Upper Pinole Creek Watershed
Salmonid Habitat Assessment

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Natural Resources Department
Fisheries & Wildlife Division
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INTRODUCTION

Two analogous creek habitat assessments for steelhead and resident rainbow trout (*Oncorhynchus mykiss*) were conducted on Pinole Creek in June of 2009. The habitat assessment in the lower creek, from Highway I-80 upstream to the Pinole City limits (2.6 miles), was conducted by the principals of Hagar Environmental Science (HES) and Pacific Biology. A similar habitat assessment for the upper creek, from the Pinole city limits up to the intersection of Bear Creek Road and Hampton Road (4.1 miles) was conducted by East Bay Municipal Utility District (EBMUD) biologists. This report pertains to the upper Pinole Creek habitat assessment performed on District watershed lands. This creek segment will be referred to in this document as the upper Pinole Creek stretch or simply upper Pinole Creek. Information from the lower creek habitat assessment will be contained in a report from HES and Pacific Biology. Together, these assessments provide a comprehensive evaluation of all known O. mykiss habitat in the main stem of Pinole Creek.

The objective of the assessment is to document the available *Oncorhynchus mykiss* habitat in Pinole Creek, and to map potential barriers to fish migration. This report will describe current habitat conditions in Pinole Creek on EBMUD watershed lands and limiting factors for steelhead and rainbow trout. Some recommendations will be made for potential habitat improvements.

WATERSHED OVERVIEW

Pinole Creek is located in the San Francisco Bay Area in Contra Costa County and is a tributary to San Pablo Bay (Figure 1). The Watershed is approximately 15.3 square miles and has approximately 33 miles of blue line streams. The lower third of Pinole Creek Watershed is urban, the middle third is protected EBMUD watershed lands and most of the upper third is in the Briones Agricultural Preserve. Elevations in the watershed range from sea level up to approximately 1000 feet in elevation.

EXISTING INFORMATION

Pinole Creek is exceptional among Bay Area creeks for a number of reasons:

- It has maintained a self-sustaining steelhead/rainbow trout population over the past decades;
- Pinole Creek has no major water diversions;
- The middle and upper watersheds are protpected lands or are sparsely developed.

Most of Pinole Creek's main stem is available to salmonids, with the I-80 culverts the only significant barrier affecting access to quality habitat upstream. In addition, salmonid habitat exists even in the lower creek within the city of Pinole.

Pinole Creek has a healthy population of native fishes including California roach (*Lavinia symmetricus*), threespined stickleback (*Gasterosteus aculeatus*), Sacramento sucker (*Catostomus occidentalis*) and Prickly sculpin (*Cottus asper*). Rainbow trout have also been documented on numerous occasions and in a number of locations on Pinole Creek (Leidy 1984, Leidy 2007, EBMUD 1996, 1997, 2001, 2005, 2006, 2008).

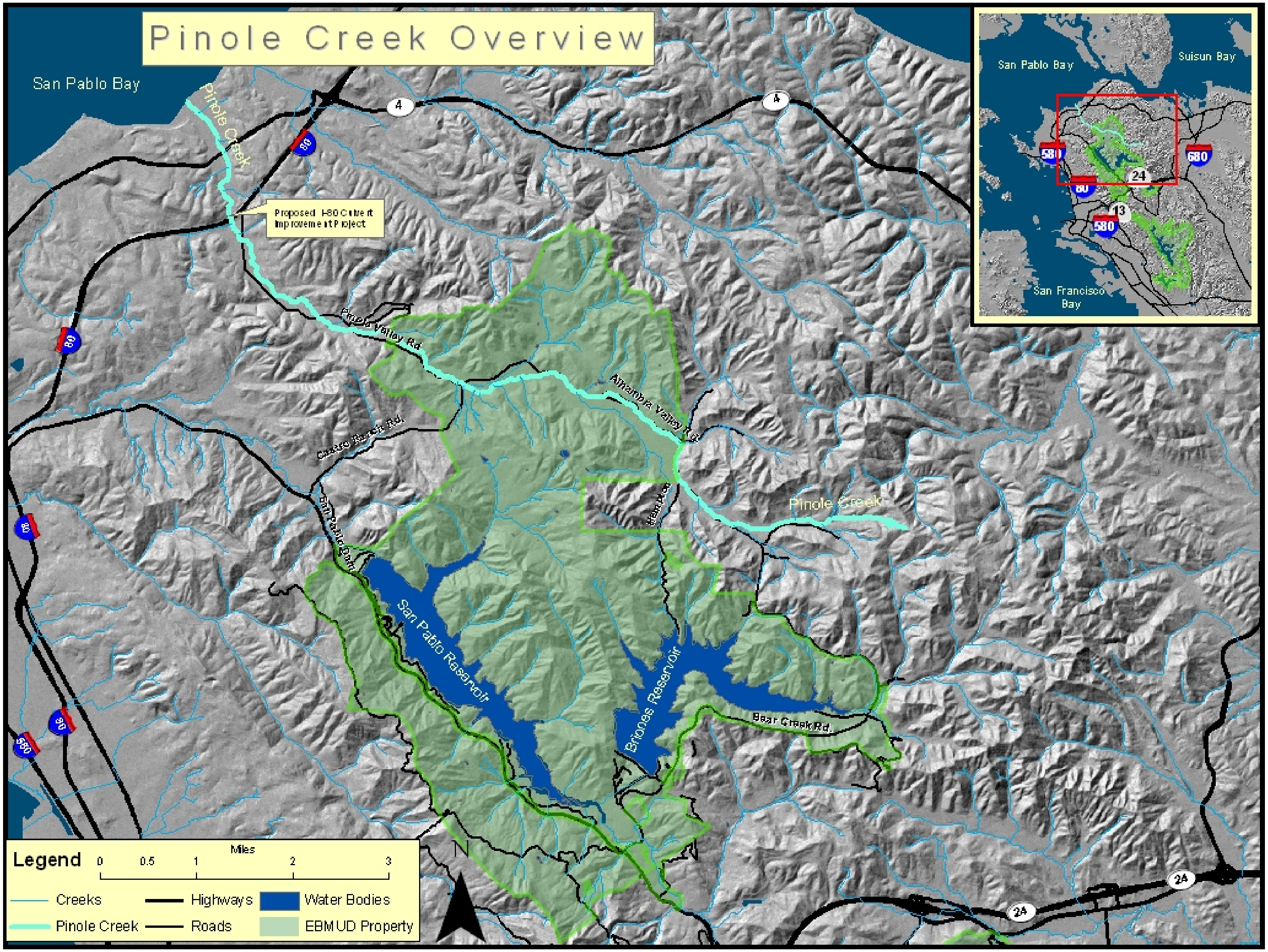

Figure 1. Pinole Creek Overview Map

Genetic analysis in 1999 showed that Pinole creek rainbow trout are most similar to the central California coastal steelhead ESU and were less similar to any of the 4 common hatchery strains tested (Nielsen, 1999). The extent to which steelhead contribute to this population is currently unknown. However, in recent years, adult steelhead have been observed in the lower reaches of Pinole Creek and in the upper watershed on East Bay Municipal Utility District land.

Pinole Creek also benefits from active community involvement. The Friends of Pinole Creek Watershed (FOPCW) and local agencies such as EBMUD, the city of Pinole, the Contra Costa County Resource Conservation District, the Contra Costa Clean Water Program and many others have worked together for the past decade to protect this unique Bay Area native salmonid resource. These efforts have resulted in several existing data sources for Pinole Creek that can be used as supplemental information for steelhead habitat assessment. Since 2001, the Contra Costa County Volunteer Monitoring Program has collected yearly benthic macroinvertebrate (BMI) data every spring at up to 11 stations along Pinole Creek. The program has also conducted yearly GPS monitoring in the lower creek which records data such as outfalls, bank vegetation composition and other creek attributes that relate to fish habitat. Other existing data sources that may be of use include the Pinole Creek Watershed Sediment Source Assessment (Pearce 2005) and ongoing temperature monitoring conducted by EBMUD.

In addition, EBMUD is currently restoring 4 tributaries known collectively as the Pavon Creeks as mitigation for a seismic upgrade project at San Pablo Dam. The Pavon Creeks sub-basin was identified in the Pinole Creek Watershed Sediment Source Assessment as the single largest source of excess sediment into Pinole Creek. Restoration of this sub-basin will greatly reduce fine sediment in the main stem of Pinole Creek, improving the quality of steelhead spawning and rearing habitat.

STEELHEAD RAINBOW TROUT HABITAT REQUIREMENTS

O. mykiss may exhibit anadromy or freshwater residency. Resident individuals are referred to as rainbow trout while anadromous individuals are referred to as steelhead. Steelhead migrate from fresh water to the ocean and return to their natal creek as adults to spawn. Resident forms spend their entire life in fresh water.

Steelhead/rainbow trout exhibit a variable life history with each life history stage exhibiting some differences in habitat preference and utilization in fresh water environments. Spawning and rearing habitats are common limiting factors in local creeks and are required to maintain healthy steelhead/rainbow trout populations. Pool habitats are of particular importance because they can provide preferred habitat characteristics for both spawning and rearing. In addition, pools are utilized to some degree by all life history stages of resident and anadromous salmonids.

Preferred spawning habitat for salmonids in local streams is found in pool tail-outs where flow and depth conditions are most often met and to a lesser degree in glides, runs or riffles. Steelhead typically prefer spawning gravel in the 1.3 to10.2 cm size range. (Reiser and Bjornn., 1979). Resident fish typically prefer gravel at the lower end of that size range. Ideal spawning substrate has a low percentage of fines resulting in high gravel permeability and high oxygen levels for developing eggs and embryos. Embryo survival is reduced in spawning areas where fine substrate makes up a significant proportion of the substrate volume and is very low when fine material is above 50%.

Rearing steelhead and resident rainbow trout require pools with sufficient depth and low temperatures for over-summering. Cover and a sufficient food source are also important. Riffle habitats may be commonly used by juveniles. In smaller local watersheds such as Pinole Creek, juvenile rearing habitat is typically reduced during low summer flows, particularly in drought years. Streams within the San Francisco Estuary often do not provide ideal trout rearing habitat. Local streams typically have lower base flows, lower gradient and reduced habitat complexity. Despite these potential deficiencies, many local streams are capable of supporting healthy but limited salmonid populations.

In local streams, higher temperatures are more of an issue for salmonids than low temperatures. In small streams like Pinole Creek, juvenile rearing temperatures are usually of greatest concern. The Steelhead Restoration and Management Plan for California lists the optimal temperature range for fry and juvenile rearing as 45 to 60^{o}F
(7 to 15.5^{o}C) but also notes that they are known to exist in relatively high temperature regimes. However, steelhead adapted to local conditions would be expected to survive and do well in environments where temperatures climb above of 20^{o}C for short periods of time.

METHODS

Habitats were classified using a modified Level IV classification system from the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al., 1998). The protocol was intended to determine the quality and quantity of habitat features of most importance to the persistence of steelhead populations. The survey was completed by a two-person team: one person collected and one recorded data. Data was taken electronically using a GPS (Trimble ProXH) with sub-meter accuracy and downloaded in the office to Microsoft Access and Excel for analysis. A position was recorded at the downstream end of each habitat unit. In a limited number of cases (< 1% of habitats), habitat positions were digitized directly into the unit when satellite coverage was insufficient. GPS positions and associated descriptive data were also recorded for all passage obstacles. One stream discharge measurement was taken during the survey period with a velocity meter (Marsh-McBirney Model 2000) using the velocity-area method (McMahon et. al.,1996).

Habitat types and lengths were recorded for every habitat unit encountered. Detailed data was recorded at every fifth habitat unit of each type encountered (20% sampling protocol). Detailed data included mean width, depth, maximum depth, shelter complexity, shelter cover, dominate and subdominate substrate, canopy cover and dominant canopy species. Detailed data was visually estimated with the exception of depths, widths and lengths which were measured with a stadia rod or 300 ft tape. Mean residual depth and maximum depth as well as depth of pool tail crest and embeddedness were recorded for every pool encountered.

Embeddedness was visually estimated by the percent of cobble and large gravel that was buried in pool tail-outs. In some cases, larger substrate was largely absent and smaller substrate was used in estimating embeddeddness. Shelter complexity was estimated and classified as low, medium or high. Percent shelter was estimated based on a percentage of the habitat unit with potential cover for juvenile salmonids. Substrate composition was estimated visually and the percentages of dominate and subdominate substrates in the habitat unit were recorded. Canopy was visually estimated as the percent canopy cover over each habitat unit for which data was being recorded, not over the entire reach. Spawning gravel area was estimated in all habitat units where flow, depth and gravel size were judged to be appropriate for spawning. Data collected for passage obstacles included barrier type, jump pool depth, obstacle height, obstacle length (where appropriate) and severity of obstacle, based on observer judgement. Judgement of severity of passage obstacles was focused on adult trout and steelhead.

The upper Pinole Creek section was divided into four distinct reaches (Figure 2). Each reach was defined based on characteristics such as gradient, habitat complexity, canopy species and other habitat characteristics. Landmarks such as road crossings were most often used as reach boundaries. Reach 1 stretched from the Pinole city limits upstream to the stream crossing at the intersection of Pinole Valley Road and Alhambra Valley Road (locally known as "The Pinole Y"). Reach 2 was from the Pinole Y up to the stream crossing at the old Tomato Stand. Reach 3 was from the Tomato Stand to the Pinole Creek waterfall. Reach 4 was from the Pinole Creek waterfall up to the intersection of Bear Creek Road and Hampton Road.

HABITAT ASSESSMENT RESULTS

The habitat survey was conducted on the EBMUD watershed on June 4, 9, 10, 11, 17, 18, 23 and 24, 2009 by Bert Mulchaey, Jessica Purificato and Thomas Newcomb of EBMUD. The total length of stream surveyed was 22,811 feet. This creek segment will be referred to in this document as the upper Pinole Creek stretch or simply upper Pinole Creek. Flow for the survey was measured at 0.11 cfs on 6/17/09 in a central reach of the survey area. This measurement is representative of the flows experienced during the 4 week survey period. Accurate thermograph data is available for this reach of Pinole Creek, so temperatures were not measured at the time of survey.

Level II habitat types are shown in Table 1. Based on frequency of occurrence, the upper Pinole Creek stretch had 51% pool units, 30% riffle units and 19% flatwater units (Figure 3). Based on total length, this stretch had 74% pools, 13% riffles and 13% flatwater units (Figure 4). Reaches 1 and 2 had a pool/riffle ratio of 2 to 1 and reaches 3 and 4 had a pool/riffle ratio of 1.5 to 1.

Nineteen Level IV habitat types were recorded in upper Pinole Creek (Table 2). Low gradient riffles (24%), Lateral scour pool-root wad formed (13%) and glides (13%) were the most frequent habitat types (Figure 5).

Mean residual depth and maximum depth for pools can be found in Table 3. Of the 217 pools encountered, 166 had a maximum depth of 2 feet or greater. Maximum pool depths ranged from 1.2 to 7 feet. Average residual depth for pools was 1.9 feet. Average residual pool depths were highest in reaches 1 and 2 (approx. 2 feet) and were lower in reaches 3 and 4 (approx. 1.5 feet).

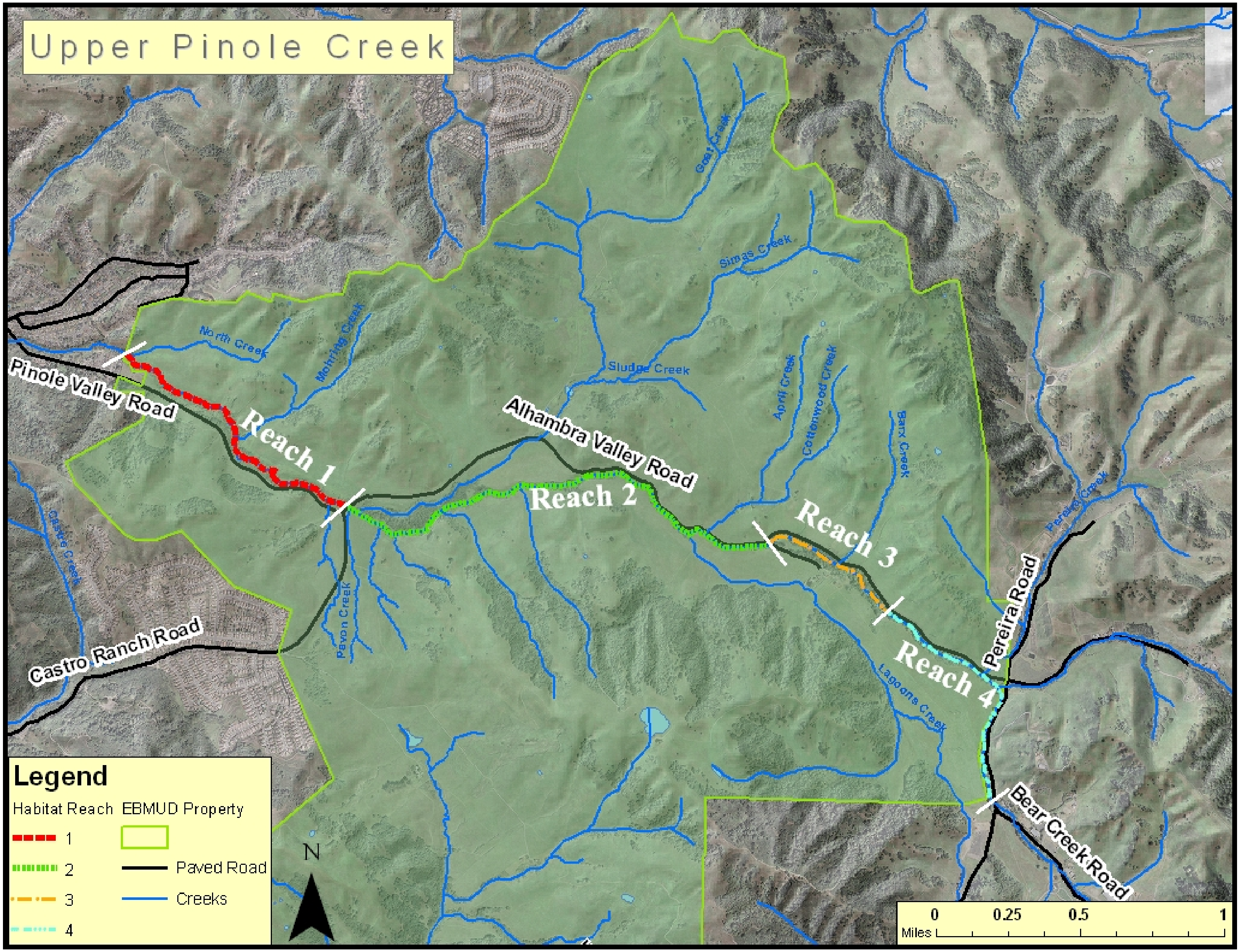

Figure 2. Upper Pinole Creek Reaches

Level II Habitat Type	% Occurrence	# Occurrences	% Length	Length (ft)
Pool	51%	217	74%	16,529
Riffle	30%	129	13%	2,806
Flatwater	19%	81	13%	2,876

Table 1. Frequency of Level II Habitat Types

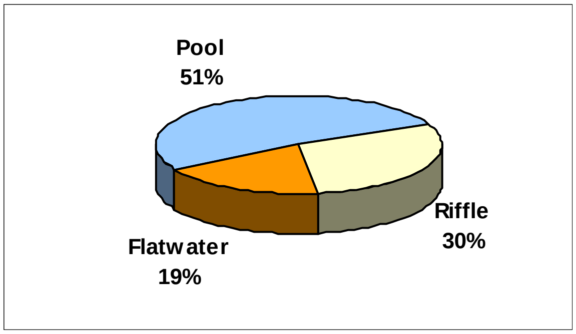

Figure 3. Frequency of Habitat Types by Occurrence

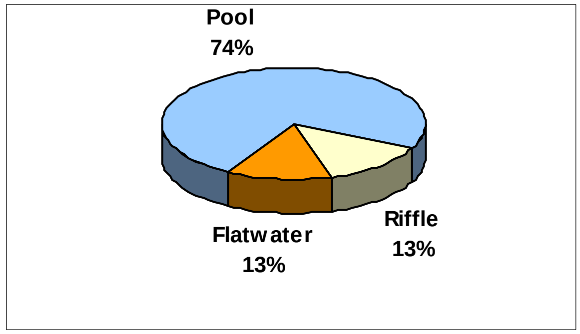

Figure 4.Frequency of Habitat Types by Length

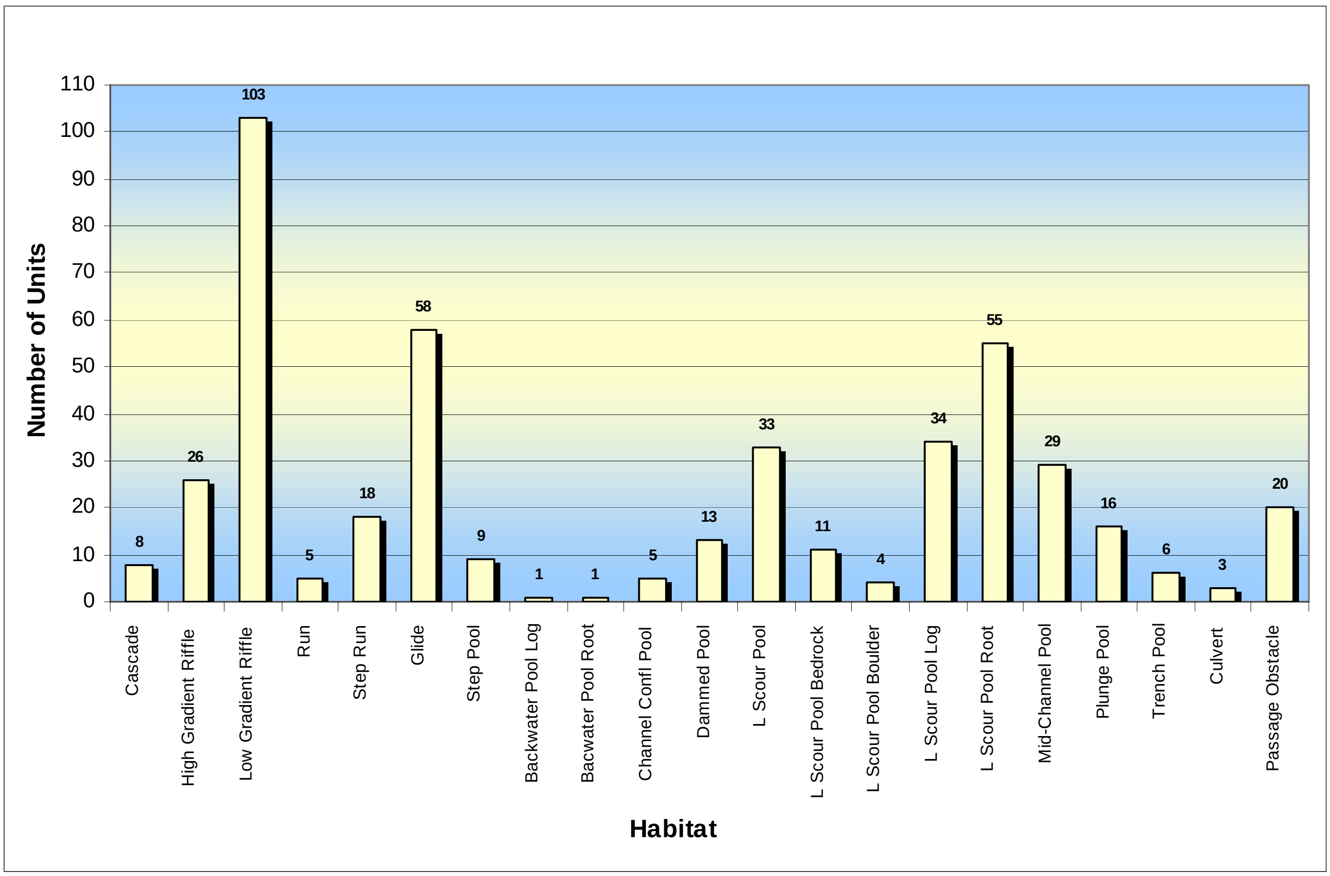

Figure 5. Habitat Types Recorded in Upper Pinole Creek

Habitat Type	# Habitat Units	#Units Fully Measured	Habitat Occurrence %	Mean Length (ft)	Total Length (ft)	Total Length %	Avg. Mean Depth (ft)	Max Depth (ft)	Mean Shelter Rating	Mean % Canopy	Total Spawning Gravel Area sq/ft	Avg. % Spawning Gravel Embededness
Backwater Pool Log Formed	1	1	0.2%	35	35	0.2%	2	3.2	45	50		
Bacwater Pool Root Wad Formed	1	1	0.2%	19	19	0.1%	1	2.1	20	80		
Cascade	8	2	1.8%	43	340	1.5%	0	0.8	30	58		
Channel Confluence Pool	5	2	1.1%	56	279	1.2%	2	3.9	30	68	32	47
Dammed Pool	13	3	3.0%	117	1523	6.8%	2	5	28	67	24	27
Glide	58	11	13.3%	37	2157	9.6%	0	1.3	17	66	218	23
High Gradient Riffle	26	4	6.0%	18	477	2.1%	0	0.8	24	63		
Lateral Scour Pool	33	8	7.6%	76	2498	11.1%	2	6.4	19	64	231	25
Lateral Scour Pool Bedrock Formed	11	2	2.5%	73	804	3.6%	2	5.1	10	75	24	43
Lateral Scour Pool Boulder Formed	4	2	0.9%	47	187	0.8%	2	3.3	43	65		
Lateral Scour Pool Log Enhanced	34	8	7.8%	73	2491	11.0%	2	6	46	74	219	26
Lateral Scour Pool Root Wad Enhanced	55	12	12.6%	77	4243	18.8%	2	5.3	35	57	610	27
Low Gradient Riffle	103	20	23.7%	23	2329	10.3%	0	0.6	12	64	53	19
Mid-Channel Pool	29	7	6.7%	69	1995	8.8%	1	3.5	28	40	122	26
Plunge Pool	16	4	3.7%	72	1147	5.1%	3	7.1	36	69	150	23
Run	5	2	1.1%	23	117	0.5%	0	0.7	13	35		
Step Pool	9	4	2.1%	83	750	3.3%	1	4.6	16	51	6	18
Step Run	18	5	4.1%	33	602	2.7%	0	1.1	24	43	14	20
Trench Pool	6	2	1.4%	93	558	2.5%	2	4.2	48	78	6	25
Total	435	100			22551						1709	26

Table 2. Level IV Habitat Statistics

	Reach 1	Reach 2	Reach 3	Reach 4	Upper Pinole Creek
Length (ft)	5492	9390	2882	5047	22811
# of habitats	88	170	79	121	458
% Pools	53	59	41	45	51
% Riffle	31	29	30	31	30
% Flatwater	16	12	29	24	19
Pool/Riffle Ratio (by habitat occurrence)	1.69	2	1.4	1.5	1.7
Length of pools (ft)	4403	7495	1800	2831	16529
# of pool habitats	44	92	31	50	217
Avg Pool Length	100	81	58	57	76
Avg Pool Depth	2.1	2.1	1.6	1.4	1.9
Max Pool Depth	6.4	7.1	4.3	5.5	7.1
# of pools with max depth < 2 ft	6	13	8	24	51
# of pools with max depth > or = 2 ft	38	79	23	26	166
% of pools with depths > or = 2 ft	86	86	74	52	76
Avg spawning gravel embededdnes within pools	32	22	29	29	28
Area (sq ft) of spawning gravel within pools	493	562	218	151	1424
Total area of spawning gravel	493	603	320	293	1709
Shelter Complexity	Low-Medium	Low-Medium	Low	Low	Low
Average % Shelter Rating	29	25	23	23	25
Dominant Shelter Type	Terrestrial Vegetation	Terrestrial Vegetation	Terrestrial Vegetation	Terrestrial Vegetation	Terrestrial Vegetation
Subdominant Shelter Type	Boulder	Undercut Bank	Large Woody Debris	Rooted Aquatic	Boulder/Root Mass/Undercut Bank
Dominant Substrate Composition	Gravel	Gravel and Silt/Clay	Sand	Silt/Clay	Silt/Clay
Subdominant Substrate Composition	Silt/Clay	Small Cobble	Silt/Clay and Gravel	Gravel	Gravel
Average % Canopy	56	55	71	63	61

Table 3. Upper Pinole Creek Pool, Shelter, Substrate and Canopy Statistics

Silt/clay was the dominant substrate and gravel was the subdominate substrate in upper Pinole Creek. Sand and boulders were also common substrates in pool tail areas. Embeddedness measured in spawning gravel areas, primarily pool tail-outs, averaged 25%.

Shelter complexity was described and cover types and percentages were measured for 20% of all habitat units. Shelter complexity was rated as high in 10% of the habitats, medium for 26% of the habitats and low for 69% of the habitats. Percent of shelter coverage averaged 25%. Terrestrial vegetation was the dominant cover type, making up 39% of the cover available for juvenile salmonids (Figure 6). Undercut bank (10%), root mass (10%), boulder (10%), large woody debris (9%) and small woody debris (8%) were other common cover types.

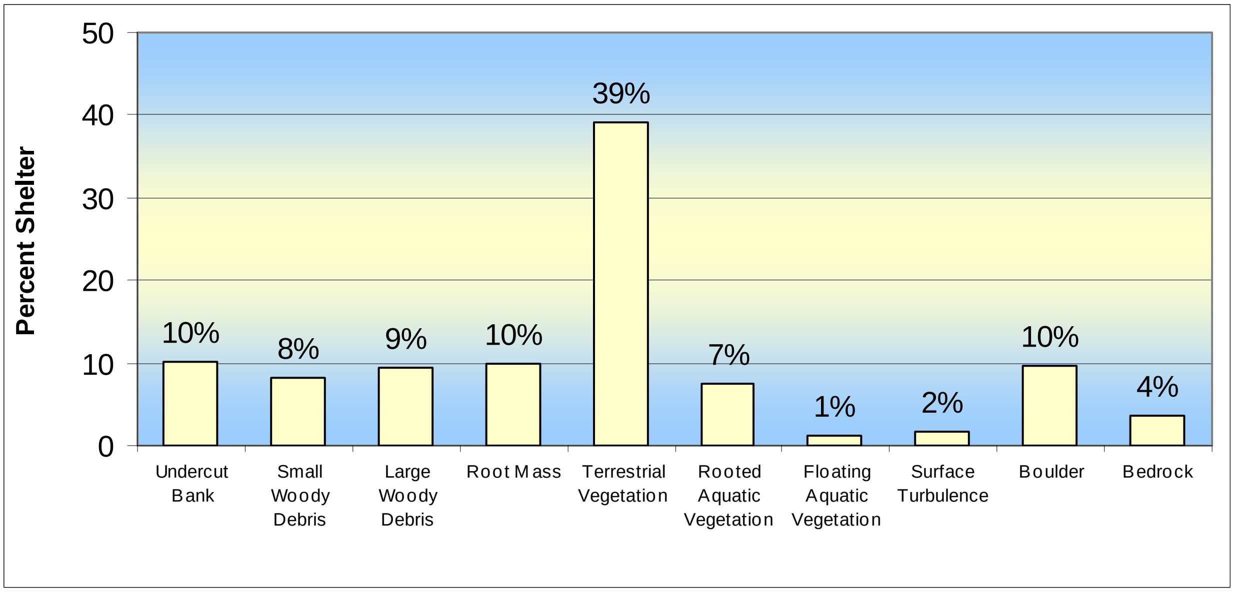

Figure 6. Shelter Complexity

Mean Canopy cover for upper Pinole Creek was 61%. Willow (*Salix* spp.) was most often the dominant canopy species (42%) followed by California bay (*Umbellularia californica*)(19%), buckeye (*Aesculus californica*) (13%), coast live oak (*Quercus agrifola*) (12%) and black walnut (*Juglans californica*) (11%) (Figure 7). Canopy cover was higher in reaches 3 and 4 (60-70%) and lower in reaches 1 and 2 (55%). There are notable gaps in canopy cover in reaches 1 and 2 where incision and bank erosion have limited the establishment of riparian vegetation (Table 3).

Reaches 1 and 2 had more frequent and larger spawning gravel areas than reaches 3 and 4 (Table 3) (Figure 8).

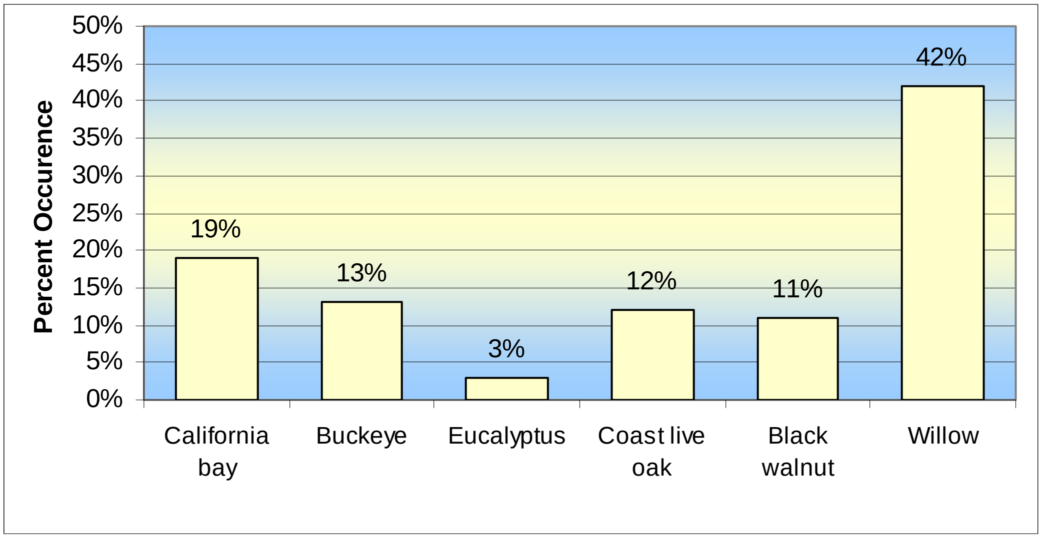

Figure 7. Dominant Canopy Species Distribution

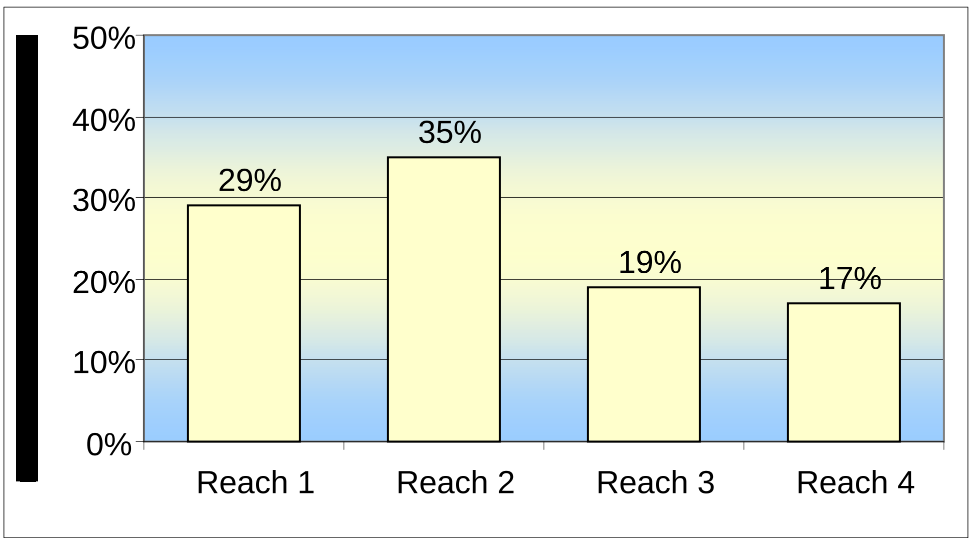

Figure 8. Distribution of Spawning Gravel Recorded by Reach

<u>Supplemental Data</u>

Hourly water temperatures are available for upper Pinole Creek on EBMUD watershed from thermographs deployed at 2 locations. EBMUD thermograph data has been collected since April of 2007 at an old bridge site a few hundred feet upstream of the Pinole city limits and at a location approximately 150 feet downstream of the Pinole Creek waterfall on EBMUD watershed. These sites are in reaches 1 and 3 respectively. Hourly temperatures are currently available through the end of May 2009. Thermograph data shows that in the past three years, monthly water temperatures in the May through September period have averaged from 14 to 17^{o}C at both sites. The highest temperature recorded in that time period was 20.4^{o}C on one day in May 2008 at the waterfall site.

The Contra County Volunteer Monitoring Program has collected benthic macroinvertebrate data on Pinole Creek since 2002. This data has shown that BMI ranking scores on the main stem of Pinole Creek vary based on location in the watershed. In general ranking scores are highest on the middle/upper section of the watershed on EBMUD lands and were lowest in the lower creek within the Pinole City limits. The middle/upper section ranks as "good" based on the Index of Biological Integrity and the lower watershed ranks as "marginal" or "fair" depending on the location. Fine sediment in riffles was noted as a potential stressor at lower ranking sites (Cressey, 2003).

DISCUSSION

Results of this habitat assessment indicate that significant steelhead/rainbow trout habitat exists within the upper Pinole Creek watershed. The persistence of a resident rainbow trout population in the watershed suggests this as well. While Pinole Creek suffers to some degree from the same issues that affect many local urban watersheds, it remains one of the top prospects for steelhead restoration in the San Francisco Bay Area. Potential limiting factors to salmonid populations in Pinole Creek are treated in detail below.

Migration Barriers

The locations of all potential passage obstacles encountered while mapping the upper Pinole Creek watershed were recorded with a GPS unit. Data such as type of obstacle, obstacle measurements and a judgement of severity of the passage obstacle were noted. Obstacles included rootwad dams, bedrock sheets, waterfalls, large woody debris jams, headcuts and man-made structures. Location data will allow EBMUD biologist to revisit these obstacles for a more thorough evaluation of passage conditions under higher flow conditions.

The only barrier in upper Pinole Creek that was judged to be impassable to steelhead was the concrete box culvert under Bear Creek Road. This structure marked the upper limit of our habitat assessment and is likely the upper limit to steelhead migration in Pinole Creek. Three passage obstacles were judged to be partial barriers to steelhead, including a waterfall, a bedrock sheet, and a headcut (Figure 9). All three of these obstacles are located high up in the watershed and do not affect steelhead access to the highest quality habitat, but are most likely total barriers to smaller adult trout and juveniles. Further study of these structures will be needed to determine the range of flows at which they are passable to steelhead and resident trout.

There were approximately 16 minor passage obstacles in the upper Pinole Creek stretch. Most of these were less than 3 feet tall and had sufficient jump pools to make them passable to all but the smallest fish. These structures likely affect the distribution of juvenile trout but do not likely impact movement of adult trout or steelhead.

The most significant barrier to steelhead migration in Pinole Creek is the double box culvert under Highway 80. This structure is in the lower creek approximately 1.9 miles upstream of San Pablo Bay. FishXing analysis shows the culvert to be a total barrier to steelhead but it is likely that a few fish get past this structure under some flow conditions.

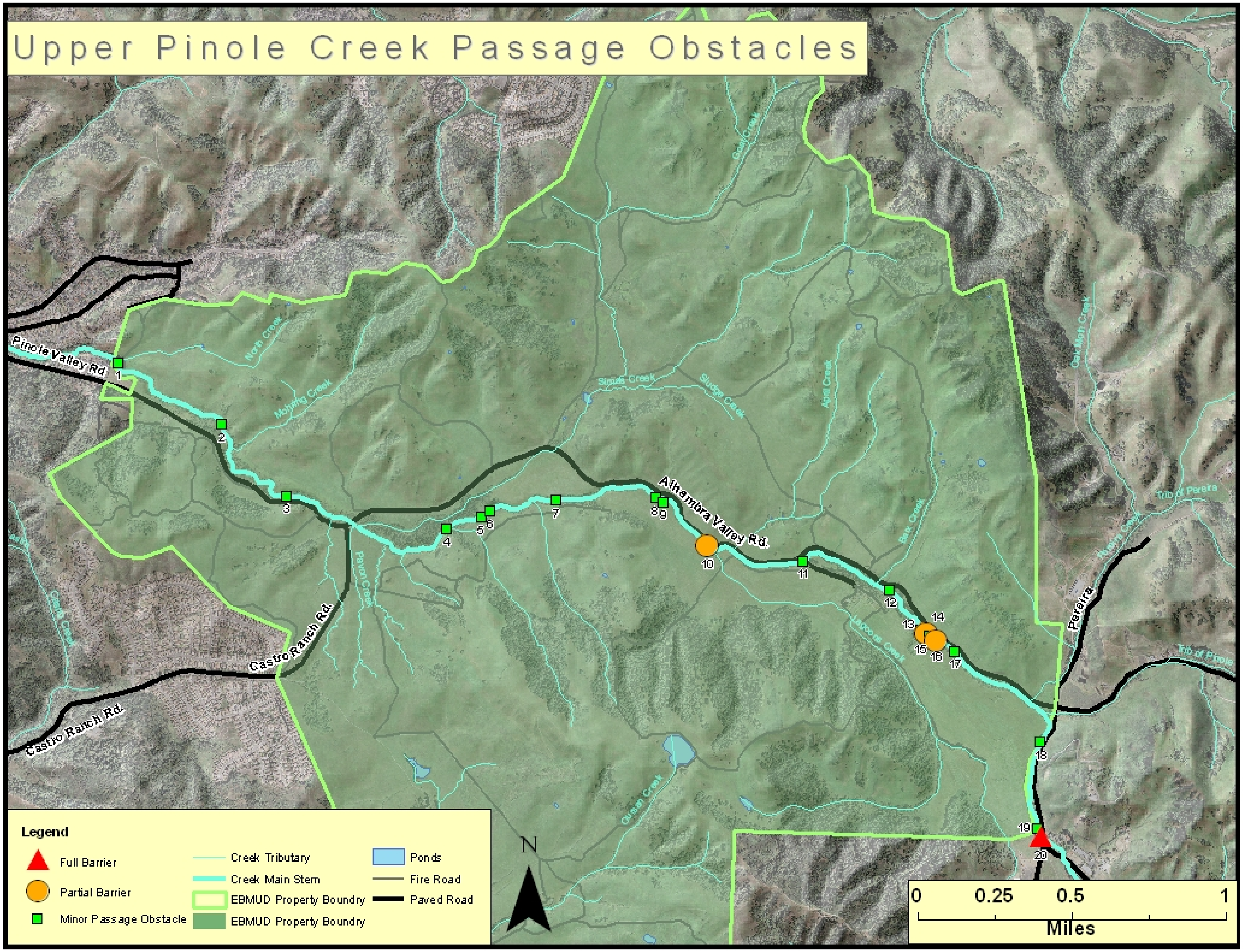

Figure 9. Upper Pinole Creek Passage Obstacle Map

Resident trout are likely responsible for the bulk of reproduction in most years as a result of this barrier to steelhead migration. Improved passage at this barrier would open up at least 6.7 miles of steelhead habitat on the mainstem of Pinole Creek. Steelhead reproduction would also enhance numbers, increase distribution, and improve genetic diversity in the population.

Temperature

This habitat assessment, along with temperature and population monitoring by EBMUD biologists, indicate that temperature is not a major limiting factor for steelhead or rainbow trout in Pinole Creek. The upper Pinole Creek riparian corridor is relatively intact and provides overhanging vegetation to keep creek temperatures within acceptable ranges for salmonids. There is an abundance of deep pools in the upper Pinole Creek watershed and pool temperatures rarely exceed preferred temperatures for rainbow trout/steelhead. Maximum recorded temperatures in the summer have reached 19 to 20 ^{o}C for short durations on some days, below temperatures that would be considered detrimental for the species (Reiser and Bjornn., 1979). In addition, EBMUD fish surveys have collected healthy trout from upper Pinole Creek for at least the past 15 years.

Rearing Habitat

Upper Pinole Creek has an abundance of deep pool habitat for rearing steelhead and resident rainbow trout. Pools made up 51% of all habitat units and over 75% of these pools had a maximum depth of 2 feet or greater. Lateral scour pools were the most common and these pool types offer good shelter in the form of undercut banks, rootwads, woody debris cover and overhanging vegetation. Shelter complexity ranged from low to medium. The quality and quantity of shelter was relatively good, however, providing plenty of habitat for rearing and adult fish.

The relatively low number of riffle habitats is potentially a limiting factor for salmonids in Pinole Creek. Benthic macroinvertebrate surveys, however, indicate that food availability is sufficient to sustain salmonid populations. It is unknown how much terrestrial insects and other food sources are utilized by steelhead and rainbow trout in the watershed. It is likely that these sources, available from the often dense overhanging vegetation, supplement the benthic macroinvertebrate food source and increase the carrying capacity for salmonids.

Spawning Habitat and Sediment

Small areas with suitable spawning gravel for steelhead/rainbow trout exist in most reaches of upper Pinole Creek. Spawning gravels are distributed sporadically and in smaller pockets in reaches 3 and 4. Reaches 1 and 2 in the middle of the watershed have the best quality and the largest quantity of spawning gravels. These reaches have the best size distribution of spawning gravel and the spawning areas are larger and more frequent. Embeddedness in these reaches averages 20 to 30%. While not expansive, many pool tail-outs in this area have suitable spawning areas. These areas are usually large enough to accommodate one or two redds, given the territorial nature of salmonid spawning. Collectively, these spawning areas appear to be sufficient to support a significant amount of spawning.

Upper Pinole Creek has considerable input of fine sediments. The Pinole Creek Watershed Sediment Source Assessment (2004) identifies landslides, bank erosion and bed incision as important sediment sources.

Sediment appears to be the most significant limiting factor to steelhead and rainbow trout in Pinole Creek. The input of excess fine sediment into the creek has likely caused a reduction in quantity and quality of spawning habitat and a reduction in benthic macroinvertebrate diversity. Fine sediment does not appear to have significantly reduced pool depths or volume in the upper watershed.

Although embeddedness figures for the creek are not particularly high (25%), sediment is probably contributing to a reduction in recruitment from redds. Much of the spawning substrate was in the 20 to 40% embedded range which is enough to cause some mortality and a significant reduction in emergence from redds (Reiser and Bjornn., 1979). The embeddedness is not in a range, however, that would cause severe declines in redd recruitment. It should be noted that the average embededness number is most likely a low estimate due to the scarcity of larger substrate sizes in spawning areas that would normally be used to estimate embeddedness.

Embeddedness is also high enough to reduce diversity of benthic macroinvertebrates. Fine sediment fills in interstitial spaces between larger particles and reduces habitat for many macroinvertebrates. BMI data shows that the macroinvertebrate community on Pinole Creek is dominated by collector and filter-feeding groups (Contra Costa County, 2008) which generally have high pollution tolerances. Despite this potential impairment, benthic macroinvertebrate densities are indicative of a suitable food source for salmonids.

Water Quality

A limited amount of water quality analysis has been conducted on Pinole Creek, thus water quality issues have yet to be identified. One potential indicator of water quality was observed during the habitat assessment: the abundance of algal growth in the uppermost stretch of Pinole Creek at the top of EBMUD watershed lands. The extensive algal growth in this stretch despite shading from a mostly intact canopy indicates upstream nutrient loading. Agriculture, horse stables, ranches and a new cemetery upstream are potential sources of excess nutrients in the upper watershed.

RECOMMENDATIONS

Pinole Creek has supported a self-sustaining steelhead/rainbow trout population for at least the past several decades. There are considerable amounts of habitat available for rearing fish with suitable temperatures, quality shelter, and an abundance of deep water habitats. The box culvert at Highway 80 is the only major barrier for migration downstream of the best quality salmonid habitat. Smaller passage obstacles exist in the upstream reaches of the creek which may limit the distribution of fish by limiting the migration of smaller resident fish. Sediment which limits the macroinvertebrate diversity and degrades salmonid spawning habitat is probably the most significant limiting factor to steelhead/rainbow trout in Pinole Creek.

Pinole Creek should be managed to increase the contribution of anadromous steelhead to the population. This can be readily achieved by improving fish passage at the Highway 80 box culvert in the lower watershed. EBMUD biologists have documented adult steelhead that were unable to pass this structure. Steelhead spawning has not been detected in Pinole Creek during limited redd surveys conducted in the past several years. Only one adult steelhead has been documented in the upper watershed during spawning season, but there is genetic analysis that anadromy occurs and anecdotal information that steelhead have spawned successfully in the upper watershed. There is little doubt that improved passage for steelhead at the Highway 80 box culverts will enhance steelhead distribution and increase population numbers in Pinole Creek.

Additional enhancements that could be undertaken to improve steelhead/rainbow trout populations include bank stabilization, riparian enhancement and potentially spawning gravel enhancements. Remediation of sediment sources is likely to have a positive impact on salmonid populations in Pinole Creek. Water quality monitoring will also be important to identify sources of pollution.

REFERENCES

Contra Costa County, 2008. Watershed Monitoring Program data.

Cressey, S. 2003. Contra Costa Monitoring and Asssessment Plan (CCMAP) 2002 Rapid Bioassessment Project Contra Costa County, California.

EBMUD Fish Population Sampling 1996, 1997, 2001, 2005, 2006, 2008. East Bay Municipal Utility District internal reports. East Bay Fisheries and Wildlife Division.

Flosi,G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual, third edition. California Department of Fish and Game.

Leidy, R.A. 1984. Distribution and Ecology of Stream Fishes in the San Francisco Bay Drainage. Hilgardia, 52 (8) 175pp.

Leidy, R.A. 2007. Ecology, Assemblage Structure, Distribution, and Status of Fishes in Streams Tributary to the San Francisco Estuary, California. San Francisco Estuary Institute. Contribution no.530.

McMahon, T.E., A.V. Zale and D.J. Orth. 1996. Aquatic Habitat Measurements. Pages 83-120. *In* B.R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Neilsen, J.L. 1999. Variation in mtDNA and Nuclear Microsatellite DNA Markers in Pinole Creek Trout. East Bay Municipal Utility District Report. 28pp.

Pearce, S., McKee, L., and Shonkoff, S., 2005. Pinole Creek Watershed Sediment Source Assessment. A technical report of the Regional Watershed Program, San Francisco Estuary Institute (SFEI), Oakland, California. SFEI Contribution no. 316, 102 pp.

Reiser, D.W. and T.C. Bjornn. 1979. Habitat Requirements of Anadromous Salmonids. Pages 83-138. *In:* Meehan, W.R., (editor). Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. U.S. Department of Agriculture, Forest Service. Special publication 19.