Title

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Author

Cervantes-Yoshida, Kristina

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Kristina Cervantes-Yoshida
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Abstract

Alameda Creek is one of the few remaining streams in the San Francisco Bay Estuary that has the potential to regain a viable steelhead trout population (*Oncorhynchus mykiss*). While great effort is underway to remove large barriers throughout the watershed, lesser known are the impacts of smaller structures in the lower reaches. The objective of my study was to determine if a decommissioned rubber dam, a check dam, and a temporary sewage pipe crossing impeded movement and/or created conditions that were unfavorable for outmigrating steelhead smolt during low flow periods. For the study I gathered data on temperature, depth, and channel form. The results showed that the rubber dam created inhospitable conditions of < 0.1 ft depth and water temperature of 20°C in April across a 54 ft flat cement surface. Although the check dam and the sewage pipe crossing were less restrictive for smolt passage, all of the structures created environments that increased the risk of smolt predation. These inhospitable conditions were likely exacerbated by low flows. Gauge data from the past 33 years showed that low flows are common throughout the smolt migration period of April in the lower reach of Alameda Creek; therefore indicating the conditions observed in this study were not uncommon. Overall, the results suggest that modification or complete removal of these structures is the most viable solution to improve smolt migration success during low flow periods.

Introduction

In 1996 Central Coast steelhead trout (*Oncorhynchus mykiss*) were listed as a threatened species under the federal Endangered Species Act. Despite recent efforts towards habitat and population restoration, the status of steelhead trout has not significantly improved. A recent report on the status of California salmonids reported that Central Coast steelhead trout have declined 80-90% in the past 50 years and are expected to become extirpated in 25-100 years unless large-scale actions occur (Moyle 2008). In particular, 58% of historically occupied San Francisco Bay streams no longer support anadromous populations as a result of extensive habitat loss, stream degradation, dams and introduced species (Leidy et al. 2005).

Steelhead trout life histories are complex and require strict habitat conditions to complete their migration from their natal freshwater stream to their saltwater feeding grounds and back to freshwater for spawning. Steelhead have a wide range of life histories, in which some individuals spend either one to two years rearing in their stream, while others only spend a few months in their natal stream before migrating to the ocean

(Moyle 2002, Moyle 2008). In particular, Central California Coast steelhead smolt migrate in early spring though late summer (Moyle 2008).

There are many factors limiting steelhead smolt survival. Smolts require cool water temperatures, sufficient stream flow, complex habitat, accessibility to downstream stretches, food sources and good water quality (McBain & Trush 2008). For example, insufficient water depth can impede fish movement, prevent oxygen intake and cause bodily injury. Regulating agencies such as The National Marine Fisheries Service (NMFS) recommend a minimum stream depth of six inches for juvenile salmonids, while the California Department of Fish and Game (CDFG) require a minimum of 0.5 ft depth for salmonids greater than six inches and 0.3 ft depth for salmonids less than six inches (Flosi 1998, NOAA 2001). Steelhead can withstand a wide range of temperatures depending on the location of their natal stream and their energy constraints; however like most organisms, they have a preferred temperature range in which growth, reproduction, migration, and physiological maintenances are optimized (Quinn 2005). At high temperatures, food consumption rates, growth rates, conversion efficiency, and oxygen consumption decline in *O. mykiss* (Myrick and Cech 2000). On the California Coast, steelhead are completely absent in streams that exceed 25-26º C (Moyle 2002). Outmigrating smolts are also subject to predation from predatory fish, especially in pools with large invasive fishes such as pikeminnow and bass (Rieman et al. 1991b). Smolts are also particularly susceptible to bird predation during low flows and in areas with limited cover (Antolos et al. 2005).

Structural barriers can also severely limit steelhead populations by adversely affecting survival and delaying smolt and juvenile migration (Raymond 1979). Specifically, they can trap, displace, expose smolts to unfavorable physical conditions and/or make them more vulnerable to predation. Barriers range from large impoundments, to smaller impoundments such as grade control structures. They also vary from absolute barriers that completely block fish passage, to those that temporally or partially restrict migration. While most literature focuses on the impacts of large absolute impounds, smaller structures can negatively affect fish survival as well (O'Hanley and Tomberlin 2005).

Alameda Creek is the largest watershed of the San Francisco Bay, with a drainage area of approximately 700 square miles (Figure 1). Despite the impacts of urbanization, three major dams, substantial water extractions, storm water runoff, and the introduction of exotic fish species, there persists an abundant and diverse assemblage of native fishes in Alameda Creek (Leidy 2007). The current steelhead trout population in Alameda Creek is not viable, mostly due to structural barriers that impede migration to and from the San Francisco Bay (McBain & Trush 2008). From 1996-2006, an average of 10 adult steelhead per year were observed returning to Alameda Creek (Miller 2006). Despite these barriers, the vast and relatively undeveloped headwaters have continually provided suitable, although not optimal, habitat to maintain a resident *O.mykiss* population. Conversely, the downstream reach of Alameda Creek is confined to a soft bottom 240-year flood control channel built by the Army Corps of Engineers (currently managed by the Alameda County Flood Control District). Within the channel there are a number of limiting factors for steelhead, such as invasive predators, storm water runoff, sewage spills, depleted oxygen levels, and high temperatures (Artz 2008, Ochikubo Chan 2008, Miller 2009). Moreover, there are many small structural barriers that impede both returning and outmigrating salmonids (Figure 2). One of the most notable barriers is the Bay Area Regional Transit (BART) weir, which was constructed to protect the BART and Union Pacific Railroad foundations from scour and instability (M. DaCosta, Alameda County Flood Control District, personal communication, March 2009). In addition to the BART weir, migrating salmonids must traverse two rubber dams installed by the Alameda County Water District, which serve to impound and divert stream water into the adjacent groundwater recharge ponds. For many years, local community members have physically transported stranded adult steelhead over the weir so that they can continue upstream to spawn. To improve access to the spawning ground, an extensive fish ladder is scheduled to be constructed by 2012 to bypass Rubber Dam #1 and the BART weir (J. Miller, Alameda Creek Alliance, personal communication, March 2009).

While the aforementioned structural barriers are of immediate priority, there are a number of smaller downstream structures that are potential barriers and could thus be included in the restoration plan for Alameda Creek steelhead. I chose to focus my study on steelhead smolt because the timing of this project coincided with their outward migration to the ocean. The objective for my project was to identify possible structural barriers below the BART weir and then to determine if conditions resulting from these structures were sufficient for steelhead smolt migration (e.g. temperature, cover from predation, depth). I also considered the long term conditions for smolts that remain in the downstream reaches over the summer until sufficient flows are regained in the following rainy season. While there have been limited studies addressing the impact of the decommissioned rubber dam in the lower reach of Alameda Creek, this is the first report that I have been able to locate that directly looks at the conditions of the Union Pacific sewage pipe crossing and the check dams and their effect on steelhead smolt migration.

Methods

To determine potential barriers downstream of the BART weir, I interviewed specialists from various agencies involved in Alameda Creek such as the Alameda County Flood Control District (ACFCD), Alameda Water District, East Bay Regional Parks District and the Alameda Creek Alliance. Additionally, I used a combination of aerial photographs and maps provided by the ACFCD, and I surveyed the entire reach from the BART weir to the salt marsh on foot. In this process I looked for physical barriers that had any of the following characteristics: pooling upstream, long flat cement sections, sharp drop offs, or habitat that would yield warm temperatures and shallow water elevations. From this preliminary step I chose to focus my study on the following structures: the decommissioned Rubber Dam #2, Check Dam #1, and the Union Sanitary District sewage pipe crossing (Figure 3).

Rubber Dam #2 was the first major structure below the BART weir complex. In early 2009, Rubber Dam #2 was decommissioned (i.e. deflated) and scheduled for removal in the summer of 2009 (K. Gandhi, Alameda

Water District, personal communication, March 2009). Once the rubber portion of the dam is removed, the large cement foundation will remain.

The next downstream structure from Rubber Dam #2 was the first of a series of check dams operated by the ACFCD. These structures were for erosion control purposes, although presently they might not be performing up to expected standards and could be considered for removal (M. DaCosta, ACFCD, personal communication, March 2009). Although there were two check dams between the BART weir and DeCoto Rd. they were virtually identical, therefore rendering it unnecessary to survey both (R. Saleh, ACFCD, personal communication, March 2009).

The third structure was the Union Sanitary District sewage pipe crossing directly upstream of Union City Blvd. It is located at the edge of the salt marsh and is therefore tidally influenced by the San Francisco Bay. The 33 inch pipeline was built in 1978 four feet (ft) below the creek bed. Due to extensive erosion and incision at the site, in 2007 a large void was discovered underneath the pipeline prompting the construction of a temporary aboveground bypass (Miller 2009). While this new structure has prevented potential sewage line breaks during high flow periods, it is unknown if its current configuration is limiting smolt migration during low flow periods. Do to safety concerns and limited accessibility, I was only able to complete a partial analysis of the site.

On April 4th and 15th, 2009 I worked with a team of students to gather quantitative and qualitative data of the stream channel around the three structures. We surveyed a long profile and cross sections above and below each impoundment. Additionally we noted depth, temperature, vegetation and channel features. At the sewage pipe crossing I took photographs of the structure at low and mid-low tide to observe changes in physical conditions that could limit smolt migration.

Upon gathering field data, I plotted my data and noted average temperatures, slopes, and depths from upstream, on top, and downstream of the structures. Next I referenced salmonid literature to determine minimum requirements for steelhead smolt migration. I then compared these physical habitat requirements with the conditions at the three structures to make some conjectures about the passibilty of these sites for steelhead smolts during mid-spring. Finally, I downloaded data from United States Geological Survey (USGS) website for Gauge #11180700 located roughly 2 miles downstream from Rubber Dam #2 and Check Dam #1 and 1.6 miles upstream from the sewage pipe crossing. I used this data to note the mean daily flow for my fieldwork dates and to make inferences of the flow conditions later in the migration period. Furthermore, I compared the 2009 discharge data with data from the past 30 years to determine if the flows observed for the study were common in Alameda Creek.

Results

Both the rubber dam and grade control sites had similar surrounding habitat features, characterized by steep riprap channel walls and followed by a smaller vegetated layer consisting of short grasses and brush adjacent to the foot of the creek. At both sites there was an absence of any medium-large size vegetation to provide shading over the stream bed. The sections upstream of the structures formed wide pools with a thick layer of fine sediment, while the sections below the structures were more heterogeneous characterized by narrow stream channels, mid-size boulders, gravel bars, side channels, and small pools. At both sites I observed as many as 15-20 large common carp (*Cyprinus carpio*) swimming in the deeper channels and pools. Because I sampled these sites on different days, it should be noted that the atmospheric temperature was 2°Celsius (C) warmer on April 4th compared to April 15th.

Rubber Dam #2

Rubber Dam #2 was characterized by a two-tiered cement platform, with the deflated rubber dam atop the first tier (Figure 4). The total area of the top tier was approximately 5920 ft^2 with a length of 37 ft. The portion of the top tier covered by the deflated rubber dam was 15 ft, had an average temperature of 20°C and an average depth of 0.26 ft (Table 1). The drop off between the two tiers was 3.28 ft at a 60% slope (Figure 5). The second tier was characterized by flat paved cement bottom with a total area of 2880 ft^2 and a length of 17 ft. The bottom tier had an evenly spread thin sheet of water with an average depth of < 0.1 ft and an average temperature of 20°C. Immediately following the second tier was a series of mid-size boulders and gravel bars, followed by a 5 ft length riffle and then a deeper channel with a fine sediment bottom. The daily mean discharge recorded at the downstream gauge (#11180700) on the date we collected the data was 4.0 cubic feet per second (cfs) (Figure 6).

Check dam #1

Check Dam #1 was constructed of cement and embedded mid-size boulders (Figure 7). Although the dam spanned the entire width of the channel (130 ft), water was only able to breach the top of it through a 22 ft wide shallow notch through the center. The length of Check Dam #1 was 8 ft, with an average depth of 0.13 ft, and an average temperature of 15°C atop the structure (Table 2). The drop off from the top of Check Dam #1 was 1.57 ft at a 78.5% slope (Figure 8). The 60 ft section below Check Dam #1 was characterized by a narrow pool (average depth of 0.79 ft) formed by a large gravel bar a few feet from the foot of the dam. Further downstream the creek reformed into a straight narrow channel (approximately 90 ft wide) until it neared the next check dam above DeCoto Road. The daily mean discharge recorded at the downstream gauge (#11180700) on the date we collected the data was 3.1 cfs (Figure 6).

Union Sanitary Sewage Pipe Crossing

Because of the inaccessibility of the sewage pipe crossing, I was limited to collecting observational data and a few depth and temperature readings. The area was characterized by a wide homogenous straight channel directly above and below the pipe crossing (Figure 9). The top of the sewage pipe crossing was constructed of large to mid-size boulders and was 31 ft long. The average depth atop of sewage pipe crossing was 0.5 ft deep with an average temperature of 19°C during mid-low tide. Unlike the other two structures, there was not a drop in water surface from the top of the structure to the downstream section. This allowed the top of the structure to be tidally influenced during low tides. I observed high tide marks that indicated that the water level rose well above the sewage pipe crossing during the daily high tides. When I visited the site at low tide levels, there were a number of predatory birds feeding on top of and below the sewage pipe (Figure 9). On 4/4/09 there were ten great egrets (*Ardea alba*) and on 4/15/09 there were five great egrets and one Western grebe (*Aechmophorus occidentalis*).

Discussion

The average depth atop tier two of Rubber Dam #2 was > 0.1 ft, far below the CDFG and NMFS recommended depth requirements for outmigrating smolt. Tier one was deeper than tier two (0.26 ft) but it was also below the minimum depth requirement. The increased depth of tier one was caused by pockets of water formed in the folds of the deflated dam. When the rubber section of the dam is removed later in the year, it is likely that the depth atop of tier one will be similar to the depth of tier 2. Although steelhead are known for their strong and fast swimming ability, it is likely that the 54 ft length of Rubber Dam #2 and its insufficient depths could strand fish atop the structure, discourage fish from attempting to cross, cause high stress and/or cause bodily injury. The other problematic condition of Rubber Dam #2 was the 3.28 ft drop from tier 1 to tier 2. The NMFS recommends a minimum drop of six inches for juveniles into a jump pool of at least two feet in depth; neither of which were met at Rubber Dam #2 (NOAA 2001). The depth atop both Check Dam #1 and the sewage pipe crossing were both under the recommended depth requirements; however the lengths of the structures were significantly shorter and there were pockets of deeper water atop the structures allowing smolts to pass more freely than through Rubber Dam #2. Additionally, the pool beneath the 1.6 ft drop at Check Dam #1 had an average depth of 1.1 ft, thus providing a more secure passage than Rubber Dam #2. The sewage pipe crossing was also less of a concern because it was completely underwater during high tide, allowing for easy passage.

The results showed that the cement tiers of Rubber Dam #2 had water temperatures of 20º C, which is estimated at the upper temperature threshold for juvenile and smolt steelhead in Alameda Creek (McBain &

Trush 2008). Under sufficient flow and depth, it is likely that smolts could quickly swim through these sections; however under the conditions that I observed, it is possible that smolt could be stranded on the tiers and thus be subjected to high temperatures for long periods of time. The temperature atop Check Dam #1 was within limits for smolt function and survival, most likely due to the deeper water and shorter distance across the dam. It is unlikely that there would be a temperature constraint at the sewage pipe crossing because it is tidally influenced, and thus has constant cool water influx from the estuary. Although I did not calculate the specific relationship of atmospheric and stream water temperature at my study sites, there is a linear correlation between the two (Stefan and Preudhomme 1993). Thus, it is probable that with the increase in atmospheric temperature through the outmigrating season, smolts could encounter lethal stream temperatures at Rubber Dam #2 and Check Dam #1. For example, the average atmospheric temperature on field day 4/4/09 was 13º C, while 17 days later the temperature rose to 26º C. Decreasing flows through late spring and summer would also likely exacerbate high temperatures.

At all three structures there was a lack of vegetation, habitat heterogeneity and deep water for protection. At the sewage pipe crossing there were a number of predatory birds actively hunting for fish moving downstream. Although I did not observe predatory fish, the East Bay Regional Park District found large predatory largemouth bass (*Micropterus salmoides*) and Sacramento pikeminnow (*Ptychocheilus grandis*) in the flood control channel pools of Alameda Creek (Ochikubo Chan 2008). Studies have shown that both native and nonnative predatory fish can consume up to 14% of juvenile salmonids; therefore posing a significant risk to the low number of migrating smolt of Alameda Creek (Rieman et al. 1991a). Additionally, smolts would be particularly vulnerable to fish predation if they were constrained to individual pools with limited cover between barriers over long periods of time.

The temperature and depth levels were not sufficient for smolt migration at the mean daily discharge when the measurements of this study were taken. This suggests that at lower discharges the depth and temperature conditions could be exacerbated. Throughout the month of April 2009, there was a steady decline in the daily mean discharge, with the lowest mean flow of 1.7 cfs on 4/23/09 (Figure 6). The average monthly flow for April from 1978-2008 was 134.5 cfs, while the average flow for April 2009 was 3.34 cfs (Figures 6 and 12). Even though 2009 was a relatively low flow year, it is important to note that 27% of the monthly discharges in April from 1978-2008 were below the mean monthly flow of 3.34 cfs seen in April 2009. Overall the hydrograph data indicated that there is a great deal of variability in the flood channel of Alameda Creek and that the impacts of these structures on steelhead smolt should be considered for both high and low flows (Figure 10). Furthermore, it indicated that flow conditions through the flood control channel are often lower than the flows I observed for this study. To better predict the effects of flow, it would be advantageous to quantify the relationship between discharge and environmental conditions at the study sites in future studies.

Based on the results of this study, it did not appear that the sewage pipeline and Check Dam #1 were absolute physical barriers nor would cause significant displacement of outmigrating smolts. In contrast, Rubber Dam #2 appeared to be a considerable barrier during low flow periods. The long stretches of the cement tiers had suboptimal depths and temperatures that could impede smolt movement through the structure. Other major concerns for all three structures were the conditions that left smolts more vulnerable to predation and stress-inducing conditions (e.g. temperature, steep drops in water elevation) that could hinder the success of steelhead migration or smoltificaiton. Furthermore, if steelhead were forced to remain in the lower channel of Alameda Creek over the summer, it is likely that decreased flows and warming temperatures would make Rubber Dam #2 and Check Dam #1 impassable and create lethal conditions. Because there don’t appear to be any studies that address these conditions, further research is needed to confirm this.

Conclusion

To restore the once thriving steelhead population of Alameda Creek, there are a number of habitat problems that need to be addressed. Because steelhead require full access to the stream to complete their life history, each section along Alameda Creek requires hospitable conditions. While larger impoundments such as the BART weir and upstream dams are top priority for local agencies, it is important that smaller structures such as those that I have discussed are considered. Additionally, when addressing barriers and structures, it is equally important to evaluate migration impediment and habitat conditions created by these structures.

Based on the findings from this report, I have outlined a few suggestions that could improve steelhead smolt migration and survival. The addition of larger native vegetation could provide habitat complexity, sufficient thermal refuge and water oxygenation (Gregory and Levings 1996, Ghermandi et al. 2009). Although plant restoration is usually avoided in flood control channels, the Alameda Creek channel was build for a 240 year flood; therefore it is possible to add vegetation without significantly putting the area at risk for flooding during a high flow periods (M. DaCosta, ACFCD, personal communication, March 2009). I also suggest creating a more natural flow regime in which the major dams along the creek are required to release flows that mimic a natural hydrograph (Poff et al. 1997). This could provide sufficient pulses of water to allow salmonids to reach their destination. Moreover, increased flow releases could provide cooler temperatures for outmigrating smolts or for individuals that take residence in the lower reaches through the summer. In addition to altering upstream dam releases, the Alameda Water District could reduce their diversions to their groundwater ponds to increase flow downstream.

While there are plans to remove the rubber portion of Rubber Dam #2, the results of my study show that this is not sufficient for smolt migration during low flows. The Alameda Water District has proposed modifications to Rubber Dam #2, such as a continuous V-notch through the middle of both tiers (Figure 11). My results suggest that this modification should provide passage. Similar modifications could be implemented for the other two structures to allow easier passage, thus reducing the time for which smolts are susceptible to predation, displacement, or unfavorable physical conditions.

To better understand the conditions and requirements for steelhead, future research should address smolt migration in Alameda Creek. While there was ample information about adult migration, I was unable to locate substantial data on smolt migration and over-summer residency in Alameda Creek. If smolts were found to be spending long periods of time in the flood control channel, further studies would be needed to quantify the long term conditions and their impact on smolt survival (e.g. food availability, temperature, flow). Seasonal outmigration traps could provide insight on smolt migratory patterns, and help guide restoration efforts and flow regulation from the upstream dams. It would also be useful to look at climate change patterns to estimate the effect of reduced flows, rising temperatures and the subsequent changes in food webs on steelhead development and migration patterns.

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	100 ft upstream	Top Tier	Bottom tier		100 ft downstream	Smolt requirements	
Length (ft)	100	37	17		100	-	
Average depth (ft)	0.78	0.26	>0.1		0.531	0.5[1]	
Slope (%)	0.2	0.55	2.2		2	-	
Water temperature (°C)	18	20	20		18	12.8	20[2]
Water elevation drop(ft)	-		3.3ft drop	> 0.1ft pool	-	< 0.5ft drop	< 2ft pool[1]

Table 1. Results from Rubber Dam #2

[1] National Marine Fisheries Service requirements (NOAA 2001)

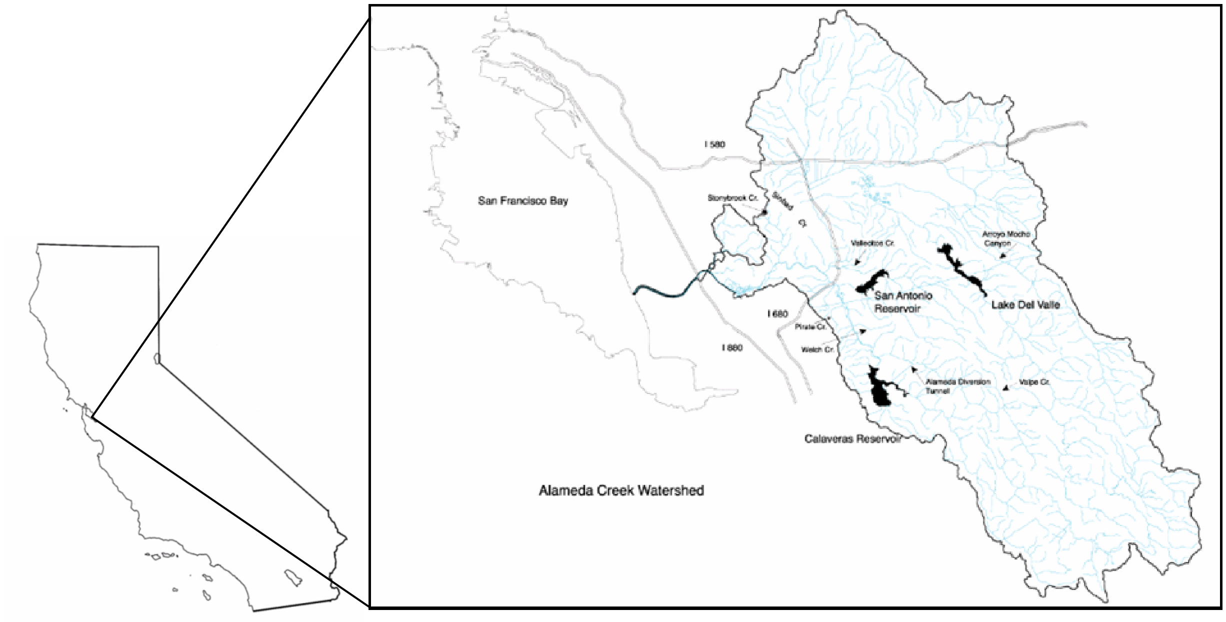
[2] Optimal temperature and upper threshold for smolts (McBain & Trush 2008)

	60 ft upstream	Check dam	60 ft downstream	Smolt requirements	
Length (ft)	60	8	60	-	
Average depth (ft)	1.68	0.13	0.41	0.5[1]	
Slope (%)	0.7	5.9	1.1	-	
Water temperature (°C)	14	15	14.5	12.8	20[2]
Water elevation drop(ft)	-	3.3	-	< 0.5ft drop	< 2ft pool[1]

Table 2. Results from Check Dam #1

[1] National Marine Fisheries Service requirements (NOAA 2001)

[2] Optimal temperature and upper threshold for smolts (McBain & Trush 2008)



Map: www.CEMAR.org

Figure 1. Alameda Creek Watershed

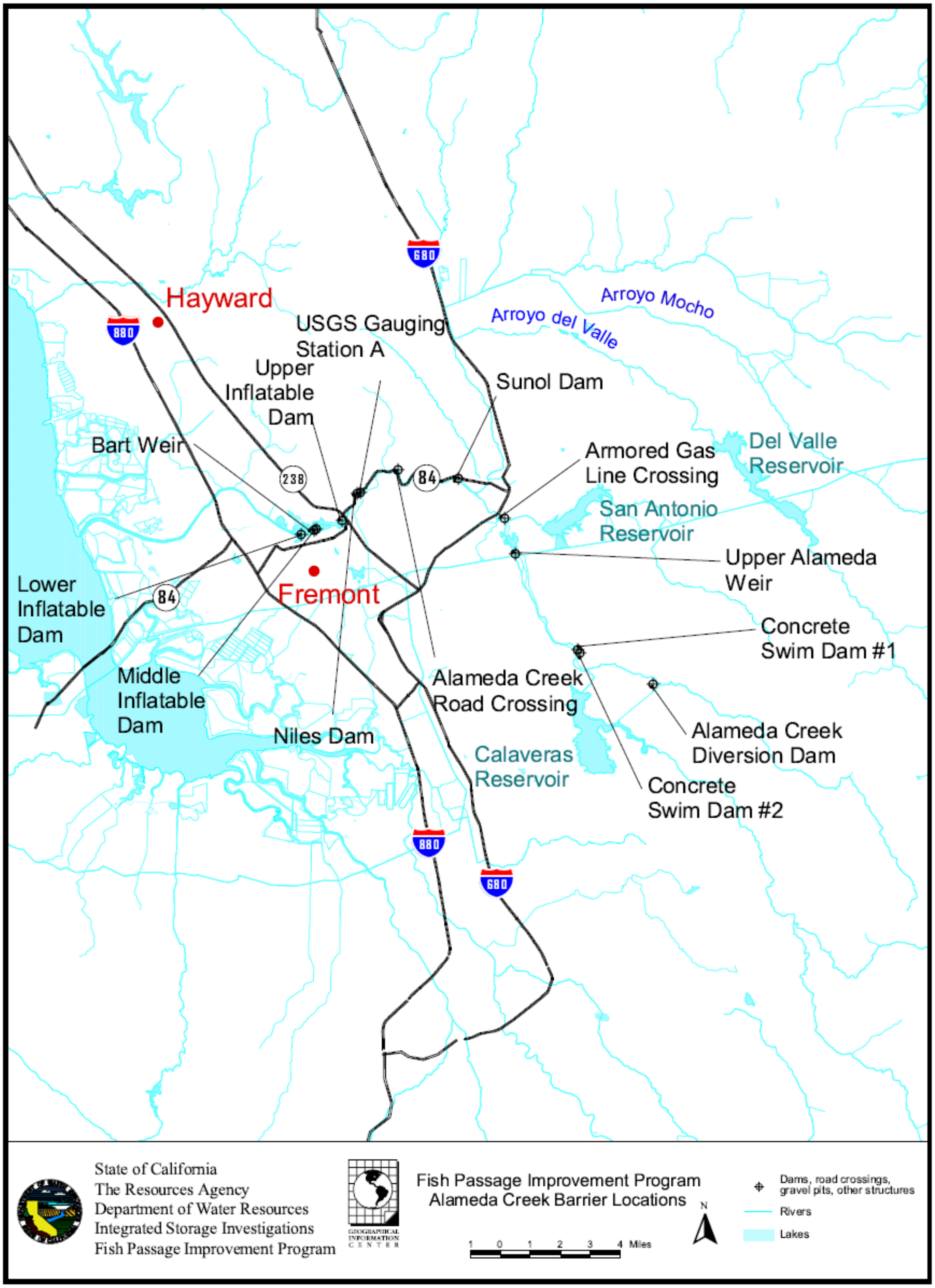


Figure 2. Map of barriers in Alameda Creek Watershed

Map: www.alamedacreek.org/Fish_Passage/Alameda watershed map.pdf

Figure 3. Map of Rubber Dam #2, Check Dam #1, and Union Sewage pipe crossing

Figure 4. Photo of Rubber Dam #2

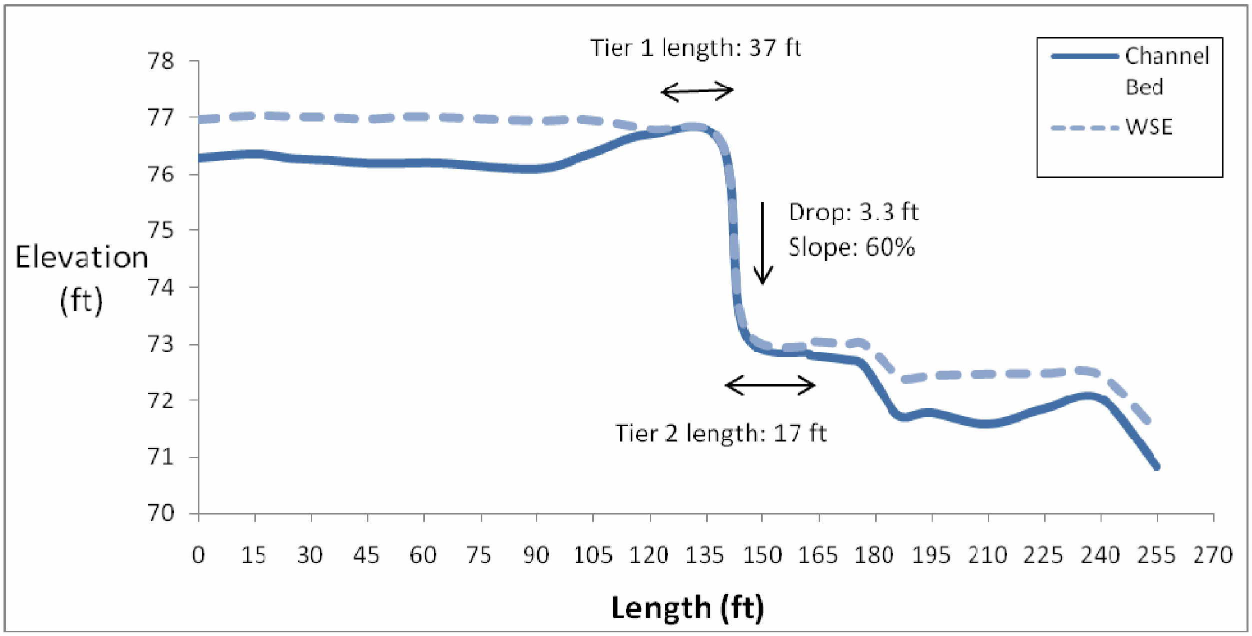


Figure 5. Long Profile of Rubber Dam #2

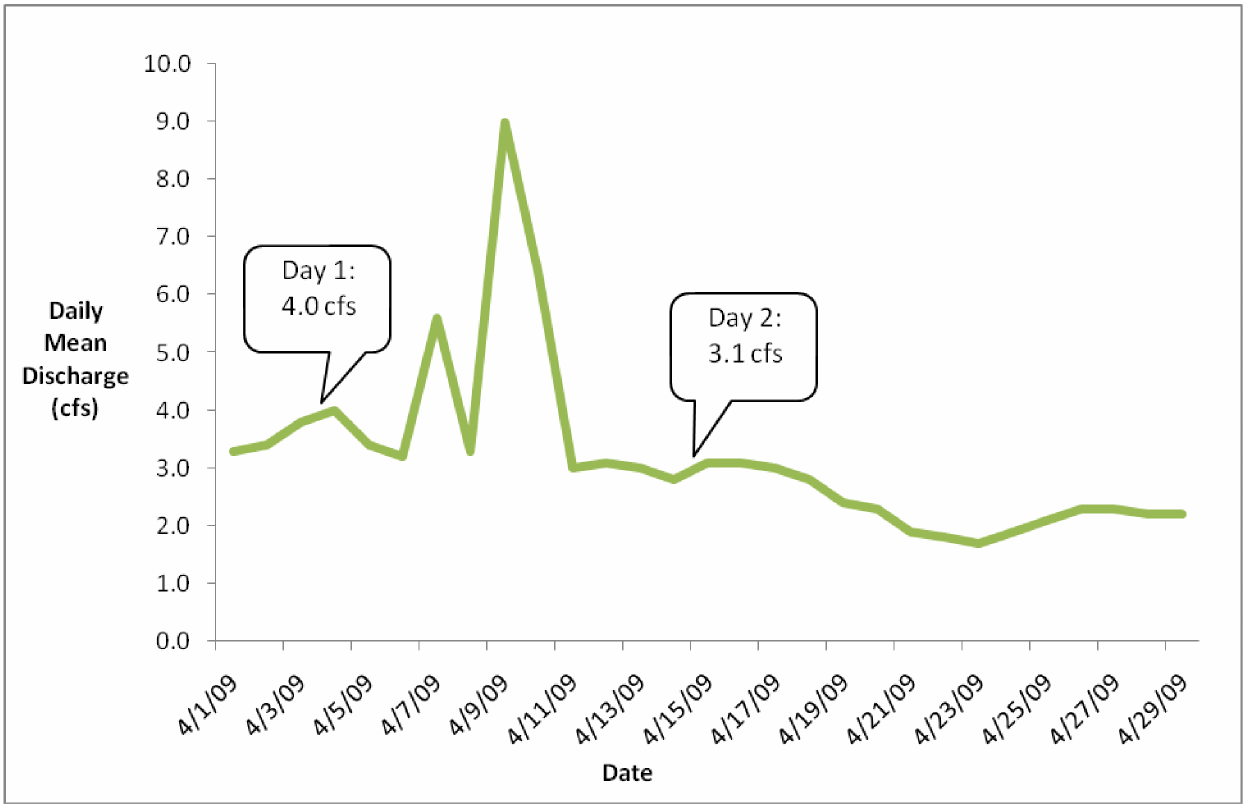


Figure 6. Daily mean discharge from USGS Gauge #11180700 near study sites

Figure 7. Photo of Check Dam #1

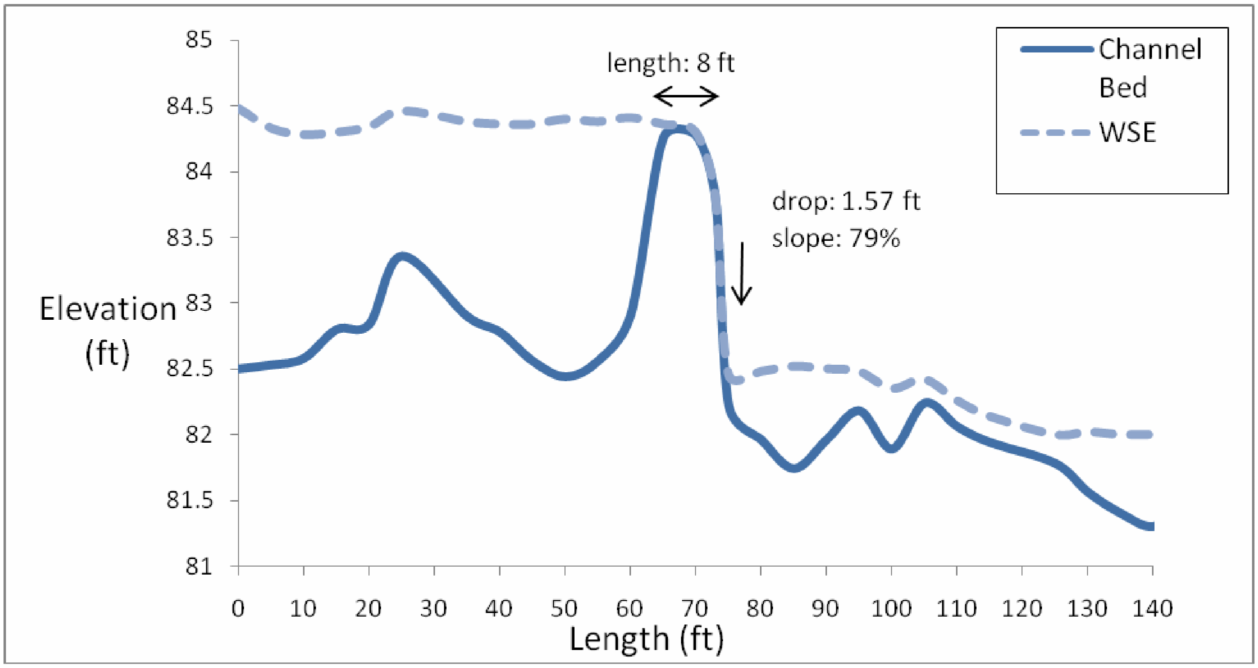


Figure 8. Long Profile of Check Dam #1

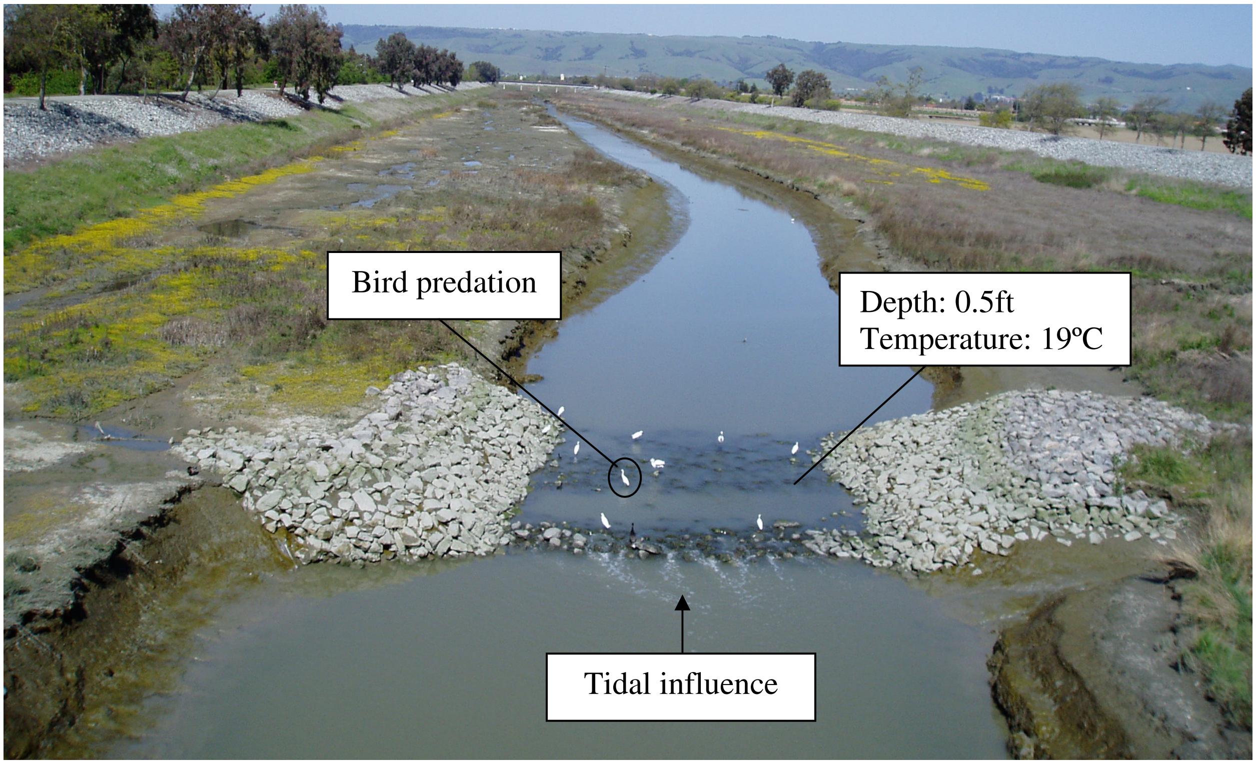


Figure 9. Union Pacific sewage pipe crossing

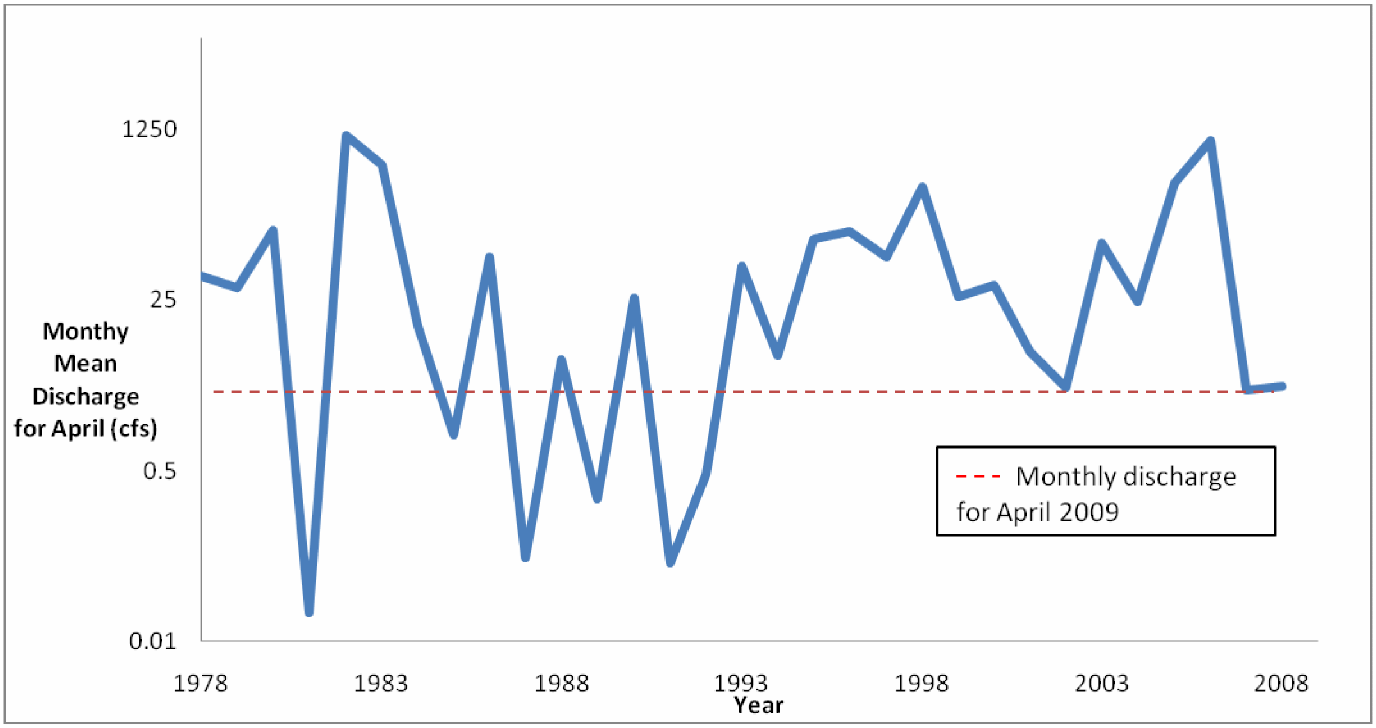


Figure 10. Monthly mean flow discharge for April 1978-2008 at USGS Gauge #11180700

Figure 11. Enhanced image of proposed modifications of Rubber Dam #2

Photo: Alameda Water District