Evaluation of the Potential Historical and Current Occurrence of Steelhead within the Livermore-Amador Valley

Prepared for

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Introduction

Steelhead (*Oncorhynchus mykiss*) historically inhabited many of the tributaries to San Francisco Bay. These tributaries provided habitat for adult spawning, egg incubation, juvenile rearing, and as migratory corridors for both adults and juveniles between the freshwater natal stream and coastal marine waters. Although historical occurrence of steelhead within Alameda Creek has been documented by a number of investigators (Skinner 1962, Leidy 1984) relatively little information is known regarding the occurrence of steelhead within the Livermore-Amador Valley with specific focus on Arroyo Mocho and Arroyo Valle (also referred to as Arroyo del Valle), which are tributaries to Alameda Creek. As part of the foundation for long-term planning, Alameda County Flood Control and Water Conservation District - Zone 7 requested that an investigation be performed to assess the potential historical occurrence of steelhead within Arroyo Mocho and Arroyo Valle. The scope of work for this investigation included:

- Discussion of the lifecycle and habitat requirements for anadromous steelhead,

- Examination of historical records and documents regarding the geomorphic characteristics of both Arroyo Mocho and Arroyo Valle historically, anecdotal information from local newspapers, mission records, and other historical documents, and an assessment of habitat conditions and limiting factors within both watersheds that may have affected habitat suitability for various life stages of steelhead,

- Identification and discussion of current opportunities and constraints for supporting steelhead adult spawning, egg incubation, juvenile rearing and over summering, and migration within the watersheds, and

- Potential future actions that would benefit habitat conditions with the watersheds for steelhead.

Specific questions to be addressed in the assessment included:

- Were steelhead historically present in Arroyo Mocho and/or Arroyo Valle y?

- Historically, was there suitable habitat for steelhead migration, spawning, and rearing?

- What is the current suitability of habitat for steelhead and their occurrence?

- What actions would be required to provide suitable habitat for steelhead in the future?

The assessment was performed by an interdisciplinary team of scientists under the direction of Dr. Charles H. Hanson, Hanson Environmental, Inc. (fishery biology), Dr. Janet Sowers, William Lettis & Associates, Inc. (geomorphology and hydrology), and Dr. Allen Pastron, Archeo-Tec (archaeology and historical document search). Results of the assessment of the potential historical occurrence of steelhead within Arroyo Mocho and Arroyo Valle, current opportunities and constraints within both watersheds, and potential future actions are briefly summarized below.

A Brief Summary of Steelhead Life History

Steelhead are an anadromous species, living part of their life in the ocean but returning to freshwater rivers and streams to spawn and for juvenile rearing (Figure 1). The general seasonal distribution of various lifestages of steelhead is shown below:

General seasonal distribution of steelhead within the San Francisco Bay area and Central Valley.

Lifestage	O	N	D	J	F	M	A	M	J	J	A	S
Upstream adult migration												
Spawning												
Egg incubation/hatching												
Fry emergence												
Downstream adult migration												
Juvenile rearing												
Smolt downstream migration												
Ocean rearing												
Primary season												
Secondary season												

Adult steelhead enter freshwater rivers and streams in the winter, usually after the first substantial rainfall, and move upstream to suitable spawning areas (typically in November through March with the peak migration period from December through February). Spawning can occur in winter or spring, generally in riffle areas with clean coarse gravel. During spawning, the female steelhead clears and cleans a depression in the gravel (redd) where eggs are deposited, fertilized, and incubate until hatching. After the eggs hatch, fry emerge from the gravel and disperse through the stream, typically occupying shallow low-velocity areas along stream margins. Juvenile steelhead often move to deeper pools and higher velocity areas as they grow, and remain in fresh water for one to two years before migrating to the ocean. Downstream movement of adults after spawning predominantly occurs from February through April. Juveniles (smolts) migrating to the ocean usually occurs from November through May with peak migration from February through April, depending on stream flow conditions. Adults can spawn more than once, although most do not spawn more than twice.

The lifehistory of steelhead is flexible, responding in part to variation in environmental conditions. For example, juvenile steelhead may migrate downstream to coastal waters (anadromous) or may remain throughout their lifecycle within freshwater habitats (resident rainbow trout). Adult steelhead may remain in coastal waters delaying spawning migration for one or more years in response to unsuitable migration conditions within their natal stream. The expression of these different lifehistory patterns varies among streams and years which are thought to reflect variation in environmental conditions such as streamflow, blockage by a sandbar or other obstruction, water temperatures, and other factors.

Clear, cold water, abundant instream cover, well-vegetated stream banks, relatively stable water flow, and stream features including pools and riffles generally characterize steelhead habitat. Although suitable water temperatures for steelhead in California are considered to range from 10 to 20 C (50 to 68 F), steelhead in southern California have been observed in streams with peak daily water temperatures above 25 C (77 F) during summer and early fall.

A well-developed riparian corridor is an important component in steelhead streams. Riparian vegetation inhibits erosion of stream banks during high flows, maintains lower stream temperatures, and provides organic input to the stream. Suitable spawning gravels are 0.5 to 3 inches in diameter, 8 inches in depth or more, not heavily compacted, and have low amounts of sand or silt; however, steelhead can successfully spawn in gravels not meeting these characteristics. Spawning gravel quality is improved by scour of fine-grained sediments (e.g., silts) during redd construction. Steelhead are known to spawn in suboptimal gravels under conditions when preferred gravels are not available. Steelhead also are known to spawn in areas where steelhead have previously spawned (redd superimposition). Relatively little quantitative information is available, however, on the variation in spawning site selection by steelhead within and among stream systems in California.

Good rearing habitat contains low current velocities (such as behind boulders or other velocity barriers) and good cover (e.g., undercut banks, logs or brush, surface turbulence). Cobble embeddedness (amount of sediment surrounding rocky substrate) is a measure of shelter availability for aquatic insects (food for fish) and young fish. Embeddedness also indirectly characterizes habitat suitability for incubation of fish eggs and for salmonid overwintering.

Streamflow within the central and southern extent of steelhead range within California varies seasonally and annually. In California coastal drainages, droughts of one or more years can cause intermittent flow in late summer and fall with reductions in pool depths, reducing the quality and quantity of available habitat. Although steelhead can withstand substantial seasonal and annual fluctuations in stream flow and other physical conditions, prolonged drought can result in substantial mortality to juvenile fish.

Migration

Adult steelhead tend to migrate upstream from the ocean after prolonged storms that provide attraction flows to a watershed and sufficient water depth within a stream channel to facilitate adult upstream migration. Adult migration into small tributaries to San Francisco Bay may begin as early as November and may extend into March if late spring storms develop. Most adult migration occurs during the wettest months, December through February.

Adult steelhead may be blocked in their upstream migration by bedrock falls, shallow riffles and, rarely, major logjams. Man-made structures such as culverts, gaging stations, bridge abutments and dams are often significant migration impediments and/or barriers. Passage barriers completely block upstream migration. Some obstructions to upstream migration in coastal streams are passable at higher streamflows but are a barrier to passage under lower flows (passage impediments – not a complete migration barrier but an obstruction that delays or impedes migration). If the barrier is not absolute, some adult steelhead are able to pass in most years, since they can time upstream movements to match peak flow conditions. Improvements in upstream migration conditions through removal of passage barriers and impediments, including construction of fish ladders and passage facilities (e.g., step pools and weirs) provide upstream access for adults and downstream passage of adults and juveniles, reduce stress and mortality, provide access to larger habitats suitable for spawning and juvenile rearing, and improve reproductive success, survival, and population productivity.

In coastal streams, smolts (young steelhead are physiologically transformed in preparation for ocean life) tend to migrate downstream to San Francisco Bay and into the ocean between the months of November and May with the majority of juvenile migration between February and April.

Spawning

Steelhead require spawning gravels (from 0.5 to 3-inch diameter) having a minimum of fine material (sand and silt). Increases in fine materials from sedimentation, or cementing of gravels with fine materials, restrict water and oxygen flow through the redd (nest) to the fertilized eggs. These restrictions increase egg mortality. In many streams, steelhead utilize substrates for spawning with high percentages of coarse sand, which may reduce hatching success. Large woody debris forms depositional sites for gravel and spawning habitat.

Steelhead that spawn earlier in the winter than others in the population are more likely to have their redds scoured out or buried by sediment deposited during winter storms. Unless hatching success has been severely reduced, survival of eggs and larvae is usually sufficient to saturate the limited available rearing habitat in most coastal streams. Production of young-of-the year (first year) steelhead is related to spawning success, which depends on the quality of spawning conditions and ease of spawning access to suitable spawning habitat in the mainstream river or tributaries.

Rearing Habitat

Except in streams with high food production, most juvenile steelhead require two summers of residence before reaching smolt size. In productive systems with suitable water temperature and food availability, a high proportion of steelhead require only one summer of residence before reaching smolt size. Juvenile steelhead are identified as young-of-the-year (first year) and yearlings (second year). Young-of-the-year steelhead growth and survival appears to be regulated by available insect food and water temperatures. Escape cover (hiding areas provided by undercut banks, large rocks not buried or embedded in finer substrate, surface turbulence, etc.) and water depth in pools, runs and riffles are also important, especially for larger fish. Pool and run habitats are the primary rearing areas for steelhead in summer, with pools most important to larger fish. Availability of cover is an important factor affecting juvenile steelhead survival during the low-flow summer months.

Growth rates of yearling steelhead usually show a large incremental increase from March through May. As smolts mature physiologically, they emigrate downstream to the ocean. For steelhead, which continue to rear in the stream over a second summer, summer growth is very low (or even negative in terms of weight). A growth period may also occur in fall and early winter after leaf-drop of riparian trees and before water temperatures decline or water clarity becomes too turbid for feeding.

Overwintering Habitat

Deeper pools, undercut banks, side channels, and large, unembedded rocks provide shelter for steelhead against the high flows of winter. Extreme floods may make overwintering habitat the critical factor in steelhead production in some years. In most years, if pools have sufficient larger boulders or undercut banks to provide summer rearing habitat for yearling steelhead, these elements are sufficient to protect juvenile steelhead against winter flows.

Historical Occurrence in Arroyo Mocho and/or Arroyo Valle

Alameda Creek and its tributaries including both Arroyo Mocho and Arroyo Valle (Figure 2) are tributaries to South San Francisco Bay. The watersheds have experienced a number of land-use and associated instream habitat changes over the last 150 years, including, but not limited to, channelization and other modifications for flood control and to increase stability of the stream channels, urbanization, farming and agricultural development, and development of domestic water supplies. In addition to natural barriers and impediments to steelhead migration into and out of Alameda Creek, Arroyo Mocho, and Arroyo Valle, these historical changes in land-use practices and activities have also resulted in a number of additional barriers and impediments to steelhead migration within the watershed (Figure 2). Becker (1999) identified and surveyed steelhead passage barriers within lower Alameda Creek, with additional information on passage barriers and impediments within the watersheds developed by Applied Marine Sciences (2000). The current and historical occurrence of passage barriers and impediments, including geomorphic conditions occurring within the historical creek channels, in combination with hydrologic conditions occurring within the watersheds, strongly affected access and quality and availability of suitable habitat for steelhead within the watersheds.

As part of this investigation, Dr. Janet Sowers evaluated the historical geomorphic conditions within both Arroyo Mocho and Arroyo Valle to assess potential access based on (1) connectivity of stream channels and (2) flood frequency and historical steelhead catches. Results of the assessment of geomorphic and hydrologic conditions affecting steelhead migration and access to potentially suitable upstream habitats for spawning, egg incubation, and juvenile rearing are briefly summarized below.

Approach

A description of Arroyo Valle and Arroyo Mocho as they probably were in the late 1800's before significant stream alterations were made was developed based on an interpretation of historical records, pre-1900 era maps, aerial photographs, engineers' reports, and stream gaging data. The focus was on the physical continuity and geometry of channels, time distribution of discharge, and the relationship of these streams to the landscape they both inhabit and shape.

This picture is not a completely natural one, as ranching of the watershed had already begun in the early 1800's. Changes in vegetation cover and soil erodibility may have already caused subtle changes in the sediment balance in the streams. However, much greater changes were to follow. The 1900's then brought agriculture, channelization of streams, pumping of groundwater, building of dams and other in-stream structures, and ultimately the urbanization of the valley.

Based on their physical characteristics, it seems clear that the upper reaches of either stream would have been suitable steelhead habitat. These upper reaches consisted of bedrock channels with riparian vegetation that shaded the channel, and deep pools that provided refuge when flows were at their lowest. Potentially suitable gravels for spawning were present, although in limited quantity, within a number of the pools present within the upper stream reaches. Surveys by Hanson (2003) provide documentation of habitat characteristics in some of these upper reaches.

The lower reaches, where the streams cross the valley floor, were the primary subjects of this analysis (Figure 3). Whether fish could swim upstream from the historic lagoon through the lower reaches will determine whether they could have arrived at the suitable spawning and rearing habitat in the upper reaches. In these lower reaches stream flow sinks into the valley alluvium, the stream channels subdivide and widen, and riparian vegetation is relatively sparse.

Results of the Evaluation of Historical Passage Opportunities

This section presents information on:

(1) The connectivity of stream channels across the valley floor. A continuous stream channel with a minimum water depth is required for fish passage during the critical months for migration. Did these two streams have continuous channels connecting the lagoon to their respective headwaters?

(2) The issue of how often such a connection might have been present is discussed. Flood frequency records are combined with other observations to make an estimate of how often flow might have been sufficient to make the channels passable for steelhead.

Connectivity of stream channels

Research suggests that under natural conditions most streams entering the Livermore-Amador Valley did not reach the lagoon via a surface channel. Most streams emerged from the hills, and then, as they crossed the alluvial valley floor they lost water to the porous alluvium and dropped their sediment building coalescing alluvial fans. Each channel divided into progressively smaller and more numerous channels then eventually disappeared on the alluvial fan. Historical information presented below provides the best available documentation of the natural condition of Arroyo Valle and Arroyo Mocho.

Written accounts

At the turn of the century, the hydrology of the Livermore -Amador Valley was the subject of intensive study. Hop and sugar beet farmers were interested in draining the marsh for farming, preserving water for irrigation, and protecting fields from flooding. Water supply engineers from San Francisco were interested in tapping into the rich artesian groundwater basin to supply the growing City of San Francisco. Their observations give us insight into the interaction between the streams and the groundwater basin.

Civil engineer Fred Tibbets (1907) describes the streams as follows.

> "…all of the creeks flowing into the Livermore Valley are dry during the summer months, the water seeping into the gravel beds as it emerges from the hills. This effect is especially marked in the two larger streams, the Arroyo del Valle and Arroyo Mocho."

Tibbets then presents measurements that illustrate this process. During the first flood in January 14, 1906, discharge was measured at 1,136 cfs at Cresta Blanca Bridge and only 600 cfs downstream in Pleasanton. This represents a 47% seepage loss. This loss was matched by a simultaneous rise in the water levels in artesian wells near Pleasanton. He notes that the percentage of water lost into the alluvium decreased through the winter season.

Another account highlights the characteristic of Arroyo Mocho to lose its water downstream. Gudde and Bright (1998) provide a 1936 quote from Elmer Still of the Livermore Herald to explain the origin of the name "*Arroyo Mocho*." "It was on account of this creek having no outlet, but sinking into the ground (except in the wettest weather) after spreading out into many smaller streams between Livermore and Pleasanton, that it was given the name Arroyo Mocho, meaning '*cut-off creek'*."

Pre-1900 maps

Historical maps illustrate stream patterns as seen by early surveyors and cartographers. Five pre-1900 historical maps were examined, plus 1939 aerial photography (Table 1). A description of the significance of each map is given below.

These early maps are in keeping with written accounts and show that many of the streams ended on the valley floor before reaching the lagoon. The maps also show that of the two streams, Arroyo Valle came much closer to connecting to the lagoon or to Arroyo de la Laguna regularly than did Arroyo Mocho (Figure 3). Four of the five historical maps and the aerial photography show Arroyo Valle to have at least one distributary that connects to the lagoon (Table 1). In contrast, four out of five historical maps and the aerial photographs show that Arroyo Mocho was NOT connected to the lagoon (Figure 3; Table 1). The cause of this is probably higher storm flows produced by the Arroyo Valle watershed, which is nearly three times (147 sq mi) as big as the Arroyo Mocho watershed (50 sq mi). In addition, with its somewhat higher elevation, rainfall per unit area is greater in the Arroyo Valle watershed (Department of Water Resources, 1963). Peak discharges illustrate the contrast. Gaging records show that during the 1956 flood, the peak discharge of Arroyo Valle was about 18,000 cfs, and that of Arroyo Mocho about 2,600 cfs.

Table 1. Stream connectivity from historical maps and aerial photographs.

Date	Author	Is stream drawn connecting to lagoon?	
		Arroyo Valle	**Arroyo Mocho**
1838	Sunol, Antonio	yes	no
1857	Higley, Horace	yes	no
1874	Allardt, Geo. F.	yes	no
1878	Thompson & West	yes to NW, but SW distributary does not connect	yes
1912	Williams, Cyril, data from 1867	no	no
1939	USDA aerial photography	yes, but not all distributaries	no

The earliest map of the valley is a circa-1838 diseño (sketch map that shows the property of the early ranchos) prepared by Antonio Sunol (Sowers 2003). The map shows an oval shaped area marked "*Tular*", representing the lagoon. A wavy line extending south from the *tular* indicates Arroyo de la Laguna, and a line coming in from the east joins the first representing the junction of Arroyo Valle (labeled *Arroyo de los Taunomines*). Arroyo Mocho, however, is shown as a line that ends in a scribble in the center of the valley.

The map of Higley (1857) is the earliest official map of Alameda County (Sowers 2003). Higley shows a large oval-shaped marsh in the western part of the valley with several streams flowing into and through the marsh, including Arroyo Valle (*labeled Arroyo Vaya*). Arroyo Mocho, however, is shown ending in the center of the valley far short of the marsh.

G. F. Allardt's 1874 map (Sowers 2003) was a more widely distributed and somewhat more detailed map than Higley's, and similarly it shows Arroyo Valle connecting to the lagoon and Arroyo Mocho ending in the center of the valley. Allardt shows the detail of the distributary pattern of Arroyo Mocho as it subdivides into progressively smaller channels on the valley floor. He also shows the wide, braided pattern of Arroyo Valle east of Pleasanton. His is the first map to show a complex boundary for the lagoon.

In 1878 Thompson & West published a map of the valley in their Historical Atlas of Alameda County (Sowers 2003). It shows all creeks as connected to the lagoon (labeled "*willow marsh*"). Arroyo Valle is shown with three distributaries, two of which connect to the lagoon, and one, the southwest fork, which ends without connecting. Arroyo Mocho is shown as a very straight channel where it flows west from Livermore parallel to the Central Pacific Railway, suggesting it was already confined in an artificial ditch. The straight ditch bends north, then ends in a wavy line that connects the creek to Arroyo Las Positas. This wavy line may be a schematic representation of the creek, rather than a mapped channel pattern. No evidence of a channel in this location is present on aerial photographs or other historical maps. Because this is the only pre-1900 map that shows Arroyo Mocho connecting to Arroyo Las Positas, we believe that it probably did not connect.

Cyril Williams, an engineer for the Spring Valley Water Company, in 1912 compiled a map of the valley that includes mapping taken from the Whitney survey of 1867 (Sowers 2003). We have traced over his lines in colors (Figure 4). The 1867 data (blue) shows the lagoon, and most streams including Arroyo Mocho and Arroyo Valle ending in "*deltas*" on the valley floor without connecting to the lagoon. The location of the deltas corresponds to our interpretation from geomorphic and soils evidence of the location of late Holocene deposition for each of the creeks. In present terminology, these "*deltas*" are called alluvial fans. The 1867 data show that the fan of Arroyo Valle is much closer to the lagoon than that of Arroyo Mocho.

Between 1900 and 1910 many ditches were dug, as shown on the map of Williams (1912) (Figure 4). These were dug to drain the lagoon for farming, and to keep the creeks in a confined channel so they would not flood the fields. Arroyo Mocho was channelized from Livermore all the way to Arroyo de la Laguna, a total of about 7 miles. Along its route the channels of Arroyo las Positas (3.5 miles from Arroyo del la Laguna) and Tassajara Creek (1 mile from Arroyo de la Laguna) were joined, an action that more than doubled the watershed area of Arroyo Mocho. Arroyo Valle was channelized only for its final one mile; this channel was named the "Rose Canal." Following channel construction, both Arroyo Valle and Arroyo Mocho each had a single stable channel all the way through the valley to the Arroyo de la Laguna.

Overflow channels from a 1911 flood are shown in green on Williams (1912) (Figure 4). Our flood frequency analysis for Alameda Creek at Niles shows this flood to be about an 11-year recurrence interval discharge. In this flood both streams flowed down their channels and into ditches, probably reaching the lagoon. Another interesting point is that the overflow channels of Arroyo Valle and Arroyo Mocho joined during this flood. An older channel of Arroyo Valle, shown in purple, similarly flows toward Arroyo Mocho (Figure 4). Flood overflow channels from Arroyo Valle may have augmented Arroyo Mocho's flow during large flood events such as this one.

Aerial Photography

Aerial photography from 1939 and 1949 (Figure 5) provides us an opportunity to document the location of old stream channels before they became obliterated by urban development in the later part of the 20th century. In many cases, the presence of the channels on aerial photography serves as confirmation of channels shown on the historical maps. Channels visible on the photographs were not necessarily active in 1939-49 as the streams had long since been put in ditches, however, the old channels are still visible over much of the landscape. We traced these channels on overlays and compiled them on a master map along with the marsh and lagoon outlines from Allardt (1874) and Williams (1912, after Whitney, 1867), respectively (Figure 6).

The aerial photographs show that both Arroyo Valle and Arroyo Mocho, as well as other streams, subdivided into progressively smaller and more numerous channels as they made their way across the valley floor (Figure 5). Multiple channels can be seen on the photographs, some channels appearing old, discontinuous, and faded, others fresh and clear, suggesting multiple generations of flow over time. Channels are deepest where they exit the hills and become shallower as they progress westward.

It is interesting to note that the small distributary channels are not consistently marked by a line of riparian vegetation (Figure 5). Presumably moisture in these channels is so infrequent and the groundwater table is so low that conditions necessary to support riparian vegetation do not exist. Without the bank stabilizing effect of vegetation, the shifting of channels during large flood events will happen more readily than in a stable vegetated channel.

Conclusions Regarding Channel Connectivity

The picture that emerges from the historical data analysis is one of a large sediment-filled valley, which gently sloped to a marsh-ringed lagoon (Figure 6). From their headwaters in the surrounding hills, streams coursed down the canyons until they emerged onto the valley floor. There the flow percolated into the valley alluvium, the channels widened and the flow divided into distributary channels, dropping sediment carried from the hills. Water soaked down through the porous sediments into the ground-water basin, and as a result, the channels became smaller downstream. In the Livermore-Amador Valley, many of the stream channels, including Arroyo Mocho disappeared before they reached the lagoon (Figure 6).

The lagoon, fed by groundwater most of the year and stream runoff in large winter floods, occupied the lowest point in the valley. The margins of this wetland shrank in the summer and expanded in the winter. Most historical maps show no lake at all, only a large marsh, suggesting that standing water was a seasonal feature. Water that collected in the lagoon exited the valley through Arroyo de la Laguna, flowed south and joined Alameda Creek in Sunol Valley (Figure 6).

The lower reaches of most of the streams did not have stable channels across the valley floor. Flowing only during the highest discharges, they were dry in the summer with little moisture to support riparian vegetation along banks. During winter high flows the old channels were readily filled, overtopped, and abandoned, and new channels were created during these flood events. Sediments were distributed across the fan surface as the channels avulsed with each significant storm.

During the highest floods, runoff would certainly have reached the lagoon. The valley floor is underlain by alluvial sediments, which grade gently toward the lagoon. The lagoon itself is underlain by fine sediments delivered by tributary streams. Why, then, is there little evidence of channels extending into the lake? First, as the streams subdivide and become progressively smaller, they become so small that they cannot be mapped from aerial photographs, and may also be too small to persist as a landscape feature visible years after a major flood. Second, much of the flow may occur as sheet flow rather than channelized flow.

Arroyo Valle is a significantly larger stream than Arroyo Mocho, its distributary point is closer to the marsh, thus, its channel had a much more consistent connection to the marsh and to Arroyo de la Laguna (Figure 6). Thus, we might expect the passage of steelhead upstream from the marsh to be more likely in Arroyo Valle than in Arroyo Mocho. Fish passage would occur only when discharges were high enough to provide a continuous connection across the valley floor from the marsh to the headwaters reaches in the hills.

After the digging of the ditches between 1900 and 1911 (Figure 4), the ability of both streams to provide passage for fish probably would have been improved. The ditches provided a continuous, relatively deep, stable channel that would confine the flow and allow greater depths of water than would the natural multiple distributaries. Other tributary streams were added to Arroyo Mocho, increasing its discharge. We might expect steelhead sightings in these streams to occur more often after 1911, all other factors being equal.

Of course, not all factors remained equal after 1911. Many other changes took place in the watershed in the 20th century that affected the steelhead migration. Sunol Dam, a 28-foot-high concrete structure located downstream of the lagoon on Alameda Creek, was emplaced around 1900 and may or may not have been a barrier to fish migration. Much of the dam is submerged within the gravels, and steelhead sightings in the tributaries upstream of Sunol Dam after 1900 suggest that this dam could be jumped by steelhead during high flows. Then, in 1968, a 220-foot-high dam was placed on Arroyo Valle (Del Valle Reservoir), preventing access to the upper watershed and regulating flows in the lower reaches. The 1960's through 1990's saw the construction of many other projects on these two creeks and on Arroyo de la Laguna and Alameda Creek that now prevent steelhead migration into the upper watersheds of Arroyo Valle and Arroyo Mocho.

The first part of the 20th century, from about 1910 to 1960, was probably the most advantageous time period, historically, for steelhead migration into Arroyo Valle and Arroyo Mocho. The ditches had been dug, but the larger projects that created major barriers had not been built.

Flood Frequency and Historical Steelhead Catches

The geomorphology and flow characteristics of these streams suggest that fish would only have been able to find passage through the lower reaches of these streams during very high discharges in the winter months. In this section we attempt to put constraints on the frequency of such discharges for both Arroyo Mocho and Arroyo Valle. Available data include gaging records for 1891 through 2000 for Alameda Creek near Niles, maps of flood extent for three twentieth century storms, and sightings of large fish from historical accounts.

Gaging data for pre-1910 flood events in the lower reaches of these two streams are not available. Documentation as to whether flow in the channel reached the lagoon during specific floods is lacking except for the 1958, 1956, and 1911 storms, all of which took place after ditching of the streams was completed. Thus, our quantitative conclusions only refer to the time period of about 1910 to 1960, the window of time between completion of most of the ditches and the beginning of the construction of major migration barriers.

Flood Records

The stream gage on Alameda Creek in Niles Canyon provides the longest continuous record of any stream in the watershed and illustrates the pattern of flooding in the larger watershed over the last 100 years. Sowers (2003) presents information from these gaging records including the highest peak discharge for each winter of record. Note the very large discharges in the 1950's.

The flood of December 1955 (water year 1956) is the largest flood of record. Its recurrence interval is about 100 years, and that of the 1958 flood about 55 years (Sowers 2003). Photographs and maps of the extent of flooding in both the 1958 and 1955 events show that flow in both Arroyo Mocho and Arroyo Valle did reach the lagoon (Alameda County, 1958) (Figure 7). Furthermore, the lagoon itself, long ago ditched and drained, received so much water from the tributaries that water again stood there in significant depths (Figure7). Under 1950's conditions, it seems safe to assume that passage for fish would have been possible in either stream in the 1956 or 1958 floods.

The flood of 1911 also may have provided passage for fish in either Arroyo Valle or Arroyo Mocho. Williams (1912) shows overflow channels from the 1911 flood that extend to the ditches (Figure 4). The flood frequency analysis shows this to be an 11-year recurrence interval flood.

Historical Steelhead Reports

Hanson (2003) reports sightings of steelhead in Arroyo Valle from historical newspaper accounts (Table 2). Assuming that these fish swam upstream from the ocean to their catch locations, we can correlate these steelhead sightings with known flood events to estimate the magnitude of flood required for fish passage.

Table 2. Historical reports of steelhead caught by recreational anglers within Arroyo Valle.

Length, weight	Year	Location
34 inches, 10 pounds	1910	Trout Creek, tributary to Arroyo Valle
30 inches, 7.5 pounds	1910	Arroyo Valle
22 inches	1953	Arroyo Valle

Note: All of these larger trout (approximately 20 inches or larger in length) would be characterized as steelhead. Using a length criterion to separate resident rainbow trout from anadromous steelhead is generally accepted but does not provide conclusive evidence that the larger fish actually inhabited ocean waters. No news articles were found discussing larger trout caught by anglers in Arroyo Mocho. Data and caption from Hanson (2003).

A steelhead is reported to have been caught in Arroyo Valle in 1953 (Table 2). Given that steelhead live only about 3 years after their migration from the sea, that fish probably came upstream in the 1951 or 1952 storm. These two similar storms had recurrence intervals of 28 to 38 years. The other year for which we have recorded steelhead catches in Arroyo Valle is 1910. Those fish probably migrated upstream in the 1909 flood, which has a recurrence interval of about 6 years (Sowers 2003).

Therefore, we conclude that in 1909, with both the ditches and Sunol Dam in place, steelhead were able to swim into Arroyo Valle in floods having a 6-year or greater recurrence interval. Migration was also possible in the 1950's in floods having a recurrence interval of about 30 years or greater. Whether migration took place in smaller floods in the 1950's could not be discerned with the available data.

After the completion of Del Valle Reservoir in 1968, peak winter flows in Arroyo Valle were moderated, and the 220-foot-high dam cut off prime summer habitat in the upper reaches of the stream. Flows are now controlled by releases from the dam. Fish passage to the base of the dam is prevented by several downstream barriers (Figure 2), and by lack of high flows. No steelhead catches have been reported in Arroyo Valle since the construction of the dam.

No steelhead sightings for specific years were available for Arroyo Mocho. We would expect that the frequency of floods that would provide passage in Arroyo Mocho would be less than for Arroyo Valle simply because it is a smaller stream with smaller discharges. A larger event would be required to provide a continuous water-filled channel in Arroyo Mocho than in Arroyo Valle. However, we do not have sufficient data to constrain the recurrence interval of such flows in Arroyo Mocho.

Conclusions of the Geomorphic Analysis

The historical geomorphology of Arroyo Valle and Arroyo Mocho in the Livermore-Amador Valley was examined in order to assess the likelihood that either stream might have been used by steelhead before agricultural and urban development. Sources of information for analysis included historical accounts, historical maps, aerial photographs, flood frequency data, and reported steelhead sightings in these two streams. The conclusions of this analysis are summarized below:

- The upper reaches of both Arroyo Valle and Arroyo Mocho within the hills were probably suitable habitat for steelhead throughout the year. Arroyo Valle, because it has three times the watershed area and many more miles of tributaries compared to Arroyo Mocho, would have provided considerably more habitat than Arroyo Mocho;

- Whether these upper reaches were actually used by steelhead was dependent on passage through the lower reaches to the lagoon;

- Under natural conditions, the lower reaches of both streams across the valley floor dried up in the summer as flow soaked into the porous valley alluvium. Neither stream would have provided migration passage or rearing habitat across the valley floor during the summer months;

- Even in winter, stream channels in the Livermore-Amador Valley did not typically connect to the lagoon via surface channels. Instead, they soaked in and became groundwater. The channel would subdivide into progressively smaller channels until it disappeared;

- Extreme flood events could have provided surface flow that reached the lagoon, and may have provided fish passage;

- Channelization of the lower reaches of these streams between 1900 and 1910 may have increased the ability of these streams to provide fish passage;

- Under natural conditions, the lower reaches of Arroyo Valle across the valley floor probably could have provided passage for fish migration during very large storm events. Although this stream did subdivide into multiple distributaries, deposit its sediment, and lose water into the porous alluvium, the distributary location was much farther down the valley than was the location for Arroyo Mocho. In addition, there is evidence from historical maps and from aerial photographs that one or more distributary channels did connect directly to either the lagoon or Arroyo de la Laguna;

- After channelization of the lower reaches of Arroyo Valle with the digging of the Rose Canal (about 1900 to 1910), Arroyo Valle may have been more likely to provide passage for fish migration. A smaller single channel and more frequent flood events would now provide sufficient water depth for passage. This interval from about 1910 to 1960 may have been the most advantageous, historically, for steelhead in Arroyo Valle;

- Steelhead are reported to have been caught in Arroyo Valle in 1910 and in 1953. The 1909 flood in which the 1910 fish may have migrated had a recurrence interval of 6 years. Therefore, we can conclude that in 1909, with both the ditches and Sunol Dam in place, steelhead were able to swim into Arroyo Valle in floods having a 6-year or greater recurrence interval;

- After the completion of the Del Valle Reservoir in 1968, peak winter flows in Arroyo Valle were moderated, and the 220-foot-high dam cut off potential access to prime summer habitat in the upper reaches of the stream. Flows are now controlled by releases from the dam. Fish passage to the base of the dam is prevented by several downstream barriers, and by lack of high flows;

- Under natural conditions, the lower reaches of Arroyo Mocho were unlikely to have provided migration passage, even in large flood events. The channel subdivided and the water sank into the alluvium a considerable distance from the marsh. In rare extreme events, very shallow channels and sheet flow would have reached the marsh. However, it is unclear whether fish could have passed through such channels;

- After channelization of the lower reaches of Arroyo Mocho across the valley and through the marsh (completed around 1910), this stream may have provided passage during large winter flood events. Channelization provided a single stable channel and made possible a greater water depth. In addition, the channelized flows from Arroyo las Positas and Tassajara Creek were joined to Arroyo Mocho, enhancing its flow; and

- The flood of 1911, an 11-year recurrence interval event, may have provided fish passage in Arroyo Mocho. Mapping by Williams (1912) that shows an overflow channel from Arroyo Mocho flowing into to a ditch that connects to Arroyo de la Laguna.

Historical Record Search

Archaeologist from Archeo-Tec conducted a search of the available records that may provide insight into the potential historical occurrence of steelhead within Arroyo Mocho and Arroyo Valle. The archaeological record search included consideration of the potential occurrence of fish bones and other remains within Indian middens and other cultural resource sites within the Alameda Creek watershed. Although numerous prehistoric archaeological sites exist along both Arroyo Mocho and Arroyo Valle, information from these sites provided little insight into the historical occurrence of steelhead within the watersheds. Not only were many of the sites located a considerable distance from the streams, the villagers often dried, pulverized, and ate the fish bones. Even archaeological sites located in close proximity to salmonid-rich streams in the Pacific Northwest rarely yield significant numbers of salmonid bones. Steelhead and resident trout have partially cartilaginous skeletons that are fragile when dry and may not be preserved within a midden. Based on discussions with various archaeological experts, it was determined that fish bone remains, particularly for steelhead, could not be used as a reliable indicator of the occurrence (or absence) of steelhead within the watershed.

Similarly, archaeological information and early Spanish Mission records, reviewed as part of this investigation, proved to be inconclusive regarding the historical occurrence of steelhead within various portions of the watersheds. No early Spanish Mission period ethnographic records related to steelhead were found. All reviewed material mentioned vague reports of "fishing" or mentioned “trout” with no specific geographical area. Dr. Randy Milliken (personal communication), a leading ethnographer and prehistoric archaeologist, was not aware of any early historical accounts of steelhead within the Arroyo Mocho or Arroyo Valle watersheds. Although records were identified regarding the occurrence of "fish" the records were not specific regarding the historical occurrence of steelhead within either Arroyo Mocho or Arroyo Valle.

The record search also included in a review of local newspapers and other historical documents from the Livermore-Amador Valley area, including a review of documentary material on file at the following archival repositories: (1) the Bancroft Library at the University of California, Berkeley, (2) the Amador-Livermore Historical Society located in Pleasanton, California, (3) the Livermore Heritage Guild located in Livermore, California, (4) Pleasanton Public Library, (5) Livermore Public Library, and (6) the Biosciences and Natural Resources Library at the University of California, Berkeley. Newspaper articles were also reviewed from the Livermore Enterprise (1874-1876), Livermore Echo (1874-189), Livermore Herald (1901-1959), Livermore News (1950-1959), and Pleasanton Times (1929-1932). Based on information presented in these newspaper accounts and other historical accounts it was concluded that:

- Hatchery trout (2-3 inches in length) were routinely planted in both Arroyo Mocho and Arroyo Valle, primarily from the Mount Whitney Hatchery, beginning as early as 1894 when 25,000 young trout were reported to be planted into the watersheds. Numerous subsequent reports mention trout planting in subsequent years,

- Rainbow trout, steelhead, and brook trout were planted on a routine basis within both Arroyo Mocho and Arroyo Valle to support recreational angling opportunities,

- Juvenile trout were or typically planted in the upper portions of the watersheds, where water temperatures and habitat conditions were most suitable, and allowed to overwinter and grow prior to opening of the trout fishing season the following spring,

- The extensive planting of hatchery produced trout within both Arroyo Mocho and Arroyo Valle that supported a popular local recreational fishery,

- The success of hatchery plants (survival and growth) was found to be highly variable among years in response to factors such as high summer water temperature, low summer flow, high winter flow, and predation on trout planted from the hatchery by a number of species,

- Recreational anglers typically were reported to have caught resident trout (12 inches in length or less) within Arroyo Mocho and Arroyo Valle, and

- Reports of large trout (thought to be steelhead based on their size) were reported to be caught in Arroyo Valle and its tributaries including a 34 inch 10 pound trout in Trout Creek (1910), a 30 inch 7.5 pound trout in Arroyo Valle (1910),

> and a 22-inch trout in Arroyo Valle (1953). No reports of large trout (steelhead) were reported to have occurred in Arroyo Mocho. Large trout (steelhead) were reported from Alameda Creek, including a 30 inch 7.25 pound trout caught in Lacosta Creek (1910).

Reports from the local newspapers throughout the late 1800s and continuing into the 1900s, showed that hatchery produced trout were planted on a regular basis within both Arroyo Mocho and Arroyo Valle to support recreational angling. The reports of large trout, characteristic of adult steelhead, occurred in both Arroyo Valle and Alameda Creek, although the number of steelhead reported was small, suggesting that under favorable hydrologic conditions adult steelhead did appear to be able to successfully migrate upstream into these two tributaries. <u>The absence of adult steelhead within Arroyo Mocho throughout the entire record reviewed as part of this investigation suggests that passage and/or habitat conditions were not suitable to allow upstream migration of adult steelhead into Arroyo Mocho (Emphasis added).</u> These reports also noted a number of factors adversely affecting the survival and growth of hatchery planted trout within both Arroyo Mocho and Arroyo Valle, including exposure to high summer temperatures, low summer flows, high winter flows, and predation as significant factors affecting habitat quality and availability for various lifestages of salmonids historically within these drainages.

In addition to the newspaper articles and other historical documents, a review was performed of scientific information available through the stream files maintained by the California Department of Fish and Game (CDFG), the review of fishery resources within the San Francisco Bay area by Skinner (1962), the review of steelhead resources and their status conducted by NOAA Fisheries as part to the Federal Endangered Species Act listing process, the review of the geographic distribution of fish within tributaries to San Francisco Bay prepared by Leidy (1984), results of fishery surveys and habitat conditions by Scoppettone and Smith (1978), and information compiled and summarized on historical and current habitat conditions occurring within the Alameda Creek watershed and its tributaries by Applied Marine Sciences (2000). Information presented from these scientific reference sources document the occurrence of juvenile and/or adult resident rainbow trout within the upper portions of both Arroyo Valle and Arroyo Mocho. No distinction has been made within these references between resident trout and migratory steelhead. The documents provide anecdotal information on planting hatchery trout to support recreational fisheries and the general occurrence of steelhead/rainbow trout within the watersheds. None of the scientific references provide documentation on the historical occurrence of steelhead within Arroyo Mocho; however, these references are consistent with results of other information suggesting the potential historical occurrence of steelhead within Arroyo Valle and Alameda Creek. Information presented in these documents also identified a number of factors affecting habitat quality and availability within these watersheds for various lifestages of steelhead, including low summer flows, elevated summer water temperatures, poor habitat conditions, and the occurrence of passage barriers and impediments as constraints on the historical occurrence of steelhead within these areas. Several of these references also noted the extensive hatchery planting of resident rainbow trout to support recreational fisheries within Alameda Creek, Arroyo Mocho, and Arroyo Valle.

Current Habitat Conditions, Opportunities, and Constraints

Currently, a number of passage barriers and impediments exist within Alameda Creek, Arroyo Mocho, and Arroyo Valle (Figure 2) that preclude access to upstream habitat for migratory steelhead within these watersheds. Currently, the BART weir, located within the flood control reach of lower Alameda Creek, serves as the lowermost complete passage barrier for upstream migration of adult steelhead into Alameda Creek. A number of efforts are currently underway to identify potential opportunities to improve and restore access to Alameda Creek and its tributaries to migratory steelhead.

In addition to the existing passage barriers and impediments, substantial portions of Alameda Creek, Arroyo Mocho, and Arroyo Valle have been extensively modified, in large part, in response to flood control concerns through areas within the lower reaches of these tributaries that have undergone extensive urban development (Figure 8). As a consequence of urban development, the lower reaches of both Arroyo Mocho and Arroyo Valle (Figure 8) have been extensively channelized and contained within riprap to stabilize banks. As a consequence, habitat conditions within these watersheds for steelhead have been significantly degraded.

Water resource development and management within the watersheds, such as construction and operation of the Del Valle Reservoir on Arroyo Valle, and the use of natural stream channels for water deliveries and conveyance from the South Bay Aqueduct, have also affected habitat conditions within portions of these tributaries.

Steelhead require relatively cold water for adult migration, spawning and egg incubation, juvenile rearing, and juvenile downstream migration. Water temperatures within many stream systems located throughout central and southern California experience elevated summer water temperatures that adversely affect quality and availability of habitat for steelhead. Water temperature, for example, was frequently identified in the historical newspaper accounts and scientific references as a factor adversely affecting growth and survival of planted trout within the Arroyo Mocho and Arroyo Valle watersheds. To further examine seasonal water temperature as a factor affecting over-summering habitat for steelhead, computerized water temperature monitoring loggers were deployed at various locations within both Arroyo Mocho and Arroyo Valle as part of this investigation. The location of water temperature loggers within Arroyo Mocho is shown in Figure 9. Summer water temperatures providing suitable habitat conditions for juvenile steelhead rearing are typically characterized as temperatures less than approximately 68 F (20 C) as providing suitable summer rearing habitat conditions, water temperatures between 68 and 72 F (20 and 22 C) as providing stressful juvenile summer rearing conditions, and water temperatures exceeding 72 F (22 C) as being unsuitable and potentially lethal for juvenile steelhead. Results of water temperature monitoring within Arroyo Mocho at Hopyard Road (Figure 10) showed that summer temperatures were within the range considered to be unsuitable and potentially lethal for juvenile steelhead. Similarly, results of water temperature monitoring within Arroyo Mocho at Robertson Park (Figure 11) also showed that summer water temperatures were within the range considered to be unsuitable and potentially lethal. Water temperatures, further upstream at Mines Road (Figure 12) similarly showed that summer temperatures were within the range considered to be unsuitable and potentially lethal. Results of periodic water temperature monitoring during summer months further upstream within Arroyo Mocho showed that at higher elevations, moderately deep pools exist where summer temperatures were within the range considered to be either suitable or stressful but would potentially support juvenile rearing. These findings are consistent with results of field fishery collections that have documented the occurrence of resident rainbow trout successfully inhabiting the upper reaches of Arroyo Mocho, characterized by higher elevations, incised channels providing greater shading and protection from exposure to solar radiation, with the occurrence of deeper and summer pools.

Similar water temperature monitoring was conducted with Arroyo Valle (Figure 13) that showed summer temperatures to be within the range considered to be unsuitable and potentially lethal at Shadow Cliffs Park (Figure 14). However, water temperature at Veterans Park (Figure 15) immediately downstream of the release from Del Valle Reservoir were within the range considered to be suitable for juvenile steelhead over-summering.

As part of the assessment fishery habitat conditions within the Livermore – Amador Valley, consideration was also given to conditions within Arroyo Las Positas. Results of the reconnaissance-level survey for Arroyo Las Positas showed that habitat conditions are poor and are considered to be unsuitable for steelhead spawning and/or juvenile rearing. The lack of riparian cover and shading would be expected to result in elevated water temperatures during summer months and unsuitable juvenile rearing conditions. Historic modifications to the stream channel, in combination with the low elevation and stream gradient, lack of riparian vegetation, high occurrence of fine sediments, and physical habitat features support a conclusion that Arroyo Las Positas does not provide suitable habitat for steelhead.

The findings of the reconnaissance survey are consistent with conclusions of a report prepared for the Alameda Creek Fisheries Restoration Workgroup by Gunther, Hager, and Salop (Applied Marine Science and Hagar 2000), titled "An Assessment of the Potential for Restoring a Viable Steelhead Trout Population in the Alameda Creek Watershed". Applied Marine Science and Hagar (2000) identified Arroyo Las Positas as non-viable habitat for steelhead. Results of a synthesis of historic information by Rob Leidy (1984) titled, "Distribution and Ecology of Stream Fishes in the San Francisco Bay Drainage" also supports the finding that habitat conditions have not been suitable for steelhead. Leidy (1984) reported results from a number of fishery studies that found juvenile and adult steelhead and/or rainbow trout within Alameda Creek and a number of tributaries but included no reports of steelhead or trout inhabiting Arroyo Las Positas. Reports cited by Leidy did, however, identify several warm water species historically present, including hitch, mosquito fish, and three-spine stickleback. These are extremely tolerant, non-migratory, resident fish species endemic to most low elevation watersheds in northern California.

Based upon results of reconnaissance-level habitat surveys, in addition to water temperature monitoring, and locations where resident rainbow trout have been collected, areas within both Arroyo Mocho and Arroyo Valle where potential habitat is currently suitable for juvenile steelhead rearing have been identified. The potentially suitable habitat areas are shown in Figure 16. These potentially suitable habitat areas are consistently located in the uppermost portions of each watershed and potentially accessible, if steelhead passage were re-established within Alameda Creek, Arroyo Mocho, and Arroyo Valle, if infrequent heavy winter storm events provided sufficient flows. Based upon the review of available scientific information, in combination with observations during the reconnaissance survey of habitat conditions, it was further concluded that the Arroyo Las Positas watershed does not provide suitable habitat for anadromous steelhead.

Actions Required to Provide Suitable Habitat in the Future

Based upon consideration of the habitat requirements for various lifestages of steelhead, in combination with results of habitat surveys conducted within both Arroyo Mocho and Arroyo Valle to assess current factors limiting habitat quality and availability for steelhead, the following actions were identified to enhance existing habitat conditions in the future if steelhead are provided access to the watershed:

- Removal of barriers and impediments to upstream and downstream migration throughout the migratory corridors within Arroyo Mocho, Arroyo Valle, and lower Alameda Creek;

- Installation and operation of positive barrier fish screens on surface water diversions to reduce and avoid entrainment mortality of juvenile steelhead;

- Habitat enhancement actions within both watersheds, including channels for suitable adult and juvenile passage and migration over a range of hydrologic conditions, and improvements in spawning and juvenile rearing habitat within the upper portion of Arroyo Valle (e.g., spawning gravel augmentation, improvements to channels form and conditions, instream overhead cover, etc.);

- Water supplies for passage and rearing would be required; and

- Downstream of the South Bay Aqueduct turnout, where naturally occurring summer water temperatures of been identified as being unsuitable and potentially lethal for juvenile steelhead, no summer rearing habitat potential appears to exist.

Summary of Findings

Based upon results with this analysis of available information on historical conditions occurring within the Alameda Creek watershed, with specific emphasis on Arroyo Mocho and Arroyo Valle, in addition to consideration of current habitat opportunities and constraints, it was concluded that:

- Arroyo Valle and Arroyo Mocho historically supported resident trout fisheries in the upper watersheds, through routine fingerling plantings from hatcheries including the Mount Whitney Hatchery;

- Resident rainbow trout sampled recently from Arroyo Mocho were found to be genetically similar to the Mount Whitney Hatchery stock (which is consistent with the prolonged and extensive hatchery stocking within the watershed) and did not appear to be genetically related to anadromous steelhead populations;

- Adult steelhead were periodically caught in Arroyo Valle and lower Alameda Creek, although the occurrence of records of adult steelhead in Arroyo Valle suggests that only a small number of fish may have occurred (on an infrequent basis) within this portion of the watershed, periodically under favorable environmental and hydrologic conditions;

- No records of adult steelhead being caught by recreational anglers were found for Arroyo Mocho;

- It is unlikely that either watershed historically provided consistent suitable habitat conditions for steelhead passage, spawning, and/or juvenile rearing to support self-sustaining populations;

- Arroyo Mocho channel form would have made adult steelhead migration unlikely prior to channelization based upon historical geomorphic conditions within the lower reaches of the Arroyo Mocho channel;

- Historically, steelhead passage in Arroyo Valle occurred infrequently, in response to high flow events that provided suitable surface water connectivity between Arroyo Valle and lower Alameda Creek;

- Opportunities and constraints exist for providing upstream and downstream passage and enhanced habitat conditions for steelhead within lower Alameda Creek, Arroyo Mocho, and Arroyo Valle. Feasibility studies and evaluations are currently being conducted to assess opportunities to improve steelhead passage and remove migration barriers and impediments within Alameda Creek and its tributaries, in addition to habitat conditions, limiting factors, and opportunities; and

- Suitable habitat exists for steelhead spawning and rearing in the upper reaches of Arroyo Mocho and immediately downstream Del Valle Reservoir, however, management actions would be required to achieve these benefits.

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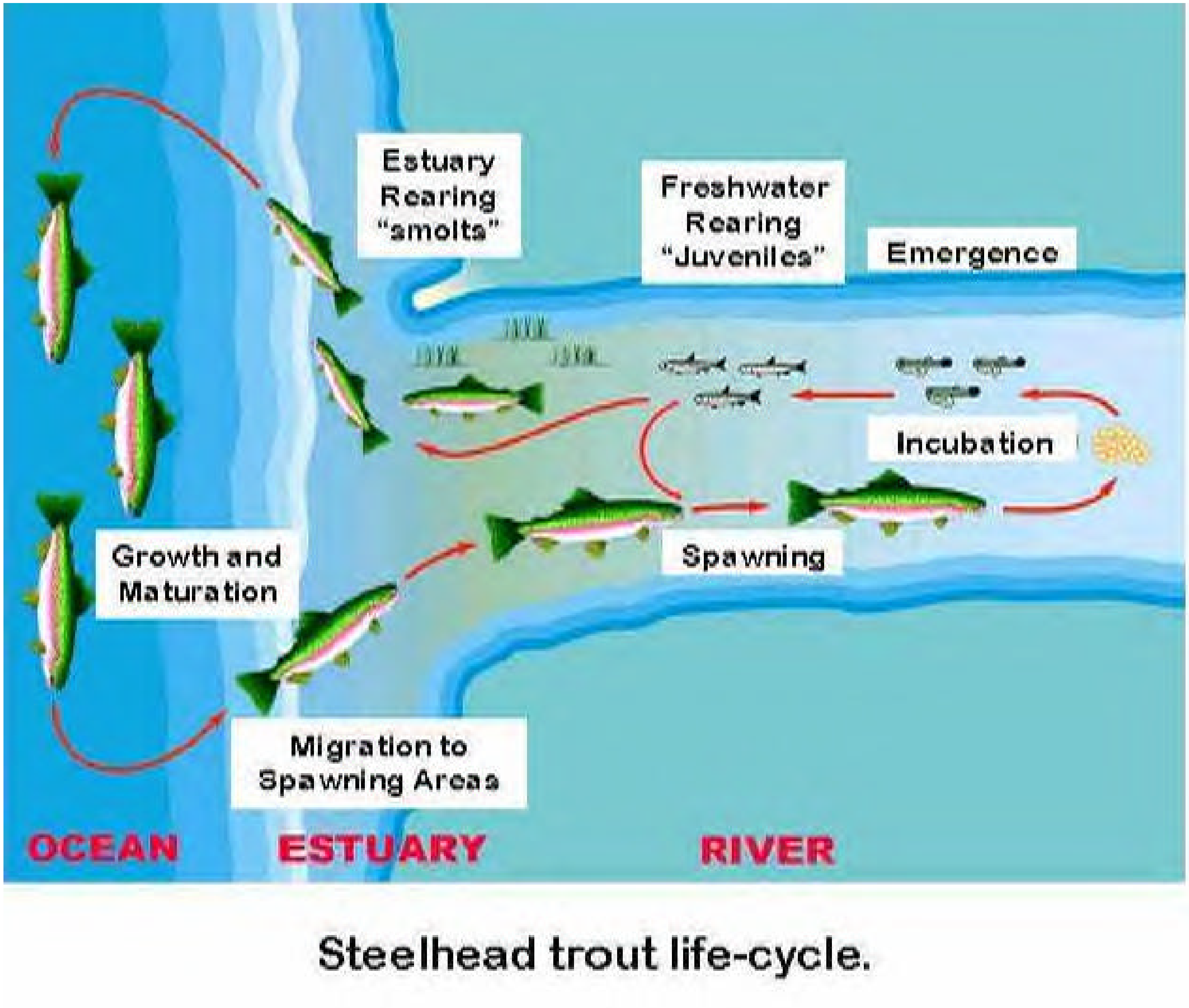

Figure 1. Steelhead lifecycle.

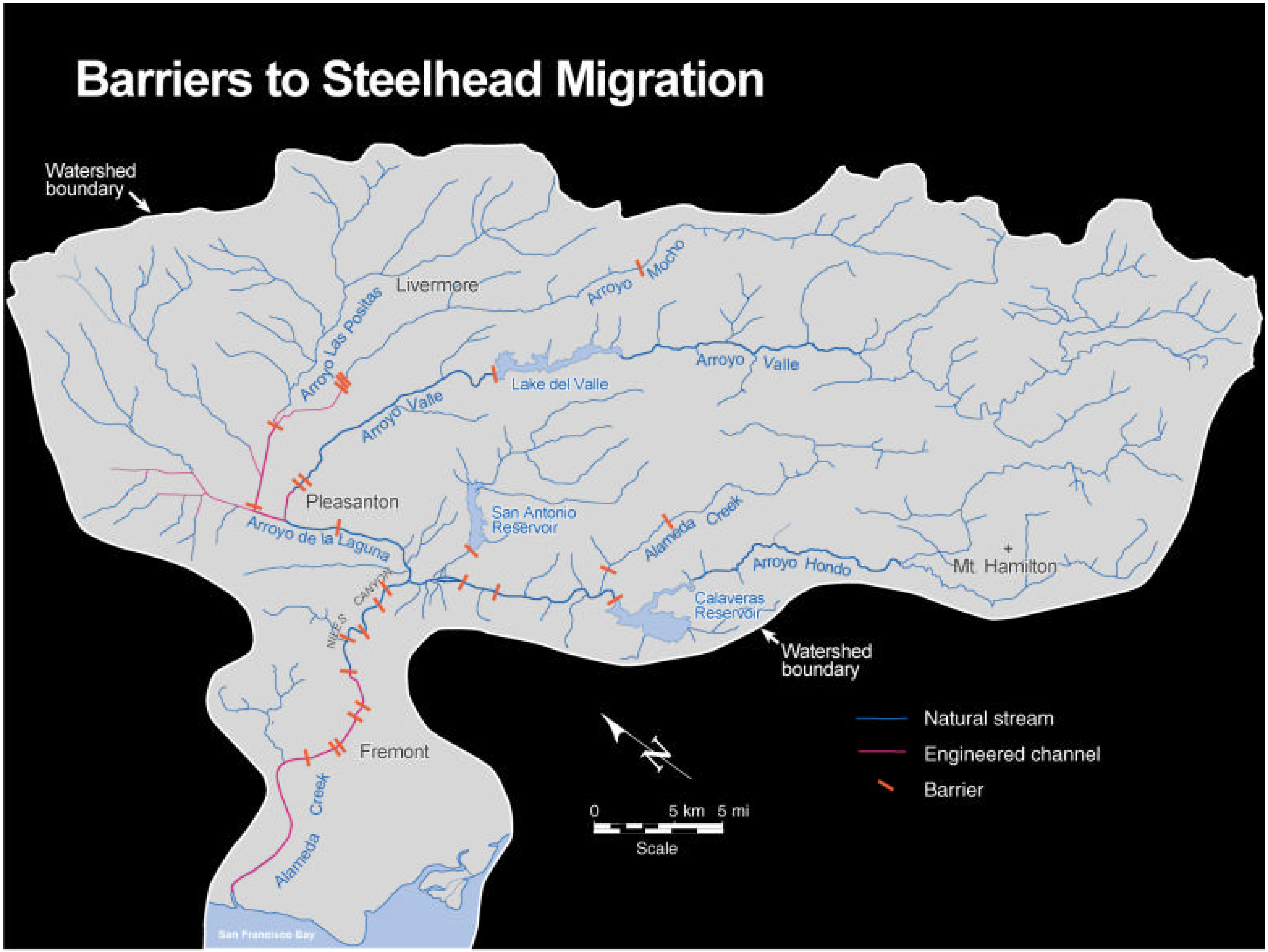

Figure 2. Alameda Creek Watershed showing barriers to steelhead migration.

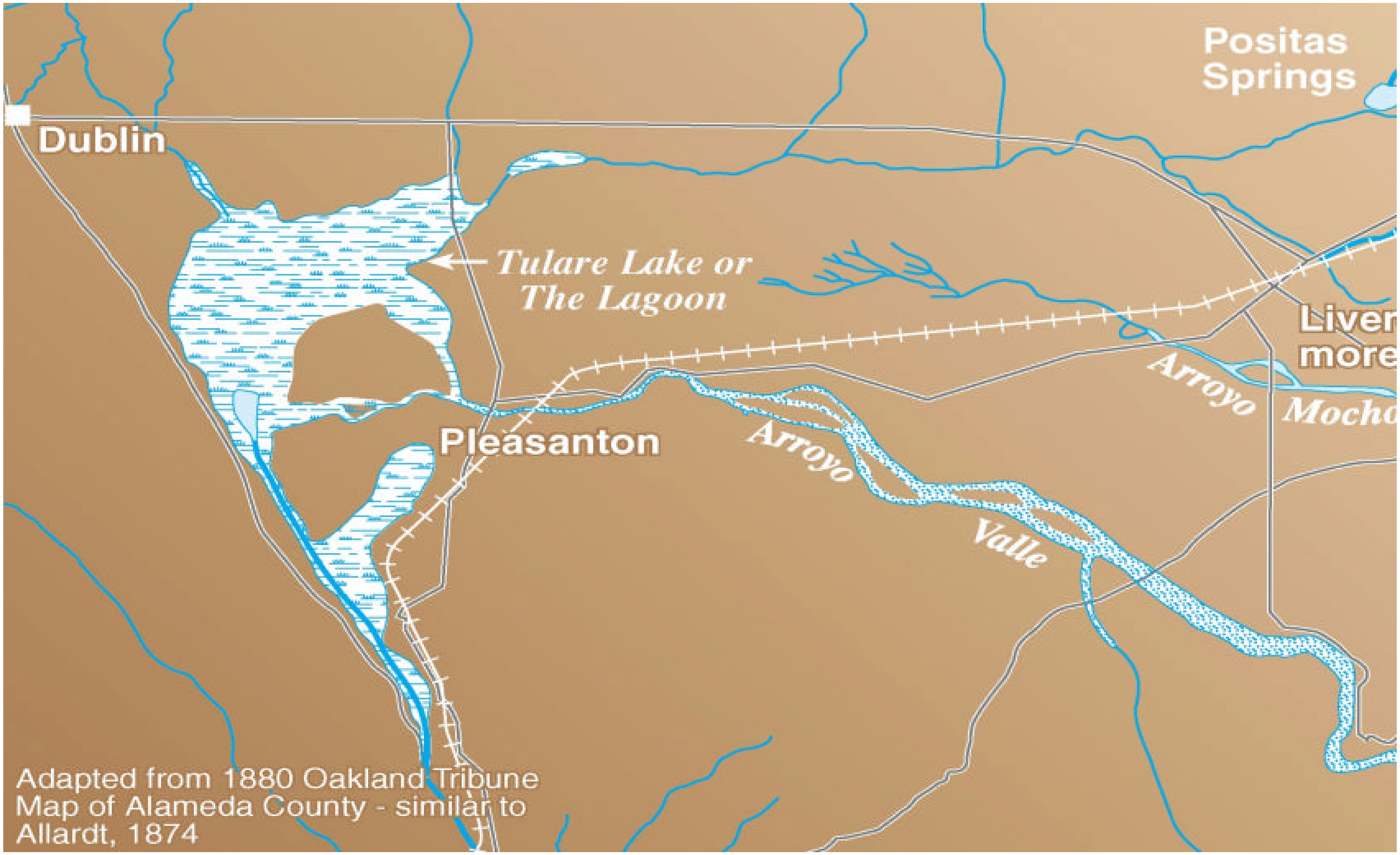

Figure 3. Lower Arroyo Mocho and Arroyo Valle in 1880.

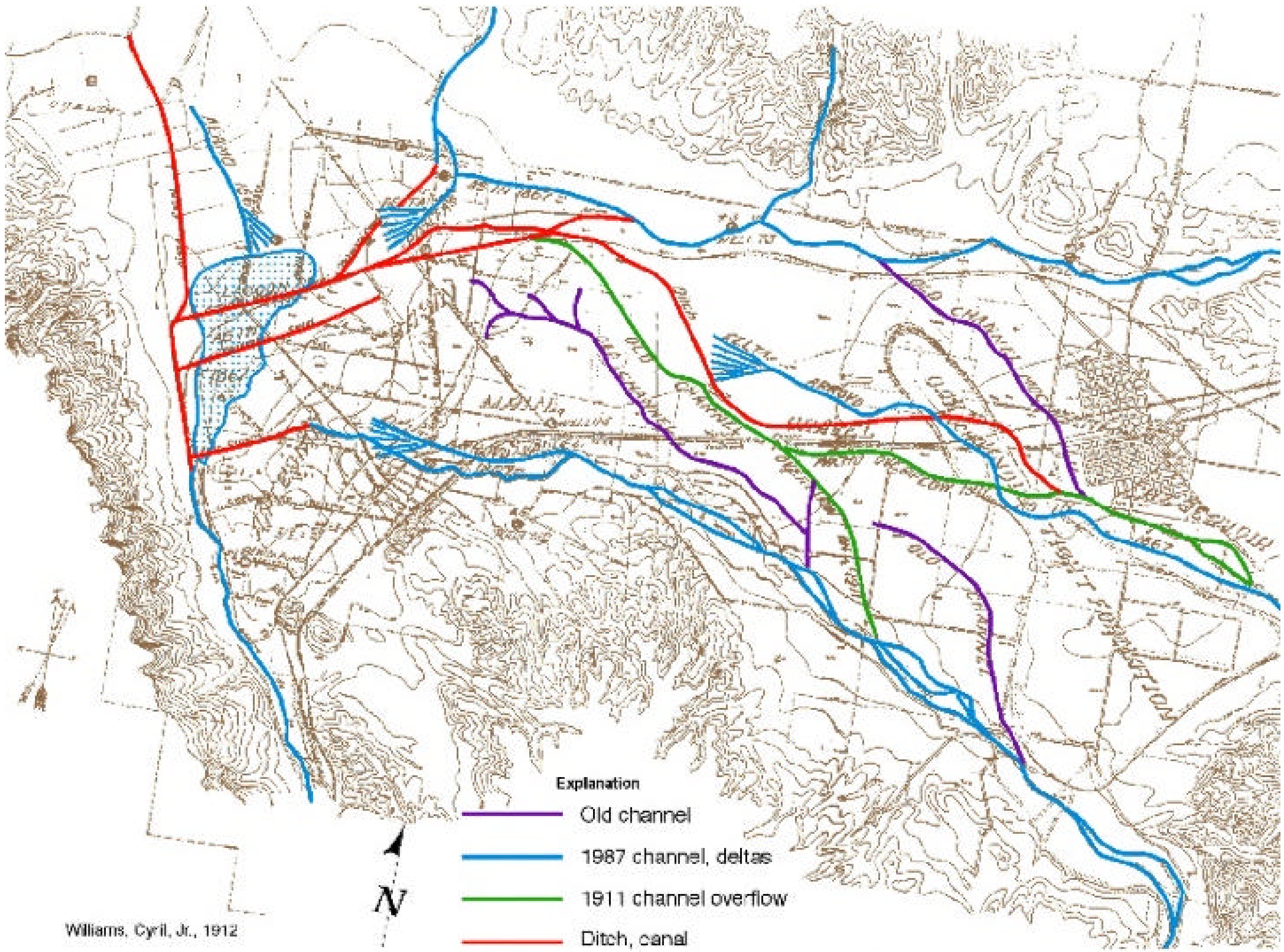

Figure 4. Historic channel development in lower Arroyo Mocho and Arroyo Valle.

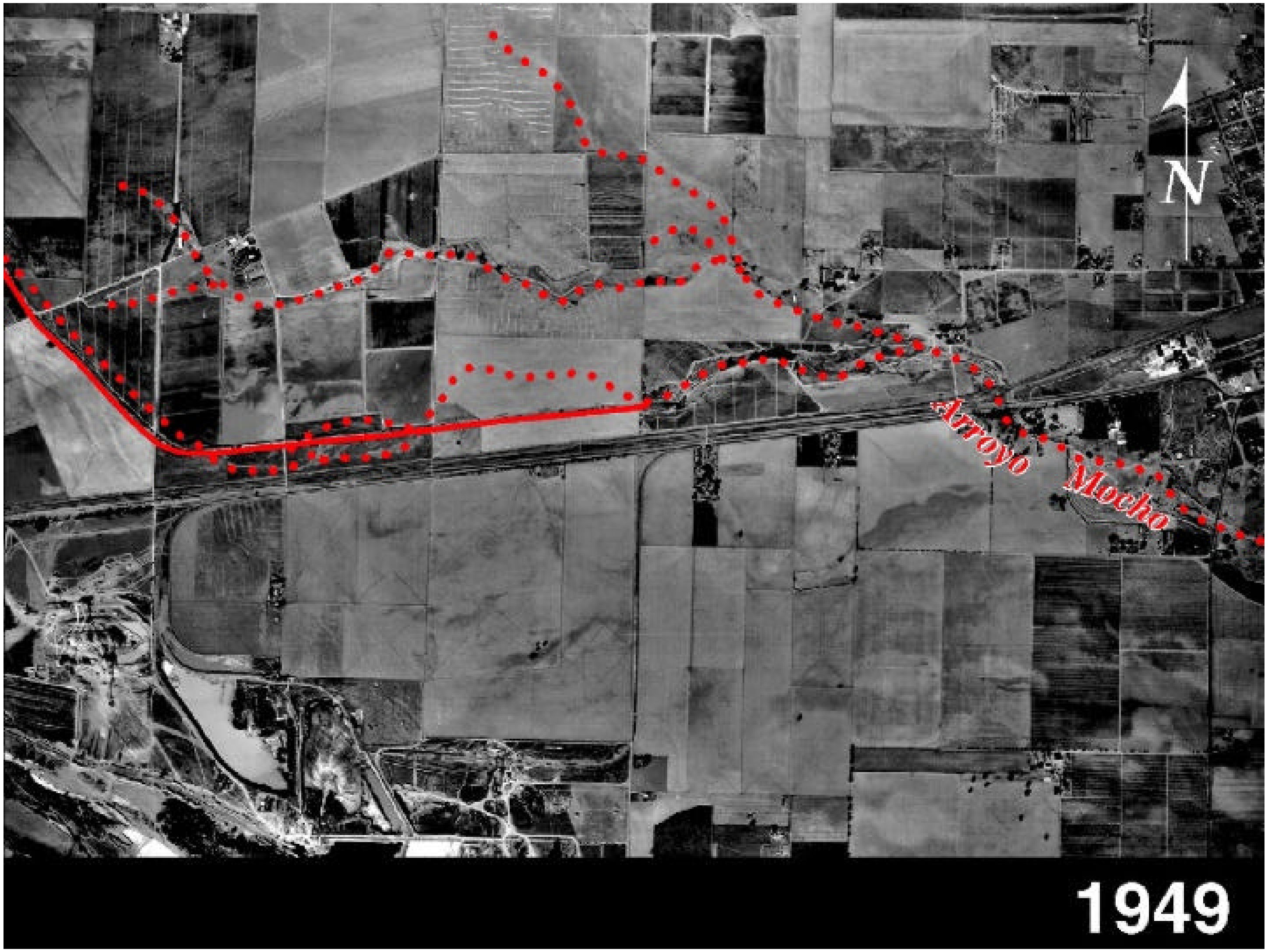

Figure 5a. Aerial photograph and channel overlay (1949) for a portion of lower Arroyo Mocho.

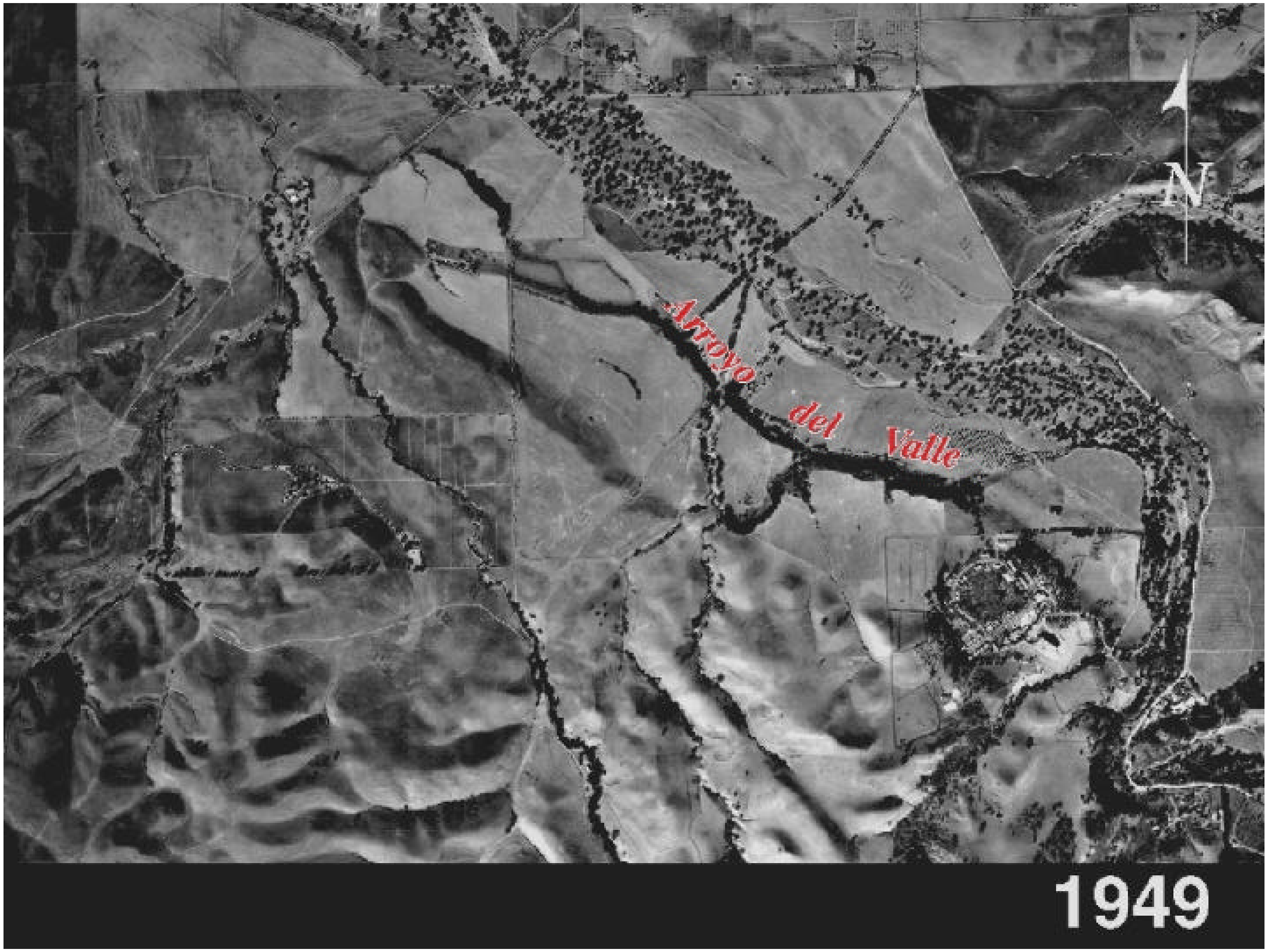

Figure 5b. Aerial photograph (1949) of a portion of Arroyo Valle.

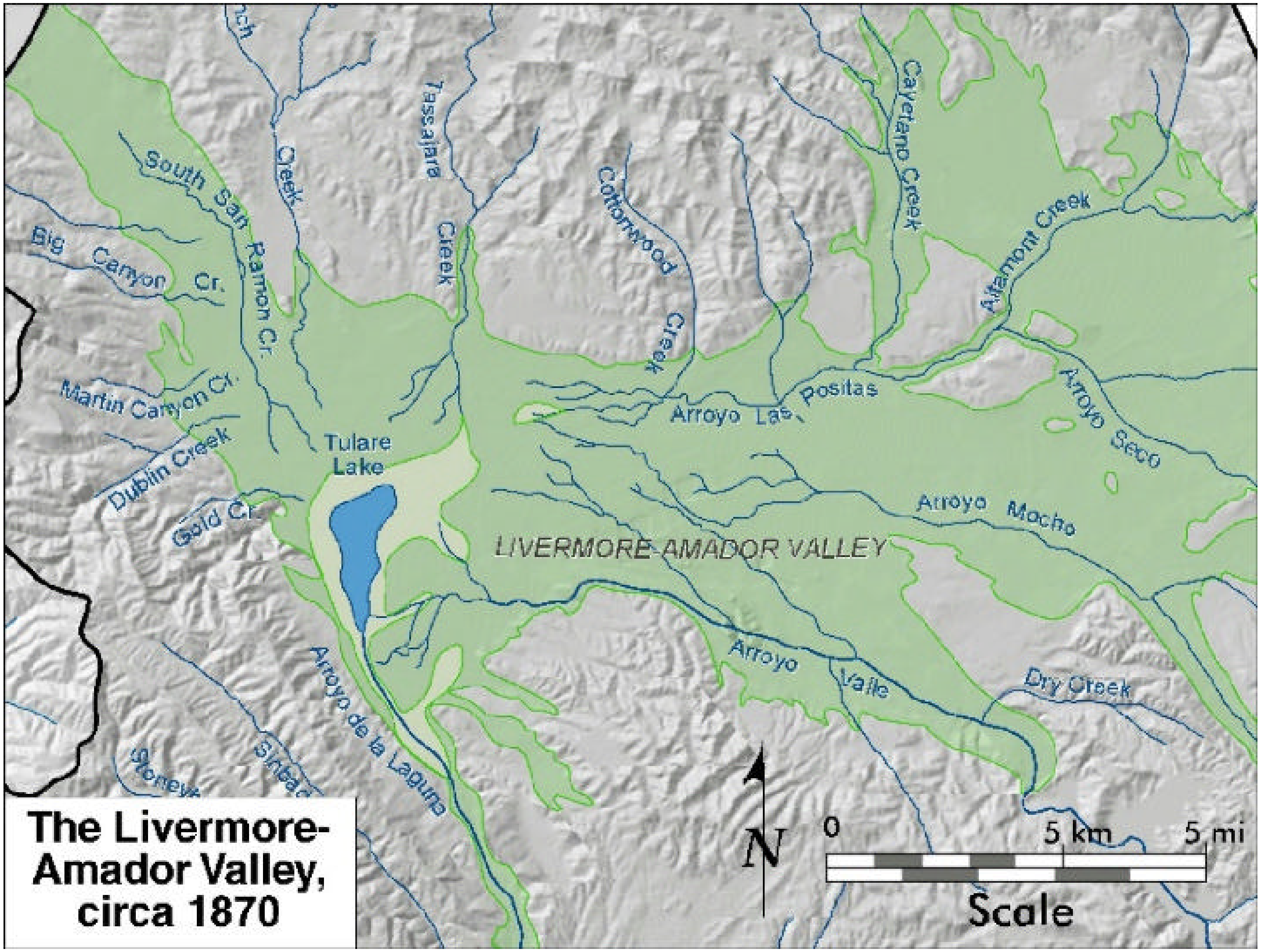

Figure 6. Channels of lower Arroyo Mocho and Arroyo Valle during the late 1800s.

Figure 7. Aerial photograph of lower Arroyo Mocho and Arroyo Valle during high flows in December 1955.

Figure 8. Lower Arroyo Mocho and Arroyo Valle channelized reaches (1999).

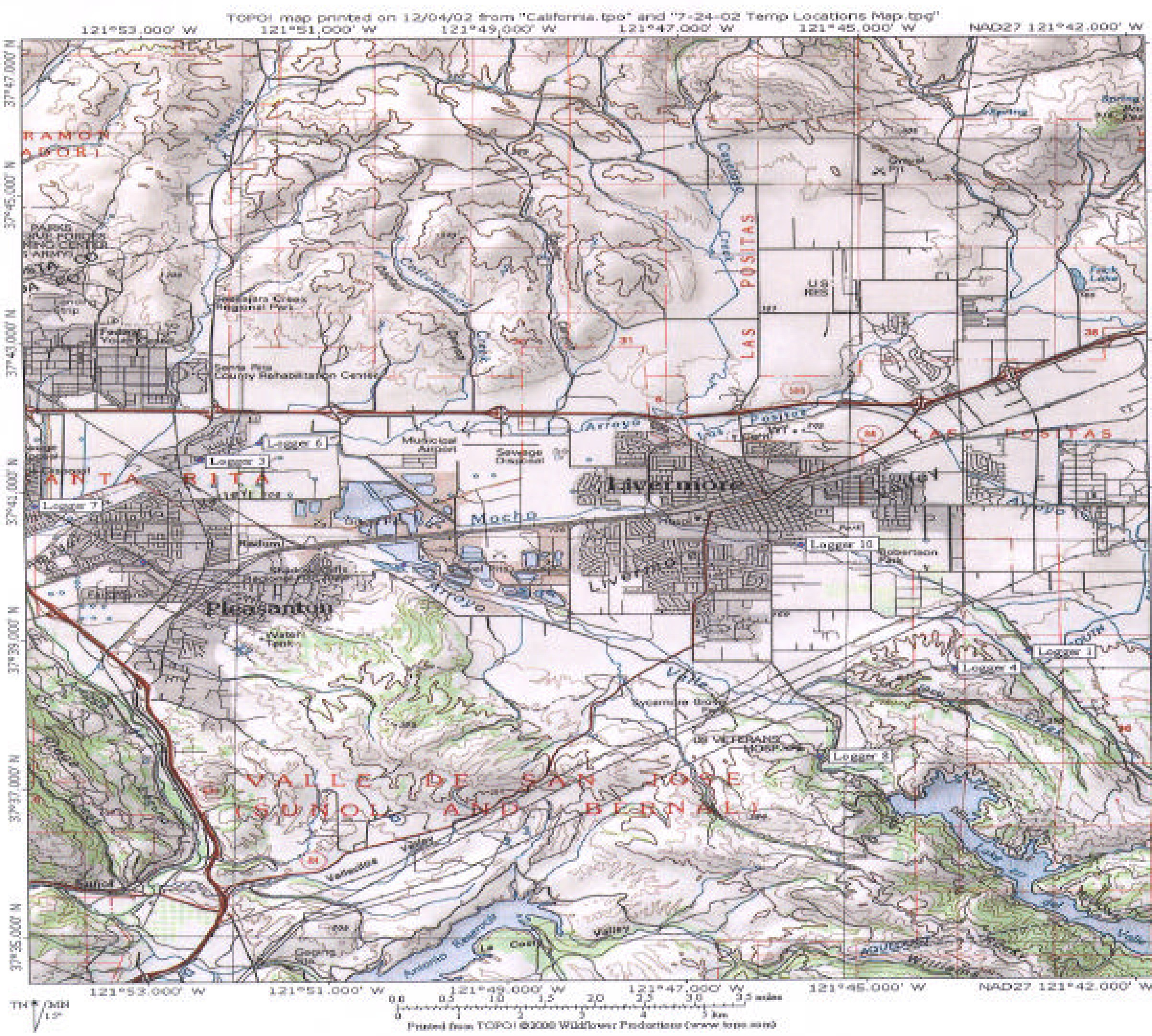

Figure 9. Location of temperature monitoring stations in Arroyo Mocho (2002).

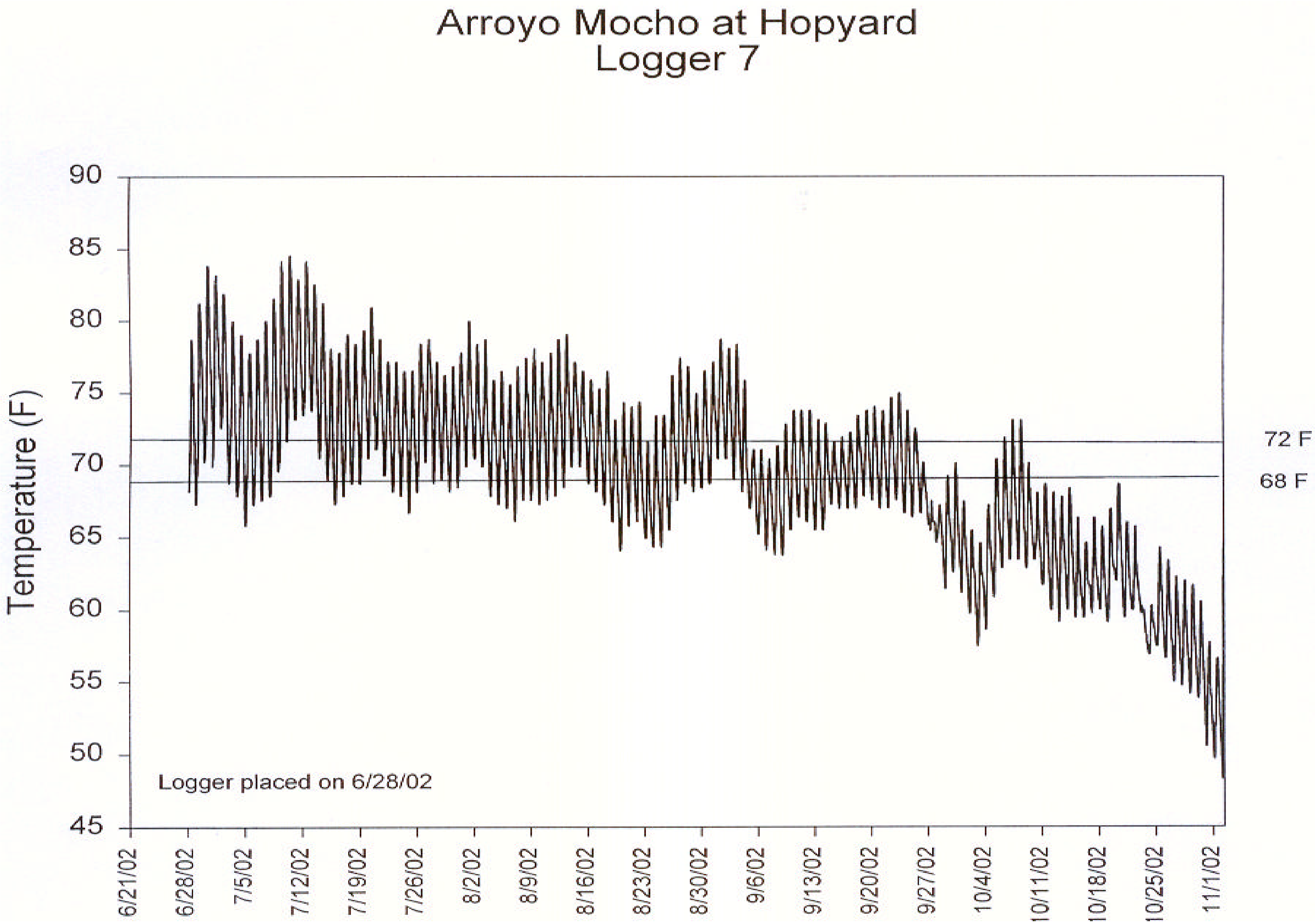

Figure 10. Hourly water temperatures measured at Arroyo Mocho at Hopyard (2002).

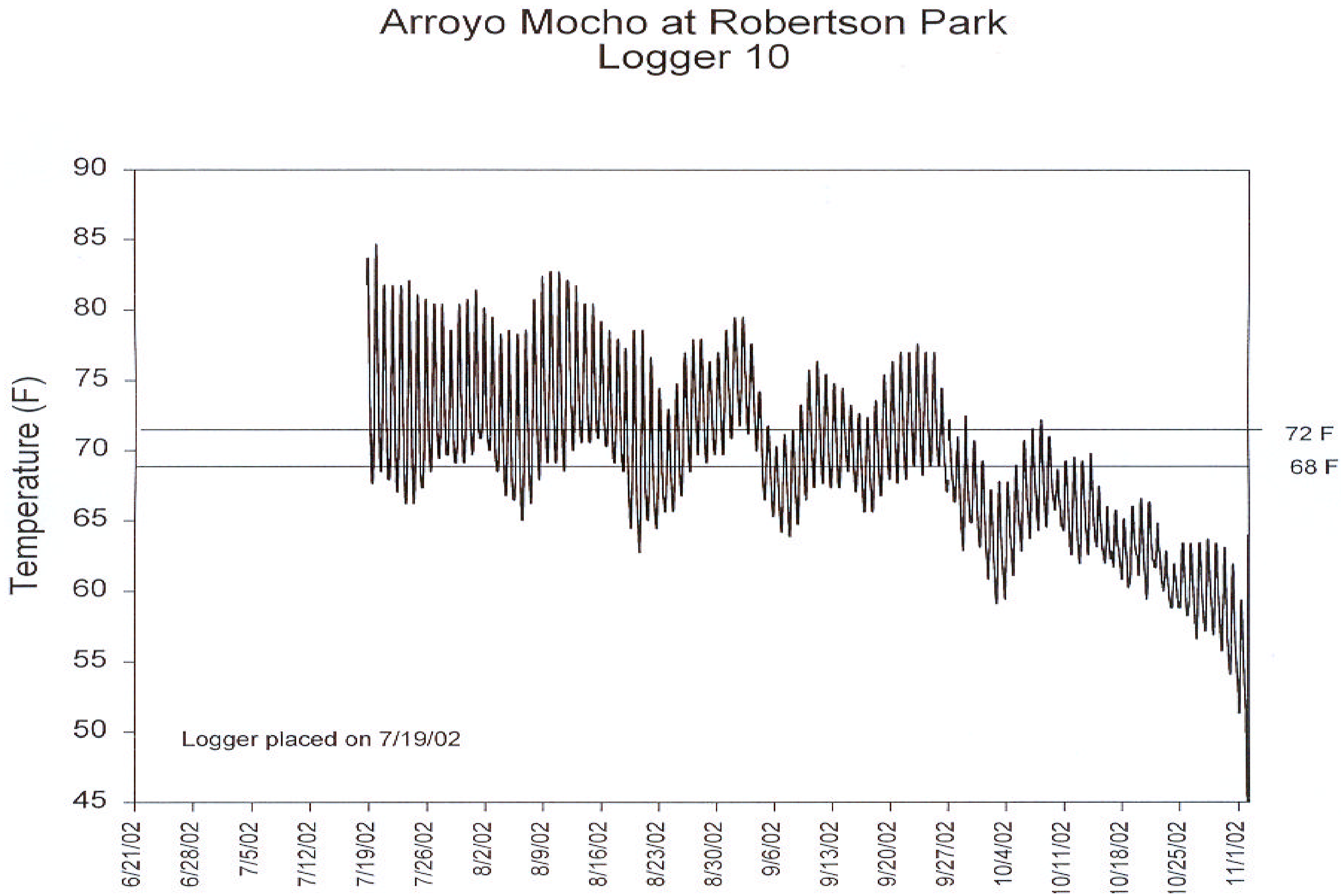

Figure 11. Hourly water temperatures measured in Arroyo Mocho at Robertson Park (2002).

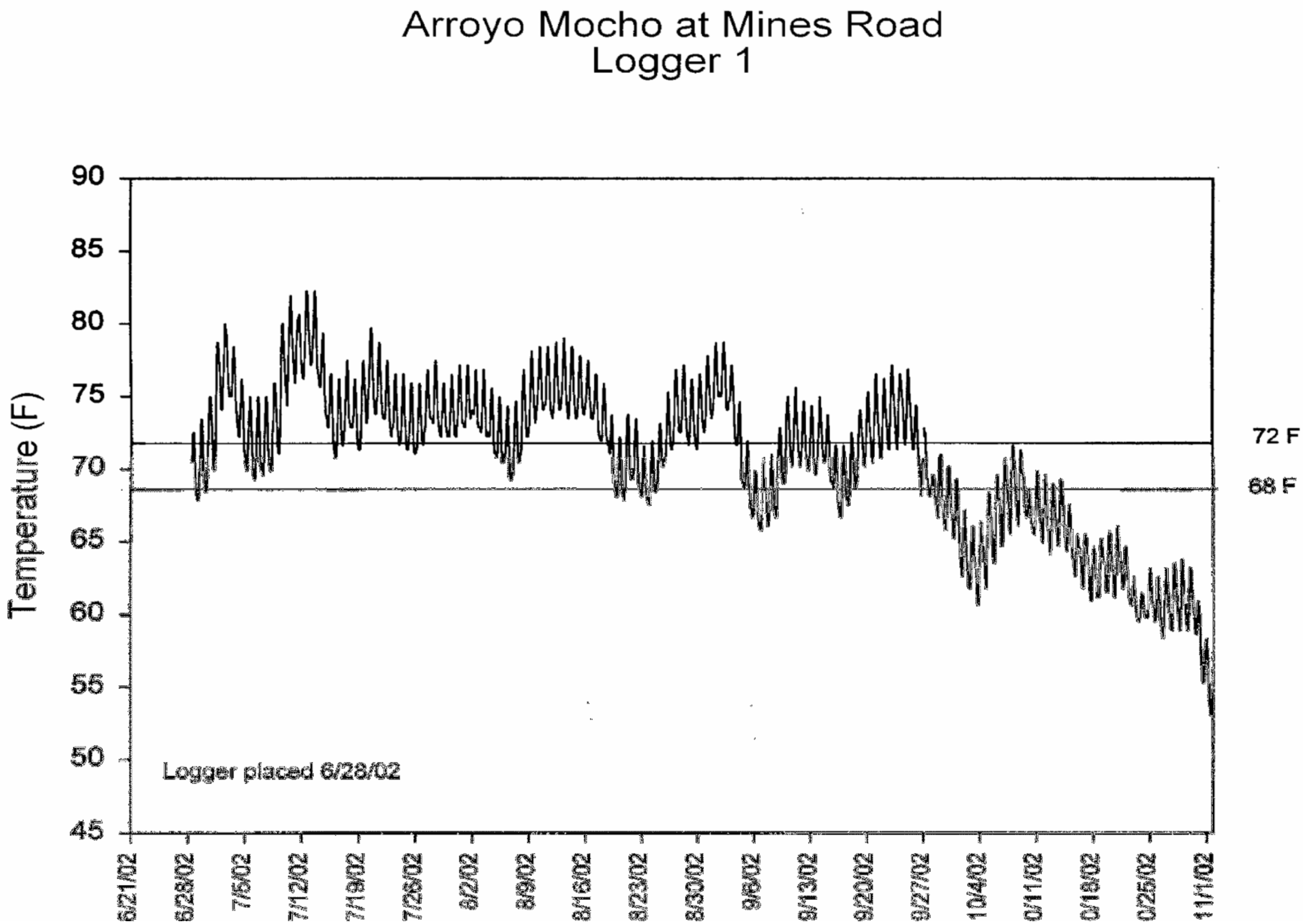

Figure 12. Hourly water temperature measured in Arroyo Mocho at Mines Road (2002).

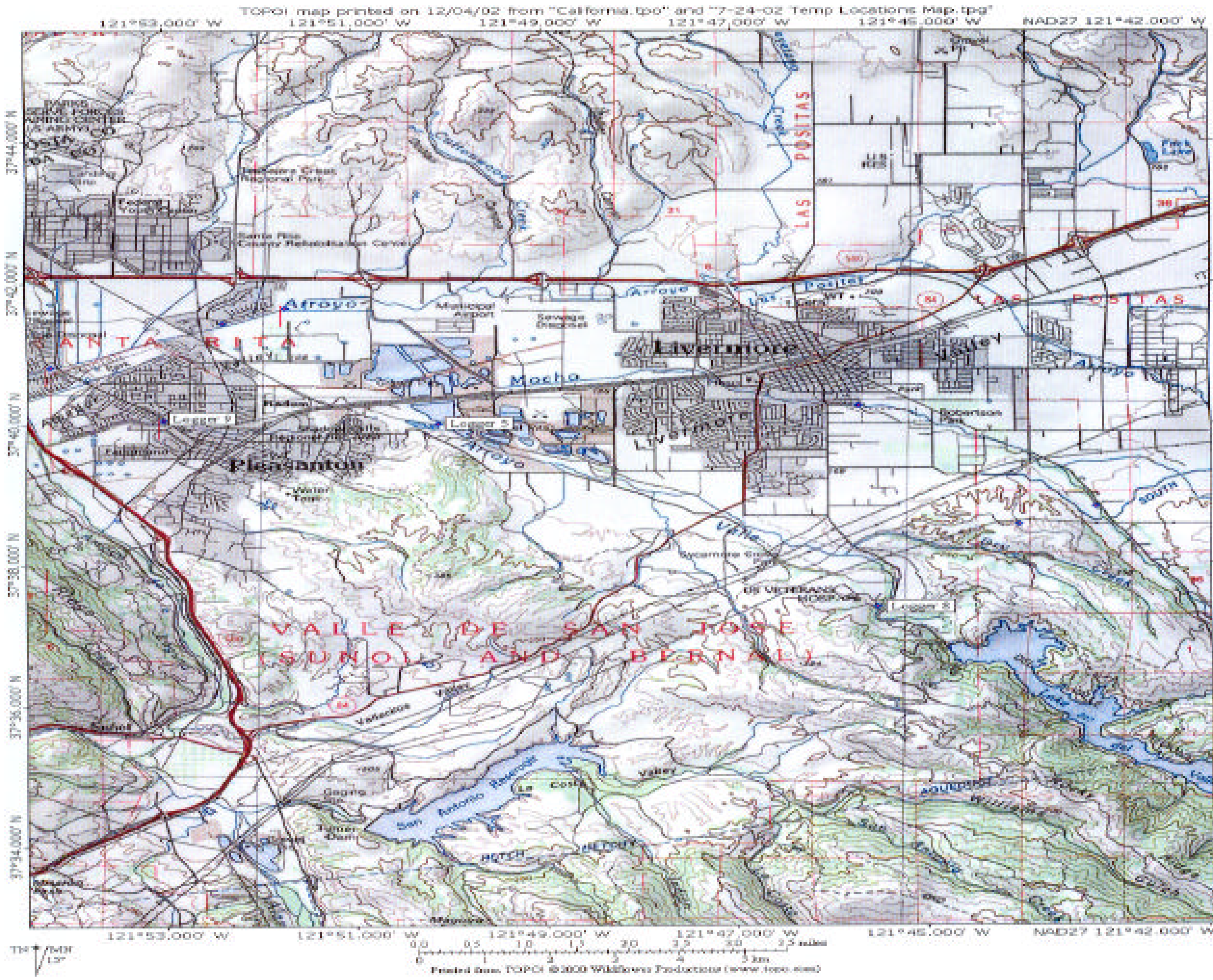

Figure 13. Locations of water temperature monitoring locations in Arroyo Valle (2002).

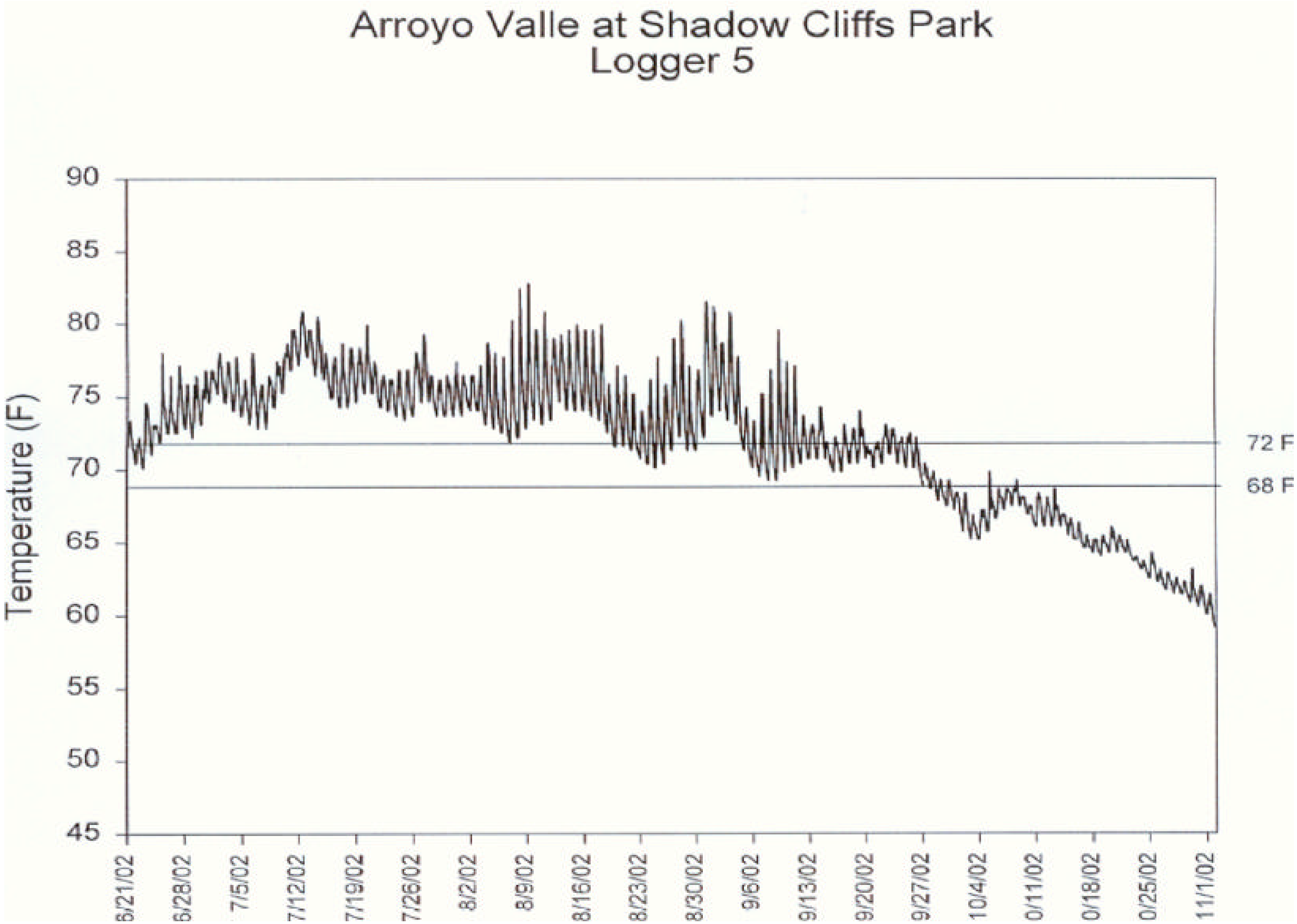

Figure 14. Hourly water temperature measured in Arroyo Valley at Shadow Cliffs Park (2002).

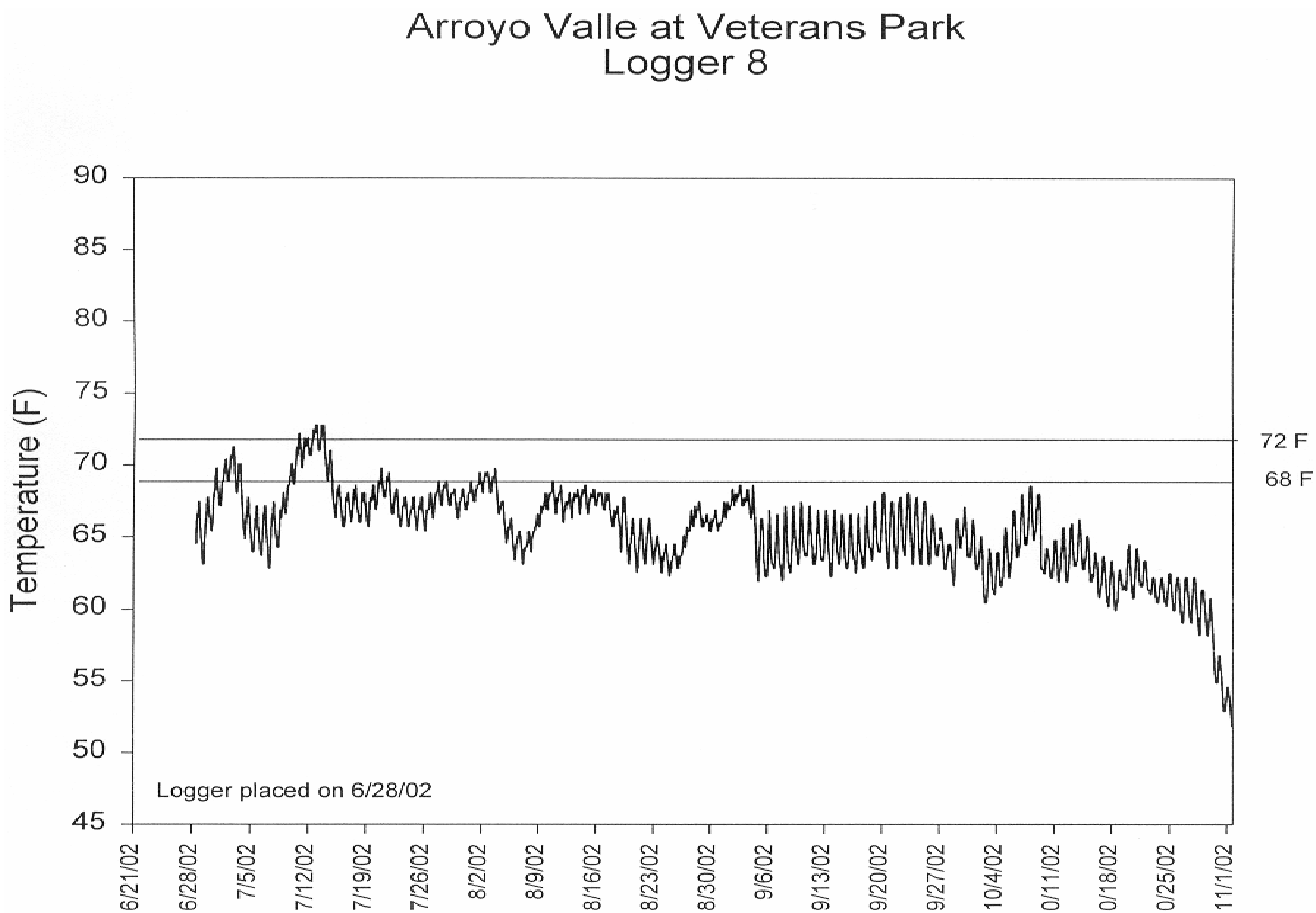

Figure 15. Hourly water temperature measured in Arroyo Valle at Veterans Park (2002).

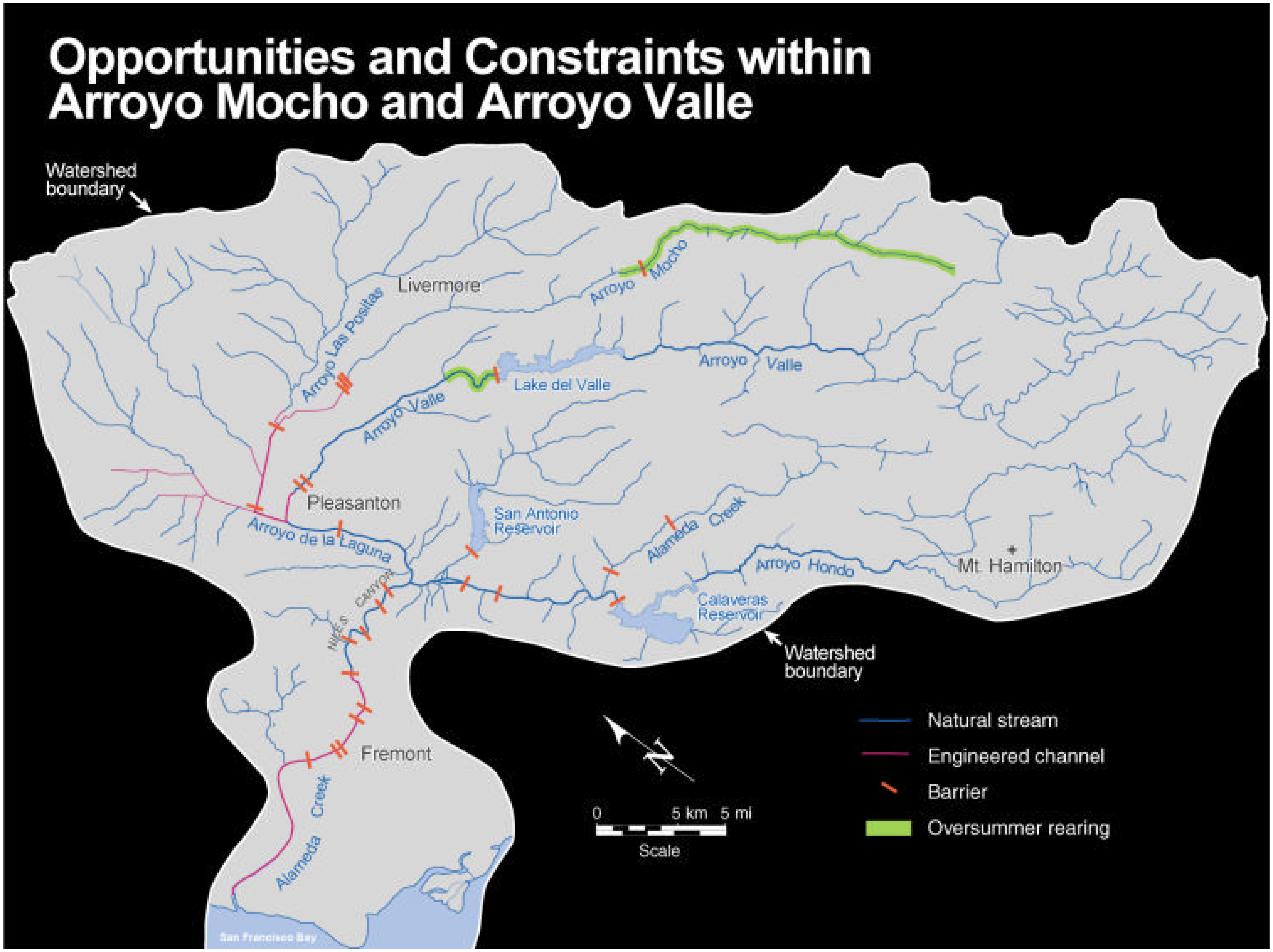

Figure 16. Habitat areas identified as potentially suitable for steelhead rearing.