained for a given flow range; however, assessments usually ignore the cumulative effects of barriers and migration delays on whether adult anadromous salmonids can actually access upstream spawning habitat given travel distance, swim speed, and the influence of flow availability on swim speed. This Study Plan Element is important to assess: (a) whether a structure or segment of stream channel can be a barrier, (b) what flow windows allow adult fish passage past artificial and natural barriers, (c) cumulative effects of multiple barriers along a single migration route, and (d) which barrier removals/retrofits are most important for increasing the likelihood of successful spawning. Although instream flows will considered primarily for improving juvenile and smolt habitat, fish passage during low unregulated streamflows could be significantly affected by instream flow releases.

5.2.1 Tasks

5.2.1.1 Task No. 1: Establish streamflow passage windows for potential barriers and stream channels along selected migration routes.

Assessing fish passage to every potential patch of spawning habitat in the watershed would be daunting and unnecessary. Selected spawning destination points that include important mainstem sections and tributaries, important to the Headwater, Dam, and Mainstem population recovery strategies, can be assessed instead. Recommended steelhead spawner destination points, and therefore spawner routes, throughout the Alameda Creek Basin (Figure 1) are:

1. Alameda Creek mainstem just below San Antonio Creek confluence
2. Arroyo Mocho and Arroyo Las Positas confluence
3. Arroyo del Valle immediately downstream of Lake del Valle
4. San Antonio Creek immediately downstream of Turner Dam
5. Stonybrook Creek 1.0 mile upstream
6. Sinbad Creek 1.5 miles upstream
7. Alameda Creek mainstem at base of Little Yosemite Canyon
8. Alameda Creek mainstem at base of Alameda Diversion Dam
9. Vallecitos Creek 0.5 miles upstream
10. Alameda Creek mainstem at Calaveras Creek confluence
11. Alameda Creek mainstem at Sunol Water Treatment Plant Bridge
12. Arroyo de la Laguna mainstem at Arroyo Mocho confluence
13. Arroyo de la Laguna mainstem at Vallecitos Creek confluence
14. Welch Creek 0.1 miles upstream
15. Arroyo Mocho 3 miles upstream of Arroyo las Positas confluence
16. Arroyo las Positas 0.5 upstream of Cottonwood Creek confluence
17. Calaveras Creek at base of Calaveras Dam

Barrier assessments and engineered designs must identify the range of streamflows necessary at each problem location to allow access. A passage window of required streamflows should be developed at each barrier. To date, the emphasis has been on identifying the highest passable streamflow, even though passage delay may be more a function of the lowest streamflows. For many structures, only low flows will create barriers. These low flow barriers can be assessed visually simply by repeat visits to quantify passable/non-passable streamflows and establish passage windows. For more complex structures, a hydraulic assessment might be necessary (e.g., using FishXing).

5.2.1.2 Task No. 2: Compute successful spawning opportunity windows for destination points at end of each migration route.

Each spawner destination in each water year between WY1990 and WY2006 (representing a wide range in water year types) will have a unique window of successful spawning opportunity (SSO). Before a migration analysis along the migration route leading to the destination point can be done, the SSO must be determined for each water year with the following steps:

1. Estimate when water temperatures surpass a threshold for emergent fry mortality. If the water is too warm when fry emerge, then the redd would not have been successful;
2. Back-calculate the number of days incubation time necessary for fry to emerge (generally 50 to 70 days) on the last day with favorable water temperature. Several models are available in the scientific literature that relate stream temperature to egg incubation time (or simply decide on a range of incubation periods for the analysis). For example, if the last day with sub-threshold water temperature at the confluence of Arroyo Mocho and Arroyo las Positas was May 20 in WY2002, then the latest date that the redd can be constructed in WY2002 was 50 days previously, or March 30, 2002. In Alameda Creek Basin, steelhead generally did not arrive earlier than mid-December, therefore the first approximation of the SSO for WY2002 would be December 15 through March 30 at the confluence of Arroyo Mocho and Arroyo las Positas.
3. Estimate streamflows that keep redds inundated. The previous back-calculation assumes that a redd constructed between December 15 and March 30 would remain inundated; however, it may not, depending on the WY2002 hydrograph. An assessment of inundation will require estimates for daily average flows and a field inspection to determine the minimum streamflow necessary to keep redds inundated. For refining the SSO, the analysis would determine which days between December 15 and March 30 in WY2002 could a redd be constructed and remain inundated during the entire incubation time. Using the above example, suppose only redds constructed January 01, 2002 through March 10, 2002 would remain inundated through the 50 day inundation period. The refined SSO for WY2002 would now be January 1 to March 10, rather than December 15 to March 30. Using this example, adult steelhead would need to negotiate the BART weir and rubber dams, swim up the Arroyo de la Laguna and into Arroyo Mocho, and finally arrive near the Arroyo las Positas confluence to spawn between January 01 and March 10.

5.2.1.3 Task No. 3: Perform ascendograph analysis on each upstream migration route for WY1990 through WY2006 and recommend lower and upper design flows for barriers along each migration route to optimize the SSO window.

The ascendograph (Figure 15) should be developed to model and assess a wide range of water years and management scenarios, including instream flow releases. The ascendograph tracks adult migration up through the stream channel network to specific spawning destinations to determine if adults can arrive and construct a redd that will successfully produce fry (SSO window). The following steps, needed to do the ascendograph analyses, requires an integration of other tasks and study plan elements: (A) estimate typical adult upstream daily migration rates from the scientific literature and field studies (when adult steelhead return, measuring migration rates might be necessary, if the modeling outcome is highly sensitive rate), (B) select spawning routes and destination points in Alameda Creek Basin for analyses (Task 1), (C) estimate streamflow passage windows at all potential adult steelhead barriers along the route (Task 1), (D) estimate the window of successful spawning opportunity at the destination point (Task 2), (E) estimate daily streamflows along each selected migration route (from SPE#8), (F) establish a minimum streamflow threshold for adult passage along selected migration routes in small channels or larger channels with diversions (Task 2), (G) run the ascendograph analysis for each migration route (including a sensitivity analysis), and (H) report the results and map where successful redds presently could have been constructed if specific complete and partial barriers had been removed or remedied.

While the ultimate goal is to encourage successful spawning in as much of the watershed as feasible, certain barriers low in the watershed will affect all the selected migration routes, and therefore all the population recovery strategies. These barriers should be assessed first, as many engineering designs are already underway (refer to SPE#3):

1. Alameda Creek from San Francisco Bay to Arroyo de la Laguna confluence, including the lower Alameda Creek flood control channel (for low flow delays), the proposed fish ladders on the BART weir and ACWD rubber dams, as well as the USGS weir at the Niles gaging station.
2. Alameda Creek from Arroyo de la Laguna confluence to Calaveras Creek confluence, including the Alameda Creek channel through Sunol Valley, the confluence at San Antonio Creek, the gravel quarry reach, the existing PG&E pipeline crossing, the proposed engineering designs for the PG&E Ercon Mat gas pipeline crossing, and SFPUC Hetch Hetchy aqueduct crossing.
3. Arroyo Mocho from Arroyo de la Laguna to headwaters, including two check dams in Livermore, as well as the Zone 7 proposed flow recapture facility.
4. Arroyo del Valle from Arroyo de la Laguna to Lake Del Valle including check dams and other barriers in Pleasanton.

Because of the hydraulic complexity of Little Yosemite Canyon, hydraulic analyses likely will not provide certainty as to whether adult steelhead can or cannot get by the canyon in various water years. This assessment will take longer than the other spawner destination points because the canyon must be observed over a naturally occurring range of high streamflows. As steelhead return to Alameda Creek watershed, systematic visits should be made to those locations in Little Yosemite Canyon where adult steelhead would be challenged while migrating. Adult spawner surveys upstream also should be planned.

5.2.2 Products

Products will be: (a) summarized results from the ascendograph analyses assessing spawning success in selected migration routes under existing conditions (WY1990 through WY2006), (b) recommended barrier removals/modifications, and (c) recommended low and high streamflow design criteria for remediation engineering designs.

5.2.3 Dependency on Other Study Elements

Developing the spreadsheet model (the ascendograph analysis) will require hydrographs at many locations from SPE#8. The existing gaging network is probably adequate to estimate streamflows at most locations along Alameda Creek and its tributaries; however, some supplemental flow analyses (using the available gaging data) may be needed. Hydraulic conditions of the stream channel during migration flows at certain locations have been developed by Hanson Environmental, but supplemental field data may be required on some stream channels (requiring visual assessment of low flow passage). Water temperatures needed for assessing spawner success will come from SPE#5. Last, the ascendograph analyses will use a range of adult travel rates from the scientific literature, but rates derived from Alameda Creek are preferred.

5.2.4 Approximate Cost and Technical Qualifications

The ascendograph analysis and associated fieldwork/office work should cost $75,000. The model, developed and performed by a fish biologist familiar with adult steelhead migration needs, will require significant oversight by technical members of the Fish Subcommittee.

5.3 Study Plan Element #3: Barrier Removal, Retrofit Design, and Remediation

Considerable work already has been done to remove barriers (e.g., Sunol and Niles dams) and to develop engineering designs for modifying barriers (e.g., BART weir). The ascendograph analyses in SPE#2 will provide low and high flow passage recommendations for the engineering designs. The primary objective for this study element is to facilitate/assist the design, permitting, and construction of barrier removal or remediation. For example, the Workgroup should make sure low and high flow passage engineering designs not only target steelhead but also target the less-athletic Chinook salmon. Instream flow releases may or may not be a factor in all the designs, but the Workgroup should keep the engineers informed of how instream flow releases may improve low flow passage at smaller barriers.

5.3.1 Tasks

5.3.1.1 Task No. 1: BART Weir

Engineering solutions to the BART Weir, likely the most important task in the short-term, have been underway. The Workgroup can evaluate existing low and high flow passage design criteria by doing the ascendograph analysis, assuming no barriers from the Bart Weir up to the spawning destination points specified in SPE#2. Annual maintenance obligations of the proposed engineered solution should be thoroughly explored.

5.3.1.2 Task No. 2: ACWD rubber dams

While the current operations of deflating dams during high flows allows fish passage, the results of SPE#2 will likely show that expanded fish passage here will greatly increase the SSO throughout the watershed. Fish ladder design will likely be the preferred alternative. The Workgroup should meet with Sonoma County Water Agency to discuss and evaluate fish ladders built for rubber dams on the Russian River. Operational constraints and demands on the rubber dams should be thoroughly explored, relative to fish ladder performance, as well as annual maintenance obligations. Low and high flow criteria, from results of the passage analysis in SPE#2, for ladders must be coordinated with those of the BART Weir passage design. Smolt downstream migration and adult steelhead returning to San Francisco Bay after spawning must be considered in the fish design and operation. This may involve directing migrating juveniles over the dams themselves, via notching (as Sonoma County Water Agency has done), rather than down the fish ladders.

5.3.1.3 Task No. 3: USGS stage control weir at Niles gaging station

A FishXing analysis of the USGS Weir indicated it was a partial barrier, though adult steelhead have been observed passing over it. The USGS Weir may be a barrier to migrating juvenile, and the Workgroup needs to determine whether this would be acceptable. Another issue is whether the weir can be replaced, modified, or completely removed without significantly impacting USGS gaging operations, e.g., create a downstream control to backwater the weir. A geomorphic field assessment could highlight whether weir removal would destabilize the station's rating curve at low streamflows.

5.3.1.4 Task No. 4: PG&E Ercon mat and gas line crossing and SFPUC Hetch Hetchy Aqueduct grade control

Preliminary evaluation has been conducted for the PGE Ercon Mat gas pipeline on mainstem Alameda Creek in Sunol; however, the evaluation needs to integrate the pipeline crossing, the SFPUC Hetch Hetchy Aqueduct grade control structure, and a geomorphic assessment through the reach to evaluate whether channel incision is occurring and the role of the two structures and adjacent levees in channel incision (if any). Methods should include longitudinal profiles, cross sections, and hydraulic and sediment transport capacity analyses. This integrated assessment then needs to inform the PG&E remediation effort, which is intended to be completed by 2009

5.3.1.5 Task No. 5: Sunol Quarry on Alameda Creek mainstem and confluence of San Antonio Creek.

Design alternatives have been discussed for the Sunol Quarry effects on baseflows in mainstem Alameda Creek. This mainstem reach is extremely important to the Dam Population Recovery Strategy of releasing instream flows from Calaveras Dam. The Workgroup must help facilitate the final design (including targeting desired baseflows passing adult steelhead and Chinook salmon), permitting, and construction of approved remediation actions. This section of mainstem channel is exposed to the sun. Given that instream flows will be considered a mechanism for reducing water temperatures, development of a riparian planting plan, and its implementation, would reduce the need for instream flows.

The confluence of San Antonio Creek with mainstem Alameda Creek has been reported highly aggraded, causing mainstem Alameda Creek to widen and thus lower water depths of baseflows. A preliminary field investigation, including limited surveying, is needed to assess the problem.

5.3.2 Products

Products of structure engineering (e.g., PG&E pipeline crossing and SFPUC grade control) should include at least two design alternatives, with a hydraulic and hydrologic evaluation that accommodates adult salmonid routing to the spawning destinations in SPE#2. Based on these design alternatives and passage assessments in SPE#2, a preferred design alternative will be adopted as the final engineering design for regulatory compliance and implementation. As part of this design, a geomorphic assessment at the PG&E and SFPUC structures should be produced to evaluate potential channel changes resulting from the structures.

5.3.3 Dependency on Other Study Plan Elements

Low and high flow passage criteria would be assessed under SPE#2. Annual hydrographs and flood frequency analyses will be required of SPE#8. Operational constraints and demands of the ACWD rubber dams will be provided by SPE#8.

5.3.4 Approximate Cost and Technical Qualifications

Hydraulic and hydrologic evaluations of a given structure should cost less than $50,000 each. The engineering design process from conceptual designs to final engineering designs should cost less than $250,000 each. The geomorphic evaluation of the PG&E and SFPUC structures should cost less than $75,000.

5.4 Study Plan Element #4: Biological and Physical Evaluation of ACWD Rubber Dam Backwater Pools

The ACWD rubber dams, located just downstream of Niles Canyon, can influence all population recovery strategies because all adult and juvenile steelhead must pass them. These backwater pools have potential detrimental effects on adults and juveniles, but they could provide benefits to juvenile growth and survival. Steelhead biological evaluations cannot be implemented until barriers are remedied and juvenile steelhead production resumes, but several tasks could be implemented during the interim period (with SPE#7).

5.4.1 Tasks

5.4.1.1 Task No. 1: Evaluate steelhead juvenile and smolt habitat potential in backwater pools.

Several important biological questions that should be addressed include:

1. Would/do the rubber dams reduce juvenile and smolt outmigration success when fish go over the dam rather than through the proposed fish ladder?
2. Would/do the backwater pools increase smolt growth rates and subsequent adult return success?
3. Would/do the backwater pools encourage salmonid predator habitat, thereby increasing salmonid predation rates and reducing smolt production?
4. Can over-summering juvenile steelhead survive and grow in the impoundments? Are juvenile steelhead growth rates in the rubber dam impoundments higher or lower than in nearby mainstem reaches of Alameda Creek?
5. Does rubber dam operation (e.g., deflation during storms) subsequently strand juveniles in the lower flood control channel?
6. Would/do the backwater pools have a net benefit or deficit to salmonid smolt success from the Alameda Creek watershed?

However, these only can be answered directly once steelhead return to the watershed. Until steelhead recovery begins, the Workgroup should assess work done by the Sonoma County Water Agency on juvenile steelhead growth and survival in a backwater pool created by a rubber dam on the Russian River. Downstream juvenile migrant trapping of rainbow trout (as a surrogate for juvenile steelhead) and other fish species at the top of Niles Cone (i.e., just upstream of the impoundments) could identify a stream temperature that greatly curtails or ceases juvenile outmigration and document if rainbow juveniles with smolt-like morphology are leaving Niles Canyon. Above a temperature of 72º F, juvenile steelhead tend to cease most downstream migration, and instead “hunker-down” in available cold/cool water refugia. This behavior, if applicable to Alameda Creek salmonids, might be considered in operating the rubber dam impoundments.

5.4.1.2 Task No. 2. Evaluate predator populations in the backwater pools.

More should be learned about how predators (mainly bass) arrive at, and use, the backwater pools. The first step would be a literature review of bass life history requirements. Then estimates of (1) predator numbers and sizes (possibly using mark-recapture) and (2) habitat quality from late-spring through early-fall would serve as a background to contrast future management actions. One desirable management option would be to passively eliminate, or greatly suppress, bass in the backwater pools. With elimination of bass unlikely, the effects of bass predation on steelhead juvenile growth and survival might be needed in the future, once steelhead begin to repopulate the watershed.

5.4.2 Products

A literature review on predator life history requirements, including thermal preferences, and a preliminary assessment of bass habitat quality in the backwater pools. In addition, an annual summary on (1) predator numbers and sizes and (2) downstream migrant trapping results (if trapping done).

5.4.3 Dependency on Other Study Plan Elements

Study Plan Element SPE#5 water temperature thresholds for steelhead life history stages and SPE#8 for daily streamflows entering Niles Cone

5.4.4 Approximate Cost and Technical Qualifications

Evaluation of steelhead habitat potential and evaluate predator populations should cost less than $75,000. Future biological assessments, such as investigating predators in the backwater pools and periodically netting fish migrating out of Niles Canyon, could cost $30,000 per year. All tasks can be accomplished by agency fish biologists.

5.5 Study Plan Element #5: Water Temperature Monitoring and Modeling

Water temperature is a key environmental variable affecting all steelhead life stages and population recovery strategies. Water temperature will be instrumental in assessing spawning success (SPE #2), estimating juvenile habitat in the backwater pools (SPE#4), and especially for the instream flow analysis (SPE#10) by identifying preferred habitat on the annual habigraphs constructed from the habitat rating curves (SPE#1) and annual hydrographs (SPE#8).

5.5.1 <u>Tasks</u>

5.5.1.1 Task No. 1: Continue annual water temperature monitoring network.

Water temperatures have been collected at many locations throughout the watershed for a few years and during different seasons of those years (Hansen Environmental, SFPUC, ACWD, ACFCWCD, and Zone 7). However, these data have not been collected systematically; some data exclude the early spring steelhead outmigration period. Year-round thermographs for the first two to three years should be installed at the following potential locations (using the historic monitoring locations): T-13, T-1, immediately below Calaveras Dam to get a release temperature (T-10 or upstream), T-3, T-5, 8-W, 25-W (Alameda Creek near Niles gaging station), 26-W, 22-W, 23-W, L-1 (Arroyo Mocho), and L-8 (Arroyo del Valle). Water temperature monitoring should continue as historically conducted, but over the entire year rather than for certain seasons.

5.5.1.2 Task No. 2: Establish water temperature thresholds for each steelhead life stage.

A scientific literature review and discussion within the Workgroup is needed to finalize water temperature objectives and thresholds for steelhead life history stages. These thresholds will be critical to developing instream flow release recommendations.

5.5.1.3 Task No. 3. Develop/test a water temperature model for assessing estimating annual thermographs in Alameda Creek watershed and to estimate the temperature effects of potential instream flow releases.

Annual thermographs should be measured at selected locations throughout the basin, but many locations will not be monitored (e.g., all the steelhead spawning destination points). A water temperature model would be needed to estimate WY1990 through WY2006 annual thermographs for evaluating good habitat in constructed habigraphs (on mainstem channels and tributaries below reservoirs) and computing windows of spawning success. These thermographs will be used collectively, in any given water year and/or instream flow release scenario, to compute longitudinal profiles for water temperatures from the three headwater dams downstream to San Francisco Bay. A key purpose of the longitudinal water temperature profiles (e.g., Figure 7) will be to assess continuity of good habitat conditions for promoting smolt out-migration and growth resulting from natural runoff and instream flow releases.

A water temperature model with an hourly time step should be developed to estimate the downstream extent of temperature change derived from instream flow releases (from the 3 headwater dams and the turnout) in summer and to assess the effect, if any, of these instream flow releases and natural runoff on mainstem water temperatures farther downstream. This model should produce annual thermographs for WY1990 through WY2006 under unregulated streamflows, present regulated conditions, and any instream flow scenarios to be investigated. The model would include all mainstem reaches and tributaries leading up to the three reservoirs, as well as, tributaries to be assessed for the SSO in SPE#2.

5.5.1.4 Task No. 4: Measure reservoir stratification dynamics and model water temperatures.

If a reservoir is large enough and deep enough to stratify, instream flows released from the hypolimnion can provide relatively cold water during the spring through early-fall compared to unregulated streamflows. The Dam Population Recovery Strategy will require cold instream flow releases to sustain summer 0+ and 1+ steelhead habitat. Considerable fieldwork is needed for understanding how each reservoir thermally stratifies and how much cold water might be available for instream flow releases. Fieldwork will entail multiple vertical water temperature profiles beginning early spring and lasting through fall and a map of reservoir bathymetry. Predicting stratification under different combinations of water year types, operations, and proposed instream flow releases will likely require a model. This model of reservoir stratification and cold pool availability will need to be incorporated into the basin-wide operations model.

5.5.1.5 Task No. 5: Measure/assess pool stratification in mainstem channels.

As water temperatures warm through summer, deeper pools could thermally stratify and provide thermal refuge for 0+, 1+, and 2+ juveniles over-summering in Niles Canyon. These steelhead juveniles can become an important source for smolts the following spring. ENTRIX (April 2003 p.24) notes: “Evaluate flow conditions at which cold pools become established in Niles Canyon. If flows are too high, turbulence will break down cold pool stratification. Summer flows in Niles Canyon may be too high and work to impair steelhead habitat.” Fieldwork by Hanson Environmental (2003) suggests summer flows (supplemented by South Bay Aqueduct water) prevent pool stratification. Beginning with Niles Canyon, a field survey shortly before, during, and following peak water temperatures can be conducted to identify and map cool water refugia and stratified pools. Additional evaluation of thermal refugia in Niles Canyon and the other mainstem channels should expand on that done by Hansen Environmental (2003), and use temperature probes to evaluate whether springs or seeps provide local thermal refugia. This assessment should take advantage of any experimental flow releases to measure the effect of streamflow on pool stratification.

5.5.1.6 Task No. 6: Evaluate thermal stratification in backwater pools.

The rubber dams and their backwatered pools will have an important influence on water temperature through the mainstem below Niles Canyon. A model for the effects of rubber dam operations on water temperatures in the backwatered pools and farther downstream in the mainstem channel should be developed.

The WY1999 water temperature monitoring at two vertical locations within the Rubber Dam #1 impoundment suggests that thermal stratification might not occur to a degree that would allow juvenile salmonid rearing the entire summer (Figure 13). Surface water temperature monitoring in WY2002 suggests that rearing temperatures are exceeded from approximately June through September. However, before dismissing this potential opportunity, a more rigorous temperature evaluation of thermal stratification in the impoundments (the backwater pools) above Rubber Dam #1 and #3 should be conducted. At minimum, thermographs should be placed on the surface, near the bottom, and midlevel in both backwater pools from late-winter through September. At least three vertical temperature profiles would be needed in each backwater pool. Continuous monitoring would help document the influence of streamflow and air temperature on thermal stratification.

5.5.2 Products

1. Annual thermographs showing daily average, daily maximum, and daily minimum values for each station on an hourly time step or smaller. Measured or computed daily average hydrographs should be plotted on a secondary axis to relate water temperatures to flow releases. In addition, hourly air temperatures should also be plotted with water temperatures to relate to local climatic conditions and evaluate causal mechanism on water temperature changes.
2. A table of recommended water temperature thresholds (objectives) for each steelhead life stage.
3. A manual on the water temperature model.
4. Report on reservoir stratification and operational constraints (to be incorporated into the operations model in SPE#8.
5. Hourly and daily average/maximum/minimum water temperature profiles in the backwater pools (at the surface, near the bottom, and in the middle of the profile) from late-winter through early-fall.

5.5.3 Dependency on Other Study Plan Elements

SPE#10 for assigning likely instream flow scenarios for analysis and SPE#8 for estimating annual hydrographs at ungaged locations and for unregulated streamflows, to in turn model water temperature.

5.5.4 Approximate Cost and Technical Qualifications

If properly coordinated, thermograph installation and monitoring could be done by participating agency staff. If a consultant was hired to install and monitor thermographs, the cost could be up to $50,000 per year. The water temperature modeler should have considerable experience modeling stream temperatures in Mediterranean climates and have experience modeling reservoir stratification. The cost of a water temperature model would be approximately $75,000 to $100,000. Temperature monitoring and reporting for the backwater pools should cost less than $15,000 per year.

5.6 Study Plan Element #6: Stream Turbidity Monitoring and Assessment

Chronic turbidity in upper Alameda Creek, Arroyo de la Laguna, Niles Canyon, and Niles Cone appear to be exceeding thresholds for reducing juvenile steelhead growth, thereby potentially reducing returning adult success.

5.6.1 Tasks

5.6.1.1 Task No. 1: Measure annual stream turbidity in the mainstem channels.

Long-term turbidity data are available on Vallecitos Creek (turnout from South Bay Aqueduct) and the ACWA water quality monitoring station (stilling well approximately 100 ft offstream from Alameda Creek). There are periods within the ACWA water quality monitoring station where the data appear questionable, which may be caused by the monitoring station location or instrumentation problems. More recently (WY2007), USGS has initiated turbidity monitoring at the Alameda Creek near Niles gaging station, which provides good quality turbidity information. USGS will expand turbidity monitoring to the Alameda Creek below Welch Creek and Arroyo de la Laguna at Verona gaging station in WY2008. At present, the locations and number of monitoring stations is adequate. The Workgroup should work with the USGS in maintaining the turbidity monitoring and making sure any additional monitoring by other agencies follow USGS standard methods.

5.6.1.2 Task No. 2: Identify turbidity sources.

A program of reconnaissance-level synoptic turbidity measurements on Alameda Creek, Arroyo de la Laguna, lower Vallecitos Creek, Arroyo Mocho, and Arroyo del Valle is needed to identify turbidity sources in high priority juvenile/smolt rearing habitats. Synoptic turbidity monitoring should be conducted one to two days after a peak of a storm event that increases flows at the Alameda Creek near Niles gaging station above 80 cfs. Hach portable turbidity test kits (or equivalent) calibrated together would be required; one or two storm events would suffice for this initial effort. The purpose of this synoptic measurement would be to identify locations where turbidity increases rapidly, indicating fine sediment sources. If chronic turbidity sources are evident, a preliminary assessment of possible remedies will be made for reducing turbidity levels below chronic thresholds detrimental to juvenile salmonid growth.

5.6.2 Products

Annual turbidigraphs showing daily average, daily maximum, and daily minimum values for each station on an hourly time-step. Measured or computed daily average hydrographs should be plotted on a secondary axis to relate turbidity to flow releases.
Longitudinal plots of synoptic turbidity measurements to identify inflections that may indicate primary turbidity sources and to show where turbidity might be significantly affecting downstream migrating steelhead juveniles/smolts in spring and/or resident juveniles in summer.

5.6.3 Dependency on Other Study Plan Elements

Study Plan Element SPE#8 for relating streamflows to turbidity.

5.6.4 Approximate Cost and Technical Qualifications

If a consultant was hired to conduct a synoptic turbidity monitoring, the cost could be approximately $1,500 per event plus reporting costs. However, this task could be completed by agency staff. USGS turbidity annual monitoring costs approximately $10,000 per station per year. New stations would require a one-time installation and construction cost of approximately $13,000 per station.

5.7 Study Plan Element #7: Develop Steelhead Population Recovery Options in Lower Alameda Creek Flood Channel

Lower Alameda Creek flood channel has been managed for maximizing flood conveyance, which is typically counter-productive to steelhead life history needs. There may be opportunities to reconsider flood channel management to improve juvenile steelhead rearing in Niles Cone without compromising flood conveyance responsibilities.

5.7.1 Tasks

5.7.1.1 Task No. 1: Quantify steelhead habitat.

The first step is for biologists to spend time in the mainstem channel observing, including the use of baited minnow traps and seining. The latest information on how juvenile and smolting steelhead use streams and estuaries in San Francisco Bay also should be gathered. A quantitative assessment of historic and contemporary habitat value of the Alameda Creek channel downstream of the BART Weir should be conducted. Given the extent of riparian colonization and sediment deposition in the mainstem channel, a map should be made of good steelhead habitat for adult holding and juvenile/smolt rearing, taken from the EHM mapping, and related to subtle depositional channel features.

5.7.1.2 Task No. 2: Evaluate mainstem channel hydraulics.

Back-calculate hydraulic roughness below the BART Weir as a function of riparian plant colonization and sediment deposition. For contemporary and future conditions, apply a hydraulic model to predict hydraulic effects of depositional features now providing good habitat and evaluate these effects with respect to ACFCWCD flood control responsibilities. Based on this information, develop design criteria (depths, velocities, inundation frequencies of channel surfaces, structure and cover, etc.) for possibly enhancing habitat features.

5.7.1.3 Task No. 3: Measure longitudinal salinity profile.

Frequent measurement of salinity flux seasonally, and as a function of streamflow, will be needed to identify where freshwater rearing habitat exists below the BART Weir.

5.7.1.4 Task No. 4: Measure detailed longitudinal profiles for water temperature.

Investigate in the field the sharp drop in mainstem water temperature downstream of the ACWD rubber dams (Figure 7). If water temperatures characteristically drop below 72 F downstream of the BART Weir, juvenile steelhead that have not smolted could find summer refuge. Frequent synoptic water temperature measurements at many locations will identify the source, and likely the mechanism, for the water temperature drop (if there really is one). The profile should include many potential thermal refugia, and will likely require streamflow measurements to assess possible groundwater inflow as a mechanism for temperature change.

5.7.1.5 Task No. 5: Develop steelhead recovery options in the flood control channel.

Following completion of Tasks 1 through 6, the Workgroup should explore physical solutions to improving juvenile rearing habitat and how restoration of the Alameda Creek Estuary will dovetail with work contemplated/recommended for the Flood Channel. This will require field trips under different streamflows.

5.7.1.6 Task No. 6: Coordinate estuary restoration.

Coordination with other agencies on estuary restoration will be vital to improving steelhead rearing habitat and smolt growth. The estuary may be a critical linkage to restoring steelhead basin-wide. A conceptual design for the entire estuary should be developed, and then have logical sub-sections designed under the overall conceptual design. The Workgroup should make sure that the requirements of anadromous salmonids are integrated into any overall estuary restoration design. Because there already is ongoing design work on salt pond restoration at the historic mouth of Alameda Creek, developing an estuary restoration strategy at the mouth of the present mainstem channel that explicitly considers steelhead life history needs can be started at the earliest stages of design and planning, and therefore should be a high priority.

5.7.2 Product

Design recovery document.

5.7.3 Dependency on Other Study Plan Elements

SPE#5 longitudinal water temperature profiles (to modify the results of Task 5 and be compatible with profiles completed elsewhere in the watershed); SPE#8 for creating annual hydrographs under different management scenarios, including upstream instream flow releases; SPE#9 consideration of Chinook salmon life stages.

5.7.4 Approximate Cost and Technical Qualifications

Approximately $375,000 for habitat fieldwork, habitat quantification, hydraulic modeling, and report writing. Work should be coordinated/partnered with: (1) qualified fish biologists with experience in juvenile salmonid use of freshwater and tidal bottomlands, (2) qualified hydraulic engineers with experience in plumbing and operation of the lower Alameda Creek channel, and (3) the ACFCWCD, ACWD, and Flows Subcommittee.

5.8 Study Plan Element #8: Basinwide Water Management Operations Model and Data Management

Devising a feasible implementation plan and achieving recovery will require background hydrological analyses, a quantitative understanding of how flow is managed basin-wide, a water operations model, and a centralized database for monitoring data and analyses.

5.8.1 Tasks

5.8.1.1 Task No. 1: Characterize basinwide hydrologic conditions.

WY1990 through WY2006 annual hydrographs will be used in fish passage analyses and constructing annual habigraphs. This time period includes the full range of water year types necessary for evaluating instream flows. While considerable stream gaging is being done, or is available from past gaging, most channel locations will require at least some additional analysis for recreating annual hydrographs. A concise synthesis of past and present hydrologic data for the entire Alameda Creek Basin should be reported to the Workgroup that highlights how and where steelhead habitat existed historically and the constraints on recovering population recovery strategies. This synthesis will require estimating unregulated hydrographs for WY1990 through WY2006 in the mainstem channels, and in tributaries for the ascendograph analysis. During baseflows, some mainstem reaches may be losing discharge (e.g., below the Calaveras Creek confluence). This can be documented during the EHM mapping by synoptic discharge measurements at selected locations.

5.8.1.2 Task No. 2: Develop a water operations/routing model.

Answers to these questions will be necessary precursors to evaluating instream flows and improving efficient water use:

1. How will potential instream flow releases from reservoirs and South Bay Aqueduct turnouts route through the lower watershed?
2. How will magnitude and timing of an instream flow release propagate downstream?
3. What will flow be at any location for a given flow release?
4. How are the reservoirs and turnouts managed during different water years and different times in the same year?
5. What are the flow losses in certain reaches, particularly in the Sunol Valley Quarry reach?

These should be addressed by developing a model that integrates all potential management actions/constraints with natural runoff (portions of the watershed not regulated). A water operations model will allow the Workgroup to evaluate potential changes to the annual hydrograph (from Task No.1) in response to specific management actions, including instream flow releases, for recovering the Dam, Headwater, Mainstem, and Niles Cone steelhead population strategies. The water temperature model would be integrated as well to estimate accompanying changes in the annual thermograph. The highest modeling priorities would be those most directly affected by instream flow releases and central to the population recovery strategies:

1. Alameda Creek from Calaveras Dam to San Francisco Bay

2. Vallecitos Creek from SBA turnout to Arroyo de la Laguna
3. San Antonio Creek from dam to Alameda Creek confluence
4. Arroyo del Valle from Lake del Valle to Arroyo de la Laguna and downstream to Alameda Creek
5. Alameda Creek from Alameda Diversion Dam downstream to the Calaveras Creek confluence

An existing operations model developed by one of the Fisheries Subcommittee agencies could be expanded to include the above reaches; if not, then a new spreadsheet-based model should be developed with the following priority components:

1. Routes natural flow events and dam releases through the reaches described above
2. Incorporates flow losses and gains through different reaches (e.g., Sunol Valley gravel quarry reach).
3. Incorporates flow augmentation and diversion from existing water resources infrastructure.
4. Predict flows on at least a daily time step at any location.

Once this steady-state model is completed, and if pulse flow releases are developed, then develop an unsteady hydraulic model to enable pulse flow releases to be routed through downstream reaches.

5.8.1.3 Task No. 3: Organize/coordinate data collection, management, and analyses.

A coordinated recovery effort will be greatly aided by a coordinated data collection and management strategy to (a) ensure data collection consistency and quality, and (b) make data available to all participants in the work group. All available Alameda Creek temperature and streamflow data should be compiled into an organized set of spreadsheets or database. Some of the available temperature information was not readily available in electronic format, so obtain these remaining data in electronic form from the original sources. McBain & Trush, Inc. has completed this task for the high priority gaging stations and some high priority thermograph and turbidity monitoring locations, but many more will not be organized as part of this study plan task.

High priority for first year

1. USGS gaging station data
2. Agency and consultant water temperature monitoring data
3. USGS and agency turbidity monitoring data (and other water quality data relevant to fishery recovery efforts)
4. Longitudinal stationing index on Alameda Creek and other significant tributaries (proposed stationing index shown on Figure 3)

Priority for future years

1. Other monitoring data, including fish outmigration data, adult returns, spawning surveys, and other data relevant to fishery recovery efforts.
2. Converting compiled data from Excel spreadsheets into a centralized database, potentially available on-line.

5.8.2 Products

1. A synthesis report on past and present hydrological conditions.
2. A spreadsheet-based steady-state water operations model for the priority reaches described above.
3. Spreadsheets with the following data over the available period of record: (1) water temperature (15-minute data and daily average/maximum/minimum values), (2) water turbidity (15-minute data and daily average/maximum/minimum values), (3) daily average streamflows, and (4) annual peak flow stream data.
4. A memo describing how the database works and can be accessed.

5.8.3 Dependency on Other Study Plan Products

All other Study Plan Elements needed.

5.8.4 Approximate Cost and Technical Qualifications

Hydrograph analyses will require approximately $20,000. Depending on whether an existing model can be expanded, the operations model would likely cost $50,000 to $100,000 if done by a hydraulic engineer. Costs could be considerably lower if one of the Flows Subcommittee agencies volunteered staff to expand one of their existing models to the priority reaches above. Completing the streamflow, water temperature, and turbidity data retrieval and compilation process would take approximately three weeks for a technician, and should cost less than $15,000. Future data management could cost up to $50,000 per year, but costs could be reduced if done in-house by one of the Workgroup agencies.

5.9 Study Plan Element #9: Consider Other Aquatic Species in Restoring the Steelhead Fishery and Assessing Instream Flows

Restoration of a steelhead fishery in Alameda Creek basin should also benefit other aquatic organisms. Subtle adjustments of restoration changes (e.g., baseflow increases) could increase benefits to these species. Environmental permitting will likely require consideration of other aquatic species.

5.9.1 Tasks

5.9.1.1 Task No. 1. Identify where/how Chinook salmon life history tactics and life history requirements can be inserted into the steelhead investigations/analyses.

1. Develop a life history periodicity chart and establish environmental criteria for water temperature preferences/thresholds for each life stage.
2. Develop a general set of habitat criteria (preferred depths, velocities, and substrate) for steelhead fry and Chinook fry, and adult steelhead and Chinook spawning, that can be used in the EHM assessment. EHM performed for steelhead could be applied to Chinook salmon without incurring additional time in the field. Chinook smolt rearing habitat preferences might be considered separately from juvenile preferences, and might be included in the EHM mapping.
3. Perform ascendograph analysis using preferred depths, preferred velocities, and migration rates for adult Chinook salmon rather than adult steelhead. If a Chinook salmon can pass the barrier, then so could an adult steelhead. However, hydrographs that focused on early-fall through mid-winter would be needed in the ascendograph analyses, rather than the mid-December through March time window for adult steelhead spawning. This will require expansion of the effort to develop unregulated and regulated hydrographs (in SPE#8), and managed hydrographs for assessing potential instream flow release scenarios (SPE#10).

5.9.1.2 Task No. 2. Identify where/how non-salmonid aquatic species life history requirements can be inserted into the instream flow analysis and possible field data collection needs.

1. Species/life stage habitats that should be considered are Pacific lamprey ammocoete rearing habitat, prickly sculpin adult habitat, Sacramento sucker fry and adult habitats, and productive benthic macroinvertebrate riffle habitat.
2. Develop a life history periodicity chart and establish environmental criteria for water temperature preferences/thresholds for each life stage of concern.
3. Decide whether these species, or which species, should be included, by the Workgroup and include these species habitats in the EHM mapping and instream flow analyses.

5.9.1.3 Task No. 3. Identify where/how amphibian life history requirements can be inserted into the instream flow analysis and possible field data needs.

1. Species/life stage habitats that should be considered are: (a) California red-legged frog oviposition and tadpole habitats, (b) Foothill yellow-legged frog oviposition and tadpole habitats, (c) western pond turtle adult habitat, and (d) Pacific treefrog oviposition and tadpole habitats.
2. Conduct field surveys in mainstem reaches and selected tributaries. Time-of-year will be important in selecting when to perform the surveys. This will be an additional cost.
3. Develop a life history periodicity chart and establish environmental criteria for water temperature preferences/thresholds for each life stage of concern.
4. Include these species/life stages in the EHM mapping, which will require developing (from the scientific literature) habitat preference criteria and an additional crew member on the EHM mapping team that is an expert on amphibians. Amphibian assessment may need particular attention below reservoirs with their unseasonably cold instream flow releases.
5. Habitat rating curves and habitats can be created as for steelhead, and included in the instream flow analysis and synthesis.

5.9.2 Products

Include each species/habitat assessment and analysis in the synthesis report of SPE#10.

5.9.3 Dependency on Other Study Plan Elements

SPE#8 for annual hydrographs, SPE#2 for the EHM mapping, and SPE#5 for the water temperature monitoring.

5.9.4 Approximate Cost and Technical Qualifications

Development of life stage periodicity and habitat preferences can be assembled from a few meetings and the scientific literature. Inclusion of the other species in the EHM mapping and analyses should increase overall costs (that of addressing steelhead) by approximately 15%.

5.10 Study Plan Element #10: Phase II Synthesis and Refinement of Population Recovery Strategies

Results of most Study Plan Elements should be synthesized as a prerequisite for conducting Phase III instream flow recommendations.

5.10.1 Tasks

5.10.1.1 Task No. 1: Establish a steelhead population recovery goal.

Adult steelhead return can be estimated by predicting the size class distribution of smolts entering San Francisco Bay and applying the SAR curve (Figure 5). The size class distribution of smolts would be based on juvenile rearing habitat densities/sizes and additional growth while migrating downstream. Although this would require the recovery process to have already begun, other analytical options are available. Regional juvenile density estimates can be obtained from local published and survey data, or rainbow trout densities used as surrogates (as done earlier in this study plan), as well as a range of typical growth rates obtained from the scientific literature. A spreadsheet-based approach for predicting annual adult return would be a good first approximation of whether 300 adults, 1000 adults, or more would be possible. Additional model refinement should wait until adult steelhead begin returning and producing fry.

5.10.1.2 Task No. 2: Summarize and integrate results of all Study Plan Elements into the instream flow analysis.

Integration of all Study Plan Elements into the instream flow analysis will require the following:

1. SPE#8 develops annual hydrographs and SPE#2 produces habitat rating curves. Melding of the two to create annual habigraphs is an important step in assessing instream flows. Annual habigraphs will be constructed, with modeled annual thermographs incorporated, to estimate the availability of dates (in a given water year) with good habitat under unregulated (modeled) and present-day annual hydrographs for WY1990 through WY2006. In Figure 16, Step 1 is the hydrograph (either measured at a gaging station or modeled) and Step 2 is the habitat rating curve constructed from the EHM habitat mapping. The two are 'melded' into seasonal habigraphs (Step 3 in Figure 16) by multiplying the flow on each date (from Step 1) by the amount of habitat at that flow (From Step 2). This analysis will establish how much habitat there was historically and how much there is today: both can serve as baselines for comparison to releasing instream flows.
2. The habigraphs portray habitat abundance on given dates, but make no assessment as to whether the habitat is needed or if the habitat is of good or poor quality. 'Good' equals abundant juvenile rearing and productive benthic macroinvertebrate habitat under physiologically favorable water temperatures. Step 4 in Figure 16 makes this assessment by (a) establishing when a particular life stage requires this habitat and (b) on what dates water temperature favors the life stage. For example, the life stage can be 1+ steelhead smolts originating from Arroyo Mocho (i.e., with a Headwater Population Strategy) migrating through the mainstem of Arroyo de la Laguna in spring WY2002. The hydrograph in Step 1 would be for WY2002 in lower Arroyo de la Laguna. The habitat rating curve in Step 2 would represent mainstem 1+ rearing

mainstem habitat in lower Arroyo de la Laguna. The habigraph in Step 3 would represent the ft^2 of 1+ juvenile rearing habitat in a 2500 ft segment of mainstem Arroyo de la Laguna. In Step 4, the time period of concern, April 01 to June 01, overlaid onto the habigraph is when we would expect/desire smolts to migrating downstream (generally portrayed on a life history periodicity chart). Also in Step 4, daily water temperatures from a thermograph are overlaid onto the habigraph (in red) as well as upper and lower temperature thresholds (determined from the scientific literature) favoring a high growth potential (shaded red). In Step 4, 'A' identifies the dates when rearing habitat in mainstem Arroyo de la Laguna for migrating 1+ steelhead smolts is abundant and favorable for growth.

3. While some may want the lower mainstem Arroyo de la Laguna to provide abundant, temperature-friendly habitat everyday during smolt outmigration, this likely rarely occurred naturally in any given water year. Steps 1 through 4 can be computed for unregulated and presently regulated WY1990 through WY2006 hydrographs for comparison. In Step 5 (Figure 16) the number of days with abundant and good growth potential in an unregulated spring hydrograph can serve as the reference condition (in the denominator) and the number of days with abundant and good growth potential in the same water year, but regulated, would serve as the numerator. In this manner using a reference condition computed for all 16 water years, an assessment can be made of how well present streamflows produced good smolt habitat compared to unregulated streamflows. This analysis would measure how well unregulated hydrological conditions performed annually in providing good habitat conditions along a juvenile's migration route. Dry years likely will not perform as well as Wet years. A measure of variable background performance would be very useful in prescribing a range of instream flow releases spanning Dry to Wet years.

4. One goal for the instream flow assessment is to provide good rearing habitat along the entire migration route of juveniles and smolts. The above example for Arroyo Mocho to Arroyo de la Laguna applied to one location along a migration route. This analysis would require many locations. Hydrographs, thermographs, and habigraphs (essentially Step 1 through Step 4 in Figure 16) from April 1 through June 1 would be required along entire downstream migration routes selected from the population strategies. The metric for performance could be number of days. If a juvenile embarks on its downstream migration on April 1, how many days (moving a constant rate for simplicity) along its journey would good habitat conditions be encountered before leaving Niles Canyon June 1? "Good habitat could be translated into more biologically meaningful measures: abundant riffle habitat for energy efficient feeding positions, high benthic macroinvertebrate production for food availability, and a high potential daily growth rate (based on water temperature). Collectively, these biologically-relevant variables could be combined to compute a rough daily growth increment. As the juvenile grows its way downstream, its chance of returning as an adult increases in the SAR curve (Figure 5). Ultimately, smolt-to-adult return rate can be the final measure of 'good'. Once this analysis was performed for unregulated hydrographs and gaged hydrographs from WY1990 through WY2006, different likely instream flow releases superimposed on unregulated runoff and other instream flow releases (creating 'managed hydrographs') would be assessed similarly for

improvement to the juvenile's smolt-to-adult return rate. In this manner, an instream flow release could be attributed to more returning adults.

5. Repeat the above analysis for summer rearing habitat in the mainstem channels and in the Flood Control channel of Niles Cone.
6. Instream flow analyses below reservoirs would proceed similarly, with two objectives assessed: (a) the amount and timing of summer rearing habitat generated annually near the dam and (b) whether a dam release measurably influences good habitat conditions farther downstream when juveniles and smolts are migrating. Both analyses will rely on the reservoir stratification model for predicting water temperature at the release site and the volume of cold water seasonally available for release.
7. Ascendograph analyses should be incorporated into the synthesis, modeling a range of instream flows that would likely be considered and/or recommended in Phase III. This analysis, synthesizing SPE#1, SPE #2, and SPE#8, would be particularly important for Arroyo Del Valle with its flows highly regulated and its channel with multiple small barriers.
8. Plot daily average water temperatures (measured and modeled) on longitudinal profiles (similar to Figure 7) for different days in one water year and for many water years (WY1990 through WY2006) for regulated and unregulated annual hydrographs. Produce a map of Alameda Creek Basin showing where juvenile steelhead could have reared through the summer based on modeled and measured annual thermographs for WY1990 through WY2006 under existing streamflows, unregulated streamflows, and different likely instream flow release scenarios. This map would include the locations of stratified pools providing favorable juvenile habitat. These longitudinal water temperature profiles, originating at the reservoirs and extending downstream to San Francisco Bay and at different times from late-winter through early-summer, will identify good rearing conditions for migrating juveniles and smolts under existing annual hydrographs, unregulated hydrographs, and different likely instream flow release scenarios.
9. Summarize results relative to the five population recovery strategies. SPE#1 develops a quantitative relationship between habitat abundance and streamflow (the habitat rating curves). But SPE#1 provides no insight as to how instream flows should be prescribed, but is a vital tool for doing so. Annual habigraphs and thermographs should be created, for any given annual hydrograph and basin location to quantify when and how much good habitat will be produced daily. Steps 1 through 8 above will move the overall analysis much closer to objectively identifying beneficial instream flow releases, but additional analyses is still needed to develop final instream flow recommendations. Phase III will address the feasibility of making these releases and establishing criteria or thresholds for recommending instream flow releases.

5.10.1.3 Task No. 3. Identify and assess important remaining uncertainties.

All the analyses require assumptions: some based on extensive field data while others might be based on the general scientific literature. A sensitivity analysis should be performed to show how a reasonable range in key assumptions will affect the analyses in Task No. 1. For example, will a 10% error in estimating daily average streamflows in ungaged channels significantly affect the analysis in Figure 16? Those assumptions most responsible will be targeted for additional fieldwork or terminated, and another analytical pathway selected.

5.10.2 Product

A synthesis report that refines and/or better quantifies recovery goals, summarizes the field data collected in the Study Plan Elements, and presents the analytical outcomes of (a) assessing the biological significance of unregulated and regulated annual hydrographs on the five population recovery strategies and (b) identifying potential benefits of releasing instream flows for the five population recovery strategies.

5.10.3 Dependency on Other Study Plan Elements

All study plan elements are integrated into this synthesis.

5.10.4 Approximate Cost and Technical Qualifications

The synthesis and report writing should cost approximately $175,000 and be conducted by a consultant, with significant oversight by technical members of the Fish Subcommittee.

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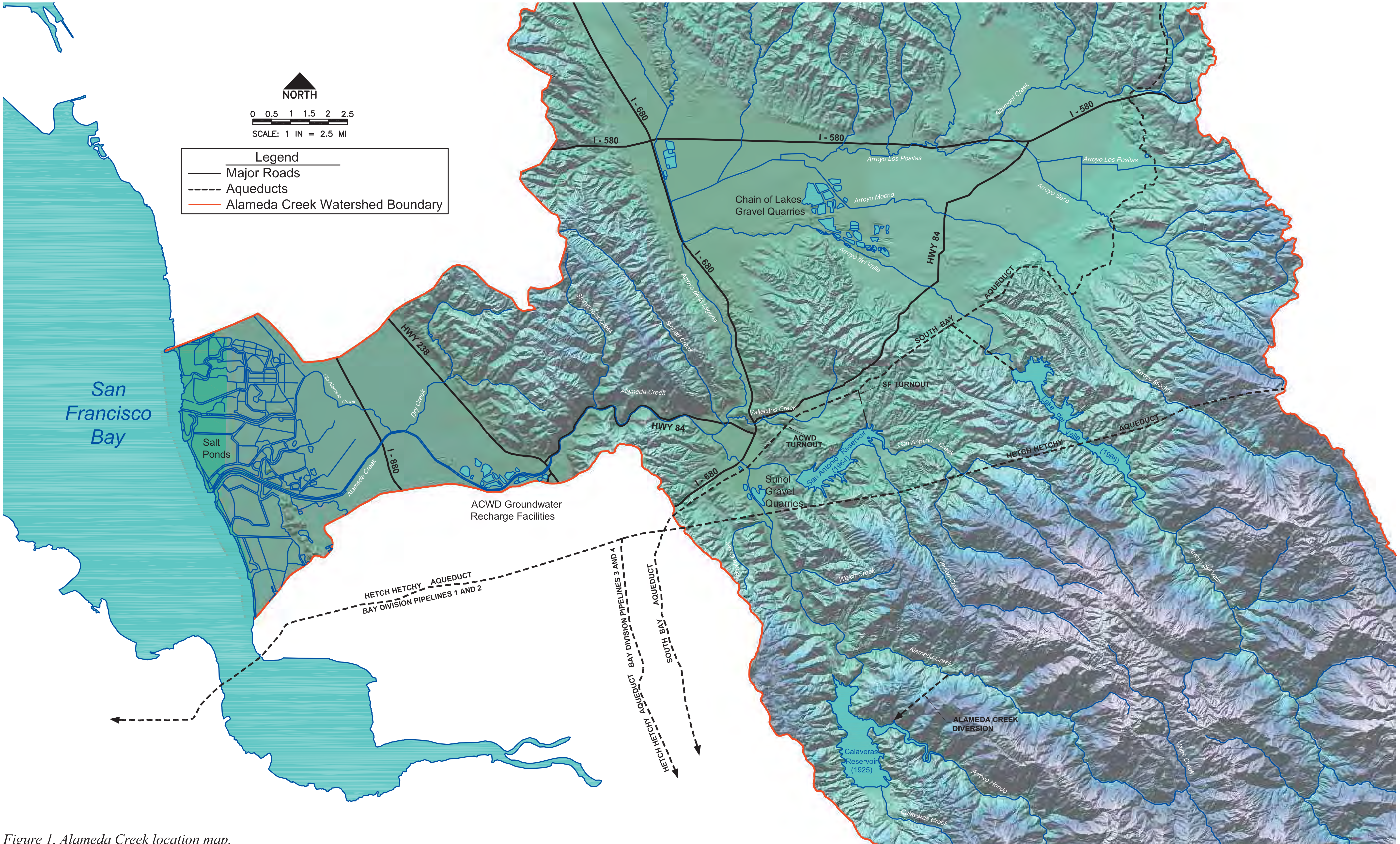

Figure 1. Alameda Creek location map.

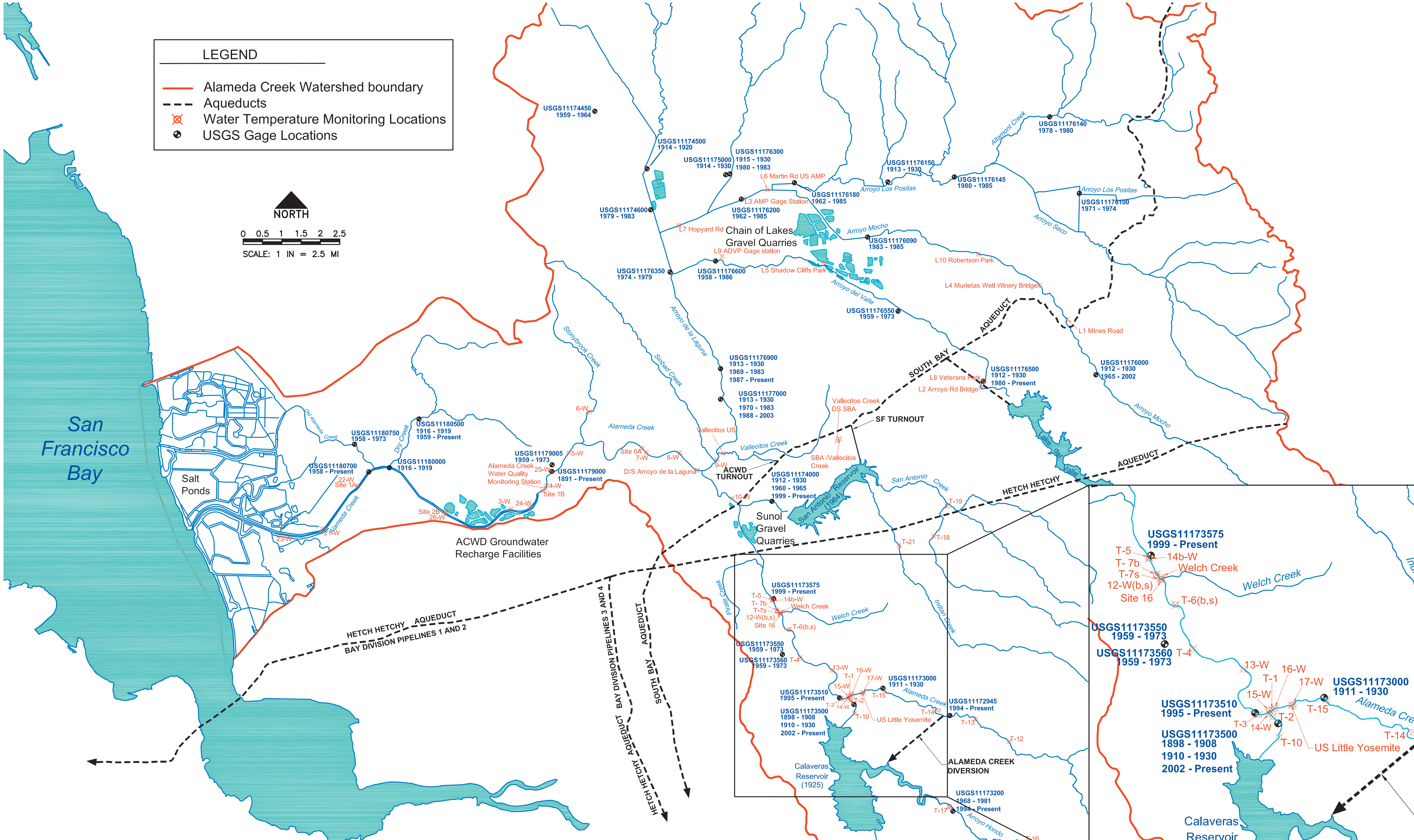

Figure 2. Streamflow gaging station and water temperature monitoring locations within the Alameda Creek watershed.

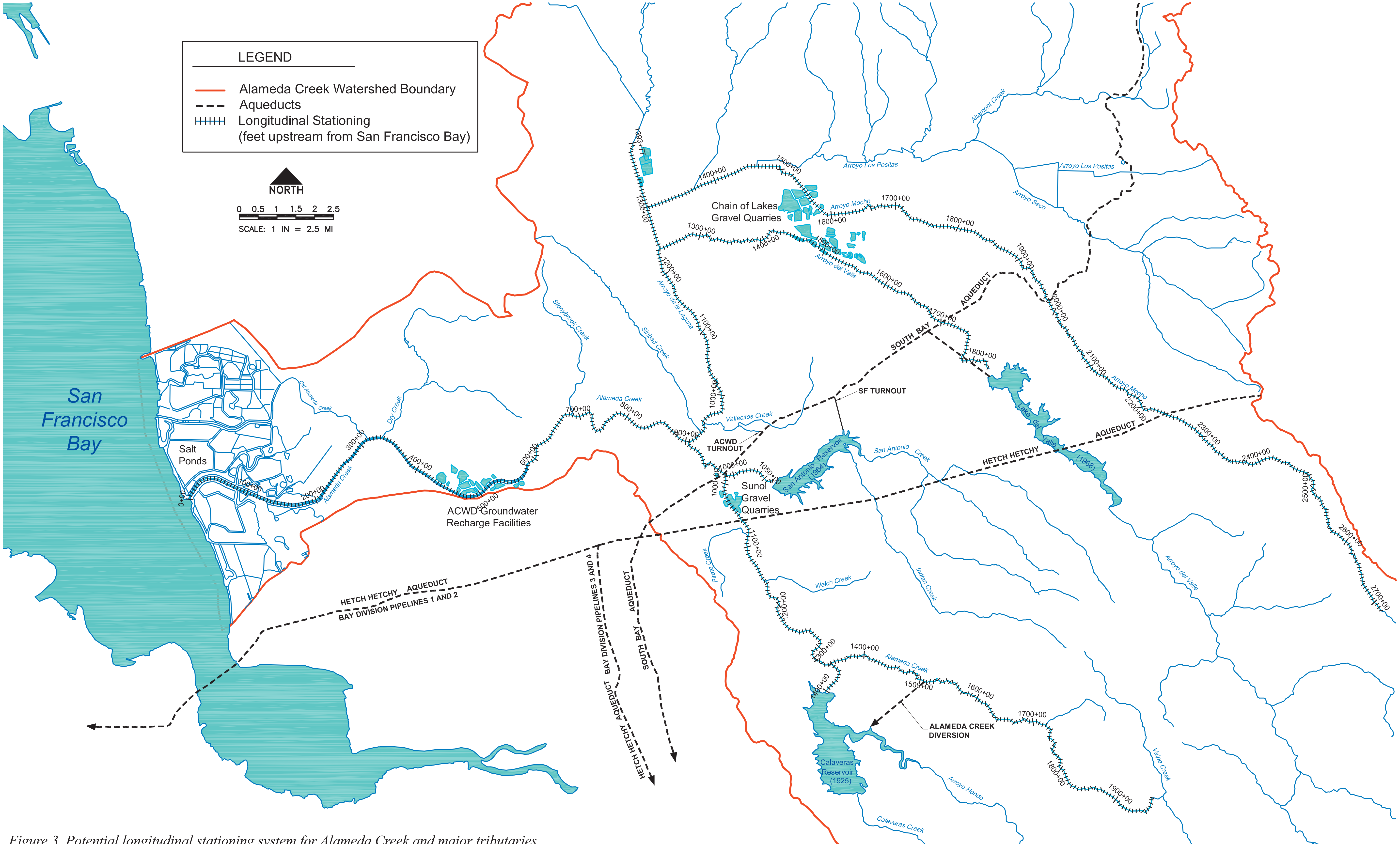

Figure 3. Potential longitudinal stationing system for Alameda Creek and major tributaries.

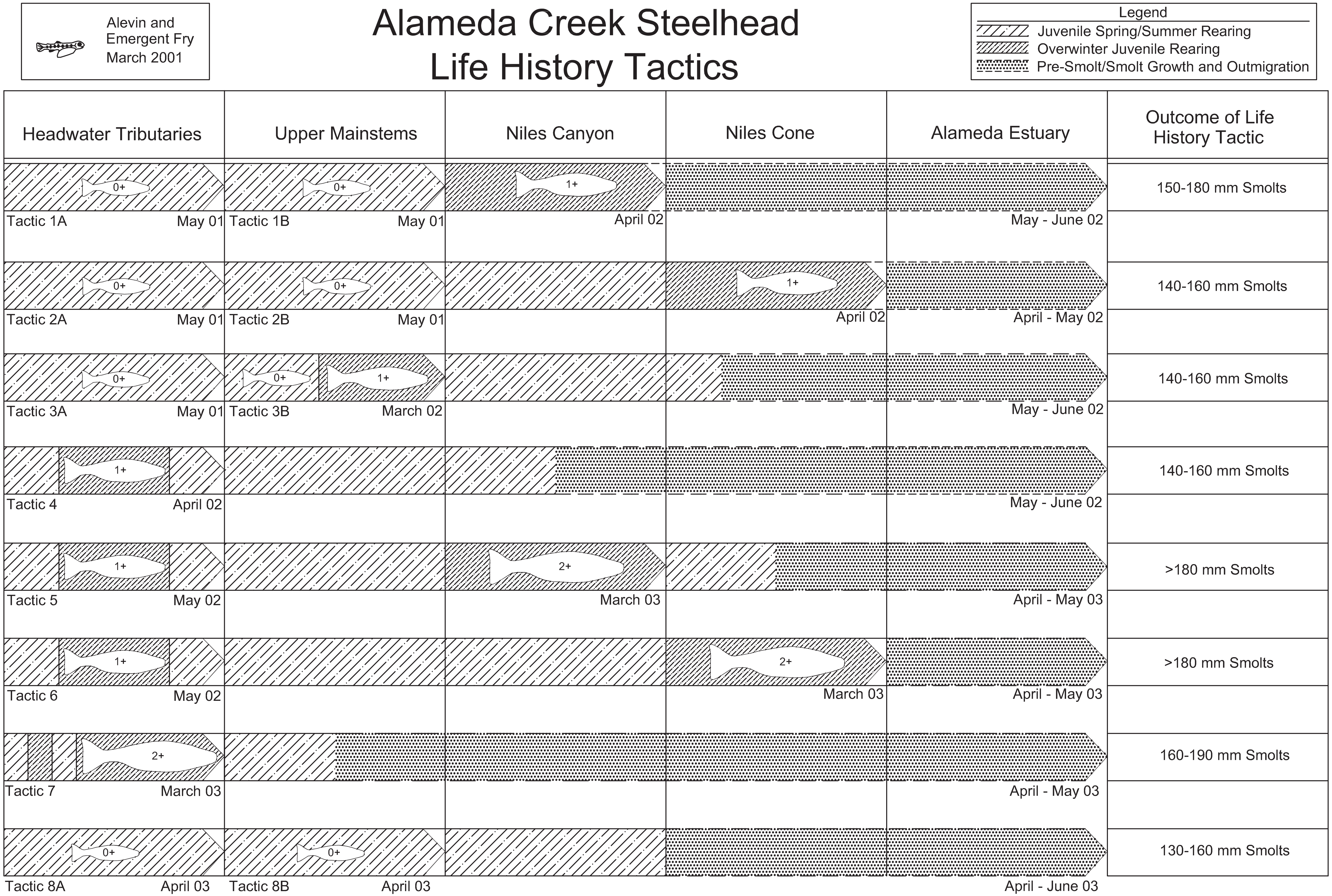

Figure 4. Possible steelhead life history tactics in the Alameda Creek watershed.

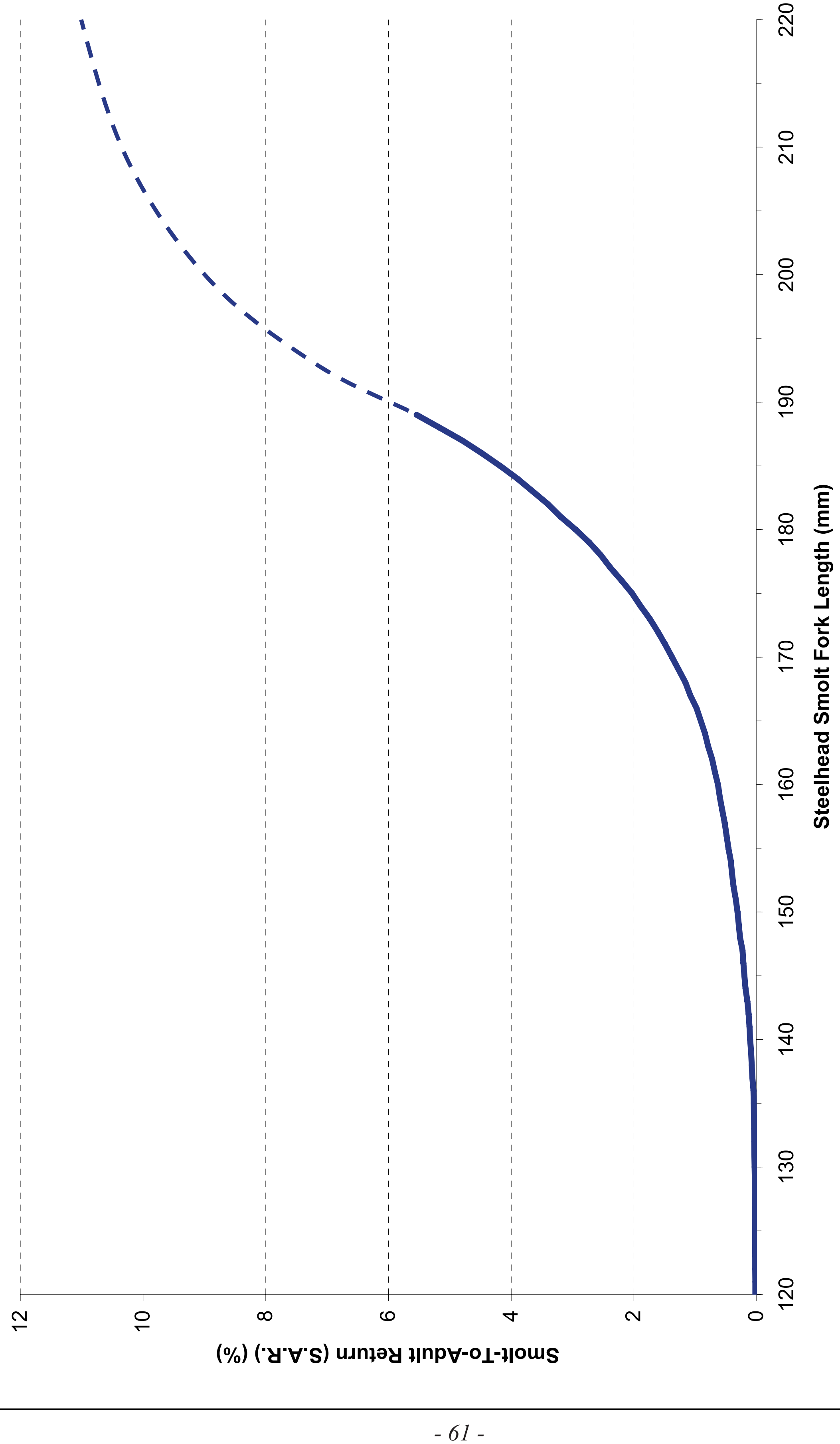

Figure 5. Smolt-to-Adult return curve (SAR) for steelhead.

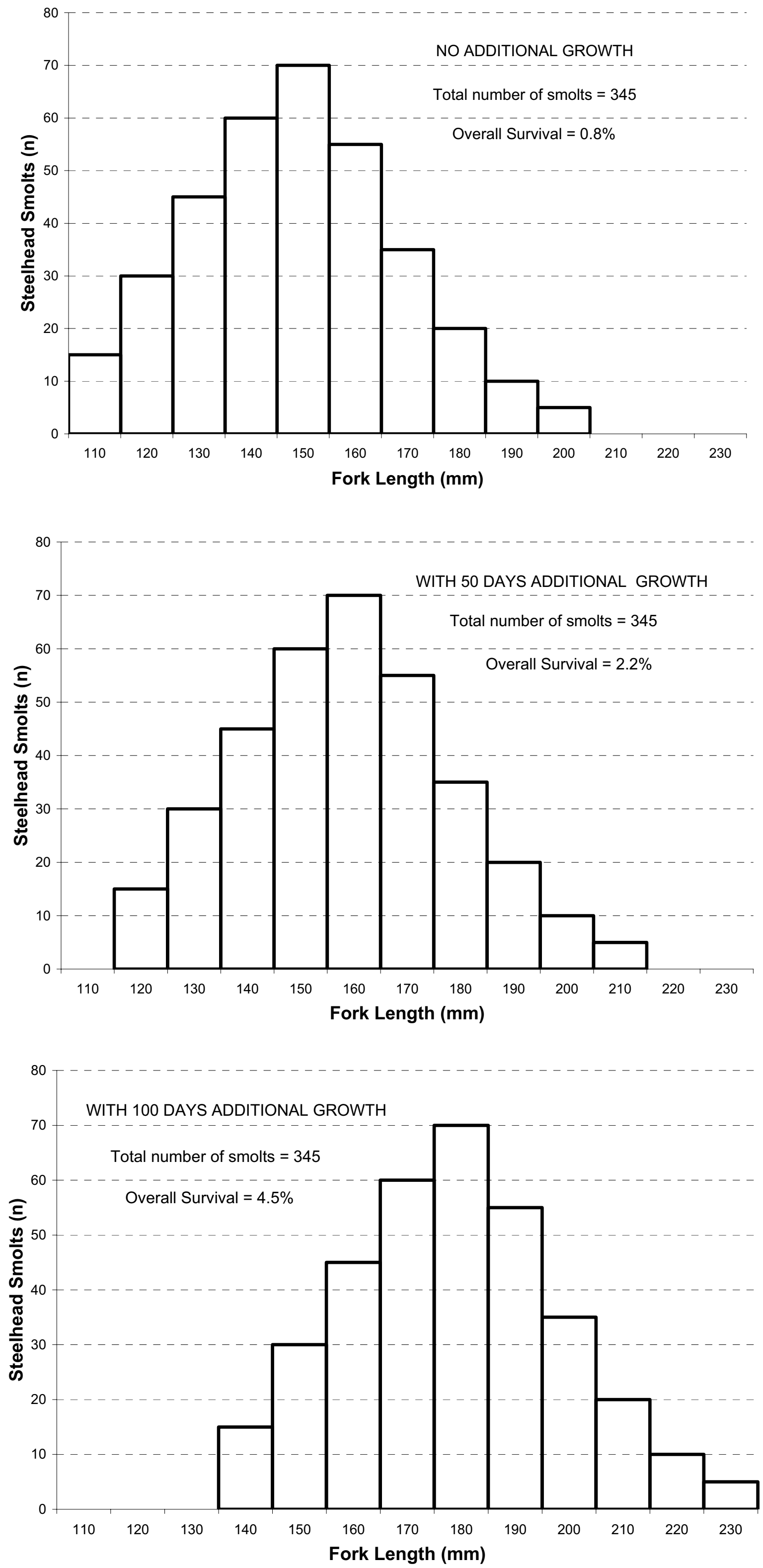

Figure 6. Potential smolt size class distributions from downstream migrant trapping results in three headwater streams above reservoirs in upper Alameda Creek Basin for WY2002 with and without additional smolt growth.

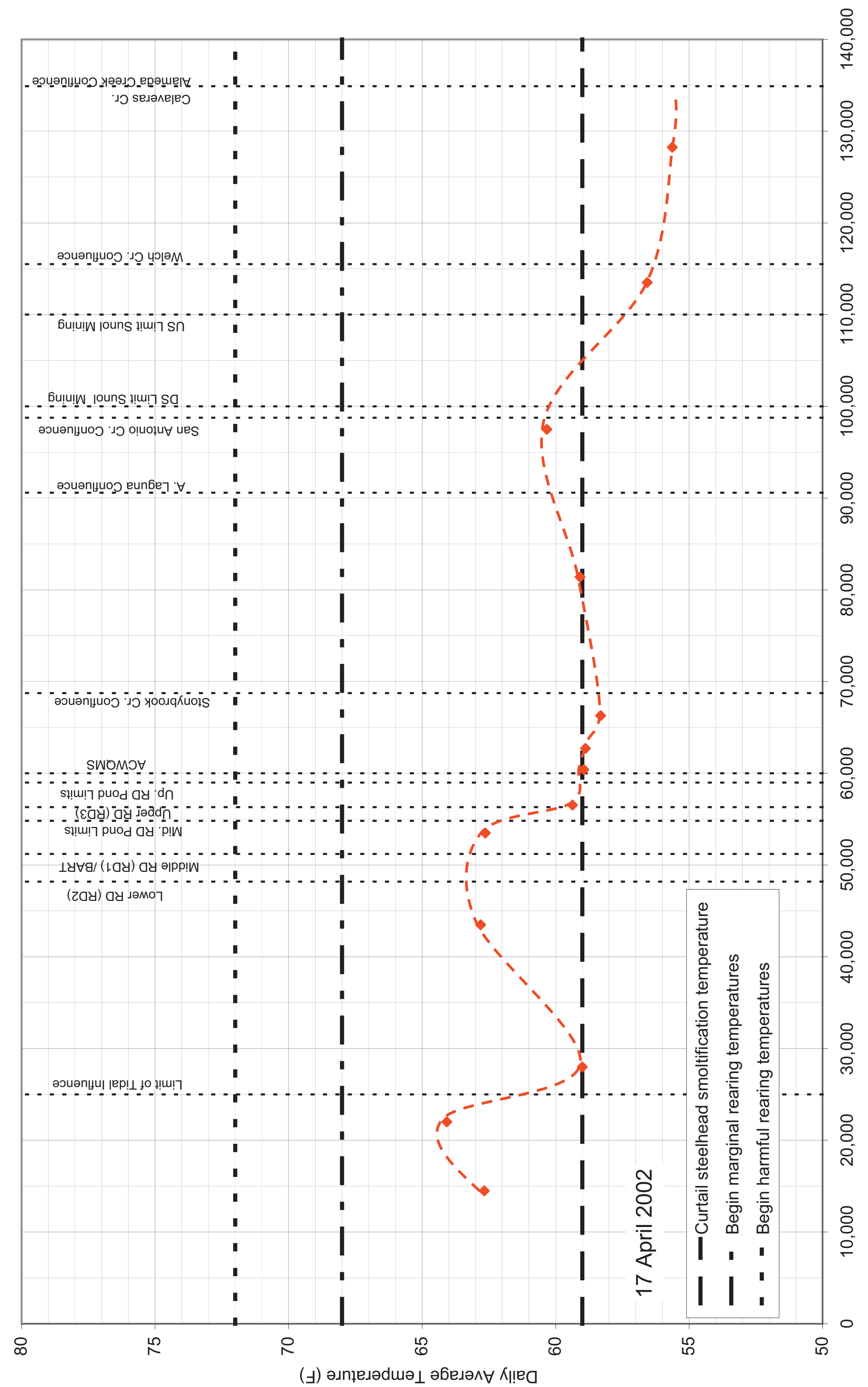

Figure 7a. Longitudinal water temperature profiles for five days during the period of April 17 to August 12, 2002 along the Alameda Creek mainstem from the Calaveras Creek confluence downstream to San Francisco Bay.

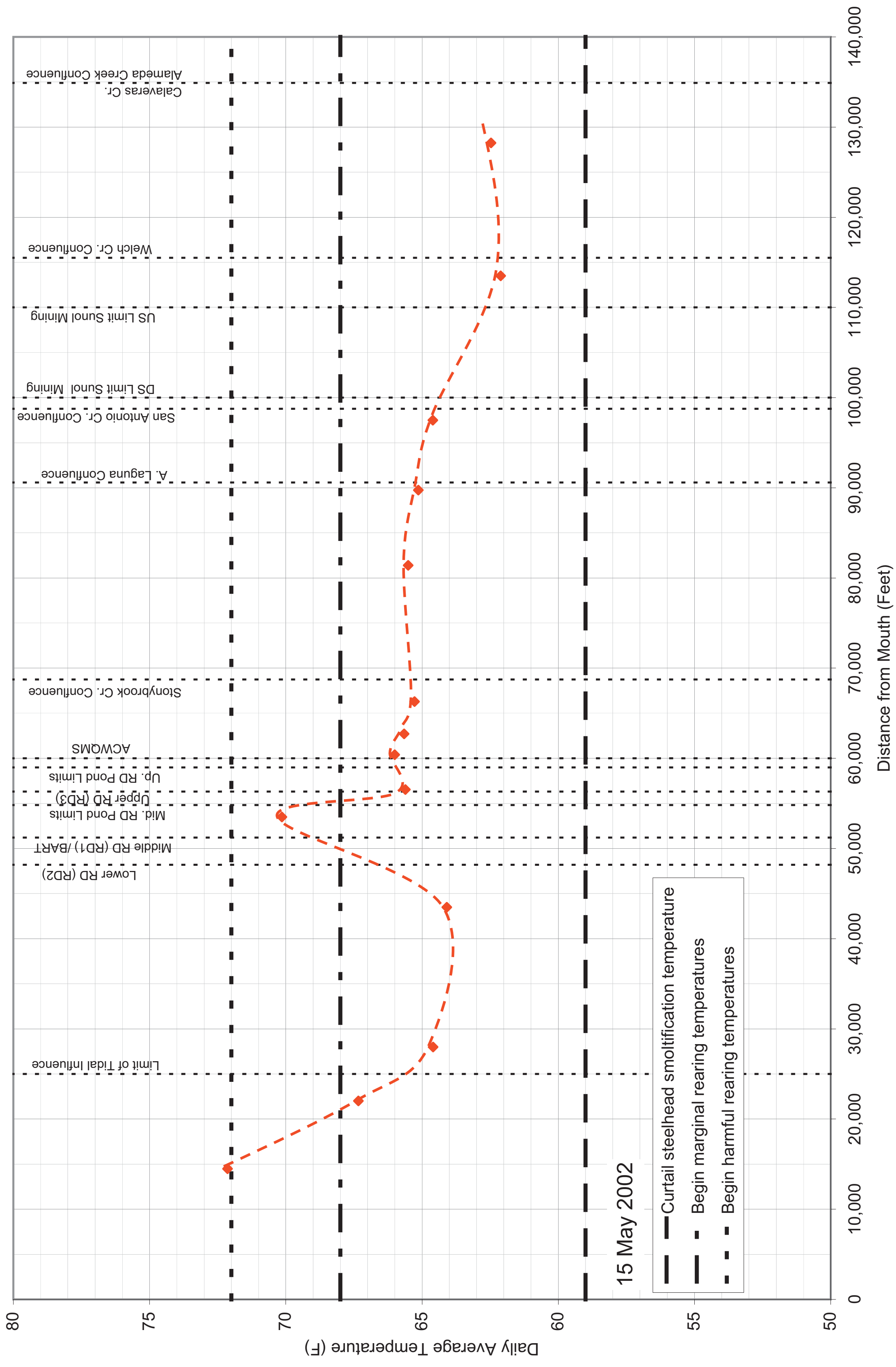

Figure 7b. Longitudinal water temperature profiles for five days during the period of April 17 to August 12, 2002 along the Alameda Creek mainstem from the Calaveras Creek confluence downstream to San Francisco Bay.

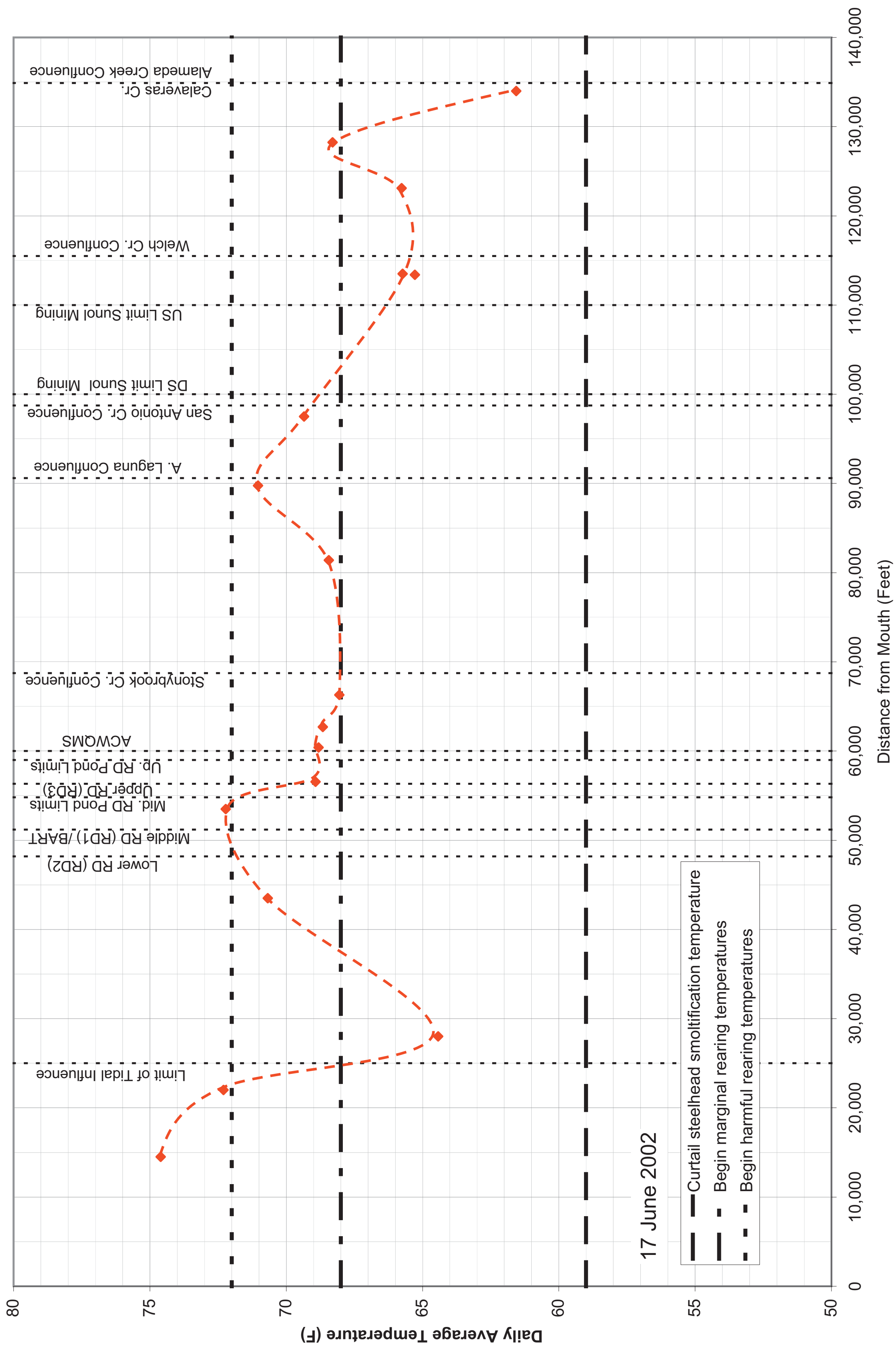

Figure 7c. Longitudinal water temperature profiles for five days during the period of April 17 to August 12, 2002 along the Alameda Creek mainstem from the Calaveras Creek confluence downstream to San Francisco Bay.

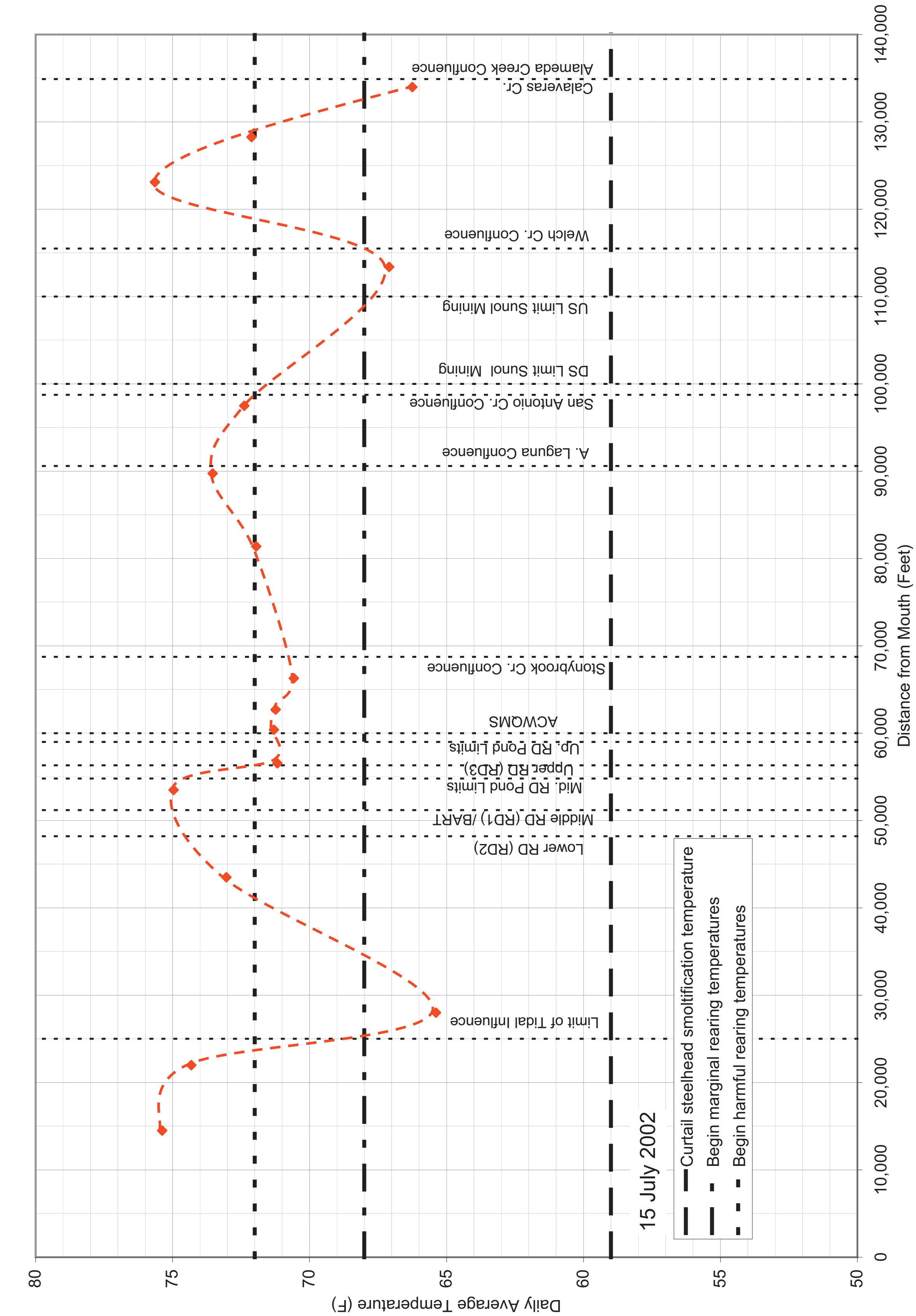

Figure 7d. Longitudinal water temperature profiles for five days during the period of April 17 to August 12, 2002 along the Alameda Creek mainstem from the Calaveras Creek confluence downstream to San Francisco Bay.

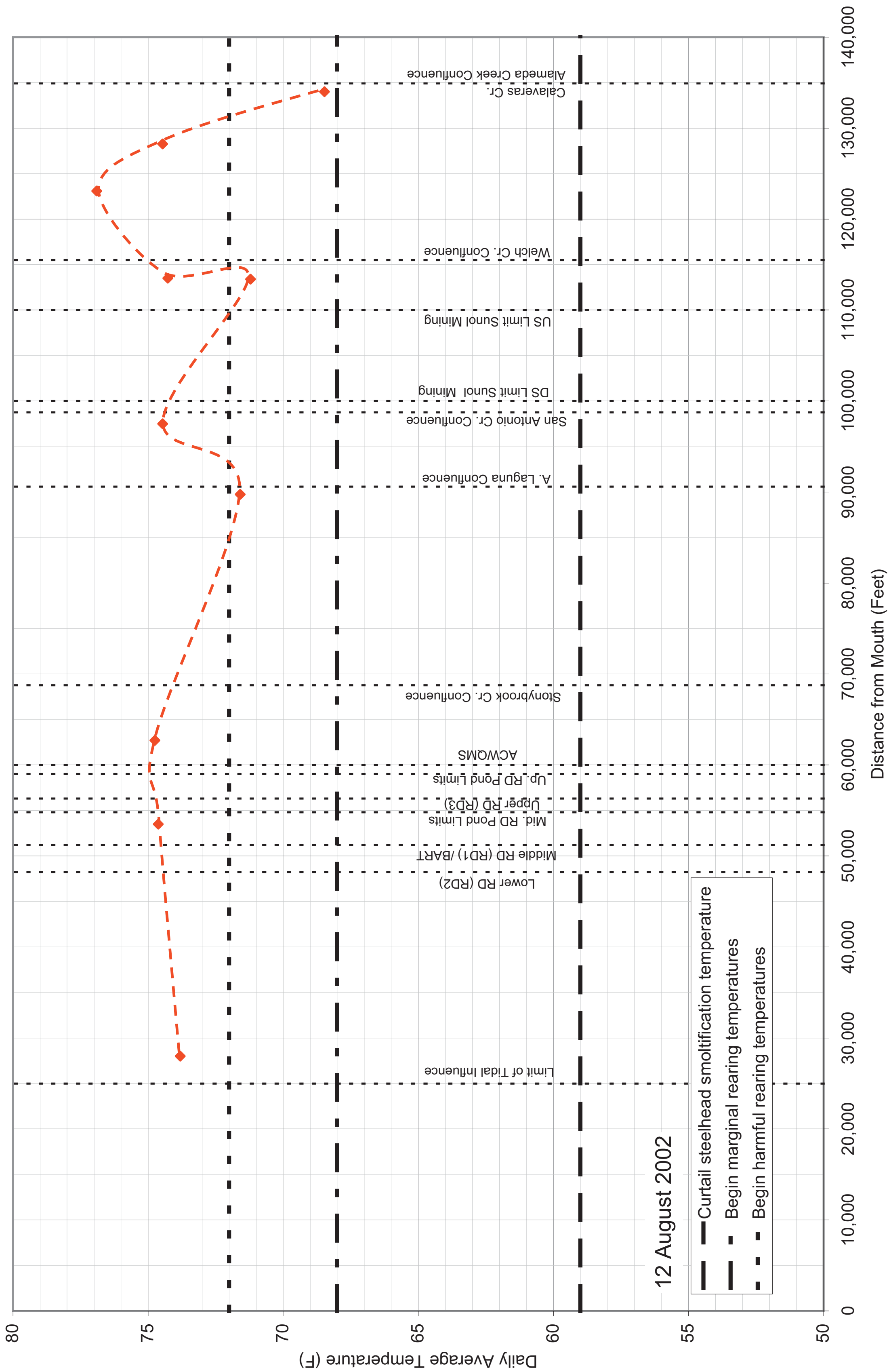

Figure 7e. Longitudinal water temperature profiles for five days during the period of April 17 to August 12, 2002 along the Alameda Creek mainstem from the Calaveras Creek confluence downstream to San Francisco Bay.

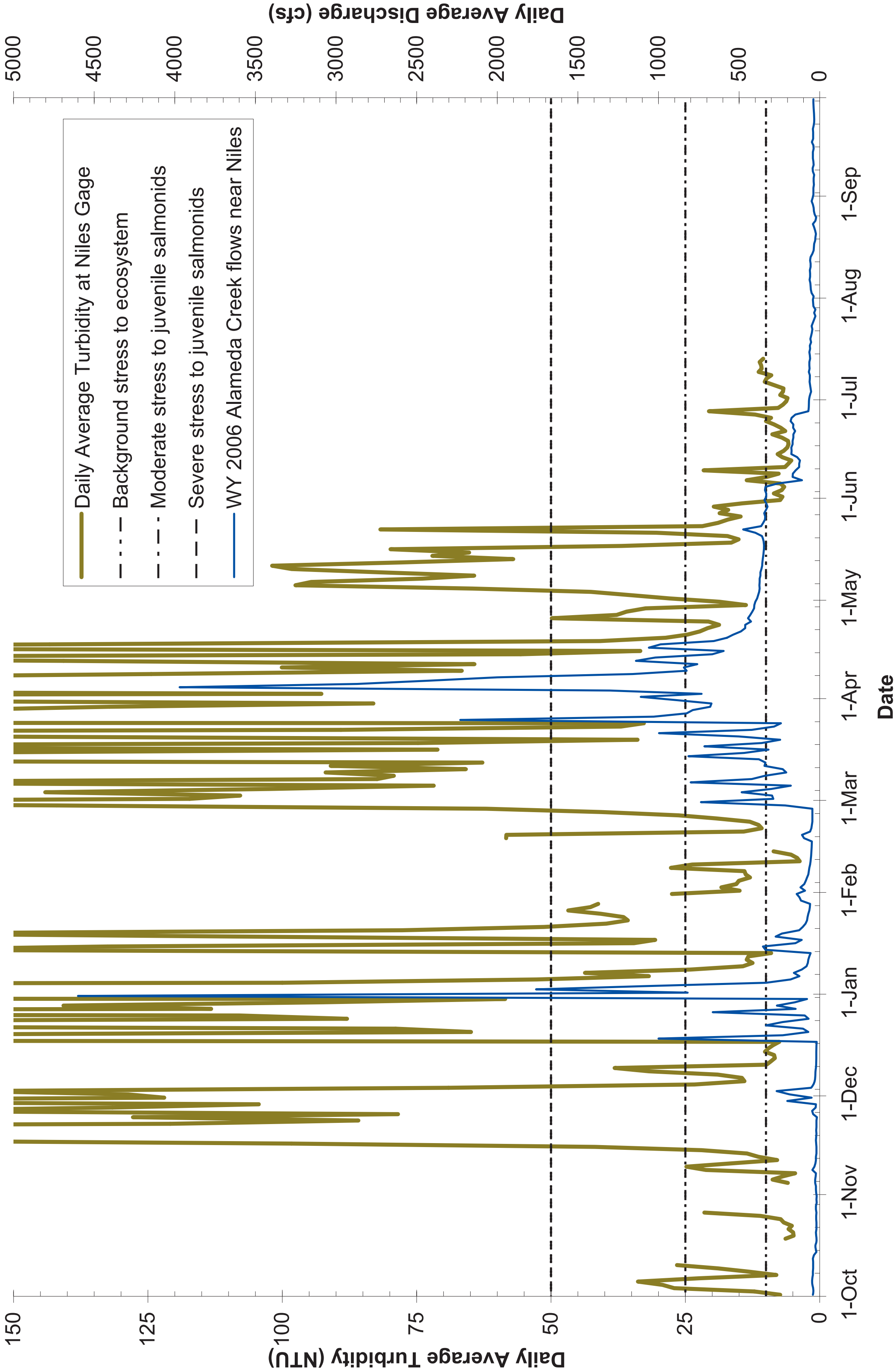

Figure 8. Annual turbidigraph for WY2006 at the Alameda Creek near Niles USGS Gaging Station with three ecological threshold NTU levels.

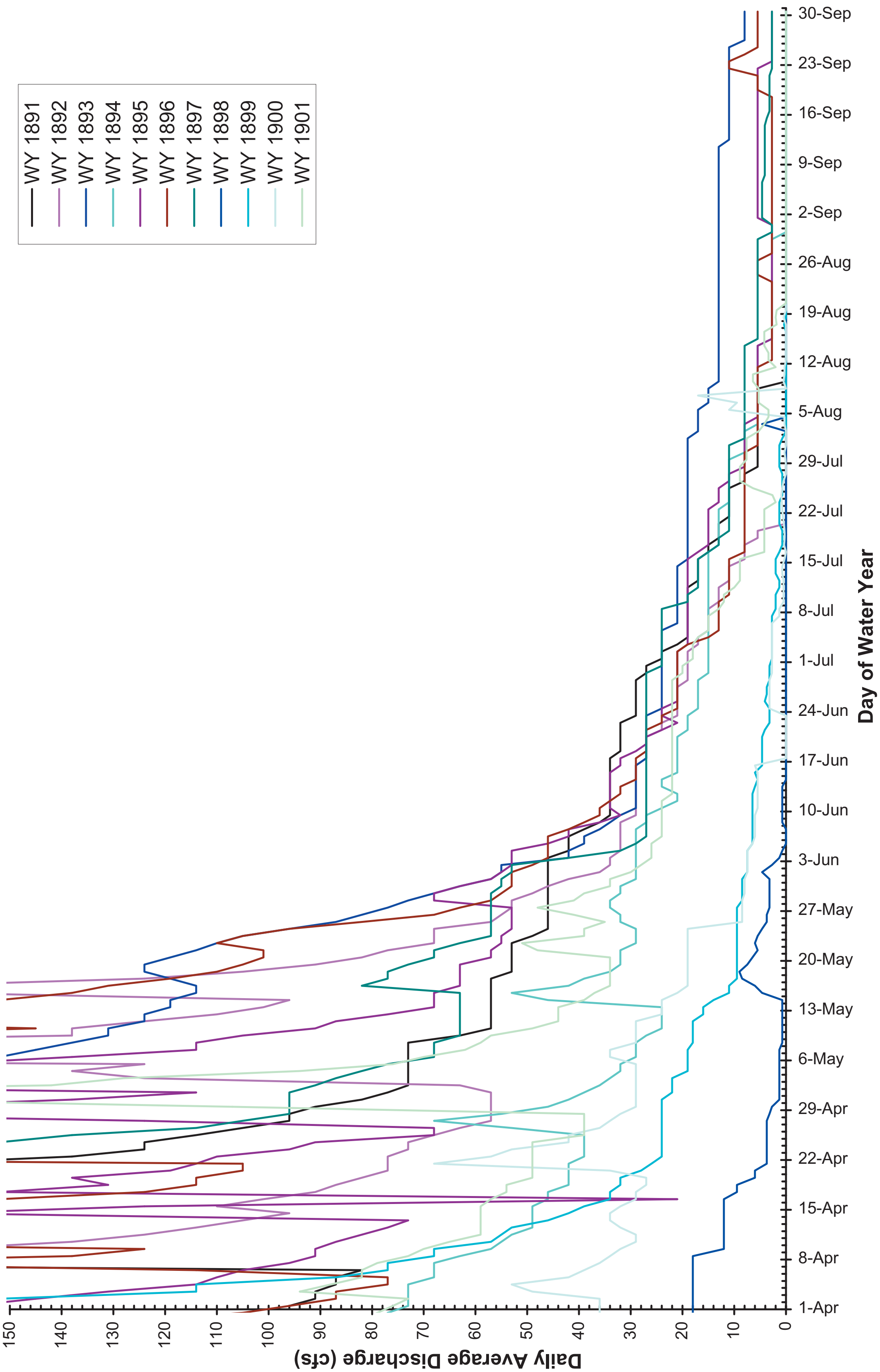

Figure 9. Historic daily average streamflows at USGS Niles gage for WY1891 through WY1901 showing flow magnitudes and variability during juvenile rearing and outmigration periods.

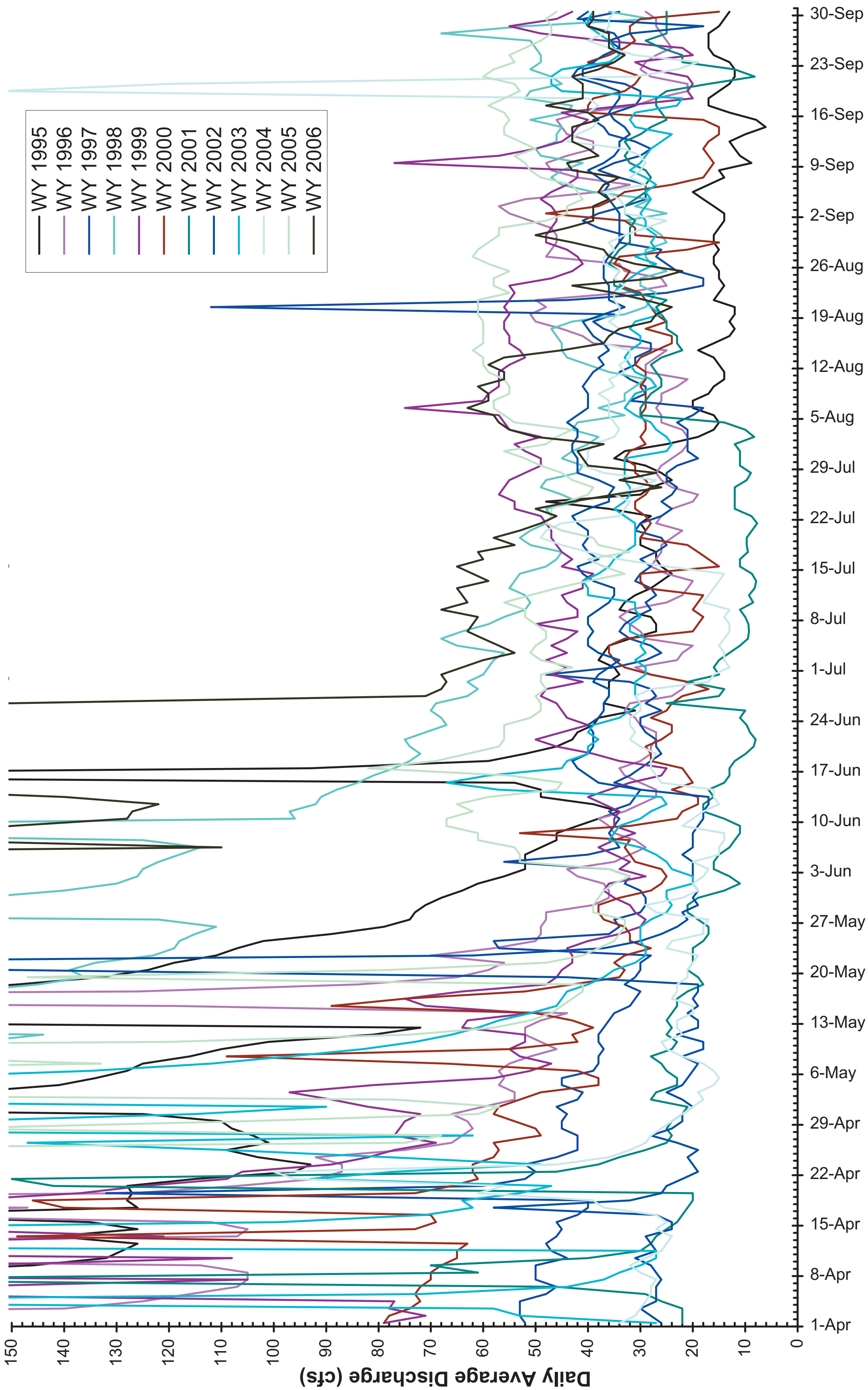

Figure 10. Recent daily average streamflows at USGS Niles gage for WY1995 through WY2006 showing increased flow magnitudes and variability during juvenile rearing and outmigration periods.

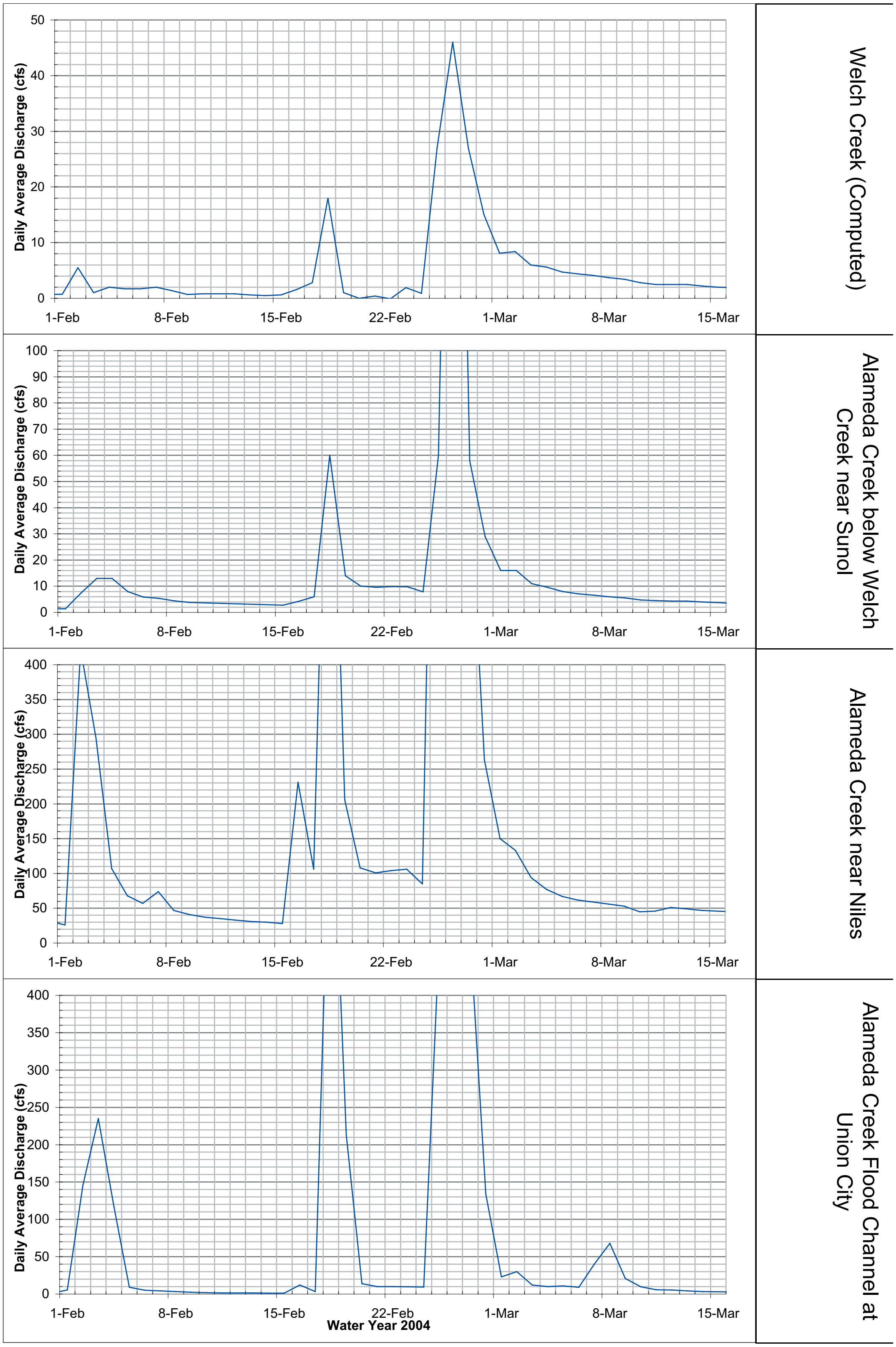

Figure 11. Daily average streamflows in WY2004 for Welch Creek, Alameda Creek near Sunol, Alameda Creek near Niles, and Alameda Creek at Union City showing potential migration flow windows and barriers along the steelhead migration route..

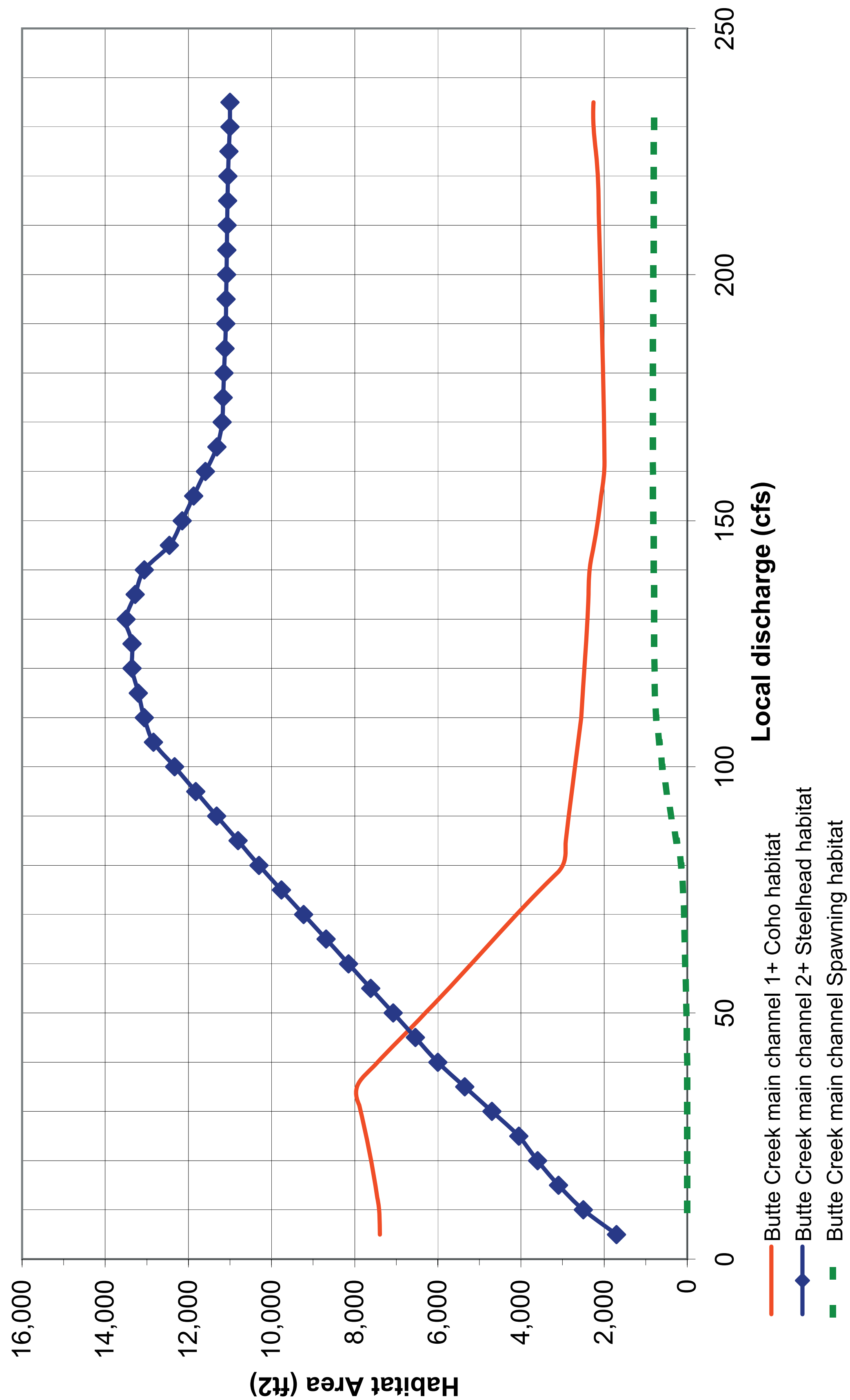

Figure 12. Example of a streamflow – habitat rating curve from the Oak Grove Fork, Oregon.

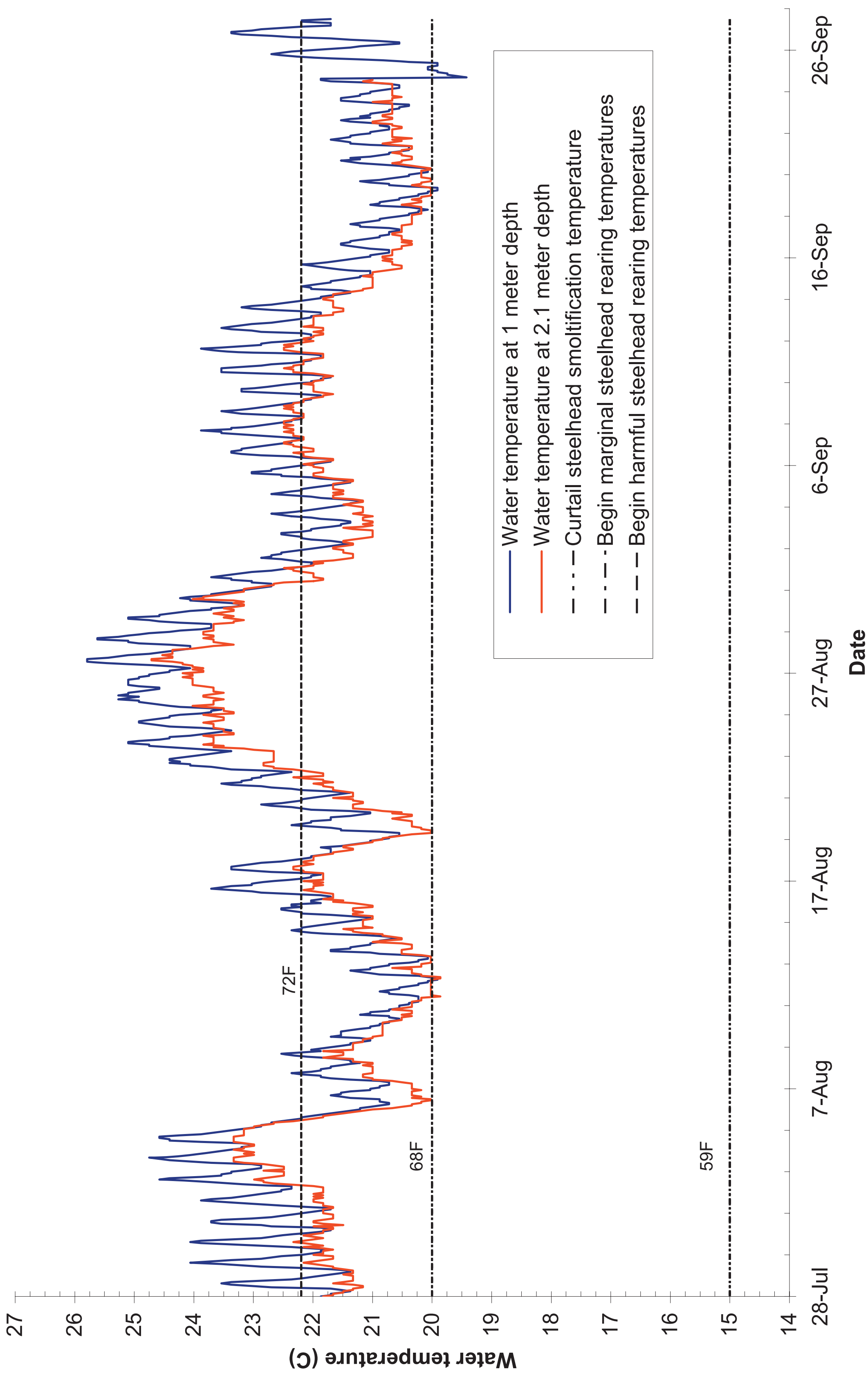

Figure 13. Water temperatures at 1.0 meter and 2.1 meter depths in the vertical profile of the middle rubber dam impoundment on lower Alameda Creek.

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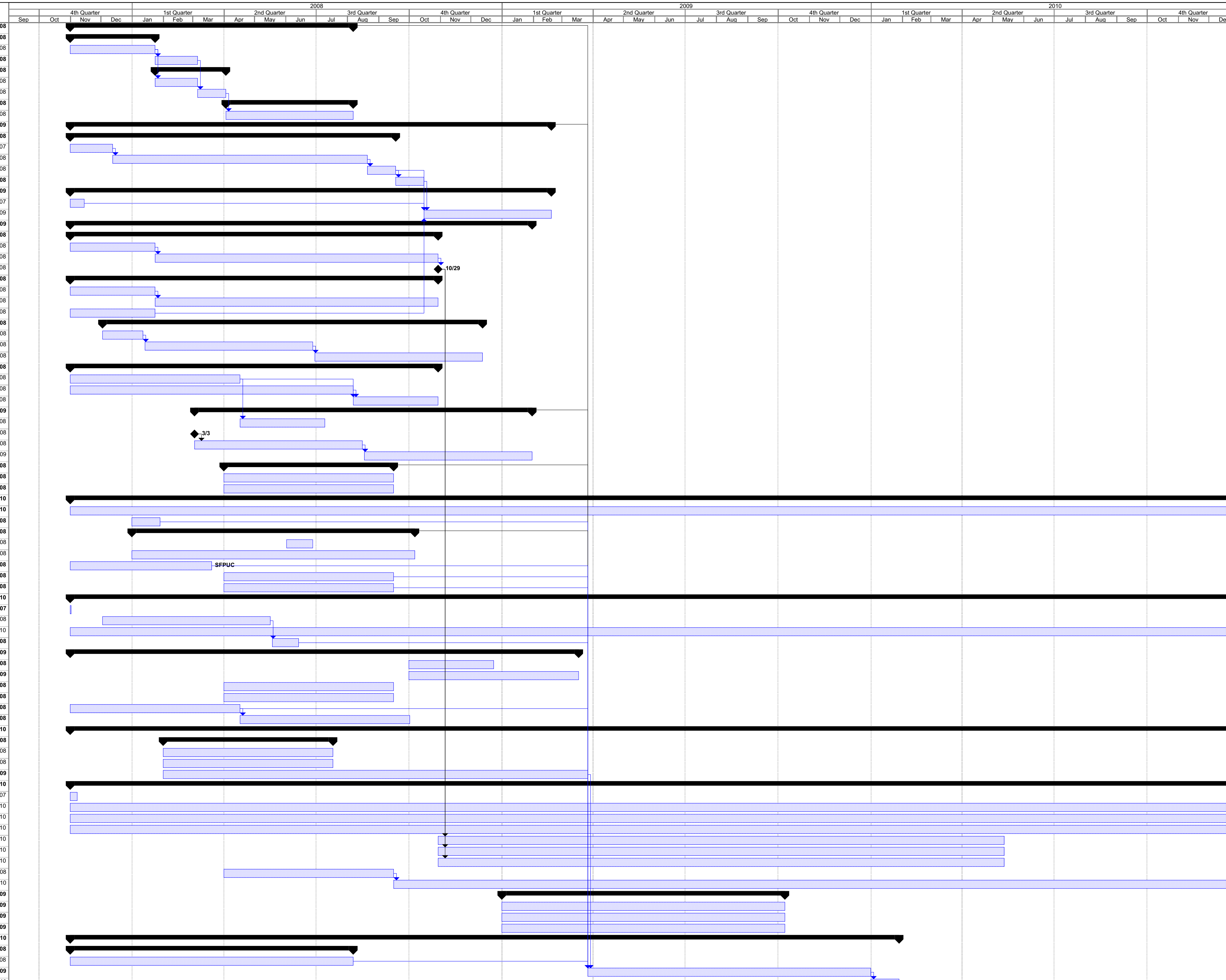
ID	Task Name	Duration	Start	Finish
1	**Element #1. Quantification of steelhead habitat - streamflow relationships**	**200 days**	**Thu 11/1/07**	**Wed 8/6/08**
2	**Task 1. Select field methodology**	**60 days**	**Thu 11/1/07**	**Wed 1/23/08**
3	Workshop(s) to develop study plan (methods, priority reaches, assessment a	60 days	Thu 11/1/07	Wed 1/23/08
4	**Task 2. Create basemaps**	**30 days**	**Thu 1/24/08**	**Wed 3/5/08**
5	**Task 3. Assemble and calibrate mapping team**	**50 days**	**Thu 1/24/08**	**Wed 4/2/08**
6	Develop Habitat Suitabiity Curves	30 days	Thu 1/24/08	Wed 3/5/08
7	Field calibration	20 days	Thu 3/6/08	Wed 4/2/08
8	**Task 4. Construct habitat rating curves**	**90 days**	**Thu 4/3/08**	**Wed 8/6/08**
9	Experimental releases and data collection	90 days	Thu 4/3/08	Wed 8/6/08
10	**Element #2. Adult steelhead passage assessment**	**340 days**	**Thu 11/1/07**	**Wed 2/18/09**
11	**Task 1. Establish streamflow passage windows**	**230 days**	**Thu 11/1/07**	**Wed 9/17/08**
12	Visual barrier assessments	30 days	Thu 11/1/07	Wed 12/12/07
13	Hydraulic barrier assessments	180 days	Thu 12/13/07	Wed 8/20/08
14	Idenfity flow windows for fish passage through barriers	20 days	Thu 8/21/08	Wed 9/17/08
15	**Task 2. Compute successful spawning opportunity windows**	**20 days**	**Thu 9/18/08**	**Wed 10/15/08**
16	**Task 3. Develop ascendograph model**	**340 days**	**Thu 11/1/07**	**Wed 2/18/09**
17	Estimate adult migration speed as a function of discharge and channel geom	10 days	Thu 11/1/07	Wed 11/14/07
18	Integrate barrier windows, travel distance, water temperatures to develop mo	90 days	Thu 10/16/08	Wed 2/18/09
19	**Element #3. Barrier removal and retrofit design and remediation**	**327 days**	**Thu 11/1/07**	**Fri 1/30/09**
20	**Task 1. Bart Weir remediation**	**260 days**	**Thu 11/1/07**	**Wed 10/29/08**
21	Complete final design and permitting	60 days	Thu 11/1/07	Wed 1/23/08
22	Implementation	200 days	Thu 1/24/08	Wed 10/29/08
23	Re-introduction of steelhead initiated	0 days	Wed 10/29/08	Wed 10/29/08
24	**Task 2. ACWD rubber dams remediation**	**260 days**	**Thu 11/1/07**	**Wed 10/29/08**
25	Fish ladder design and permitting	60 days	Thu 11/1/07	Wed 1/23/08
26	Fish ladder implementation	200 days	Thu 1/24/08	Wed 10/29/08
27	Evaluate rubber dam operations to improve adult access (link to fish ladder)	60 days	Thu 11/1/07	Wed 1/23/08
28	**Task 3. USGS wier assessment and remediation**	**270 days**	**Mon 12/3/07**	**Fri 12/12/08**
29	Re-assesment	30 days	Mon 12/3/07	Fri 1/11/08
30	Design and permitting	120 days	Mon 1/14/08	Fri 6/27/08
31	Implementation	120 days	Mon 6/30/08	Fri 12/12/08
32	**Task 4. PG&E and SFPUC crossings remediation**	**260 days**	**Thu 11/1/07**	**Wed 10/29/08**
33	Sunol Valley geomorphic assessment	120 days	Thu 11/1/07	Wed 4/16/08
34	Design	200 days	Thu 11/1/07	Wed 8/6/08
35	Implementation	60 days	Thu 8/7/08	Wed 10/29/08
36	**Task 5. Sunol Quarry flow loss and fish passage assessment**	**240 days**	**Mon 3/3/08**	**Fri 1/30/09**
37	Sunol valley fish passage evaluation	60 days	Thu 4/17/08	Wed 7/9/08
38	Gravel extraction contract signed	0 days	Mon 3/3/08	Mon 3/3/08
39	Implement flow loss mitigation structures	120 days	Mon 3/3/08	Fri 8/15/08
40	Sunol Valley flow loss assessment	120 days	Mon 8/18/08	Fri 1/30/09
41	**Element #4. Biological and physical evaluation of rubber dam pools**	**120 days**	**Tue 4/1/08**	**Mon 9/15/08**
42	**Task 1. Evaluate steelhead habitat potential in pools**	**120 days**	**Tue 4/1/08**	**Mon 9/15/08**
43	**Task 2. Evaluate predator populations in pools**	**120 days**	**Tue 4/1/08**	**Mon 9/15/08**
44	**Element #5. Water temperature monitoring and modeling**	**825 days**	**Thu 11/1/07**	**Wed 12/29/10**
45	**Task 1. Annual temperature monitoring**	**825 days**	**Thu 11/1/07**	**Wed 12/29/10**
46	**Task 2. Establish water temperature thresholds**	**20 days**	**Tue 1/1/08**	**Mon 1/28/08**
47	**Task 3. Develop water temperature model**	**200 days**	**Tue 1/1/08**	**Mon 10/6/08**
48	Experimental releases	20 days	Mon 6/2/08	Fri 6/27/08
49	Model development	200 days	Tue 1/1/08	Mon 10/6/08
50	**Task 4. Evaluate reservoir stratification dynamics**	**100 days**	**Thu 11/1/07**	**Wed 3/19/08**
51	**Task 5. Re-assess pool stratification in mainstem channels**	**120 days**	**Tue 4/1/08**	**Mon 9/15/08**
52	**Task 6. Re-assess pool stratification in rubber dam pools**	**120 days**	**Tue 4/1/08**	**Mon 9/15/08**
53	**Element #6. Turbidity monitoring and assessment**	**825 days?**	**Thu 11/1/07**	**Wed 12/29/10**
54	**Task 1. Monitor turbidity**	**1 day?**	**Thu 11/1/07**	**Thu 11/1/07**
55	Synoptic measurements	120 days	Mon 12/3/07	Fri 5/16/08
56	Long-term monitoring	825 days	Thu 11/1/07	Wed 12/29/10
57	**Task 2. Idendity turbidity sources**	**20 days**	**Mon 5/19/08**	**Fri 6/13/08**
58	**Element #7. Develop steelhead recovery options in lower Alameda Creek**	**359 days**	**Thu 11/1/07**	**Tue 3/17/09**
59	**Task 1. Quantify steelhead habitat**	**60 days**	**Wed 10/1/08**	**Tue 12/23/08**
60	**Task 2. Evaluate high flow hydraulics of different restoration actions**	**120 days**	**Wed 10/1/08**	**Tue 3/17/09**
61	**Task 3. Measure longitudinal salinity profile**	**120 days**	**Tue 4/1/08**	**Mon 9/15/08**
62	**Task 4. Measure longitudinal temperature profile**	**120 days**	**Tue 4/1/08**	**Mon 9/15/08**
63	**Task 5. Develop steelhead recovery options in the flood channel**	**120 days**	**Thu 11/1/07**	**Wed 4/16/08**
64	**Task 6. Coordinate estuary restoration**	**120 days**	**Thu 4/17/08**	**Wed 10/1/08**
65	**Element #8. Basinwide water management operations model and data manageme**	**825 days**	**Thu 11/1/07**	**Wed 12/29/10**
66	**Task 1. Characterize basinwide hydrologic conditions**	**120 days**	**Fri 2/1/08**	**Thu 7/17/08**
67	Summarize historical streamflow, reservoir, and climatic information	120 days	Fri 2/1/08	Thu 7/17/08
68	Summarize reservoir operations, criteria, capabilities, constraints	120 days	Fri 2/1/08	Thu 7/17/08
69	**Task 2. Develop water operations/routing model**	**300 days**	**Fri 2/1/08**	**Thu 3/26/09**
70	**Task 3. Organize/coordinate data collection, management, and analyses**	**825 days**	**Thu 11/1/07**	**Wed 12/29/10**
71	Logitudinal stationing	5 days	Thu 11/1/07	Wed 11/7/07
72	Streamflow gaging	825 days	Thu 11/1/07	Wed 12/29/10
73	Temperature data	825 days	Thu 11/1/07	Wed 12/29/10
74	Turbidity data	825 days	Thu 11/1/07	Wed 12/29/10
75	Fish production data	400 days	Thu 10/30/08	Wed 5/12/10
76	Adult escapement	400 days	Thu 10/30/08	Wed 5/12/10
77	Redd surveys	400 days	Thu 10/30/08	Wed 5/12/10
78	Centralized database development	120 days	Tue 4/1/08	Mon 9/15/08
79	Database O&M	595 days	Tue 9/16/08	Mon 12/27/10
80	**Element #9. Consideration of other species in steelhead recovery effort**	**200 days**	**Thu 1/1/09**	**Wed 10/7/09**
81	**Task 1. Identify opportunities for restoring Chinook salmon life history need**	**200 days**	**Thu 1/1/09**	**Wed 10/7/09**
82	**Task 2. Identify opportunities for restoring non-salmonid life history needs**	**200 days**	**Thu 1/1/09**	**Wed 10/7/09**
83	**Task 3. Identify opportunities for restoring amphibian life history needs**	**200 days**	**Thu 1/1/09**	**Wed 10/7/09**
84	**Element #10. Phase II synthesis and refinement of population recovery strategies**	**586 days**	**Thu 11/1/07**	**Thu 1/28/10**
85	**Task 1. Establish a steelhead population recovery goal**	**200 days**	**Thu 11/1/07**	**Wed 8/6/08**
86	Use SAR curves and juvenile fish densities to estimate existing and future ad	200 days	Thu 11/1/07	Wed 8/6/08
87	**Task 2. Summarize and integrate results of study plan elements**	**200 days**	**Fri 3/27/09**	**Thu 12/31/09**
88	**Task 3. Identify and assess important remaining uncertainties**	**20 days**	**Fri 1/1/10**	**Thu 1/28/10**



Project: Study plan timeline.mpp
Date: Sat 9/1/07

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Page 1

Figure 14. Gantt chart showing links between Elements and tasks, and initial timing and duration estimates.

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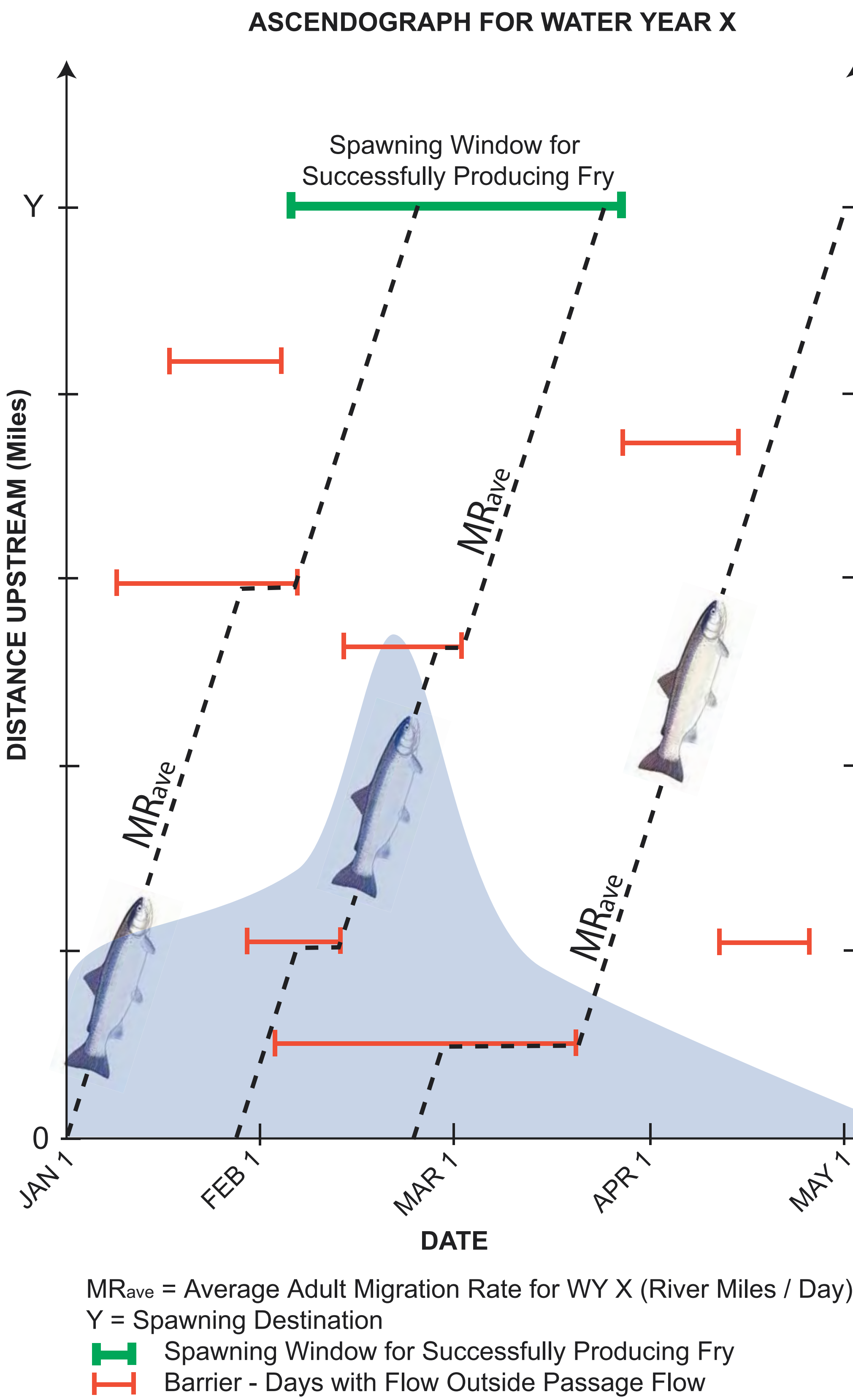

Figure 15. Ascendograph for assessing steelhead spawning success.

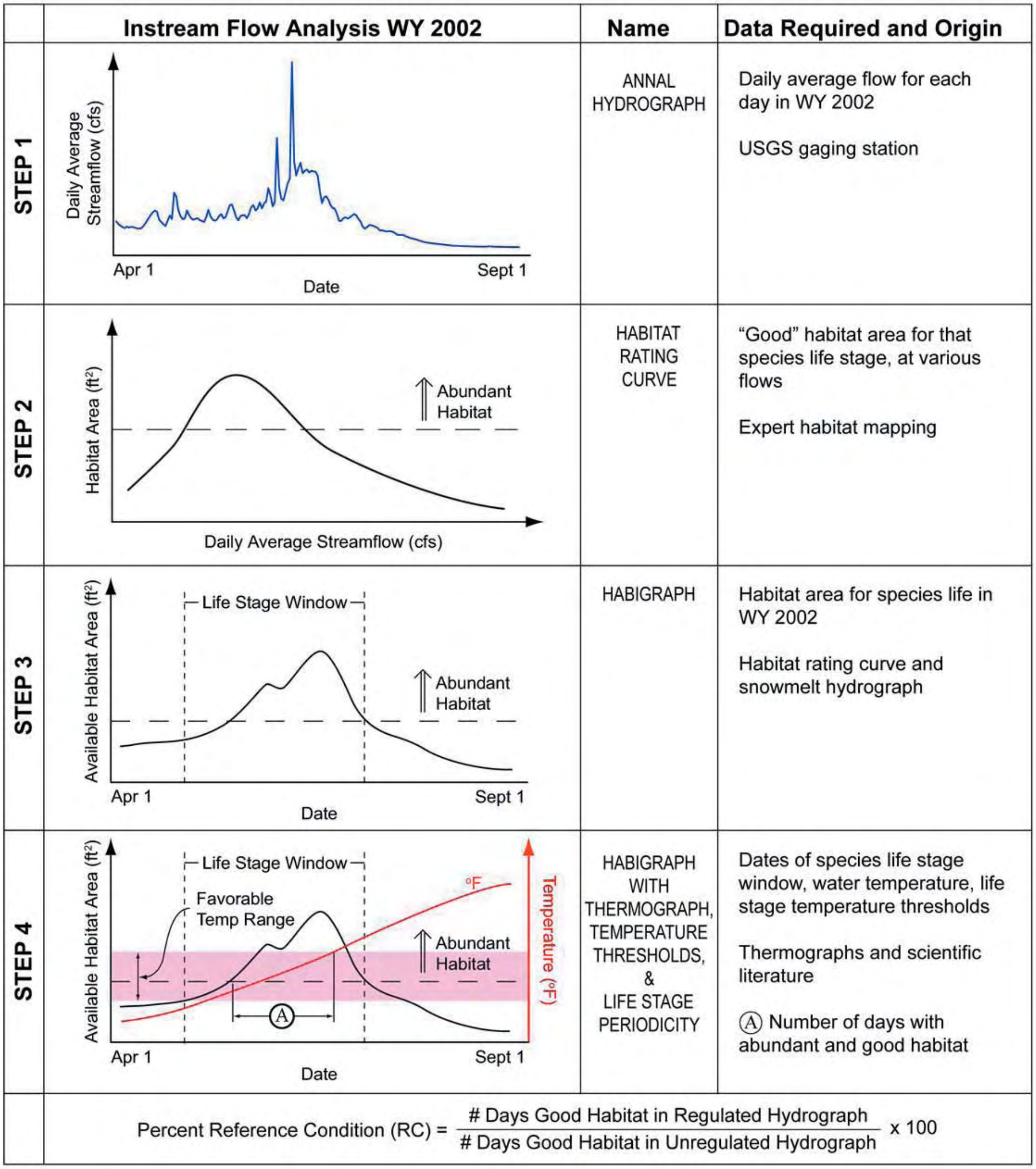

Figure 16. Framework for instream flow analysis.

Table 1. Streamflow gaging station locations within the Alameda Creek watershed.

Summary of Available Daily Average and Peak Streamflow and Reservoir Data in the Alameda Creek Watershed						
USGS Gage Number	**USGS Station Name**	**Drainage Area (sq. mi.)**	**Regulated Drainage Area (sq. mi.)**	**Period Of Record**	**Pre-Dam Period of Record**	**Post-Dam Period of Record**
11172500	LAGUNA C A IRVINGTON CA	12.5	NA	1916-1919	NA	NA
11172945	ALAMEDA C AB DIV DAM NR SUNOL CA	33.3	NA	1994-Present	NA	NA
11173000	ALAMEDA CR NR SUNOL CA	37.5	NA	1911-1930	NA	NA
11173200	ARROYO HONDO NR SAN JOSE CA	77.1	NA	1968-1981, 1994-Present	NA	NA
11173500	CALAVERAS C NR SUNOL CA	98.7	98.7	1898-1908, 1910-1930, 2002-Present	1898-1915	1916-1930, 2002-Present
11173510[a]	ALAMEDA C BL CALAVERAS C NR SUNOL CA	135.0	98.7	1995-Present	NA	1995-Present
11173550[b]	ALAMEDA C TRIB NO 2 NR WARM SPRINGS CA	0.5	NA	1959-1973	NA	NA
11173560[b]	ALAMEDA C TRIB NO 1 NR WARM SPRINGS CA	0.4	NA	1959-1973	NA	NA
11173575	ALAMEDA C BL WELCH C NR SUNOL CA	145.0	98.7	1999-Present	NA	1999-Present
11174000	SAN ANTONIO C NR SUNOL CA	37.0	37.0	1912-1930, 1960-1965, 1999-Present	1912-1930, 1960-1964	1965, 1999-Present
11174450	BIG CYN C NR DUBLIN CA	1.1	NA	1959-1964	NA	NA
11174500	ALAMO C A DUBLIN CA	38.7	NA	1914-1920	NA	NA
11174600	ALAMO CN NR PLEASANTON CA	40.8	NA	1979-1983	NA	NA
11175000	TASSAJERO C NR PLEASANTON CA	26.8	NA	1914-1930	NA	NA
11176000	ARROYO MOCHO NR LIVERMORE CA	38.2	NA	1912-1930, 1965-2002	NA	NA
11176090	ARROYO MOCHO A LIVERMORE CA	50.8	NA	1983-1985	NA	NA
11176100	ARROYO LAS POSITAS AB LIVERMORE CA	7.8	NA	1971-1974	NA	NA
11176140	ALTAMONT C NR LIVERMORE CA	13.4	NA	1978-1980	NA	NA
11176145	ARROYO LAS POSITAS A LIVERMORE CA	53.3	NA	1980-1985	NA	NA
11176150	ARROYO LAS POSITAS NR LIVERMORE CA	64.6	NA	1912-1930	NA	NA
11176180	ARROYO LAS POSITAS A ELCH RD NR PLEASANTON CA	75.0	NA	1977-1983	NA	NA
11176200	ARROYO MOCHO NR PLEASANTON CA	142.0	NA	1962-1985	NA	NA
11176300	TASSAJARA C NR PLEASANTON CA	26.8	NA	1914-1930, 1980-1983	NA	NA
11176350	ARROYO DE LA LAGUNA AB AV NR PLEASANTON CA	224.0	NA	1974-1979	NA	NA
11176400	ARROYO VALLE BELOW LANG CN NR LIVERMORE CA	130.0	NA	1963-Present	NA	NA
11176500	ARROYO VALLE NR LIVERMORE CA	147.0	147.0	1912-1930, 1957-Present	1912-1930, 1957-1967	1968-Present
11176550[b]	ARROYO VALLE TRIB NR LIVERMORE CA	3.6	NA	1959-1973	NA	NA
11176600	ARROYO VALLE A PLEASANTON CA	171.0	147.0	1957-1986	1957-1967	1968-1986
11176900	ARROYO DE LA LAGUNA A VERONA CA	403.0	147.0	1912-1930, 1969-1983, 1987-Present	NA	NA
11177000	ARROYO DE LA LAGUNA NR PLEASANTON CA	405.0	130.0	1912-2003	NA	NA
11179000	ALAMEDA C NR NILES CA	633.0	282.7	1891-Present	1891-1915	1915-Present
11179005[b]	ALAMEDA C TRIB NR NILES CA	0.3	NA	1959-1973	NA	NA
11180000	ALAMEDA C NR DECOTO CA	639.0	282.7	1916-1919	NA	1916-1919
11180500	DRY C A UNION CITY CA	9.4	NA	1916-1919, 1959-Present	NA	NA
11180700	ALAMEDA C FLOOD CHANNEL A UNION CITY CA	639.0	282.7	1958-Present	NA	1958-Present
11180750	ALAMEDA C A UNION CITY CA	653.0	282.7	1958-1973	NA	1958-1973

Notes:
(a) Low flow gage only - no data above 200 cfs
(b) Peak flow data only

Table 2. Water temperature monitoring locations within the Alameda Creek watershed.

Summary of Available Temperature Monitoring Locations in the Alameda Creek Watershed						
Source	**Location**	**Station**	**Station ID**	**Start Date**	**End Date**	**Continuous**
ACFCWCD	No Location Available	N/A	Brightside	8/1/1999	12/1/1999	Yes
ACFCWCD	In Alameda Creek at Middle Rubber Dam 51,200 feet upstream from San Francisco Bay at a depth of 1.0 meter	Alameda Creek 512+00	Middle RD 1.0 M depth	7/1/1999	9/1/1999	Yes
ACFCWCD	In Alameda Creek at Middle Rubber Dam 51,200 feet upstream from San Francisco Bay at a depth of 2.1 meters	Alameda Creek 512+00	Middle RD 2.1M Depth	7/1/1999	9/1/1999	Yes
ACFCWCD	No Location Available	N/A	Stonybrook	8/1/1999	12/1/1999	Yes
ACFCWCD	No Location Available	N/A	Sunol Dam	8/1/1999	12/1/1999	Yes
ACFCWCD	In Alameda Creek at Upper Rubber Dam 56,300 feet upstream from San Francisco Bay at a depth of 2.3 meters	Alameda Creek 563+00	Upper RD 2.3 M Depth	7/1/1999	9/1/1999	Yes
ACWD	In Alameda Creek at Alameda Creek Water Quality Monitoring Station 60,000 feet upstream of San Francisco Bay	Alameda Creek 600+00	ACWQMS	8/1/1996	2/1/2007	Yes
Hanson Environmental	No Location Available	N/A	359397	3/1/2002	9/20/2002	No
Hanson Environmental	In Alameda Creek 7,350 feet upstream of Arroyo de La Laguna confluence	Alameda Creek 973+50	10-W	4/1/2001	8/12/2002	No
Hanson Environmental	In Alameda Creek 115,500 feet upstream from San Francisco Bay at confluence of Welch Creek	Alameda Creek 1155+00	12-W	4/1/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 6,750 feet downstream from Calaveras Creek confluence	Alameda Creek 1282+50	13-W	4/3/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 2,500 feet downstream from Welch Creek confluence	Alameda Creek 1135+00	14b-W	2/24/2001	11/5/2003	No
Hanson Environmental	In Calaveras Creek 5,000 feet downstream from Calaveras Reservoir	Calaveras Creek 1350+00	14-W	4/3/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 100 feet upstream from Calaveras Creek confluence	Alameda Creek 1351+00	15-W	4/3/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 600 feet upstream from Calaveras Creek confluence	Alameda Creek 1356+00	16-W	5/17/2003	11/5/2003	Yes
Hanson Environmental	In Alameda Creek 2,200 feet upstream from Calaveras Creek confluence	Alameda Creek 1372+00	17-W	N/A	N/A	N/A
Hanson Environmental	In Alameda Creek 22,000 feet upstream from San Francisco Bay	Alameda Creek 220+00	21-W	3/18/2001	8/5/2002	No
Hanson Environmental	In Alameda Creek 28,000 feet upstream from San Francisco Bay	Alameda Creek 280+00	22-W	3/18/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek Flood Channel 14,500 feet updstream from San Francisco Bay	Alameda Creek 145+00	23-W	3/18/2001	8/5/2002	No
Hanson Environmental	In Alameda Creek 200 feet upstream from Upper Rubber Dam	Alameda Creek 565+00	24-W	3/18/2001	7/19/2002	No
Hanson Environmental	In Alameda Creek 2,750 feet upstream from Alameda Creek Water Quality Monitoring Station	Alameda Creek 627+50	25-W	3/18/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 43,500 feet upstream from San Francisco Bay	Alameda Creek 435+00	26-W	3/21/2001	8/5/2002	No
Hanson Environmental	In Alameda Creek 2,300 feet upstream from Middle Rubber Dam	Alameda Creek 535+00	3-W	4/3/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 400 feet upstream from Alameda Creek Water Quality Monitoring Station	Alameda Creek 604+00	4-W	8/26/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 6,300 feet upstream from Alameda Creek Water Quality Monitoring Station	Alameda Creek 663+00	5-W	4/3/2001	8/5/2002	No
Hanson Environmental	In Stonybrook Creek	N/A	6-W	4/3/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 8,600 feet downstream of Arroyo de La Laguna confluence	Alameda Creek 814+00	7-W	4/3/2001	8/5/2002	No
Hanson Environmental	In Alameda Creek 3,750 feet downstream of Arroyo de La Laguna confluence	Alameda Creek 862+50	8-W	4/3/2001	3/2/2002	Yes
Hanson Environmental	In Arroyo de La Laguna 3,000 feet upstream of confluence with Alameda Creek	Arroyo de La Laguna 930+00	9-W	4/3/2001	11/5/2003	No
Hanson Environmental	In Alameda Creek 250 feet downstream of Arroyo de La Laguna confluence	Alameda Creek 897+50	DS Arroyo de La Laguna	5/21/2003	11/5/2003	Yes
Hanson Environmental	No Location Available	N/A	SBA /Vallecitos Creek	6/20/2003	11/7/2003	Yes
Hanson Environmental	In Alameda Creek 100 feet upstream from Welch Creek confluence	Alameda Creek 1156+00	Site 16	4/28/2001	9/27/2001	Yes
Hanson Environmental	In Alameda Creek 28,000 feet upstream from San Francisco Bay	Alameda Creek 280+00	Site 1A	4/28/2001	9/27/2001	Yes
Hanson Environmental	In Alameda Creek 500 feet downstream from Alameda Creek Water Quality Monitoring Station	Alameda Creek 595+00	Site 1B	4/28/2001	9/27/2001	Yes
Hanson Environmental	In Alameda Creek 43,200 feet upstream from San Francisco Bay	Alameda Creek 432+00	Site 2B	4/28/2001	6/25/2001	Yes
Hanson Environmental	In Alameda Creek 9,500 feet downstream of Arroyo de La Laguna confluence	Alameda Creek 805+00	Site 6A	4/28/2001	9/27/2001	Yes
Hanson Environmental	In Alameda Creek 2,000 feet upstream from Calaveras Creek confluence	Alameda Creek 1370+00	US Little Yosemite	5/17/2003	11/5/2003	Yes
Hanson Environmental	No Location Available	N/A	Vallecitos Creek DS SBA	6/20/2003	11/7/2003	Yes
Hanson Environmental	No Location Available	N/A	Vallecitos US	5/2/2003	11/7/2003	Yes

Table 2. Continued.

Source	Location	Station	Station ID	Start Date	End Date	Continuous
Hanson Environmental	In Welch Creek at confluence with Alameda Creek 115,500 feet upstream from San Francisco Bay	N/A	Welch Creek	5/17/2003	11/5/2003	Yes
SFPUC	No Location Available	N/A	DS Arroyo Hondo (trap moving DS)	3/7/2003	6/19/2003	Yes
SFPUC	No Location Available	N/A	DS Indian (trap moving DS)	3/4/2003	6/19/2003	Yes
SFPUC	No Location Available	N/A	DS San Antonio (trap moving DS)	3/5/2003	6/8/2003	Yes
SFPUC	In Alameda Creek 500 feet downstream from Welch Creek confluence	Alameda Creek 1150+00	T- 7b	5/25/2000	1/26/2001	Yes
SFPUC	In Alameda Creek 300 feet upstream from Calaveras Creek confluence	Alameda Creek 1353+00	T-1	7/14/1998	11/30/2006	No
SFPUC	In Calaveras Creek 2,300 feet downstream from Calaveras Reservoir	Calaveras Creek 1377+00	T-10	5/22/2001	11/30/2006	No
SFPUC	No Location Available	N/A	T-11	6/18/2001	11/20/2001	Yes
SFPUC	In Alameda Creek 2,7200 feet upstream from Calaveras Creek confluence	Alameda Creek 1622+00	T-12	6/11/2003	11/30/2006	No
SFPUC	In Alameda Creek 2,1200 feet upstream from Calaveras Creek confluence	Alameda Creek 1562+00	T-13	6/13/2003	11/30/2006	No
SFPUC	In Alameda Creek 14,200 feet upstream from Calaveras Creek confluence	Alameda Creek 1492+00	T-14	6/11/2003	11/30/2006	No
SFPUC	In Alameda Creek 5,500 feet upstream from Calaveras Creek confluence	Alameda Creek 1405+00	T-15	6/11/2003	9/4/2003	Yes
SFPUC	No Location Available	N/A	T-16	7/14/2003	11/30/2006	No
SFPUC	No Location Available	N/A	T-17	7/1/2003	11/30/2006	No
SFPUC	No Location Available	N/A	T-18	6/13/2003	11/30/2006	No
SFPUC	No Location Available	N/A	T-19	6/13/2003	11/30/2006	No
SFPUC	In Calaveras Creek 4,500 feet downstream from Calaveras Reservoir	Calaveras Creek 1355+00	T-2	7/14/1998	11/30/2006	No
SFPUC	No Location Available	N/A	T-21	6/13/2003	11/30/2006	No
SFPUC	No Location Available	N/A	T-22B	6/8/2006	11/30/2006	Yes
SFPUC	No Location Available	N/A	T-22S	6/8/2006	11/30/2006	Yes
SFPUC	In Alameda Creek 100 feet downstream from Calaveras Creek confluence	Alameda Creek 1340+00	T-3	7/14/1998	11/30/2006	No
SFPUC	In Alameda Creek 12,000 feet downstream from Calaveras Creek confluence	Alameda Creek 1230+00	T-4	7/14/1998	11/30/2006	No
SFPUC	In Alameda Creek 2,100 feet downstream from Welch Creek confluence	Alameda Creek 1134+00	T-5	7/14/1998	11/30/2006	No
SFPUC	In Alameda Creek feet 3,000 feet upstream from Welch Creek confluence	Alameda Creek 1185+00	T-6b	7/10/1999	11/18/1999	Yes
SFPUC	In Alameda Creek feet 3,000 feet upstream from Welch Creek confluence	Alameda Creek 1185+00	T-6s	5/25/2000	1/26/2001	Yes
SFPUC	In Alameda Creek feet 500 feet downstream from Welch Creek confluence	Alameda Creek 1150+00	T-7s	7/10/1999	11/30/2006	No
SFPUC	No Location Available	N/A	T-8	5/25/2000	12/1/2000	No
SFPUC	No Location Available	N/A	US Arroyo Hondo (trap moving US)	1/25/2003	4/12/2003	Yes
SFPUC	No Location Available	N/A	US Indian (trap moving US)	1/15/2003	1/15/2003	Yes
SFPUC	No Location Available	N/A	US San Antonio (trap moving US)	1/10/2003	4/30/2003	Yes
USGS	In Alameda Creek 62,750 feet upstream from San Francisco Bay near Niles gaging station	Alameda Creek 627+50	USGS @ Niles	11/24/1965	4/29/2005	Yes
Zone 7 Water Agency	In Arroyo Mocho 66,925 feet upstream from confluence with Arroyo de La Laguna	Arroyo Mocho 1969+25	L1 Mines Road	6/28/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo Mocho 50,290 feet upstream from confluence with Arroyo de La Laguna	Arroyo Mocho 1802+90	L10 Robertson Park	7/19/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo del Valle 54,250 feet upstream from confluence with Arroyo de La Laguna	Arroyo del Valle 1782+50	L2 Arroyo Rd Bridge	7/3/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo Mocho 12,140 feet upstream from confluence with Arroyo de La Laguna	Arroyo Mocho 1421+40	L3 AMP Gage Station	6/21/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo Mocho 60,050 feet upstream from confluence with Arroyo de La Laguna	Arroyo Mocho 1900+50	L4 Murietas Well Winery Bridge	6/21/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo del Valle 23,000 feet upstream from confluence with Arroyo de La Laguna	Arroyo del Valle 1470+00	L5 Shadow Cliffs Park	6/21/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo Mocho 15,660 feet upstream from confluence with Arroyo de La Laguna	Arroyo Mocho 1456+60	L6 Martin Rd US AMP	7/19/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo Mocho 2,590 feet upstream from confluence with Arroyo de La Laguna	Arroyo Mocho 1325+90	L7 Hopyard Rd	6/28/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo del Valle 53,150 feet upstream from confluence with Arroyo de La Laguna	Arroyo del Valle 1771+50	L8 Veterans Park	6/28/2002	11/2/2002	Yes
Zone 7 Water Agency	In Arroyo del Valle 7,200 feet upstream from confluence with Arroyo de La Laguna	Arroyo del Valle 1312+00	L9 ADVP Gage station	6/28/2002	11/2/2002	Yes

Table 3. Historic, current, and proposed turbidity monitoring locations within the Alameda Creek watershed.

Summary of Proposed and Existing Turbidity Monitoring Locations in the Alameda Creek Watershed						
Source	**Location**	**Station**	**Station ID**	**Start Date**	**End Date**	**Continuous**
USGS	Alameda Creek near Niles Gaging Station 11-179000	Alameda Creek 630+00	11-179000	WY2007	N/A	Yes
USGS	Alameda Creek below Welch Creek Gaging Station 11-173575	Alameda Creek 1130+00	11-173575	WY2008	N/A	Yes
USGS	Arroyo de La Laguna at Verona Gaging Station 11-176900	Arroyo de La Laguna 1070+00	11-176900	WY2008	N/A	Yes
ACWA	Alameda Creek Water Quality Monitoring Station at Exit of Niles Canyon and Upstream of Rupper Dam #3	Alameda Creek 600+00	N/A	7/1/1996	Present	No
ACWA	South Bay Aqueduct on Vallecitos Creek	N/A	N/A	8/22/1996	Present	Yes

Table 4. Summary of linkages between management issues and Study Plan Elements 78

Study Plan Element #	Description of Study Plan Element	Management Issues Addressed	Approximate Cost of Study Plan Element	Approximate Duration of Study Plan Element
1	Quantification of Steelhead Habitat	#2. Quantify rearing habitat as a function of instream flows #3. Manage dam releases to improve rearing conditions	$50k to $75k per study reach, total cost $350k to $525k for 7 study reaches	Approximately one year for field work; assessment and integration is in SPE#10
2	Adult Steelhead Passage Assessment	#1. Spawning habitat accessibility #3. Manage dam releases to improve rearing conditions	Approximately $75k	Approximately 1.5 years
3	Barrier Removal, Retrofit Design, and Remediation	#1. Spawning habitat accessibility #8. Can Alameda Creek above Little Yosemite Canyon be a viable contributor to recovery? #9. Fish passage through Sunol Valley	Passage assessment less than $50k per structure, Geomorphic evaluation less than $75k	Approximately 1.5 years
4	Evaluation of Rubber Dam Backwater Pools	#4. Are rubber dam impoundments a benefit or neutral to juvenile steelhead?	Steelhead habitat evaluation and predator population less than $75k.	Approximately 5 months for initial work (Tasks 1 and 2)
5	Water Temperature Monitoring and Modeling	#1. Spawning habitat accessibility #2. Quantify rearing habitat as a function of instream flows #3. Manage dam releases to improve rearing conditions #4. Are rubber dam impoundments a benefit or neutral to juvenile steelhead? #5. Can restoring lower Alameda Creek flood channel improve smolt size and production? #6. Restore estuary to improve steelhead benefits #7. Consider other aquatic species in recovery strategy	Monitoring approximately $50k/year, develop model is approximately $100k	Monitoring over several years, model development approximately 1 year
6	Stream Turbidity Monitoring and Assessment	#4. Are rubber dam impoundments a benefit or neutral to juvenile steelhead? #5. Can restoring lower Alameda Creek flood channel improve smolt size and production? #7. Consider other aquatic species in recovery strategy #10.Establish an adult steelhead population recovery goal	Synoptic less than $1.5k per event, continuous monitoring by USGS is $10k per year per station	Synoptic over a 6-month winter period, continous monitoring done over many years
7	Recovery Options for Lower Alameda Creek Flood Channel	#5. Can restoring lower Alameda Creek flood channel improve smolt size and production? #10.Establish an adult steelhead population recovery goal	Approximately $375k	Approximately 1 year
8	Water Operations Model and Data Management	#1. Spawning habitat accessibility #3. Manage dam releases to improve rearing conditions #4. Are rubber dam impoundments a benefit or neutral to juvenile steelhead? #5. Can restoring lower Alameda Creek flood channel improve smolt size and production? #10.Establish an adult steelhead population recovery goal	Hydrologic analysis less than $20k, model approximately $50k to $100k, data management approximately $15k to $50k per year	Approximately 1.5 year
9	Considering Other Aquatic Species in Restoration	#7. Consider other aquatic species in recovery strategy	Most costs covered by other Elements	Approximately 10 months
10	Synthesis and Refinement of Recovery Strategies	#1. Spawning habitat accessibility #2. Quantify rearing habitat as a function of instream flows #3. Manage dam releases to improve rearing conditions #4. Are rubber dam impoundments a benefit or neutral to juvenile steelhead? #5. Can restoring lower Alameda Creek flood channel improve smolt size and production? #6. Restore estuary to improve steelhead benefits #7. Consider other aquatic species in recovery strategy #8. Can Alameda Creek above Little Yosemite Canyon be a viable contributor to recovery? #9. Fish passage through Sunol Valley #10.Establish an adult steelhead population recovery goal	Approximately $175,000	Approximately 2 years, but dependent on SPE#1 and others

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Appendix A

Summary of reports and data reviewed as part of the study plan effort.

Summary of Available Information on the Alameda Creek Watershed

Title	Year Published	Author	Description
Occurrence Of Native Fishes in Alameda and Coyote Creeks, California	1976	Aceituno, Nicola and Follett, CDFG	Fish species assemblages and age classes from 4 sites in Alameda Creek collected in 1973. Data compared to collections made in 1905 and 1966.
Lower Alameda Creek Fish Passage Improvements	N/A	ACOE	ACOE/ACWD plans for modificiation of fish barries in flood channel.
Lower Alameda Creek Fish Passage Improvements, PrelimiN/Ary Restoration Plan	N/A	ACOE	ACOE project description of proposed channel improvements.
ACWD Data Resources and other Relevant Operations Information (DRAFT)	N/A	ACWD	Sources of flow and temperature data for ACWD operation.
Various Web Printouts	N/A	ACWD	History of basin and diversions.
DRAFT Alternatives Evaluation Report - Lower Alameda Creek/BART Weir Fish Passage Assessment (Superceded by 12/06 Final Report)	2006	ACWD, Wood Rodgers and Ken Bates	
A Look At Fish Populations In Arroyo Mocha, Welch, And Pirates Creek (Unpublished. Electro Fishing Data).	1999	Alameda County Public Works Department	Fish findings from the Arroyo Mocho gorge area.
Background on ACWD Groundwater Recharge Facilities (DRAFT)	2007	ACWD	Workings of the groundwater facilities at the rubber dams.
Alliance Comments on SFPUC Calaveras Dam Replacement	2002	Alameda Creek Alliance	Conditions on their support fot the removal of diversion dam.
Alliance Letter Regarding Zone 7's Plans to Restore SH to Mocho and Livermore Valley	2002	Alameda Creek Alliance	Suggests Zone 7 consider steelhead in planning.
Links to Fish Passage Projects	1996	Alameda Creek Alliance	Links to reports.
Status Review for Central CA Coast Steelhead	2002	Alameda Creek Alliance	Letter to NMFS and CCC to keep steelhead on Endangered List and general watershed information.
Alameda Creek - 90 Years of Neglect	2005	Alameda Creek Alliance	Timeline of Alameda Creek dam construction and last sightings of Coho and steelhead.
Alameda Creek Alliance Position Paper on Fish Transport Issues	2005	Alameda Creek Alliance	Arguments against Endangered Species Act, transport of fish past blockages, genetic concerns.
Alameda Creek Alliance Position Paper Regarding the Proposed SFPUC Recapture Facility in Sunol Valley	2001	Alameda Creek Alliance	States concerns (habitat loss / water temperature) over planned rubber dam downstream of Calaveras Reservoir.
Alameda Creek Press Releases and Media Articles	through 2006	Alameda Creek Alliance	Listing of press releases and articles.
Termination of the Sunol Gravel Quarry Leases	2002	Alameda Creek Alliance	Position paper recommending termination of Sunol gravel leases.
Fish Passage Projectes; 8 Sites with Descriptions and Photos of Restoration to Fish Passage Barriers	N/A	Alameda Creek Alliance	Press releases and general webpages.
Initial Comments on Stream Management Master Plan (Zone 7)	2004	Alameda Creek Alliance	Comments on Zone 7's Notice of Preparation of a Master EIR for the Stream Management Master Plan.
Welch Creek Stream Survey	2003	Alameda Creek Alliance	

Title	Year Published	Author	Description
Arroyos Steelhead Documentation	N/A	Alameda Creek Alliance	
Alameda Creek: Electroshock Sampling Data Sheets	1995-1999	Alexander, P. / EBRPD	Electoshocking data from Alameda Creek. Notes that property owners stocked fish below Ohlone section of Upper Alameda over the past 50 years.
The 1955 Fish Rescue Report for Region 3	2005	Allen, J.T. / CDFG	200 fingerling steelhead rescued from dry channel in Alameda Creek.
Field Notes: Zoology Class Seine Net Fish Survey.	1967	Barlow, D.	Steelhead caught in April at Stanley Bridge, Old Canyon Road, Niles Canyon.
Steelhead Passage in Lower Alameda Creek, Alameda County, CA. Draft Manuscript	1999	Becker, G.S.	Mapped barries on Alameda Creek, surveyed below BART to identify other passage contraints.
Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan	1993	BioSystems	Feasibility of establishing a trout fishery in portions of Calaveras and Alameda Creeks using flows from Calaveras Reservoir.
Alameda Creek Watershed Study, Fishery Restoration Feasibility Evaluation and Preliminary Restoration Plan - Final Report	1993	BioSystems	Feasibility of establishing a trout fishery in portions of Calaveras and Alameda creeks using flows from Calaveras Reservoir without negatively impacting native non-game fishes.
An Analysis of Historical Population Structure for Evolutionarily Significant Units of Chinook Salmon, Coho Salmon, and Steelhead in the North-Central California Coast Recovery Domain	2005	Bjorkstedt, Eric P., Brian C. Spence, John Carlos Garza, David G. Hankin, David Fuller, Weldon E. Jones, Jerry J. Smith, Richard Macedo	NOAA Technical Memorandum NMFS
Importance of Estuarine Rearing to Central California Steelhead (Oncorhynchus mykiss) Growth and Marine Survival	2006	Bond, Morgan H.	
Conceptual Engineering Report for the Alameda Creek Fishery Water Recapture Facility	1997	Bookman-Edmonston Engineering	Assessment of alternatives for recapturing waters released from Calaveras Reservoir as defined in a 1997 MOU between CDFG and SFPUC.
Alameda Creek Water Resources Study, Report on Water Recovery Facilities	1994	Bookman-Edmonston Engineering	Engineering alternatives for recapturing flows that would be released from Calaveras Reservoir to support a rainbow trout fishery.
Alameda Creek Water Resources Study	1995	Bookman-Edmonston Engineering	Documents historical and current water resources in sections of Calaveras and Alameda Creeks that would be affected by operations of Calaveras Dam.
Alameda Creek Water Resources Study, Report on Watershed Operations	1994	Bookman-Edmonston Engineering	Documents the availability of requisite flows for supporting a trout fishery downstream of Calaveras Reservoir.
Unpublished Data from CDFG Files, Yountville Office	2002	CADGE	Documents of steelhead populations; from the 1950's.
Alameda Creek Stream Inventory Study	1996	California Department of Fish and Game	
Alameda Creek, Alameda County, Stream Inventory	1996	California Department of Fish and Game	Documents habitat conditions, fish species distributions and relative abundances in Alameda Creek in the areas that would be affected by release of water from Calaveras Dam.
Draft Steelhead Restoration Action Plan for the Alameda Creek Watershed	2003	CEMAR	Plan of action, based on Gunther, Hagar and Salop (2000), for implementation of Alameda Creek steelhead restoration.
Master Plan Development: Costestimate.xls, Evaluationmatrixtable.xls and Masterplanmemo.doc	N/A	CEMAR	
Conceptual Design and Feasibility of a Natural Fishway at the Fremont BART Weir, Alameda Creek, California. FINAL REPORT	2005	CEMAR	
Conceptual Fish Passage Designs and Cost Estimates for Lower Alameda Creek	2001	CH2MHill	Retrofits to ACOE Channel, recommend fish ladders with sliding doors and fish screens.
A Preliminary Assessment of Potential Steelhead Habitat in Sinbad Creek	2004	Christy Herron, Mary Ann King Kristen McDonald	Report on barries, gravel habitat and flows on Sinbad Creek.

Title	Year Published	Author	Description
Upper Alameda Creek Urban Study; Fish; G44251, Volume 2	1981	Corps of Engineers, San Francisco District	Surveys count 9 native and 4 non-native fish species in Alameda Creek. Steelhead thought to be gone from Creek, but recent runs noted.
Preliminary Draft Biological Assessment for the Alameda Creek Fisheries Enhancement Project	2001	EA Engineering, Balloffet and Associates, The Ellington Group	
Potential Anadramous Fish Population Size Based Upon Flow Released from Different Source Locations in the Alameda Creek Watershed	1987	EBRPD / Burger, K.	
Alameda Watershed Management Plan	2001, 2003, 2006	EDAW, Inc.	Potential impacts associated with the facility designed to recapture waters released from Calaveras Reservoir as stipulated in a 1997 MOU between CDFG and the SFPUC.
Sunol Valley Resources Management Element	1998	EDAW, Inc.	Estimate of steelhead population size assuming 10 cfs in flood channel. No analysis of how assumptions would be implemented.
Aquatic Resource Characterization of Western Mt. Hamilton Stream Fisheries	1999	Eisenberg, Olivieri & Associates	Documents SFPUC's plans and provides a policy framework for making consistent decisions about Alameda Creek Watershed activities, practices and procedures. Includes goals for habitat improvement.
Summary of Aquatic Surveys and Five-Year Study Plan for the Alameda Creek Watershed	2003	Entrix, Inc.	Documents activities in Sunol Valley and addresses the existing and future activities while minimizing the conflicts between these activities.
Aerial Survey of the Upper Alameda Creek Watershed to Assess Potential Rearing Habitat for Steelhead Fall 2002	2003	Entrix, Inc.	Status of aquatic resources, especially significant fishery resources, as well as stressors and existing activities that may alleviate such stresses.
2002 Fish Trapping Study Data Summary for San Antonio Creek and Arroyo Hondo	2003	Entrix, Inc.	Summarizes studies conducted in the Alameda Creek Watershed. Develops a study plan that addresses what is not known about the watershed.
Alameda Creek Juvenile Steelhead Downstream Migration Flow Requirements Evaluation, Phase 1: Field Survey Results	2004	Entrix, Inc.	Documents the amount of wetted channel in Upper Alameda Creek with potential to provide rearing habitat for rainbow trout.
Alameda Creek Streamflow Study	2005	Entrix, Inc.	Documents the migratory timing, to and from their tributaries, of adult, juvenile and YOY rainbow trout from SFPUC's two East Bay reservoirs.
Preliminary Report opn Alameda Creek Watershed Fish Trapping, 2002 (Unpublished Report for SFPUC)	2002	Entrix, Inc.	Documents flow losses through Sunol Valley, the relationship between flow and downstream passage conditions for juvenile salmonids, and the amount of flow required to provide suitable downstream passage under a variety of water year conditions.
Productivity of the Calaveras and Upper Alameda Creek Systems	1933	Eppler, W.L.	Flow characteristics through Sunol Valley at higher magnitude streamflow releases than what has been previously investigated.
SFPUC Sunol/Niles Dam Remove Project EIR	2005	ESA	
Fish Passage Improvement - Barrier Modification (DRAFT)	2005	Federation of Fly Fishers	
Fish Passage Improvement - Barrier Modification, Concrete Weir and Apron [aka USGS Gauging Station], Preliminary Design Report and Project Information	2005	Federation of Fly Fishers	
University Fish Collections as cited by Leidy (1984)	1953	Follett and Peckham	
University Fish Collections as cited by Leidy (1984)	1955	Follett and Peckham	
University Fish Collections as cited by Leidy (1984)	1957, 1958	Follett and Peckham	Fish species present in lower Alameda Creek.
Arroyo Mocho * Arroyo Las Positas * Arroyo Seco * Arroyo Del Valle * Arroyo De La Laguna Power Point Presentation	N/A	Friends of the Arroyos	Fish species present in lower Alameda Creek.
Memo To File Re: Alameda Creek, Alameda County Fish Population Sampling	1988	Gray, F. / CDFG	Fish species present in lower Alameda Creek.

Title	Year Published	Author	Description
An Assessment of the Potential for Restoring a Viable Steelhead Trout Population in the Alameda Creek Watershed	2000	Gunther, Hagar and Salop, Applied Marine Science, Hagar Environmental	Power Point presentation on fish resources and issues within the Arroyos in Zone 7.
Supplementation Alternatives for Restoration of a Viable Steelhead Run to Alameda Creek	2004	Hagar Environmental Science	Leidy et al. (2003) states they sampled upstream of Calaveras Creek confluence in 9/1987 and found 15 50-81mm fork length.
Presentation for the Zone 7 Board of Directors Regarding the Evaluation of the Potential Historic Occurrence of Steelhead within the Livermore Amador Valley	2003	Hanson Environmental	Potential for restoring steelhead in Alameda Creek, actions necessary to begin restoration and the remaining uncertainties facing restoration efforts.
In Stream Habitat Typing within Alameda Creek (Draft)	2002	Hanson Environmental	
Air and Water Temperature Monitoring within Alameda Creek: 2001-2002 (Draft)	2002	Hanson Environmental	Results of recent field surveys of habitat in Livermore-Amador Valley.
Air and Water Temperature Monitoring within Alameda Creek: 2003	2003	Hanson Environmental	Habitat quality, availability and constraints for steelhead spawning and rearing in Alameda Creek. Includes GPS locations of study areas.
Diel Water Quality Monitoring within Alameda Creek: 2001 (Draft)	2002	Hanson Environmental	Temperature and dissolved oxygen conditions within the Alameda Creek watershed. Identifies locations of suitable steelhead rearing habitat.
Reconnaissance Investigation of the Relationship Between in Stream Flow and Adult Steelhead Passage within Alameda Creek: 2001-2002 (Draft)	2002	Hanson Environmental	Temperature and dissolved oxygen conditions within the Alameda Creek watershed. Identifies locations of suitable steelhead rearing habitat.
Fisheries Related Feasibility Studies Power Point Presentation on Calaveras Dam	2006	HDR/SWRI	Water quality conditions within Alameda Creek.
University Fish Collections as cited by Leidy (1984)	1961	Hopkirk	Documents surveys to measure range and frequency of flow depths suitable for successful passage of adult steelhead in Alameda Creek. GPS coordinates of sections and some flow analysis.
University Fish Collections as cited by Leidy (1984)	1966	Hopkirk	Proposal to perform work.
Photograph of Coho Caught Along Concrete Wall on Old Pottery Road, Black Fly	1964	Janssen, H.	Fish species present in Lower Alameda Creek.
Population Genetic Structure of Alameda Creek Rainbow/Steelhead Trout - 2002	2003	Jennifer Nielsen	Fish species present in Lower Alameda Creek.
Paleoclimatic Signature in Terrestrial Flood Deposits	1992	Koltermann, Christine E. and Steven M. Gorelick	Photo of two (2) Coho salmon caught in Niles Canyon.
Distribution and Ecology of Stream Fishes in the San Francisco Bay Drainage	1984	Leidy R.A.	Genetic relationships between rainbow trout collected in the Alameda Creek Watershed and other regional salmonids.
Historical Records of the Fish Distribution for Streams Draining into San Francisco Bay	2003	Leidy R.A.	
Historical Distribution and Current Status of Steelhead (Oncorhynchus mykiss), Coho Salmon (O. kisutch), and Chinook Salmon (O. tshawytscha) in Streams of the San Francisco Estuary, California	2003	Leidy, Becker and Harvey	Documents all known historical fish survey records for streams draining into San Francisco Bay.
Historical Distribution and Current Status of Steelhead/Rainbow Trout (Oncorhynchus mykiss) in Streams of the San Francisco Estuary, California	2005	Leidy, Becker and Harvey	Documents the current and historical (past 125 years) fish distribution information for streams draining into San Francisco Bay.
Zoogeography, Ecology, and Distribution of Stream Fishes of the San Francisco Bay Estuary, CA	N/A	Leidy	A synthesis of the decades of observations of steelhead and rainbow trout in the streams tributary to the San Francisco Estuary, including Alameda Creek.
Historical Status of Coho Salmon in Streams in the Urbanized San Francisco Estuary, California.	2005	Leidy, Becker and Harvey	A synthesis of the decades of observations of steelhead and rainbow trout in the streams tributary to the San Francisco Estuary, including Alameda Creek.
Unpublished Stream Survey Data, 1992-2002	2002	Leidy, R.A..	Documentation of steelhead populations.

Title	Year Published	Author	Description
Historic Distribution and Current Status of Steelhead, Coho Salmon, and Chinook Salmon in Alameda County Streams	2003	Leidy, Becker and Harvey	
San Francisco Water Supply Investigations: Discharge of Calaveras and Alameda Creeks	1912	Marx, C.D. and C.E. Grunsky	Leidy et al. (2003) indicates that 1992, 1993, 1994 and 1996 samples found steelhead upstream and just downstream of diversion dam, below the Ohlone regional park, Sunol regional park, Niles Canyon and below the Old Spring Valley diversion dam at the top of Niles Canyon.
Stonybrook Creek Fish Passage Assessment	2001	Michael Love & Associates	Historic distributions in Alameda County.
Fish Passage Assement of Private Stream Crossings on Lower Stonybrook Creek	2005	Michael Love & Associates	
Stonybrook Creek Salmonid Migration Barrier Removal Project	2005	Michael Love and Associates, Winzler and Kelly	Assessment of fish passage at road crossings on Stonybrook Creek.
University Fish Collections as cited by Leidy (1984)	1939	Miller and Murphy	Fish species present in Alameda Creek within Niles Canyon.
Alameda Creek Steelhead Documentation, including subset of A. Mocho (unpublished), Alliance Position Paper	2006	Miller, J.	Rebuttal of "Evaluation of the Potential Historical and Current Occurrence of Steelhead within the Livermore-Amador Valley".
Evaluation of the Potential Historical and Current Occurrence of Steelhead within the Livermore-Amador Valley	2004	Hanson, C.H., Hanson Environmental, Inc., Sowers, J., William Letis & Associates, Pastron, A., Archeo-Tech, Inc.	Focuses on Arroyo Mocho and Arroyo Valle, historic and current presence, geomorpholoy, habitat and current opportunties and constraints for supporting steelhead.
Migratory Fish Stream Report for the Livermore, Pleasanton and Dublin-Tri-Valley (Unpublished Manuscript)	2002	Moir, R.	Migratory fish stream report for the Livermore, Pleasanton and Dublin Tri-Valley Area.
Alameda Creek, Alameda County, Stream Inventory Report - DRAFT	1995	Murphy, K. and N. Sidhom / CDFG	Leidy et al. (2003) states that authors sampled 8 sites in upper Alameda Watershed in July 1995. Electoshocked 68-79 steelhead.
Microsatellite Analyses of Alameda Creek Rainbow/Steelhead Trout	2005	Nielson, Jennifer, USGS and Monique Fountain, Stanford University	Fish in Alameda creek not related to hatchery strains, but closer to coastal trout in Lagunitas Creek, Marin County and other areas.
Final Critical Habitat Designations in Washington, Oregon, Idaho and California for Endangered and Threatened Pacific Salmon and Steelhead	2005	NOAA	NOAA's proposed inclusion of Alameda Creek Watershed resident rainbow trout as an element of the Central California Coast Steelhead Evolutionary Significant Unit.
Alameda Creek Revegetation/Restoration Report	1993	Ogden Environmental	Assessment of riparian conditions in portions of Calaveras and Alameda Creeks.
Stream Survey Alameda Creek	1957	Pintler, H.E. / CDFG	Visual assessment of 62 miles of Alameda Creek and tributaries for habitat for survival and reproduction.
Online Database of Fish Survey Data from Collections by the United States Environmental Protection Agency (1992-1998)	1999	San Francisco Estuary Institute	Qualitative fish surveys from streams draining into San Francisco Bay.
Additional Records on the Distribution and Status of Native Fishes in Alameda and Coyote Creek, California	1978	Scoppettone and Smith / CDFG	Corrected and updated information presented in Aceituno et al. (1976).
Memo To Fisheries Management Region 3: RE: Arroyo De La Laguna, Alameda County, Fish Population Sampling, 9 April 1976	1976	Scoppettone G. / CDFG	Population sampling in Arroyo de La Laguna.
Memo To Fisheries Management Region 3: RE: Arroyo De La Laguna, Alameda County, Fish Population Sampling, February 18 1976	1976	Scoppettone G. / CDFG	Population sampling in Arroyo de La Laguna.
Memo To Fisheries Management Region 3: RE: Arroyo De La Laguna, Alameda County, Fish Population Sampling, February 19 1976	1976	Scoppettone G. / CDFG	Population sampling in Arroyo de La Laguna.
Memo To Fisheries Management Region 3: RE: Stonybrook Canyon Creek (Tributary to Alameda Creek) , Fish Population Sampling, 8 April 1976	1976	Scoppettone G. / CDFG	Population sampling in Stonybrook Canyon Creek
Fish Population Sampling, Arroyo Mocho Creek, Alameda County. Memo To File	1976	Scoppettone G. / CDFG	Population sampling in Arroyo Mocho.

Title	Year Published	Author	Description
Aquarium Fishes from a California Stream	1934	Seal	Native warm water fishes from Alameda Creek that are tolerant and suitable for aquarium use.
Feasibility Study for Removal and/or Modification of Fish Passage Barriers at the Sunol and Niles Dams	2000	SFPUC	Feasibility of removing or modifying the two dams with the purpose of enhancing fish passage.
Alameda Creek Aquatic Resource Monitoring Report 2000	2002	SFPUC	Condition of Upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
Alameda Creek Aquatic Resource Monitoring Report 2001	2002	SFPUC	Condition of Upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
Sunol and Niles Dam Fish Fauna Investigations	2002	SFPUC	Fish fauna present at and near the Sunol Dam and Niles Dam removal sites as part of the environmental impact assessment process.
Sunol and Niles Dam California Red-Legged Frog Protocol Survey	2003	SFPUC	Presence or absence of CRLF's at and near the Sunol Dam and Niles Dam removal sites as part of the environmental impact assessment process.
Sunol/Niles Dam Removal Engineering Conceptual Design Draft Report	2003	SFPUC	
San Antonio Creek, Indian Creek and Arroyo Hondo Fish Trapping Data Summary 2003	2004	SFPUC	Migratory timing of adult, juvenile and YOY rainbow trout from the SFPUC's two East Bay reservoirs to and from their tributaries.
Alameda Creek Aquatic Resource Monitoring Report 2002	2004	SFPUC	Condition of Upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
Sunol Dam, Great Blue Heron Rookery Monitoring, 2003 - 2004	2005	SFPUC	Time of fledging for birds in the rookery upstream of Sunol Dam.
Accessibility of Calaveras Reservoir Fishes, Especially Rainbow Trout (Oncorhynchus mykiss), to Arroyo Hondo During Low Water Conditions	2005	SFPUC	Hydraulic and habitat conditions at the Arroyo Hondo/Calaveras Reservoir confluence while the reservoir is kept low in response to DSOD's seismic and CDFG steelhead habitat concern.
Alameda Creek Aquatic Resource Monitoring Report 2003	2005	SFPUC	Condition of Upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
Rainbow Trout Predation By Largemouth Bass at San Antonio and Calaveras Reservoirs	N/A	SFPUC	Affects that largemouth bass populations are having on YOY and juvenile rainbow trout entering the reservoirs from tributaries.
Alameda Creek Aquatic Resource Monitoring Report 2004	2006	SFPUC	Condition of Upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
2005 Urban Watershed Management Plan San Francisco	2005	SFPUC	Water supply, demand management and operational alternatives for existing and future. Plans for steelhead restoration flows and supplies.
Various Web Printouts	N/A	SFPUC	History of basin and diversions.
Water Supply Master Plan	2000	SFPUC	General history of basin and diversions, proposed demand and future plans to use Sunol gravel quarries as reservoirs.
Popluation Size Estimates for Adult Rainbow Trout (Oncorhynchus mykiss) in San Antonio and Calaveras Reservoirs	2005	SFPUC	
Needs Assessment & Alternatives Analysis, Alameda Creek Fishery Enhancement Project	2004	SFPUC	Re-assessment of the alternatives for recapturing waters released from Calaveras Reservoir as originally identified in Bookman-Edmonston (1996).
Population Size Estimates for Adult Rainbow Trout (Oncorhynchus mykiss) in San Antonio and Calaveras Reservoirs	2005	SFPUC	Size of the adult rainbow trout populations in the SFPUC's two East Bay reservoirs.
San Antonio Creek, Indian Creek and Arroyo Hondo Fish Trapping Data Summary 2004	N/A	SFPUC	Migratory timing of adult, juvenile and YOY rainbow trout from the SFPUC's two East Bay reservoirs to and from their tributaries.

Title	Year Published	Author	Description
Alameda Habitat Conservation Plan	N/A	SFPUC	
Alameda Creek Aquatic Resource Monitoring Report 2005	N/A	SFPUC	Condition of Upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
San Antonio Creek, Indian Creek and Arroyo Hondo Fish Trapping Data Summary 2005 and Project Summary	N/A	SFPUC	Migratory timing of adult, juvenile and YOY rainbow trout from the SFPUC's two East Bay reservoir to and from their tributaries. (Report is a 4-year summary).
Accessibility of Rainbow Trout to Arroyo Hondo During a Calaveras Reservoir Drawdown	2004	SFPUC	Hydraulic conditions at the Arroyo Hondo/Calaveras Reservoir confluence while the reservoir is kept low in response to DSOD's seismic concerns.
CDFG Fish Collections as cited by Leidy (1984)	1937	Shapovalov	Fish species present in Alameda Creek near its confluence with Calaveras Creek.
Field Notes Regarding Alameda Creek	1938	Shapovalov, L. / CDFG	Steelhead sightings in Alameda Creek and stocking notes.
Lake Survey Calaveras Reservoir	1905	Shapovalov, L. / CDFG	
Letter to C.E. Holladay Re: Trout Scales from Arroyo Hondo.	1937	Shapovalov, L. / CDFG	
Stream Survey Arroyo Mocho Creek	1944	Shapovalov, L. / CDFG	
Stream Survey Calaveras Creek	1938	Shapovalov, L. / CDFG	Sightings at Sunol Dam by Calaveras Dam workers, 4000 planted fish in Calaveras Creek near confluence in 1937.
A Historical Review of the Fish and Wildlife Resources of the San Francisco Bay Area	1962	Skinner / CDFG	Historic sightings from Leidy.
Steelhead and other Fish Resources of Streams on the West Side of San Francisco Bay (Unpublished)	199	Smith, J.J.	Population information
Steelhead and other Fish Resources of Western Mount Hamilton Streams	2005	Smith, Jerry	Current and historic patterns of steelhead distribution in Alameda Creek.
Notes on the Fishes of the Streams Flowing into San Francisco Bay, California	1905	Snyder	Fish species present in streams draining into San Francisco Bay.
Historical Geomorphology of Arroyo Valle and Mocho with Notes on Historical Steelhead Migration. Livermore-Amador Valley	2005	Sowers, J.M.	Flow analysis at Niles and link to Livermore-Amador steelhead passage.
University Fish Collections as cited by Leidy (1984)	1927	Stanford University and Follett	Fish species present in Alameda Creek within Niles Canyon.
Map of Fish Passage Barriers in Alameda Creek Watershed	N/A	State of California Department of Water Resources	General map of Alameda Creek Watershed with barriers to fish indicated.
Establishment of a Steelhead Fishery in Alameda Creek	1989	Technical Committee	Four alternatives with respect to establishment of a steelhead fishery.
Aquatic Resource Characterization of Western Mt. Hamilton Stream Fisheries	1999	Buchan, Leidy and Hayden / The Nature Conservancy	Native species in upper reaches.
Analysis of Impacts of Dam Removal, Niles and Sunol Dams, Alameda Creek	2000	Trihey & Associates, Inc.	Documents whether removal of the dams to improve fish passage is feasible considering the impacts to riparian vegetation, groundwater levels, sedimentation, flood control and access.
Pilot Macroinvertebrate Bioassessment, Alameda Creek Project, Draft Report.	2001	Trihey & Associates, Inc.	A baseline macroinvertebrate survey of Alameda Creek between Little Yosemite and the Sunol Valley Water Treatment Plant as an indicator of stream health.

Title	Year Published	Author	Description
Pilot Fish Trapping Study on San Antonio Creek and Arroyo Hondo (Draft)	2001	Trihey & Associates, Inc.	Feasibility of methods for conducting a fish trapping study to assess population numbers and run timing of reservoir populations of rainbow trout.
Alameda Creek Aquatic Resource Monitoring Report Summer and Fall, 1998	1999	Trihey & Associates, Inc.	Condition of Upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
Alameda Creek Aquatic Resource Monitoring Report Summer and Fall, 1999	2001	Trihey & Associates, Inc.	Condition of upper Alameda Creek and its fish populations as specified in a 1997 MOU between CDFG and SFPUC.
Sunol Valley Surface/Groundwater Interaction Study	2002	Trihey & Associates, Inc.	Flow study conducted through the Sunol Valley in the fall of 2001 to assess the flow loss to groundwater in this reach of Alameda Creek.
Sunol Valley Surface Flow Study Fall 2001	2003	Trihey & Associates, Inc.	Surface flow movements in Alameda Creek and water gains or losses in Sunol Valley at the end of the dry season (mid to late October).
Lower Alameda Creek Fish Passage Improvements Preliminary Restoration Plan	2003	USCOE	Population documentation and passage restoration.
An Appraisal of Surface Water Quality in the Alameda Creek Basin, October 1974-June 1979; G44251 M1	1979	USGS	
Hydrologic Study of the Alameda Creek Watershed above Niles	2000	Water Resources Engineering, Inc.	
Conceptual Designs for Two Stonybrook Creek Salmonid Migration Barrier Removal Projects	2005	Winzler and Kelly, Michael Love and Associates	
Alternatives Evaluation Report - Lower Alameda Creek/BART Weir Fish Passage Assessment	2006	Wood Rodgers	Fish passage alternatives studied for BART weirs.
Case Study: Chain of Lakes Project	2003	Zone 7 Water Resources Management	Study of using Chain of Lakes for groundwater infiltration, future flow diversions to Arroyo Mocho planned and un-infiltrated flows to be diverted into lakes via a rubber dam.
Various Web Printouts	N/A	Zone 7 Water Resources Management	History of basin and diversions.
2003-2004 Biennial Report	N/A	Zone 7 Water Resources Management	Report on Zone 7 Operations. Brochure.
Stream Management Master Plan Brochure	N/A	Zone 7 Water Resources Management	General information on the Master Plan.
Urban Watershed Management Plan	2000	Zone 7, Environmental Sciences Associates	Planned Chain of Lakes infiltration via Arroyo Mocho.
Zone 7 Stream Management Master Plan EIR	2006	Zone 7, Environmental Sciences Associates	EIR for Master Plan, plans for wetland creation, fisheries enhancements and background data.
Draft Program Environmental Impact Report: Zone 7 Water Agency Supply Program	1999	Zone 7, Environmental Sciences Associates	2000 operations and supply and demand.
Final Stream Management Master Plan	N/A	Zone 7 Water Resources Management	Sediment analysis, hydraulic analyses and Chain of Lakes improvements.

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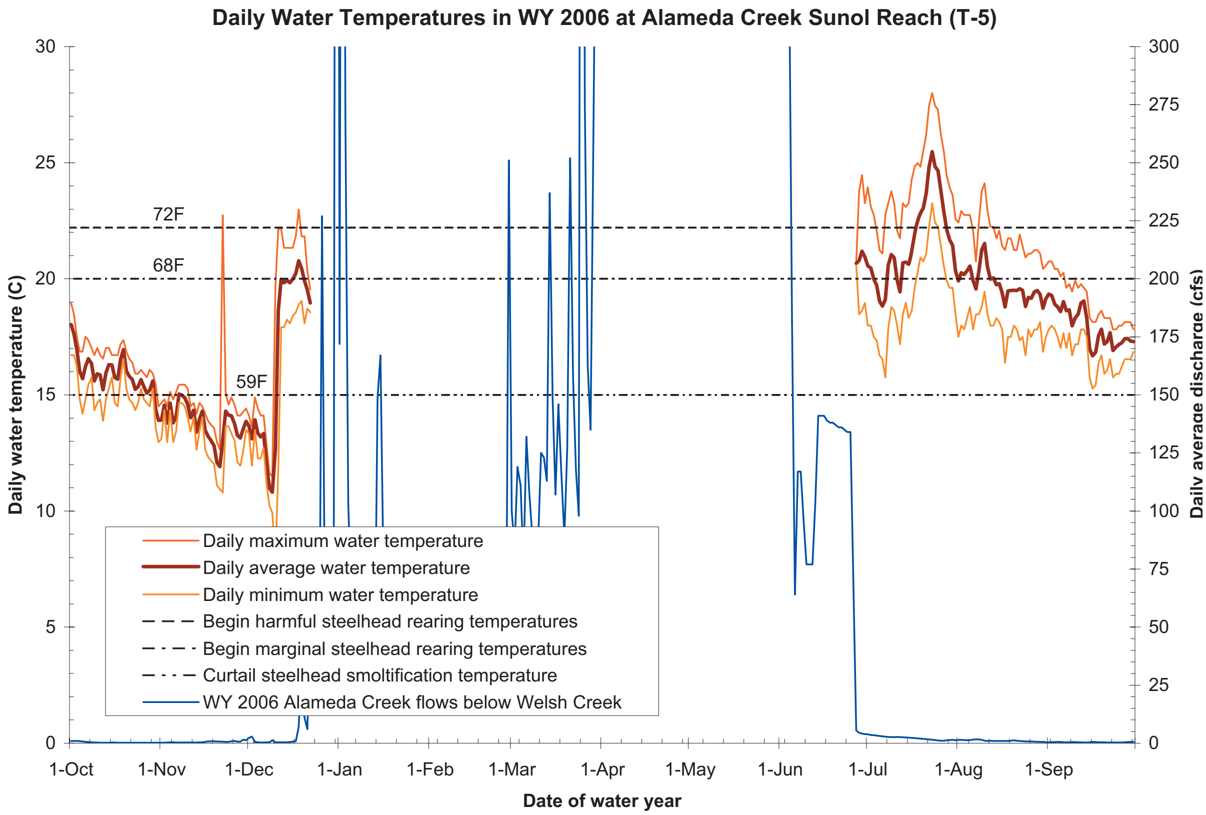
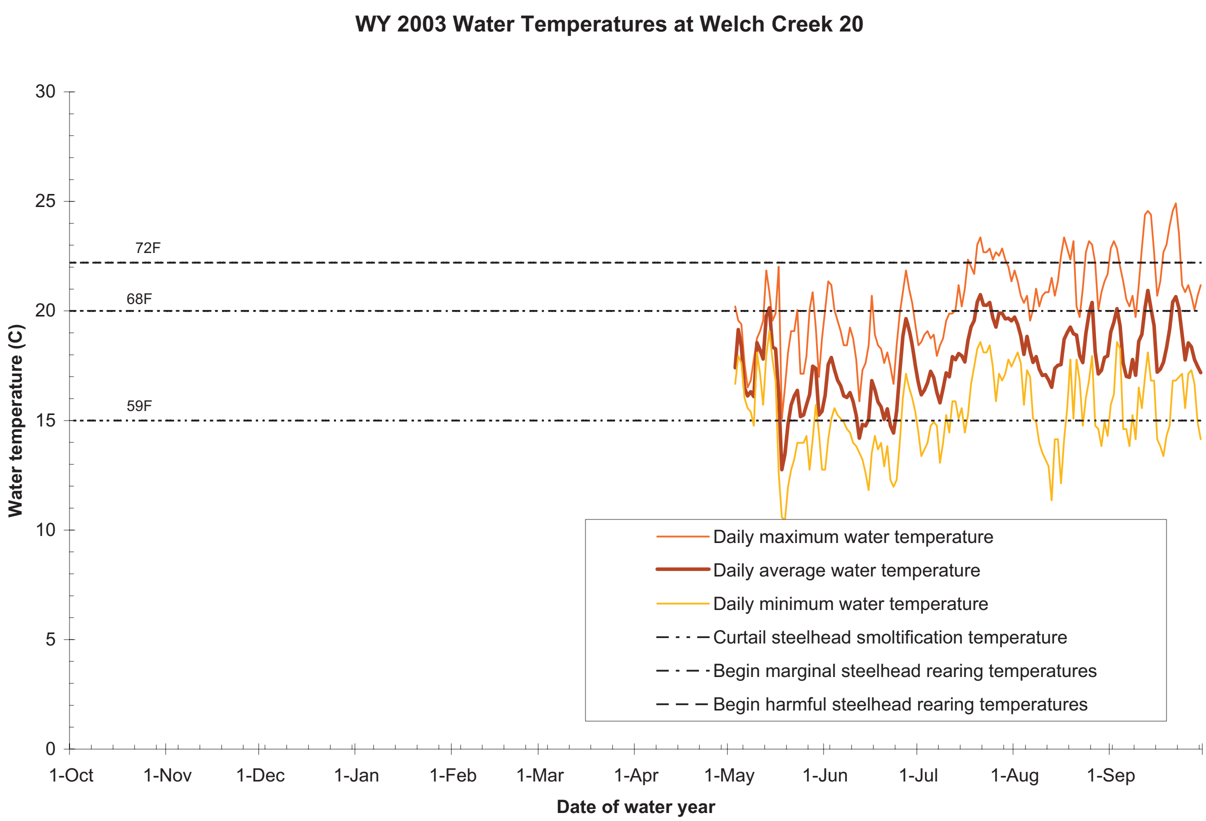
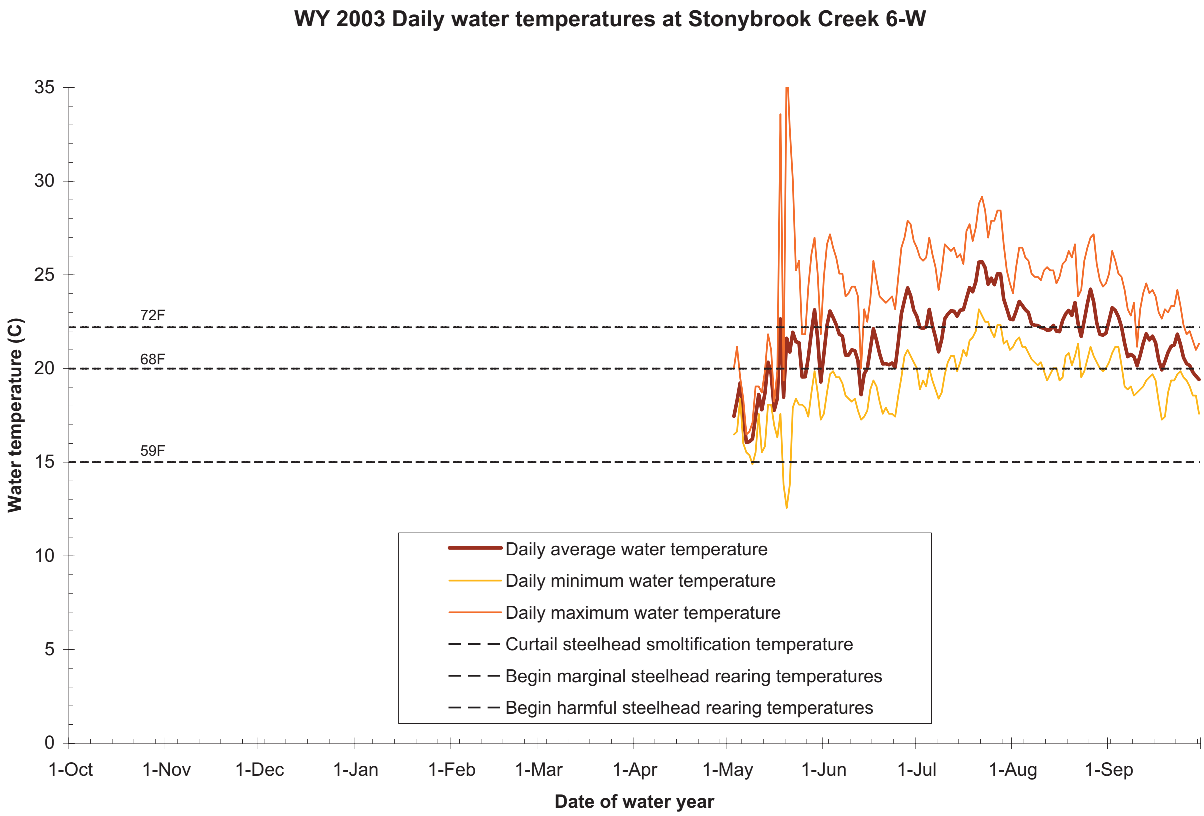
Appendix B

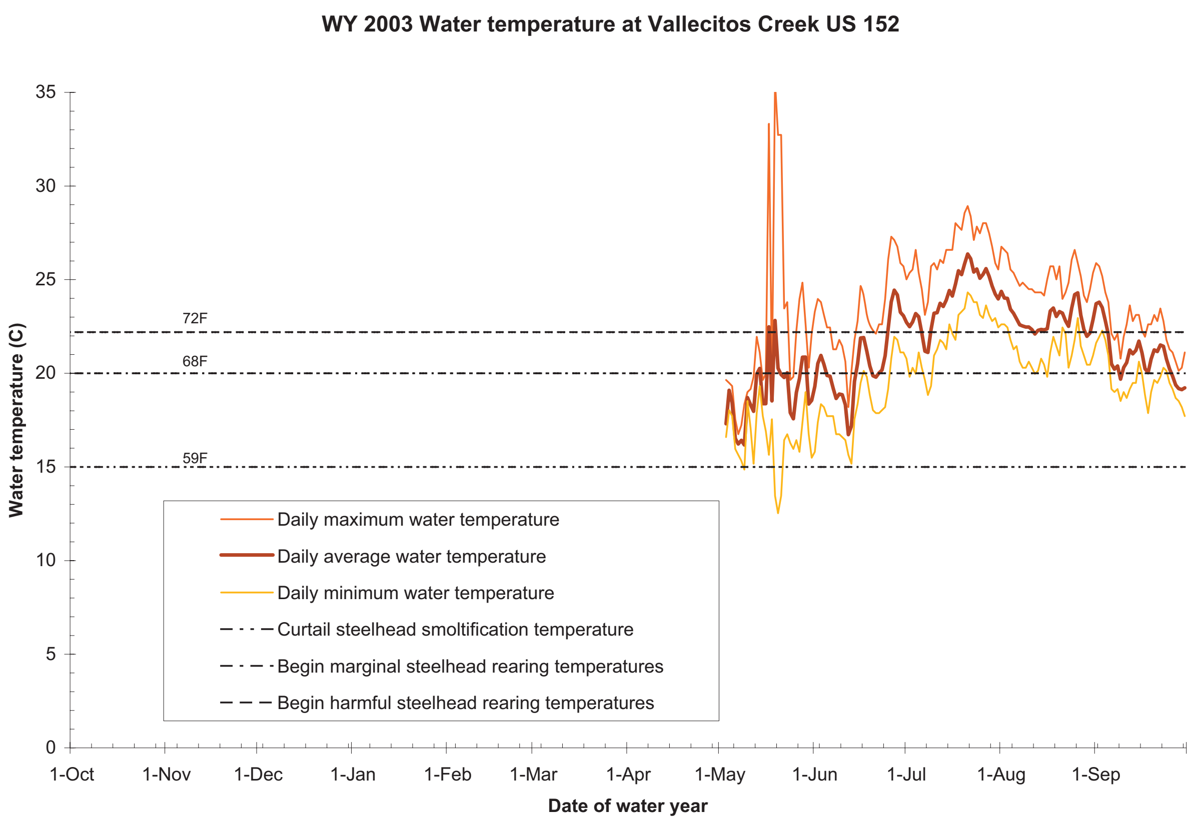
Selected plots of stream water temperatures at various locations within the Alameda Creek watershed.

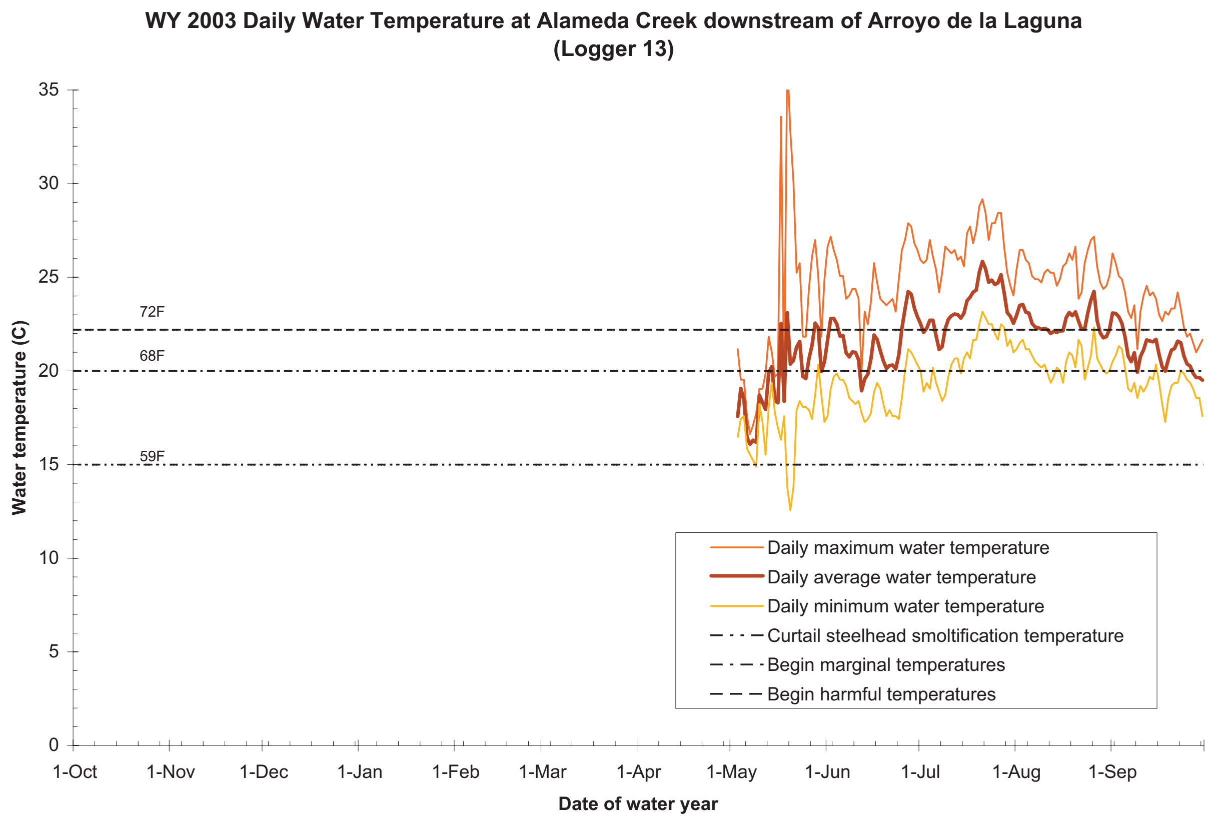
WY 2006 Alameda Creek below Welch Creek
WY 2003 Welch Creek
WY 2003 Stonybrook Creek
WY 2003 Vallecitos Creek
WY 2003 Alameda Creek below Arroyo de la Laguna
WY 2002 Arroyo de la Laguna below Vallecitos Creek
WY 2002 Alameda Creek upstream of middle rubber dam
WY 2002 Alameda Creek in lower flood control channel

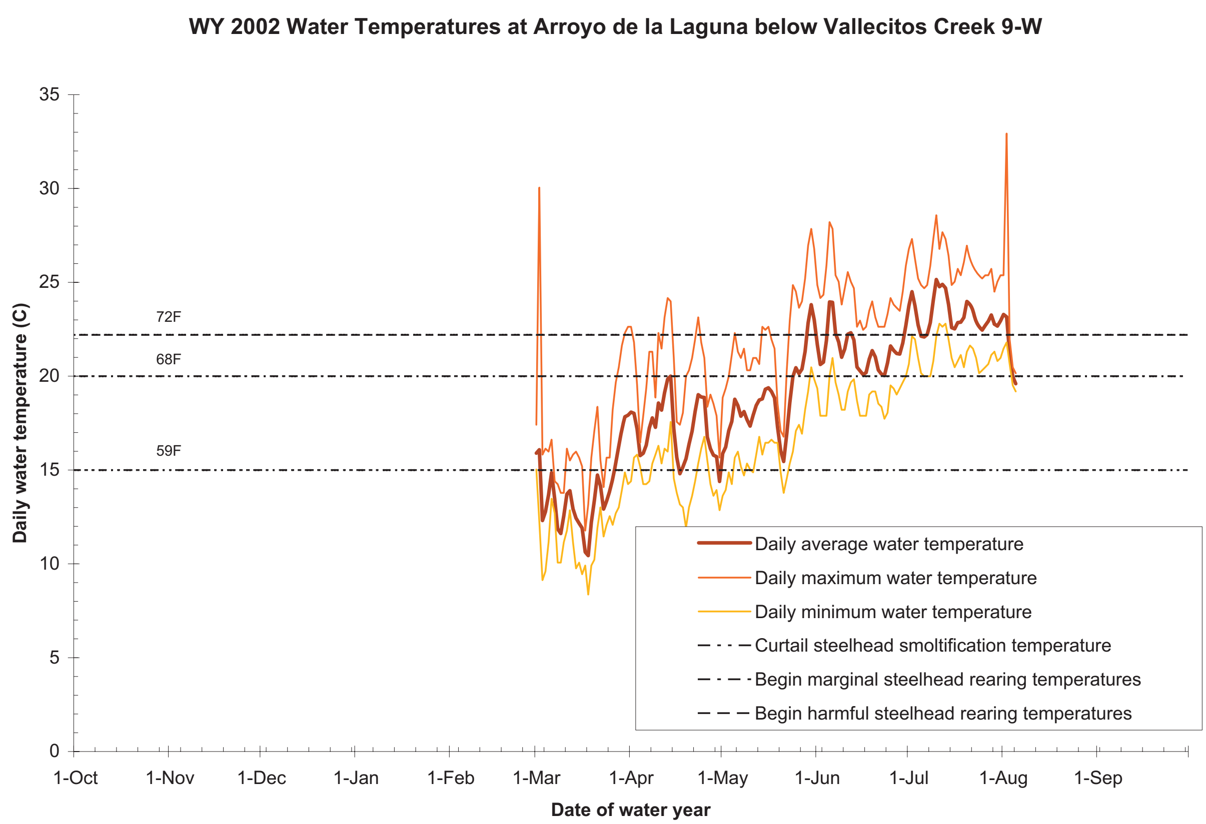

Daily Water Temperatures in WY 2006 at Alameda Creek Sunol Reach (T-5)
72F
68F
59F
Daily water temperature (C)
Daily average discharge (cfs)
Daily maximum water temperature
Daily average water temperature
Daily minimum water temperature
Begin harmful steelhead rearing temperatures
Begin marginal steelhead rearing temperatures
Curtail steelhead smoltification temperature
WY 2006 Alameda Creek flows below Welsh Creek
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Date of water year

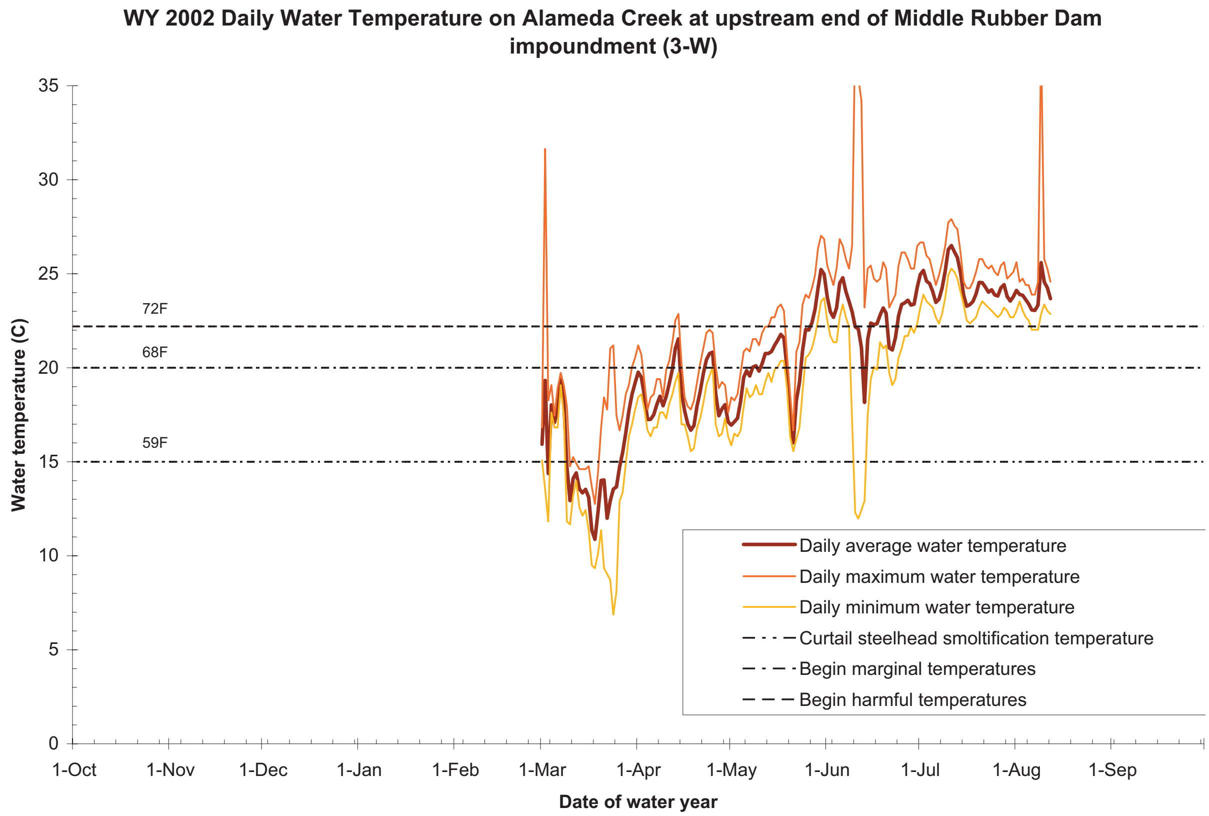

WY 2003 Water Temperatures at Welch Creek 20
72F
68F
59F
Water temperature (C)
Daily maximum water temperature
Daily average water temperature
Daily minimum water temperature
Curtail steelhead smoltification temperature
Begin marginal steelhead rearing temperatures
Begin harmful steelhead rearing temperatures
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Date of water year

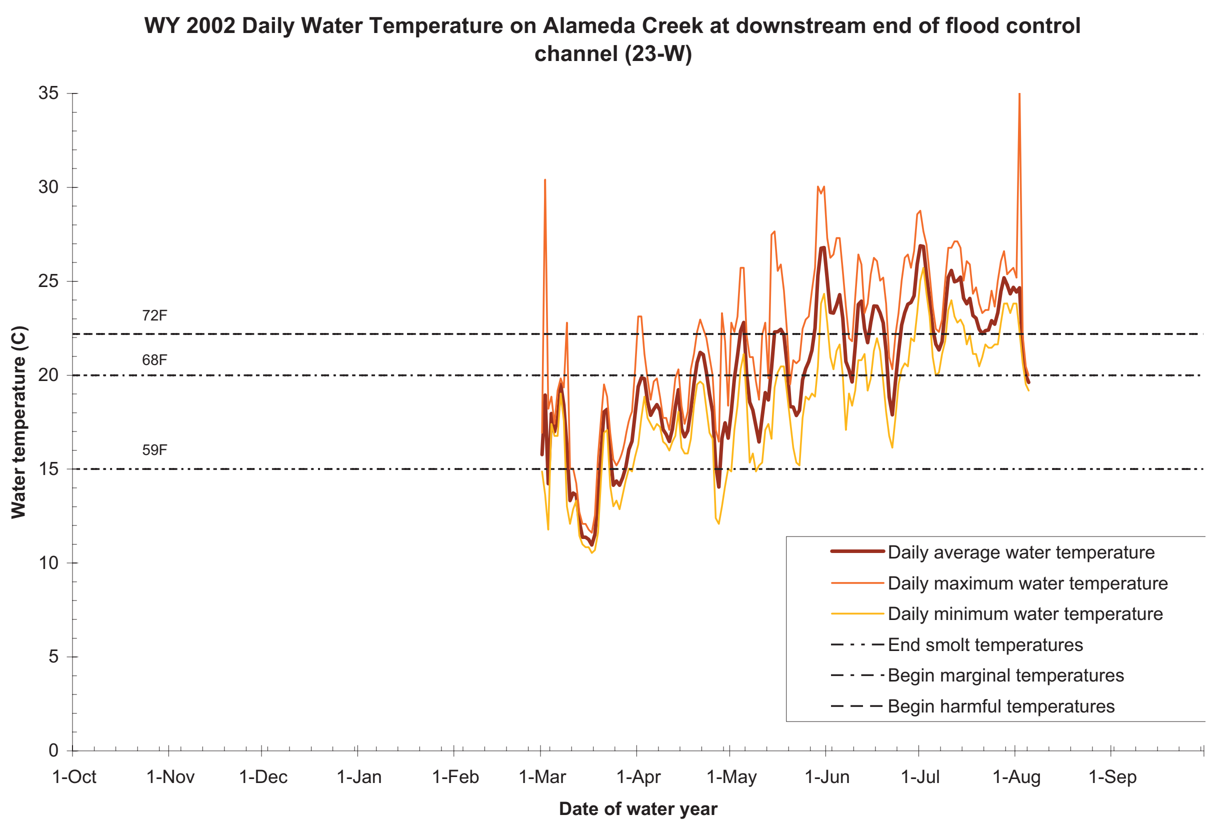

WY 2003 Daily water temperatures at Stonybrook Creek 6-W
Water temperature (C)
Date of water year
72F
68F
59F
Daily average water temperature
Daily minimum water temperature
Daily maximum water temperature
Curtail steelhead smoltification temperature
Begin marginal steelhead rearing temperatures
Begin harmful steelhead rearing temperatures
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep


WY 2003 Water temperature at Vallecitos Creek US 152
Water temperature (C)
Date of water year
72F
68F
59F
Daily maximum water temperature
Daily average water temperature
Daily minimum water temperature
Curtail steelhead smoltification temperature
Begin marginal steelhead rearing temperatures
Begin harmful steelhead rearing temperatures
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep


WY 2003 Daily Water Temperature at Alameda Creek downstream of Arroyo de la Laguna (Logger 13)
Water temperature (C)
72F
68F
59F
35
30
25
20
15
10
5
0
Daily maximum water temperature
Daily average water temperature
Daily minimum water temperature
Curtail steelhead smoltification temperature
Begin marginal temperatures
Begin harmful temperatures
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Date of water year


WY 2002 Water Temperatures at Arroyo de la Laguna below Vallecitos Creek 9-W
Daily water temperature (C)
72F
68F
59F
35
30
25
20
15
10
5
0
Daily average water temperature
Daily maximum water temperature
Daily minimum water temperature
Curtail steelhead smoltification temperature
Begin marginal steelhead rearing temperatures
Begin harmful steelhead rearing temperatures
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Date of water year


WY 2002 Daily Water Temperature on Alameda Creek at upstream end of Middle Rubber Dam impoundment (3-W)
Water temperature (C)
Date of water year
72F
68F
59F
0
5
10
15
20
25
30
35
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Daily average water temperature
Daily maximum water temperature
Daily minimum water temperature
Curtail steelhead smoltification temperature
Begin marginal temperatures
Begin harmful temperatures


WY 2002 Daily Water Temperature on Alameda Creek at downstream end of flood control channel (23-W)
Water temperature (C)
Date of water year
72F
68F
59F
0
5
10
15
20
25
30
35
1-Oct
1-Nov
1-Dec
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
Daily average water temperature
Daily maximum water temperature
Daily minimum water temperature
End smolt temperatures
Begin marginal temperatures
Begin harmful temperatures