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FISHERY RESOURCES CONDITIONS OF THE CORTE MADERA CREEK WATERSHED, MARIN COUNTY, CALIFORNIA

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Prepared for:

Friends of Corte Madera Creek Watershed
P.O. Box 415
Larkspur, California 94977

November 10, 2000

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EXECUTIVE SUMMARY

The Corte Madera Creek Watershed and its tributaries are among the few streams flowing to San Francisco Bay that retain a steelhead trout population. The Friends of Corte Madera Creek Watershed (Friends) are interested in restoring the watershed. As part of the watershed project, Friends contracted with ***A. A. Rich and Associates (AAR)***, a fisheries and ecological consulting firm, to undertake a fishery resources investigation and prepare this Fishery Resources Technical Report. The results of this study, including the proposed restoration and monitoring suggestions are part of a comprehensive watershed plan to improve water quality, fishery resources, and native vegetation and wildlife in the Corte Madera Creek Watershed. This fishery resources report identifies how the declining trend in the steelhead population can be reversed. The report identifies some of the factors limiting the steelhead trout population, formulates corrective actions, describes how to monitor the success of those actions, and presents an action plan for the restoration of the Corte Madera Creek Watershed as long-term steelhead trout habitat.

This report addresses the status of the existing fishery resources conditions within the Corte Madera Creek Watershed. More specifically, the objectives of this study are to:

- Provide life stage and habitat information on the rainbow/steelhead trout;
- Provide a historical perspective, to the extent possible, on the fishery resources conditions;
- Assess water temperature conditions from April to October;
- Assess physical habitat conditions during the low-flow season;
- Assess fishery resources population conditions during the low flow season;
- Identify some limiting factors for the rainbow/steelhead trout; and,
- Design a Steelhead Restoration Plan which will improve rainbow/steelhead populations.

To carry out the objectives, the following types of surveys were undertaken: (1) Water temperature monitoring, beginning in the spring and extending through the summer; (2) Habitat surveys during the dry months; and, (3) Fish population surveys during the dry months.

The results from the water temperature monitoring demonstrated that, despite potentially thermally stressful conditions in many areas of the watershed, there appeared to be "thermal refuge" (thermal refugia) areas where the trout could reside during the hotter summer months. The areas where water temperatures were suitable appeared to be the areas where the greatest number of salmonids were collected. With regard to smoltification, water temperatures began to become thermally stressful, beginning in May. If the fish emigrate out of the system before May, as they may, this would not be a problem.

Corte Madera Creek is highly channelized, as a result of various activities (e.g., USACE concrete flood control channel and landowners' retaining walls) undertaken to control flooding during the winter months. The U.S. Army Corps of Engineers (USACE) flood control channel serves only as a migration route for the anadromous steelhead trout. The upstream areas of Corte Madera Creek consist of long lateral scour pools alternating with riffle areas, habitat used by a variety of fish species, although none in great abundance.

San Anselmo Creek had the greatest variety of habitats of any of the creeks within the Corte Madera Creek Watershed, probably due to the fact that it flows through towns, but its origin lies in the relatively unimpacted reaches within the Cascade Canyon Open Space Preserve. Throughout its length, it was characterized by alternating lateral scour pool/riffle sequences. In the lower more urban reaches, the lateral scour pools were associated with retaining walls and rip rap, whereas in the upper more natural areas, they were associated with bedrock. The creek along Cascade Road in Fairfax was dry for more than a mile, but substrate consisted almost entirely of gravel suitable for trout spawning.

Although short on water by the end of summer, Cascade Creek offered the best trout habitat of the entire creek system. It was characterized by bedrock pools and cascades, abundant canopy, and clean clear water. Although there was no spawning gravel, the pools provided rearing habitat for trout. The uppermost boundary for fish migration was the Cascade Falls.

Sleepy Hollow Creek was characterized by low flows, and a heavily urbanized (e.g., retaining walls, bridge pillars, concrete in the creek) channel. In the lowermost reaches, the habitat during the late summer months was suitable for stickleback and roach; higher up in the drainage, there were some appropriate pools for trout. Although dry throughout much of the upper sections, the substrate was gravel suitable for trout spawning.

At the time of the habitat surveys, most of Ross Creek was dry. The only area where there was flowing water and a number of pools suitable for trout was within the Natalie Coffin Greene Park area.

From the results of our "spot check" observations, it appeared that Fairfax Creek had little water in it by the end of the dry season. There were lateral scour pools and shallow riffles throughout the Creek, substrate consisted of gravel, sand and silt, and there was abundant vegetative cover.

Fish species collected in the Corte Madera Creek Watershed included rainbow/steelhead trout, threespine stickleback, California roach, sculpin species, and Sacramento sucker. Limiting factors for trout production were lack of stream flows and high water temperatures, depending upon both the creek and location of the reach within a creek.

Of the five fish species collected, trout were the most abundant in San Anselmo, Cascade, and Ross creeks; only trout were collected in Cascade and Ross creeks. Roach, stickleback and sucker were the predominant species in Corte Madera Creek; trout and roach were the most prevalent species in San Anselmo Creek; and, stickleback and roach were the most prevalent species in Sleepy Hollow Creek.

The mean trout populations, as a function of habitat type, within the Corte Madera Creek Watershed were as follows: (1) Corte Madera Creek - 0.03-0.14 fish/square meter of fish habitat; (2) San Anselmo Creek - 0.01-12.76 fish/square meter; (3) Cascade Creek - 0.59-0.84 fish/square meter; (4) Sleepy Hollow Creek - 0.02-0.41 fish/square meter; and, Ross Creek - 0.25 fish/square meter. The greatest numbers of trout were collected in San Anselmo and Cascade creeks within the Cascade Canyon Open Space Preserve. However, there was no statistical difference in population sizes between any of the various creeks, due to the wide variability in the number of rainbow/steelhead trout in the various habitat types.

Based on the size distribution, the juvenile rainbow/steelhead trout were probably from three to four different age classes. Most of the trout were young-of-the-year (i.e., hatched during spring of 1999) fish, but there were some older fish in both San Anselmo and Sleepy Hollow creeks. The greatest variety of age classes came from these two creeks, as well, suggesting that there is a self-sustaining population of rainbow/steelhead trout in the watershed, albeit small. Of particular interest was the variety of age classes in the first bedrock pools sampled in the Cascade Canyon Open Space Preserve, upstream of the dry creek bed which extended for over a mile in length.

Based on the length data, the stickleback collected were young-of-the-year fish, the roach and suckers, from one to four years old, and the sculpin from one to five years old.

The report provides a Steelhead Restoration Plan for the Corte Madera Creek Watershed which incorporates both science and public involvement to achieve watershed improvement. The three phases to the plan are: (1) Phase I- Undertake preliminary baseline surveys; (2) Design Steelhead Restoration Plan; (3) Phase III - Implementation of restoration actions, research and surveys; (4) Phase IV - Monitoring Results of Restoration Actions; and, (5) Adaptive Management.

PREFACE

I was raised in Mill Valley during the 1950's and 1960's in a house that my parents built on the slopes of Mount Tamalpais. I spent much of my childhood playing in the creeks and on Mt. Tam. In fact, there are few creeks in Marin County that I did not plunge into as a child, including all of the creeks in the Corte Madera Watershed. I have fond memories of what was, to me, a magical place to grow up. It is a continual joy to me to study the creeks in which, as a child, I spent many a day catching unwary crayfish, using string, "baited" with raw bacon, and observing the myriad of organisms, not the least of which were trout. The Corte Madera Creek Watershed is the fifth watershed in Marin County that I have had the privilege, as an adult, to study.

ACKNOWLEDGMENTS

A number of people helped immeasurably with this project. First, I thank Sandy Guldman, both for making this project happen when I had profound doubts several years ago, and for acting as my "buffer". Secondly, I really appreciate what I affectionately referred to as the "three therms", Jack (with assistance from his sons Jonathon and Benjamin) Judkins, Charlie Kennard, and Richard Wheeler, who painstakingly checked 32 thermographs throughout the spring and summer, a tedious and boring, albeit a very essential, task. I am also indebted to my field biologists, all of whom suffered the excruciating itches of poison oak (whereas, of course, I, their boss, never got it!). To Kat Berry, my "left finned" super fisheries biologist, I owe you more than wages for the work you have done at all hours of the day and night and without whom I would never have finished writing this report. Finally, a profound thank you to Dr. Kathleen Aswell, an editor extra ordinaire.

On the financial side, I also thank Cheryl Lovato Niles, the grant manager at the National Fish and Wildlife Foundation for her efficiency and good humor. Thanks to CALFED and the Bureau of Reclamation for partially funding the study. I am grateful to the Marin Community Foundation who enabled us to distribute this report to the Watershed Planning Advisory Committee and other interested parties.

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CHAPTER 1

INTRODUCTION AND SCOPE OF WORK

A. PROJECT AREA

The Corte Madera Creek Watershed, covering about 28 square miles, is located in the southeastern quarter of Marin County and encompasses the towns of Larkspur, Corte Madera, Kentfield, Ross, San Anselmo, and Fairfax. The watershed extends from latitude 37° 55' 50" N to 38°1'30" N and from longitude 122°30' 40" to 122°36' 45" W. The watershed includes Corte Madera, Ross, San Anselmo, Tamalpais, Sleepy Hollow, Fairfax, and Cascade creeks and Phoenix Lake. Larkspur and Tamalpais creeks drain directly into the estuary/tidal portion and they were not included in this study. The watershed drains into San Francisco Bay just south of the San Quentin Peninsula, approximately 10 miles north of the Golden Gate Bridge. The watershed ranges in elevation from sea level to 2,571 feet at the East Peak of Mount Tamalpais (Figure 1).

B. BACKGROUND

The Corte Madera Creek Watershed and its tributaries are among the few streams flowing to San Francisco Bay that retain a steelhead trout population. The watershed is situated within the Central California Coast Evolutionary Significant Unit (ESU). The National Marine Fisheries Service (NMFS) listed the steelhead trout within this ESU as threatened, under the Endangered Species Act (Federal Register, 1997, 1998).

In 1995, I wrote a Watershed Plan for the Corte Madera Creek Watershed, for Friends of Corte Madera Creek (Friends) entitled, *Preliminary Outline for a Corte Madera Creek Watershed Management Plan* (Rich, 1995). Several years later, Sandra Guldman, Co-Chairperson of Friends asked if I would be willing to join Friends in submitting a proposal to the Category III CALFED Bay-Delta Program for a steelhead trout restoration planning effort. I agreed and, fortunately, we received funding.

As a result of receiving the funding, Friends contracted with my firm, ***A. A. Rich and Associates (AAR)***, to undertake a fishery resources investigation and prepare this Fishery Resources Technical Report.

The results of this study, including the proposed restoration and monitoring suggestions are part of a comprehensive watershed plan to improve water quality, fishery resources, and native vegetation and wildlife in the Corte Madera Creek Watershed. This fishery resources report identifies how the declining trend in the steelhead population can be reversed. The report identifies the factors limiting the steelhead trout population, formulates corrective actions, describes historic and current fishery resource conditions, describes how to monitor the success of those actions, and presents an action plan for the restoration of the Corte Madera Creek Watershed as long-term steelhead trout habitat. To that end, an Advisory Committee, comprised of representatives from local government, federal and state agencies, community groups, and other stakeholders, will review documents and guide formulation of the restoration plan. The proposed fishery resources effort will occur concurrently with an erosion/sedimentation planning project being conducted by Stetson Engineers (2000).

Although this study targets steelhead trout, habitat improvements in the riparian corridors will also benefit riverine aquatic habitat and the neotropical migratory bird guild that uses the riparian corridor. Similarly, improvements in water quality and water flows likely will benefit saline emergent wetland habitats in the lower reaches And, San Francisco Bay will also benefit from improvements in water quality, flow, and temperature.

Corte Madera Creek Watershed

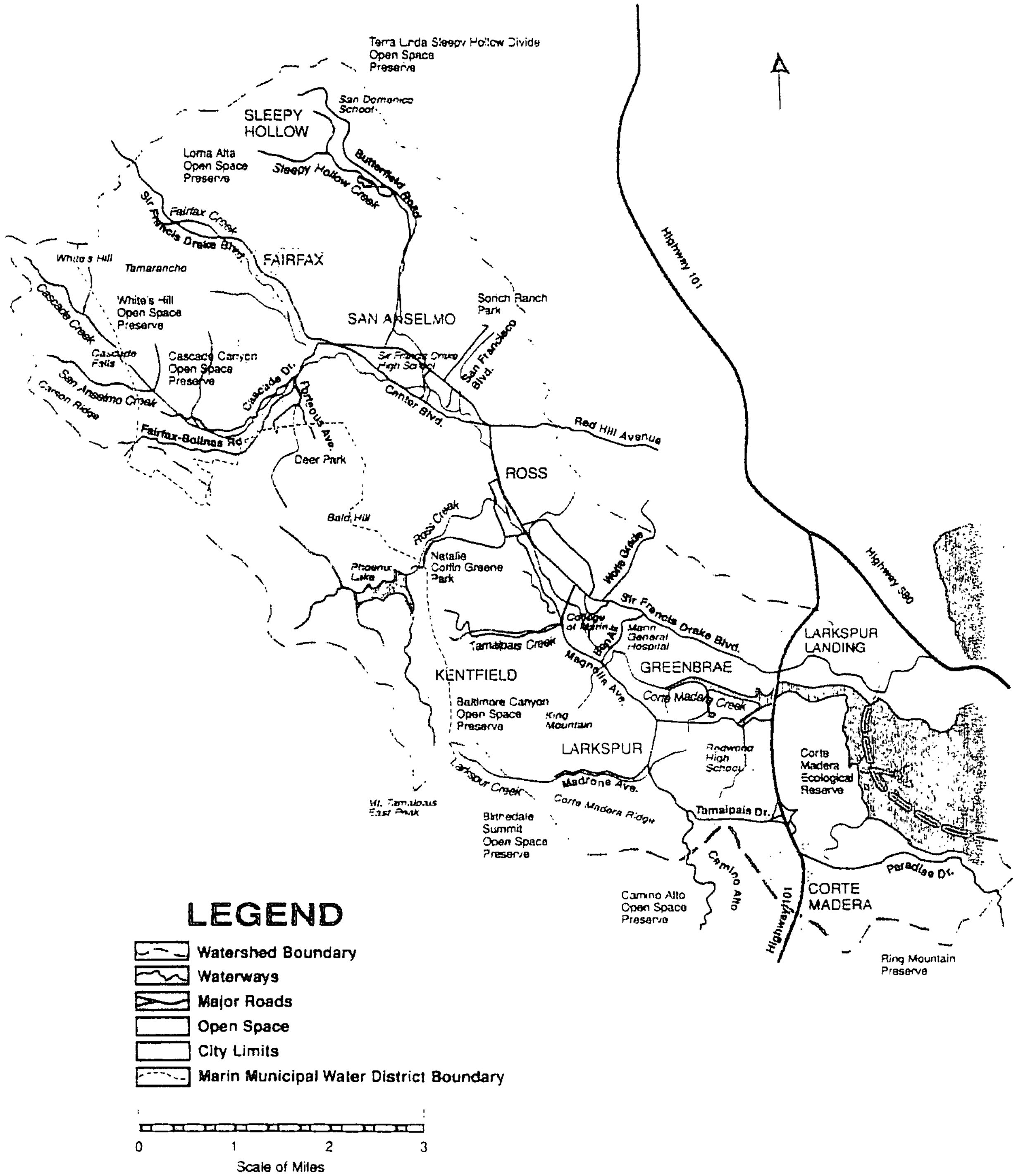

FIGURE 1. PROJECT LOCALE (Source: Friends of Corte Madera Creek Watershed)

C. SCOPE OF WORK

This report addresses the status of the existing fishery resources conditions within the Corte Madera Creek Watershed. More specifically, the objectives of this study were to:

- Provide life stage and habitat information on the rainbow/steelhead trout;
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- Assess water temperature conditions from April to October;
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- Assess fishery resource population conditions during the low flow season;
- Identify limiting factors for the rainbow/steelhead trout; and,
- Design a Steelhead Restoration Plan which will improve rainbow/steelhead populations.

With the exception of the U.S. Army Corps of Engineers (USACE) flood control channel, which is under tidal influence, this study is limited to the freshwater portions of the watershed.

CHAPTER 2

SALMONIDS AS INDICATOR SPECIES OF A WATERSHED'S ECOLOGICAL HEALTH

Although a variety of fish species inhabit the Corte Madera Creek (Table 1), the steelhead/rainbow trout is the fish species of primary interest in Corte Madera Creek Watershed. Both the anadromous (fish which spawn in freshwater, are reared for a period of time in fresh water, emigrate to sea for several years, and return to their natal streams to spawn), steelhead and resident rainbow trout, inhabit Corte Madera Creek and its tributaries. In addition, coho and chinook salmon have been sighted occasionally.

Biologists often use salmonids (salmon and trout) to assess the ecological well-being of creeks. The reason is that salmonids are what are referred to as ***indicator species*** (McCarthy and Shugart, 1990). Salmonids respond more quickly to environmental perturbations than other fishes. Thus, the condition of salmonids and their habitat provide a good indication of the relative health of a creek. Salmonids are to fisheries biologists what the canary was to miners: ***a warning sign***. The salmonid's response to its environment can provide an indication of the health of the watershed ecosystem, just as the condition of the canary was used to assess poor air quality conditions in mines. Thus, the salmonid health and salmonid habitat are ***environmental harbingers*** of events to come, if we do not remedy or remove the causative agent (s).

TABLE 1. FISH SPECIES WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Salmonidae (Trout and Salmon)							
Chinook Salmon *Oncorhynchus tshawytscha*	X	9	9	9	9	9	
Coho Salmon *Oncorhynchus kisutch*	X	4c,4d	9	7,9	9	9	9
Steelhead Trout *(adults)* *Oncorhynchus mykiss*	X	9	9	9	9	9	9
Rainbow/Steelhead Trout *Oncorhynchus mykiss*	X	1a,2,3,4a,4b	1a,2,5,6b	1a,3,5,6a,7,8	1a,4d,5,6b	6b	1a,6b
Brown Trout *Salmo trutta*		9					
Cyprinidae (Minnows)							
Sacramento Pikeminnow *Ptychocheilus grandis*	X	4a					
California Roach *Lavinia symmetricus*	X	1a,2,3,4a,4b,5		1a,3,5,7	1a,5	2	4d
Common Carp *Cyprinus carpio*		1b,9					
Catostomidae (Suckers)							
Sacramento Sucker *Catostomus occidentalis*	X	1a,3,4a,4b		1a,5,7			

TABLE 1 (CONT.). FISH SPECIES WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Cyprinodontidae (Killifish)							
Rainwater killifish *Lucania parva*	X	4a,4b					
Poeciliidae (Mosquitofish)							
Mosquitofish *Gambusia affinis*	X	4a					
Atherinidae (Silversides)							
Topsmelt *Atherinops affinis*	X	4b					
Gasterosteidae (Stickleback)							
Threespine Stickleback *Gasterosteus aculeatus*	X	1a,2,3,4a,4b,5		1a,3,5,7	1a,4d,5	2,4d	
Centrarchidae (Sunfish)							
Sacramento Perch Archoplites interruptus	X	9					
Black Crappie *Pomoxis nigromaculatus*		9					

TABLE 1 (CONT.). **FISH SPECIES WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED**

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Embiotocidae (Surfperch)							
Tule Perch *Hysterocarpus traski*	X	4a					
Shiner Perch Cymatogaster aggregata	X	9					
Gobiidae (Gobies)							
Tidewater Goby *Eucyclogobius newberryi*	X	4b					
Longjaw Mudsucker *Gillichthys mirabilis*	X	4b					
Cottidae (Sculpins)							
Pacific Staghorn Sculpin *Leptocottus armatus*	X	4b					
Prickly Sculpin *Cottus asper*	X	1a,4a,4b					
Riffle Sculpin *Cottus gulosus*	X	1a,4a,4b					
Sculpin spp. (probably riffle and prickly)	X	1a,2,3		1a,3		2	

TABLE 1 (CONT.). FISH SPECIES WHICH HAVE BEEN SIGHTED AND/OR COLLECTED IN THE CORTE MADERA CREEK WATERSHED

Common Name	Native Species	Corte Madera Creek	Ross Creek	San Anselmo Creek	Sleepy Hollow Creek	Fairfax Creek	Cascade Creek
Pleuronectidae (Righteye Flounders)							
Starry Flounder *Platichthys stellatus*	X	9					

Key

1a - Rich, 2000 (collected from August-November, 1999)
1b - Rich, 1994 (personal observation; adult spawners in USACE channel)
2 - Leidy, 1997 (collected in July, 1997)
3 - Leidy, 1993 (collected in July, 1993)
4a - Leidy, 1984 (collected in his study)
4b - Cited in Leidy, 1984 (from collections at the California Academy of Sciences in San Francisco State University: 1950's to mid 1970's)
4c - Cited in Leidy, 1984 (personal communication with Dr. John Hopkirk)
4d - Cited in Leidy, 1984 (Leidy and Fiedler, collected September 18, 1981)
5 - Michaels and Thompson, 1969 (collected in July, 1969)
6a - NMFS, 1997 (collected in September, 1996)
6b - NMFS, 1997 (collected in May, 1997)
7 - Fry, 1936
8 - Snyder, 1905
9 - Anectodal (no written record found)
10 - Marin Independent Journal, July 14, 1986

CHAPTER 3

IMPORTANCE OF IDENTIFYING HABITAT REQUIREMENTS AND LIMITING FACTORS

Understanding the biological and physical factors which are necessary to sustain the salmonid populations in the Corte Madera Creek Watershed is critical to developing management strategies to improve the habitat and enhance populations. Salmonid production is affected by environmental conditions during each life stage. Salmonids, similar to other fishes, have different habitat requirements for the successful completion of each of their life stages. Thus, it is essential to understand what the watershed has to offer fishes, before one can determine what restoration measures would be most effective in improving salmonid populations. This Chapter describes the general habitat requirements and limiting factors for salmonids. The results of the study are presented in Chapters 7 and 8.

Life history events for any organism, including salmonids, must be discussed in concert with key ***life stage requirements***. Life stage requirements are those features of an organism's environment that are essential to its continued survival and reproductive success. Critical life stage requirements for the rainbow/steelhead trout include:

- Appropriate water temperatures;
- Appropriate water quality;
- Abundant food;
- Accessibility to spawning and rearing areas; and,
- Appropriate physical habitat.

Each of the life stage requirements may vary, depending upon the season and the life stage and condition of the fish. If any life stage of any species is deprived of a life stage requirements, the population as a whole can be negatively affected. When life stage requirements are not met, or are limited in some way, the fish's survival and reproductive success can be jeopardized. One extremely important concept in enhancing fish populations is the following:

If there is no change in the limiting factors (s) for the population (s), no increase in the target population (s) will occur.

Factors which have the potential to restrict populations are called "limiting factors". The term limiting factor was originally used in a physiological context to describe environmental factors (e.g., food, dissolved oxygen, other respiratory gases) that limited the metabolic rate of fishes (Fry, 1971). However, during the past decade agency biologists have expanded the limiting factor concept to apply to ecological systems. Thus, many of the terms which were originally used to describe physiological processes that affect fish production are now used in a much broader context to describe ecological functions (Reeves et al., 1989). Potential limiting factors from an ecological context include: water temperature; water quality; and, quantity and quality of habitat suitable for spawning and rearing. Some limiting factors, such as not enough woody debris (habitat which trout prefer and need), can be influenced by human intervention. Other limiting factors, such as the lack of water, often cannot be altered. Thus, before one can determine what measures are needed to help restore Corte Madera Creek and its tributaries, one must identify the following:

- The requirements of the fishes; and,
- Any Limiting Factors which may exist.

As each life stage of the trout has specific life requirements, it is imperative to understand both the events of each life stage and the factors which affect those events.

The anadromous steelhead, and the resident rainbow, trout require special conditions for successful spawning, egg development and hatching, growth and survival of juveniles, and smoltification (during which the anadromous fish change from a freshwater to a seawater animal, and emigrate to sea). Although, many general requirements (e.g., good water quality, abundant food, etc.) are the same for the steelhead and rainbow trout, specific factors may limit production (i.e., limit the number of fish in the stream). For example, barriers to adult fish immigration may limit the success of spawning for steelhead trout. Thus, it is essential to understand what Corte Madera Creek and its tributaries have to offer these fish, before one can determine what measures are needed to help restore the Corte Madera Creek Watershed.

CHAPTER 4

LIFE HISTORY STAGES AND REQUIREMENTS OF STEELHEAD AND RAINBOW TROUT

A. LIFE HISTORY STAGES

1. *Steelhead Trout*

The steelhead trout is a polymorphic subspecies of the resident rainbow trout. Similar to other anadromous salmonids, the steelhead trout begins life in a freshwater stream or river, rears for a period of time in freshwater, emigrates to sea for several years, and returns to its natal streams to spawn. Except for their ocean-going habits and larger spawning size, the steelhead trout is visually indistinguishable from its non-migratory counterpart, the rainbow trout. Whether or not a particular stream supports an anadromous or resident trout population appears to be the result of local adaptation and geographic location. Populations may be migratory, resident, or mixed, where the two forms presumably interbreed. Both the anadromous and resident forms may exist in the stream, and, in some instances, may be physically discrete from one another, due to an impassable barrier to upstream migration, such as a waterfall. In these situations, the steelhead trout does not exist above the barrier (Utter et al., 1980; Behnke, 1992; Needham and Gard, 1959).

Steelhead trout migrate to sea at various ages, spend varying amounts of time in the ocean (one to four years), and return to their natal stream to spawn. The life history information for steelhead trout can be divided into five life stage events, which include (Figure 2 and Table 2):

- Adult immigration;
- Spawning;
- Egg and alevin incubation;
- Fry and juvenile rearing; and,
- Smoltification and emigration.

A description of the timing and general biology of each of these stages is discussed below. Life stage requirements are discussed in the subsequent section.

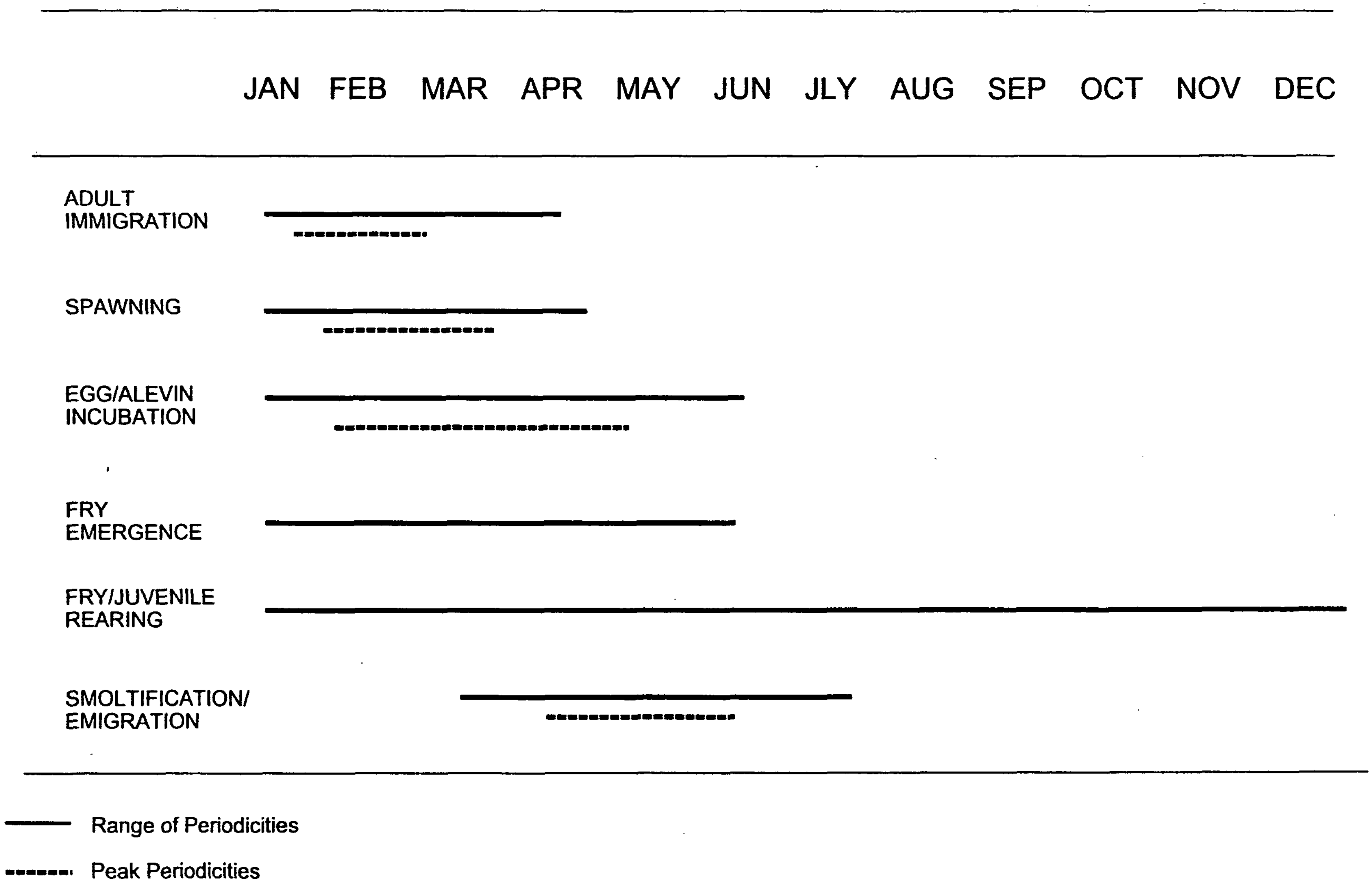


FIGURE 2. STEELHEAD TROUT LIFE STAGE PERIODICITIES IN THE CORTE MADERA CREEK WATERSHED

TABLE 2. HABITAT REQUIREMENTS FOR STEELHEAD TROUT

LIFE STAGE	OPTIMAL WATER TEMPERATURE	DISSOLVED OXYGEN (mg/l)	pH	WATER DEPTH	WATER VELOCITY	TURBIDITY (mg/l)	SUBSTRATE SIZE
IMMIGRATION/ PASSAGE	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 25 cfs	≤ 25	N/A
SPAWNING	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 15 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
INCUBATION	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 7 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
FRY EMERGENCE	8.9-11.2 °C 48.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	fry: 8-36 cm 3-14 in juvenile: 25-50 cm 10-20 in	≥ 7 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
REARING	12.8-15.6 °C 55.0-60.1 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	18.3-67.0 cm 0.6-2.2 ft	≥ 2 cfs	≤ 25	6.4-24.9 cm 2.5-9.8 in
SMOLTIFICATION/ EMIGRATION	6.98-11.3 °C 44.4-52.3 °F.	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	18.3-67.0 cm 0.6-2.2 ft	≥ 7 cfs	≤ 25	6.4-24.9 cm 2.5-9.8 in

TABLE 2 (CONT.). HABITAT REQUIREMENTS FOR STEELHEAD TROUT

LIFE STAGE	REDD (mean area of redd per spawning pair)	COVER	FOOD	POOL/RIFFLE RATIO
IMMIGRATION AND PASSAGE				
SPAWNING	4.4-5.4 square meters 47-58 square feet			
INCUBATION				
FRY EMERGENCE				
REARING		Need abundant cover to protect them from predators, reduce summer water temperatures adn provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water
SMOLTIFICATION AND EMIGRATION		Need abundant cover to protect them from predators, reduce summer water temperatures adn provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water

Sources:

cm	=	centimeters	cm/s	=	centimeters per second
ft	=	feet	ft/s	=	feet per second
C	=	centigrade	>	=	greater than
F	=	fahrenheit	<	=	less than
in	=	inches	≥	=	greater than or equal to
≤	=	less than or equal to			

Sources: Rich, 1987; Brett & Blackburn, 1981; Baracco, 1977; Hooper, 1973; Zaugg et al., 1972; Smith, 1973; Hunter, 1973; Zaugg and Wagner, 1973; Thompson, 1972; Dickson and Kramer, 1971; Doudoroff and Shumway, 1970; Orcutt et al., 1968; Hartman and Gill, 1968; Wagner, 1974; Philips and Campbell, 1961; Whitmore et al., 1960; Cloern, 1976; Bovee, 1978; Phillips et al., 1975; Adams et al., 1975; Hall and Lentz, 1969; Koski, 1966

The steelhead trout which migrate into Corte Madera Creek (beginning in December usually) to spawn is referred to as the "winter run". These are steelhead trout which enter and spawn during rising stream levels during the winter and early spring months (Withler, 1966). Most steelhead trout begin to immigrate into San Francisco Bay in November, although the timing is dependent upon streamflow levels in the riverine systems (Figure 2). Storm events result in streamflow changes, which cue anadromous fish immigration into Corte Madera Creek, and from there, into the tributaries. Immigration of steelhead trout occurs in "waves" or pulses, coinciding with storm events, resulting in temporary high water flows (freshet conditions). Studies suggest that these freshet conditions are required to initiate both movement into a lagoon or bay, and upstream into the creeks (Shapovolov and Taft, 1954; Briggs, 1953).

The entry of steelhead trout into streams is not determined entirely by either sexual maturity or age. Although, California steelhead trout typically return to freshwater after one to two years at sea, they have a highly variable life history; some return after three or four years at sea (Shapovolov and Taft, 1954; Briggs, 1953). Steelhead trout which have spent only one year at sea, but have returned to spawn, are termed "grisle"; such males are commonly called "jacks".

After the adult steelhead trout move into a stream, they will seek out a pool or glide habitat located near the spawning area; many will "hold" in these areas for two to four weeks while their reproductive products (eggs and milt) ripen. In the Corte Madera Creek Watershed, most steelhead trout spawn in January and February.

Most adult steelhead trout die after spawning, but some return to the ocean and then to the stream to spawn again; these fish are called "repeat spawners". The incidence of repeated spawning by steelhead is more common among females than males. Repeated spawning by females allows each female to return in subsequent years to release eggs and, hence, increase the number of fish produced. Males usually serve more than one female during spawning. Thus, in terms of perpetuation of the species, it is not as important for males to return to spawn year after year. Research on coastal streams has shown that the percentage of repeat spawners varies from three to over 50 percent of a run. Although, most steelhead trout return to spawn only once, as many as five returns have been recorded, although not in recent years (Fulton, 1970; Bjornn, 1969; Withler, 1966; Shapovolov and Taft, 1954; Briggs, 1953).

Steelhead trout eggs incubate for a variable period of time (usually 30-60 days), depending upon water temperature (Leitritz and Lewis, 1980; Shapovolov and Taft, 1954). In the Corte Madera Creek Watershed, most incubation probably occurs from January through March, although the incubation period may extend further in wet years.

Once the yolk sac is absorbed, steelhead trout fry begin to emerge from the gravel. In the Corte Madera Creek Watershed, most fry emergence begins in March. The distinction between fry and juvenile is, admittedly, an arbitrary one. "Fry" status is assigned to the fish emerging from the gravel; "juvenile" status is assigned to the fish when it has reached a given length; the length differs from study to study. After emerging from the gravel, the young fish feed and tend to congregate in schools close to shore. As the fish grow, they spread out, eat larger foods, and are thought to inhabit moderately swift portions of creeks. Most steelhead trout spend from one to two years in the streams, before returning to sea (smoltification), where they spend from one to three years, before returning to freshwater to spawn. A very small percentage of fish emigrate out of California creeks during their first year (Moyle, 1976; Withler, 1966; Shapovolov and Taft, 1954; Briggs, 1953).

Smoltification, or the ***parr-smolt transformation***, consists of behavioral, morphological, and biochemical changes which transform a darkly pigmented, bottom dwelling freshwater salmonid (the parr) into a pelagic silvery fish (the smolt) (Folmar and Dickhoff, 1980). During this process, salmonids emigrate from their natal streams into the sea. In the Corte Madera Creek Watershed, smoltification and emigration probably extend from March into June. The fish then emigrate out to San Francisco Bay and from there to the Pacific Ocean.

If steelhead trout undergoing smoltification are unable to reach the Pacific Ocean, due to environmental problems (e.g., low streamflow, thermal blocks), they revert to an immature parr-like condition (Folmar and Dickhoff, 1980). Depending upon conditions, the trout may de-smoltify and re-smolt the following year, or it may die, particularly if it is a small fish.

2. *Rainbow Trout*

Although not sea-dwelling, the rest of the life history of the resident rainbow trout is similar to that of the steelhead trout. Most rainbow trout are spring spawners (February to June) (Figure 3; Table 3). Most resident trout mature in their second or third year, although the time of first maturity can vary from the first to the fifth year of life (size at maturity can be 13 centimeters or larger) (Moyle, 1976).

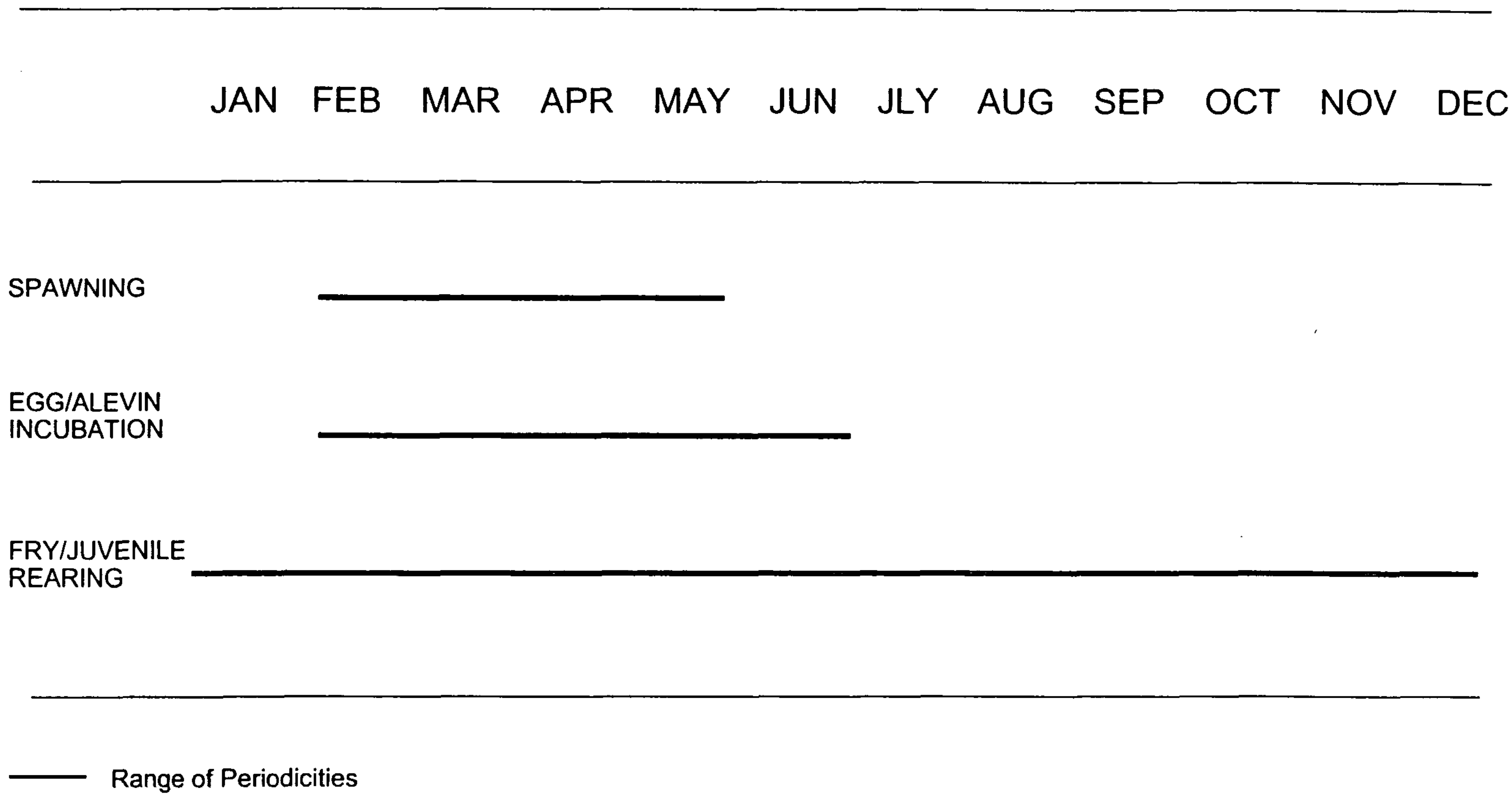


FIGURE 3. RAINBOW TROUT LIFE STAGE PERIODICITIES IN THE CORTE MADERA CREEK WATERSHED

TABLE 3. HABITAT REQUIREMENTS FOR RAINBOW TROUT

LIFE STAGE	WATER TEMPERATURE	DISSOLVED OXYGEN (mg/l)	pH	WATER DEPTH	WATER VELOCITY	TURBIDITY (mg/l)	SUBSTRATE SIZE
SPAWNING	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 122 cm/s ≤ 4 ft/s	≤ 25	fish < 50 cm long: 1.5-6.0 cm 0.6-2.4 in fish ≥ 50 cm long: 1.5-10.0 cm 0.6-4.0 in
INCUBATION	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 48-91 cm/s ≤ 1.6-3 ft/s	≤ 25	0.3-10 cm 0.1- 4 in
FRY EMERGENCE	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 8-30 cm/s ≤ .26-1 ft/s	≤ 25	0.3-10 cm 0.1- 4 in
REARING	15-18 °C 59-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	fry: ≤ 8-30 cm/s ≤ .26-1 ft/s juvenile: 10-22 cm/s .3-.72 ft/s	≤ 25	1.5-10 cm 0.6- 4 in
ADULT	15-18 °C 59-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	12-73 cm/s 0.4-2.4 ft/s	≤ 25	1.5-10 cm 0.6- 4 in

TABLE 3 (CONT.). HABITAT REQUIREMENTS FOR RAINBOW TROUT

LIFE STAGE	REDD SIZE (mean area of redd per spawning pair)	COVER	FOOD	POOL/RIFFLE RATIO
SPAWNING	0.2 square meters 2.2 square feet			
INCUBATION				
FRY EMERGENCE				
REARING		Need abundant cover to protect them from predators, reduce summer water temperatures and provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water
ADULT		" "	Fishes, invertebrates	" "

cm	=	centimeters	cm/s	=	centimeters per second
ft	=	feet	ft/s	=	feet per second
C	=	centigrade	>	=	greater than
F	=	fahrenheit	<	=	less than
in	=	inches	≥	=	greater than or equal to
≤	=	less than or equal to			

Sources: Rich, 1987; Hooper, 1973; Doudoroff and Shumway, 1970; Orcutt et al., 1968; Delisle and Eliason, 1961; Thompson, 1972; Smith, 1973; Horner and Bjornn, 1976; Hunter, 1973

B. IMPORTANT ENVIRONMENTAL FACTORS

For any given species, each life stage has specific environmental requirements, or ***life requirements***. When life requirements are not met, or are limited (i.e., limiting factors) in some way, the fish's survival and reproductive success can be jeopardized. Each of the requirements vary, depending upon the season of the year and life stage of the fish. If any life stage of any species is deprived of a life requirement, the population as a whole can be negatively affected (Figure 4).

By integrating the knowledge of salmonid habitat requirements with that of historical and current conditions, one can determine how habitat conditions for salmonids have been affected by past and ongoing watershed activities. From this information, it is possible to determine what types of activities are needed in order to help improve steelhead habitat. Restoration activities, together with monitoring of the success of those activities, could improve steelhead trout habitat and populations in the Corte Madera Creek Watershed.

The best method for identifying salmonid requirements and determining whether or not these requirements are being satisfied is to use site specific data. However, as site-specific information is incomplete for all of the life stages of both the steelhead and rainbow trout in the Corte Madera Creek Watershed, relevant data from other systems has been used. As more information becomes available, the requirements for each life stage of the trout should be re-evaluated on an ongoing basis. Then, if necessary, one or more of these requirements can be modified, if there is a scientific basis for such a change.

In the absence of studies conducted in a specific geographical area, it is common to analyze information from other areas or laboratories and to identify a "threshold" value" or "threshold" effect. Threshold values and threshold effects are two commonly used terms which are usually only defined in peer-reviewed scientific publications. Biologically speaking, a "threshold" is a level or value that must be reached before an event occurs; a "threshold effect" is the harmful effect of a small change in the environment that exceeds the limit of tolerance of an organism or population (Lawrence, 1995). There are several problems with using thresholds based on data from laboratories or areas other than the site of interest. First, in the laboratory environment, one is forced to control or eliminate many of the factors (e.g., effect of ration size on thermal requirements, effect of energy expenditure as a result of escaping predators or seeking prey, effect of previous stressors) that affect fish in the wild. Thus, laboratory data are not analogous to those collected in a stream. Data from other geographical areas can also misrepresent the requirements for the area in question; thermal and physical requirements vary from creek to creek, depending upon existing conditions.

To protect the steelhead and rainbow trout in the Corte Madera Creek, I am going to err on the side of conservatism, with regard to the various life stage requirements for these fish. For example, the results of various studies demonstrate a range of thermal optimal values for juvenile steelhead. However, until we know whether or not any or all of the creeks in the Corte Madera

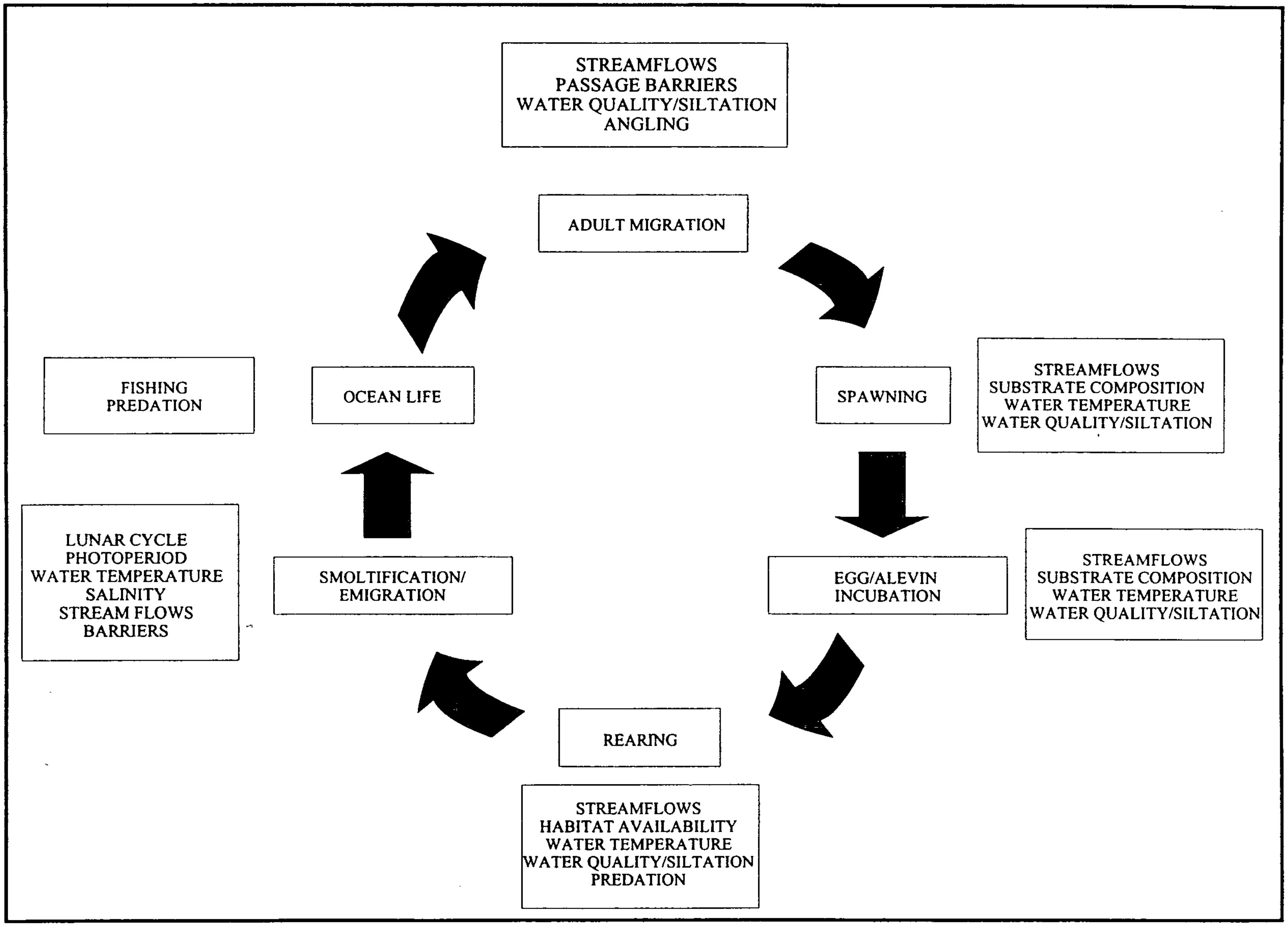


FIGURE 4. FACTORS WHICH AFFECT SALMONIDS

Creek Watershed provide the necessary food to sustain higher optimal temperatures, it is best to assume that food is a limiting factor (i.e. there is not enough food). Thus, given a choice of several optimal water temperatures, based on laboratory studies, I will, initially, choose the lowest temperature as being optimal. Then, in the future, if studies are conducted within the watershed which demonstrate that optimal water temperature are higher than those selected here, the requirements can be modified, based on the results of those site-specific studies.

In the following paragraphs, critical life stage requirement variables for salmonids are discussed. These requirements are based both on the results of peer-reviewed studies published in a variety of scientific and various agency reports and documents.

1. *Appropriate Water Temperatures*

Of all of the life stage requisites, water temperature is the most important, yet, perhaps, least understood. A major problem hindering precise understanding of temperature effects is that many environmental factors (e.g., food availability, previous exposure to stress, genetic adaptation, age and size) simultaneously influence a fish's response to temperature. Water temperature can really be considered in two ways: (1) as a factor affecting the rate of development, metabolism and growth; or, (2) as a stressful or lethal factor. The two, of course, are inseparable.

By contrast to us, as mammals, fishes are poikilotherms, which means that their internal body temperature varies, according to the external environment. This means that a fish has little physiological control (i.e., thermoregulation) over its body temperature; if the water is hot, the fish is hot and if the water is cold, the fish is cold, etc. Thus, the poikilothermic fish, unlike the homeothermic mammal (which can thermoregulate), has no physiological way to acclimate quickly to changes in water temperature. And, a fish's metabolism, which controls all aspects of its body, is directly proportional to water temperature, within certain limits. Thus, as water temperatures increase, so does the metabolic rate and the need for food. If there is enough food available and dissolved oxygen and other conditions are satisfactory, then the fish will grow, within certain thermal ranges. However, if the amount of food is limited and/or other stressors exist (e.g., low dissolved oxygen, pollution), the fish will not grow. In addition, beyond certain physiological limits, even an increase in food availability will not assist the fish; beyond this point, water temperature can be stressful and even lethal.

Despite a fish's inability to change quickly, physiologically, they often use behavior to thermoregulate. This is of great importance when their habitat provides more than one thermal option. For example, in studies on the Navarro River Watershed (Rich, 1991), juvenile coho salmon were collected in water temperatures that would be considered stressful according to the results reported in the scientific literature. Yet, the fish had good growth rates and appeared to be healthy. It was surmised that both the abundant food resources and cool "thermal refugia" accounted for this apparent anomaly (Rich, 1991). Thus, within the thermocline in the pool, the cooler areas provided a refuge for the salmonids during the hot part of the day. The fish could then digest their food at physiologically acceptable water temperatures, even though a large percentage of the pools were characterized by high water temperatures.

Chronic sublethal stressful water temperatures are usually of more importance to long-term fish population health than acute lethal temperatures. Stressful water temperatures are more common and the results less easily studied and understood than a "fish kill", resulting from lethal water temperatures. However, sublethal water temperatures can effectively block migration, reduce growth rate, create disease problems, and inhibit smoltification. Hence, it is of paramount importance that the impacts of sublethal stressful water temperatures be understood and, when possible, mitigation measures be implemented, to reduce the long-term impacts: reduced productivity within the watershed.

Water temperature standards used for selected fish species by fisheries biologists are often subject to debate. One of the primary reasons for this problem stems from the fact that it is common to base water temperature standards on selected laboratory data, rather than site specific field data for a given species. For example, water temperature requirements for salmonids, are often developed without any understanding of the physiological and/or behavioral response of the fish to changes in water temperature. Therefore, water temperature standards often do not agree with field data for a given fish species.

Thus, to identify appropriate water temperature requirements for fishes, it is of paramount importance to use site specific data, preferably temperature-physiology studies. The status of knowledge regarding the impacts of water temperature on steelhead trout is provided in Appendix G. Based on available information, physiological optimal water temperature ranges are summarized in Tables 2 and 3 for the steelhead and rainbow trout, respectively.

2. *Acceptable Water Quality Conditions*

Sensitivities of fishes differ, with regard to dissolved oxygen (DO) concentrations, siltation/sediment, and pollutants. Salmonids are particularly sensitive to low DO, high sediment loads, and various pollutants.

Dissolved Oxygen

Although sensitivity of fish to low DO concentrations differs between species (e.g., salmonids are more sensitive than suckers), the requirements (e.g., feeding, growth, reproducing, etc.) for each life stage controls the amount of oxygen needed at any given time. If these requirements are not met, the fish undergoes a stress reaction. The stress reaction can influence the fish's life processes and, sometimes, whether or not the fish lives or dies. Chronic sublethal DO levels can result in the following impacts on salmonids: (1) Cessation of immigration; (2) Negative impact on swimming performance; (3) Reduced growth rate; (4) Reduced food consumption rate; and, (5) Avoidance reactions. Any of these responses can affect the fish's ability to complete its life cycle and perpetuate the species. For salmonids, DO concentrations should generally be above 7 mg/l, although at low water temperatures, 5 mg/l is probably also suitable (Brett and Blackburn, 1981; Jones, 1971; Whitmore et al., 1960).

Sedimentation and Turbidity

Salmonids require and seek out clean (silt-free) gravel. Although, they will spawn and rear in embedded substrate if nothing else is available, there may be a subsequent reduction in survival to emergence (Folmar and Dickhoff, 1982). It is well-known that fine sediments can influence the survival of salmonids, particularly at the egg and alevin life stages. Fine sediments (defined in most studies as particles with a diameter of less than 3 mm or 0.85 mm) may reduce intergravel flow and the delivery of dissolved oxygen to incubating eggs and developing alevins in the redd, impede or obstruct the emergence of alevins, reduce the carrying capacity of rearing habitats for juvenile salmonids, and smother food organisms (McNeil and Ahnell, 1964; Cooper, 1965; Koski, 1966; Cloern, 1976; Phillips et al., 1975).

Chronic turbidity that is caused by fine sediment suspended in the water column may interfere with feeding by juvenile salmonids and, thereby, reduce growth. Other potential effects of suspended sediment on salmonids include irritation of gill tissues, avoidance behavior, and mortality (Noggle, 1978)

Although, it is generally accepted that increased input of fine sediments can be harmful to salmonids, determining the exact threshold amount that may limit production of salmonid populations in a watershed is more problematic. Many stream systems in California, including those in the Corte Madera Watershed (Stetson Engineers, 2000) have high sediment loads, including an abundance of fine materials less than 1 mm diameter. Yet, historically these streams supported healthy populations of salmonids.

Pollutants

Compared to many of the other urban creeks I have surveyed, the creeks in the Corte Madera Creek Watershed are relatively clean. However, many of the human activities in the Corte Madera Watershed result in degradation of the creeks inhabited by steelhead and other fishes. Storm drains flow into many of the creeks and San Francisco Bay. Oil from cars, detergents from washing cars, lawn and garden sprays containing herbicides, are all toxic to fishes, particularly the sensitive salmonids, and can result in chronic stress or even be lethal, depending upon the circumstances. In addition, sediment problems, originating from headwater areas, primarily, and, to a lesser extent, creek banks in the towns, result in increased siltation in the creeks (Stetson Engineers, 2000), which can be harmful to salmonids. Finally, high coliform bacteria counts have been detected during the winter months in various segments of the creek, although this is probably more a problem to humans than to fishes (Marshall et al., 1994).

3. *Abundant Food Resources*

Salmonids are opportunistic predators that eat a wide variety of aquatic invertebrates, as well as terrestrial invertebrates that fall into the stream (Mundie, 1969; Tippets and Moyle, 1978). Abundant food is particularly important to salmonids during warm summer months, when water temperatures and metabolisms are high. Young salmonids require a large and constantly replenished supply of food, in order to survive and grow.

4. *Accessibility to Spawning and Rearing Areas*

Sometimes barriers (e.g., dams, shallow riffles, waterfalls, debris jams) will delay, or even curtail immigration beyond the barrier. Migration barriers may limit the success of spawning for steelhead trout and coho salmon. Some barriers are insurmountable, but, given suitable conditions (e.g., deep pools at the base of a waterfall or cascade, etc.), steelhead trout may be able to get past many obstacles that appear to be barriers. The best method for determining whether or not a barrier to migration exists is to obtain site-specific information.

5. *Appropriate Physical Habitat*

The amount of streamflow, substrate quality and quantity, appropriate water depths, and adequate shelter or cover affect all life stages of salmonids.

The amount of streamflow affects all life stages of trout. Of the factors known to influence anadromous salmonid's ascent of creeks, streamflow connected with storm events is one of the most important. Once the fish immigrate into Corte Madera Creek, there has to be enough water for them to "pass over" barriers in order for the fish to reach their spawning areas. Streamflow regulates the amount of spawning area available; as flows increase (up to a point), more gravel is covered and becomes suitable for spawning. During egg incubation and fry emergence, adequate streamflows are necessary to cover the eggs and wash away excretory products. During rearing, streamflow is related to the amount of food and physical habitat available. Streamflow is also an important factor during the parr-smolt transformation and emigration of anadromous fishes.

A number of dam barriers which have existed in the creeks of the Corte Madera Creek Watershed for many decades may have impeded the passage of steelhead to upstream spawning areas. While some now have fish ladders which allow passage of anadromous salmonids, some of the fish ladders are very old and need to be updated with new, more efficient structures.

Trout require and seek out clean (silt free) gravel. Although they will spawn and rear in embedded substrate, if nothing else is available, there is usually a reduction in survival. Successful spawning, incubation, and fry emergence depends upon the following: (1) Size class composition of the substrate; (2) Existing degree of embeddedness; (3) Porosity of the substrate down to below the point of egg deposition in the fish's redd; and, (4) Percolation rate of water through the substrate. General substrate requirements are provided in Tables 2-3.

Water depth is important to salmonids, particularly during the immigration and spawning season. Steelhead trout in California streams rarely choose redds which will later be exposed by receding stream levels. During egg development, there must be an abundance of well-oxygenated water flowing over the redds. Preferred depths have been determined by measuring the water depth over active redds (Smith, 1973; Hooper, 1973; Hunter, 1973; Thompson, 1972; Shapovolov and Taft, 1954).

Cover is an important factor in a fish's life. Cover provides protection from predators (e.g., birds, mammals, other fishes), as well as, sometimes, reduced water temperatures during hot days. Cover can be provided by overhanging vegetation, undercut banks, submerged rocks and vegetation, submerged objects such as logs, floating debris, and even turbulence and depth, sometimes. Young salmonids prefer habitats which are characterized by abundant cover. The nearness of cover to a spawning area may be a factor in the actual selection of spawning sites; some salmonids select areas adjacent to undercut banks and overhanging vegetation (Reiser and Bjornn, 1979; Moyle, 1976).

One of the important characteristics of urban areas such as the Corte Madera Creek Watershed is the need to reduce the impacts of flooding. Unfortunately, for salmonids, reduction of in-channel structure, including large woody debris, as a result of flood control measures, may lead to the loss of habitat features important to juvenile salmonids. Reductions in structure may cause decreased frequency, depth, and complexity of pool habitat used by rearing juvenile and holding adult salmonids. In particular, the carrying capacity of streams for older age classes of juvenile salmonids may be reduced as these life stages typically prefer deeper pool habitats (Bisson et al., 1988). Stream channels tend to become simpler and less stable after removing woody debris and/or channelizing the streams. As a result, the structural complexity that provides substrate diversity, low-velocity refugia during high flows, and cover from predation is lost (McMahon and Reeves, 1989). Other potential impacts of reduced in-channel structure include: reduced retention and sorting of spawning gravels and fine sediment; reduced retention of fine and coarse organic materials important for maintaining macro invertebrate communities (used as food by juvenile salmonids); and, reduced retention of salmonid carcasses that contribute important nutrients to the stream and food for juvenile salmonids.

6. *Competition from Non-Native Fish Species*

Non-native fish species such as carp and sunfish compete with native trout for space and food. In addition, these non-native species are tolerant of high water temperatures and habitat conditions which are unsuitable for trout. Hence, enhancement of conditions suitable for trout will minimize habitation by non-native fish species, provided that non-native fishes are not released into the streams.

CHAPTER 5

LIFE HISTORY STAGES AND REQUIREMENTS OF OTHER FISHES

The main non-salmonid fish species in the Corte Madera Creek Watershed include the threespine stickleback, California roach, several species of sculpin, and Sacramento sucker (Table 4). All of these species are hardier than salmonids and are able to adapt, establish, and re-establish themselves more easily than salmonids.

A. THREESPINE STICKLEBACK

There are two types of three-spine stickleback: (1) estuarine anadromous; and, (2) freshwater resident. In all probability, the stickleback collected in the Corte Madera Creek Watershed are of both types, with the estuarine type in the lowest most reaches Corte Madera Creek which is influenced by the tides, and the freshwater resident type throughout the rest of the watershed.

Anadromous populations ascend creeks to spawn in the spring and summer months; the resident form spawns in the spring and summer, as well (Table 4). The breeding cycle lasts two or three months, during which an elaborate courtship ritual takes place. At the beginning, the females remain in schools and the males build the nests. After the male builds a nest (out of vegetation and sand, glued together with mucus secretion from the kidney) on the substrate within his territory, the gravid female, performs a zig-zag courtship dance (Tinbergen, 1953). If a female is ready, she will respond to the dance by following the male to the nest and laying the eggs; the male will fertilize the eggs, chase the female away, repair, incubate and guard the nest. Once the eggs hatch (six-eight days at 64-68 °F), the fry remain in the nest for a couple of days. Once the fry begin to swim about, the male continues to guard them, grabbing wanderers in its mouth and spitting them back into the main school. Eventually, the fry become more active, the male has more difficulty guarding them, and begins the spawning cycle again with another female, or joins a school of fish that have finished reproducing. The young fish join schools of similar-sized fish.

Stickleback live in weedy pools and backwaters, or among emergent plants at streams edges, over bottoms of sand and mud (Moyle, 1976). They require cool water for long-term survival; it is unusual to find them in water warmer than 73-75 °F. It is also unusual to find them in turbid water, since they are visual feeders, as the large eyes suggest. They feed primarily on bottom organisms or organisms living on aquatic plants (Hagen, 1967; Hynes, 1950). Anadromous populations feed more on free-swimming crustaceans, although they may also feed on bottom organisms.

TABLE 4. HABITAT REQUIREMENTS OF THREESPINE STICKLEBACK

	ESTUARINE HABITAT		FRESHWATER HABITAT	
	Overwintering	Breeding	Overwintering	Breeding
Period of Occupation	September - April	May-August	September - February	March - August
Substrate	Sand	Sand, Mud	Fine gravel	Mud
Vegetation	Variable	Abundant	Sparse	Sparse
Water Depth	More than 1 meter	Less than 1 meter	Less than 1.5 meters	Less than 0.5 meters
Water Current	Strong	Moderate	Moderate	Weak
Water Temperature	10 - 15 °C	18 - 22 °C	12 - 17 °C	18 - 22 °C
Salinity	Approximately 20 parts per thousand	0 - 1 parts per thousand	0 parts per thousand	0 parts per thousand

Sources: Moyle, 1976; Snyder and Dingle, 1989; Hagen, 1967; Hynes, 1950.

Most stickleback appear to complete their life cycle in one year. Usually a majority of the stickleback in one area will be uniform size. Freshwater stickleback seldom exceed 60 millimeters total length in California; anadromous stickleback commonly reach 80 millimeters. Females are usually larger than males.

Two adaptive features of the stickleback have enabled it to survive, despite its small size. First, the dorsal fin has three spines which the fish can maneuver into an upright position, thus diminishing its delectability to predators. Second, it is extremely euryhaline (i.e., it can withstand wide variations in salinity concentrations).

B. CALIFORNIA ROACH

California roach are habitat generalists, being found in cold "trout" streams, as well as warm intermitted streams and main channels of river (e.g., Russian and Tuolumne rivers). They are tolerant of relatively high temperatures (86-95 °F) and low oxygen concentrations (1-2 parts per million) (Moyle, 1976).

Reproduction occurs from March to June, but may be extended through late July. During the spawning season, schools of fish move into shallow areas with moderate flow and gravel/riffle substrate. Females deposit adhesive eggs in the substrate within 2-3 days and the fry remain in the substrate interstices until they are free-swimming. Roach are bottom feeders, and feed on filamentous algae, as well as crustaceans and insects. Growth is seasonal. With rapid growth occurring during the summer months.

C. SCULPIN SPECIES

Not only is the variety of sculpin species enormous, but identification of the various species is a royal headache, even for an experienced ichthyologist. Hence, as the focus of this project is on trout, sculpin collected were not keyed to species. However, based on results of previous surveys (Leidy, 1997), they were probably either prickly or riffle sculpin. Sculpin are bottom fish with a large flattened heads, fan-like pectoral fins and smooth, scaleless, but occasionally prickly, bodies. These features and the absence of the balancing organ, the swim bladder, enable sculpin to remain on the bottom, even in fast-flowing streams. In addition, these species have a darkly mottled coloration, which blends in with the rocky areas they prefer, concealing themselves from both predators and prey. Generally, this is a hardy family of fishes, which will adapt to a wide variety of coastal conditions (Moyle, 1976).

The prickly sculpin is tolerant of changing salinities and high water temperatures (78-, 82.4°F), prefers substrates of sand, silt and course gravel, and is often found in pools. Sculpin are voracious eaters, feeding mainly on benthic invertebrates, eggs and even small fishes; the food eaten varies with the size of the fish. Prickly sculpins become mature in their second through fourth year, depending upon the population. Spawning can occur from late February through June, although most spawning takes place in March and April; water temperatures usually need to be between 46-55 °G. Prior to spawning, they move into areas, in either a freshwater or intertidal zone, that contain large flat rocks and moderate currents. The male selects the nest site, prepares the nest by digging a small hollow under a large flat rock, and when the female is ready, she moves in, is courted by the male, and attaches the eggs to the ceiling of the hollow. The male then chases the female away and guards the eggs until they hatch. Movements by the male facilitate water circulation over the eggs, assuring normal development. The hatched fry are soon ready to swim, and as a result, are swept downstream, where they are planktonic for about a month. After that, they settle on the bottom and start a general upstream movement into their natal stream. Similar to other sculpin, growth is subject to much individual variation. Prickly sculpin feed mostly upon large benthic invertebrates, small fishes, and fish eggs (Patten, 1971; Moyle, 1976; Kresja, 1965; Kottcamp, 1973).

Riffle sculpin are well-named, as they are most common headwater streams where riffles predominate. In coastal streams, they are found in a variety of habitats, but seem to prefer cool water and gravel bottoms, avoiding the swifter riffle areas. They are opportunistic bottom feeders, with crustaceans the most important food. Age and growth characteristics are similar to those of other sculpins, with most growth during the spring and summer. Maturity occurs at the end of the second year of life and spawning occurs from late February through April. Riffle sculpins either spawn on the underside of rocks in riffles or inside cavities of submerged lots. Males stay in the nest guarding the eggs and fry and eggs hatch in11-24 days, depending upon water temperatures. After absorbing the yolk sac, the fry assume a benthic existence (Bond, 1963; Millikan, 1968; Moyle, 1976).

D. SACRAMENTO SUCKER

Sacramento suckers inhabit a wide variety of waters, from cold, rapidly flowing streams to warm, nearly stagnant pools. Adults tend to be most numerous in large bodies of water and juveniles tend to inhabit tributary streams where adults have spawned. They are usually associated with native minnows, such as the California roach. The food of the Sacramento sucker consists of algae, detritus, and invertebrates associated with the bottom.

Spawning usually occurs in the fourth or fifth year of life, between February and early June, although it may take place in July and August, as well. Suckers spawn over gravel riffles in streams. A sudden cooling spell may halt migration until the water warms up again. At the onset of spawning, females are accompanied by two to five males, the eggs are broadcast over the gravel to which they adhere after sinking into the interstices. Eggs hatch in three to four weeks and the young are soon washed into warm shallows, where they sometimes occur in large schools. Typically, they spend two to three years in the spawning stream before they finally move down to a larger river during fall high water (Moyle, 1976; Brauer, 1971).

CHAPTER 6 METHODOLOGY

A. GENERAL APPROACH

To understand what the Corte Madera Creek Watershed has to offer steelhead trout, one must first collect information on habitat requirements and historical and existing conditions. Most of the habitat in Corte Madera Creek and its tributaries was surveyed and representative habitats were sampled for fishes during the low flow season; water temperature was monitored in the creeks from April through September.

A Quality Assurance Project Plan was required by the EPA, one of the CALFED agencies. It was submitted in December, 1999 (Rich, 1999). The measures used for quality assurance are included in that plan which is in Appendix A, along with the Sample Survey Sheets.

B. WATER TEMPERATURE MONITORING

A total of 32 thermographs ("Tidbits" and "Hobos", Onset Computer, Massachusetts) were installed in representative areas of each stream reach in Corte Madera, San Anselmo, Cascade, Sleepy Hollow, and Ross creeks, beginning in April and extending to the end of September for the sites where water was still flowing; at some of the sites, thermographs were removed earlier because the site dried up (Figure 5; Appendix C, Tables 1-6). Each thermograph was cabled to a concrete landscaping block; each block was cabled to a tree. ***AAR's*** fisheries biologists and volunteers trained by Dr. Alice Rich (Appendix B) maintained the thermographs during their installation. At the time of their initial installation, the location of each thermograph was photographed and the latitude and longitude recorded, using a Garmin GPS 48 Personal Navigator. Prior to installation, each thermograph was calibrated to record water temperature every 10 minutes, 24 hours a day. The number of thermographs installed in each of the creeks were as follows: (1) Corte Madera Creek - 8; (2) San Anselmo Creek - 12; (3) Cascade Creek - 1; (4) Sleepy Hollow Creek - 6; and, (5) Ross Creek - 5 (Figure 5).

To monitor the water and habitat conditions of each site during the time when the thermographs were installed, photographs were taken (one facing upstream and one facing downstream) at each site on a weekly basis. Each thermograph was checked weekly to determine whether or not the thermograph was working (from the blinking light on each thermograph); (1) immersed in water; and, (2) residing in the original habitat in which it was placed. When any of the conditions did not apply, Dr. Rich was contacted and she assessed whether or not to either move or replace the thermograph. Some of the thermographs were removed early, as many of the stream reaches dried up (Tables C-1 through C-6, Appendix C). To preclude the possibility of losing data sheets, two sets of data sheets and two sets of photographs were stored at all times in the following

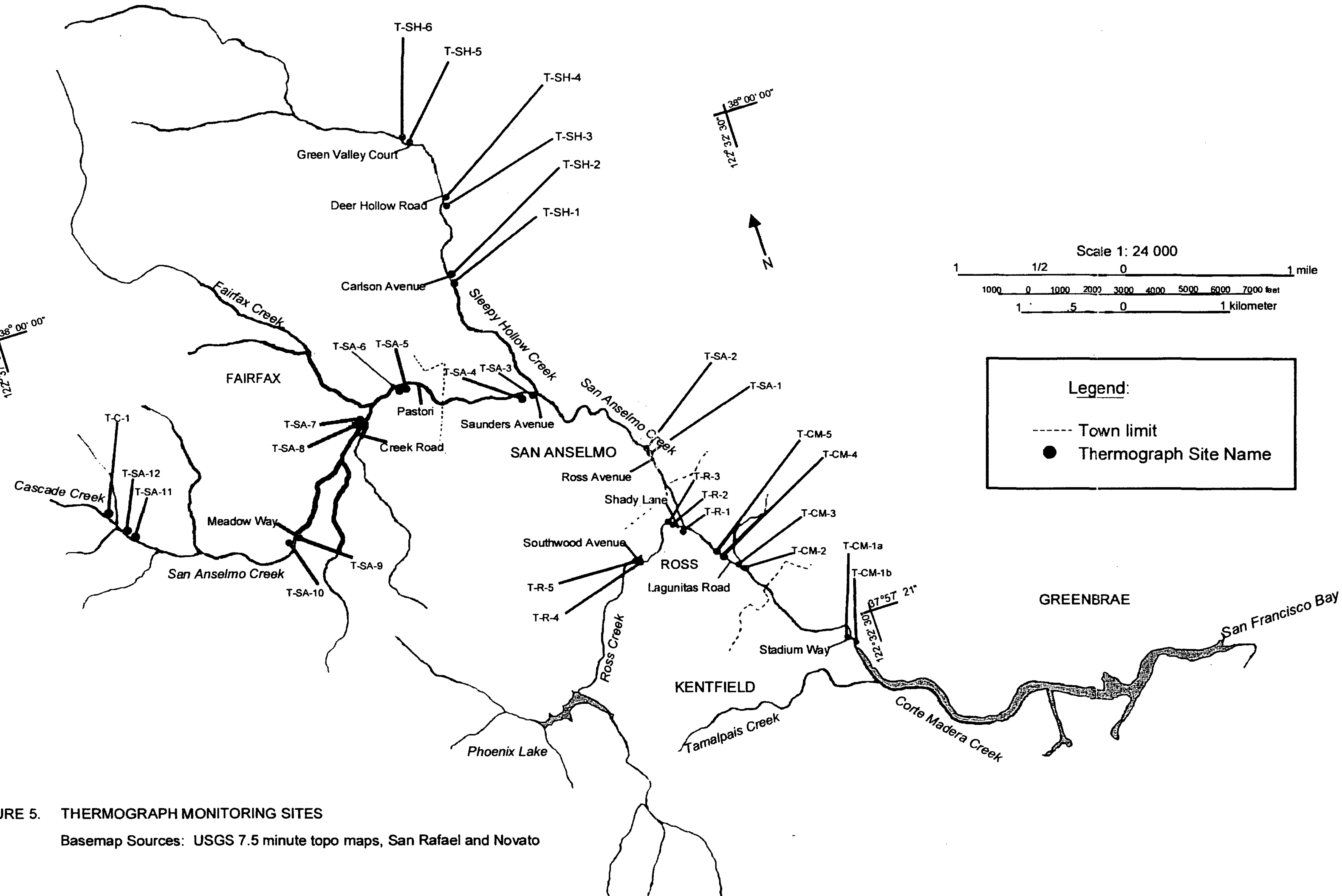


FIGURE 5. THERMOGRAPH MONITORING SITES

Basemap Sources: USGS 7.5 minute topo maps, San Rafael and Novato

locations: (1) One set in *AAR's* office; and, (2) One set at each volunteer's and/or *AAR's* biologist's house.

As the creeks have a lot of summer traffic, primarily school children, there was a good chance that some of the thermographs would be removed. Therefore, to minimize the chance of losing data (i.e., someone removing a thermograph), all thermographs were: (1) monitored weekly; and, (2) removed and replaced with new thermographs and the data downloaded on a monthly basis.

C. EXISTING FISH HABITAT CONDITIONS

To accurately describe the existing fishery resources conditions in the creeks, identification of the components of fish habitat is essential. To describe the stream habitat conditions, **Habitat Typing** (Bisson et al., 1982) and general descriptive measurements were used (Appendix A). Habitat Typing consists of measuring the individual habitat units, or types, within a selected stream. This information is then compared with the habitat needs of the fishes collected from the stream. Dr. Rich modified the habitat typing methodology to include artificial habitats created in urban and some coastal areas, but not specifically identified in the methodology developed by Bisson et al. (1982). For example, stream banks composed of rip rap, gabions, concrete, or wood walls would not be considered natural habitats, whereas a stream bank composed of an undercut bank would be considered a natural habitat according to Bisson et al (1982). However, both natural and artificial pool habitats are often inhabited by fishes. Thus, if one were to encounter a lateral scour pool associated with an undercut bank, one would call it "a lateral scour pool associated with an undercut bank", according to Bisson et al. (1982). By the same reasoning, if one or both banks were composed of rip rap and this rip rap was the physical attribute creating the lateral scour pool, this habitat would be called "a lateral scour pool associated with rip rap." Or, if a lateral scour pool had been created by a concrete wall, the habitat would be called a "lateral scour pool associated with concrete wall."

The habitat within the Corte Madera Creek Watershed was surveyed in August-November,. beginning at the mouth and proceeding upstream to the headwaters of the watershed (Figure 6). Habitat measurements were made where water existed; much of the channel and some of the creeks were dry at the time of the surveys. The following creeks were surveyed, using habitat typing: Corte Madera, San Anselmo, Cascade, and Sleepy Hollow. Due to the lack of financial resources, Ross and Fairfax creeks were surveyed in a more cursory manner; Larkspur and Tamalpais Creek were not surveyed at all. We walked and photographed all of Ross Creek, taking notes on creek conditions at each area where photographs were taken; Fairfax Creek was photographed and notes of the habitat recorded at each bridge crossing in November of 1999.

D. FISH POPULATION ESTIMATES

To assess fish population conditions within the Corte Madera Creek Watershed, electrofishing surveys were conducted from August through October, 1999. Electrofishing is commonly used by fisheries biologists for collecting fish. However, in order to minimize the capture stress on the fishes, this method must be used with caution and only by trained personnel. When used quickly, efficiently, and knowledgeably, this method is less stressful than that of beach seining and/or other collection techniques.

To accurately sample the number and species of fishes in the creeks, it was necessary to electrofish **representative samples** of each habitat type observed in the creek. Ideally, to provide a statistically-sound study, one needs, first, to identify the number of **habitat types,** and then sample (randomly) about 30% of each habitat type. As there were budgetary constraints on this project, such a methodology was not practical. However, at least one representative of each habitat type was chosen for fish sampling for each creek and, except for Ross Creek, from 10-100% of each habitat type was sampled.. Based on the results of the habitat surveys, the total number of sampling sites was as follows: (1) Corte Madera Creek - 11 sites out of 26 habitats recorded (42%); (2) San Anselmo Creek - 41 sites out of 183 habitats recorded (22%), (3) Cascade Creek - 3 sites out of 32 habitats recorded (9%); (4) Sleepy Hollow Creek - 25 sites out of 216 habitats (12%); and, (5) Ross Creek - 2 sites (Ross Creek was not habitat typed) (Figure 6).

The electrofishing proceeded as follows. To prevent the fish from escaping during the sampling procedure, block nets were placed at the lower and upper ends of the sampling site. To sample the site, an electrofisher (Smith-Root Type 12 backpack) was used. The fish sampling crew consisted of one "electrofisher", who operated the electrofishing unit, and one or two netters, depending upon the size of the habitat. Starting at the downstream block net, the electrofisher waded upstream through the sampling station, operating the electrofisher. Stunned fish were netted and placed in water-filled buckets. In order to estimate fish population sizes by the maximum-likelihood method (Van Deventer and Platts, 1983, 1986), three or more passes were completed at each station (see Appendix A for sample electrofishing survey sheet).

After each pass, fish were identified to species and enumerated. For each fish, the following items were recorded: species name; fork length; and, weight. After the electrofishing was completed, the fishes were returned to the sampling station from which they were collected. After the electrofishing was completed at each station, the physical dimensions of the habitat (e.g., length, depth, width) were recorded. The dimensions were used to calculate the number of fish (by species) per square meter of stream. The fish were weighed, using an Ohaus scale accurate to 0.1 gram. The scale was calibrated before each field session, using standard weights certifiable to the National Institute of Standards and Testing.

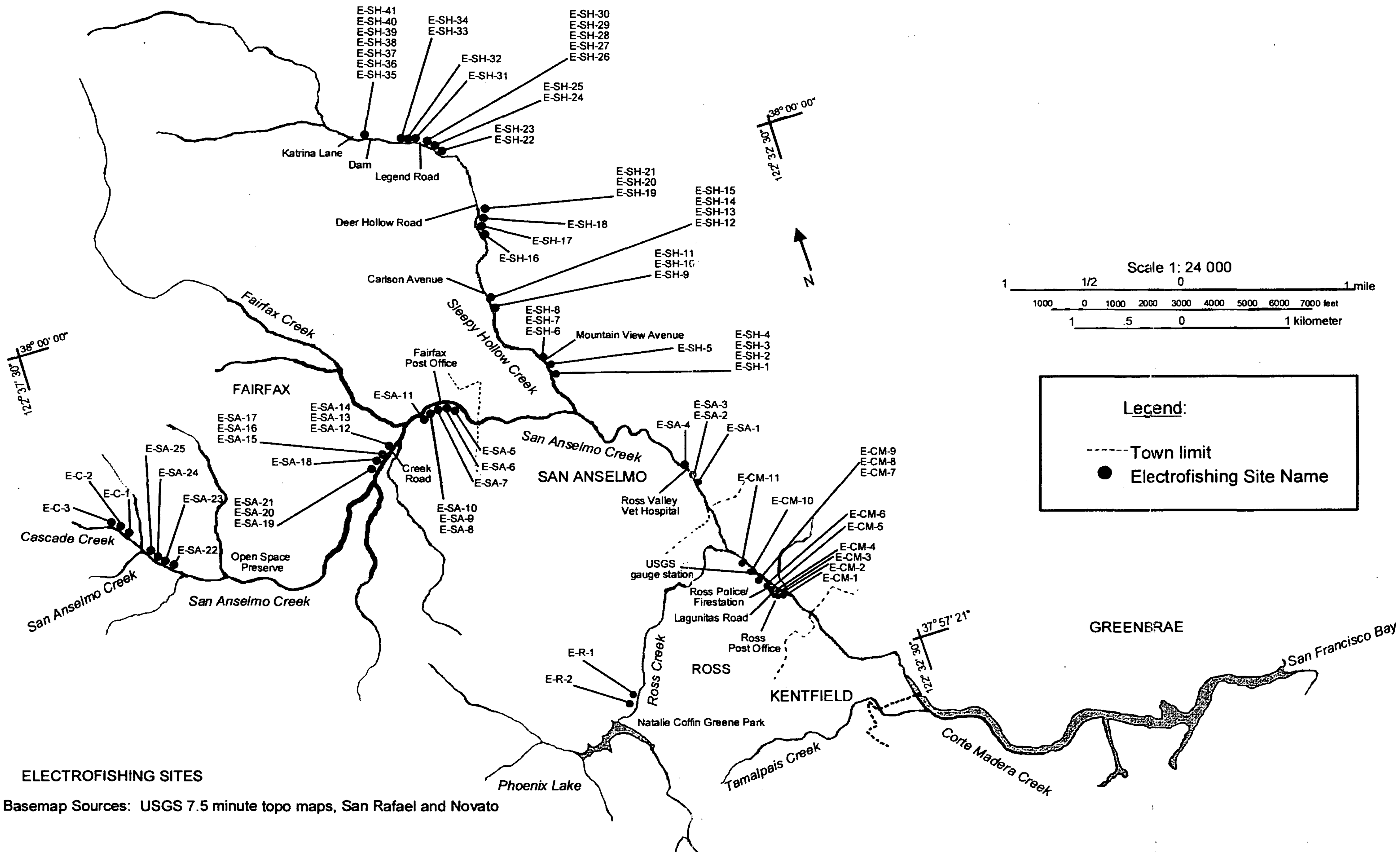


FIGURE 6. ELECTROFISHING SITES

Basemap Sources: USGS 7.5 minute topo maps, San Rafael and Novato

To reduce the stress of capture on the fishes, particularly the sensitive trout, the fish were placed in a buffered (sodium bicarbonate to pH 7.0, 75 parts per million) anaesthetic (methane trisulphonate, 50 parts per million); previous studies (Rich, 1979, 1983) demonstrated that salmonids exhibited little stress response when such a mixture was used. In addition, a battery-operated pump aerated the water in the bucket in which the fish were residing, prior to release back into the creek. We also used a special measuring board, designed by Dr. Rich over 10 years ago, which minimizes stress on fish by allowing the fish to remain in the water during length measurements. Finally, rocks were placed in buckets which had fish residing in them; this reduces the stress on fish, as well (Rich, 1979).

E. DATA ENTRY AND ANALYSIS

The data were entered into DBASE (Windows 98) , a computer data management program. Population (maximum-likelihood method) size, lengths, weights and total biomass (i.e., total weight of the fish) estimates, together with standard deviations, were calculated on the computer, using Microfish (Van Deventer and Platts, 1983). Statistical analyses (analysis of variance) were conducted, using the computer statistical program, SPSS.

CHAPTER 7 FISHERY RESOURCES HABITAT CONDITIONS

A. HISTORICAL CONDITIONS

There are few written records of "how things used to be" before the Europeans arrived, with regard to the fishery resources. However, there is no question that trout were ample enough for the Coastal Miwok Indians to rely upon for food. Malcolm Margolin (1978) quoted the nineteenth century ethnologist, Stephen Powers, when describing the California Indians as "almost amphibious. They were always splashing in water." California had so much water in those early days; freshwater swamps; San Francisco Bay rimmed with vast saltwater marshes, rivers throughout the year, springs out of the hillsides, natural lakes and enumerable creeks. The clear creeks provided the native Indians with abundant fish and freshwater.

Although previous quantitative population studies are not available, comparison of historical and anecdotal information with more recent information strongly suggests that, as the years have passed, there have been fewer and fewer salmonids in the Corte Madera Creek Watershed. Given the urbanized nature of the watershed, it is likely that the rainbow/steelhead trout is the only salmonid species persisting to the present time. Stressors include high water temperatures, hydrograph changes, water quality degradation, streambed changes, loss of riparian habitat, land use and human impacts. However, in spite of these problems, the Corte Madera Creek Watershed has been identified by EPA (Leidy 1984) as one of the watersheds that should be targeted for protection.

Stream surveys on Corte Madera, San Anselmo, Cascade, Sleepy Hollow, Fairfax, and Tamalpais creeks demonstrated a wide assortment of fish species, reflecting both the estuary and freshwater environments (Table 1) (Allen, 1960a, b; Michaels and Thomson, 1968; Scoppettone 1976; Eimoto and Walkup 1980; Leidy, 1997, 1993, 1984; Jones, 1971). However, the five dominant species present in Corte Madera Creek and its tributaries included only sucker, roach, stickleback, sculpin, and rainbow/steelhead trout. In recent years, the most frequently observed species was limited to California roach, Sacramento sucker, threespine stickleback, sculpin, and rainbow steelhead.

B. SUMMARY OF WATER TEMPERATURE CONDITIONS

The results of the water temperature monitoring discussed below identify potential thermal stress, not actual thermal stress. Due to the fact that water temperature is such an important factor for cold-blooded animals, such as salmonids, it is best to err on the side of caution and assume that if water temperatures exceed the thermal optima (based on results from the scientific literature) for a given life stage that there is thermal stress. Without site-specific food-fish growth studies, we have no way of knowing whether or not the higher water temperatures which occurred in portions of the creeks actually resulted in enough thermal stress that steelhead and rainbow trout productivity in the watershed was affected. As water temperatures increase, the trout requires more food to sustain itself. If there is more than enough food available to sustain a trout, and if the fish isn't eaten by a predator, it has a good chance of growing and emigrating out of the system. If, as this watershed project proceeds, future studies demonstrate that the salmonids are more tolerant of water temperature conditions than reported in the scientific literature, the thermal optima for the steeelhead and rainbow trout can be modified as warranted. Tables 5 and 6 summarize the potential impacts on steelhead and rainbow trout, respectively, in the Corte Madera Creek Watershed.

Generally speaking the salmonids appeared in good condition, with the exception of the larger (12-14 inches in length) ones collected in pools in Sleepy Hollow Creek. These larger fish appeared emaciated, suggesting that they were not able to obtain enough food. As the fish were collected in stranded pools, there was no flowing water to provide either drifting insects or larger prey, such as other fishes. And, as the pools appeared to have been isolated from the rest of the creek, these larger fish were probably just waiting for the winter rains to move on to better "fish pastures".

One of the really exciting (albeit, probably only to a fish physiologist!) outcomes of installing so many thermographs in a relatively small system is that it provided the opportunity to observe the varying thermal conditions, depending upon the habitat type and area. For example, the USACE concrete channel provides no refuge areas and no cover; it is generally a stressful environment for salmonids, beginning about April and extending throughout the summer. However, as one proceeds up through the drainage, despite the lack of water in many of the reaches during the summer months, the results demonstrated varying thermal regimes, depending upon the habitat type and area. For example, in San Anselmo Creek, there was a range of times when water temperatures were potentially thermally stressful. Hence, as the timing of immigration, egg incubation, fry emergence, and smolt emigration vary from year to year, the trout may have the opportunity to adapt to some degree. In other words, the areas where water temperatures are suitable appeared to be the areas where the greatest number of salmonids were collected. In summary, despite potentially thermally stressful conditions in many areas of the watershed, there appeared to be "thermal refuge" (thermal refugia) areas where, if accessible, the trout could reside during the hotter summer months. With regard to smoltification, water temperatures begin to become thermally stressful, beginning in May. This would not be a problem, if most of the emigrating steelhead exit the watershed prior

TABLE-5. POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE STEELHEAD TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Adult Immigration (Jan through March)	Spawning (Jan through first week in April)	Egg/Alevin Incubation (Jan through May)	Fry Emergence (mid-Jan through mid-May)	Juvenile Rearing (All year)	Smoltification/ Emigration (March through June)
Corte Madera	Stressful beginning in April	Stressful beginning in April	Stressful beginning in May	Stressful beginning in May	Stressful: [1] May through Sept	Stressful beginning in May
San Anselmo	*	*	Stressful beginning in May	Stressful beginning in May	Stressful: [2] May thru June June thru Aug June thru Sept Aug thru Sept Sept	Stressful beginning in May [3]
Cascade	*	*	*	*	Stressful: July through August	*

TABLE-5 (CONT.). POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE STEELHEAD TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Adult Immigration (Jan through March)	Spawning (Jan thtrough first week in April)	Egg/Alevin Incubation (Jan through May)	Fry Emergence (mid-Jan through mid-May)	Juvenile Rearing (All year)	Smoltification/ Emigration (March through June)
Sleepy Hollow	*	*	Stressful beginning in May	Stressful beginning in May	Stressful: Satisfactory from Carlson upstream with a few peaks in July	Stressful beginning in May or June, depending upon habitat type
Ross	*	*	Stressful beginning in May	Stressful beginning in May	habitats where thermographs were installed dried up in June	Stressful: May thru June habitats where thermographs were installed dried up in late June

[1] Potential thermally stressful areas dependant upon habitat type and location (see Appendix G, Table G-1)

[2] Lower reaches generally warmer than upper reaches and Cascade Canyon area was not potentially stressful until August and September. In addition, potentially thermally stressful areas dependant upon habitat types.

[3] Except for Cascade Canyon Area where it is not known, as the thermographs were not installed until after June

* Unknown, as we did not begin to monitor water temperatures prior to mid-April

TABLE-6. POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE RAINBOW TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Spawning (Feb through May)	Egg/Alevin Incubation (Feb through June)	Fry Emergence (Feb through June)	Juvenile Rearing (All year)	Adult (All year)
Corte Madera	Except for the USACE Channel (beginning in May, stressful temperatures), water temperatures were Satisfactory	Except for the USACE Channel (beginning in May, stressful temperatures), water temperatures were Satisfactory	Except for the USACE Channel (beginning in May, stressful temperatures), water temperatures were Satisfactory	Stressful: [1] June through Sept	Stressful: [1] June through Sept
San Anselmo	Satisfactory	Satisfactory	Satisfactory	Stressful: [1] July through Sept	Stressful: [1] July through Sept
Cascade	*	*	*	Stressful: July through Aug	*

TABLE-6 (CONT.). POTENTIAL IMPACTS OF WATER TEMPERATURE CONDITIONS ON THE RAINBOW TROUT IN THE CORTE MADERA CREEK WATERSHED

Creek	Spawning (Feb thru May)	Egg/Alevin Incubation (Feb through June)	Fry Emergence (Feb through June)	Juvenile Rearing (All year)	Adult (All year)
Sleepy Hollow	Satisfactory	Satisfactory	Satisfactory	Generally [2] Satisfactory	Generally [2] Satisfactory
Ross	Satisfactory	Satisfactory	Satisfactory	dried up in June	dried up in June

[1] Potential thermally stressful areas dependent upon habitat type and location (See Appendix G, Table G-2)

[2] Several thermal peaks in mid-June and mid-July in Sleepy Hollow Creek along Butterfield Road. Also, no thermographs were placed downstream of Carlson Avenue, as much of the creek dried up

* Unknown, as we did not begin to monitor water temperatures prior to mid-April

to May. Smolt trapping studies would allow us to determine when the smolt emigration was occurring.

1. *Corte Madera Creek*

In the USACE channel, beginning in late May and extending through September[1], water temperatures were high (65-75 °F). These water temperatures were probably stressful to any steelhead in the area during spring and summer months and may have been lethal during the smoltification/emigration and rearing life stages of steelhead. Based on the 1999 data, if any adults were migrating through the channel after mid-April, stressful thermal conditions may have impacted steelhead. Similarly if the parr smolt transformation was not complete by the end of April, there may have been thermal stress, beginning in May. For rearing steelhead, summer water temperatures were potentially stressful, beginning in June and extending through September (Appendix C, Tables C-1, C-5, C-6 Figures C-1 through C-5).

Upstream of the USACE channel, the months for steelhead immigration through fry emergence were probably thermally stressful by mid-April. Water temperatures during fry and juvenile rearing were probably non-stressful until June. Water temperatures were stressful by mid-April for any steelhead remaining in the creek during the the parr-smolt tranformation. For rainbow trout in Corte Madera Creek upstream of the channel, water temperatures were probably not stressful most of the time. However, there were a some days during the hot summer months (July and August) when the maximum daily temperatures could have been stressful in some of the stream reaches, if the fish could not find thermally cool refuge areas (Appendix C, Tables C-1, Figures C-6 through C-33).

[1] And probably into October, as well, although thermographs were removed from Corte Madera Creek on October 1, 1999

2. *San Anselmo Creek*

For steelhead trout, thermal conditions in San Anselmo Creek: (1) were stressful to incubation and fry emergence, beginning in May; (2) depending upon the habitat type and location, there was a number of times when juvenile rearing conditions were stressful; and, (3) with regard to smolt emigration, thermally stressful conditions began in May. For rainbow trout, thermal conditions were generally acceptable, provided the fish could find thermal refuge areas during the hot summer months (Appendix C, Table C-2, Figures C-34 through C-87).

3. *Cascade Creek*

Although, thermal conditions in Cascade Creek were potentially stressful during the hottest part of the summer (July and August), this was the area where we collected the greatest number of age classes of trout. This suggests that there is a self-sustaining resident trout population inhabiting the area. Portions of this area are heavily vegetated and relatively non-impacted by humans; there appear to be food resources to sustain the trout at higher temperatures (Appendix C, Table C-4, Figures C-88 through C-89).

4. *Sleepy Hollow Creek*

Thermal conditions in Sleepy Hollow Creek were generally satisfactory for all life stages of both steelhead and rainbow trout, with the exception of the lowest reaches near Sir Francis Drake High School. There were many areas which had dried up throughout this drainage. Yet, we collected the largest trout in this creek And, in areas where there was sufficient pool habitat, trout were collected, albeit in small numbers (Appendix C, Table C-3, Figures C-90 through C-118).

5. *Ross Creek*

Although most of Ross Creek downstream of Phoenix Lake dried up by June, water temperatures were satisfactory for spawning, egg/alevin incubation, and fry emergence. As we did not have thermographs in the upper reaches of the creeks, assuming that it too would become dry, summer water temperatures are not known. However, although we only sampled two sites in Ross Creek, due to the fact that most of the creek was dry by late spring, it appeared that what little pool habitat there was in the uppermost reaches was used extensively by the trout. It would be of value to monitor water temperatures in the upper sections of Ross Creek. (Appendix C, Table C-4, Figures C-119 through C-143).

C. SUMMARY OF HABITAT CONDITIONS

In order for trout to thrive, there must be appropriate habitat conditions, including the following: accessibility to spawning sites; adequate streamflows; acceptable water temperatures and water quality; appropriate substrate composition; and, abundant food. A summary of the general habitat conditions in the Corte Madera Creek Watershed are discussed next, followed by a more detailed discussion of habitat conditions in the subsequent pages. Data from habitat typing surveys are provided in Appendix D. Photographs of representative areas throughout each of the creeks are provided in Appendix F.

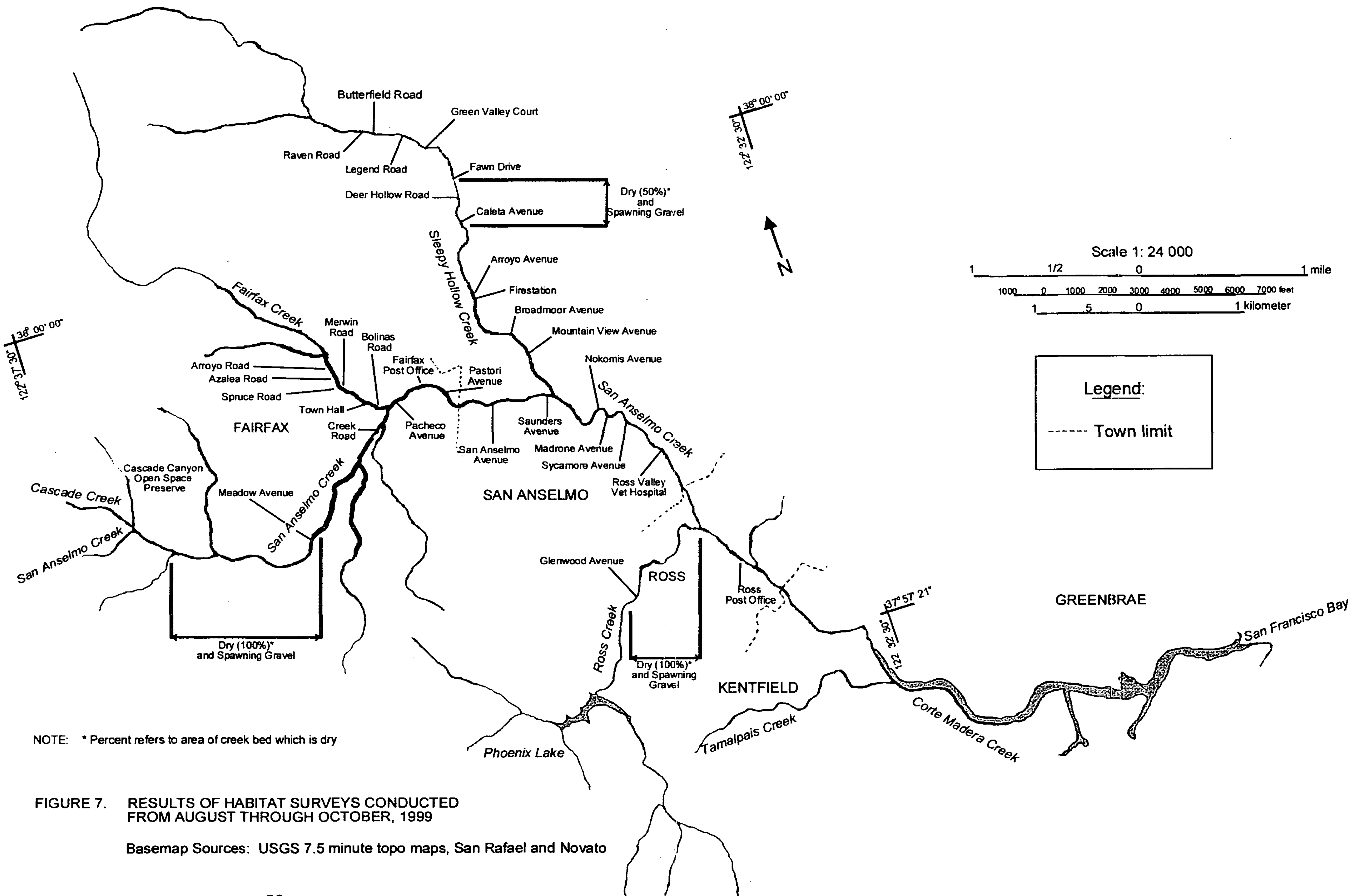
The Corte Madera Creek Watershed can be divided into the following three very broad sections: (1) The lowest reach consists of wetland habitat, which supports estuarine fish species, waterfowl and shorebirds; (2) The middle reach consists mostly of urban creek habitat with homes and roadways lining the creek channels; and, (3) The upper reaches of the watershed encompass large open space areas and light housing development.

1. *Corte Madera Creek*

Corte Madera Creek is highly channelized, as a result of various activities (i.e., USACE concrete flood control channel and landowners' retaining walls) undertaken to control flooding during the winter months. The USACE flood control channel serves only as a migration route for the anadromous steelhead trout and even as a migration route, it is of low quality. The upstream areas of Corte Madera Creek consist of long lateral scour pools alternating with riffle areas, habitat used by a variety of fish species, although none in great abundance (Figure 7).

2. *San Anselmo Creek*

San Anselmo Creek had the greatest variety of habitats of any of the creeks within the Corte Madera Creek Watershed, probably because it flows through towns, but its origin lies in the relatively unimpacted reaches within the Cascade Canyon Open Space Preserve (Figure 7). Throughout its length, it was characterized by alternating lateral scour pool/riffle sequences. In the lower more urban reaches, the lateral scour pools are associated with retaining walls and rip rap, whereas in the upper more natural areas, they are associated with bedrock. The creek along Cascade Road in Fairfax was dry for more than a mile, but substrate consisted almost entirely of gravel suitable for trout. Hence, during the winter months, it would be a good spawning area for steelhead.



NOTE: * Percent refers to area of creek bed which is dry

FIGURE 7. RESULTS OF HABITAT SURVEYS CONDUCTED FROM AUGUST THROUGH OCTOBER, 1999

Basemap Sources: USGS 7.5 minute topo maps, San Rafael and Novato

3. *Cascade Creek*

Cascade Creek flows into San Anselmo Creek in the Cascade Canyon Open Space Preserve. Although short on water by the end of summer, Cascade Creek offered the best trout habitat of the entire creek system. It was characterized by bedrock pool and cascades, abundant canopy, and clean water. Although there was no spawning gravel, the pools provided rearing habitat for trout. The uppermost boundary for fish migration is the Cascade Falls.

4. *Sleepy Hollow Creek*

Sleepy Hollow Creek flows from its headwaters above Sleepy Hollow in San Anselmo down along Butterfield Road and into Corte Madera Creek downstream of Sir Francis Drake High School (Figure 7). It was characterized by low flows, and a heavily urbanized (i.e., retaining walls, bridge pillars, concrete in the creek) channel. In the lowermost reaches, the habitat during the late summer months was suitable for stickleback and roach; higher up in the drainage, there were some appropriate pools for trout and, although dry throughout much of the upper sections, the substrate was gravel suitable for trout spawning.

5. *Ross Creek*

Ross Creek flows out of Phoenix Lake and into Corte Madera Creek in Ross (Figure 7). At the time of the habitat surveys, most of the creek was dry. The only area where there was flowing water and a number of pools suitable for trout was within the Natalie Coffin Greene Park area.

6. *Fairfax Creek*

Fairfax Creek flows down the slopes above and through the town of Fairfax its confluence with San Anselmo Creek (Figure 7). From my cursory observations (photos taken at bridge crossings), the physical appearance of Fairfax Creek suggested that this creek was similar to that of Sleepy Hollow in the dry months of a wet or normal year. From the results of our "spot check" observations, it appeared that Fairfax Creek had little water in it by the end of the dry season, there were lateral scour pools and shallow riffles throughout the Creek, substrate consisted of gravel, sand and silt, and there was abundant vegetative cover. A survey conducted by Leidy (1997) characterized the stream as follows: (1) channel incising; (2) bank vegetation trampled with bank erosion; (3) some good spawning gravel, but extensive sand and fines; and, (4) no salmonids sighted.

D. EXISTING FISHERY RESOURCES HABITAT CONDITIONS

In the following paragraphs, stream reaches are summarized; a detailed listing of habitat types and characteristics for Corte Madera, San Anselmo, Cascade, and Sleepy Hollow creeks is provided in Appendix D (Tables D-1 to D-4). The abbreviations in parentheses, such as SA-16, depict the habitat type number reported in Appendix D; in this example, "SA-16" would represent the sixteenth habitat as we proceeded upstream, from the beginning of San Anselmo Creek.

1. *Corte Madera Creek*

Corte Madera Creek is formed by the confluence of Ross Creek and San Anselmo Creek. Beginning at the downstream end, Corte Madera Creek extends from the USACE concrete channel in Kentfield upstream to the confluence with Ross Creek in Ross (Figure 7). Proceeding upstream, summer habitat conditions can be divided into the following four general stream reaches: (1) Lowermost USACE concrete flood control channel; (2) Fish ladder; (3) Long, shallow, alternating pool/riffle sequences from the fish ladder upstream to just beyond the Lagunitas Road bridge; and, (4) Longer and deeper pool/riffle sequences with more structure (e.g., large woody debris, rootwad) than the downstream areas (Appendix D, Table D-1).

The USACE concrete flood control channel is under tidal influence and serves as a migration corridor (both upstream and downstream) for steelhead trout and, at times, depending upon the tides and season, contains other fish species, as well. Due to the absence of any structure or cover for protection, and the poor quality of the old fish ladder, the channel also provides an excellent opportunity for birds to prey upon juvenile emigrating steelhead. In summary, the USACE flood control channel was created for flood control, not for fishes, particularly not for salmonids.

From the fish ladder joining the USACE flood control channel upstream to about 25 m upstream of the Lagunitas Road, the habitat was characterized by long (25-30 m), shallow (0.04 - 0.4 m average depth) alternating lateral scour pool/riffle sequences; riffles were very narrow (1-2 m wide) and shallow. Although there was abundant shade, the low streamflows, rip rap and wooden retaining walls resulted in fairly stagnant pool areas. Riffle areas were extremely shallow. Substrate in the pool areas consisted of sand, silt and organic detritus; in the riffles, small gravel was the predominant substrate.

From just beyond Lagunitas Road and extending upstream to the confluence with Ross Creek, the pool habitat was characterized by longer (10-140 m) and had deeper (0.25 - 0.50 m average depth) lateral scour pool/riffle sequences, with more structure (e.g., large woody debris, rootwad) than in the downstream areas. Abundant shade, some structure, wider riffle areas (5-7 m average width), with much of the substrate composed of small gravel offered better salmonid habitat than in the downstream reaches of Corte Madera Creek. However, the reach was deeply incised throughout with concrete retaining walls along much of the area. Substrate in pool areas was primarily sand and silt. Just downstream of the confluence with Ross Creek, there was a large woody debris jam (about 30 m length) which was difficult to walk through; pool depth in that area was over a meter in many areas and the water was stagnant; the woody debris needs to be modified, although not removed, so that the stream can flow through it.

2. *San Anselmo Creek*

San Anselmo Creek extends from the confluence with Ross Creek upstream through Ross, San Anselmo, and Fairfax, and well into the Cascade Canyon Open Space Preserve (Figure 7). San Anselmo Creek had the greatest variety of habitat types of any of the creeks within the Corte Madera Creek Watershed, probably due to the fact that it flows through the towns, but its origin lies in the relatively unimpacted reaches within the Open Space Preserve. Proceeding upstream, summer habitat conditions are described by general stream sections, as follows (Appendix D, Table D-2).

Confluence with Ross Creek Upstream to Sir Francis Drake Boulevard Bridge at San Anselmo Town Limit (just downstream of Bolinas Road) (SA-1 to SA-7)

The lowermost reach of San Anselmo Creek was characterized by long alternating lateral scour pool/riffle sequences, again with a lot of man-made retaining walls and concrete in the creek. Except for the large pool underneath Sir Francis Drake bridge near the town limit of San Anselmo, pools were generally shallow (0.1 - 0.2 m average depth) and ranged from 20-70 m long; riffles ranged from 4-6 m in width, with substrate composed of gravel; several potential spawning areas were seen in this area. Although there was abundant shade, sand and silt substrate and low streamflows limited summer trout habitat. A hose, which appeared to be a diversion hose (although not pumping water at the time of the survey) was located on the left (facing upstream) side of the creek under the Sir Francis Drake bridge.

Sir Francis Drake Bridge at San Anselmo Town Limit (near Bolinas Road) Upstream to Sir Francis Drake Boulevard Bridge at Ross Valley Veterinary Hospital (near Bank Street) (SA-8 to SA-17)

This reach of San Anselmo Creek was characterized by long alternating lateral scour pool/riffle sequences, again with a lot of man-made structures, including a rock dam at SA-12, concrete retaining walls, what appeared to be an old asphalt/concrete boat ramp (right bank as one faced upstream), and concrete in the creek. Pools (lateral scour associated with concrete walls, primarily) were generally shallow (0.2 - 0.5 m average depth) and ranged from 15-90 m long, with gravel substrate, but covered with organic detritus; riffles ranged from 3-6 m average width, with substrate composed of gravel and cobble; one potential spawning area was seen. Again, hoses in the creek were spotted (SA-12 and SA-16), one with a pump at the Sunnyside Nursery. Although there was abundant shade and clean gravel, low streamflows limited summer trout habitat.

Sir Francis Drake Bridge Upstream through Downtown San Anselmo to Sycamore Avenue Bridge (SA-18 to SA-22)

Except for a similar reach through downtown Fairfax, the reach of San Anselmo Creek flowing through downtown San Anselmo consists of very poor trout habitat, but is very suitable for roach (we collected more roach in one of the pools in this section than anywhere else in the entire watershed). This reach was characterized by long, deep (some more than 1 m deep) stagnant lateral scour pools created by concrete retaining walls and huge pieces of concrete strewn throughout the creek bottom. Even in the section adjacent to Creek Park, the faster moving riffle area was full of concrete pieces. The fish species observed throughout the area was the hardy California roach, which thrive in this type of urban environment. Cover was provided by bridges and buildings.

Sycamore Avenue Bridge Upstream to Madrone Avenue Bridge (SA-23 to SA-36)

Compared to the previous section, creek habitat improved a bit in this reach, with lateral scour pools associated with logs and root wads interspersed with those associated with rip rap and concrete walls. Pools ranged from 8-37 m in length, 1-6 m average width, and 0.1-0.4 m average depth. Abundant canopy/overhanging was present, substrate consisted of gravel, primarily, with several potential trout spawning areas in riffle areas. Some concrete blocks were strewn about, although few by comparison to those in the creek in downtown San Anselmo. A log (about 30 cm diameter) in SA-26, although not an anadromous fish passage barrier, created a stagnant pool behind it. A large (about 2/3 m long and 30 cm diameter) iron pipe lay in the substrate at SA-28. A hose, with pump attached, was sighted in SA-30. Just downstream (SA-37) of the Madrone Avenue Bridge, there was an eroding bank on the left side (facing upstream) of the creek, which appeared to be contributing silt to the creek.

Madrone Avenue Bridge Upstream to Nokomis Avenue Bridge (SA-37 to SA-48)

Proceeding upstream from Madrone Avenue to Nokomis Avenue, the pool/riffle sequence continued, with pools (20-35 m length; 3-5 m average width; 0.1-0.4 average depth) mostly associated with rip rap walls. Substrate consisted primarily of sand in the pools and gravel in the riffles (4-12 m length; 1-5 m average width; 0.05-0.1 average depth) and abundant canopy/ overhanging cover was present. California roaches were seen throughout this reach. At SA-64, there was a tributary (dry) on the right (facing upstream). This tributary, Sorich Creek, runs underneath Sir Francis Drake Blvd from under the Red Hill Shopping Area.

Nokomis Avenue Bridge Upstream to Saunders Avenue Bridge (SA-49 to SA-76)

From Nokomis Avenue upstream to Saunders Avenue, the habitat was characterized by the continuation of the pool/riffle sequences. There were a combination of pool types (10-95 m length; 2.5-8.5 m average width; 0.2-0.6 m average depth), but most associated with concrete walls, rip rap, with a few root wads and cut banks. At the most upstream end there was a cascade consisting of three bedrock pools (15 m long), some concrete in the channel, and a denil fish ladder underneath the Saunders Avenue bridge. Substrate consisted primarily of gravel in both the pools and riffles (6-20 m length; 1-7 m average width; 0.03-0.08 m average depth) and abundant canopy/overhanging cover was present. A good portion of this habitat had long concrete or wood retaining walls for flood control, thereby channelizing the creek and creating good roach habitat and poor trout habitat.

Saunders Avenue Bridge Upstream to San Anselmo Avenue Lansdale Station) (SA-77 to SA-102a)

Upstream of the denil fish ladder, the creek flows adjacent to Sir Francis Drake High School. The habitat continued with pool/riffle sequences. The pools (10-50 m length; 2-8 m average width; 0.1-0.5 m average depth) were associated primarily with concrete walls and rip rap, although there were also a few pools associated with bank cuts. Substrate consisted primarily of gravel and sand in the pools and gravel in the riffles (3-18 m length; 0.5-5.3 m average width; 0.03-0.07 m average depth). There were several long (e.g., 105 m) concrete and wood retaining walls (at both the downstream and upstream ends of the reach) for flood control, thereby channelizing the creek and creating good roach habitat and poor trout habitat in those areas. There was also abundance of huge concrete slabs and a radiator discarded in the creek bed near Lansdale Station. A very long curved concrete culvert ran underneath the road at Lansdale Station.

San Anselmo Avenue (Lansdale Station) Upstream to Dam at Pastori Avenue, Fairfax (SA-102b to SA-122)

This portion of the creek, upstream of Lansdale Station was fairly shallow (lateral scour pools mostly from 0.1-0.3 m depth), but the gradient increased and there were a series of cascades near the upstream end of the reach (before the old denil fish ladder under Pastori Avenue). This provided some added current down through the reach. The habitat continued with pool/riffle sequences. The pools (14-80 m length; 3.5-8 m average width) were associated primarily with concrete walls, root wads, and cut banks. Substrate consisted primarily of gravel and sand in the pools and gravel in the riffles (4-13 m length; 1.8-5.3 m average width; 0.04-0.05 m average depth) and abundant canopy/ overhanging cover was present. There were fewer retaining walls than in the previous reach which gave the creek the feel a more natural feel. There were some large concrete blocks in the creek and a collapsed left bank at SA 110, where an old wood retaining wall was falling into the creek.

Pastori Avenue Upstream to Behind Fairfax Post Office (SA-123 to SA-128)

The habitat in this reach was of very poor quality, similar to that in downtown San Anselmo. Much of this reach ran under an overhang of the Fair-Anselm Plaza. It was characterized by lateral scour pools created by concrete pilings and a collapsing wooden wall behind the Fair Anselm Plaza. The pools were stagnant and only stickleback were seen swimming about.

Behind Fairfax Post Office Upstream to Dam at Pacheco Road (SA-129 to SA-144)

From the Fairfax Post Office upstream to a concrete dam at Pacheco Road, the habitat was characterized by the continuation of the lateral scour pool/riffle sequences. There was a combination (rootwad, cut bank, backwater, rip rap, concrete wall) of lateral scour and dam pool types (8-47 m length; 1.4-8.8 m average width; 0.7-0.4 m average depth). Substrate consisted primarily of sand and gravel in the pools and gravel in the riffles (8-22 m length; 1-5 m average width; 0.02-0.05 m average depth) and abundant canopy/overhanging cover was present. Behind 40 Inyo Avenue the left bank (as one faced upstream) in a curve in the creek was bare and appeared to be eroding into the creek. At the upstream end of the reach, at Pacheco Road, there was a large (about 3 m high, 9 m wide, and over 0.5 m deep) concrete dam, with a cut in the middle at its base, which allowed the creek to flow down through it.

Pacheco Road Upstream to Creek Road (SA-145 to SA-169)

From Pacheco Road bridge upstream to Creek Road, the habitat was characterized by the continuation of the lateral scour pool/riffle sequences. There was a combination (bedrock, rootwad, cut bank and a few concrete walla) of lateral scour pool types (6-39 m length; 2.2-13 m average width; 0.1-0.5 m average depth). A more natural habitat (i.e., bedrock, rootwad) was characteristic of the lower half of this reach; the upper reach was characterized by a number of lateral scour pools associated with large concrete and wood retaining walls. Substrate consisted primarily of gravel in both the pools and riffles (3-41 m length; 1- 4.5 m average width; 0.02-0.05 m average depth) and abundant canopy/overhanging cover was present.

Creek Road Upstream to Upstream of Bolinas Road Bridge (SA-170 to SA-196)

From the Creek Road bridge upstream to SA-196 (upstream of the Bolinas Road bridge), the habitat was characterized mostly by lateral scour pools, with a few riffles in the downstream portion of the reach. In addition, this was the first reach in San Anselmo Creek where significant (i.e., over 100 m length) dry areas (i.e., creating stranded pools) appeared during the course of the surveys. The downstream half of the reach was heavily channelized, by numerous wooden and concrete retaining walls constructed for flood control purposes. In addition, there were a number of man-made concrete dams (slabs of concreate as substrate) which created pools over 0.5 m deep. There were a few good-sized root wad and lateral scour pools associated with cut banks throughout the reach. Lateral scour pools ranged from 3 to 43 m length, 1-6 m average width, and 0.04-0.5 m average depth. Substrate consisted primarily of sand and silt in the pools and gravel in the riffles (1.5-16 m length; 1-1.5 m average width; 0.04-0.05 m average depth) and abundant canopy/ overhanging cover was present. The upstream end of the reach ended in a bedrock pool. Just downstream of the bedrock pool was a large (9 m length, 6 m average width, more than 1 m deep) lateral scour pool with rootwads and woody debris; it formed at the confluence with an unnamed tributary.

Dry Reach for about 1700 Meters (about 1 mile), Upstream into Cascade Canyon Open Space Preserve (SA-197 to SA-199)

San Anselmo Creek was dry for over a mile of creek bed, beginning at SA-197 and extending to SA-199. The downstream end of this reach began at a bedrock pool just upstream of the junction of an unnamed tributary. Upstream of this point, there was no water until well into the Cascade Canyon Open Space Preserve. Although the creek bed was dry, the substrate for almost the entire reach was composed of spawning gravel. About 150 m upstream of the beginning of the reach there was a 1.1 m high and 5.8 m wide concrete dam. With low flows, it might be a passage barrier for anadromous salmonids during the winter months. However, with typical high winter flows, the height of the dam would not be sufficient to prevent steelhead trout from passing during the spawning season.

Cascade Canyon Open Space Preserve Upstream to Cascade Creek (SA-200 to SA-214)

Although short on water by the end of summer, there is no question that San Anselmo Creek within the Cascade Canyon Open Space offered the best trout habitat of the entire creek. The reach was characterized by alternating lateral scour pools associated with bedrock, followed by riffles and, in some, cases, cascades and pocket water areas. Pools ranged from 3-14 m length, averaged from 1.5-4.5 m width, and averaged 0.1-.75 m depth. Although there really was no spawning gravel within the area of the creek which was flowing, downstream of this area there was spawning gravel. There was abundant cover in the form of canopy, overhanging vegetation, and bedrock areas.

3. *Cascade Creek*

Although higher in gradient, Cascade Creek offered some of the same good quality habitat as San Anselmo Creek within the Cascade Canyon Open Space Preserve. The reach was characterized by alternating cascades with bedrock pools, followed by high gradient riffles and, in the lower portion a few lateral scour pools and pocket water areas. The cascades ranged from 3-26 m length, with pools averaging 1-3.5 m width, and 0.1-0.2 m. Although there really was no spawning gravel within Cascade Creek, the pools provided rearing habitat and downstream of this area there was spawning gravel for over 1700 m (approximately a mile) distance. There was abundant cover in the form of canopy, overhanging vegetation, and bedrock areas, similar to the uppermost reach of San Anselmo Creek (Appendix D, Table D-3).

4. *Sleepy Hollow Creek*

Sleepy Hollow Creek extends from the confluence with San Anselmo Creek in San Anselmo, several hundred meters downstream of the denil fish ladder at the Saunders Avenue bridge, and extends upstream through residential areas, mostly along Butterfield Road and into the hills of Sleepy Hollow (Figure 7). Proceeding upstream, summer habitat conditions are described by general stream sections, as follows (Appendix D, Table D-4).

Confluence with San Anselmo Creek to the Upstream Side of Sir Francis Drake Boulevard (SH 1 to SH-2)

From the confluence with San Anselmo Creek to the upstream side of the Sir Francis Drake Boulevard culvert, the creek was partially channelized by concrete and wood retaining walls. In addition, there were numerous areas where rip rap had fallen into the creek Although there was water, much of it was not flowing, and the areas where it was deeper, forming lateral scour pools associated with walls, the substrate was composed primarily of sand and silt. Generally, this was habitat suitable for stickleback and roach, not salmonids.

Sir Francis Drake Boulevard Upstream to the Arroyo Avenue Bridge (SH-3 to SH-50)

This portion of the creek flowed under Mountain View Avenue and Broadmoor Avenue and upstream along Butterfield Road. It was characterized by the lack of stream flow, with some areas only a trickle; the creek was mostly dry behind Roble Court. The habitat consisted primarily of lateral scour pools and trickles, with a few shallow pocket water areas. The lateral scour pools were associated with rip rap and concrete retaining walls, primarily. The pools were ranged from 6-84 m in length, 1.2-4.7 m average width and 0.03-0.35 m in average depth. Substrate consisted primarily of sand, silt and concrete. Cover consisted of canopy and some cut bank areas, but mostly it was in the form of concrete or rip rap blocks. The habitat appeared suitable for roach and stickleback, but not trout. In addition to numerous pieces of concrete and rip rap, there was a water heater (SA-17), a hose (SA-25) in the creek, and two recently dead (whether from natural causes or poisoning was not known) racoons (just upstream of Sir Francis Drake Boulevard).

Arroyo Avenue Bridge Upstream to Caleta Avenue Bridge (SH-51 to SH-97)

From Arroyo Avenue upstream to Caleta Avenue, San Anselmo Creek was characterized mostly by lateral scour pools associated with retaining walls (concrete, wood, rip rap) and concrete pilings from bridges; there were a few rootwad pools, as well. Although pools were larger and deeper than downstream of Arroyo Avenue, there generally was not enough flowing water to create pool/riffle sequences at the time of the survey. Many of the pools were not connected and, hence, stranded any fish which had been residing in them. The lateral scour pools ranged from 5 to 42 m in length, 1-5 m average width, and 0.03-0.4 m average depth;. Substrate consisted primarily of small gravel and sand, asphalt, and concrete blocks, and abundant canopy/overhanging cover was present. A hose was seen in one pool (SH-60) and an various pieces garbage (cans, plastic, water heaters) had been strewn into the creek throughout this section. Although the upstream end of the reach ended with a good-sized (14 m length by 5 m width) rootwad lateral scour pool, such types of habitat were not common.

Caleta Avenue Upstream to Deer Hollow Road (SH-98 to SH-114)

From Caleta Avenue upstream to Deer Hollow Road, the habitat was characterized, primarily, by lateral scour pools associated with rootwad and cut banks, with a few concrete retaining walls. Although, there was an increase in structure within the pool habitats, compared to downstream areas, almost 50% of this section had dried up. Hence, as before, many of the pools were stranded. The lateral scour pools ranged from 5 to 21 m in length, 1-5 m average width, and 0.07-0.3 m average depth and there was abundant canopy cover. Substrate consisted primarily of gravel, particularly in the dry areas which, presumably are riffles during the wet season. A hose and old metal pipes were seen at SH-107. At the upstream end of the section just below Deer Hollow Road bridge, there was a series of bedrock/concrete pools. During the winter, the upper pool is deep (over 2 m) and water cascades down through the pools. In summary, although much of the section was dry at the time of the survey, this section was characterized by a great deal of spawning gravel and some good rearing pools with structure in them.

Deer Hollow Road Upstream to Fawn Drive (SH-115 to SH-125)

Over 50% of the creek was dry from Deer Hollow Road upstream to Fawn Drive. Lateral scour pools and dam in this reach were associated with bedrock (7-13 m in length; 1-3 m average width; and, 0.04 - 0.14 m depth). As with the preceding sections, dry areas in this section were comprised of substrate suitable for spawning trout. A hose was seen at SH-121 and at the upstream end of the section, just below the bridge, the pool was stagnant and had a rotten smell to it.

Fawn Drive Upstream to Culvert Underneath Butterfield Road, Just Downstream of Legend Road (SH-126 to SH-163)

This section was characterized by alternating pools, and a few bedrock cascades, with dry sections in the creek. The pools in the lower portions were associated with bedrock; the pools in the upper areas were associated with cut banks, rootwads, and concrete pilings (from foot and driveway bridges). Pools ranged from 4-28 m in length,0.8-4 m average width, and, 0.05 - 0.36 m depth. As with the downstream areas, the substrate in the dry areas was suitable for trout spawning. Just upstream of Butterfield Lane, extending upstream for about 100 m, the pools were stagnant, completely covered with duckweed.

Culvert Underneath Butterfield Road, Just Downstream of Legend Road Upstream to Dam (SH-164 to SH-179) Across From 33 Raven Lane

This section was characterized by very limited amounts of water, most of which was found at the beginning and the end of the section. The pool just upstream of Butterfield Road was 25 m long, and averaged 2.8 m wide and 0.12 m depth. At the end of the section there was a bedrock pool and a man-made concrete dam, approximately 2.5 m high (impassable to steelhead immigration); the pool was 13 m long and about 6 m wide, with a depth of over 0.5 m in the deepest part. The rest of the section was alternately dry or almost dry, with a few shallow (0.1-0.2 m depth) lateral scour pools associated with bedrock, cut bank and root wads. As the gradient increased as one proceeded up the creekbed, this section is probably really "ripping" during the winter season. During the summer, though, there is limited habitat, due to the lack of water.

Upstream of Dam Across From 33 Raven Lane (SA-180 to SA-183)

Upstream of the dam to Katrina Lane, there were a few stranded shallow pools. The area directly below Katrina Lane was very dense with overgrown vegetation. The section above Katrina Lane continued with alternating stranded pools and dry reaches. Substrate consisted of small gravel throughout most of the area, smaller than in the downstream areas.

5. *Ross Creek*

At the time of the survey, Ross Creek was dry from its confluence with Corte Madera/San Anselmo creeks upstream to Glenwood Avenue. In the lower reaches of the dry area there was gravel substrate suitable for spawning trout. Within Natalie Coffin Greene Park, extending upstream to just below the spillway at Phoenix Lake, the habitat was characterized by lateral scour pools associated with bank cut, rootwads and large woody debris. There was a lot of structure in the creek in the upstream areas and the water in the creek was concentrated in a few pools. These areas provided rearing habitat for trout, albeit to a rather limited extent.

6. *Fairfax Creek*

Fairfax Creek flows down the slopes above and through the town of Fairfax to its confluence with San Anselmo Creek. From my cursory observations (photos taken of Fairfax Creek at the bridge crossings), it appeared that the habitat in Fairfax Creek was similar to that of Sleepy Hollow in the dry months of a wet or normal year. From the results of our "spot check" observations, it appeared that Fairfax Creek had little water in it by the end of the dry season, there were lateral scour pools and shallow riffles throughout the creek, substrate consisted of gravel, sand and silt, and there was abundant vegetative cover.

Allen (1960a) stated that Fairfax Creek usually went dry, beginning in April or May. He also stated that the lack of summer flows, heavy pumping by private landowners, and trashing of the creek by humans had destroyed the creek for salmonids for all practical purposes.

CHAPTER 8 EXISTING FISH POPULATION CONDITIONS

A. POPULATION SIZES

Fish species collected in the Corte Madera Creek Watershed included rainbow/steelhead trout, threespine stickleback, California roach, sculpin species, and Sacramento sucker (Appendix E). Limiting factors for trout production were lack of stream flows and probably high water temperatures, depending upon both the creek and location of the reach within a creek.

Compared to the other four fish species, trout were the most numerous in San Anselmo Creek; only trout were collected in Cascade and Ross creeks. Roach, stickleback and sucker were the predominant species in Corte Madera Creek; trout and roach were the most prevalent species in San Anselmo Creek; and stickleback and roach were the most prevalent species in Sleepy Hollow Creek. Only trout were collected in Cascade and Ross creeks (Figures 8-15).

The mean trout populations, within the Corte Madera Creek Watershed were as follows: (1) Corte Madera Creek - 0.03-0.14 fish/square meter[1]; (2) San Anselmo Creek - 0.01-12.76 fish/square meter; (3) Cascade Creek - 0.59-0.84 fish/square meter; (4) Sleepy Hollow Creek - 0.02-0.41 fish/square meter; and, Ross Creek - 0.25 fish/square meter. The greatest numbers of trout were collected in San Anselmo and Cascade creeks within the Cascade Canyon Open Space Preserve. However, there was no statistical difference in population sizes between any of the various creeks, due to the wide variability in the number of rainbow/steelhead trout in the various habitat types (Figure 8).

B. AGE OF THE FISH SPECIES COLLECTED

1. *Rainbow/Steelhead Trout*

Based on the size distribution (Figures 17-21 and Appendix E, Tables E-10 to E-14), the juvenile rainbow/steelhead trout were probably from three to four different age classes. Most of the trout were young-of-the-year (i.e., hatched last spring) fish, but there were some older fish in both San Anselmo and Sleepy Hollow creeks. The greatest variety of age classes came from these two creeks, as well, suggesting that there is a self-sustaining population of rainbow/steelhead trout in the watershed, albeit small. Of particular interest was the variety of age classes in the first bedrock pools sampled in the Cascade Canyon Open Space Preserve, upstream of the dry creek bed (i.e., approximately 1700 m of dry creek). In other urban systems that I have sampled, such an area would usually produce most, if not all, young-of-the-year fish, not a variety of age classes. Hence, it is important that the area be protected from man-made stressors.

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[1] square meter = surface area = length (meters) X width (meters) of fish habitat

2. *Other Fishes*

Based on the length data (Figures 17-21 and Appendix E, Tables E-10 to E-14), the stickleback collected were young-of-the-year fish, the roach and suckers, from one to four years old, and the sculpin from one to five years old.

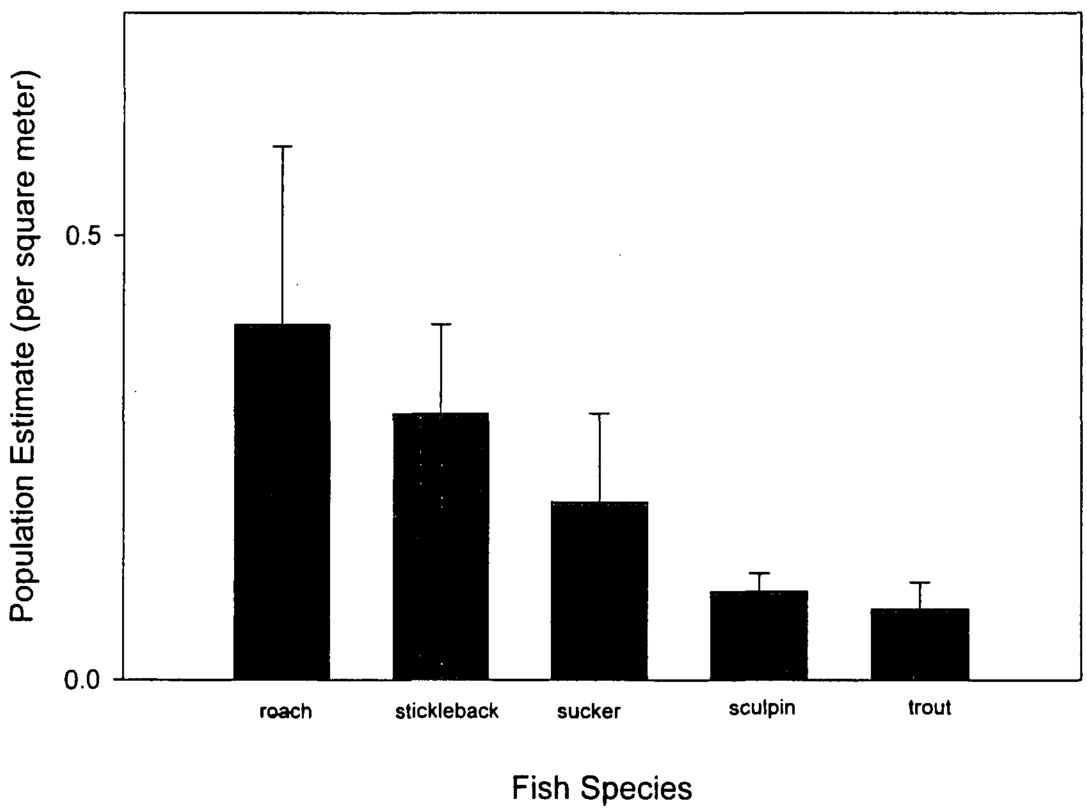

Figure 8. Relative Numbers of Each Fish Species Within Corte Madera Creek (mean +/- s.e.m.)

s.e.m. = standard error of the mean

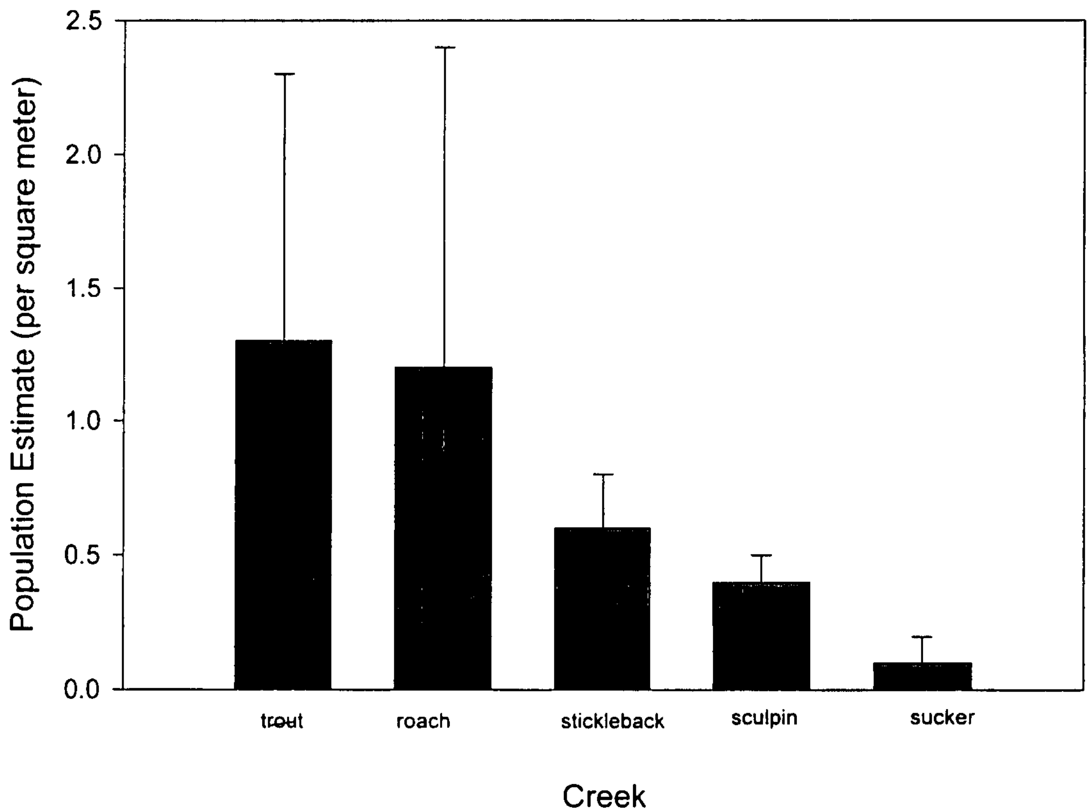

Figure 9. Relative Numbers of Each Fish Species Within San Anselmo Creek (mean +/- s.e.m.)

s.e.m. = standard error of the mean

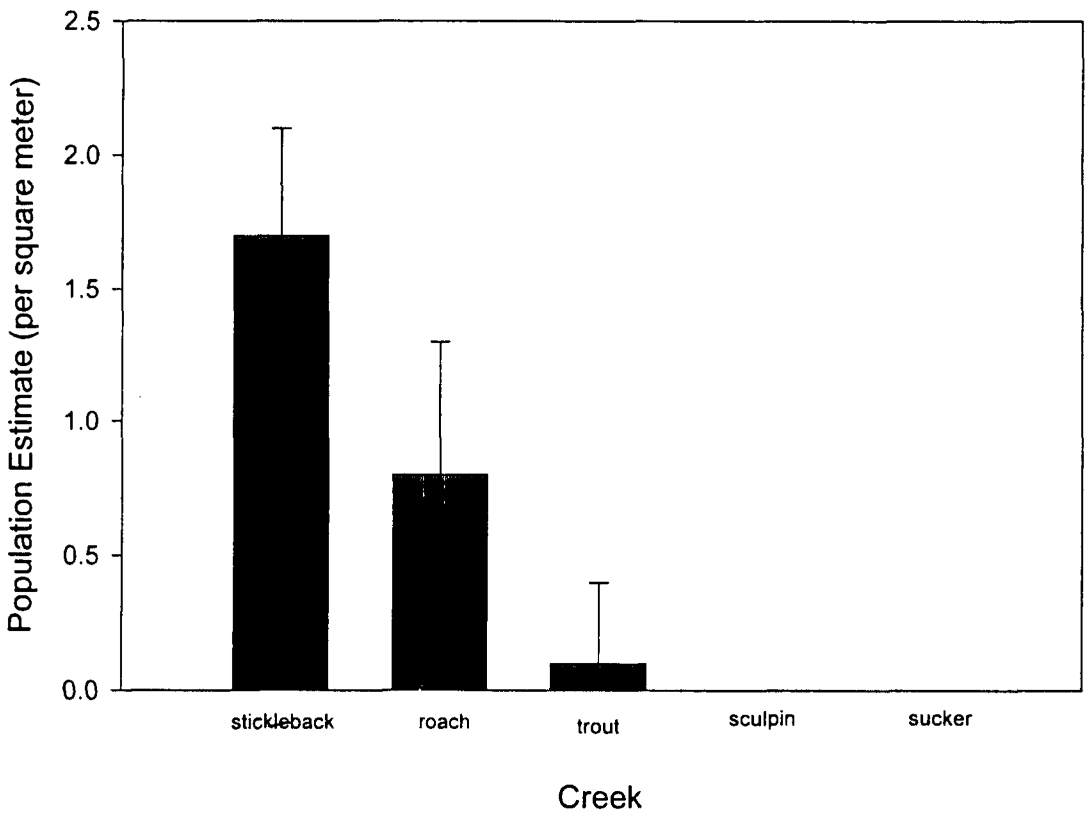

FIGURE 10. RELATIVE NUMBERS OF EACH FISH SPECIES WITHIN SLEEPY HOLLOW CREEK (mean +/- s.e.m.)

s.e.m. = standard error of the mean

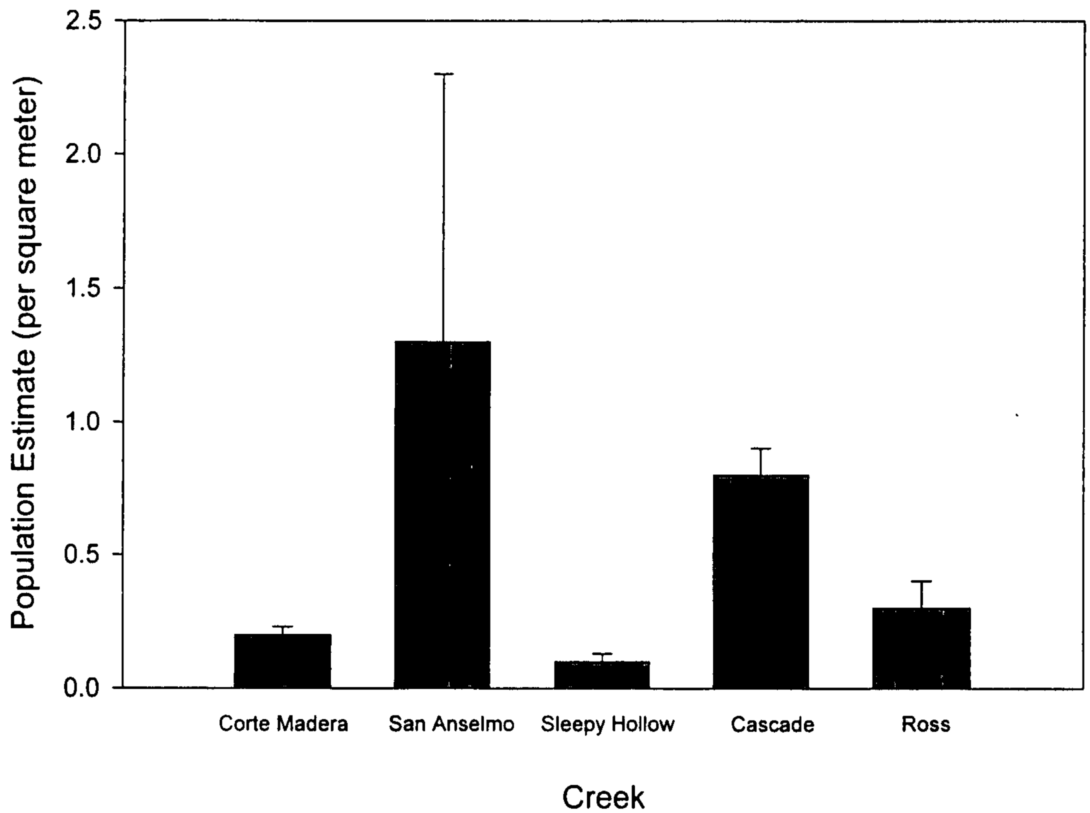

FIGURE 11. RAINBOW/STEELHEAD TROUT POPULATIONS WITHIN THE CORTE MADERA CREEK WATERSHED (mean +/- s.e.m.)

s.e.m. = standard error of the mean

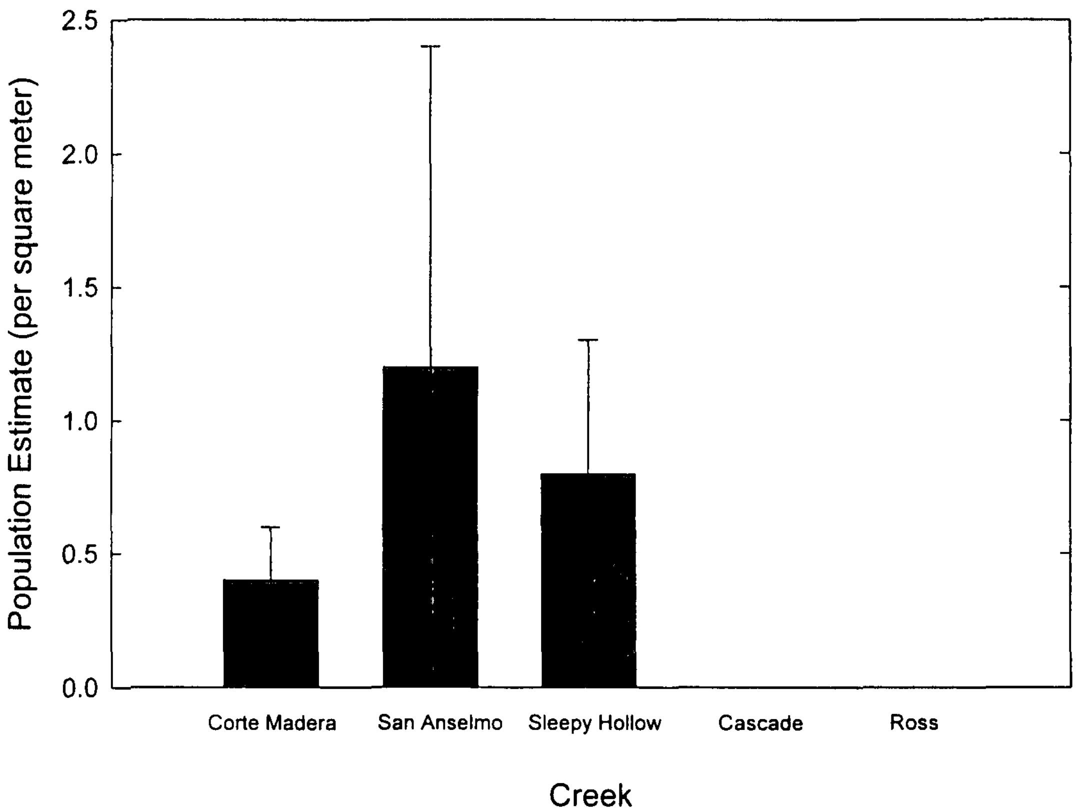

FIGURE 12. CALIFORNIA ROACH POPULATIONS WITHIN THE CORTE MADERA CREEK WATERSHED (mean +/- s.e.m.)

s.e.m. = standard error of the mean

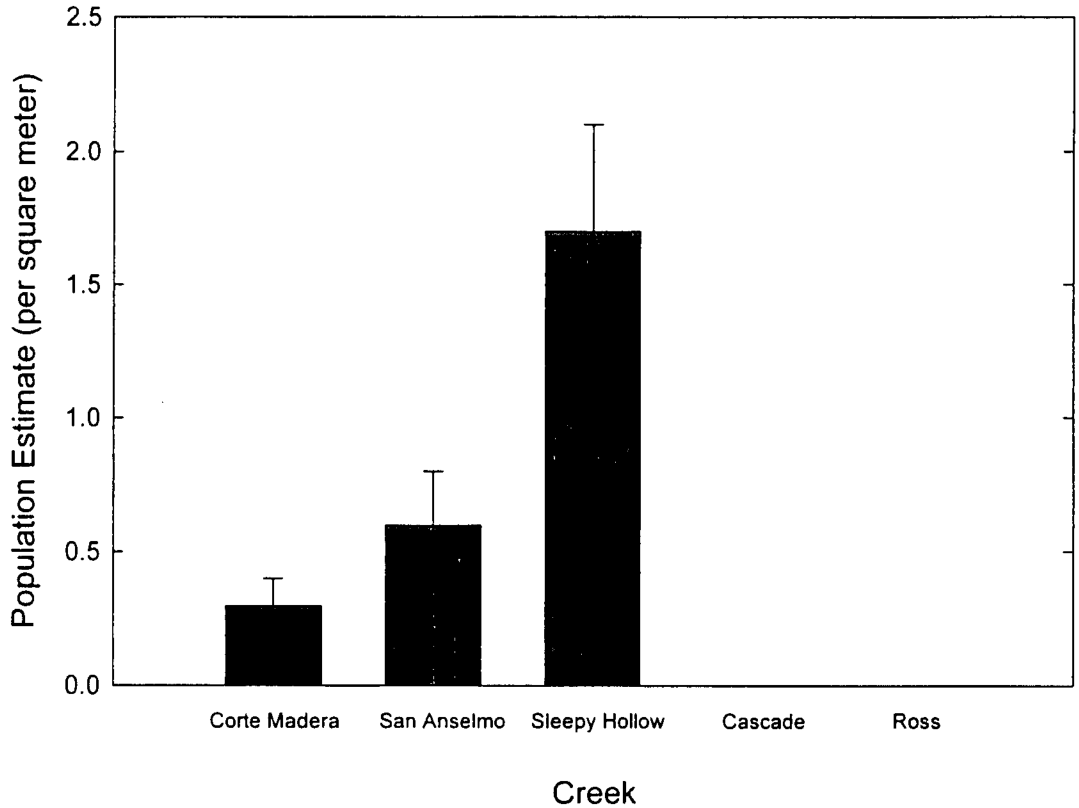

FIGURE 13. THREESPINE STICKLEBACK POPULATIONS WITHIN THE CORTE MADERA CREEK WATERSHED (mean +/- s.e.m.)

s.e.m. = standard error of the mean

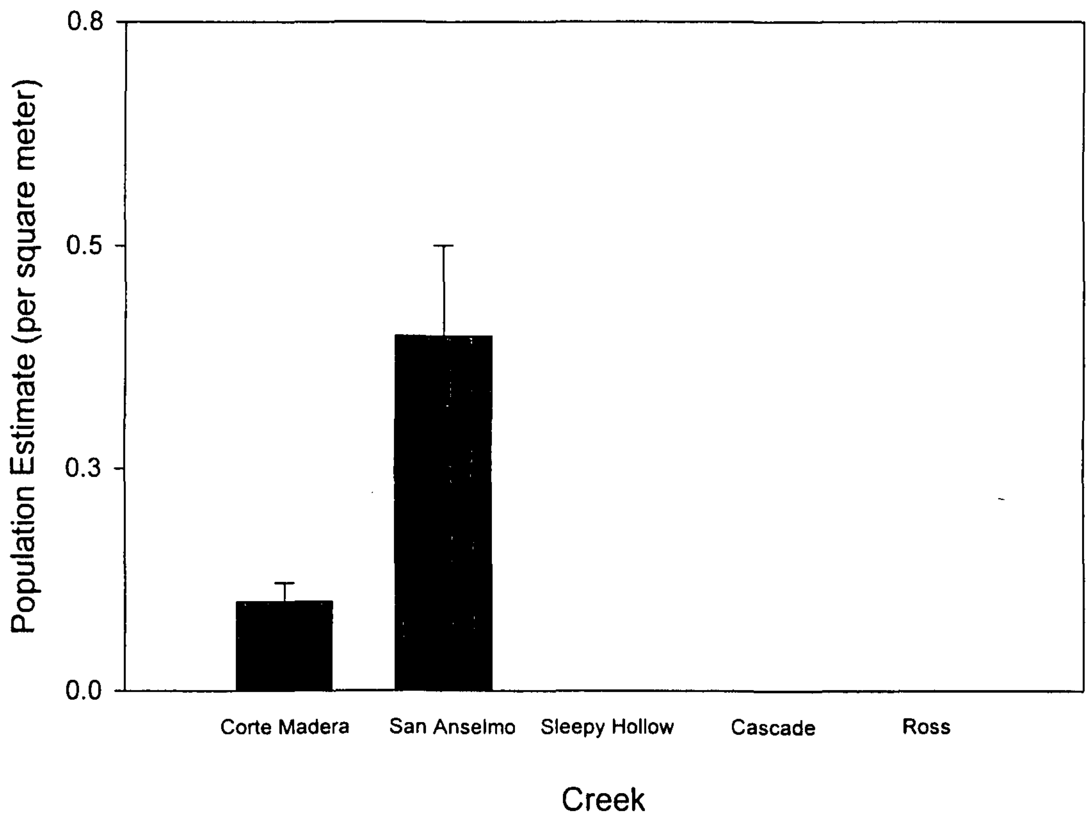

FIGURE 14. SCULPIN POPULATIONS WITHIN THE CORTE MADERA CREEK WATERSHED (mean +/- s.e.m.)

s.e.m. = standard error of the mean

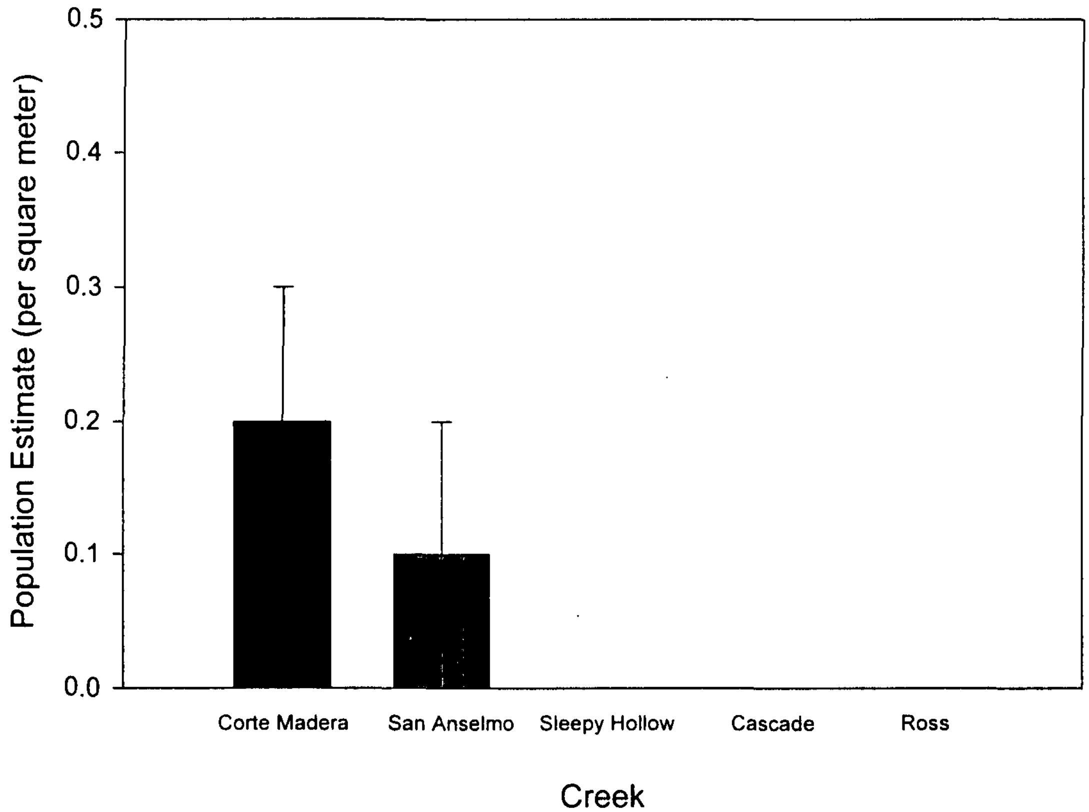

FIGURE 15. SACRAMENTO SUCKER POPULATIONS IN THE CORTE MADERA CREEK WATERSHED (mean +/- s.e.m.)

s.e.m. = standard error of the mean

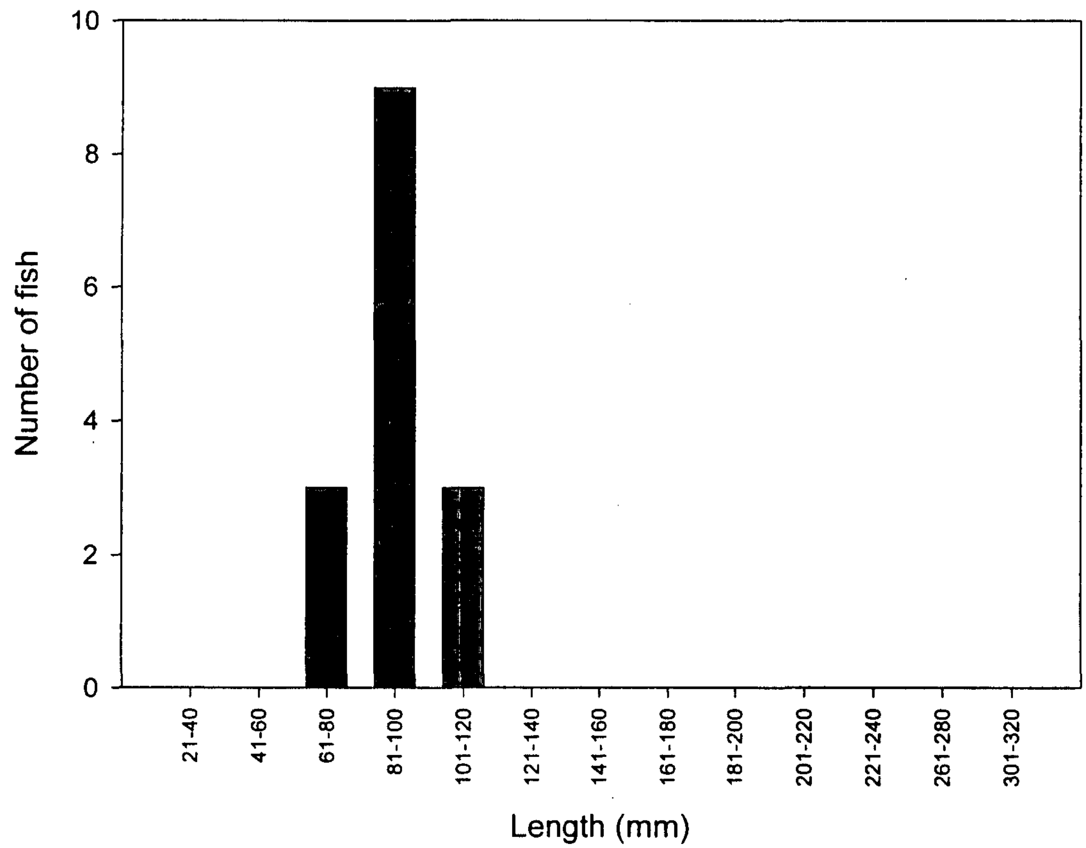

FIGURE 16. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN CORTE MADERA CREEK.

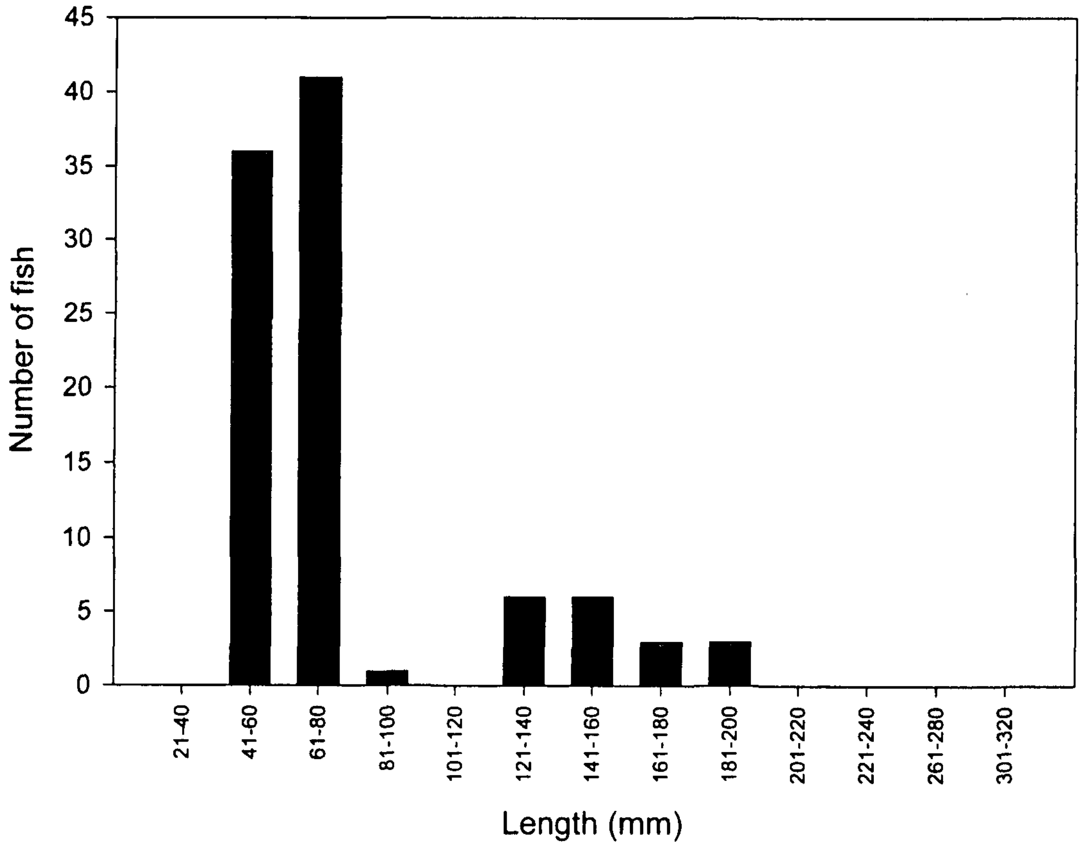

FIGURE 17. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN SAN ANSELMO CREEK.

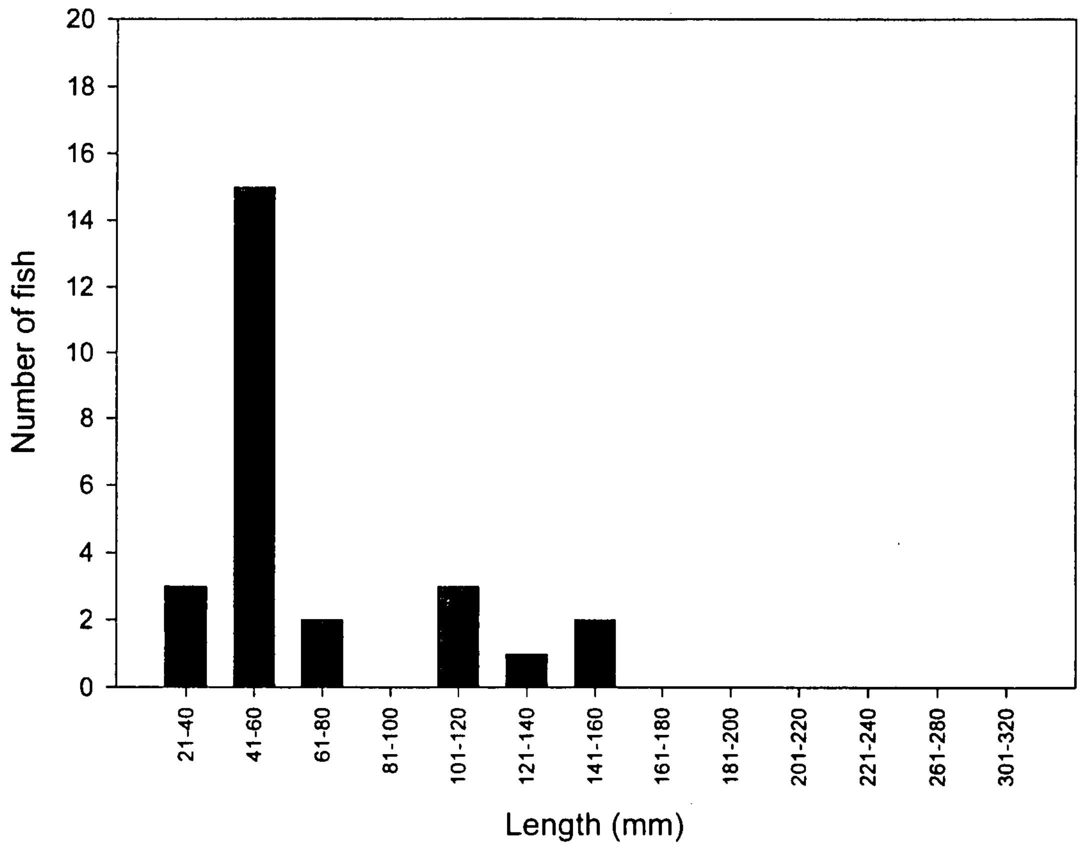

FIGURE 18. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN CASCADE CREEK.

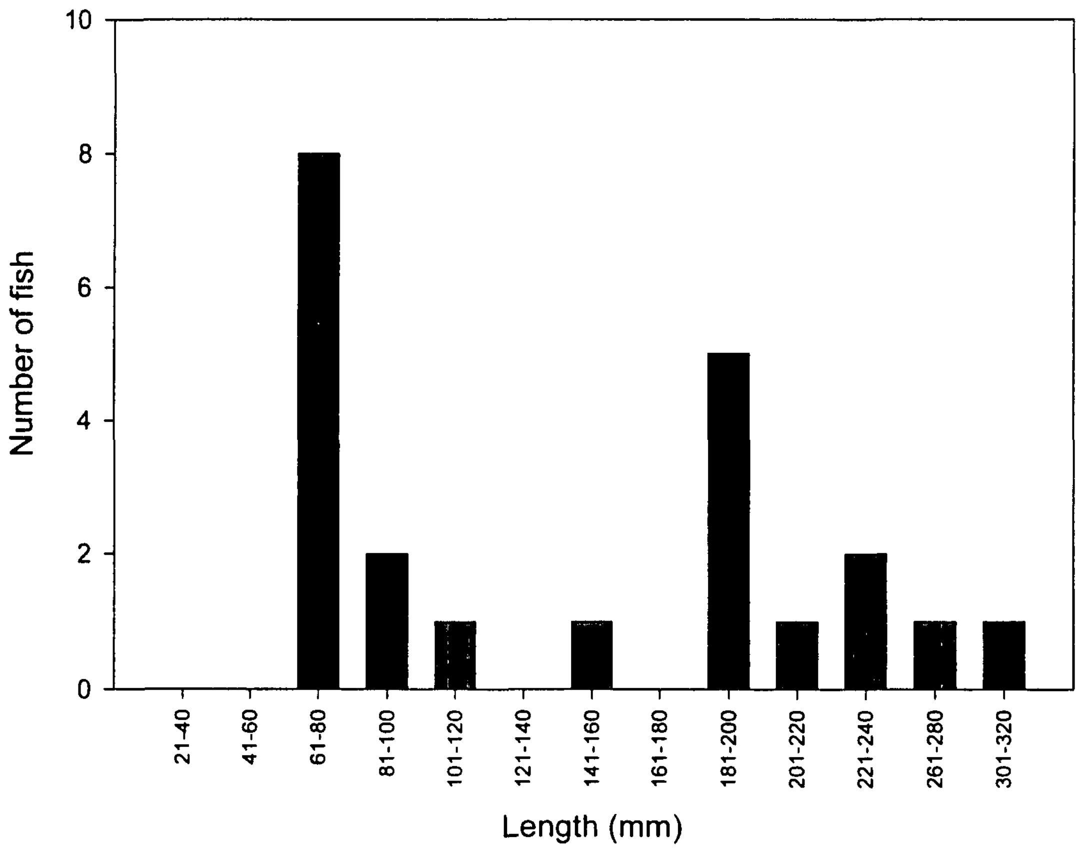

FIGURE 19. RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN SLEEPY HOLLOW CREEK.

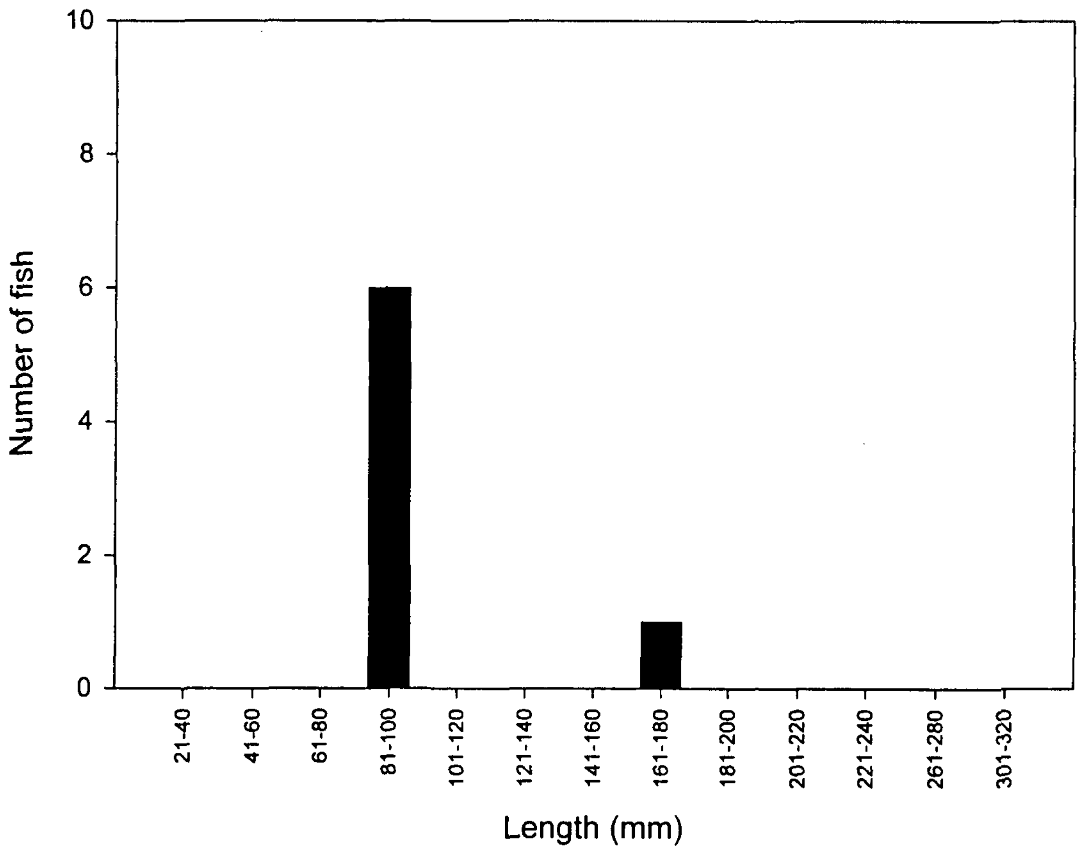

FIGURE 20 RAINBOW/STEELHEAD TROUT LENGTH-FREQUENCY DISTRIBUTION IN ROSS CREEK.

CHAPTER 9 STEELHEAD RESTORATION PLAN

A. OBJECTIVES AND SCOPE

The overall objective for steelhead restoration in the Corte Madera Creek Watershed is to improve creek water quality and habitat conditions to increase productivity of salmonids. However, before embarking on any improvement in the Corte Madera Creek Watershed, with regard to steelhead/rainbow trout, specific objectives need to be defined. Are we trying to restore the watershed to conditions which existed decades or even a hundred years ago? This would not be a practical objective, as its success would never be achieved, due to the human-caused impacts which have occurred and will continue to occur in this watershed. The fact that a steelhead/rainbow trout population exists in the heavily-impacted Corte Madera Creek Watershed is testament to the durability of this species. Durable as the species is, though, we must be practical and acknowledge that conditions are not, and never will be, the same as they were years ago. However, if the community works together and adequate funding becomes available to implement habitat improvement measures and continue the necessary scientific studies, I believe we, as a community, can not only improve habitat conditions, but demonstrate an increase in steelhead/rainbow trout populations in the Corte Madera Creek Watershed. Thus, the objective presented here is not to restore the watershed to "how it once was", but to improve or restore it to some extent. The degree to which the watershed improves will be directly dependent both on community involvement and scientific studies which will enable us to determine both the causes of, and solutions to, problems, with regard to steelhead trout habitat and populations. Two examples illustrate the importance of both science and the community involvement.

For a steelhead rehabilitation project to be successful, one must first identify the sources of the problems and limiting factors to the fish, and tailor the solutions (restoration) to rectifying or reducing the problems, if possible. Although there are a number of man-made dams in the creeks and a few large woody debris jams, most are probably not passage barriers for the anadromous steelhead. Some of the dams are low enough that we can be confident that they are not barriers; others are so high that they definitely are barriers to salmonid migration. However, without spawning studies to determine when and where the fish immigrate and spawn, we do not know which, if any, of these dams, actually prevent or impair immigration. We do not want to repeat the mistakes of the 1960's and 1970's, when resource agencies required that all potential barriers be removed from our rivers and creeks. The results of this state-wide creek "clean up" were disastrous for salmonids, as excellent physical habitat in the form of woody debris was removed from rivers and creeks all over the state. Thus, before removing any dams or other potential barriers, no inexpensive proposition, we need to know whether or not there is a need to remove them; are they a problem for the trout? If they are, restoration measures can be designed to remove the problem and help fish passage. And, if any of the potential barriers are not a problem to salmonids, time and money are not wasted on unnecessary activities.

Erosion and flood management are big issues for the people who live along or near the creeks in the Corte Madera Creek Watershed. Historically, flood control projects measures resulted in channelization of creeks and annual removal of woody debris and riparian vegetation before the winter rains. It is very important that any measures undertaken to improve steelhead habitat conditions not be sabotaged by measures undertaken to prevent flooding of human homes; the woody debris that is removed is probably home to juvenile, or even adult, salmonids.

One way of viewing steelhead trout restoration in the Corte Madera Creek Watershed which integrates science and public involvement to achieve watershed improvement, is to divide the project into the following phases (see Figure 21):

- Phase I: Undertake Preliminary Baseline Surveys
- Phase II: Steelhead Restoration Plan
- Phase III: Implementation of Restoration Actions Research and Surveys
- Phase IV: Monitoring Results of Restoration Measures
- Phase V: Adaptive Management

This Five-Phase Plan is modeled after CALFED's Comprehensive Monitoring, Assessment, and Research Program (CMARP, 1998). The approach integrates hands-on restoration activities with assessing the needs of the trout. CMARP (1998) states that "Appropriate and timely assessment of monitoring and research data is critical to effective management."

Phase I (Preliminary Baseline Surveys) was completed in 1999. The results of the preliminary baseline surveys provided information necessary to design the Steelhead Restoration Plan (Phase II), including the identification of limiting factors in the watershed. Phase II (Steelhead Restoration Plan) will be started with the submission of the Conceptual Steelhead Restoration Plan. The Plan will be completed as more information is gathered. Phase III (Implementation of Restoration Measures/Research and Surveys) will evolve over time. It will include both hands-on restoration actions and site-specific research and surveys, both of which will be dependent upon what the community wishes and budgetary constraints (Table 7). One possible type of research endeavor would be a study to determine whether or not water temperature is limiting to steelhead and/or rainbow trout (Figure 22). Phases IV (Monitoring Results of Restoration Measures) and V (Adaptive Management) will be works- in-progress. They will consist of future monitoring efforts to assess the relative success of the restoration efforts, and continual re-evaluation, and adaptation (Adaptive Management). If, after evaluating the results of a monitoring effort, a limiting factor is

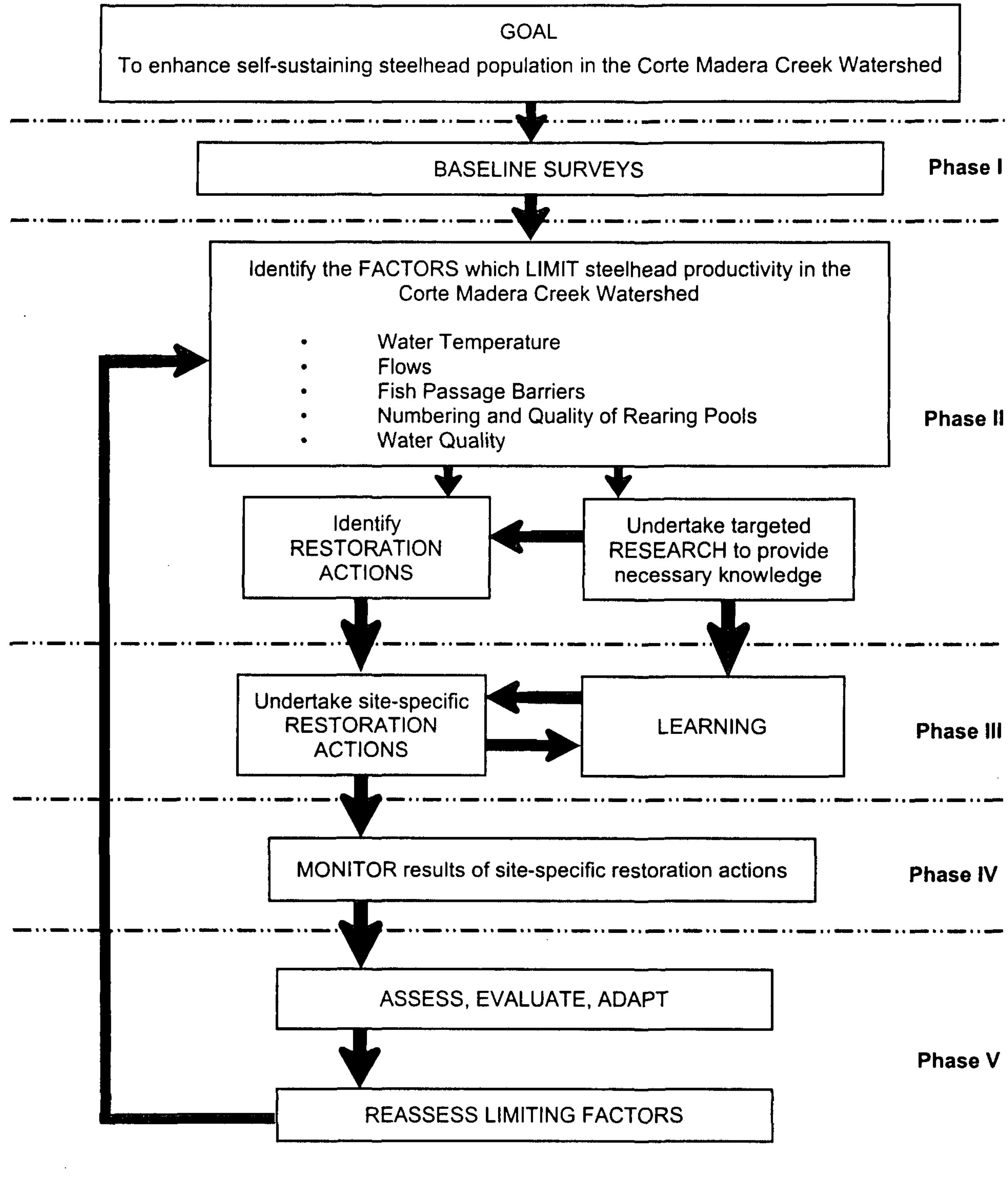

FIGURE 21. CONCEPTUAL PLAN TO RESTORE CONDITIONS IN THE CORTE MADERA CREEK WATERSHED

Table 7. SAMPLE OF RECOMMENDED RESTORATION ACTIONS AND RESEARCH ACTIVITIES [1]

Potential Limiting Factor	Recommended Restoration Actions	Recommended Research/ Surveys
Lack of Water	• Encourage landowners to stop/reduce diverting of water (diversions/wells) • Encourage natural geomorphic processes • Work with community to enhance groundwater (e.g., reduce impervious surfaces, promoto infiltration of winter rains)	• Identify streamflow requirements for salmonids in each creek • Identify which diversions are operating [1] • Identify locations where hydrologic/ geomorphic processes could be modified
Water Temperatures	• Plant appropriate vegetation along riparian corridors • Increase water supply	• Food/Growth/Temperature Bioenergetics Studies • Water temperature monitoring
Fish Passage Barriers	• If warranted, remove barriers • Replace denil fish ladders with more effective structures	• Spawning Surveys • Evaluate adequacy of denil fish ladders
Rearing Habitat	• Remove concrete slabs from creeks [1] • Improve rearing habitat areas • Planting appropriate vegetation along eroded banks • Stream clean-up projects by community	• Productivity (i.e., spring smolt, summer rearing) surveys • Food/Growth/Temperature Bioenergetics Studies • Habitat Studies
Water Quality	• Education of community with regard to problem of pollutants in storm drains • Community should work with MCSTOPP	• Water quality sampling

1 See Appendix H for list of Stream Reach Units (SRU's) which have diversion hoses and large slabs of concrete in them, and eroded stream banks

shown to be non-limiting, then no restoration activities will be needed. If, on the other hand, the factor is shown to be limiting to salmonids, than restoration activities can be designed to improve salmonid conditions (Figure 21).

B. PHASE I: UNDERTAKE BASELINE SURVEYS OF THE WATERSHED

To determine if and what restoration actions are necessary, baseline surveys are necessary. The results of such information can be used to assess existing water temperature, physical habitat, and water quality conditions within the watershed. By comparing the results of those types of data with the requirements of the species in question, one is able to identify factors which may be limiting to the steelhead productivity. The 1999 surveys provided much-needed information on the fishery resources conditions in the Corte Madera Creek Watershed. Habitat and water temperature conditions were assessed, and potential factors which may limit salmonid productivity were identified. As the restoration project continues, it is likely that additional baseline surveys and research will be required.

C. PHASE II: STEELHEAD RESTORATION PLAN

A steelhead Restoration Plan should have the following elements (Figure 21):

(1) Identification of Objectives;

(2) Determination of existing water quality and habitat conditions and factors limiting steelhead/rainbow trout;

(3) Identification of what restoration measures are possible, from both an economic and practical standpoint;

(4) Implementation of restoration actions;

(5) A Monitor Program to assess the relative success of the restoration actions; and,

(6) If warranted, re-evaluation of restoration actions, and adaptation.

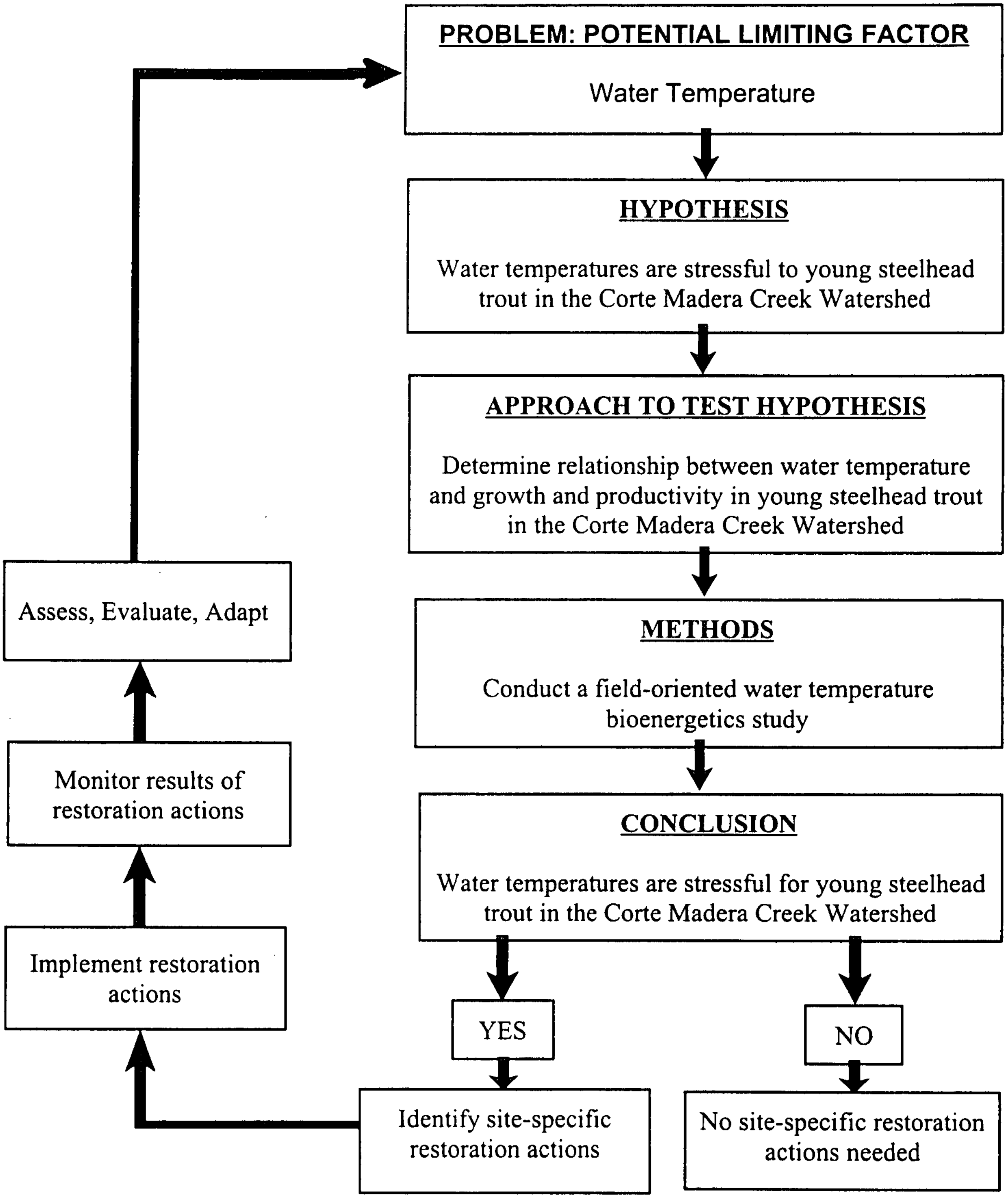

FIGURE 22. CONCEPTUAL PLAN TO DETERMINE WHETHER OR NOT WATER TEMPERATURES ARE STRESSFUL TO STEELHEAD AND/OR RAINBOW TROUT IN THE CORTE MADERA CREEK WATERSHED

1. *Identification of Objectives*

Identification of objectives is the most important aspect of any restoration plan. At the May 8, 2000 meeting of the Watershed Planning Advisory Committee, the group concluded that the overall goal of the restoration plan was, "To enhance a self-sustaining healthy steelhead population in the Corte Madera Creek System". The community needs to build on the conceptual Steelhead Restoration Plan by preparing a more detailed Plan . It should also be understood that the objectives of the community may change with time, as the restoration project evolves.

2. ***Determination of Existing Conditions and Factors which Limit Steelhead/Rainbow Trout Productivity***

Before we can improve steelhead/rainbow trout conditions and, hence, population size, it is imperative that we know what the watershed provides, with regard to water temperature, water quality, and habitat conditions. From the results of the 1999 surveys (Phase I), we know enough about watershed conditions to be able to identify potential limiting factors. In addition, based on the results of the 1999 surveys, there are some site-specific restoration activities which could be undertaken that would improve habitat conditions immediately. Provided that studies and surveys continue to be functional (i.e., their objective is to identify cause-and-effect mechanisms which affect the salmonids), there really is a wide variety of types of studies/surveys that can be undertaken. The results of these and future studies will enable us to determine existing conditions within the watershed. From that information, we can determine the effectiveness of restoration measures.

3. *Selection of Restoration Actions*

The community needs to determine what type of restoration measures it wishes to undertake. To begin to restore the Corte Madera Creek Watershed, there is a wide assortment of activities which could be undertaken (Table 7). It would be prudent to begin with the least expensive options and proceed to more extensive, and hence, expensive, restoration actions (such as buying property to allow the removal of structures too near the creek).

4. *Implementation of Restoration Actions*

After selecting restoration measures, they need to be implemented. As the project evolves, so too will the restoration measures undertaken, as part of the adaptive management strategies included in the Restoration Plan (Figure 21).

5. ***Monitoring the Results of the Restoration Actions.***

To determine whether or not the restoration undertaking has been successful, with regard to steelhead/rainbow trout productivity, the results of the restoration measures should be monitored. This monitoring could be undertaken in several ways. For example, the results of the various fishery resources-related studies which provide data on existing conditions would provide information upon which to base the relative success of the restoration activities. Or, to determine whether or not water quality conditions had improved in a certain area, the community could work with the State Water Quality Control Board; water quality conditions could be monitored in selected areas.

Regardless of what level of monitoring is undertaken, one of the most effective methods for tracking success/failure and having a continual running dialogue between scientists, the community, agency personnel, etc. is to design a *Watershed-Based Database on a GIS system*. Developing such a system should be a priority, not only for monitoring the effectiveness of the steelhead restoration efforts, but for all other efforts implemented as part of the watershed plan.

D. PHASE III: RESTORATION ACTIONS/RESEARCH AND SURVEYS

The following potential limiting factors were identified, based on the results of the 1999 surveys and other relevant information:

(1) Lack of water (i.e., stream flows);

(2) High water temperatures;

(3) Fish passage barriers (i.e., man-made dams);

(4) Rearing habitat; and,

(5) Water quality conditions.

The following two general outcomes resulted from 1999 surveys:

(1) The identification of a number of restoration actions which could begin as soon as funding becomes available; and,

(2) Some "data gaps" were identified, for which further research is necessary before one can determine whether or not restoration actions are required.

Each of these is discussed below.

1. *Recommended Restoration Actions*

Based on the results of the 1999 surveys, the following types of restoration actions are recommended, as soon as funding becomes available (Table 7):

- Reduce number of diversions;
- Remove numerous concrete slabs from creeks;
- Work with community to reduce water quality problems;
- Plant appropriate vegetation along eroded banks;
- Stream clean-up projects by community; and,.
- Education of the community to enhance watershed, as a whole.

There are dozens of hoses in the creeks that appear to be used to divert water from the creeks. Are these hoses used to pump water out of creek or do they drain swimming pools, or do they drain off roads and/or property into the creeks? Do the owners have permits, and if they are pumping water out of the creek, is this really necessary? Enquiring fish minds want to know! To determine whether or not they would be willing to cease robbing the fish of their water, homeowners need to be educated about the needs of the fish.

Other than the lack of water in the summer and the resultant high water temperatures, the single most problematic issue, with regard to trout habitat, is the quantity of concrete, asphalt, and other garbage in the creeks. The large concrete slabs in the various creeks range in size from one meter to more than 10 meters in length. The creeks flowing through downtown San Anselmo, downtown Fairfax, and Ross are the biggest problem areas. The concrete slabs block flows and provide a haven for roaches and stickleback, but very poor habitat for salmonids.

There are hundreds of channels which ultimately contain runoff from streets into the creeks. This is probably a real problem, with regard to water quality, particularly during the winter months. However, it is the washing of cars with non-biodegradable soap, and washing of paintbrushes, etc. which are summer-related problems. Identification of problem areas and perhaps a community outreach program could be undertaken to help reduce non-point source pollution.

There were a few sites where severe bank erosion was occurring. The community needs to consult with a geologist/geomorphologist and, perhaps, landscaper, and determine what, if anything, could be done to contain them in a "fish friendly" fashion (i.e., vegetative planting rather than rip rap).

Stream clean-up projects need to be undertaken several times a year. Although most of the towns already have some form of fall stream clean-up, a few hours by a handful of volunteers on one day of a weekend is helpful, but insufficient. We now have a photographic database of the major creeks. These photos can be used to identify where the smaller garbage is and what needs to be removed. Water heaters, old pipes, and concrete blocks can all be manually removed with a lot of human power and not much expense. The expensive part of creek clean-up will be the removal of the really big concrete slabs.

It is essential to plan activities that will further educate the public, both about the steelhead/rainbow trout and the factors which affect them. For example, there could be a series of field trips for the public, led by a group of scientists, such as a fisheries biologist, a geologist, and a hydrologist. The focus would be to understand what the trout require, the interaction of the factors which affect trout needs, and how landowners can help the fish. So often I have found that the public believes that all we scientists do are "studies", which have no basis in practical reality. Such field trips would provide the opportunity for the interested public to observe functional fisheries biology, where the surveys and studies focus on cause-and-effect mechanisms, rather than academic science.

It would also be beneficial to involve school children in the importance of protecting and helping the animals in the creeks. Field trips could be scheduled with local schools. The watershed project could be described and students could observe first-hand, ways of improving creek conditions. Perhaps they, too, would become interested in contributing to the restoration effort of the steelhead trout in their creeks, both as children and, later, as adults.

Other restoration actions which may be implemented later include (Table 7):

- Plant appropriate vegetation along riparian corridors to increase shade and cover for salmonids;
- Remove barriers, if warranted, to allow passage by salmonids;
- Replace denil fish ladders with more effective structures, if warranted; and,
- Improve salmonid rearing habitat conditions.

However, before these restoration actions are undertaken, further research is needed to assess the utility and location of such actions.

2. *Data Gaps/Further Research Needs*

Based on the results of the 1999 surveys, some "data gaps" were identified. Before one can determine whether or not restoration actions are required, further research is necessary for the following (Table 7):

- Food/growth/temperature bioenergetics studies;
- Spawning surveys/adequacy of denil fish ladders;
- Productivity studies (e.g., smolt trapping, summer rearing);
- Water quality monitoring; and,
- Salmonid streamflow requirement studies.

Steelhead are both state- and federally-listed and, hence, of great importance, with regard to protection. Water temperature requirements are site-specific and data from laboratory studies really should not be used to determine optimal thermal ranges. Having already collected the beginnings of a large thermal database in the watershed, the next obvious step would be to take those data, together with future site-specific studies to determine whether or not the high water temperatures during the spring and summer months were detrimental to trout productivity (i.e., is temperature a major limiting factor in this watershed?). To determine whether or not water temperature is a limiting factor to steelhead and/or rainbow trout, a food/temperature/growth (i.e., "bioenergetics") study (some of which could be done in conjunction with the smolt trapping studies), is necessary.

Is there a passage problem for anadromous steelhead? Where and when do steelhead spawn in the creeks of the Corte Madera Creek Watershed? Do any of the concrete dams in the creeks present a physical barrier to these fish during their spawning immigration? Are the denil fish ladders useful in terms of fish migration? To answer these questions, steelhead trout spawning surveys need to be conducted. In addition, most, if not all, of the denil fish ladders should be replaced with new, more effective passage structures.

What is the relationship between rearing habitat and productivity in the Corte Madera Creek Watershed? How does it compare with other watersheds in Marin or in other areas of the state? To answer these questions, spring smolt trapping studies are needed. In addition, the summer habitat/electrofishing surveys should be continued, as there is so much variability from year to year, with regard to both habitat and populations.

Are water quality conditions in the Corte Madera Creek Watershed suitable for salmonids? Little is known about the water quality conditions in the watershed. To assess water quality conditions, water quality monitoring is needed (Table 8).

The flow requirements for each of the life stages of steelhead and rainbow trout in the Corte Madera Creek Watershed are unknown. To assess flow requirements, several types of site-specific studies could be conducted. For spawning, the Thompson (1972) method would be useful. For rearing, the instream flow incremental methodology (IFIM) has been used (Bovee, 1978). However, unless suitable biological data (e.g., thermal requirements, water quality requirements, habitat requirements) can be integrated into an IFIM, it is of limited value.

E. PHASE IV: MONITORING THE RESULTS OF THE RELATIVE SUCCESS OF THE RESTORATION ACTIONS

Monitoring the results of restoration measures will be a process, occurring over many years. In the current funding environment, it is necessary to undertake restoration measures based on the results of scientific studies, with monitoring that will document the effectiveness of the measures we have implemented. Designing a *Watershed-Based Database on a GIS system* should be a priority in developing, undertaking, and monitoring the effectiveness of the steelhead restoration efforts. It would be the most effective method for tracking success/failure and having a continual running dialogue between scientists, the community, agency personnel.

The Watershed-based GIS system could be on a Web site, so that anyone with a computer and modem could access the information at any time. The results of scientific studies, anecdotal information, restoration activities could be depicted in layers of information which could be "pulled up" on the Internet. Examples of types of information which could be posted include:

- Results of past surveys (i.e., the raw data) such as the ones we conducted in 1999, including photographs and whom to contact to ask questions;
- Potential (and actual, once spawning surveys have been conducted) steelhead/rainbow trout spawning areas;
- Examples of good rearing areas for steelhead/rainbow;
- Sites of potential anadromous salmonid migration barriers;
- Restoration activities (past, ongoing, proposed future);
- Dates of meetings, field trips; and,
- Status of Corps of Engineers Corte Madera Creek Flood Control Project

TABLE 8. IMPORTANT WATER QUALITY PARAMETERS TO MONITOR IN THE CORTE MADERA CREEK WATERSHED [1]

Parameter	Reason for Monitoring
Biological Oxygen Demand (BOD)	BOD is a measure of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter. When BOD is high, it is an indication that a creek, or area within a creek is stagnant and there is either not much or no free oxygen. Trout do not live well in stagnant water.
Fecal Coliform	Indication of human and/or animal waste products
Herbicides/Pesticides or Specific Heavy Metals	Many of the herbicides/pesticides used on lawns and plants end up in creeks. Such herbicides and pesticides, which contain heavy metals, can be extremely toxic to fishes, particularly trout.
Oil and Grease	Oil and grease flow into the creeks from the streets. If present in sufficient quantities, they can result in asphyxiation of trout and other species within the watershed
Oxygen, Dissolved	Essential for life; low (e.g., less than 5 mg/l) concentrations can stress trout
Nitrates	Although nitrogen is an element needed by all living plants and animals, high nitrate concentrations in creeks can lead to algae blooms which, in turn, decrease the habitat value for trout. Stormwater runoff can carry nitrate-containing fertilizers from laws into the creeks. As a result, water can cease flowing, habitat conditions decline for trout, and other more hardy fishes will replace the trout..
pH	Indication of acid, neutral, or alkaline conditions. Salmonids generally prefer pH of 7-9
Phosphates	Phosphates are part of living plants animals, their by-products, and their remains. High phosphate concentrations are indications of eutrophication. Phosphorus stimulates plant growth and eventually, an entire reach may fill with aquatic vegetation. Such habitat is unsuitable for trout and other more hardy fishes will replace the trout.
Temperature, Water	Water temperature controls the life of trout and all other fishes. Water temperatures which are stressful to trout can lead to decreased survival of a species. Water temperatures should always be measured over time, using continuously operating thermographs in representative habitats within a creek.

TABLE 8 (CONT.). IMPORTANT WATER QUALITY PARAMETERS TO MONITOR IN THE CORTE MADERA CREEK WATERSHED [1]

Parameter	Reason for Monitoring
Turbidity or some measure of suspended solids	Turbidity is a measure of the relative clarity of water: the greater the turbidity, the murkier the water, and the less habitable for trout. Turbidity increases as a result of suspended solids in the water. High turbidity may be caused by soil erosion, urban runoff, abundant bottom feeders (e.g., carp) that stir up bottom sediments, or algal growth.

1

When monitoring water quality with the purpose of determining existing conditions for trout, there are a variety of parameters which can be used. Those listed in Table 8 are some of the more important ones. However, regardless of what parameters are chosen, monitoring should only be undertaken as part of a Watershed Plan and a detailed Water Quality Monitoring Plan should be designed as part of that Watershed Plan.

F. PHASE V: ADAPTIVE MANAGEMENT

Adaptive Management is a useful tool for watershed restoration. The process of Adaptive Management uses the following incremental approach (Brown et al., 1998):

(1) Defining the problem (s);
(2) Taking action;
(3) Evaluating the benefits of the action; and,
(4) Modifying subsequent actions, as necessary.

Thus, for example, instead of spending time and money on removing dams which may not be passage barriers for anadromous steelhead, the dams are first assessed to determine whether or not they present a problem to the migrating fish. As a result, one might discover that some of the dams were passage barriers, but others were not. One can then remove only those which present a problem to fish migration. Or, the community might spend considerable time and cost planting riparian vegetation with the intent of reducing water temperatures by providing shade. Instead, to determine whether or not such actions are warranted and where such restoration should occur, both temperature monitoring and modeling studies should be undertaken beforehand, Then, if water temperature appeared to be a problem and the results of the water temperature studies demonstrated that the planted vegetation could improve water temperature conditions for salmonids, restoration actions could be undertaken in the watershed. However, if the results of water temperature studies demonstrated that the planted vegetation did not improve water temperature conditions for salmonids, then such restoration actions would not be undertaken. The use of Adaptive Management to enhance steelhead conditions in the Corte Madera Creek Watershed will allow one to either proceed with restoration actions, or to modify the planned actions, if those actions do not appear to be achieving the intended results (Figure 21).

CHAPTER 10 LITERATURE CITED

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1975. Inhibition of salt water survival and Na+-K+-ATPase elevation in steelhead trout (*Salmo gairdneri*) by moderate water temperatures. Trans. Amer. Fish. Soc. 104(4): 766-769.

Adams, B. L., W. S. Zaugg and L. R. McLain. 1973. Temperature effect on parr-smolt transformation in steelhead trout (*Salmo gairdneri*) as measured by gill sodium-potassium stimulated adenosine triphosphatase. Comp. Biochem. Physiol. 44A: 1333-1339.

Allen, J. T. 1960a. California Department of Fish and Game Stream Survey, Corte Madera Creek, Marin County. January 15, 1960. Calif. Dept. Fish and Game Files, Region 3, Yountville. 2 pp.

Allen, J. T. 1960b. California Department of Fish and Game Stream Survey, Fairfax Creek, Marin County. January 15 and 18, 1960. Calif. Dept. Fish and Game Files, Region 3, Yountville. 3 pp.

Baracco, A. 1977. Instream flow requirements in Dry Creek, Sonoma County, below Warm Springs Dam. CFG, Region 3, unpubl. Report, 34 pp.

Behnke, R. J. 1992. Native trout of western North America. Am. Fish. Soc. Monograph 6. 275 pp.

Bisson, P. B., J. Nielson, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 in Proc. Sympos. Acquisition and Utilization of Aquatic Habitat Inventory Information, Portland, Oregon, October 28-30, 1981.

Bjornn, T. C. 1969. Embryo survival and emergence studies. Job No. 5, Federal Aid in Fish and wildlife Restoration. Job Completion Rept. Project F-49-R-7. Idaho Fish and Game Dept., Boise. 11 pp.

Bond, C. E. 1963. Distribution and ecology of freshwater sculpins, genus *Cottus*, in Oregon. PhD Thesis, University of Michigan, 198 pp.

Bovee, K. D. 1978. A guide to stream habitat analysis using the instream flow incremental methodology. IFIM Paper NO. 12 FWS/OBS-82/26. U. S. Fish and Wildlife Service.

Brauer, C. O. 1971. A study of the wester sucker *Catostomus occidentalis* Ayres in lower Hat Creek, Califonia. M. S. Thesis, Calif. State University, Humboldt, Arcata. 41 pp.

Brett, J. R. and J. M. Blackburn. 1981. Oxygen requirements for growth of young coho (*Oncorhynchus kisutch*) and sockeye (*O. nerka*) salmon at 15 °C. Can. J. Fish. Aquat. Sci. 38: 399-404.

Briggs, J. C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Calif. Fish Game 94: 62 pp.

Cech, J. J. and C. A. Myrick. 1999. Steelhead and chinook salmon bioenergetics: temperature, ration and genetic effects. Univ. Calif. Water Resources Center, Davis, CA. UCAL-WRC-W-885. 72 pp.

Cherry, D. S., K. L. Dickson, J. Cairns Jr. and J. R. Stauffer. 1977. Preferred, avoided and lethal temperatures selected and avoided by fish at various acclimation temperatures. J. Fish. Res. Bd. Can. 32: 485-491.

Cloern, J. E. 1976. The survival of coho salmon (*Oncorhynchus kisutch*) eggs in two Wisconsin tributaries of Lake Michigan. Amer. Midl. Nat. 96: 451-561.

CMARP (Comprehensive Monitoring Assessment and Research Program Steering Committee). 1994. A proposal for the development of a comprehensive monitoring assessment and research program. Developed for CALFED. Final Report, April 24, 1998. 55 pp.

Cooper, A. C. 1965. The effect of transported stream sediments on the survival of sockeye and pink salmon eggs and alevins. Int. Pac. Salmon Fish. Comm. Bull. 18: 71 pp.

Coutant, C. C. 1977. Compilation of temperature preference data. J. Fish. Res. Bd. Can. 34: 739-745.

Craigie, D. E. 1963. An effect of water hardness in the thermal resistance of rainbow trout, *Salmo gairdneri* Richardson. Can. J. Zool. 41: 825-830.

Currie, R. J., W. Bennett and T. L. Beitinger. 1998. Critical thermal minima and maxima of three freshwater game fish species acclimated to constant temperatures. Env. Bio. Fish. 51: 187-200.

Delisle, G. E. and B. E. Eliason. 1961. Stream flow required to maintain trout populations in the Middle Fork Feather River Canyon. Water Proj. Branch Rept. No. 12, Appendix, Calif. Dept. Fish and Game, Sacramento. 19 pp.

Dickson, I. W. and R. H. Kramer. 1971. Factors influencing scope for activity and active standard metabolism of rainbow trout (*Salmo gairdneri*). J. Fish. Res. Bd. Can. 28(4): 587-596.

Dockray, J. J., I. J. Morgan, S. D. Reid and C. M. Wood. 1998. Responses of juvenile rainbow trout, under food limitations to chronic low pH and elevated summer temperatures, alone and in combination. J. Fish. Biol. 52: 62-82.

Doudoroff, P. and D. L. Shumway. 1970. Dissolved oxygen requirements of freshwater fishes. U. N. Food Agric. Org., Tech. Paper 86. 291 pp.

Eimoto, D and P. Walkup. 1980. California Department of Fish and Game Stream Survey, Corte Madera and San Anselmo creeks, September 9-10, 1980. Calif. Dept. Fish and Game Files, Region 3, Yountville. 11 pp.

Federal Register. 1998. Endangered and threatened wildlife and plants; listing of several evolutionarily significant units of west coast steelhead. Federal Register. Volume 63: 32996-32998.

Federal Register. 1997. Endangered and threatened species: listing of several evolutionary significant units (ESU's) of west coast steelhead. Federal Register. Volume 62: 43937-43954.

Folmar, L. and W. Dickhoff. 1980. The parr-smolt transformation (smoltification) and seawater adaptation in salmonids. Aquaculture. 21: 1-31.

Fry, D. H. 1936. Life history of *Hesperoleucas venustus* Snyder. Calif. Dept. Fish and Game 22(2): 65-98.

Fry, F. E. J. 1971. The effect of environmental factors on the physiology of fish. *In* "Fish Physiology", Volume 6 (W. S. Hoar and D. J. Randall, editors). Academic Press, N.Y., N.Y.

Fulton, L. A. 1970. Spawning areas and abundance of steelhead and coho, sockeye and chum salmon in the Columbia River Basin: past and present. Natl. Mar. Fish. Serv. Spec. Sci. Rept. Fish. 618. 37 pp.

Garside, E. T. and J. S. Tait. 1958. Preferred temperature of rainbow trout (*salmo gairdneri* Richardson) and its unusual relationship to acclimation temperature. Can. J. Zool. 36: 563-567.

Hagen, D. W. 1967. Isolating mechanisms in three-spine stickleback (*Gasterosteus*). J. Fish. Res. Bd. Can. 24(8): 1637-1692.

Hall, J. D. and R. L. Lentz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 *in* T. G. Northcote (ed) Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Univ. British Columbia, Vancouver. 388 pp.

Hartman, G. F. and C. A. Gill. 1968. Distribution of juvenile steelhead and cutthroat trout (*Salmo gairdneri* and *S. clarki clarki*) within streams in southwestern British Columbia. J. Fish. Res. Bd. Can. 25(1): 33-48.

Hokansen, K. E. F., C. F. Kleiner and T. W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations in specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri*. J. Fish. Res. Bd. Can. 34: 639-648.

Holt, R. A., J. E. Sanders, J. L. Zinn, J. L. Fryer, and K. S. Pilcher. 1975. Relation of water temperature to *Flexibacter columnaris* infection in steelhead trout (*Salmo gairdneri*), coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon. J. Fish. Res. Bd. Can. 32: 1553-1559.

Hooper, D. R. 1973. Evaluation of the effects of flows on trout stream ecology. Pacific Gas and Electric Company, Dept. Eng. Res., Emeryville, CA 97 pp.

Horner, N. and T. Bjornn. 1976. Survival, behavior, and density of trout and salmon fry in streams. Univ. of Idaho, For. Wildl. Exp. Stn., Contract 56, Prog. Rept. 1975. 38 pp.

Hunter, J. W. 1973. A discussion of game fish in the State of Washington as related to water requirements. Report by the Washington State Department of Game, Fishery Management Division, to the Washington state Department of Ecology, Olympia.

Hynes, H. B. N. 1950. The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungititius*) with review of methods used in studies of the food of fishes. J. Anim. Ecol. 19(1): 36-58.

Jones, D. R. 1971. The effect of hypoxia and anemia on the swimming performance of rainbow trout (*Salmo gairdneri*). J. Exp. Biol. 55: 541-551.

Jones, W. 1969. Corte Madera Creek, Marin County, Steelhead population survey. November 25, 1969. Calif. Dept. Fish and Game Files, Region 3, Yountville. 9 pp.

Kaya, C. M. 1978. Thermal resistance of rainbow trout from a permanently heated stream and of two hatchery strains. Prog. Fish. Cult. 40: 138-142.

Koski, K. V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis, Oregon State University, Corvallis. 84 pp.

Kottcamp, G. 1973. Variation, behavior and ecology of the prickly sculpin (*Cottus asper* Richardson) from the San Joaquin River, California. M. A. Thesis, California State University, Fresno, 56 pp.

Kresja, R. J. 1965. The systematics of the prickly sculpin, *Cottus asper*: an investigation of genetic and non-genetic variation within a polytypic species. Ph.D. Thesis, University of British Columbia, 109 pp.

Lawrence, E., editor. 1995. Henderson's dictionary of biological terms. Eleventh edition. John Wiley & Sons, New York.

Lee, R. M. and J. N. Rinne. 1980. Critical thermal maximum of five trout species in the southwestern United States. Trans. Amer. Fish. Soc. 109: 632-635.

Leidy, R. 1997. Fisheries Biologist for U.S. EPA. Fish sampling data sheets, Corte Madera Creek, San Anselmo Creek, Ross Creek, Fairfax Creek

Leidy, R. 1993. Fisheries Biologist for U.S. EPA. Fish sampling data sheets for creeks within the Corte Madera Creek Watershed

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

Leitriz, E. and R. C. Lewis. 1980. Trout and salmon culture. Calif. Fish. Bull No. 164. 197 pp.

Margolin, M. 1978. The Ohlone Way, Indian life in the San Francisco-Monterey Bay Area. Heyday Books, Berkeley.

Marshall, J., C. Denisoff, and D. Hopkins. 1994. Corte Madera Watershed resource evaluation and information report. California Regional Water Quality Control Board, San Franciso Region, Oakland. April, 1994. 38 pp.

Marshall, J., C. Denisoff. 1994. Corte Madera Watershed Report field methods and results of sampling study conducted in June 1992 and February 1993. California Regional Water Quality Control Board, San Franciso Region, Oakland. April, 1994.

Matthews, K. R. and N. H. Berg. 1997. Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. J. Fish Biol. 50: 50-67.

McCarthy, J. F. and L. R. Shugart. 1990. Biomarkers of environmental contamination. Lewis Publishers. 457 pp.

McMahon, T, and G. Reeves. 1989. Large woody debris and fish. Paper presented at the COPE workshop "Silvicultural management of riparian areas for multiple resources" held at Salishan Lodge, Gleneden Beach, Oregon on 12-13 December 1989. USDA Forest Service Pacific Northwest Research Station, Portland and Oregon State University College of Forestry, Corvallis.

McNeil, W. J. and W. H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed material. U. S. Fish and Wild. Serv. Sec. Sci. Rep. Fish. 469. 15 pp.

Michaels, J. and B. Thomson. 1969. California Department of Fish and Game Stream Survey, Corte Madera Creek, Marin County. July 24-25, 1968. Calif. Dept. Fish and Game Files, Region 3, Yountville. 2 pp.

Millikan, A. E. 1968. The life history and ecology of *Cottus asper* Richardson and *Cottus gulosus* (Girard) in Conner Creek, Washington. M.S. Thesis, University of Washington, 81 pp.

Moyle, P. B. 1976. Inland Fishes of California. U.C. Press. 405 pp.

Mundie, J. H. 1969. Ecological implications of the diet of juvenile coho in streams. Pages 135-152 *in* T. G. Northcote, editor. Symposium on salmon and trout in stream. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

National Marine Fisheries Service. 1997. Fish surveys of creeks in the Corte Madera Creek Watershed. NMFS, Tiburon Laboratory, September 19, 1996 and May 14-15, 1997.

Needham, P. R. and R. Gard. 1959. Rainbow trout in Mexico and California with notes on the cutthroat series. Univ. Calif. Pub. in Zool. 7: 1-124.

Noggle, C. C. 1978. Behavioral, physiological and lethal effects of suspended sediment on juvenile salmonids. Masters Thesis. University of Washington, Seattle.

Orcutt, D. R., B. R. Pulliam, and A. Arp. 1968. Characteristics of steelhead trout redds in Idaho streams. Trans. Amer. Fish. Soc. 97: 42-45.

Patten, B. G. 1971. Spawning and fecundity of seven species of northwest American *Cottus*, Am. Midl. Nat. 85(2): 493-506.

Peterson, R. H., A. M. Sutterlin and J. L. Metcalfe. 1979. Temperature preference of several species of *Salmo* and *Salvelinus* and some of their hybrids. J. Fish. Res. Bd. Can. 36: 1137-1140.

Phillips, R. W. and H. J. Campbell. 1961. The embryonic survival of coho salmon and steelhead trout as influenced by some environmental conditions in gravel beds. Fourteenth annual report. Pacific Marine Fisheries Commission, Portland, Oregon.

Phillips, R. W., R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Amer. Fish. Soc. 104: 461-466.

Reeves, G. H., F. H. Everest, and T. E. Nickelson. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. Gen. Tech. Rept. PNW-GTR-245. U.S. Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Reiser, D. W. and T. C. Bjornn. 1979. Habitat requirements of anadromous salmonids. Pages 1-54 *in* W. R. Meehan, editor. Influence of forest and rangeland management on anadromous fish habitat in western North America. Gen. Tech. Rept. PNW-96. USDA For. Serv., Pacific Northwest For. Range Exp.Stat, Portland,

Rich, A. A. 1999. Steelhead Trout Plan, Corte Madera Creek Watershed Marin County, California. Quality Assurance Project Plan. Prep. for Friends of Corte Madera Creek Watershed, Larkspur, Calif. December 10, 1999. 15 pp + attachments.

Rich, A. A. 1995. Preliminary outline for a Corte Madera Creek Watershed Management Plan. Presented to Friends of the Corte Madera Creek Watershed, April 29, 1995. 31 pp + appendices.

Rich, A. A. 1991. The impacts of timber harvest practices on the fishery resources of the Navarro River Watershed, Mendocino County, California. Prep. for Louisiana Pacific Corp. July 7, 1991.

Rich, A. A. 1987. Water temperatures which optimize growth and survival of the anadromous fishery resources of the lower American River. Prep. for Sacramento County, Sacramento. April 1987. 24 pp.

Rich, A. A. 1983. Smolting: Circulating Catecholamine and Thyroxine Levels in Coho Salmon (*Oncorhynchus kisutch*). Ph.D. Dissert., University of Washington, Seattle. 97 pp.

Rich, A. A. 1979. The use of Stress to Quantitate the Survival Potential of Three Strains of Trout. M. S. Thesis, University of Washington, Seattle. 65 pp.

Scoppettone, G. 1976. The status of steelhead and silver salmon spawning success in Redwood, Pine Gulch, Lagunitas, and Corte Madera creeks, Marin County, mid-February, 1976. March 25, 1976, Calif. Dept. Fish and Game Files, Region 3, Yountville. 2 pp.

Shapovolov, L. and A. C. Taft. 1954. The life histories of steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*). Calif. Dept. Fish and Game Fish Bull. 98: 373 pp.

Smith, A. K. 1973. Development and application of spawning velocity and depth criteria for Oregon salmonids. Trans. Am. Fish. Soc. 102(2): 312-316.

Snyder, J. D. 1905. Notes on the fishes of the streams flowing into the San Francisco Bay area. Calif. Dept. Fish. Game Water Projects Branch Rept. 1. 225 pp.

Snyder, R. J. and H. Dingle. 1989. Adaptive, genetically based differences in life history between estuary and freshwater threespine sticklebacks (*Gasterosteus aculeatus*). Can. J. Zool. 67: 2448-2454.

Spigarelli, S. and M. M. Thommes. 1979. Temperature selection and estimated thermal acclimation by rainbow trout (*Salmo gairdneri*) in a thermal plume. J. Fish. Res. Bd. Can. 36: 366-376.

Stetson Engineers, Inc. 2000. Geomorphic Assessment of the Corte Madera Creek Watershed. Prep. for Friends of Corte Madera Creek Watershed and Marin County Department of Public Works. 40 pp + appendices.

Strange, R. J., R. B. Petrie, and J. J. Cech, Jr. 1993. Slight stress does not lower critical thermal maximum in hatchery-reared rainbow trout. Folia Zool. 42: 251-256.

Thompson, K. E. 1972. Determining streamflows for fish life. *In*: proceedings, instream flow requirement workshop. Pacific Northwest River Basins Commission, Portland, Oregon. pp 31-50.

Threader, R. W. and A. H. Houston. 1983. Heat tolerance and resistance in juvenile rainbow trout acclimated to diurnally cycling temperatures. Comp. Biochem. Physiol. 75A: 153-155.

Tinbergen, N. 1953. Social Behavior of Animals. Methuen and Company, Limited, London. 150 pp.

Tippets, W. E. and P. B. Moyle. 1978. Epibenthic feeding by rainbow trout (*Salmo gairdneri*) in the McCloud River, California. J. Animal Ecol. 47: 549-559.

Utter, F. M., D. Campton, S. Grant, G. Milner, J. Seeb, and L. Wishard. 1980. Population structures of indigenous salmonid species of the Pacific northwest. Pages 285-304 *in* W. J. McNeil and D. C. Himsworth, eds. Salmonid ecosystems of the north Pacific. Oregon State Univ. Press and Oregon State Univ. Sea Grant Coll. Prog. Corvallis, OR.

Van Deventer, J. S. and W. S. Platts. 1986. Sampling and estimating populations from streams. Trans. N. A. Wildlife and Natural Res. Confer. 48: 349-354.

Van Deventer, J. S. and W. S. Platts. 1983. User's guide for MICROFISH 3.0. A software package for processing electrofishing data obtained by the removal method. U. S. F. S. Forestry Sciences Lab., Boise, Idaho.

Wagner, H. H. 1974. Photoperiod and temperature regulation of smolting in steelhead trout (*Salmo gairdneri*). Can J. Zool. 52: 219-234.

Whitmore, C. M., C. E. Warren, and P. Doudoroff. 1960. Avoidance reactions of salmonids and centrarchid fishes to low oxygen concentrations. Trans. Amer. Fish Soc. 89(1): 17-26.

Withler, I. F. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific Coast of North American. J. Fish. Res. Bd. Can. 23(3): 365-392.

Wurtsbaugh, W. A. 1977. Effects of temperature, ration, and size on the growth of juvenile steelhead trout, *Salmo gairdneri*. M. S. Thesis, Oregon State University, Corvallis, Oregon. 69 pp.

Wurtsbaugh, W. A. and G. E. Davis. 1977. Effects of temperature and ration level on the growth and food conversion efficiency of *Salmo gairdneri*, Richardson. J. Fish. Biol. 11: 87-98.

Zaugg, W. S. and H. H. Wagner. 1973. ATPase activity related to parr-smolt transformation and migration in steelhead trout (*Salmo gairdneri*): influence of photoperiod and temperature. Comp. Biochem. Physiol. 45B: 955-965.

Zaugg, W. S., B. L. Adams, and L. R. McLain. 1972. Steelhead migration: potential temperature effects as indicated by gill adenosine triphosphatase activities. Science. 176: 415-416.

APPENDICES

APPENDIX A

SAMPLE SURVEY SHEETS

AND

QA/QC PLAN

TITLE AND APPROVAL PAGE

Steelhead Trout Plan, Corte Madera Creek Watershed
Marin County, California

Friends of Corte Madera Creek Watershed

December 10, 1999

Project Manager:	Sandra Guldman (signature) Sandra Guldman	12/10/99 (date)
Project QA Officer:	Gregory Andrew (signature) Gregory Andrew	12/10/99 (date)
US EPA Project Manager:	(signature) Sam Ziegler	(date)
US EPA Region 9 QA Officer:	(signature) Vince S. Fong, P.E.	(date)

TITLE AND APPROVAL PAGE

Steelhead Trout Plan, Corte Madera Creek Watershed
Marin County, California

Friends of Corte Madera Creek Watershed

December 10, 1999

Project Manager: Sandra Guldman (signature) — 12/10/99 (date)

Sandra Guldman

Project QA Officer: Gregory Andrew (signature) — 12/10/99 (date)

Gregory Andrew

US EPA Project Manager: ______________ (signature) ______ (date)

Sam Ziegler

US EPA Region 9 QA Officer: ______________ (signature) ______ (date)

Vince S. Fong, P.E.

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I. PROJECT MANAGEMENT

I.A. DISTRIBUTION LIST

- Sandra Guldman, Friends of Corte Madera Creek Watershed
- Cheryl Lovato Niles, National Fish and Wildlife Foundation
- Vance S. Fong, U.S. Environmental Protection Agency (EPA)
- Sam Ziegler U.S. EPA Region 9 Quality Assurance Officer
- Greg Andrew, Marin Municipal Water District, Quality Assurance Manager
- Elizabeth Lewis, Marin County Department of Public Works
- Rick Wantuck, National Marine Fisheries Service
- William Cox, California Department of Fish and Game

I.B. RESPONSIBILITY

Dr. Alice A. Rich will be responsible for this fishery resources project. She will oversee all aspects of the project. Dr. Alice A. Rich, founder and manager of A. A. Rich and Associates (***AAR***), has over 25 years experience in a wide range of fishery resources-related projects. Her professional experience encompasses work as a fisheries consultant, fisheries biologist, fish physiologist, analytical chemist, and university lecturer. She is a recognized expert in fishery resources habitat needs and fish physiology and has been called upon as a an expert witness on the impacts of water temperature, water quality, water diversions, migration barriers, timber harvest practices, and catch-and-release fishing on fishery resources (see Dr. Rich's résumé for additional information on her credentials).

The Quality Assurance Manager for the project is Gregory Andrew, Senior Aquatic Ecologist Marin Municipal Water District (MMWD). Mr. Andrew is MMWD's representative on the Advisory Committee and its Technical Subcommittee.

I.C. BACKGROUND

The Corte Madera Creek Watershed covers 28 square miles located in the eastern part of central Marin County. It drains into San Francisco Bay just south of the San Quentin Peninsula, approximately 10 miles north of the Golden Gate. The watershed ranges in elevation from sea level to 2,571 feet at the East Peak of Mount Tamalpais. Corte Madera Creek and its tributaries are among the few streams flowing to San Francisco Bay that retain a steelhead trout population.

Stream surveys conducted by Leidy (1984) and the California Department of Fish and Game (CDFG) from 1960 through 1980 (Allen 1960; Jones 1969; Michaels and Thomas 1968; Scoppettone 1976; Eimoto and Walkup 1980) demonstrated a wide assortment of fishes inhabiting Corte Madera Creek, reflecting both the estuary and freshwater environments. However, the five dominant species present in Corte Madera Creek and its tributaries included only sucker, roach, stickleback, sculpin, and rainbow/steelhead trout, with occasional sightings of coho salmon. In 1992, the Regional Water Quality Control Board (RWQCB) staff conducted field surveys, using both visual observation and beach seine nets (RWQCB 1994, 1992). During their survey, the three most frequently observed species were the California roach, Sacramento sucker, and three-spine stickleback. Given the number of successive drought years and the timing of the sampling, few salmonids were anticipated; eleven rainbow/steelhead trout were trapped and others observed.

Although population studies are not available, comparison of historical and anecdotal information with more recent information strongly suggests that steelhead trout populations have declined in the last few decades in the Corte Madera Creek Watershed. Given the urbanized nature of the lower watershed, it is likely that the rainbow/steelhead trout is the only salmonid species persisting to the present time. Stressors include high water temperatures, hydrograph changes, water quality degradation, streambed changes, loss of riparian habitat, land use and human impacts. However, in spite of these problems, the Corte Madera Creek Watershed has been identified by EPA (Leidy 1984), as one of the watersheds that should be targeted for protection. The proposed study will identify how this trend can be reversed and present an action plan for the restoration of the Corte Madera Creek Watershed as long-term steelhead trout habitat.

Although this study targets steelhead trout, habitat improvements in the riparian corridors will also benefit riverine aquatic habitat and the neotropical migratory bird guild that uses the riparian corridor. Similarly, improvements in water quality and water flows likely will benefit saline emergent wetland habitats in the lower reaches of the watershed that may support other species of fish, such as the Sacramento splittail and striped bass. San Francisco Bay will also benefit from improvements in water quality, flow, and temperature.

To address the issues raised, regarding steelhead trout, ***AAR*** was contracted to undertake a fishery resources investigation and prepare a Fishery Resources Technical Report. The Technical Report will address the status of the existing fishery resources conditions within the Corte Madera Creek Watershed. More specifically, the objectives of this study are to:

- Provide life stage and habitat information on the rainbow/steelhead trout;
- Provide a historical perspective, to the extent possible, on the fishery resources conditions;
- Assess water temperature conditions from April to October;
- Assess physical habitat conditions during the low-flow season;
- Assess fishery resources population conditions during the low flow season;
- Identify limiting factor (s) for the rainbow/steelhead trout;
- Design measures which will help restore rainbow/steelhead populations; and,
- Design a Steelhead Monitoring Plan for the Corte Madera Creek Watershed.

The steelhead trout plan is one component of a comprehensive watershed plan to improve water quality, fishery resources, and native vegetation and wildlife in the Corte Madera Creek Watershed. The steelhead trout plan will identify the factors limiting the steelhead trout population, formulate corrective actions, and describe how to monitor the success of those actions. Preparation of the plan will be an integral part of the watershed planning process, which begins in February 1999, with an erosion and sedimentation study of the watershed. The fishery resources assessment, conducted as part of this program, will provide essential information (which is lacking at this time) about creek biota. Implementation of the plan will improve steelhead trout habitat and population size.

The steelhead trout plan will focus on identifying limiting factors and formulating a practical restoration plan that will enjoy local support. To that end, an Advisory Committee, comprised of representatives from local government, federal and state agencies, community groups, and other stakeholders, will review documents and guide formulation of the restoration plan. The proposed effort will occur concurrently with the erosion/sedimentation planning.

I.D. TASKS /SCHEDULE

Task 1:	Review and analysis of existing information	May-October 1999
Task 2:	Fish habitat surveys	August - October 1999
Task 3:	Fish population surveys	August- October 1999
Task 4:	Thermograph installation and operation	April - October 1999
Task 5:	Analysis and report of results	
	Draft Fishery Resources Technical Report	January 15, 2000
	Final Fishery Resources Technical Report	July 31, 2000
Task 6:	Restoration plan to address limiting factors	
	Draft Technical Report	March 15, 1999
	Final Technical Report	July 31, 2000
Task 7:	Monitoring Plan	
	Draft Technical Report	March 15, 1999
	Final Technical Report	July 31, 2000

The final work product will be a Fishery Resources Technical report describing the full effort, with the following table of contents:

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II. METHODOLOGY

II.A. GENERAL APPROACH

Understanding the biological and physical factors which are necessary to sustain the steelhead trout population in the Corte Madera Creek Watershed is critical to developing management strategies to improve the habitat and enhance populations. Life history events for any organism must be discussed in concert with key ***life requisites***. Life requisites are those features of an organism's environment which are essential to its continued survival and reproductive success. Critical life requisite variables for the rainbow/steelhead trout include:

- Acceptable water temperatures and water quality;
- Accessibility to spawning sites;
- Adequate streamflows;
- Appropriate substrate composition; and,
- Abundant food.

When life requisites are not met, or are limited in some way, the organism's survival and reproductive success can be jeopardized. The factors that limit fish populations are called limiting factors. One extremely important concept in enhancing fish populations is the following:

> ***If there is no change in the limiting factors(s) for the population(s), no increase in the target population(s) will occur.***

Some limiting factors, such as not enough woody debris (habitat which trout prefer and need), can be influenced by human intervention. Other limiting factors, such as the lack of water, often cannot be altered. Thus, before one can assess whether or not a watershed can be restored, one must identify the following:

- The requirements of the fishes; and,
- Any limiting factors which may exist.

As each life stage of the trout has specific life requirements, it is imperative to understand both the events of each life stage and the factors that affect those events.

The anadromous steelhead and the resident rainbow trout require special conditions for successful spawning, egg development and hatching, growth and survival of juveniles, and smoltification (during which the anadromous fish change from a freshwater to a seawater animal, and emigrate to sea). Although, many general requirements (e.g., good water quality, abundant food, etc.) are the same for the steelhead and rainbow trout, specific factors may limit production (i.e., limit the number of fish in the stream). For example, barriers to adult fish immigration may limit the success of spawning for steelhead trout. Thus, it is essential to understand what the Corte Madera Creek Watershed has to offer these fish, before one can design measures that will help restore the trout to the watershed. This study is limited to the freshwater portions of the creek and will not cover the condition of the estuary or its ability to support smolts.

II.B. REVIEW OF EXISTING INFORMATION

Thus, to understand what the Corte Madera Creek Watershed has to offer steelhead trout, one must first collect information on habitat requirements, and historical and existing conditions. Existing information will be reviewed, including previous fish surveys and data on water quality, water flow, and water temperatures, and anecdotal information.

Sources of information will include, but not be limited, to the following: (1) Previous surveys; (2) Previous reports; (3) Biologists familiar with the area; (4) Data from agency files; (5) oral histories of long-time residents; (6) Old newspaper stories; (7) GIS maps from Marin County; (8) Aerial photographs; and, (9) Old photographs and maps.

There are no records of quantitative fish population surveys having been conducted in the watershed, so all of the historic information is qualitative. It will be used for the background information it provides about the historic and current diversity of species in the watershed, but it will not (indeed it cannot) be used to provide numerical population estimates. For anecdotal information, an attempt will be made to obtain the same information from more than one source.

Quantitative water flow information is available from one gauging station in the watershed, which for many years was maintained by the USGS and is now maintained by Marin County. These data have been evaluated by the Army Corps of Engineers and the Marin County Water Conservation and Flood Control District and are considered an accurate record of flow within the main Corte Madera Creek channel just upstream of the Lagunitas Road Bridge in Ross. There are no other gauging stations in the watershed. The gauging station does not accurately reflect discharge from the watershed during flood conditions because much of the flow is out of the channel during floods. Other observations about streamflow are anecdotal and report observations about areas where there are pools that persist during the summer or, alternatively, areas where the streambed is dry.

Water quality sampling is not part of this project, due to the limited budget. However, there are some historical water quality data (Regional Water Quality Control Board, USACE files), which will be reviewed. If water quality appears to be a problem, the Restoration Measures and Monitoring Plan (Chapters 10 and 11 in the report) will include recommendations for water quality measurements in the future.

II.C. FIELD SAMPLING METHODS

II.C.1. Summary Table

Parameter	Sampling Equipment	Sampling Method
Physical Habitat *	Tape measure, meter stick, range finder, visual, camera	Measurements in metric units Visual (type of habitat, type of substrate, cover, etc.)
Water Temperature **	Thermographs (Tidbits and Hobo Temps)	Continuously (every 10 minutes a recording is made) recording thermograph
Fish Population Sizes ***	Backpack electrofisher	Electrofishing
Fish Measurements	Measuring board, scales	Lengths (fork for salmonids) and weights in metric units

* See Attachment 1 for sample habitat survey data sheet
** See Attachment 2 for volunteers' instructions, sample weekly monitoring log, and sample thermograph output
*** See Attachment 3 for sample electrofishing survey data sheet

II.C.2. Physical Habitat

To accurately describe the existing fishery resources conditions in the creeks, identification of the components of fish habitat is essential. To describe the stream habitat conditions, **Habitat Typing** (quantitative measurements of length, width, depth of each habitat type) and general descriptive measurements will be used (see Attachment 1 for sample physical habitat data sheet). Habitat Typing consists of measuring the individual habitat units, or types, within a selected stream. This information is then compared with the habitat needs of the fishes collected from the stream.

Summer fish habitat surveys, using Habitat Typing (see Attachment 4 for Bisson *et al.* (1982) which describes the methodology and defines terms used in habitat typing), will be conducted in all portions of the Corte Madera Creek system accessible to steelhead where water is present at the time the surveys are conducted. This includes Corte Madera Creek (Ross, San Anselmo), San Anselmo Creek (San Anselmo and Fairfax), Cascade Creek (Fairfax), Sleepy Hollow Creek (adjacent to Butterfield Road in San Anselmo), and Ross Creek (Ross). Because of budgetary constraints, Fairfax Creek will not be surveyed. Habitat typing will be conducted beginning at the mouth of Corte Madera Creek and its tributaries and extend to the headwaters of the Corte Madera Creek watershed.

Dr. Rich has modified the methodology to include artificial habitats created in urban and some coastal areas, but not specifically identified in the methodology developed by Bisson *et al.* (1982). For example, stream banks composed of riprap, gabions, concrete, or wood walls would not be considered natural habitats, whereas a stream bank composed of an undercut bank would be considered a natural habitat according to Bisson *et al.* (1982). However, both natural and artificial pool habitat is often inhabited by fish. Thus if one were to encounter a lateral scour pool associated with an undercut bank, one would call it a "lateral scour pool associated with an undercut bank," according to Bisson *et al.* (1982). By the same reasoning, if one or both banks are composed of riprap and this riprap is the physical attribute creating the lateral scour pool, this habitat would be called a "lateral scour pool associated with riprap." Or if a lateral scour pool had been created by a concrete wall, the habitat would be called a "lateral scour pool associated with cement wall."

Dr. Rich will conduct all habitat typing surveys. She has conducted over 50 habitat surveys during the past 16 years.

II.C.3. Water Temperatures

Thermographs ("tidbits" or "hobo temps", Onset Computer, Mass.) will be placed in representative areas of each reach (at least duplicates of each habitat type for each creek) of the Corte Madera, Ross, and Cascade, and Sleepy Hollow creeks. These thermographs are extremely reliable and we have used them for years on numerous creeks and rivers throughout the western states. They are adjusted to record temperature every 10 minutes, 24 hours a day, prior to installation.

As these creeks have a lot of summer traffic, in the form of children, primarily, there is a good chance that some of the thermographs could be removed. Therefore, we need to make certain that we have "downloaded" as much of the data as possible, up to the date when the thermograph was taken. To maximize the amount of data collected, we will: (1) Replace each thermograph on a monthly basis (i.e., download existing thermograph and install a new one at the site); (2) Monitor each thermograph site weekly.

The number and location of each thermograph will be determined by Dr. Rich, first during a reconnaissance visit to the creeks, prior to thermograph installation and during subsequent visits to the creeks, as they dry up. Many of the thermographs will be removed by mid-July, as many of the stream reaches will have dried up. Figure 1 shows the locations of thermographs when they were placed in the streams during April and May 1999. When the thermographs need to be removed, Dr. Rich will assess whether or not there are other sites where water temperature data would provide useful information. Dr. Rich will install and remove all thermographs.

AAR's biologists and trained volunteers will maintain the thermographs throughout their installation, under Dr. Rich's supervision. Dr. Rich will train each of the volunteers (see Attachments 1 and 2 for instructions to volunteers). ***AAR's*** biologists are already familiar with thermograph monitoring, having monitored thermographs on numerous projects.

At the time of initial installation, each location of each thermograph will be photographed and the latitude and longitude recorded using a Garmin GPS 48 Personal Navigator. To monitor the water and habitat condition of each site, photographs will be taken of each site (one of site, one facing upstream, and one facing downstream), on a weekly basis. Monitors will also check weekly to determine whether or not the thermograph is: (a) working (from the blinking light on each thermograph); (b) immersed in water; and (c) residing in the original habitat in which it was placed. If any of the conditions do not apply, Dr. Rich will be contacted and she will asses the situation and either move or replace the thermograph.

To preclude the possibility of losing data sheets, two sets of data sheets and two sets of photographs will be stored at all times in the following locations: (1) One set in ***AAR's*** office; and, (2) One set at each volunteer's and/or ***AAR's*** biologist's house.

II.C.4. FISH POPULATION ESTIMATES, Fish Size and Fish Age

Electrofishing is commonly used by fisheries biologists for collecting fish. However, to minimize the capture stress on the fishes, this method must be used with caution and only by trained personnel. When used quickly, efficiently, and knowledgeably, this method is less stressful than that of beach seining and/or other collection techniques (Rich 1983, 1979). Dr. Rich is an expert on the stress physiology of fishes, particularly salmonids. Her methods minimize stress on fishes, as demonstrated by previous studies (Rich 1983, 1979).

To accurately sample the number and species of fishes in the creeks, it will be necessary to electrofish **representative samples** of each habitat type observed in the creek. Ideally, to provide a statistically sound study, one needs, first, to identify the number of **habitat types,** and then sample (randomly) about 30% of each habitat type. As there are budgetary constraints on this project, such a methodology may not be practical. However, at least one representative of each habitat type will be chosen for fish sampling for each creek. In addition, for the more common types of habitat, numerous habitats will be chosen for the fish sampling. Based on the results of nearly 60 habitat and electrofishing surveys she has conducted, Dr. Rich has determined that, provided from 10 - 30% of each habitat type is electrofished for a given creek, statistically meaningful results can be obtained. The budget for this project will probably allow 10% of each habitat type to be electrofished. We will sample at least two of each habitat type for each creek.

The electrofishing will proceed as follows. To prevent the fish from escaping during the sampling procedure, block nets will be placed at the lower and upper ends of each sampling site. To sample the site, an electrofisher (Smith-Root Type 12 backpack) will be used. The fish sampling crew will consist of one "electrofisher", who operates the electrofishing unit, and one or two netters, depending upon the size of the habitat. Starting at the downstream block net, the electrofisher will wade upstream through the sampling station, operating the electrofisher. Stunned fish will be netted and placed in water-filled buckets. In order to estimate fish population sizes by the maximum-likelihood method, three or more passes will be completed at each station (Van Deventer and Platts 1983, 1986) (see Attachment 3 for sample electrofishing survey sheet).

After each pass, fish will be identified to species and enumerated. For each fish, the following items will be recorded: species name, fork length, and weight. In addition, for determination of age, scales will be removed from the upper left lateral area of each of the salmonids. After the electrofishing is completed, the fishes will be returned to the sampling station from which they were collected. After the electrofishing is completed at each station, the physical dimensions of the habitat (e.g., length, depth, width) will be recorded. The dimensions will be used to calculate the number of fish (by species) per square meter of stream. The fish are weighed using an Ohaus scale accurate to 0.1 gm. The scale is calibrated before each field session using standard weights certifiable to the National Institute of Standards and Testing.

To reduce the stress of capture on the fishes, particularly as trout are sensitive, the fish will be placed in a buffered (sodium bicarbonate to pH 7.0, 75 parts per million) anaesthetic (methane trisulphonate, 50 parts per million); previous studies (Rich 1979, 1983) demonstrated that salmonids exhibited little stress response when such a mixture is used. In addition, a battery-operated pump will aerate the water in the bucket in which the fish are residing, prior to release back into the creek. We also use a special underwater measuring board, designed by Dr. Rich over 10 years ago, which minimizes stress on fish. Finally, rocks will be placed in buckets which have fish residing in them; this reduces the stress on the fish, as well (Rich 1979).

Dr. Rich will select all the electrofishing sites and supervise the electrofishing surveys. The fisheries biologists who work for ***AAR*** and who will be working on this project are well-trained and experienced in electrofishing surveys. All of them have at least five years of electrofishing survey experience.

II.D. DATA ENTRY AND ANALYSIS

The data will be entered into RBASE for Windows 98) , a computer data management program. Population (maximum-likelihood method) size, lengths, weights and total biomass (i.e., total weight of the fish) estimates, together with standard deviations, will be calculated on the computer, using Microfish (Van Deventer and Platts 1983). Statistical analyses will be conducted, using the computer statistical program, SPSS.

Relevant information (e.g., thermograph sites, spawning areas, rearing areas, electrofishing sites, etc.) will be depicted on either the Geographic Information System (GIS) being developed by the Marin County Department of Public Works or the Riparian Station GIS at the San Francisco Bay Model, if either of those systems have been completed in time. If not, detailed maps will be prepared by ***AAR***, which will depict relevant information.

Information collected, including previous studies and anecdotal information, will be analyzed and compared with life stage periodicities (i.e., when each life stage occurs during the year) and requirements for steelhead and rainbow trout (See Attachments 5 and 6 for preliminary data on life stage requirements). As many of the life stage requirements are site specific (e.g., water temperature), the results of the field studies may alter the results of the life state requirements. For example, steelhead trout are temperate (i.e., cool water) fish and, hence, normally require cool (< 60 %F) water temperatures. However, if there is abundant food available, they may thrive at higher water temperatures (Rich 1990; Smith, 1990). Therefore, in the absence of site specific data, it is best to err on the side of caution and identify conservative thermal optimal ranges. However, if the rainbow/steelhead trout in one or more of the creeks were growing well at summer temperatures which exceeded 60 %F, then one could conclude that there was abundant food and the upper optimal thermal range was higher than 60 %F. Obviously, the opposite would be true, as well. Thus, if the trout were very small and did not appear to be growing quickly at temperatures above 60 %F, than the use of 60 %F as an upper optimal temperature would be appropriate.

II.E. REPORTS

Prior to the submittal of the Draft Fishery Resources Technical Report, we will submit drafts of each of the sections (See ID. Tasks/Schedule) for review. A Draft Fishery Resources Report will be prepared which discusses the project (see Table of Contents provided previously). Included in the report will be a Steelhead Trout Restoration Plan and Fishery Resources Monitoring Plan to measure the effectiveness of the Restoration Plan. Once the public has had an opportunity to review the Draft Fishery Resources Technical, Dr. Rich will meet with the Advisory Committee to discuss any further research needs for the project and to review ways in which the Restoration and Monitoring Plans can be implemented. Dr. Rich will incorporate both the public's responses to the Draft Report and the results of the discussions with the Advisory Committee into the Final Fishery Resources Technical Report. This report is a work product and will be submitted by the NFWF contract manager to the EPA for review.

III. QUALITY CONTROL

III.A. REVIEW OF EXISTING INFORMATION

Dr. Rich will be in charge of all information and data collection. When anecdotal information is used, she will attempt to find at least one additional corroborative source. A thorough search for all relevant information will be undertaken. As Dr. Rich has worked extensively in Marin County creeks for years, as well as having grown up here, she has a thorough knowledge of the types of reports, data, and studies that are available.

III.B. PHYSICAL HABITAT SURVEYS

To ensure the collection of complete and useful data, the following activities will be used in connection with the physical habitat data:

- Dr. Rich will conduct all physical habitat surveys; and,
- All data sheets will be checked in the field by Dr. Rich at the end of each field day.

III.C. WATER TEMPERATURE MONITORING

To ensure the collection of complete and useful data, the following activities will be used in connection with the water temperature monitoring activities:

- Use at least two similar (in some cases, we will have more than two) sites for each habitat type in each creek;
- *AAR's* biologists are well-trained and experienced with thermograph monitoring;
- Dr. Rich will train the volunteers to monitor the thermographs;
- The thermographs are hidden well; Dr. Rich secures the thermographs to large landscape bricks and the bricks are then cabled to trees; one would need a pair of wire cutters to cut the cable; as there (unfortunately) are already a number of large bricks in the creeks, it has been our experience

that people have a tendency to ignore such structures; hence, this minimizes the chance that the thermographs will be discovered and tampered with;

- Dr. Rich will install many more thermographs than she usually does for an area this size; thus, if thermographs are lost, we will still have enough data to cover the watershed;

- Weekly monitoring of all sites;

- Dr. Rich's name and phone number are on each of the thermographs; thus, if someone finds one or more of them and is responsible, they can call us; on other projects, people have often called ***AAR*** to report missing thermographs,

- To preclude the possibility of losing data sheets, two sets of data sheets and two sets of photographs will be stored at all times in the following locations: (1) One set in ***AAR's*** office; and, (2) One set at each volunteer's and/or ***AAR's*** biologist's house;

- Dr. Rich reviews all data sheets, including photos on a weekly basis, and, thus, can determine whether or not the area appears to be drying up; if the area is drying up, Dr. Rich will remove thermograph; by reviewing the data sheets each week, Dr. Rich can also check for accuracy on data sheets (e.g., correct film roll number = photograph taken); and,

- Dr. Rich will replace thermographs once per month and download the ones removed, so that if any of the thermographs are taken, we will maximize the amount of data collected.

III.D. FISH POPULATION SURVEYS

To ensure the collection of complete and useful data, the following activities will be used in connection with the electrofishing data, AAR has:

- Two electrofishers and they have been checked out and are ready to use; and

- Six electrofisher batteries and chargers, more than enough for a project this size;

Dr. Rich will:

- Select all electrofishing sites;

- Use well-trained (at least five years' experience) crew, used to conduct electrofishing (including identifying fish, taking scales, and recording lengths and weights) surveys;

- Check all data at the end of each sampling day to ensure that the forms were correctly completed; and,

- Minimize possibility of mortalities (we rarely have any fish kills), using Dr. Rich's methods (see Section II.C.4).

III.E. DATA ENTRY AND ANALYSIS

To ensure the quality and usefulness of the data entered into the computer, the following activities will be used:

- To ensure that all of the required information has been recorded on the data sheets, all data sheets will be checked a second time by the field crew;
- An experienced fisheries technician will enter all data into the computer;
- All data entered into the computer will be double-checked by field crew;
- Any departure from standard operating procedures is recorded in the comments field of the data sheets. As Dr. Rich supervises all activities and has been conducting these types of surveys for over 16 years, there is rarely a departure from the "norm" in the field. As the types of data collection differ, there is no numerical percentage of data that must be valid and reliable in order to use the data for their intended purposes. Thus, for example, if a thermograph ceases to function (e.g., someone removes the thermograph from the water or the thermograph malfunctions) the data collected prior to that time will be used; data collected after the event will be used only when the thermograph is placed in the water and is functioning properly. If there is a faulty thermograph (this is determined when the data are to be downloaded and there is an error message stating that the data cannot be downloaded), the data are not used at all.
- We will try to electrofish at least 10% of each habitat type for each creek to ensure that statistically valid results are derived.
- The program that we use to age the trout is a digitally-based program, developed by National Institutes of Health; this program, modified for use on fish scales and other bony parts of fish by Dr. Rich, enables one to more accurately assess age than either looking under a microscope or using a Microfiche reader; either Dr. Rich or one of her trained biologists will read the scales and;
    - Dr. Rich will be in charge of all analyses of data.

III.F. REPORTS

Dr. Rich will be responsible for writing all reports for this project. These reports are work products under the grant and will be submitted by the NFWF contract manager to the EPA for review.

IV. REFERENCES CITED

Allen, J. T. 1960. Corte Madera Creek, Marin County, Stream Survey. August 1-15 and 18, 1960. Calif. Dept. Fish and Game, Region 3. 3 pp.

Bisson, P.B., J. L. Nielsen, and R. A. Palmison, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Proc. Sympos. Acquisition and Utilization of Aquatic Habitat Inventory information. Portland, OR, October 28-30. Pages 62-73.

Eimoto, D. and P. Walkup. 1980. Corte Madera Creek, Marin County, Stream Survey. September 9-10, 1980. Calif. Dept. Fish and Game, Region 3. 3 pp.

Jones, W. 1969. Corte Madera Creek, Marin County, Steelhead population survey. November 25, 1969. Calif. Dept. Fish and Game, Region 3. 9 pp.

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

Michaels, J. and B. Thomas. 1968. Corte Madera Creek, Marin County, Stream Survey. July 24-25, 1968. Calif. Dept. Fish and Game, Region 3. 3 pp.

Rich, A. A. 1990. The impacts of timber harvest practices on the fishery resources of the Navarro River Watershed, Mendocino County, California. Prep. for Louisiana-Pacific Co., April 19, 1990. 66 pp + Appendices

Rich, A. A. 1983. Smolting: Circulating Catecholamine and Thyroxine Levels in Coho Salmon (*Oncorhynchus kisutch*). Ph.D. Dissert., Univ. Wash., Seattle. 97 pp.

Rich, A. A. 1979. The use of Stress to Quantitate the Survival Potential of Three Strains of Trout. M.S. Thesis, Univ. Wash., Seattle. 65 pp.

RWQCB (Regional Water Quality Control Board). 1994. Corte Madera Watershed Report. Field Methods and Results of Sampling Study Conducted in June 1992 and February 1993. April, 1994.

RWQCB (Regional Water Quality Control Board). 1992. Corte Madera Resource Evaluation and Information Report.

Scoppettone, G. 1976. Corte Madera Creek, Marin County, Stream Survey. February, 1976. Calif. Dept. Fish and Game, Region 3. 2 pp.

Smith, J. J. 1990. The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell, and Pomponio Creek estuary/lagoon system, 1985-1989. Prepared for the California Department of Parks and Recreation.

Van Deventer, J. S. and W. S. Platts. 1986. Sampling and estimating populations from streams. Trans. N. A. Wildlife and Natural Res. Confer. 48: 349-354.

Van Deventer, J. S. and W. S. Platts. 1983. User's guide for MICROFISH 3.0. A software package for processing electrofishing data obtained by the removal method. U. S. F. S. Forestry Sciences Lab., Boise, Idaho.

Attachment 1:

Sample habitat survey data sheet

Page ____ of _____

Corte Madera Creek Habitat Survey

STREAM: ________________________ DATE ________________ CREW __________

LATITUDE ______________ LONGITUDE ______________ WEATHER ______________

SRU __________ HABITAT TYPE ____________________________ TIME __________

LENGTH (m) ____ LENGTH (Total) _____

WIDTH (m) ____ WIDTH (mean) _______

DEPTH (m) ____ DEPTH (mean) _______

GRADIENT (%) _____ SPAWNING GRAVEL

____

TEMP, AIR (°C) _______ TEMP,WATER,BOTTOM _______ °C TEMP,WATER, SURFACE _____ °C

COVER TYPE (0=NONE 1= LITTLE 2 = MODERATE 3 = ABUNDANT)

ROCK ___ ROOTWAD ___ BEDROCK ___ WOODY DEBRIS ___ DEPTH (> 0.5 M) ___

CANOPY ___ AQUATIC VEGETATION ___ TURBULENCE ___ OVERHANG. VEG. _____

DEPTH (> 0.5 M) ___ UNDERCUT BANKS ___ OTHER ______________________

SUBSTRATE, TYPE (DOMINANT TO LESS DOMINANT) ____________________________

PHOTOS

ROLL	FRAME	DESCRIPTION

COMMENTS ____

____

Attachment 2:

Volunteers' instructions, sample weekly monitoring log, and sample thermograph output

A.A. RICH AND ASSOCIATES

Alice A. Rich, Ph.D.
Principal

150 Woodside Drive
San Anselmo, CA 94960
Tel: (415) 485-2937
Fax: (415) 485-9221
Email: aarfish@nbn.com

June 5, 1999

To: Thermograph Monitoring Volunteers

From: Alice A. Rich, Ph.D.

Re: Instructions

Objectives: (1) Monitor status of thermographs weekly

(2) Determine whether or not thermographs need to be moved (i.e., Thermographs are about to be or are no longer immersed in the creek)

Instructions

I am providing each of you with film (ASA 200 seems to work best in the afternoon; ASA 400 in the early morning for some of the darker sites), a camera for any who need one, the waterproof data sheets, clip board and pencils (do not use ink on data sheets-ink does not work), a AAA map of the area with the thermograph sites marked on it, and these Instructions. Each week, I need each of you to check your assigned thermographs. You will determine whether or not the thermograph exists (!), the light is on, and the thermograph is still immersed in water. The first entry line on your data sheet will be on the day I meet with you to show you what to do. In approximately one week, you will repeat this process and continue, weekly, until October 31. Although, it is not imperative that the weekly monitoring be exactly 7 days apart, please do not let it slide more than one day on either side. One of the main reasons for this is that I want to know as soon as possible if any of the thermographs have been taken, so that I can replace it.

As I realize that it is almost summer and often people leave for vacations, it is important that you contact me ahead of time (phone: 485-2937) if you plan to be gone or cannot do your monitoring, so that I can either line up another volunteer or have one of my assistant take over the monitoring of your creek reach. I also realize that this is not the most exciting thing you have ever done or will do! Hence, if you really do not want to continue with the thermograph monitoring, please let me know immediately and one of my assistants will take over your creek reach.

A.A. RICH AND ASSOCIATES

Alice A. Rich, Ph.D.
Principal

150 Woodside Drive
San Anselmo, CA 94960
Tel: (415) 485-2937
Fax: (415) 485-9221
Email: aarfish@nbn.com

Instructions (Cont.)

Finally, each week drop off at my house (if I am not home, you can drop them in the garage mail slot at 150 Woodside Drive, San Anselmo) your firm and a copy of the data sheets you have filled out. Or, call me and we can arrange to meet somewhere mutually convenient. This will allow me to see the status of the creek (via the photos) throughout the summer. In addition, when you have completed one set (i.e., two pages or 4-8 monitoring days, depending on the amount of information you include on each line) of data for a thermograph site, please drop it off at my house. After your last day of monitoring (end of October), please drop off your last roll of film and the remainder of the data sheets.

Replacement of Thermographs

We installed the thermographs in April and May. In case any of thermographs are taken by someone during the summer, I want to make certain that we have "downloaded" as much of the data as possible, up to the data when the thermograph is missing. Hence, we will be replacing each thermograph monthly during the monitoring period. One of my assistants will be replacing all of the thermographs this week. Similarly, it will be near the beginning of the month when we replace the thermographs again in July, August, September, and October.

Moving Thermographs

If a thermograph appears as if it is going to be "stranded" (i.e., out of water), call me immediately and I will come down and determine whether or not to move it. If I decide to move it, the thermographs will be removed, a new spot selected which is comparable to the one it was in, and a new thermograph installed at the new location.

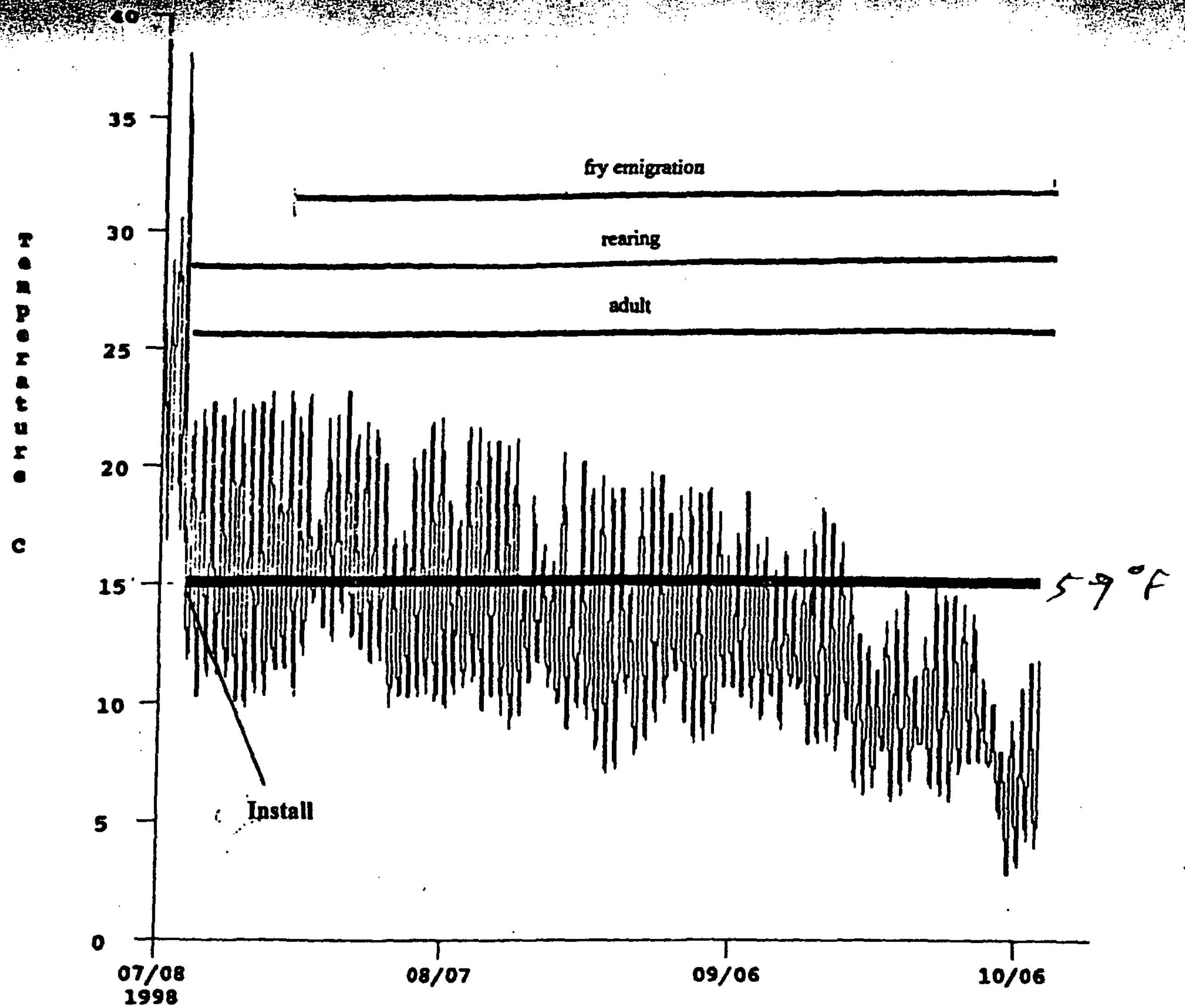
Corte Madera Creek Thermograph Monitoring

Weekly Monitoring Log

THERMOGRAPH NO. (provided) **LATITUDE** (provided) **LONGITUDE** (provided)

Observation No	Additional Comments

A.A. RICH AND ASSOCIATES



RELATIONSHIP BETWEEN MAXIMUM OPTIMAL WATER TEMPERATURES FOR SOME LIFE STAGES OF CUTTHROAT TROUT AND WATER TEMPERATURES IN LOWER DRY VALLEY CREEK FROM JULY 7-OCTOBER 8, 1998

A.A. RICH AND ASSOCIATES

Corte Madera Creek Thermograph Monitoring

Weekly Monitoring Log

THERMOGRAPH NO. ____(provided)________ **LATITUDE** ______(provided)______________ **LONGITUDE**________(provided)________________

Observation No.	Date	Time of Day	Status of Thermograph				Thermograph Removed?		Film Roll/No.	Name of Volunteer (s)/ Phone No.
			Status of Light		Immersed in Water?		Yes	No		
			on	off	yes	no				

Attachment 3:

Sample electrofishing survey data sheet

A.A. RICH AND ASSOCIATES

Page ____ of ____

Corte Madera Creek Electrofishing Survey

STREAM: ____________ **DATE** ____________ **CREW** ____________

LATITUDE ____________ **LONGITUDE** ____________ **WEATHER** ____________

SRU ____________ **HABITAT TYPE** ____________ **TIME** ____________

LENGTH (m) ____________ **LENGTH (Total)** ______

WIDTH (m) ____________ **WIDTH (mean)** ______

DEPTH (m) ____________ **DEPTH (mean)** ______

TEMP, AIR (°C) ______ **TEMP,WATER,BOTTOM** ______ **°C** **TEMP,WATER, SURFACE** ______ **°C**

FREQ ___ **VOLTS** ______ **SHOCK TIME** ____ **SHOCKING EFFICIENCY:** ____________

PHOTOS

ROLL	FRAME	DESCRIPTION

COMMENTS ____________

PASS NO.	SPECIES	LENGTH FORK (mm)	BIOMASS (g)	PASS NO.	SPECIES	LENGTH FORK (mm)	BIOMASS (g)

Attachment 4:

Bisson, P.B., J. L. Nielsen, and R. A. Palmison, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Proc. Sympos. Acquisition and Utilization of Aquatic Habitat Inventory information. Portland, OR, October 28-30. Pages 62-73.

Flows

647-2
c

A SYSTEM OF NAMING HABITAT TYPES IN SMALL STREAMS, WITH EXAMPLES OF HABITAT UTILIZATION BY SALMONIDS DURING LOW STREAMFLOW[1]

Peter A. Bisson, Jennifer L. Nielsen, Ray A. Palmason
and Larry E. Grove[2]

Abstract.--Fish habitat in small streams is classified into a number of types according to location within the channel, pattern of water flow, and nature of flow controlling structures. Riffles are divided into three habitat types: low gradient riffles, rapids, and cascades. Pools are divided into six types: secondary channel pools, backwater pools, trench pools, plunge pools, lateral scour pools, and dammed pools. Glides, the last habitat type, are intermediate in many characteristics between riffles and pools. Habitat utilization by salmonids was studied during summer low streamflow conditions in four western Washington streams. Most age 0+ coho salmon (Oncorhynchus kisutch) reared in pools, particularly backwaters, and preferred cover provided by rootwads. A few large coho occupied riffles and sought the cover of overhanging terrestrial vegetation and undercut banks. Age 0+ steelhead trout (Salmo gairdneri) selected riffles with large wood debris; while age 1+ steelhead preferred plunge, trench, and lateral scour pools with wood debris and undercut banks. The largest individuals of both steelhead age classes were found in swiftly flowing riffle habitats. Age 0+ cutthroat trout (S. clarki) preferred low gradient riffles but switched to glides and plunge pools when steelhead and coho were present, thus suggesting that they had been competitively displaced from a preferred habitat. Age 1+ and 2+ cutthroat preferred backwater pools when coho were absent but avoided them when coho were present. Cutthroat of all age classes generally favored cover provided by wood debris in both pool and riffle habitats.

INTRODUCTION

Identification of the important components of stream habitat is essential if we are to accurately assess environmental change, understand ecological segregation within multispecies communities, or determine the need for stream enhancement projects. Most fishes in small streams are habitat specialists (Gorman and Karr 1978) and utilize specific locations within stream channels throughout their freshwater life cycles in response to different spawning, feeding, and overwintering requirements (Northcote 1978). Within the Salmonidae competition plays a key role in habitat utilization when food is limited (Kalleberg 1958; Keenleyside and Yamamoto 1962; Hartman 1965; Chapman 1966a; Mason 1969; and many others) and such density dependent interactions result in habitat partitioning that facilitates the coexistence of several species as well as multiple age classes (Rosenzweig 1981). Habitat shifts can occur when conditions unsuitable to feeding develop (Hunt 1969; Bustard and Narver 1975a; Mason 1976; Peterson 1980) leading to the breakdown of territories and the aggregation of individuals into protected spaces. Utilization of particular locations within the stream varies greatly in time and space, and although small streams tend to be structurally complex, few if any areas of the channel are not occupied at one time or another.

Fishery biologists have traditionally classified streams into a variety of zones based on channel characteristics (e.g. Platts 1974; Moreau and Legendre 1979), associated biota (e.g., Huet 1959), or a combination of physical, chemical, and biological features (e.g. Binns and Eiserman 1979). Habitat requirements have often been presented as tolerance ranges or preferenda for certain water quality conditions. While tolerance limits for such parameters as

[1]Paper presented at the symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information (Portland, Ore., October 28-30, 1981).

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dissolved oxygen and temperature have been defined with relative precision for many fish species, lack of a precise language describing the components of the physical environment may limit our ability to predict a stream's productivity for a species of interest. The often-used names 'riffle' and 'pool' convey a notion of relative water depth and current velocity, but beyond this they give little indication of living conditions relative to substrate, flow patterns, and cover. Not surprisingly, considerable variation exists in fish utilization of these general categories within the stream (Allen 1969). The terminology discussed in this paper represents an attempt to classify habitat in greater detail. Results of limited field evaluations indicate that the system can be a useful tool in assessing stream conditions and in describing spatial segregation among coexisting fish populations.

METHODS

Terminology

There appears to be no widely accepted set of habitat definitions for small streams. Although riffles and pools are the basic units of channel morphology and will always develop in natural streams as a mechanism of self-adjustment to the law of least time rate of energy expenditure (Yang 1971), the actual configuration and hydraulic properties of these units are highly variable. The continuous gradation in depth and velocity between pools and riffles has spawned terms such as 'run', which appear frequently in fisheries literature, often without detailed explanation. In attempting to construct a precise and consistent set of descriptive terms we have utilized definitions from the Glossary of Geology (Gary et al. 1974) wherever possible.

Riffles

Three types of riffle habitats were identified. Low gradient riffles (Fig. 1) were shallow (< 20 cm deep) stream reaches with moderate current velocity (20-50 cm/sec) and moderate turbulence. Substrate was usually composed of gravel, pebble, and cobble-sized particles (2-256 mm). An upper gradient limit for this habitat type was arbitarily set at 4%. Rapids (Fig. 2) possessed a gradient greater than 4% with swiftly flowing water (>50 cm/sec)

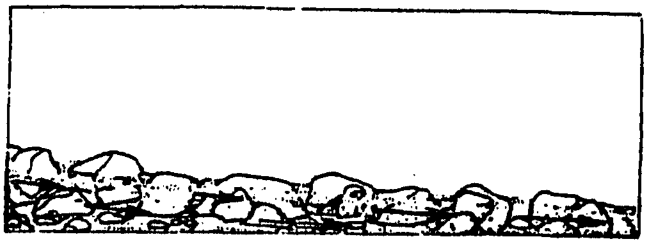

Figure 1. Low gradient riffle.

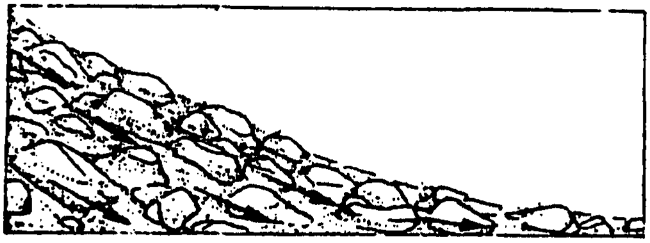

Figure 2. Rapids.

Figure 3. Cascade.

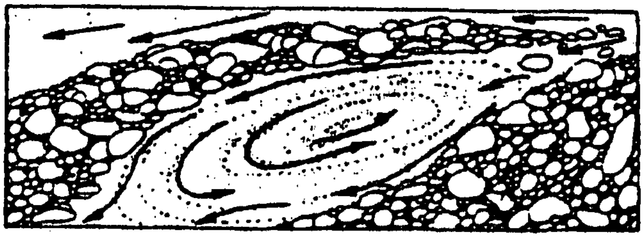

Figure 4. Secondary channel pool.

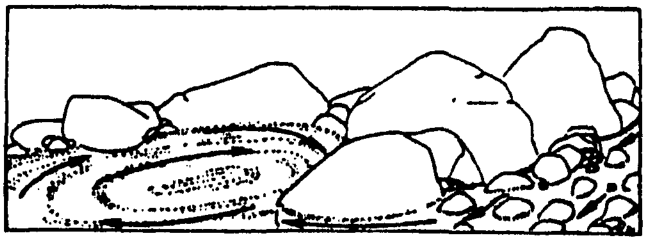

Figure 5. Backwater pool associated with boulders.

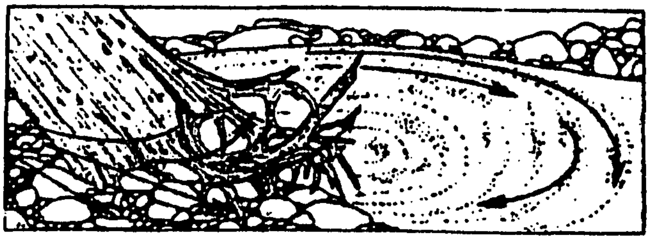

Figure 6. Backwater pool associated with rootwad.

Figure 7. Backwater pool associated with large debris.

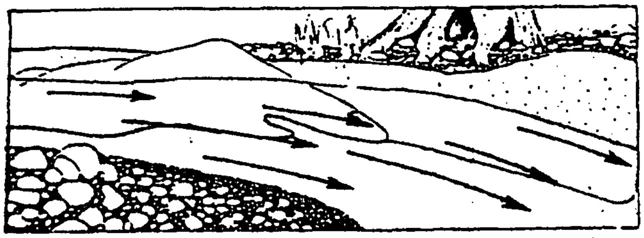

Figure 8. Trench pool associated with bedrock.

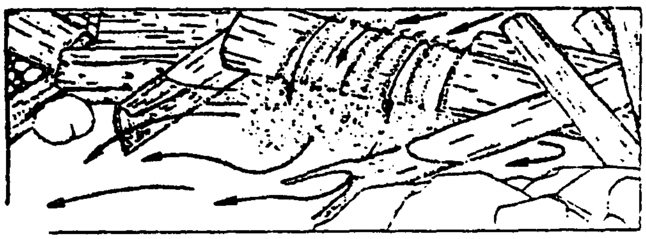

Figure 9. Plunge pool associated with large debris.

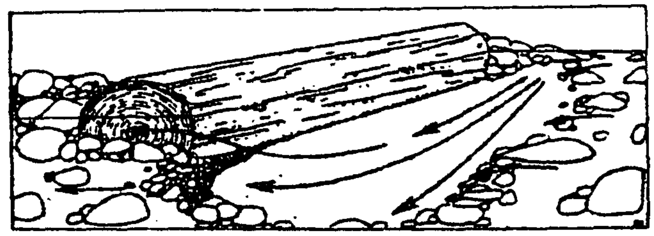

Figure 10. Lateral scour pool associated with large debris.

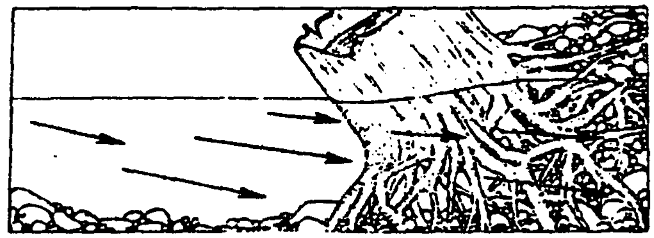

Figure 11. Lateral scour pool associated with rootwad.

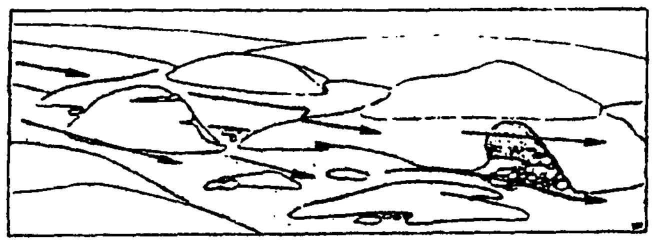

Figure 12. Lateral scour pool associated with bedrock.

having considerable turbulence. The substrate of rapids was generally coarser than the substrate of low gradient riffles, and during low streamflow conditions large boulders typically protruded through the surface. <u>Cascades</u> (Fig. 3), the third type of riffle habitat, were the steepest. Unlike rapids, which had an even gradient, cascades consisted of a series of small steps of alternating small waterfalls and shallow pools. The usual substrate of cascades was bedrock or an accumulation of boulders; however, this habitat type was occasionally found on the downstream face of woody debris dams.

Pools

During low streamflow conditions there were six pool types, which were associated with the presence of bedrock outcroppings, large rocks, or large tree stems and rootwads in the channel. <u>Secondary channel pools</u> (Fig. 4) were those that remained within the bankful margins of the stream after freshets. During the survey period (June-September) most of these pools had disappeared, and those remaining had little flow through them. Secondary channel pools were usually associated with gravel bars, but many contained sand and silt substrates. <u>Backwater pools</u> (Figs. 5-7) were found along channel margins and were caused by eddies behind large obstructions such as rootwads or boulders. This pool type was often quite shallow (>30 cm) and tended to be dominated by fine-grained substrates. Like secondary channel pools, backwater pools possessed current velocities that were very low. <u>Trench pools</u> (Fig. 8) were long, generally deep slots in a stable substrate. Channel cross sections were typically U-shaped with a coarse-grained bottom flanked by bedrock walls. Current velocities in trench pools were the swiftest of any pool type and the direction of flow was most uniform. <u>Plunge pools</u> (Fig. 9) occurred where the stream passed over a complete or nearly complete channel obstruction and dropped vertically into the streambed below, scouring out a depression. This pool type was often large, quite deep (>1 m), and possessed a complex flow pattern radiating from the point of water entry. Substrate particle size was also highly variable. <u>Lateral scour pools</u> (Figs. 10-12) differed from plunge pools in that the flow was directed to one side of the stream by a partial channel obstruction. Often an undercut bank was associated with this pool type. <u>Dammed pools</u>

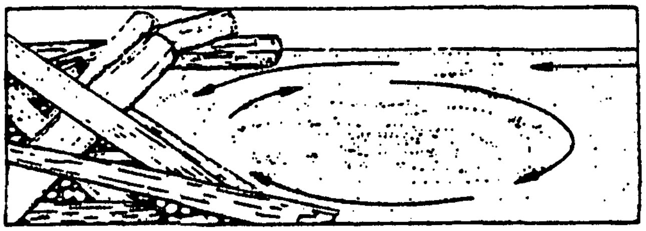

Figure 13. Dammed pool associated with large debris.

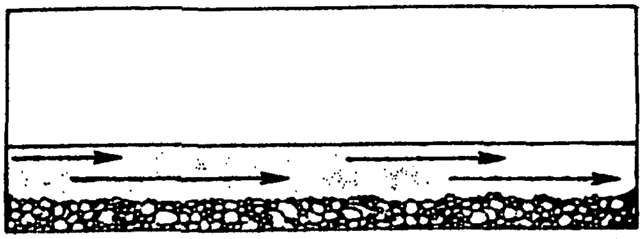

Figure 14. Glide.

(Fig. 13) consisted of water impounded upstream from a complete or nearly complete channel blockage. Typical causes of dammed pools were debris jams, rock landslides, or beaver dams. Depending upon the size of the blockage, dammed pools could be very large. Water velocity in this pool type was characteristically low and substrates tended toward smaller gravels and sand.

Glides

A third general habitat category existed that possessed attributes of both riffles and pools. Glides (Fig. 14) were characterized by moderately shallow water (10-30 cm deep) with an even flow that lacked pronounced turbulence. Although they were most frequently located at the transition between a pool and the head of a riffle, glides were occasionally found in long, low gradient stream reaches with stable banks and no major flow obstructions. The typical substrate was gravel and cobbles. The term 'run' has been applied to this habitat type, but we feel that the designation 'glide' is a more precise descriptor of the habitat conditions. Similar usage of the term has previously been adopted by Cuinat et al. (1975) and Chapman and Knudsen (1980).

Cover

Eight distinct kinds of cover for fishes were identified. These included three kinds of wood debris - rootwads, large debris (tree stems), and small debris (branches, twigs, etc.) - that differed in the amount of overhead cover and flow modifications they provided within the channel. Overhanging terrestrial vegetation and undercut banks were two kinds of cover that we largely governed by the condition of the riparia. zone. Water turbulence acted as cover when the presence of bubbles prevented a clear view of the water beneath (Lewis 1969). Rocks functioned as cover in two ways, by providing overhanging ledges and by providing crevices for hiding. Finally, maximum depth was itself a form of cover from non-diving terrestrial predators (Stewart 1970). We assumed that the primary function of cover during the summer was protection from predation.

Sample Locations and Inventory Techniques

Sample locations were chosen to encompass a wide variety of stream conditions in western Washington. Nineteen sites consisting of channel reaches 0.2 - 1.3 km long were located in four streams. Three of the streams (Newaukum River, Salmon Creek, Thrash Creek) were Chehalis River tributaries; the fourth stream (Fall River) was part of the Willapa Bay drainage system. The sites included 700 individual habitats totaling approximately 7,800 m axial length, 33,600 m^2 wetted surface area, and 8,900 m^3 volume. Channels ranged in size from third to fifth order with 1-8% gradient. Parent rock type was either sandstone or basalt. Streamside vegetation varied according to forest management history; recently clearcut sites were dominated by shrubs. second growth forested sites were dominated by red aler (Alnus rubra), and old growth foreste sites were dominated by mixed conifers. All sample locations possessed natural populations of salmonids, although some sites were above upstream migration blockages and contained only resident non-migratory cutthroat trout. There was no evidence that any of the sites had been fished by anglers.

Each stream reach was surveyed on foot and the location of different habitat types, as well as significant flow controlling structures, was drawn to scale on a map (Fig. 15). Contour lines based on depth measurements were drawn within pools to enable volume estimation. Wetted surface areas were determined by counting squares on gridded paper that was superimposed on the maps. Axial length was figured as the distance along the thalweg or greatest linear dimension of a habitat unit parallel to the direction of flow. Reach summaries were constructed by summing the lengths, areas, and volumes of each habitat type and expressing each group as a percentage of the total. The amount of cover in each habitat was rated on a relative abundance scale of 0-3, where a score of zero indicated that the particular kind of cover was essentially absent and a score of three indicated a very abundant condition. Substrate was noted as predominant type, i.e., the physical and/or biological type most prevalent within a habitat unit.

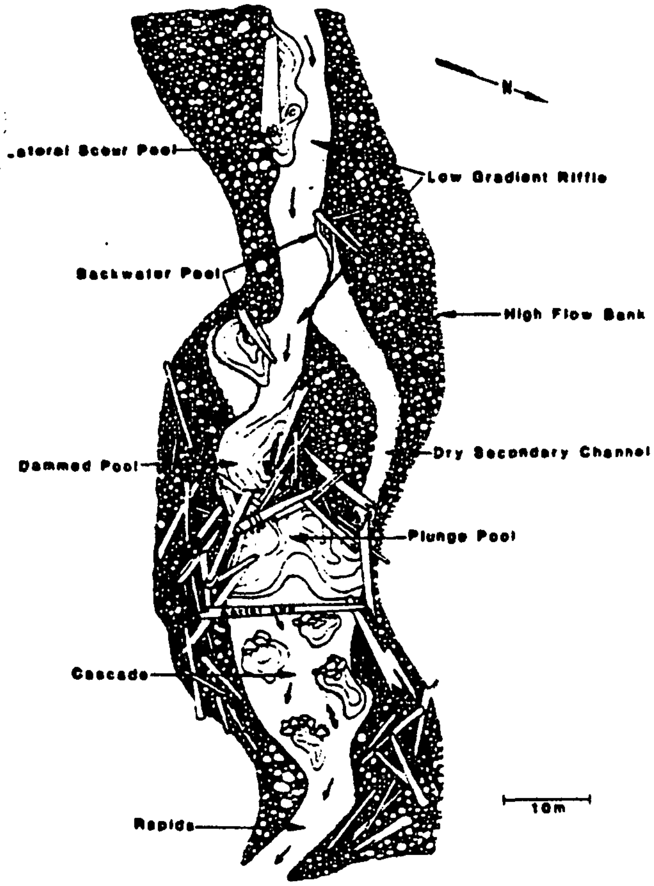

Figure 15. An example of a stream channel map showing locations of various habitat types.

Fish populations were sampled by isolating individual habitat types with blocking nets and electrofishing the habitat three times, retaining separately the fish captured on each pass. Individual biomasses were determined from length-weight relationships (Bisson and Sedell 1982 in press) and age class abundance was figured from size frequency distributions and scale samples. Population density and biomass estimates were based on a removal summation method of calculation (Carle and Strub 1978). Sculpins (Cottus spp.) were also captured but their biomasses are not reported in this paper. Approximately 28% of the total number of habitats inventoried were sampled for fish populations, resulting in the capture of 11,385 salmon and trout.

In order to quantify habitat utilization by species and individual age classes it was necessary to relate the fraction of the population found within a particular habitat type to the relative abundance of that habitat type in the stream. The formula used was based on the electivity index of Ivlev (1961):

$$(1)\ \text{Utilization} = \frac{\text{habitat specific density} - \text{average total density}}{\text{average total density}}$$

where

habitat specific density = average density in the habitat type of interest

average total density = average density over the entire stream reach, all habitats combined

Values of this habitat utilization coefficient theoretically range from minus one, indicating total non-use of a habitat type, to positive infinity as a greater proportion of the population resides in the habitat type of interest. A value of zero indicates that the population occurs in the habitat type in proportion to that type's abundance in the stream.

FIELD TRIALS

Habitat Characteristics

Although variation in size and frequency of habitat types was related to stream order, basin geology, and land management history, average dimensions of the different habitats are given in Table 1 for comparison. Overall, glides had the greatest individual length and surface area but pools had the greatest volume. Despite their relatively large size, glides were infrequent and accounted for a small fraction of total stream space. Pools were the dominant habitat category, accounting for about 50% of stream length and almost 80% of stream volume. Lateral scour pools were the most common type and also possessed the greatest surface area. Secondary channel pools, backwater pools, and dammed pools were smallest and least frequent. None of the sample sites contained beaver dams, log jams, or major landslides, thus accounting for the absence of large dammed pools in the reaches that were surveyed. Low gradient riffles were both the largest and most abundant riffles type, while rapids and cascades tended to be small and less frequent. Riffles averaged 40% of stream length but accounted for only 16% of stream volume

Large woody debris, including rootwads, was the most abundant cover in pools, while rocks were the primary cover in riffles. Depth was important cover in pools having large water volumes (lateral scout, plunge, and trench). Turbulence created cover where falling water formed bubbles in plunge pools, rapids, and cascades. In general, cover quantity and diversity was greater in pools than in riffles or glides.

Habitat Utilization

During the summer very few individuals of any fish species occupied secondary channel pools (Table 2). Many of these habitats had become isolated from the main channel and they often possessed high temperatures and dense algal growths. Although it is likely that secondary channel pools are utilized at other times of the year, particularly in large rivers (Sedell et al. 1980), lack of use of these habitats during low streamflow periods by salmonids is similar to the findings of studies of other stream fishes (Tramer 1977; Williams and Coad 1979).

Backwater pools were heavily utilized by age 0+ coho salmon, although coho in backwaters were smaller than average (Table 3). Preferential use of this habitat type by coho may have been related to a dependency on terrestrial food during summer that has been found by other investigators (Chapman 1966b; Mundie 1969). No other species displayed as strong an association with backwater pools as did coho; however, where anadromous forms were absent, yearling and older cutthroat also preferred this habitat type. In general, fish size in backwaters tended to be smaller than average.

Trench pools were selectively utilized by coho and yearling steelhead, and by age 1+ and 2+ cutthroat in anadromous zones. Where coho and steelhead were absent, all cutthroat age classes exhibited a mild avoidance of this pool type. Underyearling cutthroat collected from trench pools were smaller than average. Plunge pools were selected by coho, yearling steelhead and all cutthroat age classes except age 0+ fish in areas upstream from an anadromous zone. Coho in plunge pools were the largest of those taken in any pool type.

Lateral scour pools were preferred by older age classes of both steelhead and cutthroat. Individuals collected from this pool type were average size, except for age 0+ cutthroat which tended to be slightly smaller than average in non-anadromous areas. Owing to the relative abundance of this habitat type, over 25% of all salmonids occurred in lateral scour pools.

An insufficient number of dammed pools were sampled to yield satisfactory evidence of relative habitat utilization or average fish weight. Flow pattern in this pool type would seem to be favorable to coho and there is ample evidence from other studies (Bustard and Narver 1975b; Nickelson and Hafele 1979; Everest and Meehan 1981) that coho utilize impounded water in streams. Provided there is sufficient depth and cover, dammed pools should also provide favorable habitat for age 1+ steelhead and age 1+ and older cutthroat.

Low gradient riffles were selectively occupied by underyearling steelhead and

Table 1. Average habitat size and percent of total stream (in parenthesis).

Habitat Type	n	Average Habitat Size / % of Total: Length (m)	Area (m^2)	Volume (m^3)
Pools				
Secondary Channel	26	9 (<1)	34 (<1)	8 (<1)
Backwater	74	8 (10)	29 (7)	8 (7)
Trench	34	15 (8)	70 (8)	26 (10)
Plunge	38	14 (5)	77 (5)	45 (10)
Lateral Scour	146	16 (28)	102 (35)	43 (50)
Dammed	5	7 (<1)	30 (<1)	18 (1)
Riffles				
Low Gradient Riffles	197	11 (26)	51 (25)	7 (12)
Rapids	114	7 (13)	25 (9)	3 (3)
Cascades	21	8 (<1)	30 (<1)	6 (<1)
Glides	43	15 (9)	92 (11)	15 (6)

Table 2. Habitat specific utilization coefficients.

Habitat Type	Anadromous Zone Coho 0+	Anadromous Zone Steelhead 0+	Anadromous Zone Steelhead 1+	Anadromous Zone Cutthroat 0+	Anadromous Zone Cutthroat 1+	Anadromous Zone Cutthroat 2+	Above Anadromous Zone Cutthroat 0+	Above Anadromous Zone Cutthroat 1+	Above Anadromous Zone Cutthroat 2+
Pools									
Secondary Channel	-1.00	-0.99	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Backwater	6.74	-0.46	0.21	-1.00	-0.52	-0.75	-0.36	0.42	0.80
Trench	1.07	0.14	1.16	-1.00	0.54	0.99	-0.21	-0.16	-0.23
Plunge	0.93	0.10	2.23	1.41	0.79	0.92	-0.54	1.09	1.61
Lateral Scour	-0.46	0.07	0.89	-0.08	1.14	1.83	0.18	1.04	0.88
Dammed	Insufficient Samples								
Riffles									
Low Gradient	-0.75	0.50	-0.70	0.26	-0.23	-0.71	0.45	-0.73	-0.78
Rapids	-0.99	0.50	0.98	-0.45	-0.67	-0.20	-0.10	-0.83	-0.90
Cascades	-0.97	0.79	0.58	-1.00	0.70	-1.00	-0.24	-0.80	-0.89
Glides	-0.91	0.34	0.86	1.42	-0.77	-0.92	0.00	-0.79	-0.33

Table 3. Size differences among salmonids captured in individual habitat types, expressed as percent deviation from overall average weight. Data for $n \leq 5$ are omitted.

Habitat Type	Anadromous Zone Coho 0+	Anadromous Zone Steelhead 0+	Anadromous Zone Steelhead 1+	Anadromous Zone Cutthroat 0+	Anadromous Zone Cutthroat 1+	Anadromous Zone Cutthroat 2+	Above Anadromous Zone Cutthroat 0+	Above Anadromous Zone Cutthroat 1+	Above Anadromous Zone Cutthroat 2+
Pools									
Backwater	-12	-11	-2		+4	-9	+27	-2	-21
Trench	-2	0	+5		-1	+3	-21	-5	
Plunge	+14	-1	-2		-4	+2	+8	-2	+3
Lateral Scour	+1	-2	-5		+4	+4	-9	0	+1
Riffles									
Low Gradient	+1	+5	-16		-13	-7	+11	+26	
Rapids	+21	+12	+15		+10		-20	+7	
Cascades		+29	-4		+18		-8	-6	
Glides	+5	-15	-19			-26	+6	-9	

cutthroat, and were not preferentially used by other age classes. Cutthroat in anadromous zones were smaller than average while those in non-anadromous areas were larger than average, thus suggesting that competition with steelhead had reduced cutthroat growth rates in low gradient riffles. Evidence for competitive dominance of underyearling cutthroat by underyearling steelhead was also provided by the reduced utilization of low gradient riffles by cutthroat where steelhead were present compared to sites where steelhead were absent. Platts (1977) found that cutthroat were displaced to secondary habitats in the presence of juvenile chinook salmon and steelhead, but Hartman and Gill (1968) speculated that differences in the distribution of underyearling cutthroat and steelhead were related to microhabitat variation in spawning preferences of adults.

Utilization of rapids and cascades was limited mostly to steelhead. Both habitats were strongly avoided by most coho, yet the few individuals that occurred in rapids were much larger than average. Underyearling and yearling steelhead favored both habitats and seemed to grow well there. Chapman and Bjornn (1969) have also observed that steelhead occupy swifter water as they become larger and these authors felt that preference for faster water was associated with increased exposure to food organisms However, while steelhead preferred fast wate riffles, cutthroat, for the most part, did not.

Glides were selectively utilized only by steelhead and by underyearling cutthroat. Insufficient numbers of age 0+ cutthroat were collected from sites possessing coho and steelhead to permit determination of size variation; however, ages 0+ and 1+ steelhead occurring in glides were the smallest of those found in any habitat type.

Cover Associations

In both pool and riffle habitats the densities of age 1+ and older trout tended to increase in association with increased cover (Table 4) but age 0+ salmon and trout were relatively unaffected by cover conditions, although some positive associations did exist between underyearling densities and certain cover types. Our finding that older trout were more responsive to increased cover agrees with the

Table 4. Average correlations (r^2) between age class density and cover types within habitats.

Cover Type	Coho 0+	Steelhead 0+	Steelhead 1+	Cutthroat 0+	Cutthroat 1+	Cutthroat 2+
	Pools					
Rootwad	+0.19	-0.05	+0.34	+0.05	+0.04	+0.13
Large Wood Debris	-0.27	-0.11	+0.23	+0.05	+0.40	+0.25
Small Wood Debris	-0.16	-0.07	+0.18	+0.20	+0.15	+0.17
Terrestrial Vegetation	0.00	+0.12	+0.09	-0.24	+0.04	+0.12
Undercut Bank	0.00	+0.12	+0.26	-0.13	+0.22	+0.37
Turbulence	-0.01	-0.26	-0.04	-0.34	+0.05	+0.21
Underwater Boulders	-0.78	-0.25	-0.54	-0.49	-0.23	-0.09
Maximum Depth	-0.14	-0.29	-0.02	-0.42	+0.03	+0.44
	Riffles					
Rootwad	-0.03	-0.21	-0.29	+0.02	-0.16	+0.24
Large Wood Debris	-0.03	+0.31	+0.42	-0.30	+0.46	+0.43
Small Wood Debris	0.00	+0.03	+0.11	+0.40	+0.07	+0.27
Terrestrial Vegetation	+0.80	+0.11	-0.13	-0.04	+0.07	+0.11
Undercut Bank	+0.37	-0.50	-0.42	0.00	+0.35	+0.43
Turbulence	-0.42	-0.27	+0.19	-0.31	+0.40	+0.20
Underwater Boulders	-0.46	-0.08	-0.19	-0.25	+0.43	-0.07
Maximum Depth	-0.51	-0.20	+0.46	-0.45	+0.43	+0.57

stream enhancement results of Saunders and Smith (1962) and Hunt (1978), who noted that cover additions improved the productivity of older out more than it did underyearlings.

Wood debris proved to be a preferred cover type for age 1+ steelhead and age 1+ and 2+ cutthroat. The strongest associations were observed with large debris pieces, especially in riffle habitats. Preference of yearling steelhead for large debris has been documented by Bustard and Narver (1975a) and both Osborn (1981) and June (1981) have shown that older cutthroat rely heavily on large wood debris for cover. Underyearling steelhead did not respond positively to increased wood debris in pools but utilized large debris in riffles. Underyearling cutthroat showed a slight positive response to increased debris in pools and a definite preference for small debris in riffles. The utilization of small debris by underyearling cutthroat may be similar to the cover preferences of age 0+ brown trout (S. trutta), which have been shown to decline following small debris removal (Mortensen 1977). Age 0+ coho exhibited a mild positive response to increased rootwad abundance in pools, but were unaffected by other kinds of debris. Association of coho with wood debris has been previously demonstrated by Lister and Genoe (1970) and Bustard and Narver (1975a, 1975b).

Overhanging terrestrial vegetation and undercut banks along riffles were strongly preferred by coho, although riffles were inhabited by relatively few individuals of this species (Table 2). Overhead banks and vegetation may have been selected because they provided more terrestrial food, resulting in bigger fish (Table 3). It seems unlikely that coho used these kinds of cover for shade because no obvious preferences for bank cover were observed in pools, and Ruggles (1966) has shown that addition of shade structures to experimental channels actually reduced coho holding capacity. Weak positive responses to increased bank undercuts and overhanging vegetation along riffles were displayed by age 1+ and 2+ cutthroat, which, like coho, were rare there. However, steelhead in riffles did not select overhanging vegetation and actually appeared to avoid riffles with undercut banks. Ages 0+ and 1+ steelhead and ages 1+ and 2+ cutthroat showed mild preferences for bank cover in pools.

Turbulence and underwater boulders were not selected by most species, except yearling cutthroat in riffles. The absence of significant response by steelhead to increased boulder cover was surprising in view of the strong attachment to this cover type shown for steelhead by Hartman (1965) and Facchin and Slaney (1977), and increases in age 1+ steelhead carrying capacity following experimental boulder placement in a Vancouver Island stream (Ward and Slaney 1979). We have no explanation for this disparity in observations except to speculate that increased turbulence and boulder density may have hindered feeding activity by making visual sighting of food organisms more difficult. Within habitats, deeper water was preferentially utilized only by age 1+ and older trout. Underyearlings of all species avoided deep water, preferring instead to reside in shallower areas along habitat margins. Positive associations between increased depth and fish size have been observed in both rainbow trout (Lewis 1969) and cutthroat (Griffith 1972).

APPLICATION OF THE SYSTEM

The system of naming habitat types that is described in this paper proved to be workable during low streamflow conditions. The habitat types became easy to recognize after some practice, and disagreements between independent classifiers were usually few. Approximately 100 m of stream channel could be mapped by one person in a day depending upon channel complexity. However, rapid inventory of the habitat types present in a stream, without dimensional measurements, could proceed much faster.

We were generally less satisfied with the cover evaluations. The majority of disagreements arose over what numerical score was to be assigned to the cover conditions within a particular habitat. In addition, the technique that was employed treated all kinds of cover equally, and it was obvious that a score of 3 (very abundant) for one cover type was not necessarily equivalent, in terms of overhead shading or protection from predation, to a high score for another cover type. For example, the kind of cover provided by wood debris, bank characteristics, or channel morphology was different from one another in nature and did not fit well into an equally weighted scale that was based on relative abundance. Wesche (1980) has discussed the subjectivity involved in measuring cover and has proposed a cover rating that intregrates bank, channel, and substrate characteristics for both small and large streams. Other workers have devised comprehensive numerical indices of habitat conditions that have been used to predict stream carrying capacity, (Bovee and Cochnauer 1977; Binns and Eisermann 1979) but these models do not easily separate fish preference for habitat type from preference for cover type.

We found that within individual habitats certain kinds of cover were preferred to others; however, a more rigorous approach would be to follow population changes after experimentally adding different kinds of cover to streams. For example, Boussu (1954) added small debris (interwoven willow branches) to a Montana stream and recorded large increased in underyearling and yearling rainbow trout and brook char biomasses. More recently, Ward and Slaney (1979) found that logs and boulders placed together in riffle areas of a Vancouver Island stream significantly enhanced ages 1+ and 2+ steelhead, but were not heavily utilized by underyearling coho. The results of our summer field studies indicate that wood debris, especially large stems and rootwads, was the most generally favored cover type and may hold the greatest promise for enhancement projects.

Although the terms 'selected' and 'preferred' have been applied in this paper to habitat and cover utilization by salmon and trout, it is likely that the spatial segregation we observed was an outcome of both physical habitat requirements and biological interactions. What appeared to be a preferred habitat in one stream was not always so in another; cutthroat trout, for example, occurred in different habitats when coho and steelhead were present than when they were the sole salmonid species. Chapman (1966a) has pointed out the importance of interspecific competition in governing habitat selection by salmonids, but behavioral observations have shown that competitive displacment can occur both within a single age class (Mason 1969) and between cohorts of a species (Jenkins 1969). The intensity of territorial defense in certain tropical reef fishes is related to physical habitat conditions, high quality habitats being aggressively defended (Itzkowitz 1979). However, Slaney and Northcote (1974) have shown that when food is abundant territories are small and agression is minimized in underyearling rainbow trout. Thus, the actual location of fishes in a stream channel will be influenced by the presence of competitor and predator species, population density, and food availability, as well as preferences for specific habitat types.

The complex interaction of a fish population with its physical and biological environment usually makes it difficult, if not impossible, to accurately predict either the standing crop or production of a species of interest in a particular stream. What can be determined, however, is the suitability of stream conditions irrespective of a species' presence or absence, which may be due to a variety of factors other than physical habitat. The detailed classification system presented here can be used to assess stream suitability once specific habitat and cover associations are known. We might predict, for example, that underyearling coho will be favored in streams possessing many backwater pools with rootwad cover and terrestrial vegetation overhanging the riffles, whereas yearling and older cutthroat will be favored where there are deep plunge and lateral scour pools with large logs and undercut banks. Although the system worked for the western Washington streams we studied, it is by no means comprehensive. Other habitat types may exist in larger rivers, or in small streams during freshets, and these will require additional description.

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REFERENCES

Allen, K. R. 1969. Limitations on production in salmonid populations in streams. Pages 3-20 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Institute of Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Binns, N. A., and F. M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Transactions of the American Fisheries Society 108:215-228.

Bisson, P. A., and J. R. Sedell. 1982. Salmonid populations in logged and unlogged stream sections of Western Washington; proceedings of a symposium on old-growth forest -- fisheries relationships. Alaska District of the American Institute of Fishery Research Biologists, Juneau, Alaska, USA. In press.

Boussu, M. F. 1954. Relationship between trout populations and cover a small stream. Journal of Wildlife Management 18:229-239.

Bovee, K. D. and T. Cochnauer. 1977 Development and evaluation of weighted criteria probability of use curves for instream flow assessments: fisheries. Instream Flow Information Paper Number 3. Cooperative Instream Flow Service Group, Fort Collins, Colorado, USA.

Bustard, D. R., and D. W. Narver. 1975a. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 32:667-680.

Bustard, D. R. and D. W. Narver. 1975b. Preferences of juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada 32:681-687.

Carle, F. L., and M. R. Strub. 1978. A new method for estimating population size from removal data. Biometrics 34:621-630.

Chapman, D. W. 1966a. Food and space as regulators of salmonid populations in streams. The American Naturalist 100:345-357.

Chapman, D. W. 1966b. The relative contributions of aquatic and terrestrial primary producers to the trophic relations of stream organisms. Pages 116-130 in K. W. Cummins, C. A. Tryon, Jr., and R. T. Hartman, editors. Volume 4, Special Publications of the Pymatuning Laboratory of Ecology, University of Pittsburg, Pittsburg, Pennsylvania, USA.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Institute of Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Chapman, D. W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in Western Washington. Transactions of the American Fisheries Society 109:357-363.

Cuinat, R., J. Dumas, J. A. Timmermans, J. Arrignon, and G. Tuffery. 1957. Ecological diagnosis in salmonid streams: method and example. Technical Paper Number 22. European Inland Fisheries Advisory Commission (EIFAC), Food and Agriculture Organization of the United Nations, Rome, Italy.

Everest, F. H., and W. R. Meehan. 1981. Some effects of debris torrents on habitat of anadromous salmonids; abstracts to presentations at the 1981 west coast regional meeting. Pages 67-74. National Council for Air and Stream Improvement, Portland, Oregon, USA.

Facchin, A., and P. A. Slaney. 1977. Management implications of substrate utilization during summer by juvenile steelhead trout (Salmo gairdneri) in the South Alouette River. Province of British Columbia, Ministry of Recreation and Conservation, Fish and Wildlife Branch, Fisheries Technical Circular Number 32, Victoria, British Columbia, Canada.

Gary, M., R. McAfer, Jr., and C. L. Wolf, editors. 1974. Glossary of geology. American Geological Institute, Washington, District of Columbia, USA.

Gorman, O. T., and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507-515.

Griffith, J. S., Jr. 1972. Competitive behavior and habitat utilization of brook trout (Salvelinus fontinalis) and cutthroat trout (Salmo clarki) in small streams in northern Idaho. Journal of the Fisheries Research Board of Canada 29:265-273.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon. (Oncorhynchus kisutch) and steelhead trout (Salmo gairdneri). Journal of the Fisheries Research Board of Canada 22:1035-1081.

Hartman, G. F., and C. A. Gill. 1968. Distributions of juvenile steelhead and cutthroat trout (Salmo gairdneri and S. clarki clarki) within streams in southwestern British Columbia. Journal of the Fisheries Research Board of Canada 25:33-48.

Huet, M. 1959. Profiles and biology of western Eurpoean streams as related to fish management. Transactions of the American Fisheries Society 88:155-163.

Hunt, R. L. 1969. Effects of habitat alteration on production, standing crops, and yield of brook trout in Lawrence Creek, Wisconsin. Pages 281-312 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Hunt, R. L. 1978. Instream enhancement of trout habitat. Pages 19-27 in K. Hashagen, editor. Proceedings of a national symposium on wild trout management. California Trout, Inc. San Francisco, California, USA.

Itzkowitz, M. 1979. Territorial tactics and habitat quality. The American Naturalist 114:585-614.

Ivlev, V. S. 1961. Experimantal ecology of the feeding of fishes. (Translated from the Russian by Douglas Scott). Yale University Press, New Haven, Connecticut, USA.

Jenkins, T. M., Jr. 1969. Social structure, position choice and micro-distribution of two trout species (Salmo trutta and Salmo gairdneri) resident in mountain streams. Animal Behaviour Monographs 2:55-123.

June, J. A. 1981. Life history and habitat utilization of cutthroat trout (Salmo clarki) in a headwater stream on the Olympic Peninsula, Washington. Master's thesis, University of Washington, Seattle, Washington, USA.

Kalleberg, H. 1958. Observations in a stream tank of territoriality and competition in juvenile salmon and trout (Salmo salar L. and S. trutta). Reports of the Institute of Freshwater Research Drottningholm 39:55-98.

Keenleyside, M. H. A., and F. T. Yamamoto. 1962. Territorial behavior of juvenile Atlantic salmon (Salmo salar L.). Behavior 19:138-169.

Lewis, S. L. 1969. Physical factors influencing fish populations in pools of a trout stream. Transactions of the American Fisheries Society 98:14-19.

Lister, D. B., and H. S. Genoe. 1979. Stream habitat utilization by cohabiting underyearlings of chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada 27:1215-1224.

Mason, J. C. 1969. Hypoxial stress prior to emergence and competition among coho salmon fry. Journal of the Fisheries Research Board of Canada 26:63-91.

Mason, J. C. 1976. Response of underyearling coho salmon to supplemental feeding in a natural stream. Journal of Wildlife Management 40:775-788.

Moreau, G., and L. Legendre. 1979. Relation entre habitat et peuplements de poissons: essai de definition d'une methode numerique pour des rivieres nordiques. Hydrobiologia 67:81-87.

Mortensen, E. 1977. Density-dependent mortality of trout fry (Salmo trutta L.) and its relationship to the management of small streams. Journal of Fish Biology 11:613-617.

Mundie, J. H. 1969. Ecological implications of the diet of juvenile coho in streams. Pages 135-152 in T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries. Institute of Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada.

Nickelson, T. E., and R. E. Hafele. 1978. Streamflow requirements of salmonids. Oregon Depratment of Fish and Wildlife, Progress Report AFS-62, Portland, Oregon, USA.

Northcote, T. G. 1978. Chapter 13: migratory strategies and production in freshwater fishes. Pages 326-359 in S. D. Gerking, editor. Ecology of freshwater fish production. Blackwell Scientific Publications, Oxford, England.

Osborn, J. G. 1981. The effects of logging on cutthroat trout (Salmo clarki) in small headwater streams. Fisheries Research Institute, FRI-UW-8113, University of Washington, Seattle, Washington, USA.

Peterson, N. P. 1980. The role of spring ponds in the winter ecology and natural production of coho salmon (Oncorhynchus kisutch) on the Olympic Peninsula, Washington. Master's thesis. University of Washington, Seattle, Washington, USA.

Platts, W. S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification. United States Forest Service, Surface Environment and Mining Report, Washington, District of Columbia, USA.

Platts, W. S. 1977. Validity of methodologies to document stream environments for evaluating fishery conditions. Pages 267-284 in Proceedings of the symposium and special conference on instream flow needs, volume II. Western Division, American Fisheries Society and American Society of Civil Engineering, Boise, Idaho, USA.

Rosenzweig, M. L. 1981. A theory of habitat selection. Ecology 62:327-335.

Ruggles, C. P. 1966. Depth and velocity as a factor in stream rearing and production of juvenile coho salmon. Canadian Fish Culturist 38:37-53.

Saunders, J. W., and M. W. Smith. 1962. Physical alterations of stream habitat to improve brook trout production. Transactions of the American Fisheries Society 91:185-188.

Sedell, J. R., P. A. Bisson, and J. A. June. 1980. Ecology and habitat requirements of fish populations in South Fork Hoh River, Olympic National Park. Pages 47-63 in Proceedings of the Second Conference on Scientific Research in National Parks, Volume 7. National Park Service, NPS/ST-80/02-7, Washington, District of Columbia, USA.

Slaney, P. A., and T. G. Northcote. 1974. Effects of prey abundance on density and territorial behavior of young rainbow trout (Salmo gairdneri) in laboratory stream channels. Journal of the Fisheries Research Board of Canada 31:1201-1209.

Stewart, P. A. 1970. Physical factors influencing trout density in a small stream. Doctoral dissertation. Colorado State University, Fort Collins, Colorado, USA.

Tramer, E. J. 1977. Catastrophic mortality of stream fishes trapped in shrinking pools. The American Midland Naturalist 97:469-478.

Ward, B. R., and P. A. Slaney. 1979. Evaluation of in-stream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River: progress 1977 and 1978. Province of British Columbia, Ministry of Environment, Fish and Wildlife Branch, Fisheries Technical Circular Number 45, Victoria, British Columbia, Canada.

Wesche, T. A. 1980. The WRRI trout cover rating method: development and application. Water Resources Research Institute, Water Resources Series Number 78, University of Wyoming, Laramie, Wyoming, USA.

Williams, D. D., and B. W. Coad. 1979. The ecology of temporary streams III. Temporary stream fishes in southern Ontario, Canada. Internationale Revue der Gesamten Hydrobiologie 64:501-515.

Yang, C. T. 1971. Formation of riffles and pools. Water Resources Research 7:1567-1574.

Attachment 5:

Habitat Requirements for Steelhead Trout

TABLE 1. HABITAT REQUIREMENTS FOR STEELHEAD TROUT *

LIFE STAGE	OPTIMAL WATER TEMPERATURE	DISSOLVED OXYGEN (mg/l)	pH	WATER DEPTH	WATER VELOCITY	TURBIDITY (mg/l)	SUBSTRATE SIZE
IMMIGRATION/ PASSAGE	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 25 cfs	≤ 25	N/A
SPAWNING	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 15 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
INCUBATION	7.8-11.2 °C 46.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	≥ 18 cm ≥ 0.6 ft	≥ 7 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
FRY EMERGENCE	8.9-11.2 °C 48.0-52.0 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	fry: 8-36 cm 3-14 in juvenile: 25-50 cm 10-20 in	≥ 7 cfs	≤ 25	0.6-13 cm 0.2-5.0 in
REARING	12.8-15.6 °C 55.0-60.1 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	18.3-67.0 cm 0.6-2.2 ft	≥ 2 cfs	≤ 25	6.4-24.9 cm 2.5-9.8 in
SMOLTIFICATION/ EMIGRATION	6.98-11.3 °C 44.4-52.3 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	7-8	18.3-67.0 cm 0.6-2.2 ft	≥ 7 cfs	≤ 25	6.4-24.9 cm 2.5-9.8 in

cm	=	centimeters	cm/s	=	centimeters per second
ft	=	feet	ft/s	=	feet per second
C	=	centigrade	>	=	greater than
F	=	fahrenheit	<	=	less than
in	=	inches	≥	=	greater than or equal to
≤	=	less than or equal to			

Sources: Rich, 1987; Brett & Blackburn, 1981; Hopkirk and Northen, 1980; Baracco, 1977; Hooper, 1973; Zaugg et al., 1972; Smith, 1973; Hunter, 1973; Zaugg and Wagner, 1972; Thompson, 1973; Dickson and Kramer, 1971; Doudoroff and Shumway, 1970 Orcutt et al., 1968; Hartman and Gill, 1968; Wagner, 1974; Hermann et al., 1962; Philips and Campbell, 1961; Whitmore et al., 1960; Cloern, 1976; Thompson, 1972; Smith, 1973; Bovee, 1978; Phillips et al., 1975; Adams et al., 1975; Hall and Lentz, 1969; Koski, 1966

* Note: Thes eare general conservatively-based requirements for steelhead. As requirements are site specific, once the analysis of information has been completed, there may be some changes in the ranges for each of the requirements provided in Table 1

TABLE 1 (CONT.). HABITAT REQUIREMENTS FOR STEELHEAD TROUT *

LIFE STAGE	REDD (mean area of redd per spawning pair)	COVER	FOOD	POOL/RIFFLE RATIO
IMMIGRATION AND PASSAGE				
SPAWNING	4.4-5.4 square meters 47-58 square feet			
INCUBATION				
FRY EMERGENCE				
REARING		Need abundant cover to protect them from predators, reduce summer water temperatures adn provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water
SMOLTIFICATION AND EMIGRATION		" "	" "	" "

cm	=	centimeters	cm/s	=	centimeters per second
ft	=	feet	ft/s	=	feet per second
C	=	centigrade	>	=	greater than
F	=	fahrenheit	<	=	less than
in	=	inches	≥	=	greater than or equal to
≤	=	less than or equal to			

Sources: Rich, 1987; Hooper, 1973; Dickson and Kramer, 1971; Doudoroff and Shumway, 1970; Orcutt et al., 1968; Thompson, 1972; Smith, 1973; Bovee, 1978; Phillips and Campbell, 1961; Hunter, 1973; Davis et al., 1963; Hartman and Gill, 1968; Hartman, 1965.

* Note: These are general conservatively-based requirements for rainbow trout. As requirements are site specific, once the analysis of information has been completed, there may be some changes in the ranges for each of the requirements provided in Table 2

Attachment 6:

Habitat Requirements for Rainbow Trout

TABLE 2. HABITAT REQUIREMENTS FOR RAINBOW TROUT

LIFE STAGE	WATER TEMPERATURE	DISSOLVED OXYGEN (mg/l)	pH	WATER DEPTH	WATER VELOCITY	TURBIDITY (mg/l)	SUBSTRATE SIZE
SPAWNING	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 122 cm/s ≤ 4 ft/s	≤ 25	fish < 50 cm long: 1.5-6.0 cm 0.6-2.4 in fish ≥ 50 cm long: 1.5-10.0 cm 0.6-4.0 in
INCUBATION	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 48-91 cm/s ≤ 1.6-3 ft/s	≤ 25	0.3-10 cm 0.1- 4 in
FRY EMERGENCE	12-18 °C 54-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	≤ 8-30 cm/s ≤ .26-1 ft/s	≤ 25	0.3-10 cm 0.1- 4 in
REARING	15-18 °C 59-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	fry: ≤ 8-30 cm/s ≤ .26-1 ft/s juvenile: 10-22 cm/s .3-.72 ft/s	≤ 25	1.5-10 cm 0.6- 4 in
ADULT	15-18 °C 59-64 °F	≥ 7 at ≤ 15 °C ≥ 9 at > 15 °C	6.5-8	> 18 cm > 7 in	12-73 cm/s 0.4-2.4 ft/s	≤ 25	1.5-10 cm 0.6- 4 in

cm	=	centimeters	cm/s	=	centimeters per second
ft	=	feet	ft/s	=	feet per second
C	=	centigrade	>	=	greater than
F	=	fahrenheit	<	=	less than
in	=	inches	≥	=	greater than or equal to
≤	=	less than or equal to			

ATTACHMENT #5 (CONT.)

TABLE 2 (CONT.). HABITAT REQUIREMENTS FOR RAINBOW TROUT

LIFE STAGE	REDD SIZE (mean area of redd per spawning pair)	COVER	FOOD	POOL/RIFFLE RATIO
SPAWNING	0.2 square meters 2.2 square feet			
INCUBATION				
FRY EMERGENCE				
REARING		Need abundant cover to protect them from predators, reduce summer water temperatures and provide food resources Often use turbulence cover as they feed on drifting insects	Primarily insects, captured as drifting organisms	1:1 pool-to-riffle ratio, with areas of slow, deep water
ADULT			Fishes, invertebrates	

cm = centimeters cm/s = centimeters per second
ft = feet ft/s = feet per second
C = centigrade > = greater than
F = fahrenheit < = less than
in = inches ≥ = greater than or equal to
≤ = less than or equal to

Sources: Rich, 1987; Hooper, 1973; Doudoroff and Shumway, 1970; Orcutt et al., 1968; Duff, 1980; Delisle and Eliason, 1961; Thompson, 1972; Smith, 1973; Horner and Bjornn, 1976; Hunter, 1973

APPENDIX B

VOLUNTEERS' INSTRUCTIONS
AND
SAMPLE WEEKLY MONITORING LOG

APPENDIX C

SUMMARY RESULTS OF WATER TEMPERATURE MONITORING

Table C-1. Dates of Thermograph Installation in Corte Madera Creek

Thermograph Number[1]	Habitat Type	Dates of Thermograph Installation	Dates of Thermograph Removal	Thermograph Location
T-CM-1a	Concrete channel (USACE)[2]	4/19/99 6/9/99 7/28/99 9/13/99	6/9/99 7/28/99 9/13/99 10/1/99	Beginning of USACE concrete channel, right bank
T-CM-1b	Concrete channel (USACE)[2]	5/4/99 6/9/99 7/28/99 9/13/99	6/9/99 7/28/99 9/13/99 10/1/99	Beginning of USACE concrete channel, left bank
T-CM-2a	P-LS-BC/RR	6/12/99 7/27/99 9/13/99	7/27/99 9/13/99 10/1/99	D/s of Ross Post Office
T-CM-2b	P-LS-BC/RR	6/12/99 7/27/99 9/13/99	7/27/99 9/13/99 10/1/99	D/s of Ross Post Office
T-CM-3a	P-LS-BC/RR	4/20/99	6/8/99	Behind Ross Post Office
T-CM-3b	P-LS-BC/RR	5/4/99	6/8/99	Behind Ross Post Office
T-CM-4	P-LS-BC	4/20/99 6/9/99 7/27/99 9/13/99	6/9/99 7/27/99 9/13/99 10/1/99	U/s of Lagunitas Bridge
T-CM-5	LGR	5/4/99 6/9/99 7/27/99 9/13/99	6/9/99 7/27/99 9/13/99 10/1/99	U/s of Lagunitas Bridge

[1] Please see Figure 5

[2] At junction of cement channel and Corte Madera Creek estuary

Key :

D/s	-	Downstream
LGR	-	Low Gradient (<4%) Riffle
P-LS-BC	-	Pool, Lateral Scour, associated with cut banks
P-LS-BC/RR	-	Pool, Lateral Scour, associated with cut banks and rip rap
U/s	-	Upstream
USACE	-	United States Army Corps of Engineers

Table C-2. Dates of Thermograph Installation in San Anselmo Creek

Thermograph Number[1]	Habitat Type	Dates of Thermograph Installation	Dates of Thermograph Removal	Thermograph Location
T-SA-1	P-LS-BC	4/20/99 6/18/99 7/27/99 9/13/99	6/18/99 7/27/99 9/13/99 10/1/99	Behind Ross Valley Vet Hospital
T-SA-2	P-LS-BC	5/4/99 6/18/99 7/27/99 9/13/99	6/18/99 7/27/99 9/13/99 10/1/99	D/s of Sir Francis Drake Blvd bridge, behind Ross Valley Vet Hospital
T-SA-3	P-MC-Dam	5/4/99 6/18/99	6/18/99 7/6/99	D/s of Saunders Avenue bridge
T-SA-4	P-LS-Wall (cement)	5/4/99 6/18/99 7/27/99 9/13/99	6/18/99 7/27/99 9/13/99 10/1/99	U/s of Saunders Avenue bridge
T-SA-5	P-LS-RT	5/4/99 6/18/99 7/27/99 9/13/99	6/18/99 7/27/99 9/13/99 10/1/99	Behind Fair Anselm Plaza
T-SA-6	LGR	5/4/99 6/18/99 7/27/99 9/13/99	6/18/99 7/27/99 9/13/99 10/1/99	Behind Fairfax Post Office
T-SA-7	P-LS-BC	5/24/99 6/18/99 7/27/99 9/14/99	6/18/99 7/27/99 9/14/99 10/1/99	D/s of Creek Road bridge
T-SA-8	P-LS-BED	5/24/99 6/18/99 7/27/99 9/14/99	6/18/99 7/27/99 9/14/99 10/1/99	D/s of Creek Road bridge

[1] Please see Figure 5

Table C-2 (cont.) **Dates of Thermograph Installation in San Anselmo Creek**

Thermograph Number[1]	Habitat Type	Dates of Thermograph Installation	Dates of Thermograph Removal	Thermograph Location
T-SA-9	P-LS-RR	5/18/99	7/6/99	U/s of Meadow Way bridge
T-SA-10	P-LS-RR	5/18/99	7/5/99	U/s of Meadow Way bridge
T-SA-11	P-LS-BC	7/23/99 9/14/99	9/14/99 10/5/99	In Cascade Canyon Open Space Preserve, d/s of trail bridge
T-SA-12	P-LS-BED	7/23/99 9/14/99	9/14/99 10/5/99	In Cascade Canyon Open Space Preserve, d/s of trail bridge

Key :

D/s	-	Downstream
LGR	-	Low Gradient (<4%) Riffle
P-LS-BED	-	Pool, Lateral Scour, associated with bedrock
P-LS-BC	-	Pool, Lateral Scour, associated with cut banks
P-LS-RR	-	Pool, Lateral Scour, associated with rip rap
P-LS-RT	-	Pool, Lateral Scour, associated with root wads
P-LS-Wall	-	Pool, Lateral Scour, associated with a wall
P-MC-Dam	-	Pool, Mid Channel, associated with a dam
U/s	-	Upstream

Table C-3. Dates of Thermograph Installation in Sleepy Hollow Creek

Thermograph Number[1]	Habitat Type	Dates of Thermograph Installation	Dates of Thermograph Removal	Thermograph Location
T-SH-1	P-LS-RR (concrete)	6/9/99 7/26/99 9/14/99	7/26/99 9/14/99 9/30/99	D/s of Carlson Avenue
T-SH-2	P-LS-RT	5/6/99 6/9/99 7/26/99 9/14/99	6/9/99 7/26/99 9/14/99 9/30/99	D/s of Carlson Avenue
T-SH-3	P-LS-BED (concrete dam)	5/18/99 6/9/99 7/23/99 9/14/99	6/9/99 7/23/99 9/14/99 9/30/99	D/s of Deer Hollow Road bridge
T-SH-4	P-MC-BED	5/14/99 6/9/99 7/19/99 9/14/99	6/9/99 7/19/99 9/14/99 9/30/99	D/s of Deer Hollow Road bridge
T-SH-5	P-LS-BC	5/14/99 6/18/99 7/26/99 9/14/99	6/18/99 7/26/99 9/14/99 9/30/99	U/s of #970 Butterfield Road
T-SH-6	P-LS-BC	5/18/99 6/18/99 7/26/99 9/14/99	6/18/99 7/26/99 9/14/99 9/30/99	U/s of #970 Butterfield Road

[1] Please see Figure 5

Key :

D/s	-	Downstream
P-LS-BC	-	Pool, Lateral Scour, associated with cut banks
P-LS-BED	-	Pool, Lateral Scour, associated with bedrock
P-LS-RR	-	Pool, Lateral Scour, associated with rip rap
P-LS-RT	-	Pool, Lateral Scour, associated with root wads
P-MC-BED	-	Pool, Mid Channel, associated with bedrock
U/s	-	Upstream

Table C-4. Dates of Thermograph Installation in Ross and Cascade Creeks

Thermograph Number[1]	Habitat Type	Dates of Thermograph Installation	Dates of Thermograph Removal	Thermograph Location
T-R-1	P-LS-Stump	5/4/99	7/1/99	D/s of Locust bridge
T-R-2	P-LS-Concrete block	5/4/99	7/1/99	D/s of Locust bridge
T-R-3	P-LS-Wall (wood)	5/4/99	7/6/99	U/s of Locust bridge
T-R-4	P-MC-Bedrock dam	5/4/99	7/1/99	End of Southwood Drive
T-R-5	P-PL	5/4/99	7/1/99	End of Southwood Drive
T-C-1	P-LS-BED	7/23/99 9/14/99	9/14/99 10/5/99	In Cascade Canyon Open Space Preserve, u/s of trail bridge

[1] Please see Figure 5

Key :

D/s	-	Downstream
P-LS-BED	-	Pool, Lateral Scour, associated with bedrock
P-LS-Concrete block	-	Pool, Lateral Scour, associated with a concrete block
P-LS-Stump	-	Pool, Lateral Scour, associated with a stump
P-LS-Wall	-	Pool, Lateral Scour, associated with a wall
P-MC-Bedrock dam	-	Pool, Mid Channel, associated with a bedrock dam
P-PL	-	Pool, Plunge
U/s	-	Upstream

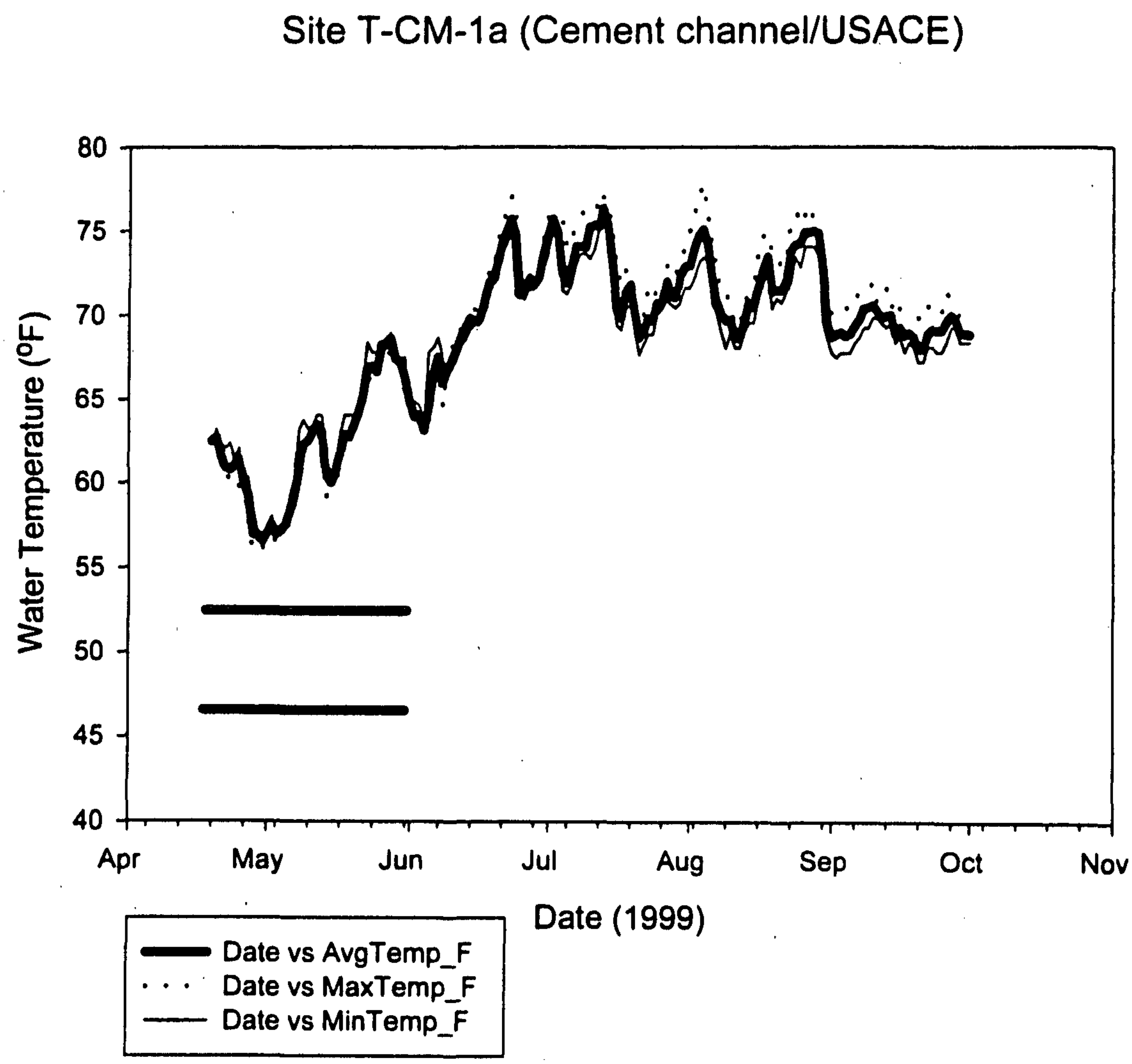


FIGURE C-1. STEELHEAD TROUT-IMMIGRATION THROUGH FRY EMERGENCE. Daily mean, minimum and maximum water temperatures at Thermograph Site T-CM-1a. Horizontal bold lines represent lower (bottom) and upper (top) optimal water temperatures.

APPENDIX D

SUMMARY OF HABITAT RESULTS

KEY

Substrate:

BED .... Bedrock
BO .... Boulder
CC .... Concrete
CO .... Cobble
GR .... Gravel
ORG .... Organic
P.GR .... Pea Gravel
RR .... Rip Rap
SA .... Sand
SI .... Silt

Cover:

AB .... Asphalt blocks
AL .... Algae
AV .... Aquatic Vegetation
BE .... Bedrock
BO .... Boulder
BR .... Bridge
BU .... Building
CA .... Canopy
CB .... Concrete Block
CC .... Concrete
CS .... Concrete Slab
DE .... Depth
LE .... Leaves
MA .... Material (fabric)
OR .... Organic Material
OV .... Overhanging Vegetation
RO .... Rocks
RR .... Rip Rap
RT .... Rootwad
SC .... Scum Layer
TU .... Turbulence
UB .... Undercut Bank
WD .... Woody Debris

KEY (CONT)

Habitat Types:

BC .... Bank Cut
BW .... Backwater
BED .... Bedrock
BO .... Boulder
BRDG .... Bridge
CAS .... Cascade
CB .... Concrete Blocks
GABION .... Gabion Retaining Wall
HGR .... High Gradient Riffle
LB .... Left Bank
LGR .... Low Gradient Riffle
LS .... Lateral Scour
LWD .... Large Woody Debris
MC .... Mid-Channel
P .... Pool
PW .... Pocketwater
RB .... Right Bank
RR .... Rip Rap
RT .... Rootwad

TABLE D-1. RESULTS OF HABITAT TYPING DATA FOR CORTE MADERA CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
USACE - Concrete Channel								
CM-01	08/06/99	P-CONCRETE CHANNEL				NO	CONCRETE	
CM-02	08/06/99	P-LS-BC/RR	61	5.9	0.35	NO	SA/SI	RO=1 WD=1 DE=1 CA=2 AV=1 OV=1 UB=2 RR=2
CM-03	08/06/99	LGR	3	1.5	0.04	NO	GR	RO=2 CA=1 TU=2 LE=1 CC=1
CM-04	08/06/99	P-LS-BC/CONCRETE WALL	30	5	0.17	NO	SA/GR	DE=1 CA=2 AV=2 CC=1
CM-05	08/06/99	LGR	17	1.2	0.05	NO	GR	CA=2 TU=1 AV=1 LE=1
CM-06	08/06/99	P-LS-BC	15	2	0.06	NO	SA/GR	CA=2 OV=2 UB=2 LE=2 OR=2
CM-07	08/06/99	LGR	13	1.2	0.06	NO	GR	CA=1 TU=2 OV=2 UB=2 LE=2
CM-08	08/06/99	P-LS-BC	27	4.6	0.18	NO	LARGE GR/ORGANIC	WD=1 DE=1 CA=2 OV=2 UB=2 LE=1 OR=2
Lagunitas Road								
CM-09	08/06/99	P-LS-BRIDGE (BRAIDED)	8	7	0.19	NO	SA/GR	LE=2 BR=3
CM-10	08/06/99	P-LS-BC	19	3.3	0.14	NO	SA/SI	CA=2 OV=2 UB=2 LE=2
CM-11	08/06/99	LGR	4	1.7	0.09	NO	GR	WD=1 CA=2 TU=2 OV=3 LE=2
CM-12A,B,C	08/06/99	P-LS-BC/WALL/LWD	134	6.3	0.25	NO	SA/P.GR/ORG/LARGE GR	RT=1 WD=2 DE=2 CA=2 OV=2 RR=1
CM-13	08/06/99	LGR	9	1.5	0.05	NO	GR	TU=2 LE=2
CM-14	08/06/99	P-LS-RR/BC/RT	42	6.5	0.31	NO	SA/GR	RT=2 WD=1 DE=2 UB=1 AL=2
CM-15	08/06/99	LGR	7	2	0.06	YES	GR/ORGANIC	CA=3 TU=1 LE=1
CM-16	08/06/99	P-LS-BC	40	5	0.1	NO	GR	RO=1 RT=1 WD=1 CA=2 OV=1 UB=2 LE=1 OR=2
CM-16	08/06/99	P-LS-BC	23	8	0.52	NO	GR	
CM-17	08/06/99	P-LS-RT/LWD	10	7	0.5	NO	GR	WD=2 DE=2 CA=3 OV=1
CM-18	08/06/99	P-LS-BC	21	5.8	0.25	NO	GR/SA/CO	WD=1 CA=2 OV=1 UB=2 CB=1
CM-19	08/06/99	LGR	5	7	0.07	NO	GR/COCNRETE BLOCKS	RO=3 CA=1 TU=1 LE=2
CM-20	08/06/99	P-LS-RR	37	5.5	0.29	NO	GR/SA/ORGANIC	RO=1 WD=1 DE=2 OV=2 RR=1 AL=1
CM-21	08/06/99	LGR	3	6.5	0.04	YES	GR	CA=2 TU=1 LE=3
CM-22	08/06/99	P-LS-RT	25	5	0.13	NO	GR/SA/ORGANIC	CA=2 UB=2 LE=1
CM-23	08/06/99	LGR (BRAIDED-3 CHANNELS)	20	2.3	0.04	NO	GR/CO	CA=1 TU=1 LE=3
CM-24	08/06/99	P-LS-BC	80	9.7	0.32	NO	GR/ORGANIC	RT=1 WD=1 DE=2 CA=2 OV=1 UB=2
CM-25	08/06/99	P-LS-RR	38	5.8	0.21	NO	SA/GR	WD=1 DE=1 CA=1 OV=1
Ross Creek (tributary)								

TABLE D-2. RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
Ross Creek (tributary)								
SA-001	08/06/99	LGR	6	4	0.05	YES	GR/CO	RO=1 CA=2 TU=1 LE=1
SA-002	08/06/99	P-LS-BC/CONCRETE	20	4	0.14	NO	GR/CO	RO=2 CA=2 OV=2 UB=2 LE=1
SA-003	08/06/99	LGR	6	5	0.04	YES	GR/CO	RO=2 WD=1 CA=2 TU=2 OV=1 LE=2
SA-004	08/06/99	P-LS-RR/WOOD/BC	58	6.3	0.18	NO	GR/ORGANIC	RT=1 WD=2 DE=2 CA=2 UB=2 LE=2 AL=1
SA-005	08/06/99	LGR	7	4	0.05	YES	GR	CA=2 TU=1 LE=1
SA-006	08/06/99	P-LS-CONCRETE/RT	67	7	0.21	NO	GR/ORGANIC	RT=1 DE=1 CA=2 OV=1 LE=2
Sir Francis Drake Blvd								
SA-007	08/11/99	P-LS-CONCRETE/BED	30	6	1	NO	SA/GR	RO=2 DE=3 CA=2 OV=1 LE=2
SA-008	08/11/99	P-LS-BED	15	4	0.48	NO	SA/GR	DE=1 CA=2 LE=1
SA-009	08/11/99	LGR	15	3	0.17	YES	GR/CO	RO=2 CA=2 TU=1 OV=1 UB=1 LE=2
SA-010	08/11/99	P-LS-BC	45	5	0.21	NO	GR/CO	RO=1 WD=1 DE=2 CA=2 OV=1 LE=1
SA-011	08/11/99	LGR(FAUX)	15	6	0.09	NO	CEMENT/CO	CA=2 TU=1 LE=2 CB=3
SA-012	08/11/99	P-LS-BC	42	9.5	0.22	NO	GR/ORGANIC/SA	RT=1 WD=1 CA=2 OV=1 UB=2 LE=3
SA-013	08/11/99	P-LS-CONCRETE/WALL	90	7	0.36	NO	GR/SA	RT=1 WD=1 DE=2 CA=2 OV=1 CB=2
SA-014	08/11/99	LGR-SINGLE CHANNEL	8			NO	ARTIFICIAL ROCK/CONCI	TU=2 BR=3
Winship								
SA-015	08/06/99	P-LS-BED/BC	60	4.5	0.26	NO	CO/GR	RO=2 RT=1 WD=1 CA=2 OV=2 UB=1 LE=1
SA-016	08/06/99	LGR(a)/P-LS-WALL(b)/LGR(c)	30	4.5	0.07	NO	CO/CONCRETE BLOCKS	RO=2 CA=2 TU=1 OV=1 LE=2 AB=1
SA-016	08/06/99	LGR(a)/P-LS-WALL(b)/LGR(c)	20	6	0.11	NO	CO/CONCRETE BLOCKS	RO=2 CA=2 TU=1 OV=1 LE=2 AB=1
(Sunnyside Nursery)								
SA-017	08/06/99	P-LS-BC	63	6.8	0.34	NO	GR/ORGANIC	RT=2 WD=1 DE=2 CA=2 OV=1 UB=2 LE=1
SA-018A	08/26/99	P-LS-RR				NO		
SA-018B	09/28/99	P-LS-RR	8	6	0.27	NO	SI/RR	RO=2 DE=1 CA=1 OV=1 OR=3
Sir Francis Drake Blvd								
SA-019,020	09/28/99	LGR/P-CONCRETE	27	8	0.25	NO	GR	DE=2 BR=3
SA-021	09/28/99	P-LS-BC/CONCRETE/RR/PILLAR	300	6	0.22	NO	SA/GR/SI	BRIDGE, STREET, BUILDINGS
Bridge Avenue								
SA-022	09/29/99	P-LS-CONCRETE DAM/ WALL	37	5.3	0.3	NO	GR/CONCRETE BLOCKS	DE=1 CA=2 OV=1 UB=2 CB=2
SA-023	09/29/99	P-LS-CONCRETE WALL	8	6		NO	GR/SA	WD=1 BR=3

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-024	09/29/99	P-LS-WALL/LOG	35	5.4	0.34	NO	GR/SA	RT=2 WD=2 DE=2 CA=2 OV=1 LE=1
SA-025	09/29/99	P-LS-BC	18	3.5	0.18	NO	GR/SA	WD=2 LE=2
SA-026	09/29/99	LGR/P-LS-BC	10	1.3	0.07	YES	GR/LEAVES	CA=2 OV=1 LE=2
SA-027	09/29/99	P-LS-BC/RT	35	3.7	0.15	NO	GR	RT=2 CA=2 OV=2 UB=2 LE=2
SA-028	09/29/99	P-LS-RT	8	3.5	0.18	NO	GR/SA	WD=2 CA=2 OV=2
SA-029	09/29/99	P-LS-BC/RT/LGR(2)	12	1	0.14	YES	GR	RT=1 WD=1 CA=2 TU=1 LE=2
SA-030	09/29/99	P-LS-BC	30	4	0.21	NO	GR/ORGANIC	WD=2 CA=2 LE=2 OR=3
SA-031	09/29/99	LGR	5	4	0.03	NO	GR	TU=1 LE=3 CB=2
SA-032	09/29/99	P-LS-RR	33	5.3	0.29	NO	GR/ORGANIC/SI	RT=2 DE=2 CA=2 LE=2 RR=2 OR=3
SA-033	09/29/99	P-LS-GABION/RR	10	5	0.34	NO	SI/GR	CA=2 OV=1 LE=1 MA=2
SA-034	09/29/99	LGR		1	0.03	YES	GR	CA=1 AV=3 TU=1
SA-035	09/29/99	P-LS-BC	32	6	0.26	NO	GR/SA/ALGAE	DE=2 CA=2 OV=2 AL=2
SA-036	09/29/99	P-LS-BC/LWD		5	0.42	NO		WD=2 DE=2 OV=1
SA-037	09/29/99	P-LS-RT	25	3.3	0.21	NO	GR	RT=2 DE=2 CA=2 OV=2 LE=1
Madrone Avenue								
SA-038	09/29/99	LGR UNDER BRIDGE	10	0.9	0.06	YES	GR	TU=1 LE=1 BR=3
SA-039	10/08/99	P-LS-BC	25	3	0.13	NO	GR	RO=2 RT=2 CA=2 AV=2 LE=2 OR=2
SA-039	10/08/99		35	3.4	0.26	NO		
SA-040	10/08/99	LGR	7	1.6	0.08	YES	GR	RO=2 CA=1 TU=1 OV=1 LE=2 CB=2
SA-041	10/08/99	P-LS-RR	11	4.5	0.43	NO	GR/SA	WD=1 DE=2 CA=2 RR=2
SA-042	10/08/99	P-LS-RR/RT	12	4.6	0.37	NO	GR/SA	DE=2 CA=2
SA-043	10/08/99	LGR	7	1.2	0.12	YES	GR	RO=1 CA=2 TU=2 RR=1
SA-044	10/08/99	P-LS-RR	22	2.3	0.09	NO	GR/ORGANIC	RT=1 CA=2 OV=2 UB=2
SA-045	10/08/99	LGR	12	3	0.06	YES	GR	WD=1 CA=1 AV=2 TU=1 CB=2
SA-046	10/08/99	P-LS-RR	15	5	0.31	NO	GR/SA	DE=2 CA=1 AV=2 OV=2
SA-047	10/08/99	LGR	4	4.5	0.03	YES	GR/RR	CA=2 TU=2 OV=1 LE=2 RR=2
Nokomis Avenue								
SA-048	10/08/99	P-LS-BRIDGE	7	3.3	0.15	NO		
SA-049	10/08/99	LGR	15	1.6	0.06	YES	GR	CA=2 TU=2 LE=1 OR=2
SA-050	10/08/99	P-LS-CONCRETE WALL	95	7.3	0.39	NO	GR/ORGANIC	RO=2 RT=2 DE=3 CA=2 OV=2 AL=2
SA-051	10/08/99	P-LS-CB	17	5.5	0.17	NO	GR	RO=2 CA=2 CS=2

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-052	10/08/99	LGR	2	7	0.03	NO	GR	RO=2 CA=2 TU=2
SA-053	10/08/99	P-LS-BC/RT	20	5.7	0.28	NO	GR/ORGANIC	RO=2 RT=2 CA=2 OV=2
SA-054	10/08/99	P-LS-CONCRETE WALL	60	4.7	0.36	NO	GR/ORGANIC	DE=1 CE=2
SA-055	10/08/99	P-LS-RR	10	3.2	0.23	NO	GR/ORGANIC	CA=2 AV=1 LE=2 RR=2
SA-056	10/08/99	LGR	20	0.6	0.05	NO	GR	RO=2 CA=2 TU=2
SA-057	10/08/99	P-LS-BC/CB	44	8.3	0.26	NO	GR/SA	RO=2 DE=2 CA=2 OR=3
SA-058	10/08/99	P-LS-RR	42	7.8	0.2	NO	GR/SA/RR	CA=2 OV=2 RR=2 OR=3
SA-059	10/08/99	LGR	6	4.2	0.03	YES	GR	CA=2 TU=2 LE=2 RR=1 OR=3
SA-060	10/08/99	P-LS-BC/CONCRETE WALL	40	6.7	0.38	NO	GR/SA	DE=2 CA=1 UB=2 OR=3
SA-061	10/08/99	LGR	6	7	0.04	YES	GR	CA=2 LE=2 RR=1
SA-062	10/08/99	P-LS-CONCRETE WALL	48	5.2	0.13	NO	GR/SA	CA=2 OV=1
SA-063	10/08/99	LGR	6	7	0.03	YES	GR/CO	CA=2 TU=1
SA-064	10/08/99	P-LS-BC	30	4.8	0.18	NO	GR/CO/SA	RO=2 RT=1 CA=2 OV=2 UB=2 OR=3
SA-065	10/08/99	P-LS-CONCRETE/RR	64	5.2	0.22	NO	SA/RR	DE=2 CA=2 OV=1 RR=2 CS=2
SA-066	10/08/99	LGR	15	2.5	0.08	YES	GR	RO=2 CA=2 TU=1 OV=2 LE=2
SA-067	10/08/99	P-LS-CB WALL RB	15	6.4	0.42	NO	GR/SA	RO=1 DE=2 CA=2 AV=1
SA-068	10/08/99	P-LS-BC	30	5.3	0.58	NO	GR/SA	RT=1 CA=2 OV=2 UB=1
SA-069	10/08/99	P-LS-BED	15	5.3	0.42	NO	GR/SA	RT=2 BE=2 DE=2 CA=2
SA-070	10/08/99	P-LS-RR/CONCRETE BANK	27	5.8	0.3	NO	GR/SA	CA=2 OV=2 RR=2
Sleepy Hollow Creek (tributary) @ 7 Agatha Court								
SA-071	10/08/99	P-LS-CONCRETE WALL (LB)	62	3.3	0.4	NO	GR/CO	DE=3 CA=2 OV=2 UB=2
SA-072	10/08/99	P-LS-CONCRETE SLAB		2.5	0.13	NO	GR/CO	CA=2 RR=2 CS=3
SA-073	10/08/99	LGR/P-LS-CB	15	3.6	0.07	NO	GR/ORGANIC	CA=2 TU=2 LE=2 RR=1 CS=1
SA-074	10/08/99	P-LS-CONCRETE WALL	30	4.8	0.29	NO	GR/CO/ORGANIC	RO=2 RT=1 DE=2 CA=2 OV=1 UB=2
SA-075	10/08/99	CASCADE (3 POOLS)	15	5.5	0.12	NO	RR/SA	CA=2 OV=2
Saunders Avenue/Sir Francis Drake High School								
SA-076	10/08/99	DENIL FISH LADDER*	24	0.5		NO	CONCRETE	
SA-077	10/18/99	P-LS-CONCRETE WALL	105	6.5	0.45	NO	GR/SA	RT=2 DE=2 CA=2 OV=1 LE=2 RR=1
SA-078	10/18/99	P-LS-BC	20	5	0.18	NO	GR/SA	RT=1 CA=2 UB=2 LE=1
SA-079	10/18/99	P-LS-RT(BAY)	12	3	0.05	NO	GR/ORGANIC	RO=2 RT=2 WD=1 CA=2 LE=1

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-080	10/18/99	LGR	13	4.2	0.05	YES	GR/SA	RO=1 CA=2 TU=1
SA-081	10/18/99	P-LS-RT	10.5	2.1	0.06	NO	GR/ORGANIC	RT=2 CA=2 OR=3
SA-082	10/18/99	P-LS-BC/RR	82	5.5	0.2	NO	GR/ORGANIC	RT=1 DE=2 CA=2 AV=1 OV=1 LE=3 RR=2 AL=1 OR=2
SA-083	10/18/99	P-LS-BC	15	1.8	0.09	NO	GR/ORGANIC	CA=1 AV=1 OV=2 LE=1 AL=1 OR=2
SA-084	10/18/99	P-LS-RR	10	5.7	0.28	NO	GR/SA	RT=1 DE=2 CA=2 OV=1 LE=2 RR=2
SA-085	10/18/99	LGR	11	5.3	0.04	NO	GR/RR	CA=2 AV=1 TU=1 LE=1 RR=2
SA-086	10/18/99	P-LS-BC	44	5.8	0.22	NO	GR/ORGANIC	RT=2 DE=1 CA=2 OV=2 UB=1 LE=2
SA-087	10/18/99	P-LS-RR/CONCRETE WALL	28	3.3	0.09	NO	GR/RR/ORGANIC	CA=2 OV=2 RR=2 OR=3
SA-088	10/18/99	P-LS-CONCRETE WALL	20	5.8	0.36	NO	SA	DE=2 CA=1 OV=3 CS=2
SA-089	10/18/99	LGR	5	5	0.03	NO	GR	RO=2 CA=2 TU=1 OV=2 LE=2
SA-090	10/18/99	P-LS-RR/CONCRETE WALL	18	3.2	0.07	NO	GR/ORGANIC	CA=2 OV=1 LE=2 RR=1 OR=3
SA-091	10/18/99	LGR	5	0.5	0.07	NO	GR	CA=2 TU=1 LE=2 RR=1
SA-091	10/18/99	LGR	5	1.2	0.05	NO	GR	CA=2 TU=1 LE=2 RR=1
SA-092	10/18/99	P-LS-CONCRETE WALL	9	2.3	0.08	NO	GR/ORGANIC	CA=2 OR=3
SA-093	10/18/99	LGR	3	2	0.03	NO	GR	CA=2 TU=1 LE=1
SA-094	10/18/99	P-LS-CONCRETE WALL	48	5	0.24	NO	GR/SA	DE=2 CA=2 UB=1 LE=2 RR=2 CS=2
SA-095	10/18/99	LGR	10	1.5	0.04	NO	GR/RR	CA=1 AV=1 TU=1 OV=1 LE=1 RR=1
SA-096	10/18/99	P-LS-WOOD WALL	15	3.5	0.23	NO	GR/ORGANIC	CA=1 OV=1 LE=2 OR=2
SA-097	10/18/99	P-LS-RT	22	4.3	0.33	NO	GR/SA	RT=2 DE=2 CA=2 AV=1 OV=2 LE=1 OR=2
SA-098	10/18/99	P-LS-CONCRETE WALL	30	5.3	0.34	NO	SA	DE=2 CA=2 OV=2 LE=2 CS=2
SA-099	10/18/99	LGR	18.5	2.3	0.04	YES	GR	CA=2 TU=2 LE=1
SA-100	10/18/99	P-LS-RT/BC/CB	65	6.5	0.26	NO	GR/ORGANIC	RT=2 DE=2 CA=1 OV=2 LE=2 RR=2 OR=2
SA-101	10/18/99	P-LS-CB	38	5.5	0.19	NO	GR/CONCRETE BLOCKS	RT=1 CA=2 OV=2 LE=1 CB=3
<u>San Anselmo Avenue/Lansdale Station</u>								
SA-102A	10/18/99	BRIDGE				NO	CONCRETE	
SA-102B	10/18/99	P-LS-CONCRETE WALL	16	8	0.53	NO	SA	WD=1 CA=1 OV=2 LE=2
SA-103	10/18/99	P-LS-BC	36	7.8	0.32	NO	SA/GR	RT=2 CA=2 OV=2 LE=2 AL=2
SA-104	10/18/99	P-LS-CONCRETE WALL	80	6.1	0.21	NO	SA/GR	RT=2 WD=1 DE=2 CA=2 OV=1 LE=2 RR=2
SA-105	10/18/99	LGR	13	5.3	0.04	NO	GR/CO	CA=2 OV=1
SA-106	10/18/99	P-LS-BC	28	6.2	0.15	NO	GR/CO	RT=1 WD=1 CA=2 OV=2 LE=2

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-107	10/18/99	LGR	4	4.5	0.04	YES	CO/GR	CA=2 TU=1 LE=1 RR=1
SA-108	10/18/99	P-LS-CONCRETE/GABIAN WALL	58	4.8	0.07	NO	CO/RR	CA=2 OV=2LE=2 RR=2
SA-109	10/18/99	P-LS-BC/RT	34	7.1	0.24	NO	SA/GR	RT=1 WD=1 CA=2 OV=2 LE=2
SA-110	10/18/99	P-LS-PILINGS/RR	20	5.5	0.29	NO	SA/GR	DE=1 CA=2 OV=2 LE=2 RR=2
SA-111	10/18/99	CASCADE	7	2.5	0.1	NO	BO/CO/RR	DE=1 CA=2 TU=2 OV=3
SA-111	10/18/99	CASCADE	18	4.5	0.33	NO	BO/CO/RR	DE=1 CA=2 TU=2 OV=3
SA-111	10/18/99	CASCADE	6	3	0.13	NO	BO/CO/RR	DE=1 CA=2 TU=2 OV=3
SA-111	10/18/99	CASCADE	8	3.5	0.21	NO	BO/CO/RR	DE=1 CA=2 TU=2 OV=3
SA-111	10/18/99	CASCADE	5	1.7	0.15	NO	BO/CO/RR	DE=1 CA=2 TU=2 OV=3
SA-112	10/18/99	P-LS-BC	45	4.4	0.26	NO	GR/ORGANIC	RT=2 WD=2 DE=2 CA=2 OV=2
SA-113	10/18/99	LGR SERIES	19	1.8	0.05	YES	GR	CA=2 TU=1 OV=1 LE=2
SA-114	10/18/99	P-LS-RT/BC	16	5.2	0.21	NO	GR/SA	RT=2 WD=2 DE=2 CA=2 OV=1 LE=1
SA-115	10/18/99	P-LS-RT	31	6	0.22	NO	GR/ORGANIC	RT=2 WD=2 CA=2 OV=1 LE=2
SA-116	10/18/99	P-LS-RR	23	3.5	0.14	NO	GR	CA=2 OV=2 RR=2
SA-117	10/18/99	P-LS-RT	14	5	0.31	NO	GR/SA	RT=2 CA=2
# 10 Adler Court								
SA-118	10/18/99	P-LS-RR	16	3.5	0.06	NO	GR/RR	CA=2 OV=2 LE=1 RR=2
SA-119	10/18/99	P-LS-RT	16	3.9	0.19	NO	GR/SA	RT=2 CA=2 OV=1 LE=2
SA-120	10/18/99	LGR	10	6	0.05	NO	RR/GR	CA=2 OV=2 RR=3
SA-121	10/18/99	PLUNGE-P- CONCRETE WALL		11	0.4	NO	SA/P.GR	RT=1 WD=1 DE=2 CA=2 OV=2 LE=2 CS=1
Pastori Avenue								
SA-122	10/18/99	FISH LADDER				NO	CONCRETE	
SA-123	10/18/99	DRY	14			NO	GR	
SA-124	10/18/99	P-LS-CONCRETE WALL	27	7.3	0.15	NO	SA/SI	RT=1 CA=2 OV=2 LE=1 CS=1
SA-125	10/18/99	P-LS-RT	21	4.3	0.22	NO	GR/SA	RT=2 DE=2 CA=2 OV=1 LE=2
SA-126	10/18/99	P-LS-RR/PILINGS*	30	2.3	0.11	NO	GR/RR/SA	BU=3
SA-127	10/20/99	P-LS-RR	21	5	0.32	NO	SI/SA/GR	DE=2 CA=2 OV=1 RR=2
SA-128	10/20/99	LGR	2	5	0.03	YES	GR	CA=2 TU=1 LE=3
SA-129	10/20/99	P-LS-RT	21	3.7	0.13	NO	GR/SI/SA	RT=1 CA=2 LE=1
Fairfax Creek (tributary)								
SA-130	10/20/99	LGR	10	2.4	0.05	NO	GR/CO	RO=1 CA=2 TU=1 OV=1

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-131	12/20/99	P-LS-BC/RR/CB WALL	47	4.2	0.17	NO	GR/ORGANIC	DE=1 CA=2 OV=1 LE=1 RR=1
SA-132	10/20/99	P-LS-RT*	4	1.4	0.08	NO	GR	RT=3 CA=2 LE=1
SA-133	10/20/99	P-LS-BC	19	5.3	0.38	NO	GR/ORGANIC/SA	WD=2 DE=2 UB=2 LE=2
SA-134	10/20/99	LGR	8	1.5	0.02	NO	CO/GR	TU=1 LE=1
SA-135	10/20/99	P-LS-CINDER BLOCK WALL	10	5	0.06	NO	CO/GR/SI	RO=1
# 40 Inyo Avenue								
SA-136	10/20/99	P-LS-RT (BAY)	24	6	0.39	NO	SA	RT=2 DE=3 CA=2 OV=2 LE=1 CS=1
SA-137	10/20/99	LGR	12	4.9	0.03	NO	GR/CO	RO=1 CA=2 TU=1 OV=1 LE=1
SA-138	10/20/99	P-LS-CONCRETE WALL	10	4.8	0.07	NO	GR	CA=2 LE=2
SA-139	10/20/99	P-LS-BC/RT	14	4.5	0.22	NO	GR/ORGANIC	RT=2 CA=2 OV=2 LE=1
SA-140	10/20/99	P-LS-CONCRETE WALL	26	3.3	0.22	NO	GR/SI	DE=2 CA=1 OV=2 UB=2 LE=1
SA-141	10/20/99	LGR	20	3	0.02	YES	GR/SA	AV=2 TU=1
SA-142	10/20/99	P-LS-RT/P-BW	8	3	0.25	NO	GR/SA	RT=2 DE=2 CA=2 OV=2
SA-143	10/20/99	LGR	15	2.5	0.04	YES	CO/GR	CA=1 TU=1 OV=1
Pacheco Avenue								
SA-144	10/20/99	P-MC-DAM (SPLIT BY LOG)	19	8.8	0.35	NO	RR/SA	RT=1 DE=2 CA=2 OV=2
SA-145	10/20/99	LGR	22	1	0.03	YES	GR	CA=1 TU=2 OV=2
SA-146	10/20/99	P-LS-BC	18	2.2	0.18	NO	SA/GR	OV=3
SA-147	10/20/99	P-LS-BC	39	4.3	0.18	NO	GR/SI	RT=2 OV=3
SA-148	10/20/99	P-LS-BED	19	2.9	0.15	NO	GR/SA	CA=2 OV=1
SA-149	10/20/99	LGR	3	1.2	0.03	NO	GR	CA=2 TU=1
SA-150	10/20/99	P-LS-RT	6	2.9	0.1	NO	GR/SI	RT=1 CA=2 OV=3
SA-151	10/20/99	LGR	2	2.5	0.02	YES	GR	CA=1 TU=1 LE=2
SA-152	10/20/99	P-LS-RT	18	3.7	0.27	NO	GR/SI	RT=2 DE=2 CA=1 OV=1 LE=2
SA-153	10/20/99	P-LS-BC	19	2.5	0.13	NO	CO/GR/SA/SI	CS=1
SA-154	10/20/99	LGR	3	3	0.03	NO	GR	CA=1 TU=1
SA-155	10/20/99	P-LS-RT	11	2.8	0.07	NO	GR/CO/SI	RT=1 CA=2 LE=1
SA-156	10/20/99	P-LS-CONCRETE WALL/RT	11	13	0.46	NO	GR/SA	RT=1 DE=3 CA=3 CS=2
SA-157	10/20/99	LGR	18	0.9	0.04	NO	GR/CO	CA=2 TU=1 LE=1 BR=1
SA-158A,B	10/20/99	P-LS-CONCRETE WALL/RT; P-LS	17	3.1	0.18	NO	GR/SI/SA	DE=1 CA=2 LE=2
SA-159	10/20/99	LGR	40.5	1.7	0.05	YES	CO/RR	CA=2 TU=1 RR=1

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-160	10/20/99	P-LS-BC/RR	23	4	0.33	NO	GR/SA	RT=1 DE=2 CA=2 OV=1 LE=1 RR=2
SA-161A,B	10/20/99	P-LS-RT, P-LS-RT	27	6.6	0.48	NO	GR/SA	RT=2 DE=2 CA=2 OV=1 LE=1
SA-162	10/20/99	LGR	10	4.5	0.05	NO	CO/GR	RO=2 CA=2 TU=1 OV=1
SA-163	10/20/99	P-LS-BC	27	4.9	0.13	NO	CO/GR/SA	CA=1 OV=2 LE=1
SA-164	10/20/99	LGR	10	1.2	0.03	NO	CO/RR	CA=2 TU=1
SA-165	10/20/99	P-LS-BED	17	4.5	0.29	NO	P.GR/SA	RT=2 BE=1 DE=2 CA=2 OV=2 LE=2
SA-166	10/20/99	LGR/PW	16	2	0.04	NO	CO/RR/GR	CA=1 TU=1 OV=1 LE=2
SA-167	10/20/99	P-LS-BC	27	4.7	0.12	NO	GR/SA/CO	CA=1 OV=2 LE=1 RR=1
SA-168	10/20/99	TRICKLE-LGR	19	1.7	0.03	NO	CO/RR	CA=1 TU=1 OV=1
SA-169	10/14/99	P-LS-BRIDGE ABUTTMENT	8	1.5	0.09	NO	GR/CO	RO=1 RR=1 BR=3
Creek Road								
SA-170	10/14/99	LGR-RR	1.5	1.5		NO	RR/CO	TU=1 RR=3 BR=3
SA-171	10/14/99	P-LS-BC/RR	3	1.5	0.04	NO	CO/RR	WD=1 RR=2 BR=2
SA-172	10/14/99	LGR	16	1	0.05	NO	CO/RR	WD=1 CA=2 TU=1 OV=2 UB=2 LE=1 RR=2 CS=1
SA-173	10/14/99	P-BW	5	0.8	0.1	NO	GR	WD=2 CA=2 UB=2
SA-174A,B	10/14/99	P-LS-RT, P-LS-CONCRETE WAL	16	3.5	0.41	NO	GR/SA	RT=2 DE=2 CA=2 OV=1 UB=2 LE=2
SA-175	10/14/99	P-LS-BC/RR	13	3.3	0.09	NO	GR	CA=2 OV=2 UB=2 LE=1 RR=1
SA-176	10/14/99	P-LS-CONCRETE WALL	25	4.2	0.2	YES	GR/SA	RT=2 WD=2 CA=2 OV=1 UB=1 LE=2
SA-177	10/14/99	P-LS-CONCRETE/WOOD WALL	7	1.5	0.15	NO	GR	CA=2 OV=2 LE=2
SA-178	10/14/99	P-LS-CB/LGR	5	2	0.11	NO	GR/CO	CA=2 OV=1 CS=2
SA-178	10/14/99	P-LS-CB/LGR	10	0.7	0.04	NO	GR/CO	CA=2 OV=1 CS=2
SA-179	10/14/99	P-LS-CONCRETE DAM	9.5	6	0.51	NO	GR/SA	RT=2 DE=2 LE=1
SA-180	10/14/99	P-MC-BED/CONCRETE	12	2.5	0.02	NO	CONCRETE SLAB	CA=2 LE=2
SA-181	10/14/99	P-LS-CONCRETE	21	2.9	0.16	NO	GR	CA=2 OV=2 UB=1
SA-182	10/14/99	P-LS-RR	32	1.7	0.08	NO	GR/CO	CA=2 OV=1 LE=1 RR=2
SA-183	10/14/99	LGR-TRICKLE	7	1	0.03	NO	GR/CO	CA=2 TU=2
SA-184	10/14/99	P-LS-RT	9	3.3	0.25	NO	GR/CO	RO=1 RT=2 DE=2 CA=2 LE=1
SA-185	10/14/99	P-LS-RR/CONCRETE WALL	19	2.3	0.22	NO	GR/RR	CA=2 OV=1 RR=2
SA-186	10/14/99	LGR	7	1.8	0.03	NO	CO	RO=2 WD=1 CA=2 TU=1 OV=1
SA-187	10/14/99	P-LS-BED/CONCRETE WALL*	43	3.7	0.24	NO	GR/SA	RT=2 DE=2 CA=2 OV=2 LE=1

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-188	10/14/99	P-LS-BC	13	2.5	0.1	YES	GR	RT=1 CA=1 UB=2 LE=1
SA-189	10/14/99	BRIDGE-CONCRETE CULVERT	15			NO	CONCRETE	
Bolinas Road								
SA-190	10/14/99	P-LS-RR	23	4	0.28	NO	GR/SA	WD=1 CA=2 OV=1 LE=1 RR=2
SA-191	10/14/99	P-LS-BC	6	1.5	0.06	NO	SI/RR	CA=2 OV=2
SA-192	10/14/99	P-LS-CONCRETE BAG	20	3.9	0.29	NO	GR/SA	RT=2 DE=2 CA=2 OV=2 UB=2 LE=1
SA-193	10/14/99	P-LS-RR	9	2.6	0.16	NO	GR/SA	CA=2 LE=1 RR=2
SA-194	10/14/99	P-LS-RT	19	1.8	0.12	NO	GR/CO	RT=1 CA=2 UB=1 LE=2
SA-195	10/14/99	MAJOR P-LS-RT	9	5	0.45	NO	SA	RT=2 DE=3 CA=2 OV=1 LE=1
SA-196	10/14/99	P-LS-BED	16	3.6	0.27	NO	GR/SA	RT=1 BE=1 DE=1 CA=2 OV=1 LE=1
SA-197	10/14/99	DRY	145			YES	GR/CO W/SOME RR	
SA-197	10/14/99	DRY	240			YES	GR/CO W/SOME RR	
SA-197	10/14/99	DRY	137			YES	GR/CO W/SOME RR	
Meadow Way								
SA-198A	11/03/99	P-LS-CONCRETE WALL	10	1.3	0.15	YES	GR	WD=1 DE=1 OV=2 LE=2
Canyon Road								
SA-198B	11/03/99	DRY@MEADOW AVE BRDG	331			YES	GR/CO	
SA-198B	11/03/99	DRY (CONT'D)	107			YES	GR/CO	
SA-198B	11/04/99	DRY@CANYON RD BRDG	362			YES	GR/CO	
SA-198B	11/04/99	DRY (CONT'D)	350			YES	GR/CO	
SA-198B	11/04/99	DRY (CONT'D)	327			YES	GR/CO	
SA-199	09/08/99	P-LS-BED	3.4	1.7	0.21	NO	GR/CO	RO=2 BE=2 WD=1 CA=2 LE=2
SA-200	09/08/99	P-LS-BO	7	1.5	0.75	NO	GR/CO	RO=2 CA=2 AV=2 AL=3
SA-201	09/08/99	P-LS-BED	6	4.5	0.1	NO	CO/GR	RO=2 CA=2 AL=2
SA-202	09/08/99	P-LS-BED	7	0.8	0.06	NO	GR/CO	RO=2 BE=1 CA=2
SA-203	09/08/99	CAS (TRICKLE)	1	0.3	0.03	NO	CO/BED	RO=2 BE=1
SA-204	09/08/99	P-LS-BED	4	1.3	0.75	NO	CO/GR	RO=2 BE=1 CA=2
SA-205	09/08/99	CAS-TRICKLE	5	0.3	0.06	NO	CO	RO=2 CA=2
SA-206	09/08/99	P-LS-BED	8	1.3	0.1	NO	CO/GR	RO=2 CA=2 AV=1 OV=1 AL=2
SA-207	09/08/99	CAS/DRY	3	0.3	0.03	NO	CO	RO=2 CA=2

TABLE D-2 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SAN ANSELMO CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SA-208	09/08/99	P-LS-BC	6	2.2	0.13	NO	CO/BED	RO=1 WD=1 CA=2 AL=3
SA-209	09/08/99	P-LS-BED	5	2.5	0.16	NO	CO/BED	RO=2 BE=1 WD=1 CA=2 OV=1
SA-210	09/10/99	POOL, STRANDED/TRICKLE	10	0.2	0.02	NO	CO	RO=2 CA=2 AV=2 LE=2
SA-211	09/10/99	P-LS-BED	8	2.9	0.15	NO	CO/GR	RO=2 CA=2 AV=2 AL=3
SA-212	09/10/99	PW	13	1.4	0.08	NO	CO/BO	RO=2 CA=2 AV=2 OV=1 LE=2
SA-213	09/10/99	DRY (TRICKLE)	11			NO		
SA-214	09/10/99	P-LS-BED	14	2.3	0.16	NO	GR/CO/BO	RO=2 WD=1 CA=3 LE=2
SA-215	09/10/99	PSEUDO CASCADE	17	1	0.11	NO	CO/BO	RO=3 WD=1 CA=3 LE=2
SA-216	09/10/99	P-LS-BED	13	2.2	0.14	NO	BO/BED/GR	RO=2 WD=1 CA=3 OV=2 LE=2

Cascade Creek (tributary)

TABLE D-3. RESULTS OF HABITAT TYPING DATA FOR CASCADE CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
CC-O-01	09/10/99	PSEUDO CASCADE	26		0.15	NO	BO/CO/BED	RO=3 RT=1 CA=3 OV=1 LE=2 BR=1
CC-O-02	09/10/99	P-LS-TRAIL	7.5	3	0.13	YES	GR/CO/BED	RO=2 CA=2 LE=1
CC-O-03	09/10/99	P-LS-BED	10.4	2.4	0.14	NO	BED	RO=2
CC-O-04	09/10/99	PW	5	0.9	0.06	NO	CO/BED	RO=2
CC-O-05	09/10/99	PW	3.4	0.5	0.05	NO	CO/BED	RO=2
CC-O-06	09/10/99	P-LS-RT				NO	CO/GR	RO=2 RT=1
CC-O-07	11/03/99	LGR	5	1.3	0.04	NO	CO/BO	RO=2 CA=2 TU=1 LE=1
CC-O-08	11/03/99	P-LS-BC/BED	4	1.2	0.11	YES	GR/CO/BED	RO=1 CA=2 OV=1 LE=2
CC-O-09	11/03/99	CASCADE POOLS (BED)	3	1.3	0.06	NO	BED/BO	CA=2 LE=1
CC-O-09	11/03/99	CASCADE POOLS (BED)	1	1.5	0.16	NO	BED/BO	CA=2 LE=1
CC-O-10	11/03/99	HGR	11			NO	CO/GR/BO/BED	RO=2 CA=2 TU=1 LE=2
CC-O-11,	11/03/99	P-LS-BC	11	1.1	0.03	NO	GR/CO	RO=1 CA=2 LE=2
CC-O-12	11/03/99	CASCADE POOLS (BED)	9	1.8	0.24	NO	GR/CO	RO=2 CA=2 TU=1 LE=2
CC-O-13	11/03/99	P-LS-BED	8	2.1	0.21	NO	GR/BED	RO=1 BE=1 DE=1 CA=2 LE=2
CC-O-14	11/03/99	HGR	12			NO	BED/GR/CO	RO=2 CA=2 TU=1 OV=1 LE=2
CC-O-15	11/03/99	CASCADE POOLS (BED)	1.5	2.1	0.1	YES	GR/BO	RO=1 BE=1 CA=2 OV=1 LE=2
CC-O-15	11/03/99	CASCADE POOLS (BED)	5.5	1.3	0.13	YES	GR/BO	RO=1 BE=1 CA=2 OV=1 LE=2
CC-O-15	11/03/99	CASCADE POOLS (BED)	4.5	1.9	0.22	YES	GR/BO	RO=1 BE=1 CA=2 OV=1 LE=2
CC-O-16	11/03/99	HGR	10			NO	CO/BO	AV=2 TU=1 LE=1
CC-O-17	11/03/99	P-LS-BED	4	1.2	0.12	NO	GR/BED	RO=1 CA=1 LE=1
CC-O-18	11/03/99	HGR	7			NO	CO/BO	CA=2 AV=1 TU=1 LE=2
CC-O-19	11/03/99	P-LS-BC/BED	6.2	3.5	0.3	NO	GR/BED	RO=1 BE=2 DE=1 CA=2 OV=1 LE=2
CC-O-20	11/03/99	SMALL CASCADE P./HGR	5			NO	CO	RO=1 CA=2 AV=2 TU=1
CC-O-21	11/03/99	P-LS-BC	5	2.2	0.18	YES	GR/CO	RO=1 WD=1 CA=1 AV=1 BO=1
CC-O-22	11/03/99	P-LS-BC/(SERIES) BED	4.2	1.3	0.11	NO	GR/CO/BO	CA=2 AV=1 LE=2
CC-O-22	11/03/99	P-LS-BC/(SERIES) BED	6.5	0.9	0.19	NO	GR/CO/BO	CA=2 AV=1 LE=2
CC-O-23	11/03/99	HGR	23			NO	GR/BO	CA=1 AV=2 TU=1 OV=1 LE=2
CC-O-24	11/03/99	P-LS-BC	5.3	2.4	0.15	NO	GR/CO/BO	CA=2 LE=2
CC-O-25	11/03/99	HGR	14			NO	CO/GR	CA=1 TU=1 LE=2

TABLE D-3 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR CASCADE CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
CC-O-26	11/03/99	P-LS-BED	6.5	1.2	0.15	NO	GR/BED	BE=1 WD=1 CA=1
CC-O-27	11/03/99	P-LS-BED (PLUNGE POOL)	5.3	2.2	0.32	NO	GR/BED	BE=3 CA=2
CC-O-28	11/03/99	HGR	14.3			NO	BED/BO	RO=2 CA=2 TU=2 LE=2
CC-O-29	11/03/99	P-LS-BC	7.6	2.8	0.2	NO	CO/GR/ORGANIC	RO=1 WD=1 CA=2 LE=2
CC-O-30	11/03/99	CASCADE P. (BED, BC) SER.	5			NO	BO/CO	RO=2 CA=2
CC-O-30	11/03/99	CASCADE P. (BED, BC) SER.	3.1	2.1	0.14	NO	BED/GR	CA=2 OV=1 LE=2
CC-O-30	11/03/99	CASCADE P. (BED, BC) SER.	4.1	1.5	0.1	NO	CO/BED	CA=2 LE=2
CC-O-31	11/03/99	CASCADE P. SER.	4	1.8	0.25	NO	BED/BO/GR	RO=2 CA=2 OV=1 LE=1
CC-O-31	11/03/99	CASCADE P. SER.	2.3	2.2	0.2	NO	BED/BO/GR	RO=2 CA=2 OV=1 LE=1
CC-O-31	11/03/99	CASCADE P. SER.	2.3	1.9	0.26	NO	BED/BO/GR	RO=2 CA=2 OV=1 LE=1
CC-O-31	11/03/99	CASCADE P. SER.	3.4	1.8	0.14	NO	BED/BO/GR	RO=2 CA=2 OV=1 LE=1
CC-O-32	11/03/99	CASCADE P. SER.	4.2	3	0.36	NO	BED/GR/BO	RO=2 BE=1 CA=2 LE=2
CC-O-32	11/03/99	CASCADE P. SER.	3	2.5	0.26	NO	BED/GR/BO	RO=2 BE=1 CA=2 LE=2

TABLE D-4. RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
Confluence with San Anselmo Creek @ 7 Agatha Court								
SH-001	11/16/99		158			NO	CO/CONCRETE	CO=2 RO=2 OV=2
SH-002	11/16/99		174			NO	CONCRETE/GR	CC=2 OV=2 RO=2
Sir Francis Drake Blvd @ Sir Francis Drake High School								
SH-003	10/22/99	RR-TRICKLE	5	1.3	0.07	NO	RR	OV=2 RR=3
SH-004	10/22/99	P-LS-RR	18.5	2	0.12	NO	SA/RR	CA=2 OV=1 LE=1 RR=1
SH-005	10/22/99	HGR (TRICKLE)	9	0.8	0.06	NO	RR/ORGANIC	OV=2 RR=3
SH-006	10/22/99	P-LS-RR/BC	6	2.5	0.12	NO	GR/SA	CA=2 OV=1 RR=1
SH-007	10/22/99	P-LS-RR/BC	10	3	0.35	NO	SA/SI	DE=2 CA=2 OV=1 UB=2 LE=1 RR=1
SH-008	10/22/99	P-LS-RR/BC	40	2.5	0.2	NO	SA/SI	DE=2 CA=1 OV=2 LE=2 RR=2
SH-009	10/22/99	HGR (TRICKLE)	11	0.8	0.02	NO	RR/SI	CA=2 OV=1 RR=3
SH-010	10/22/99	P-LS-BC	32	2.2	0.2	NO	SA/SI	WD=1 DE=1 CA=2 AV=1 OV=2 UB=1 LE=2
SH-011	10/22/99	P-LS-BC	20	3.1	0.13	NO	SI/SA/RR	RT=1 CA=2 OV=2 LE=1 RR=2
SH-012	10/22/99	P-LS-BC	46	2.4	0.14	NO	SA/SI/ALGAE	CA=2 OV=1 UB=2 AL=2
SH-013A,B	10/22/99	P-LS-BC, P-LS-BRIDGE	21	2.8	0.07	NO	ORGANIC/SA	AV=2 LE=1
SH-014	10/22/99	BRIDGE	10			NO	CONCRETE	BR=3
Mountain View Avenue								
SH-015	10/22/99	P-LS-BC	27	4.7	0.3	NO	SA/SI/RR	RT=1 CA=2 OV=2 UB=2 LE=1
SH-016	10/22/99	POCKET WATER (RR)	12	2.9	0.14	NO	SA/SI/RR	CA=2 OV=2 LE=2 RR=2
SH-017	10/22/99	P-LS-BC/RR/P-BW	22	3	0.08	NO		CA=2 OV=2 LE=2 RR=1
SH-018	10/22/99	P-LS-BC	10	4	0.09	NO	SI/SA	CA=1 OV=1 LE=1 RR=1
SH-019	10/22/99	BRIDGE	11			NO	CONCRETE	BR=3
Morningside Drive								
SH-020	10/22/99	P-LS-CONCRETE WALL/CB	10	3.3	0.14	NO	CONCRETE BOTTOM 10M	CA=1 OV=2 LE=1
SH-021	10/22/99	P-LS-CONCRETE WALL	26	3.2	0.27	NO	SI/SA/RR	CA=1 OV=1 RR=2 AL=2
SH-022	10/22/99	P-LS-RR	27	3.2	0.14	NO	SI/SA/RR-CONCRETE BLOX	CA=2 OV=2 RR=2 AL=1
SH-023	10/22/99	TRICKLE	11			NO	GR/CO	CA=2 RO=2
SH-024	10/22/99	P-LS-BC	17	3	0.1	NO	SI/SA	WD=1 CA=2 OV=1 LE=2 AL=1
SH-025	10/22/99	P-LS-CONCRETE WALL	84	3.4	0.18	NO	SA/SI/RR/SLAB	CA=2 AV=1 OV=2 UB=1 AL=2 CS=1

TABLE D-4 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SH-026	10/22/99	BRIDGE	12			NO	CONCRETE	BR=3
Broadmoor Avenue								
SH-027	10/22/99	DRY	8			YES	GR	
SH-028	10/22/99	P-LS-CB WALL	21	1.8	0.09	NO	SA/SI	CA=2 OR=3
SH-029	10/22/99	P-LS-WOOD WALL	22	1.5	0.03	NO	GR/SA	CA=2 OV=1 LE=1
SH-030	10/22/99	P*-LS-WOOD WALL	12	1.4	0.18	NO	P.GR/SA/RR	LE=1 RR=2
SH-031	10/22/99	P-LS-CONCRETE WALL	44	3.5	0.23	NO	SA/P.GR	DE=2 CA=2 OV=2 UB=1 LE=2 RR=2 CS=1
SH-032	10/22/99	P-LS-CONCRETE WALL	9	1.5	0.1	NO	SA/SI/RR	CA=2 OV=1 LE=1
SH-033	10/22/99	P-LS-WALL	9	1.5	0.31	NO	SA/SI/RR	CA=2 LE=1
SH-034	10/22/99	P-LS-WOOD WALL	10	3.5	0.29	NO	SI/SA	DE=2 OV=2
SH-035	10/22/99	HGR (DRY)	10			NO		
SH-036	10/22/99	P-LS-CONCRETE WALL	30	2.1	0.14	NO	SA/SI/P.GR	DE=2 CA=2 OV=2 AL=3
SH-037	10/22/99	P-LS-CONCRETE WALL	12	3	0.09	NO	P.GR/SA/SI	OV=2
SH-038	10/22/99	P-LS-RR	11	1.7	0.06	NO	SI/SA/LEAVES	CA=2 OV=2 LE=2 RR=2
SH-039	10/22/99	P-LS-RR	21	1.2	0.18	NO	SI/SA/LEAVES	CA=2 UB=1 LE=2
SH-040	10/22/99	P-LS-BC	15	2.2	0.09	NO	SI/SA/LEAVES	CA=1 OV=1 LE=2
SH-041	10/22/99	P-LS-RR	10	2.5	0.11	NO	GR/SA	CA=2 LE=2 RR=2
SH-042	10/22/99	P-LS-CONCRETE WALL	6	1.5		NO	GR/SA	CA=2 RR=1
SH-043	10/22/99	P-LS-CONCRETE WALL/CB	33	3.7	0.27	NO	SA/SI/P.GR	CA=2 UB=1 LE=2 RR=2 AL=1 BR=2
SH-044	10/22/99	P-LS-RT	26	3.7	0.28	NO	P.GR/SA/SI	RO=2 DE=2 CA=2 OB=1 LE=1 RR=2
SH-045	10/22/99	BRIDGE	6			NO	CC	BR=3
SH-046	10/22/99	P-LS-RR	9			NO	RR	CA=2 RR=2
SH-047	10/22/99	P-LS-BC	12	3.4	0.13	NO	P.GR/SI	CA=1 OV=2 RR=1
SH-048	10/22/99	TRICKLE	10			NO	GR/RR	CA=1 RO=2
SH-049	10/22/99	P-LS-RR	12	4	0.2	NO	CO/SI/ALGAE	OV=2 AL=2
SH-050	10/22/99	BRIDGE	12			NO	GR	BR=3
Arroyo Avenue								
SH-051	10/22/99	TRICKLE/POCKET WATER	19			NO	CO/GR	CA=2 RO=2
SH-052	10/22/99	P-LS-BC/RR	13	5	0.32	NO	SI/SA	DE=2 CA=2 UB=2 RR=1

TABLE D-4 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SH-053	10/22/99	P-LS-CONCRETE WALL	15	1.8	0.24	NO	SI/RR	AV=2
SH-054	10/22/99	P-LS-BC	8	1.5	0.07	NO	SI	UB=2
SH-055	09/26/99	P-LS-CONCRETE/RR	18.7	2.5	0.26	NO	CC	CA=2
SH-056	09/26/99	P-LS-BC/RR	12	0.7	0.09	NO	SA/P.GR	RO=1 CA=2 OV=1 LE=2
SH-057	09/26/99	P-LS-LWD=RT*	16	2.5	0.19	NO	GR	RO=1 RT=2 WD=2 CA=2 OV=1 LE=1
SH-058	09/26/99	P-LS-BC/P-LS-RT	22	1.7	0.07	YES	GR;GR/CO	WD=2 CA=2 OV=2 UB=2 LE=1
SH-059	09/26/99	MINI LGR-TRICKLE	9			YES	GR	CA=2
SH-060	09/26/99	P-LS-RR/WOODEN WALL	27	2.3	0.24	NO	GR	DE=1 CA=2 OV=2 CB=2
SH-061	09/26/99	PSEUDO LGR=TRICKLE	6	1		YES	GR/ASPHALT BLOX	
SH-062	09/26/99	P-LS-WALL/RR	42	3	0.07	NO	CO/GR/ASPHALT BLOX	RO=1 CA=1 OV=1 LE=1 AL=1
SH-063	09/26/99	P-LS-RR(LB)	15	1.5	0.12	NO	GR/CO/ASPHALT BLOX	RO=1 WD=1 CA=1 OV=1 UB=2
SH-064	09/26/99	P-LS-RR	15	1.8	0.05	NO	GR/RR	RO=1 CA=1 OV=1 LE=2 AL=3
SH-065	09/26/99	TRICKLE=LGR	15	1	0.22	NO	GR/ORGANIC	CA=2 LE=2 BR=3
SH-066	09/26/99	P-LS-WALL(LB)	19	3.8	0.28	NO	GR	RO=1 CA=2 OV=1 LE=1
SH-067	09/26/99	P-LS-CONCRETE ABUTTMENT	6	3	0.22	NO	GR/SA	DE=2 CA=2 OV=1 UB=2
SH-068	09/26/99	P-LS-RR/BRDG ABUTT.	41	4.2	0.4	NO	GR/RR CHUNKS	RO=2 DE=2 CA=2 AV=1 OV=1 LE=1
SH-069	09/26/99	STAGANT POOL-RIFFLE	10			NO	CO	RO=3 AV=3 AL=3
@ 222 Butterfield Road								
SH-070	09/26/99	P-LS-RR(RB)/CONCRETE WALL	20	1.8		NO	SI/RR CHUNKS	AV=2 AL=2
SH-071	09/26/99	P-LS-RR/WALL/BED	35	2.6	0.18	NO	RR/SI	WD=1 DE=1 CA=2 LE=3 RR=3
SH-072	10/01/99	P-LS-CONCRETE WALL/RR	18	2.6	0.24	NO	SA/CONCRETE BLOX	DE=1 CA=2 OV=1 LE=2 CB=2
SH-073	10/01/99	P-LS-BC	5	3	0.32	NO	SA/SI	CA=2 OV=1 LE=1
SH-074	10/01/99	P-LS-CONCRETE WALL (BRDG)	16	2.5	0.16	NO	SA/SI	RO=1 CA=2 OV=1 LE=2 BR=2
SH-075	10/01/99	DRY-TRICKLE	12	2	0.11	NO	SI/COCNRETE BLOX	RO=3 OV=2 LE=2 BR=2
SH-076	10/01/99	P-LS CONCRETE WALL/BRDG/BC	15	1	0.03	NO	SA/SI/COCNRETE BLOX/AL	CA=2 OV=1 LE=2 BR=2
SH-077	10/01/99	P-LS-CONCRETE PILING	12	2.2	0.23	NO	GR/SA	RO=1 WD=1 CA=2 OV=1 LE=2 BR=2
SH-078	10/01/99	P-LS-WOOD RETAINING WALL	16	2	0.06	NO	SA/SI/ORGANIC	RT=2 WD=1 CA=2 OV=1 LE=2
SH-078	10/01/99	P-LS-WOOD RETAINING WALL	16	2	0.06	NO	SA/SI/ORGANIC	RT=2 WD=1 CA=2 OV=1 LE=2
SH-079	10/01/99	P-LS-WOOD RETAINING WALL	15	4	0.33	NO	SA/COCNRETE BLOX	WD=1 CA=2 OV=2 UB=2

TABLE D-4 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SH-080	10/01/99	P-LS-CONCRETE WALL	15	2.5	0.09	NO	SA/SI/ORGANIC	RO=1 CA=2 OV=1 UB=2 LE=2
SH-081	10/01/99	P-LS-CONCRETE WALL/BRDG PIL	20	2.1	0.16	NO	BED/SA/SI	RO=1 CA=2 LE=2 BR=2
SH-082	10/01/99	TRICKLE	13			NO	CO/GR	RO=2 CA=2
SH-083	10/01/99	P-LS-BC	30	4.4	0.15	NO	SA/SI/GR	RO=1 CA=2 AV=1 OV=2 UB=2 LE=2
SH-084	10/01/99	P-LS-BC	13	1.1	0.22	NO	SA/SI	RO=1 WD=2 CA=1 OV=3
SH-085	10/01/99	P-LS-BC	18	2	0.11	NO	SA/SI/ALGAE/GR	CA=2 OV=1 LE=2
SH-086	10/01/99	P-LS-BC/RT(BAY TREE)	7	1.5	0.15	NO	SA/SI	RT=2 LE=2
SH-087	10/01/99	P-LS-BC	20	3.3	0.29	NO	SA/SI/CONCRETE BLOCKS	CA=2 OV=1 UB=1 LE=2 CB=2
SH-088	10/01/99	P-LS-BC (STRANDED POOL)	35	2.8	0.22	NO	GR/SA/CONCRETE BLOCKS	WD=1 DE=2 CA=2 LE=2
SH-089	10/01/99	P-LS-GABIAN WALL	20	2	0.09	NO	SA/GR/SI	CA=2 BR=2 CB=2
SH-090	10/01/99	P-LS-RT (BAY TREE)	20	2.5	0.17	NO	SA/GR/ORGANIC	RT=2 LE=2
SH-091	10/01/99	P-LS-CONCRETE WALL	20	4	0.06	NO	SA/SI	RT=2 CA=2 UB=2 LE=2
SH-092	10/01/99	P-LS-RR	24	3.5	0.26	NO	SA/SI/GR	RT=2 DE=2 CA=2 AV=1 OV=1 LE=2 RR=2
SH-093	10/01/99	P-LS-RR	13	1.8	0.2	NO	SA/SI	OV=2 LE=2 RR=2
SH-094	10/01/99	P-LS-BC/RT (STRANDED)	12	2.3	0.29	NO	SA/SI	RT=2 WD=1 CA=2 OV=1 UB=2
SH-095	10/01/99	P-LS-CONCRETE WALL	6			NO	GR	CA=2
SH-096	10/01/99	P-LS-RT (BAY)/CONCRETE WALL	14	4.8	0.24	NO	SA/GR	RT=2 DE=2 CA=2 LE=1
SH-097	10/01/99	P-LS-CONCRETE WALL-CALETA E	15	2.9	0.11	NO	SA/SI/RR	OV=2 RR=2 BR=2
<u>**Caleta Avenue**</u>								
SH-098	10/01/99	DRY (STRANDED)	13			YES	GR	
SH-099	10/01/99	P-LS-RT (BAY) (STRANDED)	8	2	0.13	NO	GR/SA	RT=2 CA=2 LE=2
SH-100	10/01/99	DRY	28			YES	GR	
SH-101	10/01/99	P-LS-BC	18	3.5	0.26	NO	GR/SA	RT=1 DE=2 CA=1 AV=3 OV=1 UB=2
SH-102	10/01/99	P-LS-CB WALL	12	2.2	0.16	NO	GR	AV=3
SH-103	10/01/99	DRY	10			YES	GR	
SH-104	10/01/99	P-LS-LOG (STRANDED)	10	1.9	0.16	NO	GR	WD=3 CA=2 OV=1
SH-105	10/01/99	P-LS-RT (STRANDED)	21	3.3	0.32	NO	SA/SI/GR	RT=2 DE=3 CA=2 OV=1
SH-106	10/01/99	DRY	13			YES	GR	
SH-107	10/01/99	P-LS-RT	10	2.2	0.22	NO	SA/GR	RT=2 AV=2 LE=1 AL=2

TABLE D-4 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SH-108	10/01/99	DRY	25			YES	GR	
SH-109	10/01/99	P-LS-BC (STRANDED)	16	4.3	0.12	NO	GR/SA	CA=1 AV=3 OV=1
SH-110	10/01/99	DRY	16			YES	GR	
SH-111	10/01/99	P-LS-BC (STRANDED)	10	1.8	0.11	NO	GR/SA	WD=2 CA=1 OV=2
SH-111	10/01/99	P-LS-BC		1.6	0.12	NO	GR/SA	RT=1 CA=2 OV=2
SH-111	10/01/99	P-LS-BC/CB	15	1.8	0.13	NO	GR/SA	CA=2 OV=1 LE=1 CB=2
SH-111	10/01/99	P-LS-BC/CONCRETE RO. OVERHANG		0.9	0.07	NO	GR/SA	BE=2 CA=2 LE=2 CB=2
SH-111	10/01/99	P-LS-CONCRETE WALL	7	1.6	0.13	NO	SA/CONCRETE BLOCKS	CA=2 LE=2 CC=2
SH-111	10/01/99		5	1.2	0.2	NO	GR/SA	WD=1 CA=2 LE=1
SH-112	10/01/99	P-LS-BED/CONCRETE DAM	5	2.5	0.23	NO	GR/CONCRETE BLOCKS	BE=3 WD=3 LE=2 CB=2
SH-113	10/01/99	P-MC-BED	5.5	5.3	0.32	NO	GR/SA	DE=2 CA=2 LE=1 CS=2
SH-114	10/13/99	DRY (BRIDGE)	12			NO		BR=3
Deer Hollow Road								
SH-115	10/13/99	DRY	160			YES	GR	
SH-116	10/13/99	P-LS-BED	7	0.8	0.04	NO	GR	CA=2 LE=2
SH-117	10/13/99	P-LS-BED	13	2	0.13	NO	GR/CO/LEAVES	CA=2 LE=3
SH-118	10/13/99	DRY	22			YES	GR	
SH-119	10/13/99	P-LS-BED	7	2	0.14	NO	GR	CA=2 LE=2
SH-120	10/13/99	P-LS-BED	8	2.9	0.09	NO	GR	CA=2 AV=3 LE=2
SH-121	10/13/99	P-LS-CONCRETE WALL (BRDG)	27	2.8	0.21	NO	GR	RT=2 WD=2 CA=2 OV=1 LE=3
66 Fawn Drive								
SH-122	10/13/99	TRICKLE	11			NO	SA/SI	CA=2 OV=2
SH-123	10/13/99	P-LS-CONCRETE BRIDGE	12	4	0.1	NO	RR	CA=2 AL=3
SH-124	10/13/99	BRIDGE (CONCRETE CULVERT)	18			NO	CC	BR=3
Fawn Drive								
SH-125	10/13/99	P-LS-DAM (CONCRETE CULVERT)	4	1	0.28	NO	CC	CA=3 AL=2
SH-126	10/13/99	DRY	11			YES	GR	
SH-127	10/13/99	P-LS-RR/BC	21	1.8	0.19	NO	SA	CA=2 AV=2 OV=2 LE=2 RR=2
SH-128	10/13/99	TRICKLE	35			NO	GR/CO	CA=2 RO=2

TABLE D-4 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SH-129	10/13/99	P-LS-RR/BC	20	2	0.08	NO	GR/SA	WD=1 CA=2 AV=1 OV=2 LE=2 AL=2
SH-130	10/13/99	P-LS-BED	10	2		NO	GR/SA	BE=2 CA=2 AV=3
SH-131	10/13/99	P-LS-BED	10	4	0.36	NO	GR	RT=1 BE=2 DE=1 CA=2 AV=1 LE=2
SH-132	10/13/99	P-LS-BED	10	4		NO	GR/SA	CA=1 OV=2
SH-133	10/13/99	P-LS-RR	13	1.3	0.09	NO	GR/SA	RT=2 WD=1 CA=1 AV=3 OV=2 RR=2
SH-134	10/13/99	P-LS-BRIDGE COCNRETE WALL	20	2.3	0.22	NO	GR/SA	DE=2 CA=1 AV=3 OV=2 AL=1 BR=2
Between # 854 & # 870 Butterfield Lane								
SH-135	10/19/99	DRY	6			YES	GR	
SH-136	10/19/99	P-LS-RR	4	1.5	0.05	NO	SA/P.GR	AV=2 OV=2
SH-137	10/19/99	P-LS-BRDG CONCRETE WALL/BEI	10	1.8	0.14	NO	P.GR/SA	AV=3 BR=3
SH-138	10/19/99	CASCADE POOLS	1.2	0.8	0.12	NO	BED	BED=2 CA=1
SH-138	10/19/99	CASCADE POOLS	3		0.07	NO	BED	BED=2 CA=1
SH-139	10/19/99	P-LS-CONCRETE WALL	12	2.5	0.1	NO	P.GR/SA	AV=3 OV=2
SH-140	10/19/99	P-LS-BRIDGE CONCRETE WALL	4	0.7	0.15	NO	GR/SA	AV=2 BR=3
SH-141	10/19/99	P-LS-CONCRETE WALL	15	3.8	0.24	NO	P.GR/SA	DE=2 CA=1 AV=1 OV=2 LE=2 SC=3
SH-142	10/19/99	DRY	22			YES	GR	
SH-143	10/19/99	P-LS-BC	4			NO	GR	CA=2 OV=2
SH-144	10/19/99	DRY	158			YES	GR	
SH-144	10/19/99	DRY	54			YES	GR	
Green Valley Court								
SH-145	10/19/99	P-LS-BC	12.6	1.6	0.1	NO	GR/SA	CA=2 OV=2 UB=1
SH-146	10/12/99	P-LS-BC	15.7	1.8	0.28	NO	GR/SA	DE=2 CA=2 OV=1 UB=3 LE=2
# 970 Butterfield Road								
SH-147	10/12/99	DRY	26			YES	GR	
SH-148	10/12/99	P-MC-DAM				NO	GR/SA	RT=2 WD=1 DE=2 CA=2 OV=1 UB=1 LE=1
SH-149	10/12/99	DRY	20			NO	GR/SA	
SH-149	10/12/99	DRY	39			NO	GR/SA	
SH-150	10/12/99	P-LS-BC/CONCRETE PILINGS	13	1.1	0.12	NO	GR/SA/LEAVES	CA=2 OV=2 LE=2 AL=2 BR=2
SH-151	10/12/99	DRY	17			NO	GR	

TABLE D-4 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SH-152	10/12/99	P-LS-BRDG CONCRETE WALL/BC	15	1.3	0.07	NO	GR/SA	RO=1 CA=2 OV=2 BR=2
SH-153	10/12/99	P-LS-BC/BRIDGE ABUTT.	19	1.5	0.12	NO	GR	RO=2 CA=2 AV=2 OV=2 BR=2
SH-154	10/12/99	P-LS-RT	12			NO	GR/SA	RT=2 CA=2 OV=1 LE=3
SH-155	10/12/99	TRICKLE CONNECTOR	10			NO	SA/SI	CA=2
SH-156	10/12/99	P-LS-BC/RR	14	2.7	0.23	NO	SA	RT=2 DE=2 CA=2 OV=1 LE=2 RR=1
SH-157	10/12/99	TRICKLE HABITAT	10			NO	SA/GR	CA=2
SH-158	10/12/99	P-LS-BC	20	2	0.19	NO	GR/SA	CA=2 OV=2 LE=2
SH-159	10/12/99	DRY	14			YES	GR	
SH-160	10/12/99	P-LS-RR/BC	7	0.9	0.05	YES	GR	CA=2 LE=2 RR=2
SH-161	10/12/99	P-LS-BC	17	2.7	0.22	YES	GR/SA	RO=1 CA=2 UB=2 LE=2
SH-162	10/12/99	P-LS-RR	22	2.4	0.2	NO	GR/SA	CA=2 LE=1 RR=1
SH-163	10/12/99	CULVERT UNDER BUTTERFIELD	28			NO	CC	BR=3
<u>Butterfield Road</u>								
SH-164A,B	10/12/99	P-LS-BC, P-LS-RR/WOOD WALL	35	2.8	0.12	NO	GR/SA	CA=2 UB=2
SH-165	10/12/99	P-LS-RR	10	2	0.1	NO	GR/SA/ORGANIC	CA=2 OV=1 LE=1 RR=2 OR=2
SH-166	10/12/99	TRICKLE	9			YES	GR	CA=2 RO=2
SH-167	10/12/99	P-LS-RR	15	1.8	0.1	NO	GR	AV=2 OV=2 RR=1
SH-168	10/12/99	P-LS-RT (BERRY BUSHES)	8	2.3	0.08	NO	GR/SA	CA=2 OV=2 UB=2
SH-169	10/12/99	P-LS-RR	21	1.8	0.11	NO	GR/CO	CA=2 AV=1 OV=2 RR=2
SH-169	10/12/99	P-LS-RR	20			NO	GR	CA=2 RO=2
SH-169	10/12/99	DRY	10			NO	GR	
SH-170	10/12/99	P-LS-RT/BC	20	4	0.35	NO	SA/LITTLE GR	OV=2 LE=1
SH-171	10/20/99	TRICKLE	16	0.6	0.03	NO	CO/GR	CA=2 TU=1 OV=1
<u>Across from # 17 Raven Road</u>								
SH-172	10/20/99	P-LS-BC/RT	23	3.8	0.19	NO	GR/SI	RT=2 DE=2 CA=2 OV=2
SH-173	10/20/99	TRICKLE (LGR)	9	0.9	0.03	NO	CO/RR/SI	CA=2 TU=1 OV=1
SH-174	10/20/99	P-LS-BC	14	2.1	0.07	NO	P.GR/RR/SI	RT=2 CA=2 OV=2 LE=1
SH-175	10/20/99	P-LS-RR	10	1.6	0.1	NO	SI/P.GR	CA=2 OV=2 LE=1 RR=2 AL=2
SH-176	10/20/99	PSUEDO DRY	11			NO	CO	CA=2 AV=2

TABLE D-4 (CONT'D). RESULTS OF HABITAT TYPING DATA FOR SLEEPY HOLLOW CREEK

SRU	DATE	HABITAT TYPE	LENGTH	AVG_W	AVG_D	SPWN_GRAVL	SUBSTRATE	COVER
SH-177	10/20/99	P-LS-BED	10	5.8	0.16	NO	P.GR/SA	CA=2 OV=1 OR=3
SH-178	10/20/99	P-LS-BED/RR	4	2	0.23	NO	SI/P.GR	CA=2 RR=2
SH-179	10/20/99	P-MC-DAM	13	5.5	0.38	NO	P.GR/ALGAE/SI	LE=1 AL=3
Major dam across from # 33 Raven Road								
SH-180	10/20/99	DRY/P-LS-BC (TRICKLE)				NO		CA=2 RO=2
SH-180	10/20/99	TRICKLE (CONT'D)				NO		CA=2 RO=2
Katrina Lane								
SH-181	10/20/99	TRICKLE/P-LS,STRANDED				NO		CA=3
SH-182	10/22/99	P-LS-BC=STRANDED				NO		CA=3
Van Winkle Avenue								
SH-183	10/22/99	DRY				NO		
Upstream of Van Winkle Avenue								

APPENDIX E

SUMMARY OF ELECTROFISHING RESULTS

KEY

Habitat:

BC	Bank Cut
BED	Bedrock
BW	Back Water
CAS	Cascade
HGR	High Gradient Riffle
LGR	Low Gradient Riffle
LS	Lateral Scour
LWD	Large Woody Debris
MC	Mid-Channel
P	Pool
PW	Pocket Water
RR	Rip Rap
RT	Root wad

Site Location:

d/s	downstream
SFD	Sir Francis Drake Boulevard
u/s	upstream

Fish Species Collected:

rbt	Rainbow/Steelhead
rch	California Roach
sck	Sacramento Sucker
scu	Prickly Sculpin
stb	Threespine Stickleback

Other:

C.F.	Condition Factor
s.d.	Standard Deviation

Table E-1. Electrofishing Sites in Corte Madera Creek

Map Number	Site Number	Site Location	Habitat Type
E-CM-1	CMC-2	Behind Ross Post Office	P-LS-BC/RR
E-CM-2	CMC-5	Behind Ross Post Office	LGR
E-CM-3	CMC-6	Behind Ross Post Office	P-LS-BC-RT
E-CM-4	CMC-9	Ross, under Lagunitas Avenue bridge	P-LS-Bridge (braided)
E-CM-5	CMC-10	Ross behind police/fire station	P-LS-BC
E-CM-6	CMC-11	Ross behind police/fire station	LGR
E-CM-7	CMC-12a	Ross, near USGS gauge station	P-LS-BC
E-CM-8	CMC-12b	Ross, near USGS gauge station	P-LS-BC/LWD
E-CM-9	CMC-12c	Ross, near USGS gauge station	P-LS-LWD
E-CM-10	CMC-13	Ross, u/s of USGS gauge station	P-LS-LWD
E-CM-11	CMC-17	Ross, about 350 ft. u/s of USGS gauge station	P-LS-LWD

Table E-2. Electrofishing Sites in San Anselmo Creek

Map Number	Site Number	Site Location	Habitat Type
E-SA-1	SA-16c	San Anselmo, d/s of SFD bridge, behind Sunnyside Nursery	LGR
E-SA-2	SA-17	San Anselmo, d/s of SFD bridge behind Ross Valley Vet Hospital	P-LS-BC
E-SA-3	SA-18	San Anselmo, d/s of SFD bridge behind Ross Valley Vet Hospital	P-LS-RR
E-SA-4	SA-19	San Anselmo, under SFD bridge, u/s of Ross Valley Vet Hospital	LGR
E-SA-5	SA-124	Fairfax, d/s of Fair-Anselm Plaza	P-LS-Concrete wall overhang
E-SA-6	SA-125	Fairfax, behind Fair-Anselm Plaza	P-LS-RT
E-SA-7	SA-126	Fairfax, under Fair-Anselm Plaza	P-LS-RR (Pilings)
E-SA-8	SA-129	Fairfax, behind Post Office	P-LS-RT
E-SA-9	SA-130	Fairfax, behind Post Office	LGR
E-SA-10	SA-131	Fairfax, behind Post Office	P-LS-BC
E-SA-11	SA-132	Fairfax, u/s of Post Office	P-LS-RT
E-SA-12	SA-161b	Fairfax, d/s of Creek Road bridge	P-LS-RT
E-SA-13	SA-163	Fairfax, d/s of Creek Road bridge	P-LS-BC
E-SA-14	SA-165	Fairfax, d/s of Creek Road bridge	P-LS-BED
E-SA-15	SA-166	Fairfax, d/s of Creek Road bridge	PW

Table E-2 (Cont.). Electrofishing Sites in San Anselmo Creek

Map Number	Site Number	Site Location	Habitat Type
E-SA-16	SA-167	Fairfax, d/s of Creek Road bridge	P-LS-BC (concrete slabs)
E-SA-17	SA-168	Fairfax, d/s side of Creek Road bridge	LGR
E-SA-18	SA-169	Fairfax, under Creek Road bridge	P-LS-Bridge (pilings)
E-SA-19	SA-171	Fairfax, u/s side of Creek Road bridge	P-LS-BC/RR
E-SA-20	SA-172	Fairfax, u/s side of Creek Road bridge	LGR
E-SA-21	SA-173	Fairfax, u/s side of Creek Road bridge	P-LS-BW
E-SA-22	SA-197	Cascade Canyon, Open Space Preserve	P-LS-BED
E-SA-23	SA-203	Cascade Canyon, Open Space Preserve	CAS (trickle)
E-SA-24	SA-208	Cascade Canyon, Open Space Preserve	P-LS-BC
E-SA-25	SA-209	Cascade Canyon, Open Space Preserve	P-LS-RT/BC

Table E-3. Electrofishing Sites in Cascade and Ross Creeks

Map Number	Site Number	Site Location	Habitat Type
E-C-1	C-1	Cascade Canyon, Open Space Preserve	P-LS-BED
E-C-2	C-2	Cascade Canyon, Open Space Preserve	PW
E-C-3	C-3	Cascade Canyon, Open Space Preserve	PW
E-R-1	RC-1	Ross,Within Natalie Coffin Greene Park	P-LS-BED
E-R-2	RC-2	Ross, Within Natalie Coffin Greene Park	HGR

Table E-4. **Electrofishing Sites in Sleepy Hollow Creek**

Map Number	Site Number	Site Location	Habitat Type
E-SH-1	SH-12	San Anselmo, d/s of Mountain View Avenue bridge	P-LS-BC
E-SH-2	SH-12b	San Anselmo, d/s of Mountain View Avenue bridge	P-LS-BC
E-SH-3	SH-13a	San Anselmo, d/s of Mountain View Avenue bridge	P-LS-BC/RR
E-SH-4	SH-13b	San Anselmo, d/s of Mountain View Avenue bridge	P-LS-Bridge
E-SH-5	SH-14	San Anselmo, Mountain View Avenue bridge	P-LS-Bridge (trickle)
E-SH-6	SJ-16	San Anselmo, u/s of Mountain View Avenue bridge	PW
E-SH-7	SH-17	San Anselmo, u/s of Mountain View Avenue bridge	P-LS-BC /RR
E-SH-8	SH-17a	San Anselmo, u/s of Mountain View Avenue bridge	P-BW
E-SH-9	SH-55	San Anselmo, d/s of Carlson Avenue	P-LS-Concrete/RR
E-SH-10	SH-56a	San Anselmo, d/s of Carlson Avenue	P-LS-RR
E-SH-11	SH-56b	San Anselmo, d/s of Carlson Avenue	P-LS-Concrete/RR
E-SH-12	SH-57	San Anselmo, at Carlson Avenue	P-LS-RT/LWD
E-SH-13	SH-58a	San Anselmo, at Carlson Avenue	P-LS-RT/BC
E-SH-14	SH-58b	San Anselmo, at Carlson Avenue	P-LS-RT/LWD
E-SH-15	SH-58c	San Anselmo, at Carlson Avenue	P-LS-RT/BC

Table E-4 (Cont). Electrofishing Sites in Sleepy Hollow Creek

Map Number	Site Number	Site Location	Habitat Type
E-SH-16	SH-111a	San Anselmo, d/s of Deer Hollow Road bridge	P-LS-BC
E-SH-17	SH-111b	San Anselmo, d/s of Deer Hollow Road bridge	P-LS-Concrete/RR
E-SH-18	SH-111c	San Anselmo, d/s of Deer Hollow Road bridge	P-LS-Concrete Blocks/BED
E-SH-19	SH-111d	San Anselmo, d/s of Deer Hollow Road bridge	P-LS-Concrete Blocks
E-SH-20	SH-112	San Anselmo, d/s of Deer Hollow Road bridge	P-LS-BED
E-SH-21	SH-113	San Anselmo, d/s of Deer Hollow Road bridge	P-MC-BED
E-SH-22	SH-145	San Anselmo, d/s of 970 Butterfield Road	P-LS-BC
E-SH-23	SH-146	San Anselmo, d/s of 970 Butterfield Road	P-LS-BC
E-SH-24	SH-148	San Anselmo, u/s of 970 Butterfield Road	P-MC-Dam
E-SH-25	SH-150	San Anselmo, u/s of 970 Butterfield Road	P-LS-BC (concrete pilings)
E-SH-26	SH-152	San Anselmo, u/s of 970 Butterfield Road	P-LS-BC (concrete pilings)
E-SH-27	SH-158	San Anselmo, d/s of Legend Road bridge	P-LS-BC
E-SH-28	SH-160	San Anselmo, d/s of Legend Road bridge	P-LS-BC/RR
E-SH-29	SH-161	San Anselmo, d/s of Legend Road bridge	P-LS-BC
E-SH-30	SH-162	San Anselmo, d/s of Legend Road bridge	P-LS-RR (bridge)

Table E-4 (Cont). **Electrofishing Sites in Sleepy Hollow Creek**

Map Number	Site Number	Site Location	Habitat Type
E-SH-31	SH-163	San Anselmo, Legend Road culvert	P-LS-Concrete (bridge)
E-SH-32	SH-164a	San Anselmo, 1101 Butterfield Road, u/s of Legend Road	P-LS-BC
E-SH-33	SH-164b	San Anselmo, 1101 Butterfield Road, u/s of Legend Road	P-LS-RR
E-SH-34	SH-168	San Anselmo, u/s of Legend Road	P-LS-RT
E-SH-35	SH-180a	San Anselmo, u/s of concrete dam, d/s of Katrina Lane	P-LS-RR
E-SH-36	SH-180b	San Anselmo, u/s of concrete dam, d/s of Katrina Lane	P-LS-RT
E-SH-37	SH-180c	San Anselmo, u/s of concrete dam, d/s of Katrina Lane	P-LS-Wall (concrete)
E-SH-38	SH-180d	San Anselmo, u/s of concrete dam, d/s of Katrina Lane	P-LS-RR (trickle)
E-SH-39	SH-180e	San Anselmo, u/s of concrete dam, d/s of Katrina Lane	P-LS-BC
E-SH-40	SH-180f	San Anselmo, u/s of concrete dam, d/s of Katrina Lane	P-LS-RR (trickle)
E-SH-41	SH-180g	San Anselmo, u/s of concrete dam, d/s of Katrina Lane	P-LS-BC

APPENDIX F

PHOTOGRAPHS OF THE CORTE MADERA CREEK WATERSHED

Photo Key

Photo Number	Creek	Subject	SRU
CMC 1	Corte Madera Creek	USACE concrete channel	CM-01
CMC 2	Corte Madera Creek	Thermograph site CMC-1b at beginning of concrete channel	CM-01
CMC 3	Corte Madera Creek	Large California roach	CM-02
CMC 4	Corte Madera Creek	Electrofishing field crew	CM-02
CMC 5	Corte Madera Creek	P-LS-BC/RR	CM-02
CMC 6	Corte Madera Creek	LGR	CM-05
SA 1	San Anselmo Creek	Rainbow/Steelhead trout	SA-199
SA 2	San Anselmo Creek	Electrofishing field crew	SA-209
SA 3	San Anselmo Creek	Thermograph site	SA-130
SA 4	San Anselmo Creek	Thermograph site	SA-198B
SA 5	San Anselmo Creek	Diversion	SA-012
SA 6	San Anselmo Creek	P-LS-BC	SA-012
SA 7	San Anselmo Creek	Concrete Slab	SA-015
SA 8	San Anselmo Creek	P-LS-BED/BC	SA-015
SA 9	San Anselmo Creek	P-LS-Concrete pillars in downtown San Anselmo	SA-021
SA 10	San Anselmo Creek	LGR	SA-016
SA 11	San Anselmo Creek	Water Heater	SA-063
SA 12	San Anselmo Creek	P-LS-Concrete Wall	SA-054
SA 13	San Anselmo Creek	Denil Fish Ladder at Saunders Ave.	SA-076
SA 14	San Anselmo Creek	P-LS-Concrete overhang	SA-072
SA 15	San Anselmo Creek	P-LS-RR	SA-084
SA 16	San Anselmo Creek	LGR	SA-080
SA 17	San Anselmo Creek	Diversion	SA-094
SA 18	San Anselmo Creek	Radiator	SA-090
SA 19	San Anselmo Creek	P-LS-BC	SA-103
SA 20	San Anselmo Creek	Crayfish	SA-102
SA 21	San Anselmo Creek	P-LS-Concrete pilings at Fair-Anselm Plaza	SA-126
SA 22	San Anselmo Creek	Denil Fish Ladder at Pastori Ave.	SA-122
SA 23	San Anselmo Creek	P-LS-BC	SA-112
SA 24	San Anselmo Creek	Cascade pools	SA-111
SA 25	San Anselmo Creek	P-LS-BC with eroded right bank	SA-133
SA 26	San Anselmo Creek	P-LS-RT (stranded pool)	SA-132
SA 27	San Anselmo Creek	P-MC-Dam	SA-144

Photo Key (Continued)

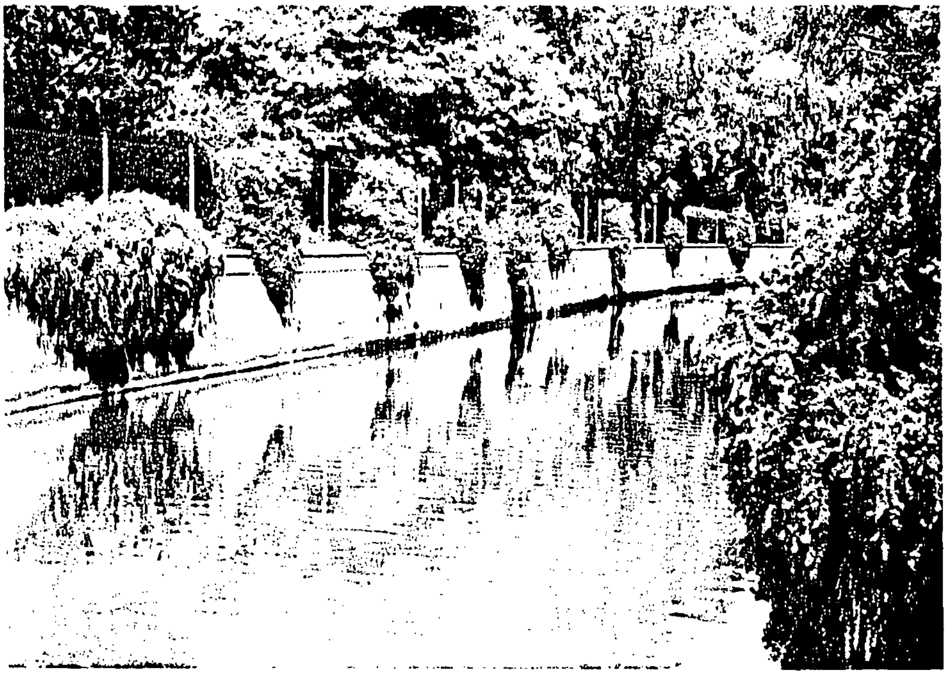
Photo Number	Creek	Subject	SRU
SA 28	San Anselmo Creek	P-LS-RT	SA-136
SA 29	San Anselmo Creek	Electrofishing site (P-LS-RT)	SA-161B
SA 30	San Anselmo Creek	P-LS-Concrete Wall	SA-158A
SA 31	San Anselmo Creek	P-LS-BED	SA-165
SA 32	San Anselmo Creek	LGR/PW	SA-196
SA 33	San Anselmo Creek	P-LS-RT with tributary	SA-195
SA 34	San Anselmo Creek	P-LS-BED	SA-196
SA 35	San Anselmo Creek	Dry habitat; spawning gravel	SA-197
SA 36	San Anselmo Creek	Spawning gravel	SA-197
SA 37	San Anselmo Creek	Wood/Concrete dam	SA-197
SA 38	San Anselmo Creek	Denil Fish Ladder at Canyon Rd.	SA-198B
SA 39	San Anselmo Creek	Cascade Open Space dry habitat	SA-198B
SA 40	San Anselmo Creek	Cascade Open Space dry habitat	SA-198B
SA 41	San Anselmo Creek	Pseudo Cascade	SA-215
SA 42	San Anselmo Creek	P-LS-BED	SA-216
CC 1	Cascade Creek	HGR	CC-O-10
CC 2	Cascade Creek	Gravel	CC-O-12
CC 3	Cascade Creek	P-LS-BED	CC-O-13
CC 4	Cascade Creek	HGR	CC-O-16
CC 5	Cascade Creek	P-LS-BC/BED	CC-O-19
CC 6	Cascade Creek	HGR	CC-O-23
CC 7	Cascade Creek	P-LS-BED (Plunge pool)	CC-O-27
CC 8	Cascade Creek	Cascade waterfall (fish migration barrier)	CC-O-32
SH 1	Sleepy Hollow Creek	P-LS-Concrete Wall	SH-001
SH 2	Sleepy Hollow Creek	HGR (trickle)	SH-005
SH 3	Sleepy Hollow Creek	P-LS-BC	SH-024
SH 4	Sleepy Hollow Creek	Bridge	SH-014
SH 5	Sleepy Hollow Creek	Dry habitat; spawning gravel	SH-028
SH 6	Sleepy Hollow Creek	Spawning gravel	SH-028
SH 7	Sleepy Hollow Creek	P-LS-Concrete/RR	SH-055
SH 8	Sleepy Hollow Creek	P-LS-RT	SH-057
SH 9	Sleepy Hollow Creek	Rainbow/Steelhead trout	SH-055
SH 10	Sleepy Hollow Creek	Rainbow/Steelhead trout	SH-113

Photo Key (Continued)

Photo Number	Creek	Subject	SRU
SH 11	Sleepy Hollow Creek	California roach	SH-057
SH 12	Sleepy Hollow Creek	Algae	SH-085
SH 13	Sleepy Hollow Creek	Drainage pipe	SH-060
SH 14	Sleepy Hollow Creek	P-LS-Concrete abutment	SH-067
SH 15	Sleepy Hollow Creek	P-LS-RR with Maggie (dog)	SH-092
SH 16	Sleepy Hollow Creek	P-LS-RT with Maggie (dog)	SH-094
SH 17	Sleepy Hollow Creek	P-LS-Concrete wall under Caleta Rd.	SH-097
SH 18	Sleepy Hollow Creek	Duckweed-covered pool	SH-101
SH 19	Sleepy Hollow Creek	P-LS-RT with debris and pipe	SH-107
SH 20	Sleepy Hollow Creek	Dry habitat; spawning gravel	SH-108
SH 21	Sleepy Hollow Creek	Spawning gravel	SH-098
SH 22	Sleepy Hollow Creek	P-MC-BED	SH-113
SH 23	Sleepy Hollow Creek	P-LS-Concrete Wall	SH-121
SH 24	Sleepy Hollow Creek	Diversion	SH-121
SH 25	Sleepy Hollow Creek	P-LS-Concrete bridge with surface scum	SH-123
SH 26	Sleepy Hollow Creek	P-LS-BC (trickle)	SH-128
SH 27	Sleepy Hollow Creek	P-LS-BED	SH-131
SH 28	Sleepy Hollow Creek	P-LS-BED with surface scum	SH-132
SH 29	Sleepy Hollow Creek	P-LS-BED (trickle)	SH-132
SH 30	Sleepy Hollow Creek	Dry habitat	SH-144
SH 31	Sleepy Hollow Creek	P-LS-RT	SH-154
SH 32	Sleepy Hollow Creek	P-LS-BC	SH-161
SH 33	Sleepy Hollow Creek	Drainage pipe	SH-164A
SH 34	Sleepy Hollow Creek	P-LS-BC/RT	SH-172
SH 35	Sleepy Hollow Creek	P-LS-RR	SH-169
SH 36	Sleepy Hollow Creek	Trickle	SH-176
SH 37	Sleepy Hollow Creek	P-LS-BED/RR (stagnant)	SH-178
SH 38	Sleepy Hollow Creek	P-MC-Dam	SH-179
SH 39	Sleepy Hollow Creek	Trickle	SH-166
SH 40	Sleepy Hollow Creek	Dry habitat off Van Winkle Ave.	SH-183

Photo Key (Continued)

Photo Number	Creek	Subject	SRU
RC 1	Ross Creek	Rainbow/Steelhead trout (Electrofishing site RCE1)	RC-6
RC 2	Ross Creek	Rainbow/Steelhead trout (Electrofishing site RCE1)	RC-6
RC 3	Ross Creek	Thermograph site (RC-1)	
RC 4	Ross Creek	Thermograph site (RC-3)	
RC 5	Ross Creek	Dry habitat (spawning gravel)near Katherine Branson School	RC-1
RC 6	Ross Creek	Dry habitat; spawning gravel	RC-1
RC 7	Ross Creek	LGR	RC-5
RC 8	Ross Creek	Natalie Coffin Greene Park	RC-6
RC 9	Ross Creek	P-LS-BED (Electrofishing site RCE1)	RC-6
RC 10	Ross Creek	HGR (Electrofishing site RCE2)	RC-6
FC 1	Fairfax Creek	Just off Bolinas Rd. in Fairfax	
FC 2	Fairfax Creek	Behind Fairfax Town Hall	
FC 3	Fairfax Creek	Behind Youth Center	
FC 4	Fairfax Creek	Behind Youth Center	



CMC 1

CMC 2

CMC 3

CMC 4

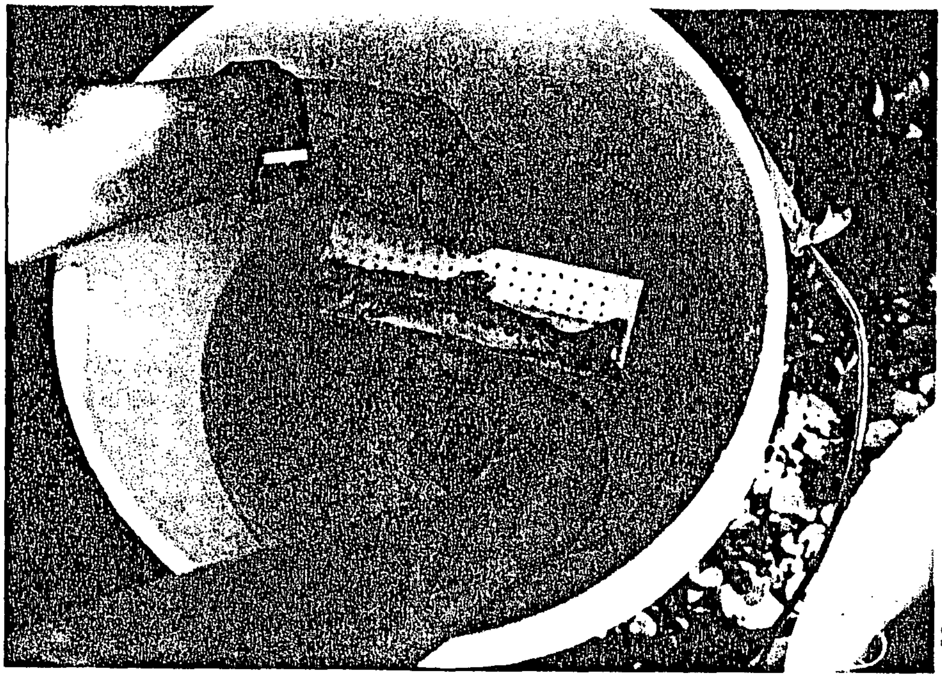
CMC 5

CMC 6

A.A. RICH AND ASSOCIATES

DRAFT

San Anselmo Creek

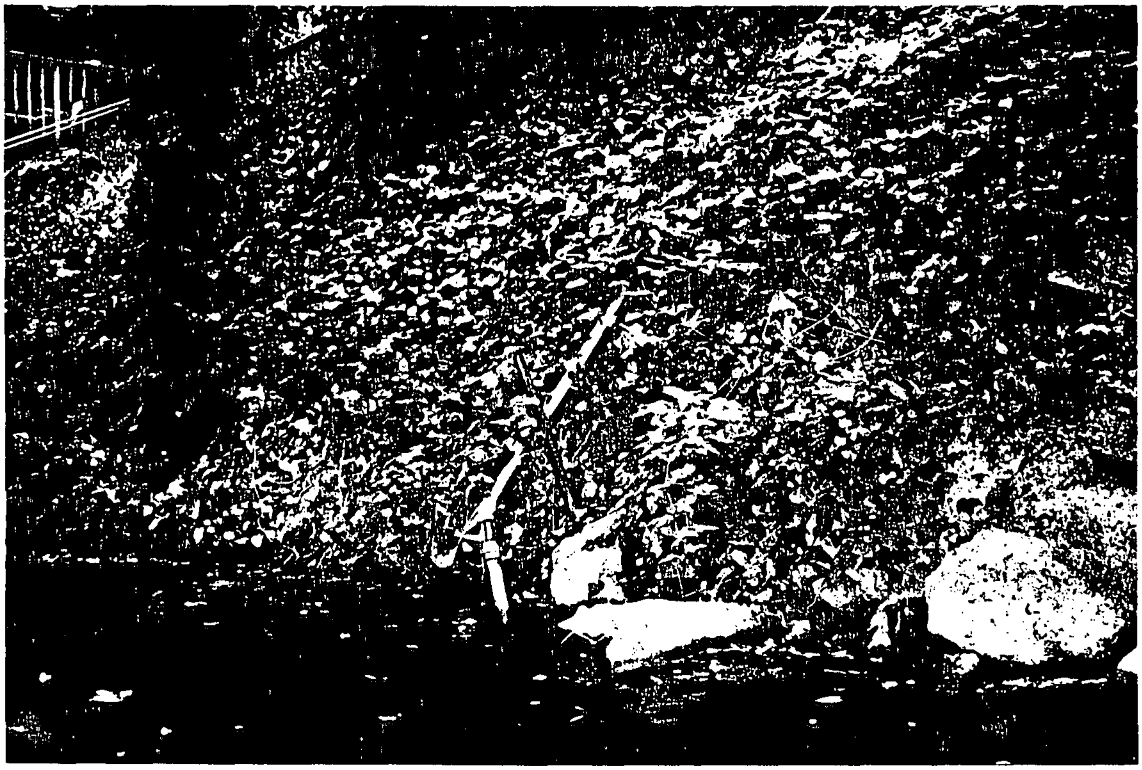


SA 1

SA 2

SA 3

SA 4



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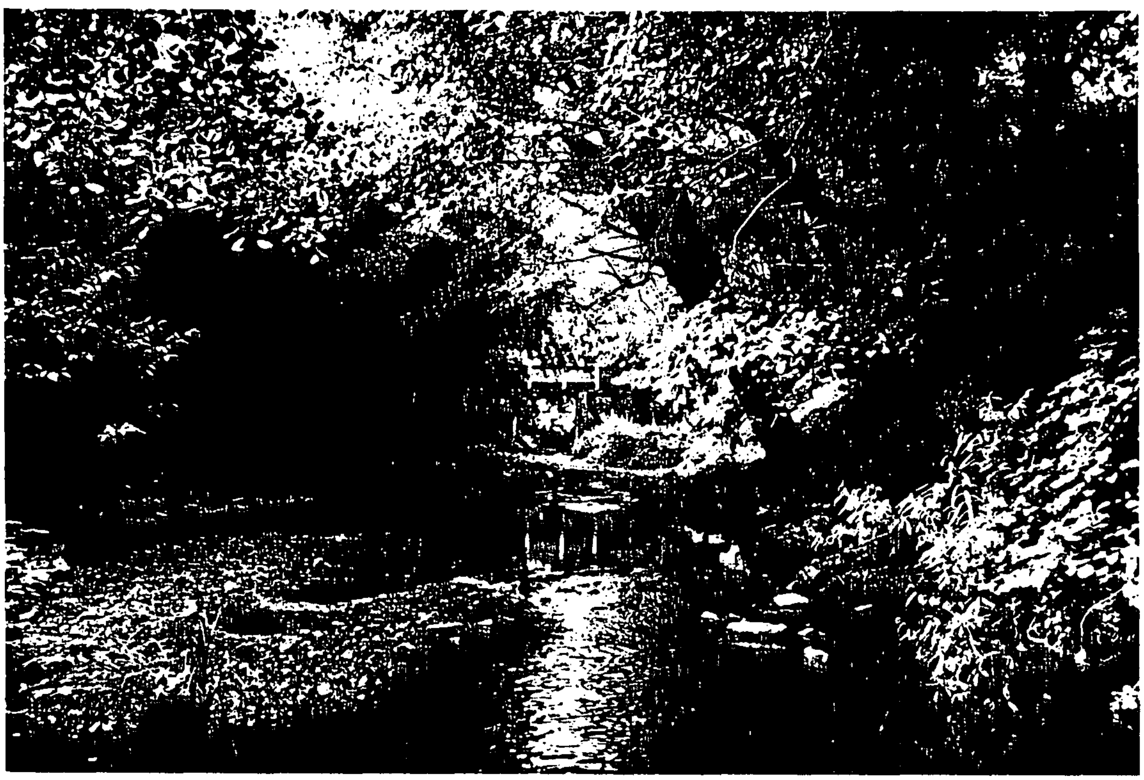
SA 6

SA 7

SA 8

SA 9



SA 10

SA 11

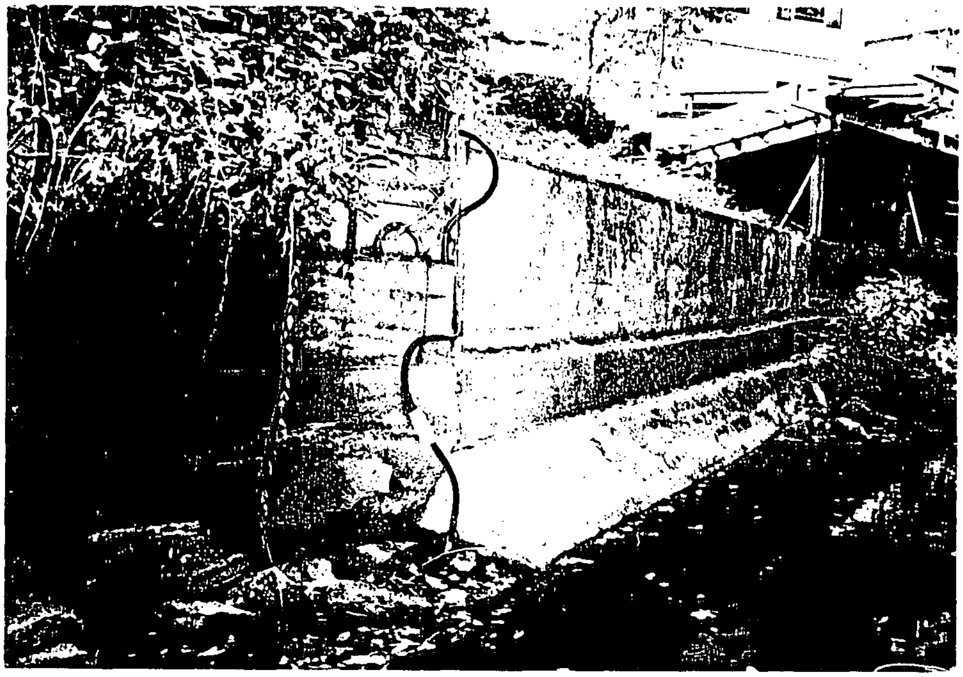
SA 12

SA 13

SA 14

SA 15

SA 16



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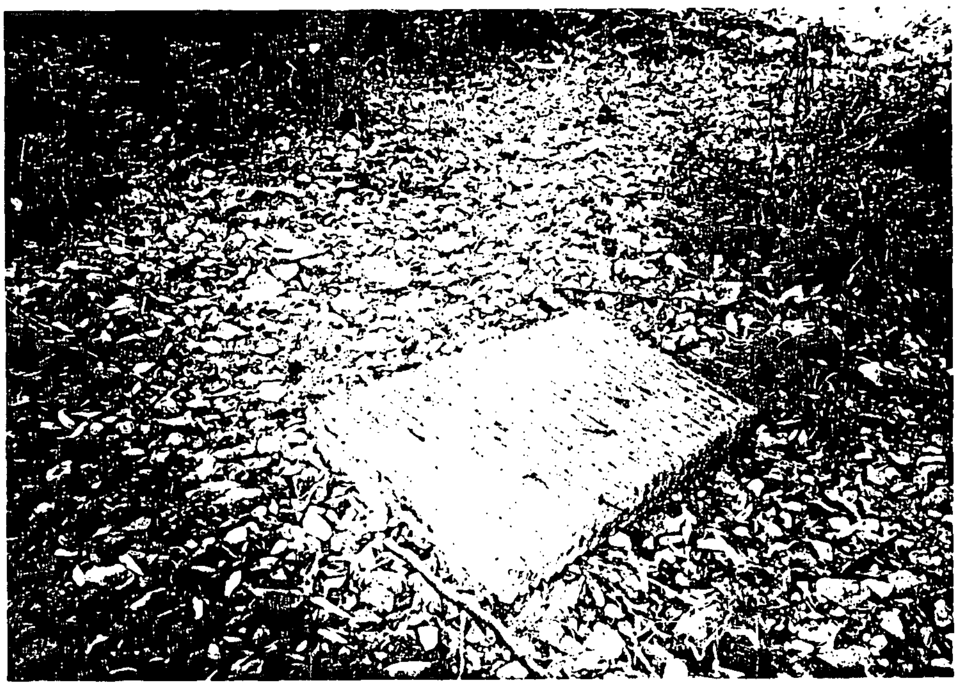

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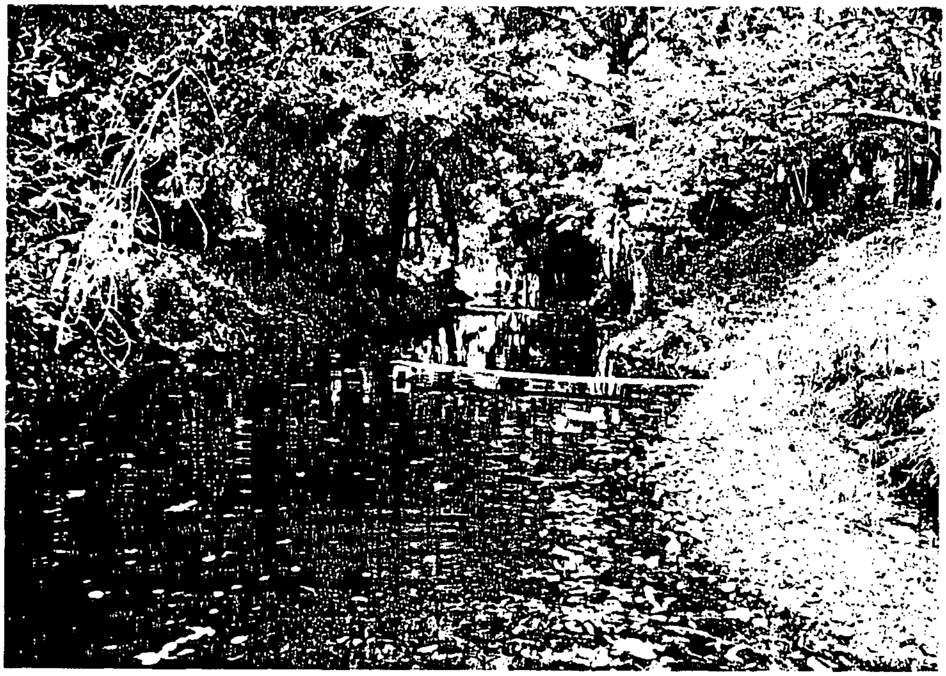

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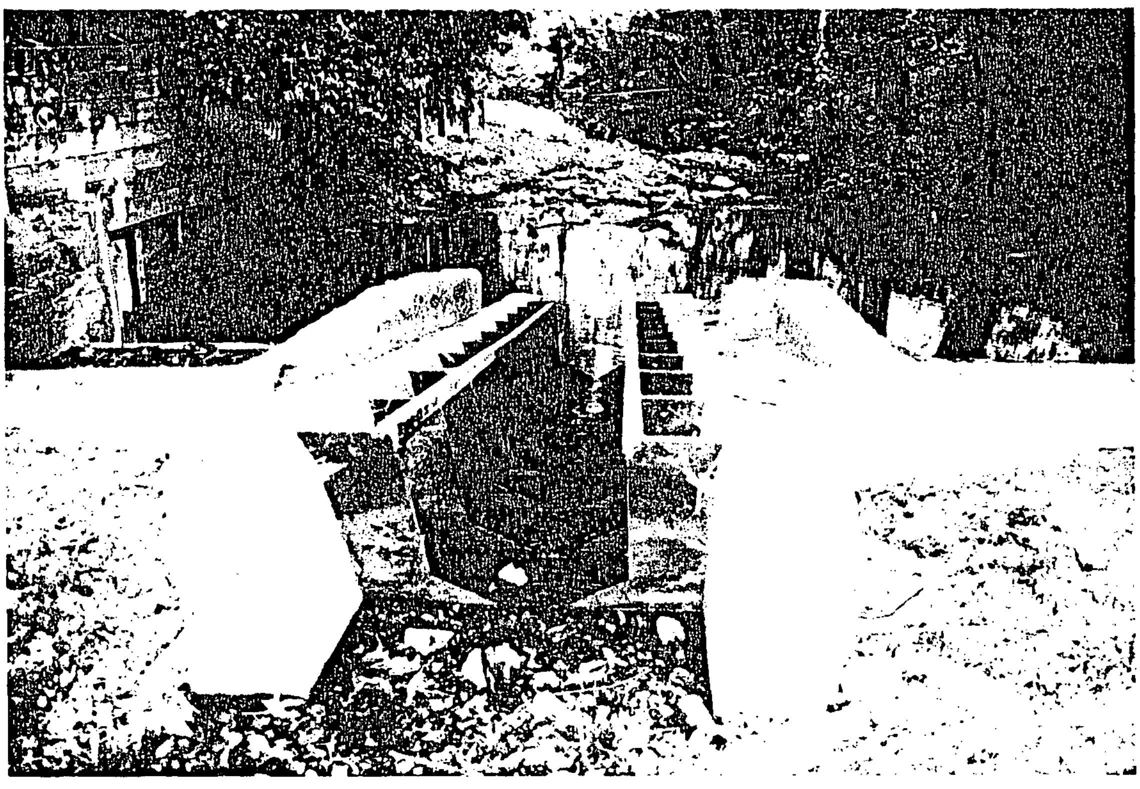
SA 20

SA 21



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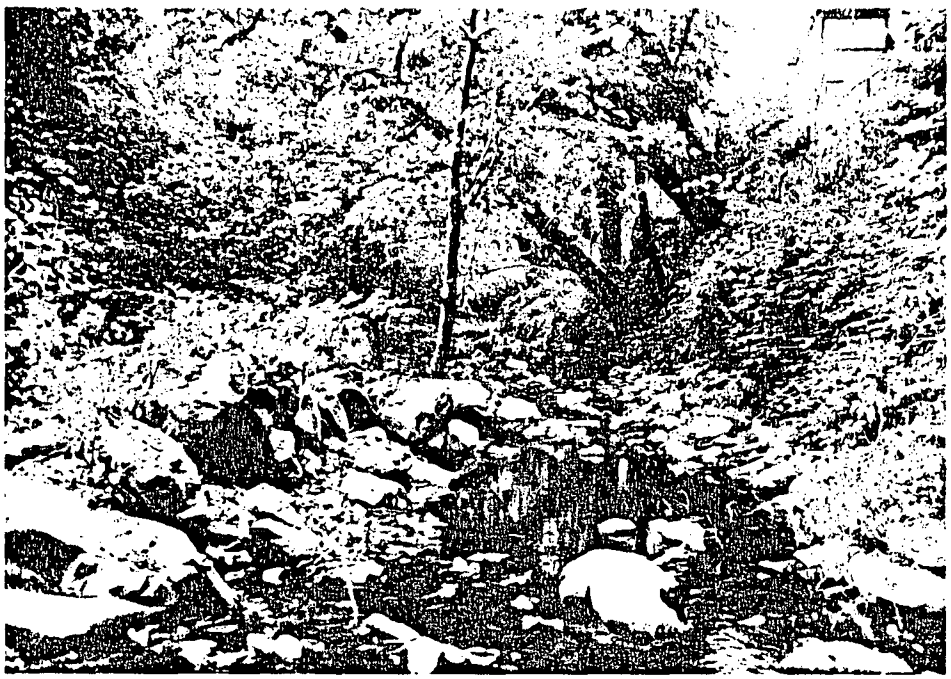
SA 23



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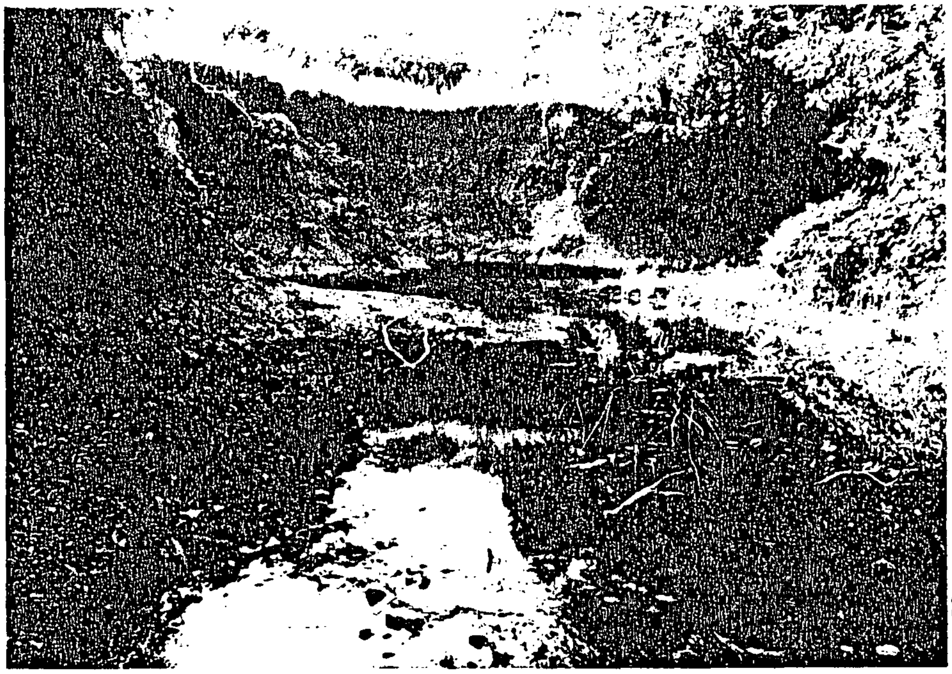

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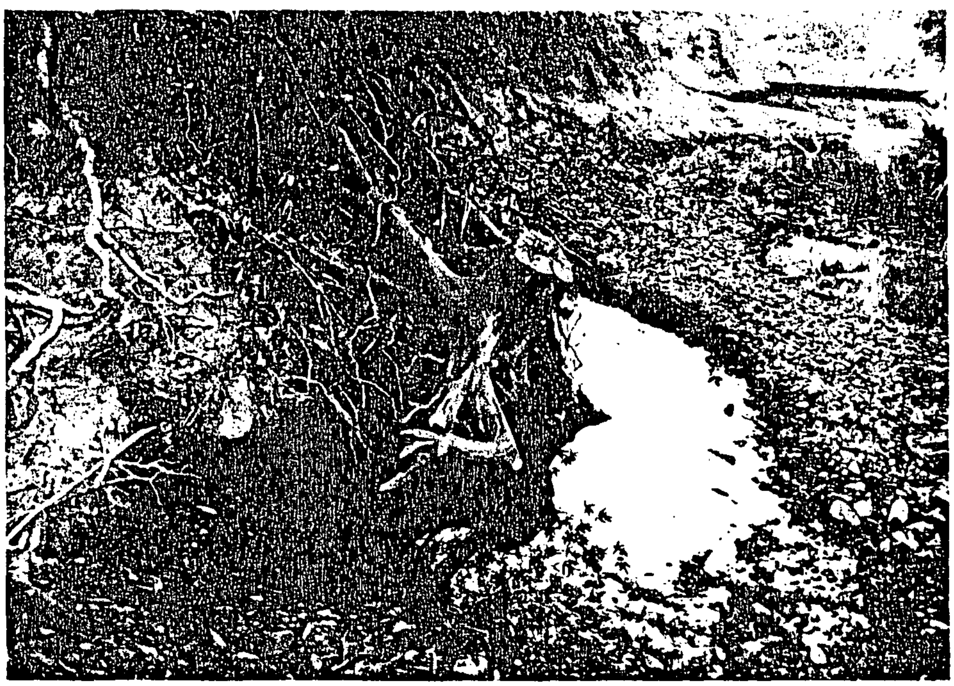

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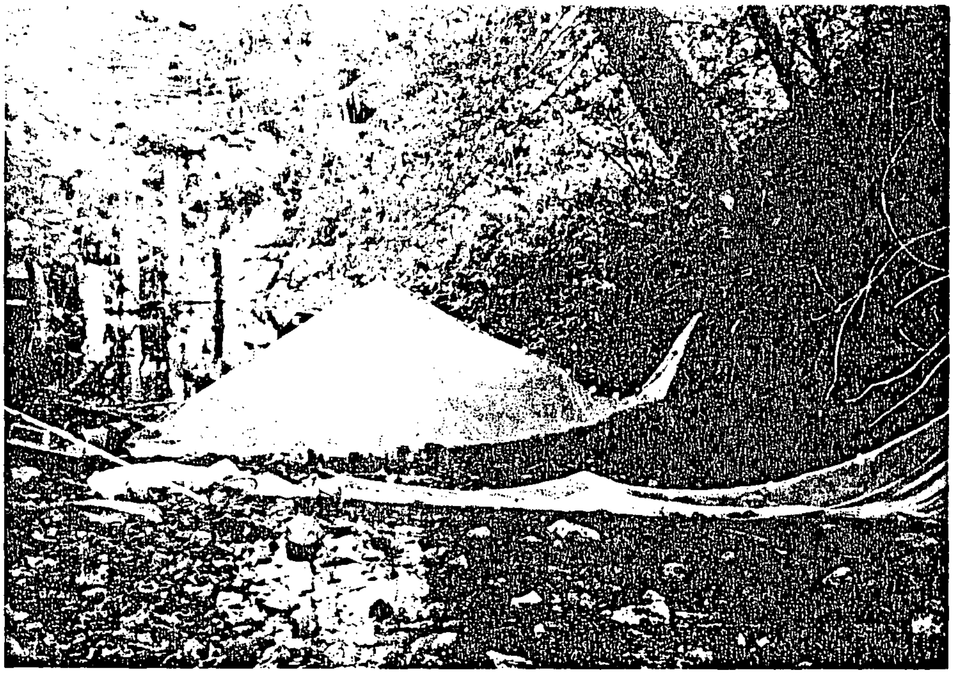
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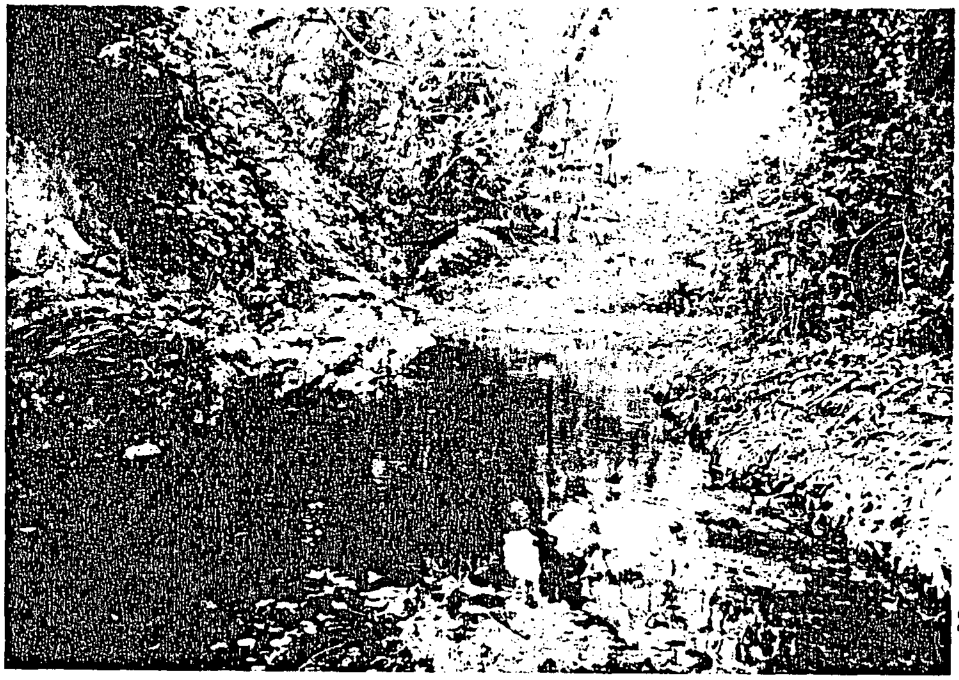

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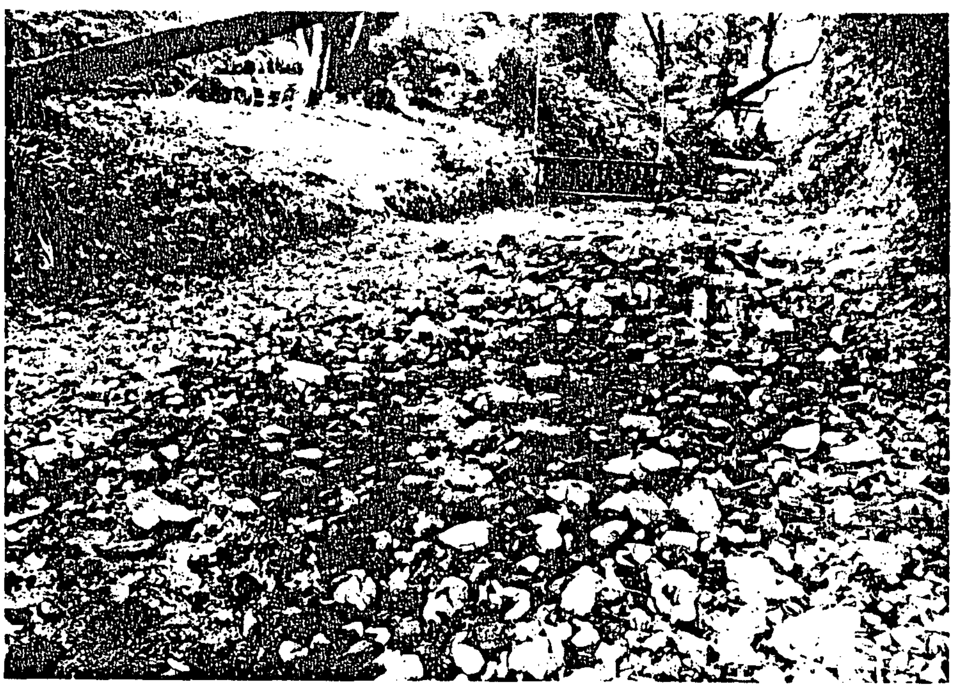

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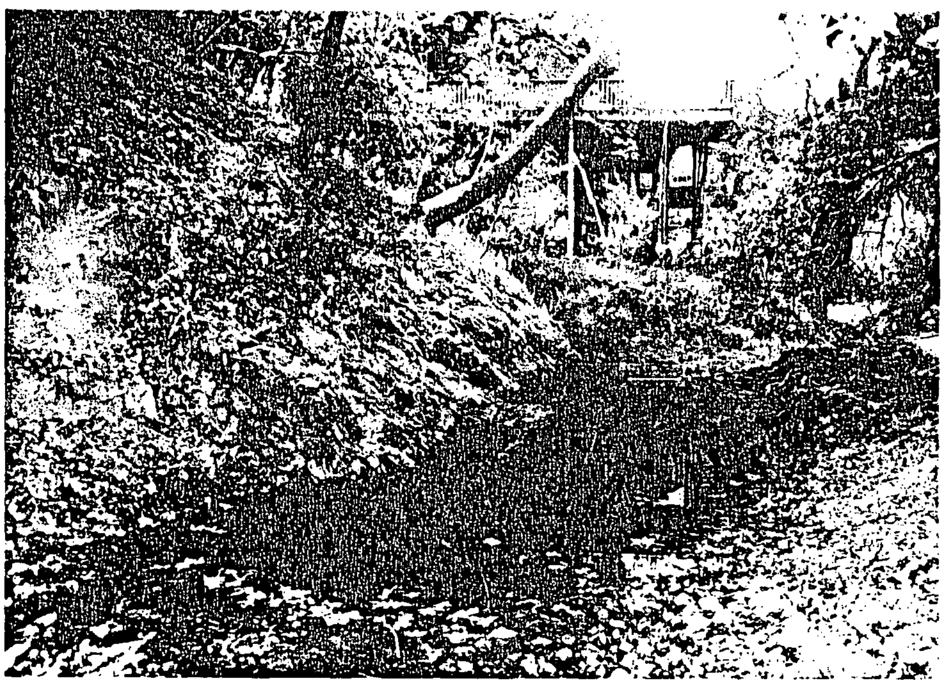

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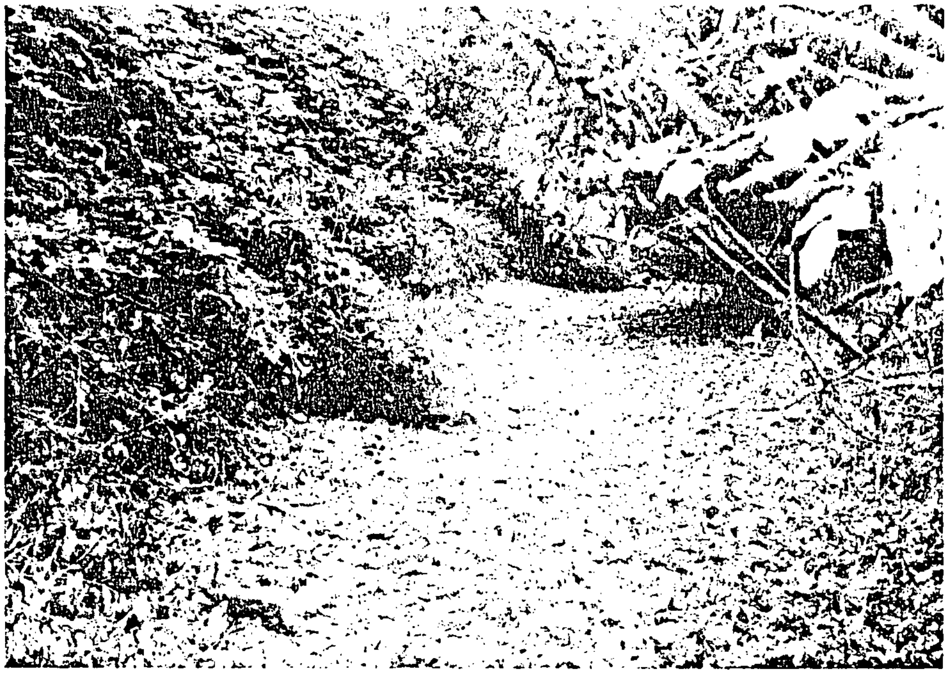

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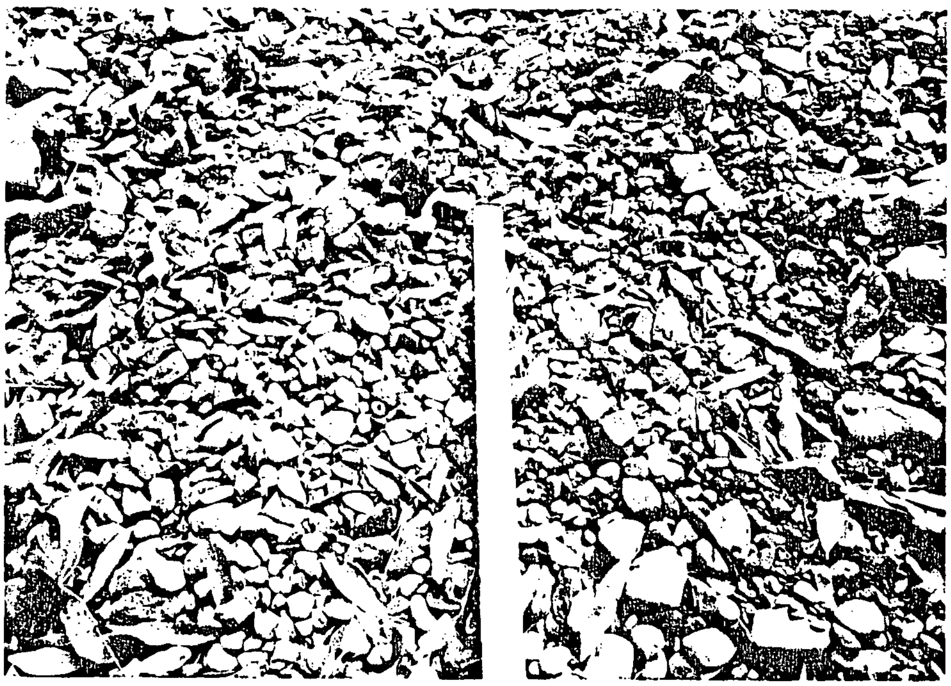

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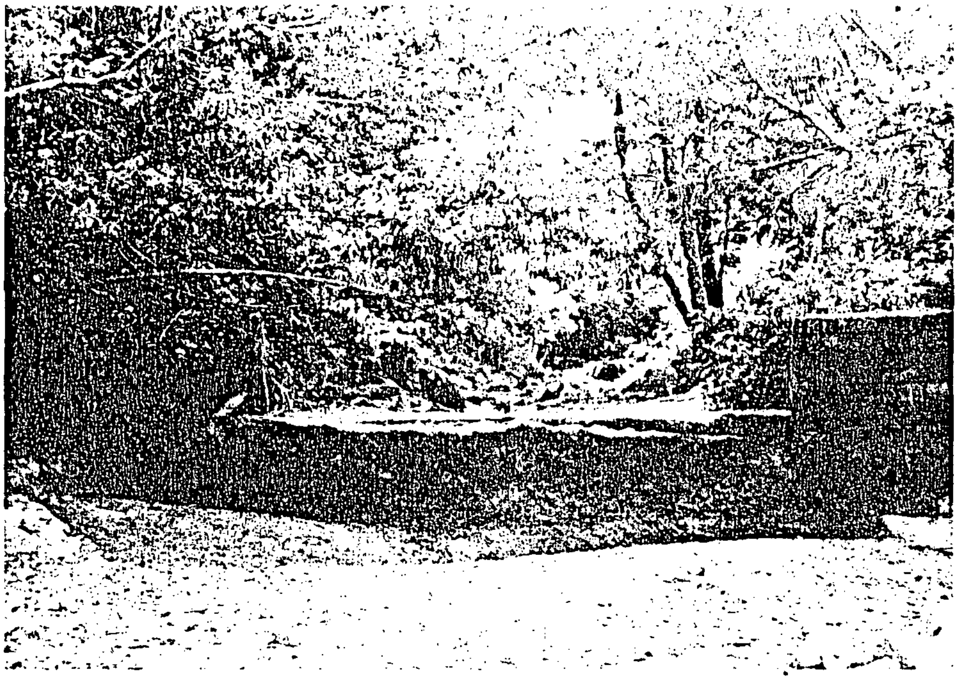

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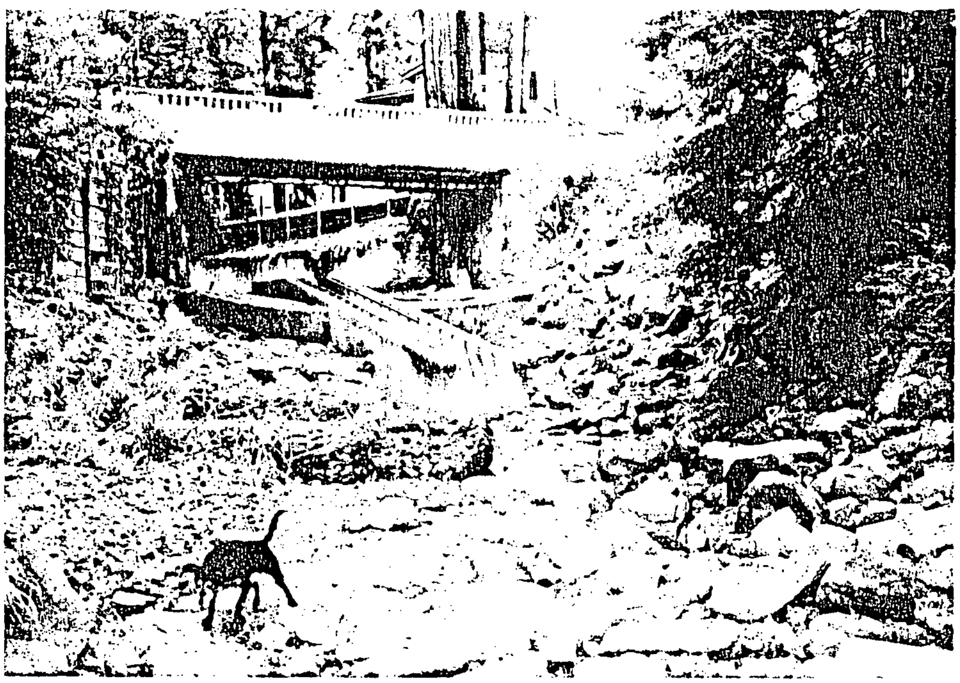

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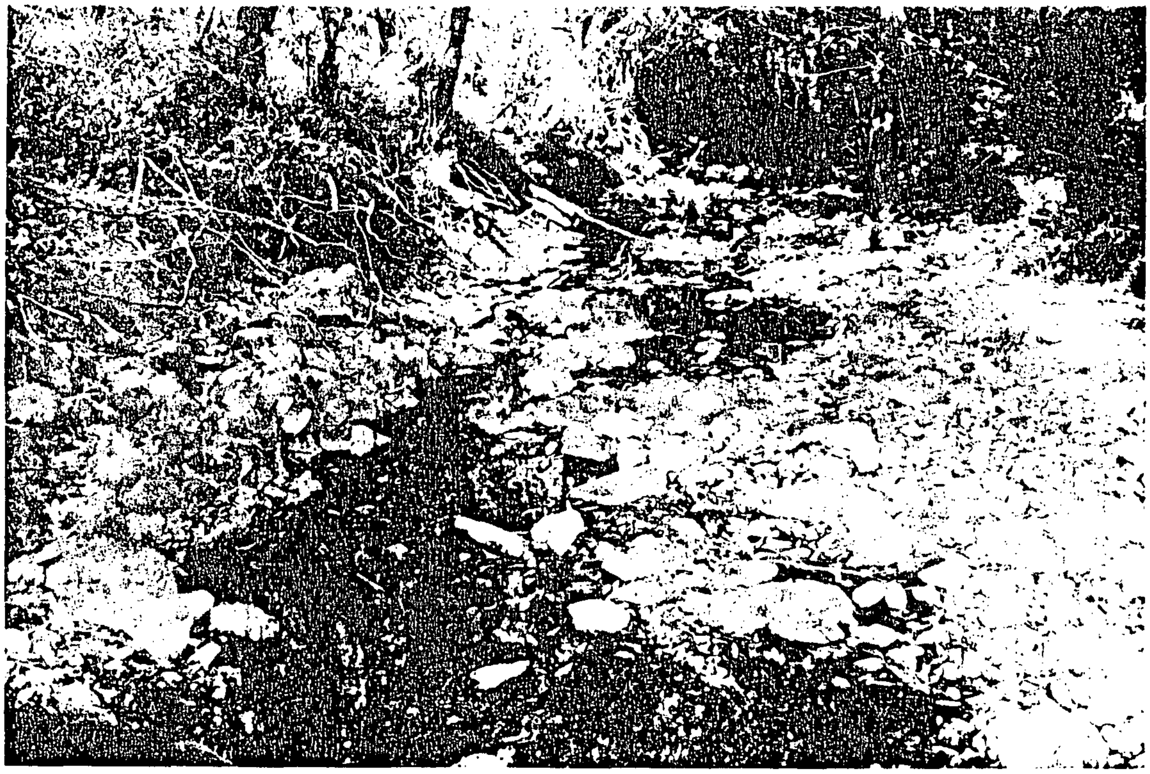
SA 39

SA 40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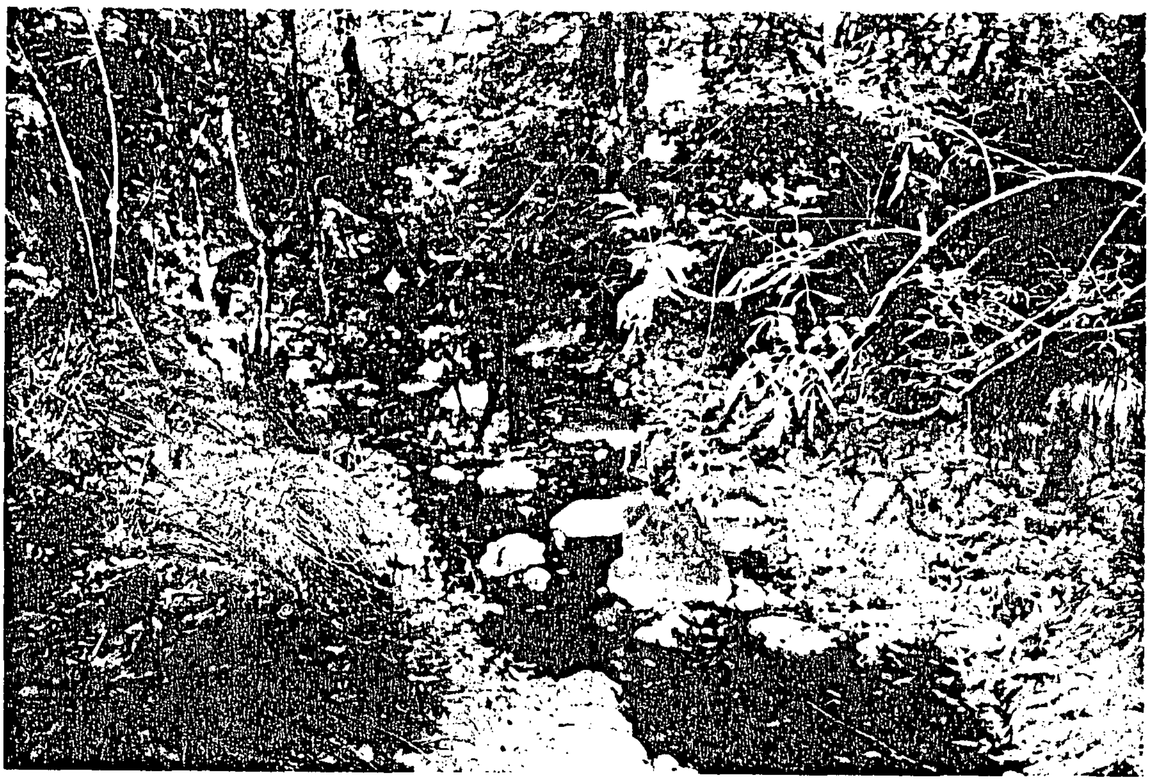
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A.A. RICH AND ASSOCIATES

DRAFT

Cascade Creek

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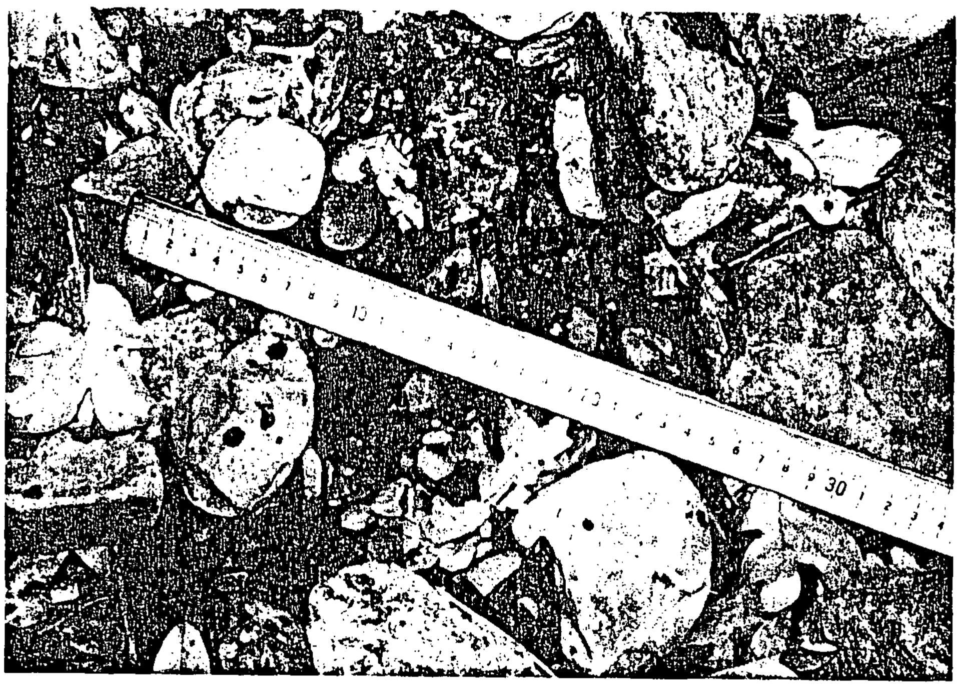

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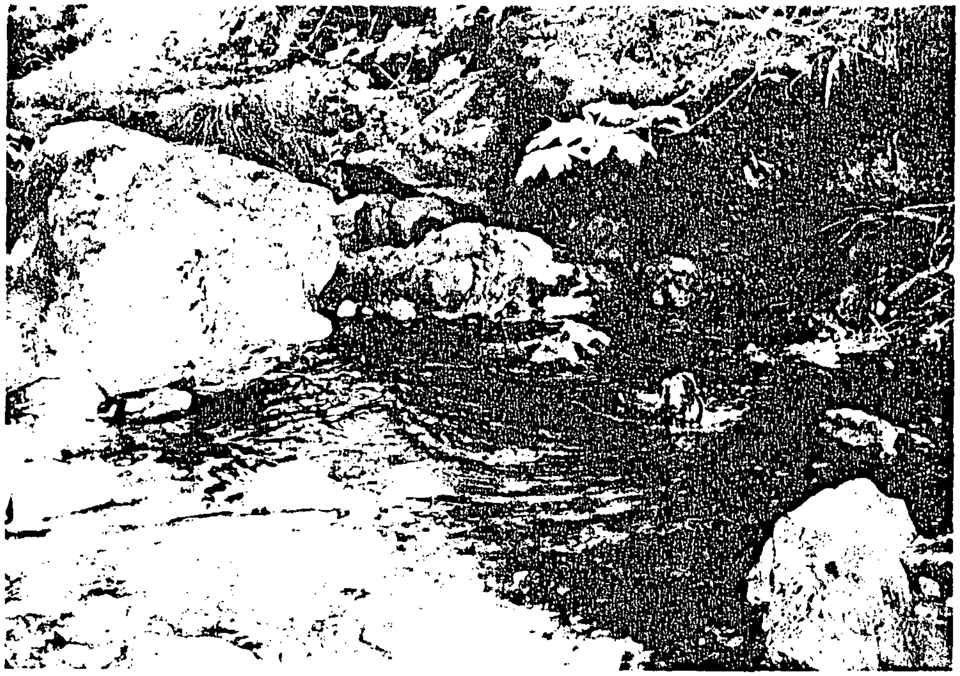

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CC 6

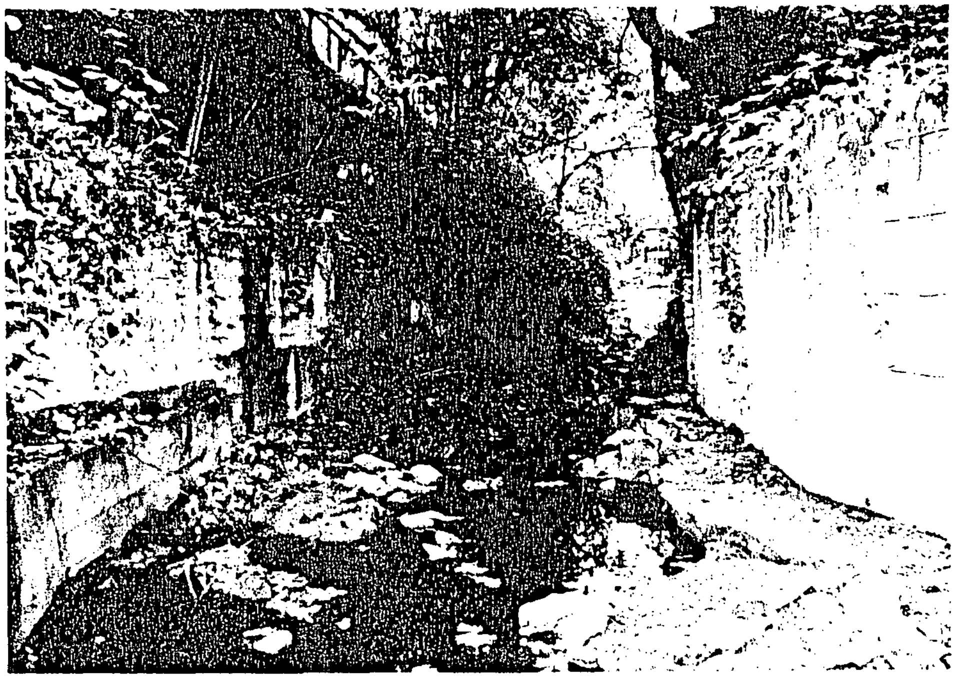
CC 7

CC 8

A.A. RICH AND ASSOCIATES

DRAFT

Sleepy Hollow Creek



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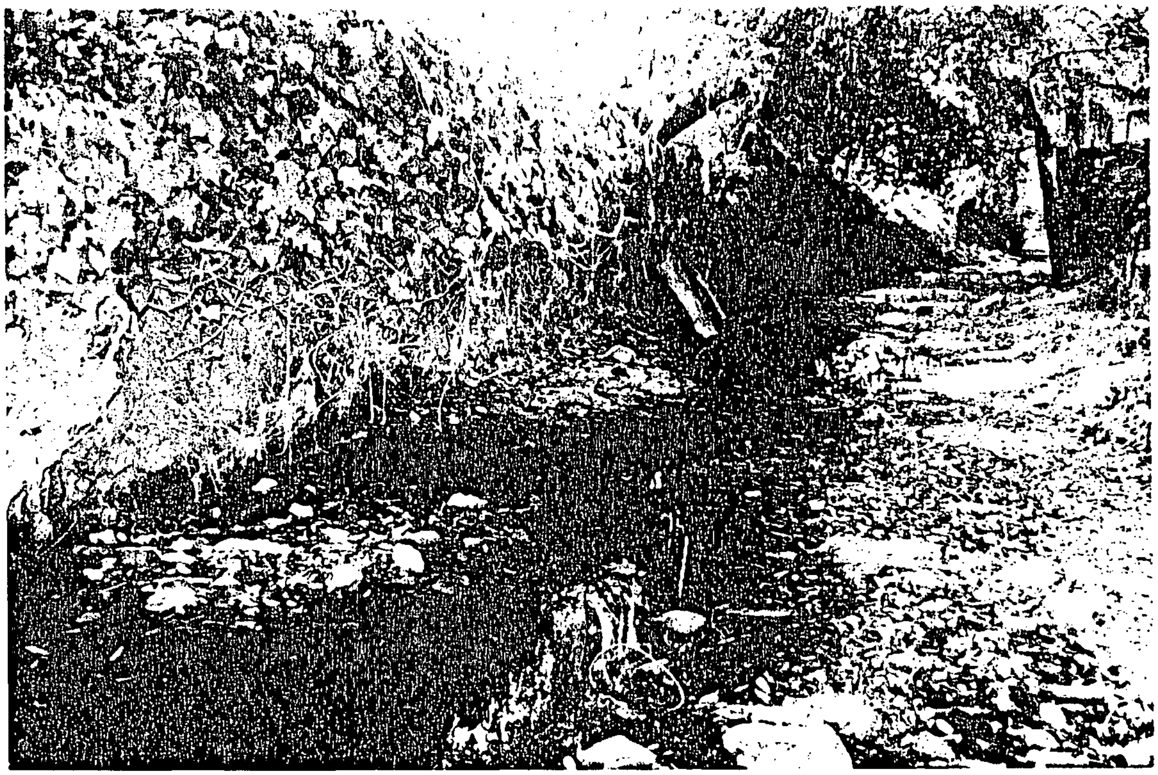

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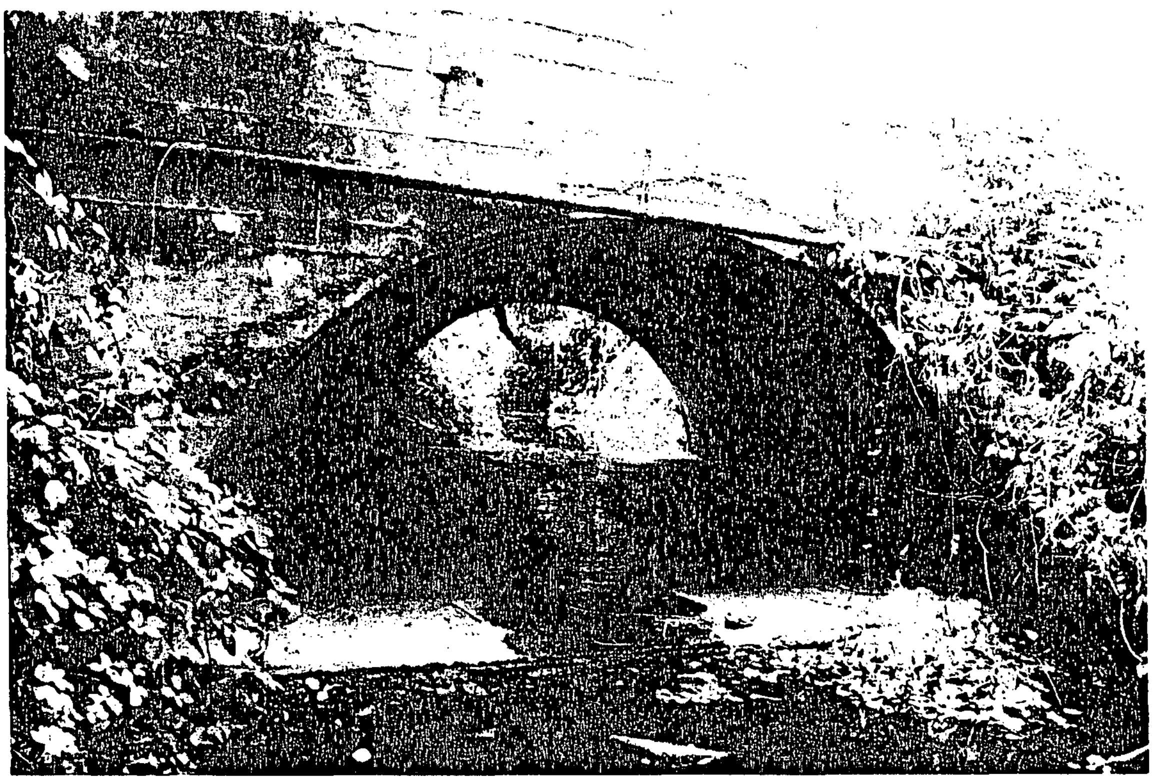

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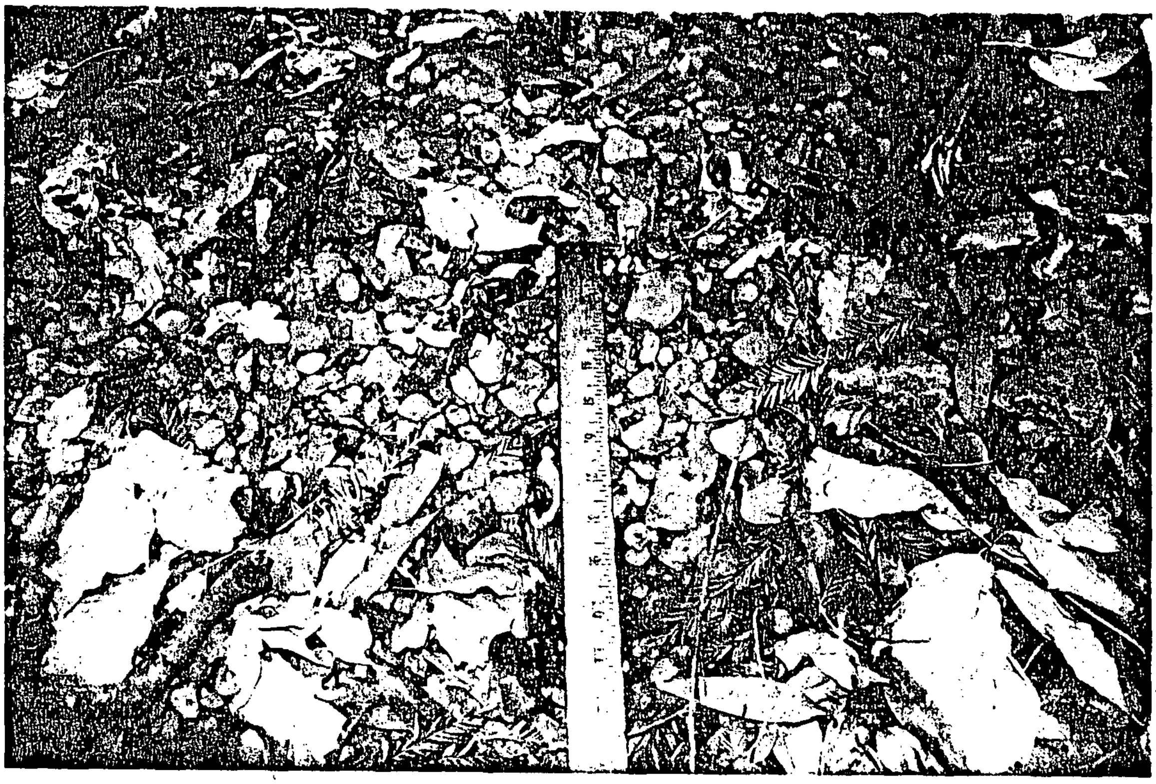

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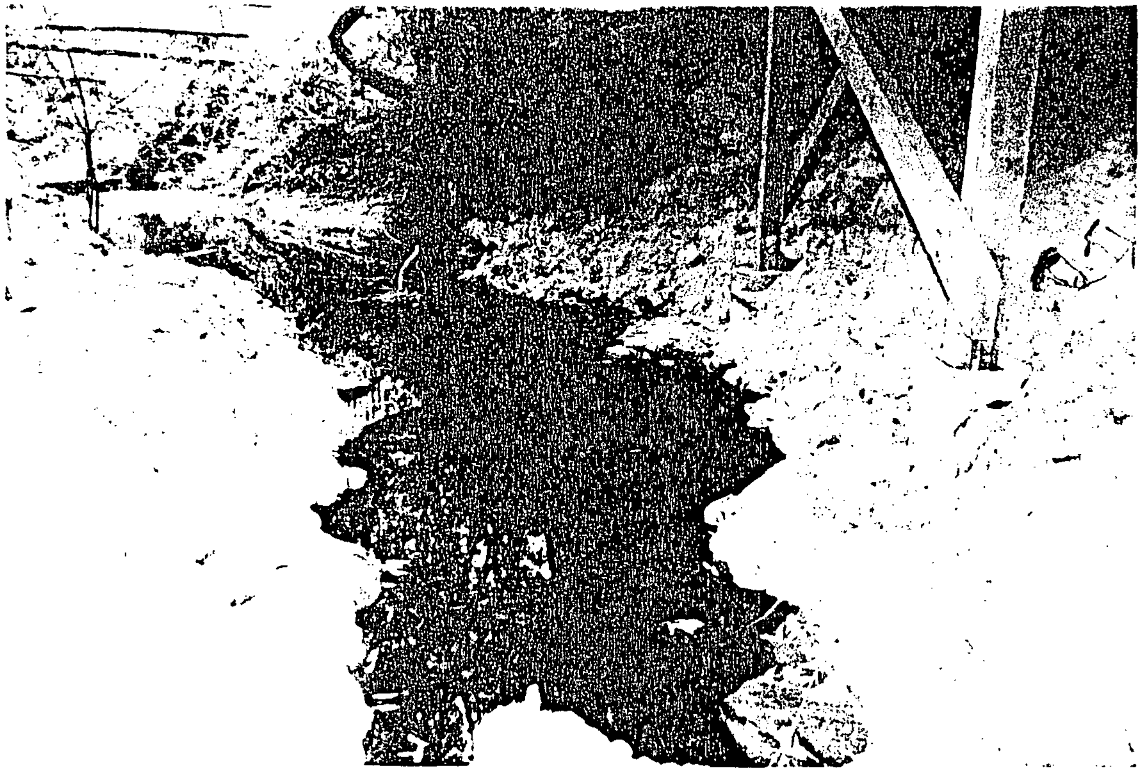

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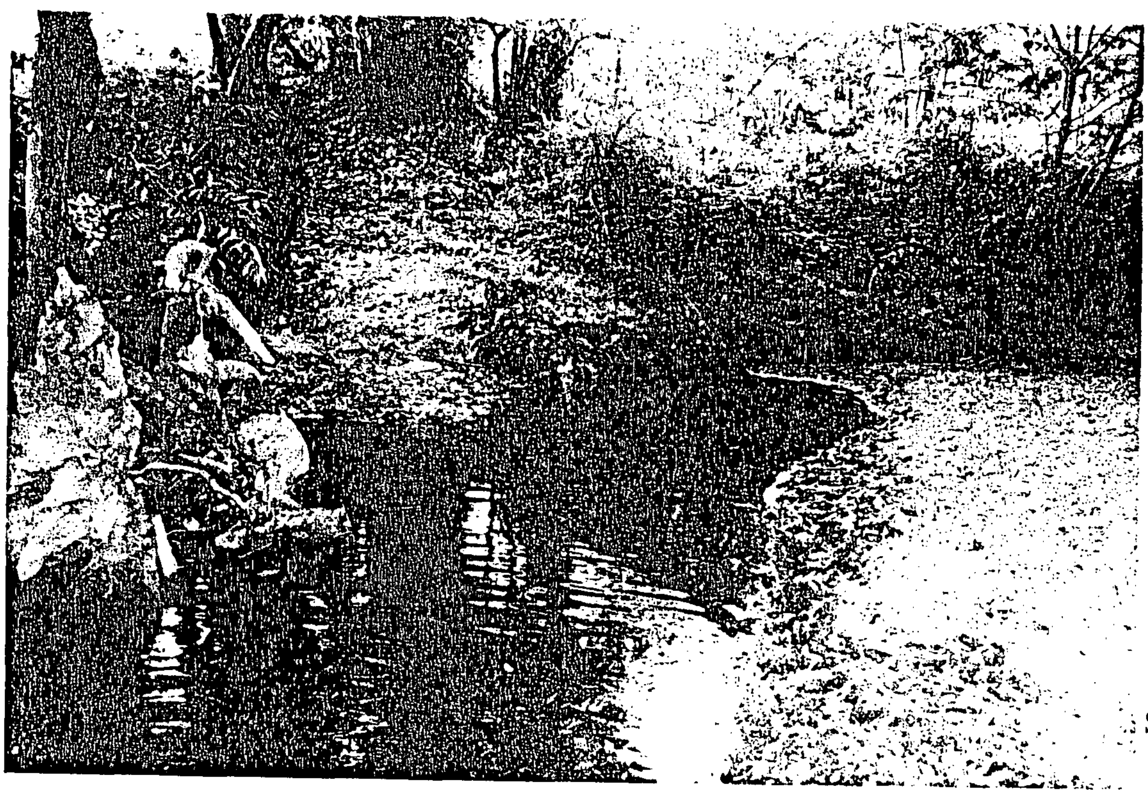

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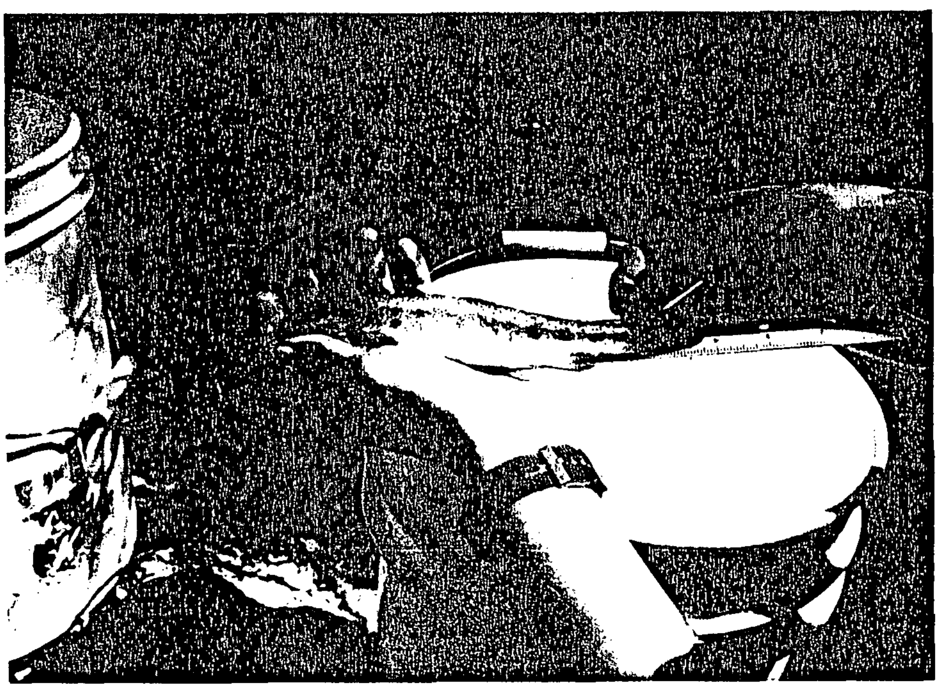

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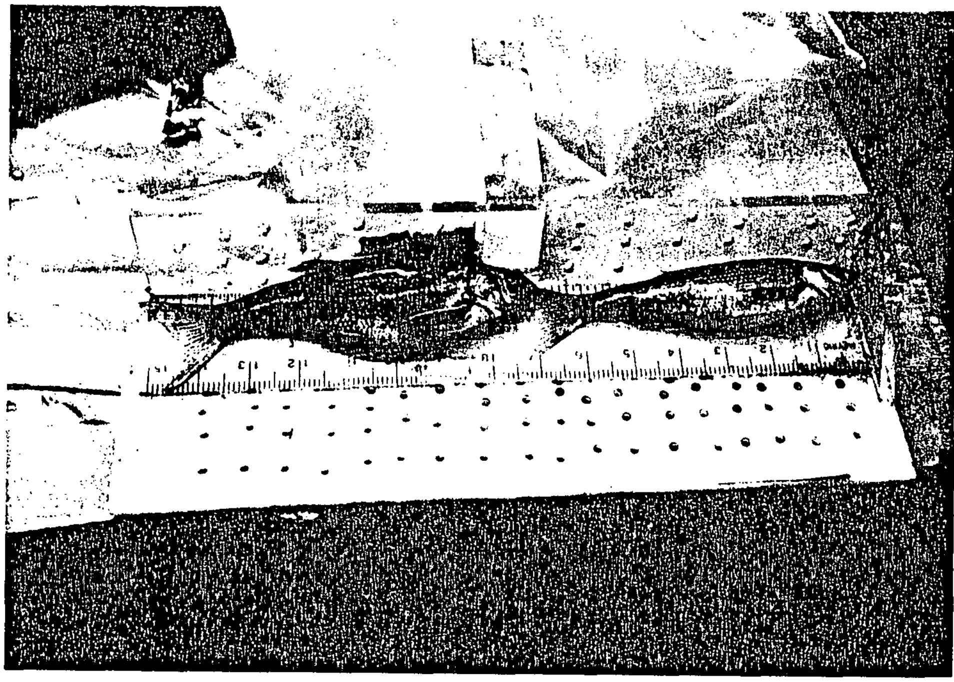

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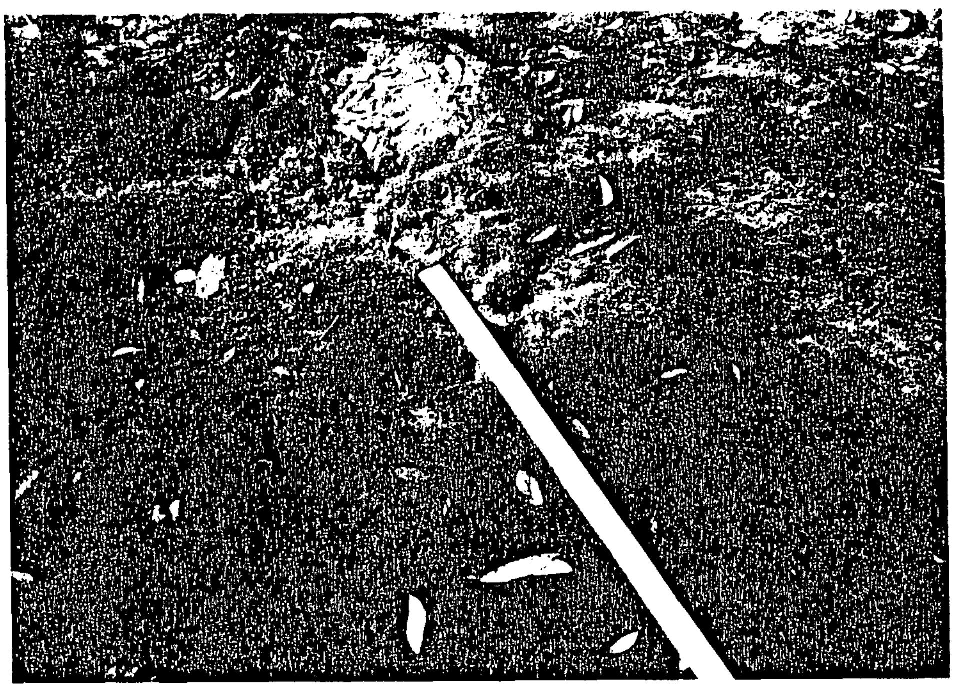

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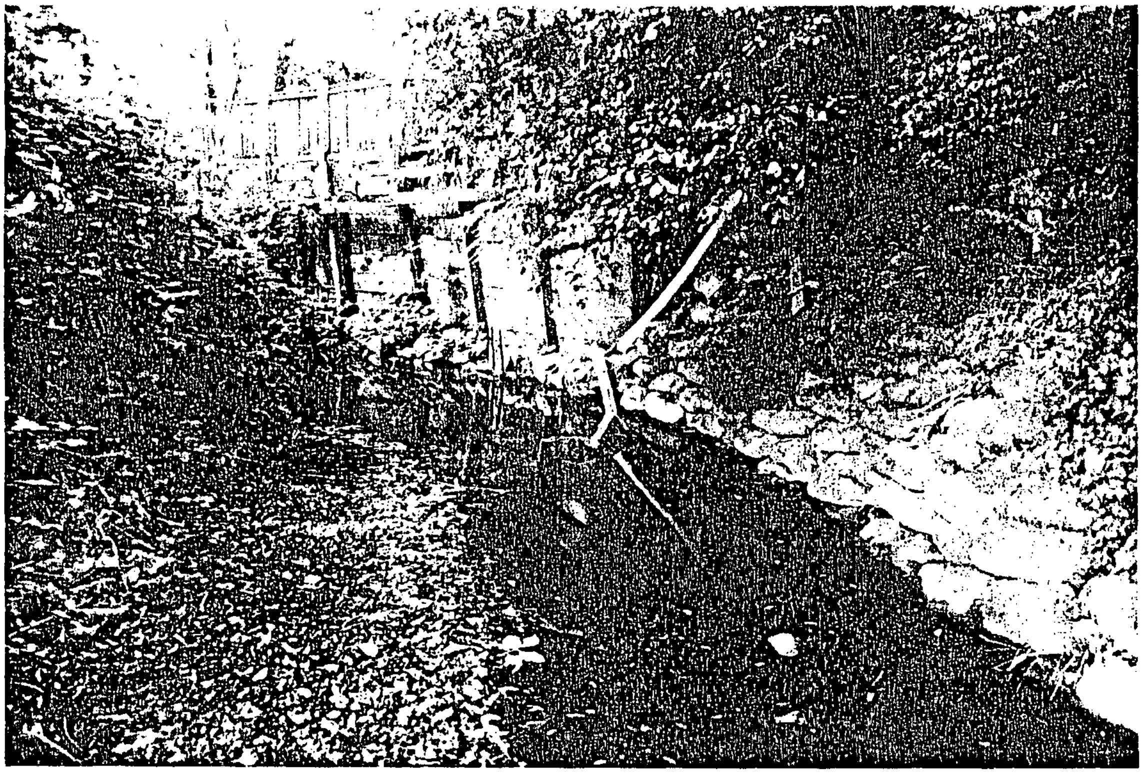

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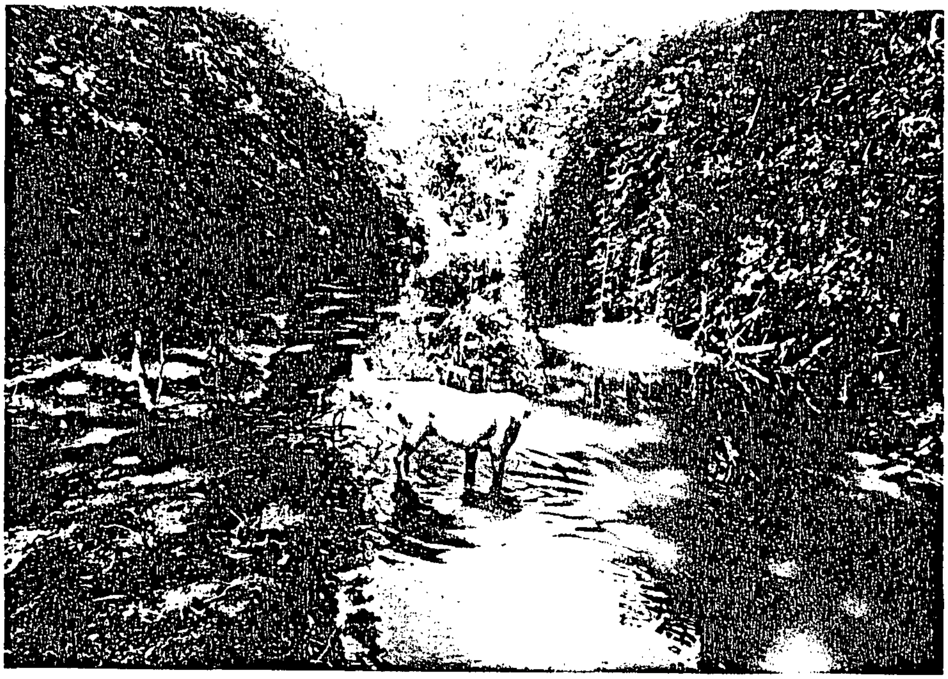

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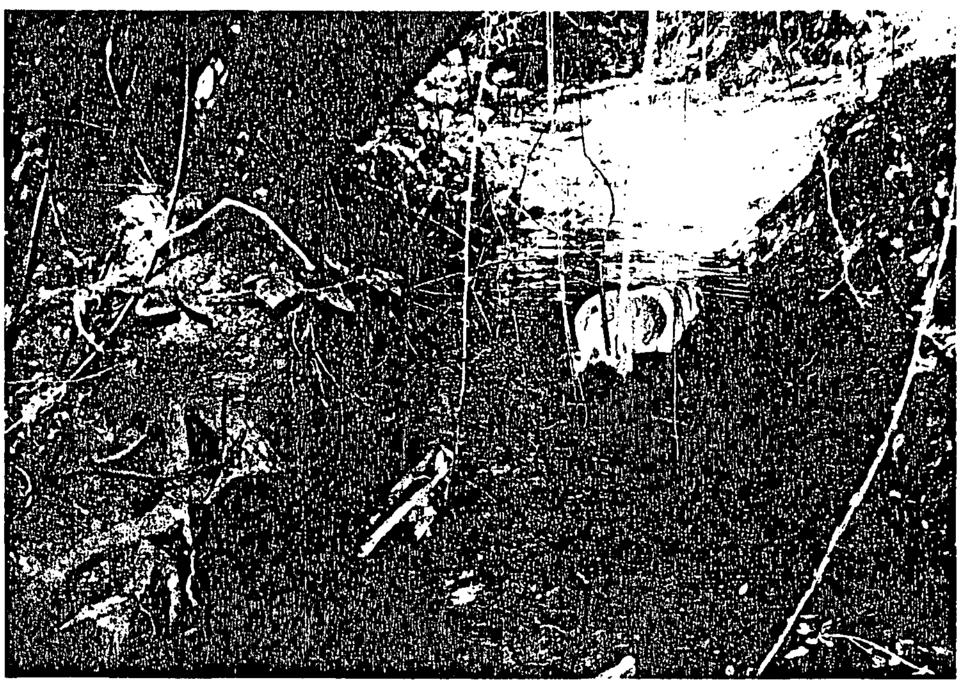

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SH 17

SH 18

SH 19

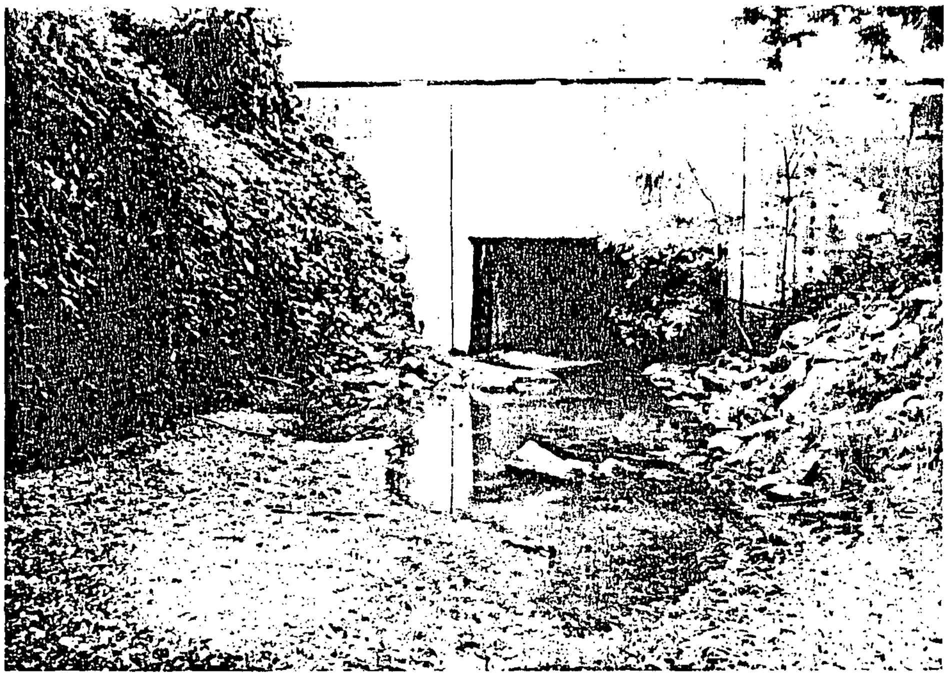
SH 20

SH 21

SH 22

SH 23

SH 24



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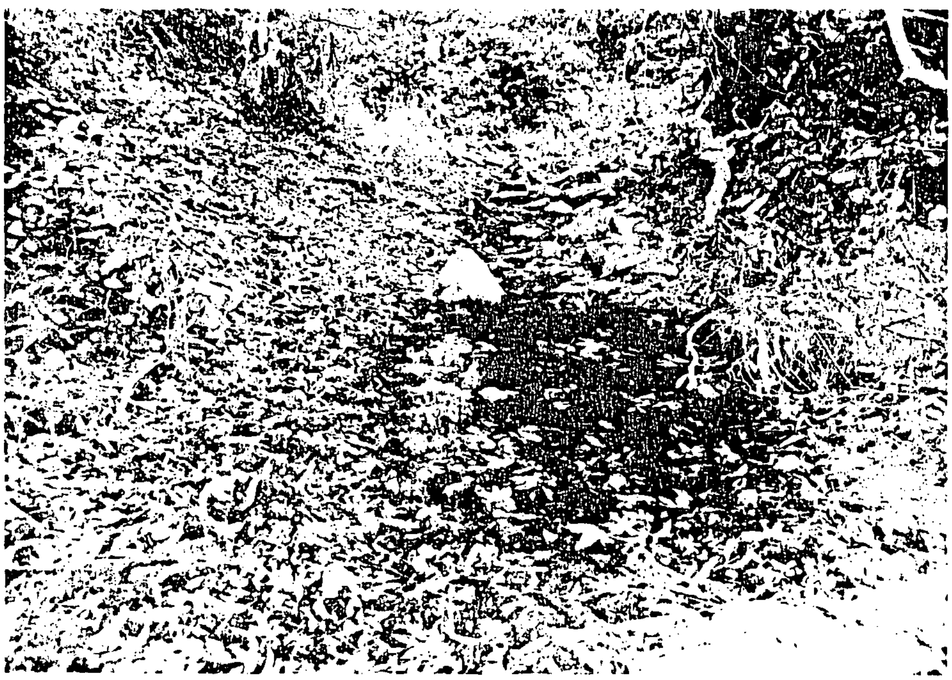

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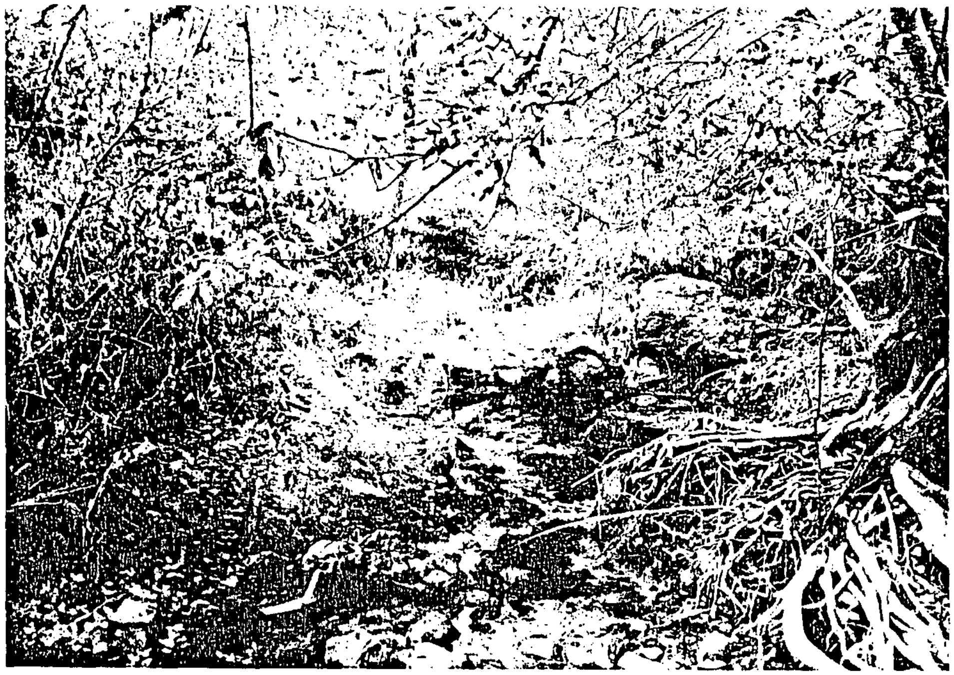

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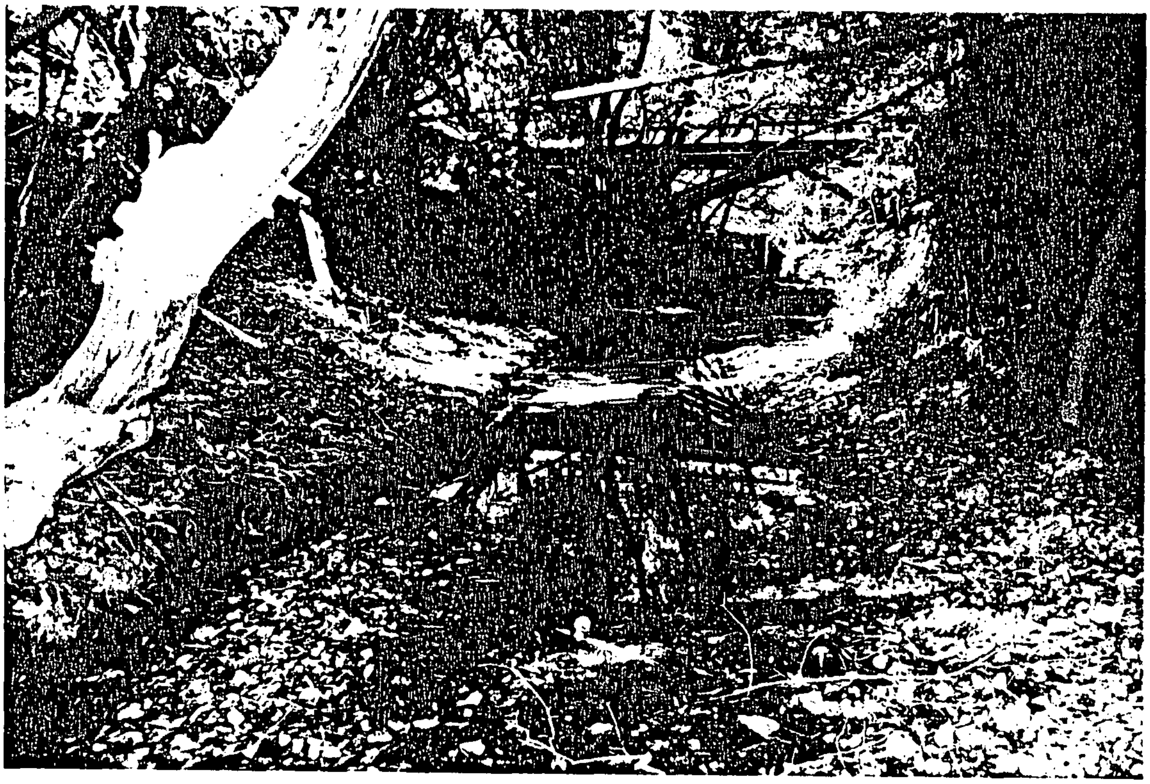

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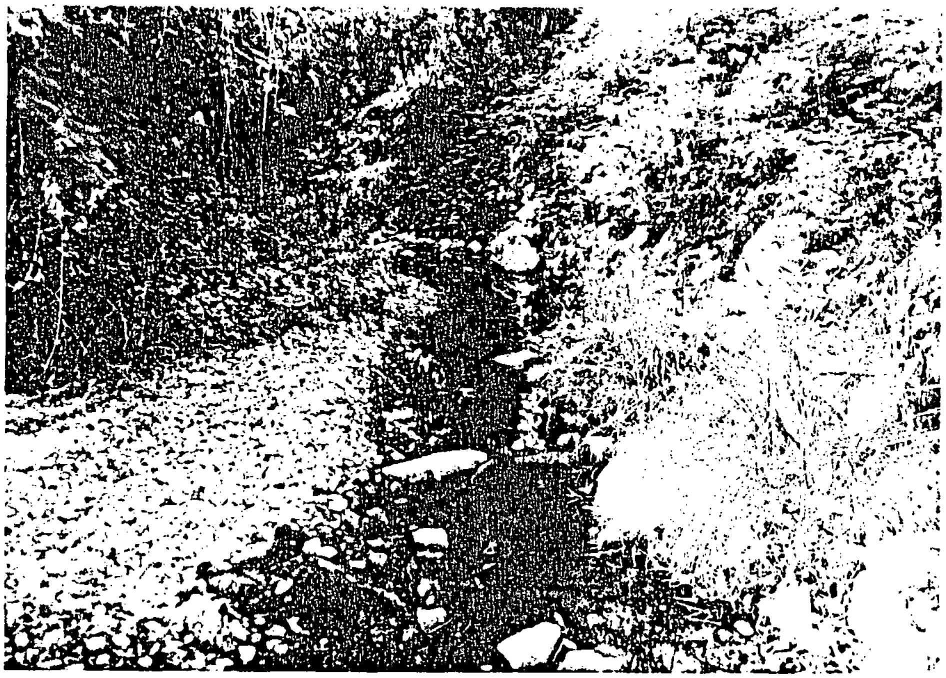

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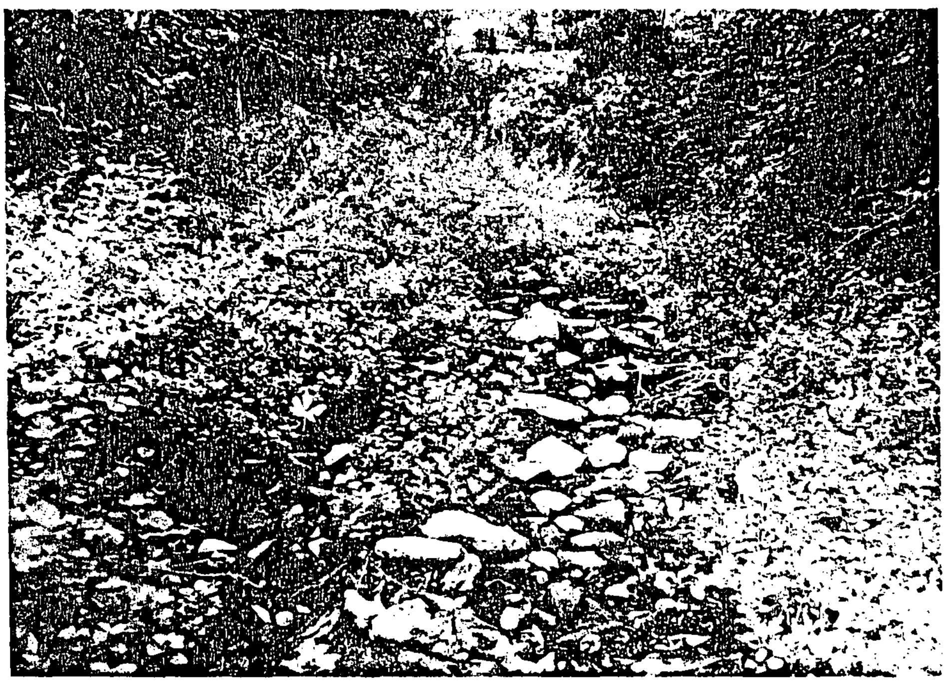

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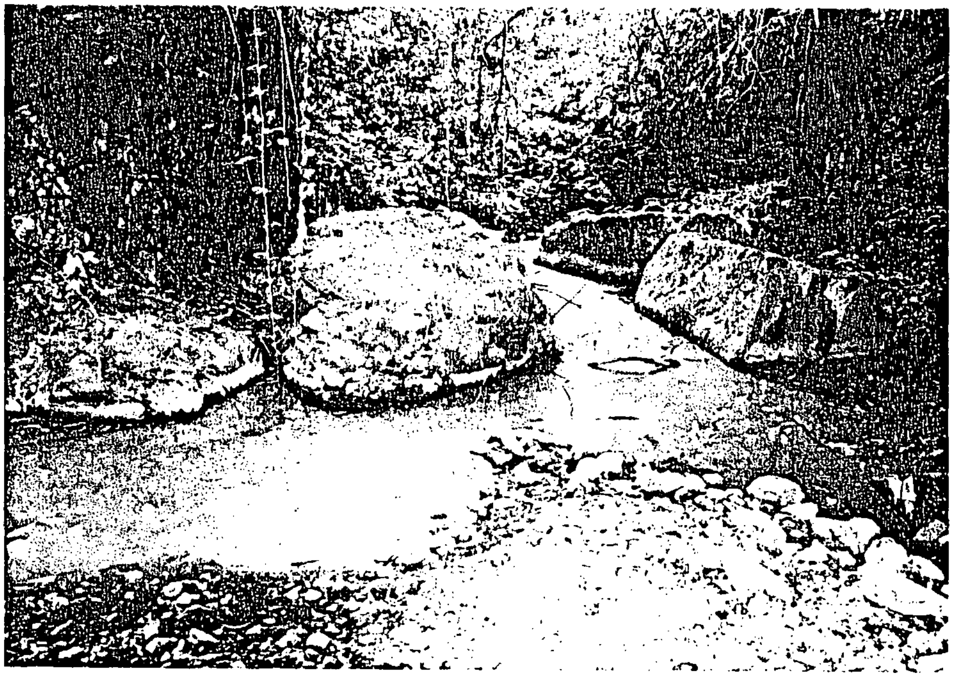

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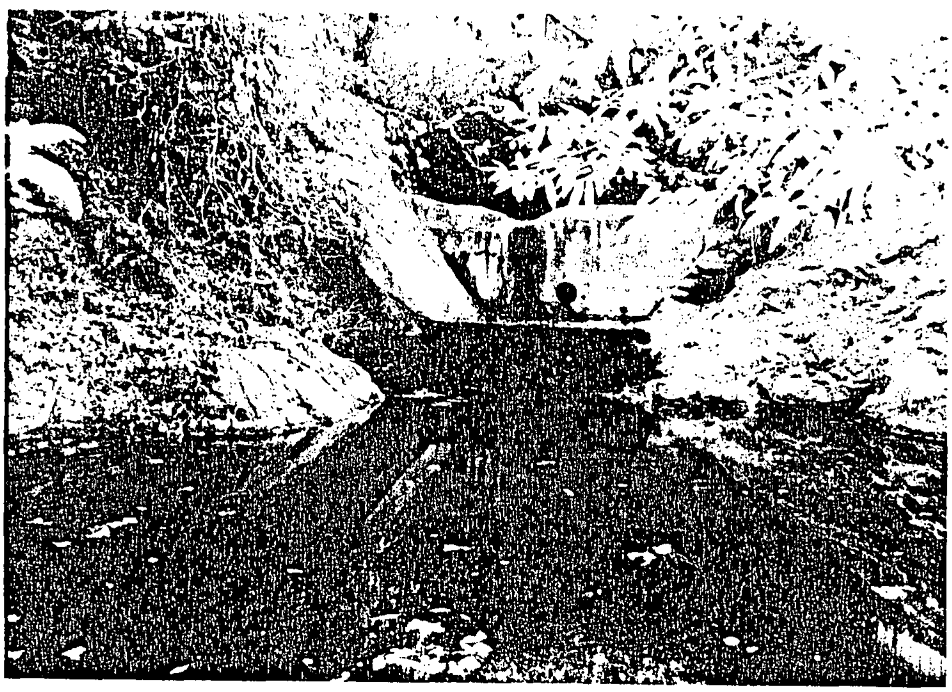

SH 38

SH 39

SH 40

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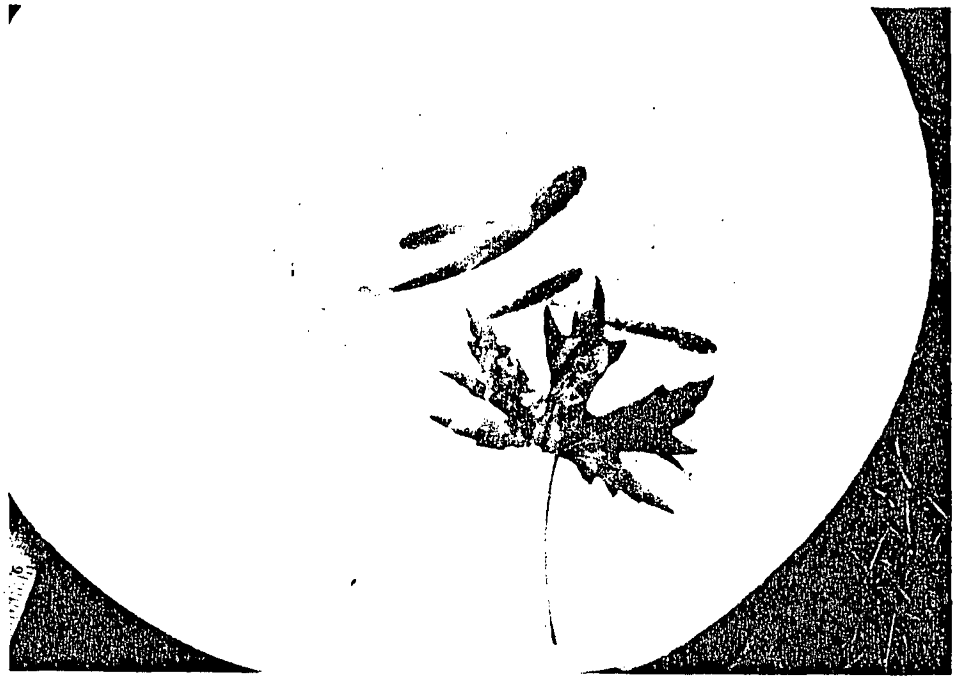
Ross Creek



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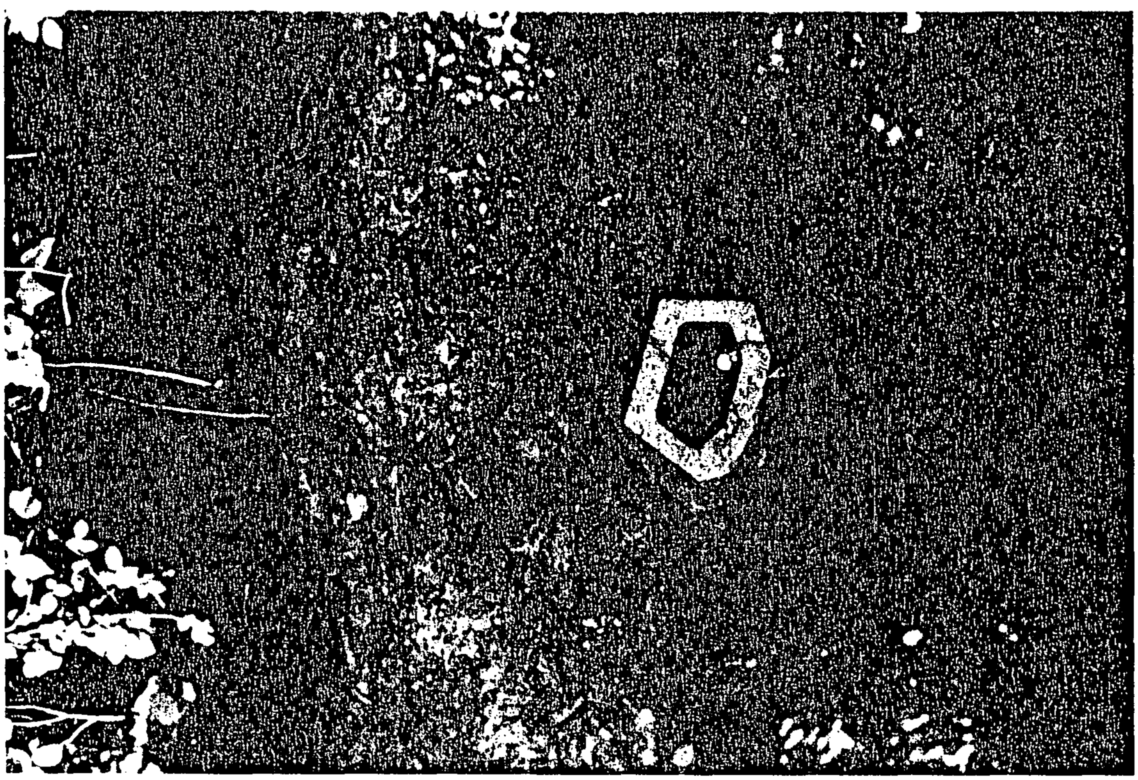

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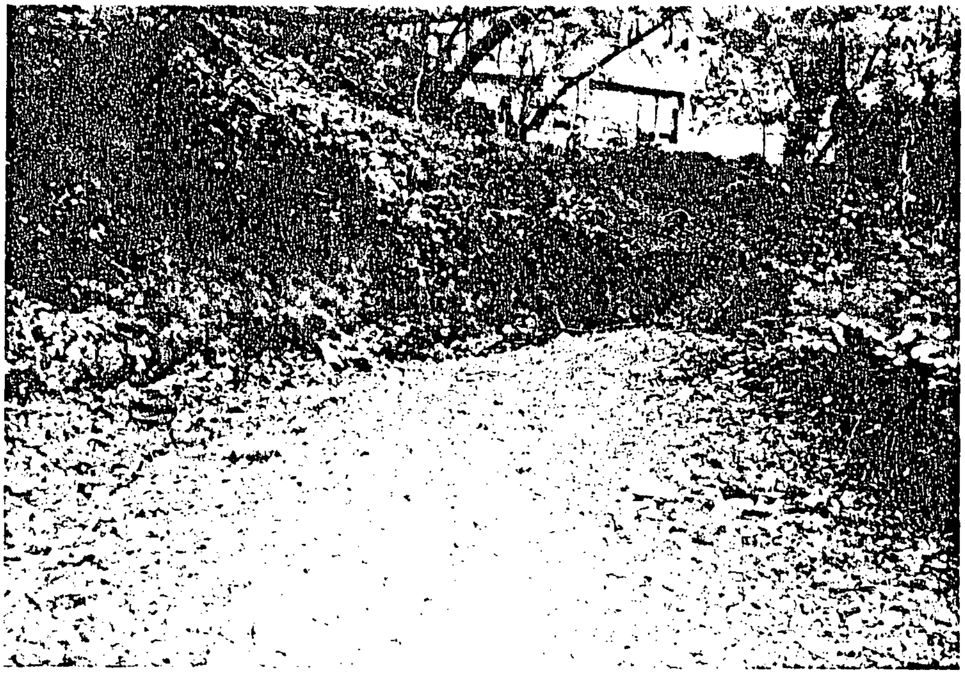

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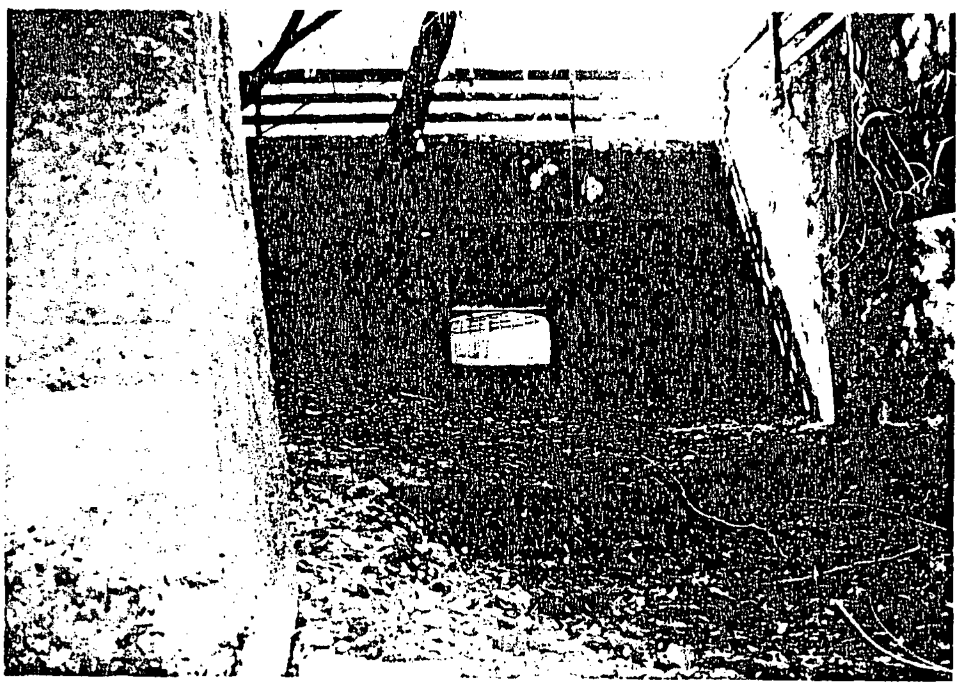

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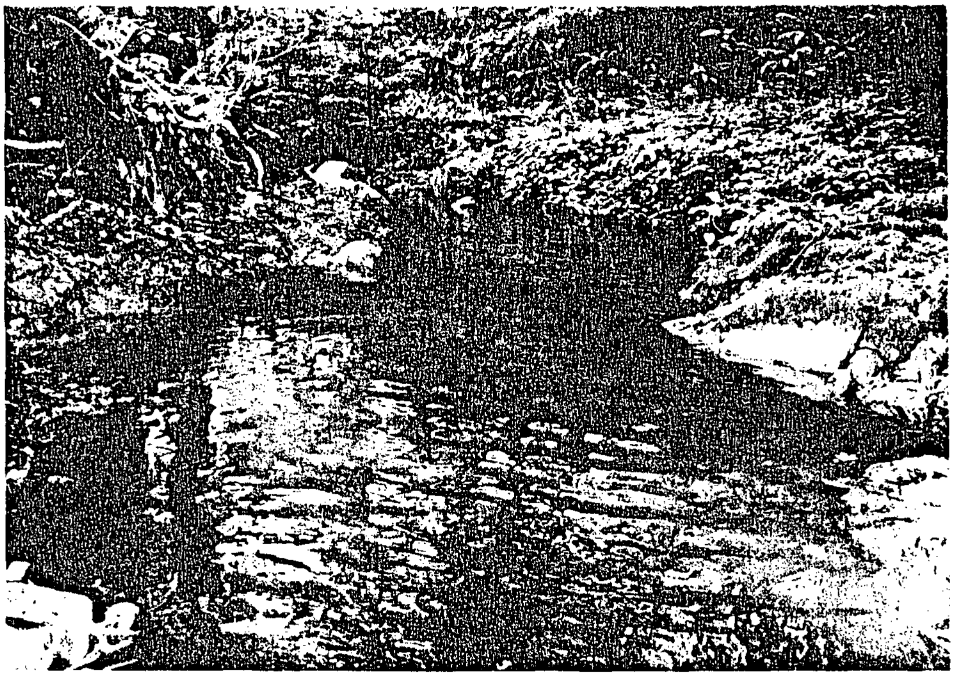
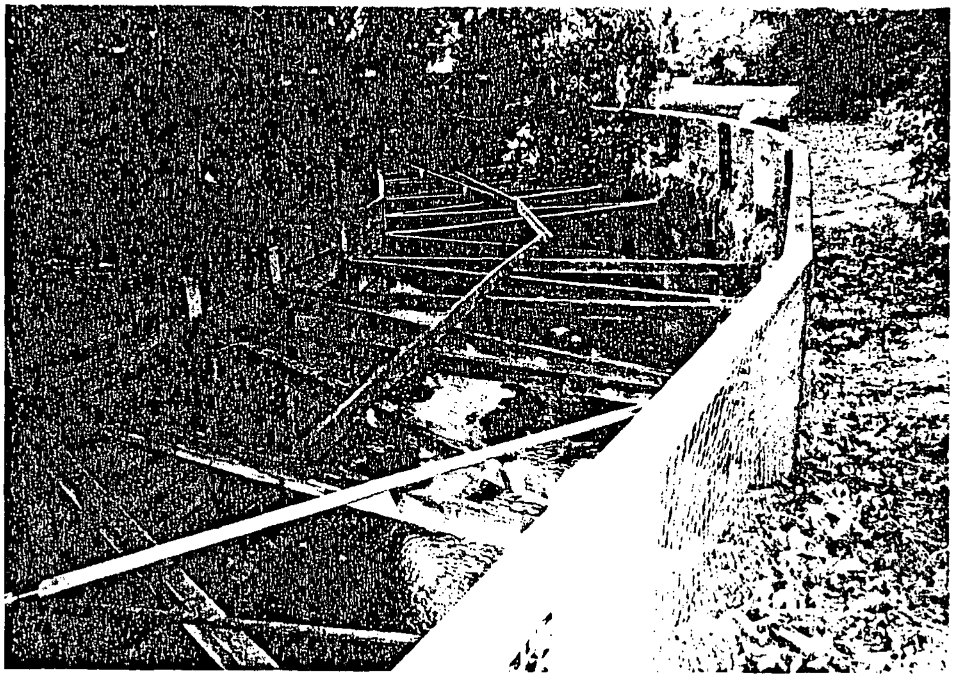


RC 9

RC 10

DRAFT

Fairfax Creek



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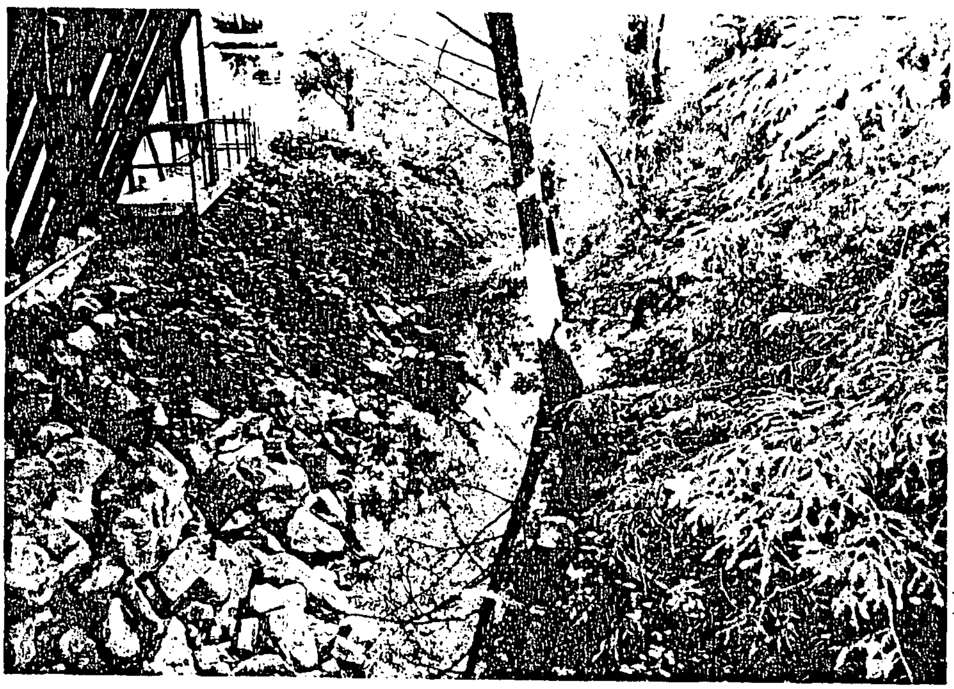

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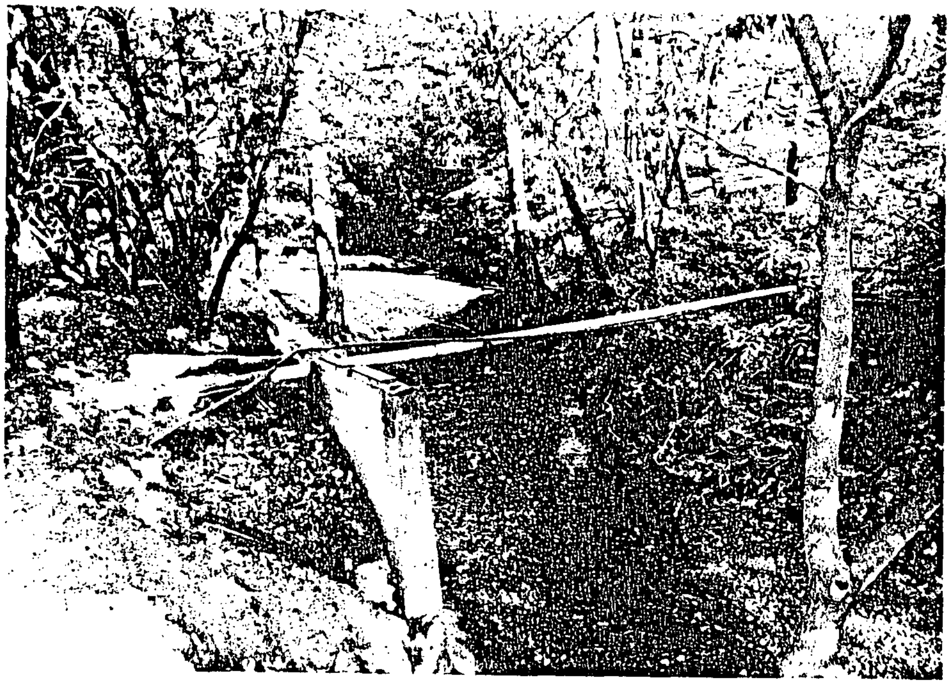

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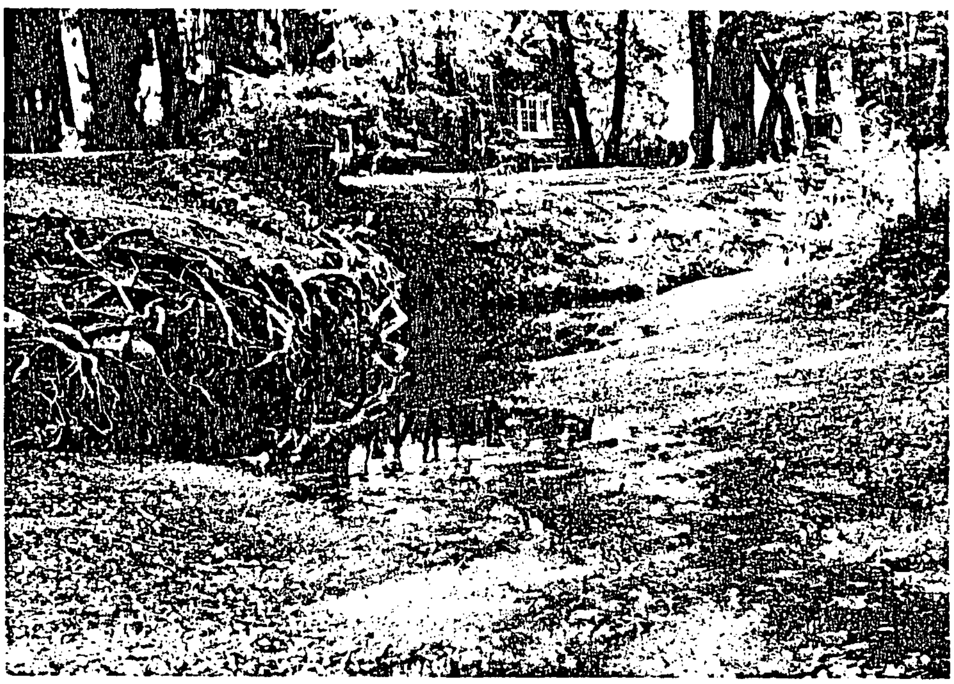
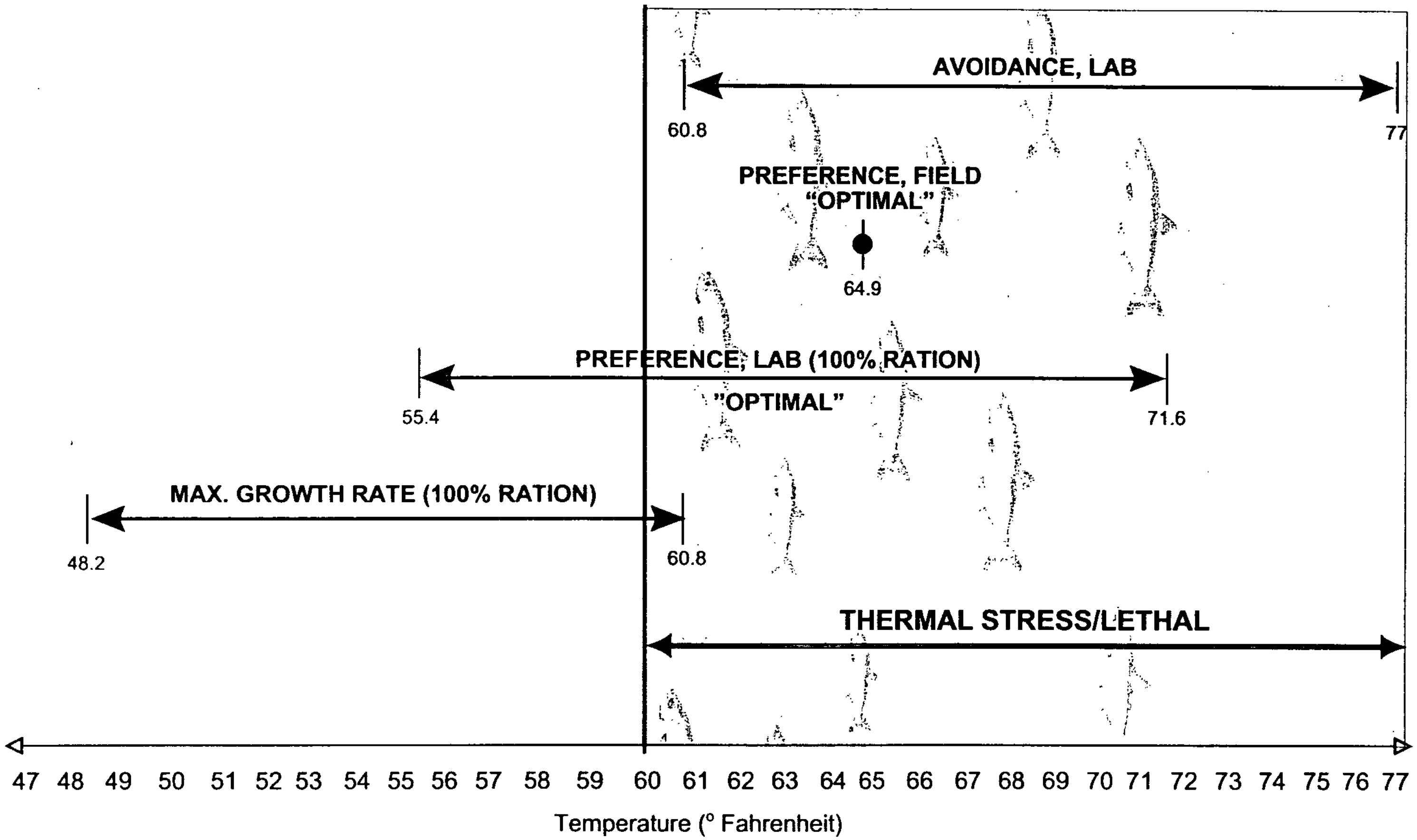


FC 4

APPENDIX G

SUMMARY DEPICTION ON THE RESULTS OF STUDIES ON WATER TEMPERATURES EFFECTS ON STEELHEAD AND RAINBOW TROUT

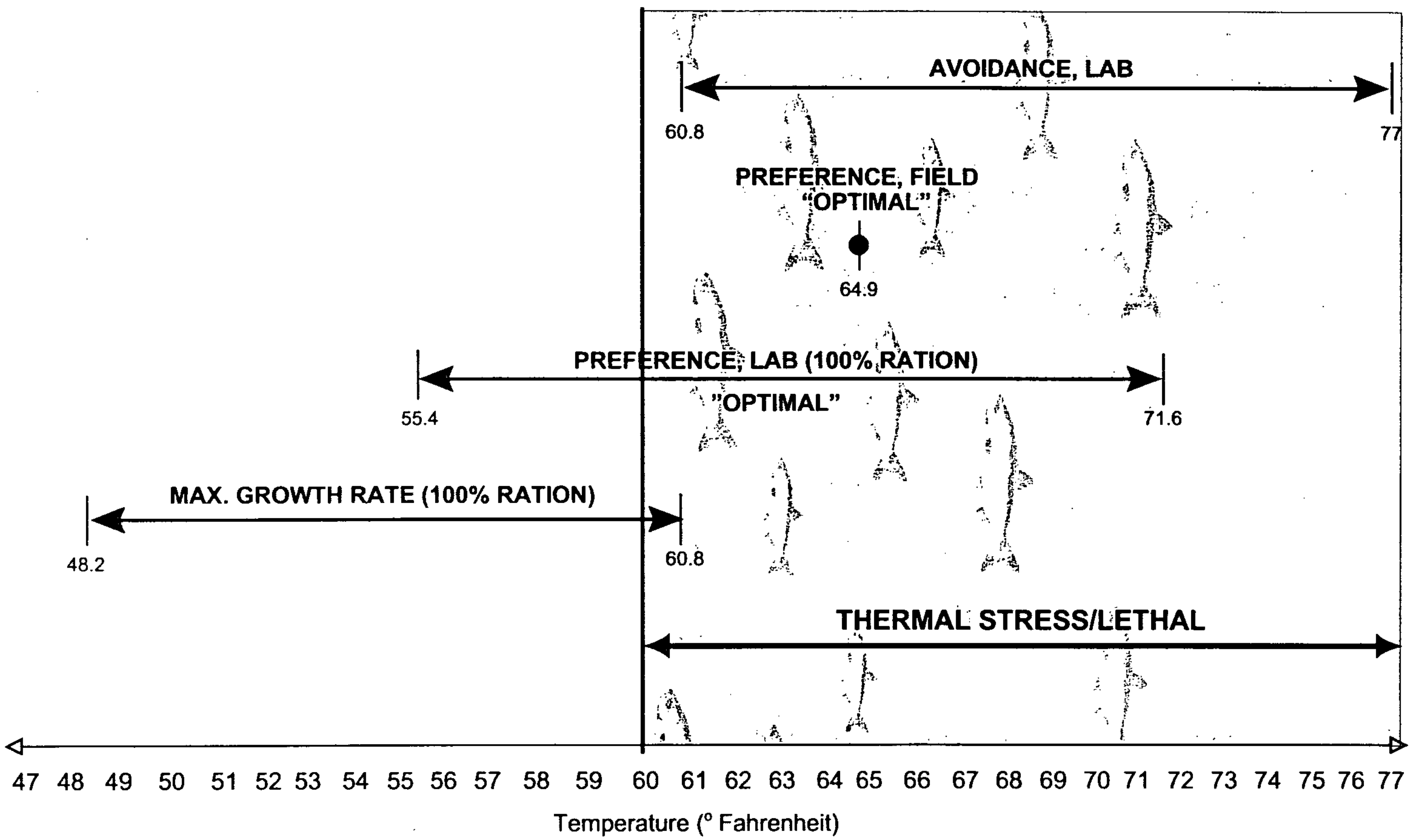
YOUNG RAINBOW TROUT



Sources: Wurtsbaugh and Davis, 1977; Hokanson et al., 1977; Peterson et al., 1979; Coutant, 1977; Garside and and Tait, 1958; Dockray et al., 1998; Matthews and Berg, 1997; Craigie, 1973; Kaya, 1978; Cherry et al., 1977, 1975; Lee and Rinna, 1980; Strange et al., 1993; Spigarelli and Thommes, 1979; Threader and Houston, 1983; Currie et al., 1998.

FIGURE G-2. SUMMARY OF THE RESULTS OF THE PHYSIOLOGICAL AND BEHAVIORAL RESPONSES OF RAINBOW TROUT TO WATER TEMPERATURE.

YOUNG RAINBOW TROUT



Sources: Wurtsbaugh and Davis, 1977; Hokanson et al., 1977; Peterson et al., 1979; Coutant, 1977; Garside and and Tait, 1958; Dockray et al., 1998; Matthews and Berg, 1997; Craigie, 1973; Kaya, 1978; Cherry et al., 1977, 1975; Lee and Rinna, 1980; Strange et al., 1993; Spigarelli and Thommes, 1979; Threader and Houston, 1983; Currie et al., 1998.

FIGURE G-2. SUMMARY OF THE RESULTS OF THE PHYSIOLOGICAL AND BEHAVIORAL RESPONSES OF RAINBOW TROUT TO WATER TEMPERATURE.

APPENDIX H

POTENTIAL RESTORATION AREAS

TABLE H-1. SRU'S WITH CONCRETE SLABS IN CORTE MADERA CREEK

SRU	HABITAT TYPE	LENGTH (m)	AVERAGE WIDTH (m)	AVERAGE DEPTH (cm)
CM-25	P-LS-RR	38	5.8	0.21

TABLE H-2. SRU'S WITH DIVERSION HOSES IN CORTE MADERA CREEK

SRU	HABITAT TYPE	LENGTH (m)	AVERAGE WIDTH (m)	AVERAGE DEPTH (cm)
CM-08	P-LS-BC	27	4.6	0.18
CM-14	P-LS-RR/BC/RT	42	6.5	0.31
CM-20	P-LS-RR	37	5.5	0.29
CM-22	P-LS-RT	25	5	0.13

TABLE H-3. SRU'S WITH MISCELLANEOUS DEBRIS IN CORTE MADERA CREEK

SRU	HABITAT TYPE	TYPE OF DEBRIS
CM-12	P-LS-BC	suitcase
CM-14	P-LS-RT	large metal sheet
CM-17	P-LS-LWD	large woody debris needs to be "thinned out"
CM-18	P-LS-BC	wheel barrow
CM-20	P-LS-RR	declayed plastic sheets
CM-20	P-LS-RR	metal pipe

TABLE H-4. SRU'S WITH CONCRETE SLABS IN SAN ANSELMO CREEK

SRU	HABITAT TYPE	LENGTH (m)	AVERAGE WIDTH (m)	AVERAGE DEPTH (cm)
SA-006	P-LS-CEMENT/RT	67	7	0.21
SA-012	P-LS-BC	42	9.5	0.22
SA-015	P-LS-BC	60	4.5	0.26
SA-021	P-LS-BC/CEMENT/RR/PILLARS		6	0.22
SA-024	P-LS-WALL/LOG	35	5.4	0.34
SA-025	P-LS-CEMENT BLOCKS	18	3.5	0.18
SA-051	P-LS-CEMENT BAGS	17	5.5	0.17
SA-054	P-LS-CEMENT WALL	60	4.7	0.36
SA-070	P-LS-RR/CEMENT BANK	27	5.8	0.3
SA-072	P-LS-CEMENT OVERHANG		2.5	0.13
SA-088	P-LS-CEMENT WALL	20	5.8	0.36
SA-094	P-LS-CEMENT WALL	48	5	0.24
SA-098	P-LS-CEMENT WALL	30	5.3	0.34
SA-099	LGR	18.5	2.3	0.04
SA-101	P-LS-CEMENT BLOCK	38	5.5	0.19
SA-110	P-LS-PILINGS/RR	20	5.5	0.29
SA-118	P-LS-RR	16	3.5	0.06
SA-124	P-LS-CEMENT WALL	27	7.3	0.15

TABLE H-4 CONT'D. SRU'S WITH CONCRETE SLABS IN SAN ANSELMO CREEK

SRU	HABITAT TYPE	LENGTH (m)	AVERAGE WIDTH (m)	AVERAGE DEPTH (cm)
SA-127	P-LS-RR	21	5	0.32
SA-136	P-LS-RT	24	6	0.36
SA-144	P-MC-DAM (SPLIT BY LOG)	19	8.8	0.35
SA-153	P-LS-BC	19	2.5	0.13
SA-156	P-LS-CEMENT WALL/RT	11	13	0.46
SA-157	LGR	18	0.9	0.04
SA-160	P-LS-BC/RR	23	4	0.33
SA-167	P-LS-BC	27	4.7	0.12
SA-172	LGR	16	1	0.05
SA-173	P-BW	5	0.8	0.1
SA-174B	P-LS-CEMENT WALL	16	3.5	0.41
SA-178	P-LS-CEMENT BLOCK	5	2	0.11
SA-179	P-LS-CEMENT DAM	9.5	6	0.51
SA-180	P-MC-BED/CEMENT	12	2.5	0.02
SA-181	P-LS-CEMENT	21	2.9	0.16
SA-197	DRY	145		

TABLE H-5 SRU'S WITH DIVERSION HOSES IN SAN ANSELMO CREEK

SRU	HABITAT TYPE	LENGTH (m)	AVERAGE WIDTH (m)	AVERAGE DEPTH (cm)
SA-002	P-LS-BC/CEMENT	20	4	0.14
SA-006	P-LS-CEMENT/RT	67	7	0.21
SA-012	P-LS-BC	42	9.5	0.22
SA-016	LGR(a)/P-LS-WALL(b)/LGR(c)	50	5.3	
SA-028	P-LS-RT	8	3.5	0.18
SA-030	P-LS-CEMENT BAGS	30	4	0.21
SA-057	P-LS-BC/CEMENT BAGS	44	8.3	0.26
SA-062	P-LS-CEMENT WALL	48	5.2	0.13
SA-065	P-LS-CEMENT/RR	64	5.2	0.22
SA-067	P-LS-CEMENT BAG WALL RB	15	6.4	0.42
SA-081	P-LS-RT	10.5	2.1	0.06
SA-094	P-LS-CEMENT WALL	48	5	0.24
SA-100	P-LS-RT/BC/CEMENT CHUNKS	65	6.5	0.26
SA-176	P-LS-CEMENT WALL	25	4.2	0.2
SA-177	P-LS-CEMENT/WOOD WALL	7	1.5	0.15
SA-184	P-LS-RT	9	3.3	0.25
SA-197	DRY	240		

TABLE H-6. SRU'S WITH BARE/ERODED STREAM BANKS IN SAN ANSELMO CREEK

SRU	HABITAT TYPE	DESCRIPTION OF ERODED AREA
SA-37	P-LS-RT	eroded left (as face upstream) bank, downstream of Madrone bridge
SA-63	LGR	steep right bank; needs plants
SA-111	CASCADE	bare left bank
SA-133	P-LS-BC	bare left bank in sharp curve in creek; near 40 Inyo
SA-162	LGR	left bank is bare and steep
SA-184	P-LS-RT	right bank has good large woody debris pool, but is silted in probably due to non-vegetated right bank
SA-197	DRY	bare right bank just upstream of concrete dam
SA-198	DRY	several bare and eroded banks on both sides of creek and extending up into the Open Space Preserve

TABLE H-7. SRU'S WITH MISCELLANEOUS DEBRIS IN SAN ANSELMO CREEK

SRU	HABITAT TYPE	TYPE OF DEBRIS
SA-24	P-LS-LOG WALL	cement pipe
SA-26	P-LS-BC	log (needs to be cut so that water can pass through)
SA-33	P-LS-GABION WALL	roof covering (large sheets)
SA-90	P-LS-WALL, RIP RAP	radiator
SA-98	P-LS-CONCRETE WAL	large cinder blocks
SA-100	P-LS-RT/BC	blue tank
SA-110	P-LS-WALL, WOOD	wooden wall (left bank) collapsing
SA-127	P-LS-RR	wooden wall (left bank) collapsing
SA-197	DRY	water heater just upstream of dam

TABLE H-8. SRU'S WITH CONCRETE SLABS IN SLEEPY HOLLOW CREEK

SRU	HABITAT TYPE	LENGTH (m)	AVERAGE WIDTH (m)	AVERAGE DEPTH (cm)
SH-020	P-LS-CEMENT WALL/BAGS	10	3.3	0.14
SH-021	P-LS-CEMENT WALL	26	3.2	0.27
SH-036	P-LS-CEMENT WALL	30	2.1	0.14
SH-045	BRIDGE	6		
SH-046	P-LS-RR	9		
SH-68	P-LS-RR/BRIDGE ABUTTMENT	41	4.2	0.4
SH-111	P-LS-CEMENT WALL	7	1.6	0.13
SH-112	P-LS-BED/CEMENT DAM	5	2.5	0.23
SH-113	P-MC-BED	5.5	5.3	0.32
SH-120	P-LS-BED	8	2.9	0.09
SH-128	TRICKLE	35		
SH-141	P-LS-CEMENT WALL	15	3.8	0.24
SH-149	DRY	20		
SH-179	P-MC-DAM	13	5.5	0.38

TABLE H-9. SRU'S WITH DIVERSION HOSES IN SLEEPY HOLLOW CREEK

SRU	HABITAT TYPE	LENGTH (m)	AVERAGE WIDTH (m)	AVERAGE DEPTH (cm)
SH-025	P-LS-CEMENT WALL	84	3.4	0.18
SH-100	DRY	28		
SH-107	P-LS-RT	10	2.2	0.22
SH-121	P-LS-CEMENT WALL (FOOTBRIDGE)	27	2.8	0.21
SH-158	P-LS-BC	20	2	0.19

TABLE H-10. SRU'S WITH MISCELLANEAOUS DEBRIS IN SLEEPY HOLLOW CREEK

SRU	HABITAT TYPE	DESCRIPTION
SH-89	P-LS-GABION WALL	water heater
SH-107	P-LS-RT	metal pipes
SH-158	P-LS-BC	eroded pipe in stream bed

APPENDIX I

GLOSSARY OF TERMS

GLOSSARY OF SOME TERMS USED IN THE REPORT [1]

acclimate: Adaptation to slowly changing new conditions

alevin: A young salmonid that still has it's yolk sac attached (pre "fry" stage)

anadromous: Fishes which migrate from fresh to salt water and vice versa

carrying capacity: The maximum number of individuals of a particular species that can be supported indefinitely by a given part of the environment

crustacean: Primarily aquatic, gill-breathing animals, such as shrimp, crabs, and lobsters

euryhaline: Ability to withstand high salinity concentrations

eutrophication: The enrichment of bodies of fresh water by inorganic plant nutrients (e.g., nitrate, phosphate). It may occur naturally, but can also be the result of human activity (e.g., fertilizer runoff, sewage discharge). The biomass of phytoplankton and herbivorous zooplankton increases, and species diversity decreases. The water becomes turbid in the summer, the growth of the large aquatic plants may eventually become suppressed and algal blooms are frequent. The water may be low in dissolved oxygen through the decay of large amounts of organic matter.

fry: Term assigned to the young salmonid that has recently emerged from the gravel (pre "juvenile" stage)

grisle: Male anadromous salmonid that has spent only one year at sea before returning to fresh water.

jack: See "grisle"

juvenile: Term assigned to young salmonid that has reached a given length, the length differs from study to study (after the "fry" stage)

limiting factor: Factor which has the potential to restrict an individual or population

metabolic rate: A measure of the rate of metabolic activity in a living organism. The rate at which an organism uses energy to sustain essential life processes such as respiration, growth, reproduction, blood circulation, muscle tone, and activity.

GLOSSARY OF SOME TERMS USED IN THE REPORT (CONT.)

milt: Testis or sperm of fishes

natal stream: Stream where fish hatch

parr: See "parr-smolt transformation"

poikilotherm: A "cold-blooded" animal. An animal which has very limited capability in terms of regulating body temperature.

redd: Nest

repeat spawners: Adult steelhead that returns to the ocean and then to the stream to spawn again

resident: Fish which does not migrate to sea (e.g., rainbow trout)

salmonid: Trout and salmon.

smolt: See "parr-smolt transformation"

parr-smolt tranformation (smoltification): Behavioral, morphological, and biochemical changes which transform a darkly pigmented, bottom dwelling freshwater salmonid (the parr) into a pelagic silvery fish (the smolt)

threshold effect: The harmful effect of a small change in environment which exceeds the limit of tolerance of an organism or population, and which becomes evident

threshold value: A critical level or value which must reached before an event occurs

yolk sac: The membranous sac rich in blood vessels which develops around the yolk in the eggs of vertebrates, such as fishes and mammals, and which is attached to the embryo and through which nutrients pass from the yolk.

[1] Sources: Lawrence, E. 1995. Henderson's dictionary of biological terms. Eleventh Edition. John Wiley & Sons. 693 pp

Bond, C. E. 1979. Biology of Fishes. W B. Saunders Company. 514 pp.